Defence Industrialisation in the NICs:

Case Studies from Brazil & India

Carol Vervain Evans

Ph.D International Relations

London School of Economics and Political Science

ABSTRACT

Accompanying the emergence of the newly industrialising countries (NICs) in the 1980s was the remarkable growth in these states' defence manufacturing and export capabilities. An important objective of this Ph.D. thesis is to explore and clarify the relationship between defence production and industrialisation in the NICs.

My research employs an international political economy approach since neither the prevailing scholarship in the fields of international relations (which emphasises strategic and political factors), nor of development economics (which concentrates on the relationship of military expenditure and growth) are adequate. In addition, existing explanations of defence industrialisation have paid little if any attention to the critical role of the firm and of technology. As a consequence, they analytically fail to capture the complex process by which firms as well as states succeed or fail to achieve international competitiveness.

As is argued in this thesis, firms play a crucial role in the generation, utilisation and diffusion of technology, which is essential to the attainment of arms production and export capabilities. Thus, a more insightful, powerful conceptualisation of the relationship between "defence" and "industrialisation" necessarily involves a discussion of firms and their technological capabilities, and how their behaviour is influenced by their strategic interaction with the state. This framework also explicates the differing levels of defence manufacturing and export performance among the NICs.

The case studies in this thesis are of Brazil and India -- two industrialising countries whose defence/industrial bases are similar though their respective external

security environments differ markedly. A comparative analysis of these states suggests that the relative success of Brazil's arms industry in the 1980s was attributable to its highly developed, competitive capital goods firms and to a government technology policy that reinforced linkages between the defence and capital goods industries.

CONTENTS

ILLUSTRATIONS

Tables

Charts

Figures

PREFACE

I have received much assistance and support in completing this Ph.D thesis, and would like to express my special gratitude and thanks to several institutions and individuals.

A number of universities and research institutions provided me with fellowships to support the writing of this thesis. They include the London School of Economics (LSE); the Brookings Institution (Washington, D.C.); the Center in Political Economy, Washington University (St. Louis); and the Center for International Affairs, Harvard University. My field research in Brazil and India was funded by the LSE's Montague Burton studentship, the Gallatin Foundation and the Institute for the Study of World Politics. In particular, I am indebted to Dr. Lincoln Gordon, a former U.S. ambassador to Brazil, as well as to Jack Wyant and Gabriela Sa Erp of British Petroleum, Rio de Janeiro for their excellent and warm logistical assistance during my first, auspicious visit to Brazil. *"Muito obrigada!"*

This thesis is also a reflection of the encouragement, guidance and constructive criticism I have received from many colleagues and friends in Britain and in the United States. An enormous tribute is paid to my Ph.D supervisor, Professor Susan Strange, who stimulated my interest in International Political Economy and firms in the first place. American adacemics often label me, a "*Strange*" student. Indeed I am. A colleague, Professor Frederic Raines of the Economics Department, Washington University lended superb guidance with the econometric methodology. Bill Keller of the Office of Technology Assessment, U.S. Congress, has been a constant voice urging me to bridge the theoretical and applied worlds of research.

Finally, perhaps the largest debt of gratitude is to Dr. Robert Powell for his wisdom, patience, love and ... pesto. Thank you.

Carol V. Evans

August 1993

Chapter I

INTRODUCTION

The newly industrialising countries (NICs) are frequently perceived to be manufacturers and exporters of simple, low-cost, labor-intensive products. As producers of, for example, textiles, shoes and electrical components, these countries are assumed to have little or no indigenous technological capability, except the capacity to adapt and make minor modifications to imported foreign technologies. On this basis, one would not expect the NICs to enter international markets as competitive manufacturers of a range of high technology, defence products.

Nevertheless, a number of newly industrialising countries have emerged as sizeable defence producers and exporters in the past two decades. These NICs include: Argentina, Brazil, India, South Korea, China, Singapore, Indonesia, and Taiwan, among others.[1] The growth of the defence industries in the NICs has also been accompanied by the increasing technological sophistication of their military products -- advanced fighter aircraft, armoured personnel carriers and main battle tanks, rockets and missiles, and naval craft.

The ramifications arising from defence production and exports by the NICs are far-reaching. By contributing to the surplus capacity in the global arms market and to the wide diversity of arms supply, the NICs have degraded the ability of the major powers to use arms transfers as an instrument of foreign policy. The development of defence industrial capabilities by the NICs has also accelerated the proliferation of conventional as well as ballistic weapons and technology. The dangers of increased proliferation were graphically demonstrated by the recent Persian Gulf War, in which the Iraqi invasion of Kuwait was demonstrably aided by the transfer of arms and missile technology by Brazil and China.

Underlying the broader emergence of the NICs as significant defence producers and exporters are differing levels of defence manufacturing and international competitiveness. Brazil was the world's seventh largest arms exporter and was ranked first or second (after China) in terms of defence production output and exports among the NICs during the 1980s.[2] Building on indigenous R & D and international collaborative agreements, Brazil's defence industries became highly diversified and sophisticated producers of military equipment. The Persian Gulf and Middle East states such as Iraq, Libya and Saudi Arabia have been the largest purchasers of Brazilian defence products. Still, Brazil's arms exports have not been limited to the Third World. Both the air forces of the United Kingdom and France deploy Brazilian designed and manufactured fighter trainer aircraft.

India, by contrast, provides a paradoxical example of a country that possesses the largest military-industrial-research complex among the NICs, and, at the same time, depends disproportionately on transfers of foreign defence technology. Its failed policy of self-sufficiency in arms production has necessitated substantial weapons imports from and licensing agreements with the former Soviet Union and, more recently, with West European states.

The defence industrial capabilities of the East Asian countries also vary. Unlike India's self-sufficient approach, South Korea is developing its arms industry through weapons coproduction and other collaborative agreements with U.S. and other foreign defence companies. Taiwan's technical expertise and moderately diversified industrial base enabled it to develop and build (with some foreign assistance) an indigenous high performance fighter aircraft (the Ching Kuo) in less than ten years. The lack of a sufficient technological base and financial resources have precluded Singapore and Indonesia from embarking on similarly ambitious defence projects. Instead, Singapore's and Indonesia's more modest defence production efforts consist largely of component manufacture and assembly work for the larger, international aircraft, shipbuilding and ordnance industries.

This thesis seeks to explain how these countries derived their defence production capabilities and what accounts for the variance in capabilities and competitiveness in the international arms market among the NICs. While technology obviously has played an important role in shaping the defence-industrial transformation of the NICs, what lies at the heart of this transformation are the strategies and policies of the main actors participating in the generation and diffusion of technology; namely, firms and states.

Much of the literature on the emergence of the NICs in the international political economy has tended, however, to focus solely on the state, ignoring the important role played by firms. The purpose of this thesis is to elucidate both how firm behaviour and firms' strategic interaction with the state determines the development of and variance in the defence industrial capabilities and international competitiveness of the NICs.

This thesis is divided into three broad sections. The first provides the author's conceptual framework for analysing the rise of the NICs and their defence industries.

It contains an extensive review and critique of existing explanations from the political science and economics literature.

The second section consists of case studies on Brazil (Chapter 3) and on India (Chapter 4). Based on the author's primary research in these two NICs, Chapters 3 and 4 describe and assess the respective development and competitiveness of the Brazilian and Indian arms industries. These case study chapters discuss three topics. First, in each of the chapters the author examines whether the strategic environment was an important factor influencing the defence industrialisation process in Brazil and India, respectively. Second, the author describes these countries' defence industries at the firm level. She describes the firms, their main products and markets, and whether their technology and other strategies have led to the manufacture of internationally competitive defence products. Third, in both chapters the author investigates the extent and type of linkages existing between the capital goods and defence industries of Brazil and India.

The third and final section of the thesis integrates the empirical findings of the Brazilian and Indian case studies into her conceptual framework. Drawing upon the research elaborated in Chapters 3 and 4, Chapter 5 provides a comparative analysis of the strategic interaction between firms and states in Brazil and India. In this chapter, the writer examines the forms and effects of the Brazilian and Indian governments' trade, industrial and technology policies on the development of these strategic industries.

The striking performance and competitiveness of Brazil's defence firms in contrast to India's, which emerges from the case studies, is explained in terms of the differences between Brazilian and Indian firms' technology strategies as well as their strategic interaction with the state. Using a game theoretic approach the author shows that the relative success of Brazil's arms industry is attributable to the interaction between firms and government that stimulated the technological competitiveness of Brazilian defence and capital goods manufacturers. In contrast, she shows that the strategic interaction between Indian firms and the government has stultified the development of both the defence and capital goods industries.

Chapter 6 concludes the thesis. The author re-states the broad objectives of her thesis on defence industrialisation in the NICs and re-evaluates her conceptual framework for explaining the variance in these countries' capabilities and export competitiveness. In this last chapter the author also shows how her research on the role of firms in Brazil's and India's defence industrial bases has important theoretical implications for the political science and economics literature discussed in Chapter 2. Finally, in noting some of the limitations in her work, the author suggests avenues for future research.

Endnotes

[1]Throughout this thesis, the author's definition of newly industrialising country is based on the structural industrial characteristics of these countries rather than on the narrower and more conventionally used criterion of rates of manufactured exports. The author's broader definition of a NIC includes: the size and structure of demand for industrial products, the share of industrial manufacturing (output or value added) in GNP/GDP, the central role of the state in fostering industrialisation, heavy reliance on foreign sources of technology, and some indicators of international competitiveness.

[2]Brazil is ranked seventh during the 1987-91 period after the former Soviet Union, the United States, France, China, the United Kingdom, and West Germany. These rankings are provided by the Stockholm International Peace Research Institute, *SIPRI Yearbook of World Armaments and Disarmament, 1992* (New York: Humanities Press), 272.

Chapter II

DEFENCE & INDUSTRIALISATION: Why Firms Matter

Two fundamental issues pervade the scholarship in international relations. First, what are the effects of changes in the international distribution of power and wealth on inter-state conflict and cooperation. And, second, what causes these shifts in the international distribution of power and wealth. Much of international relations theory addresses the first question.[1] This thesis is broadly concerned with the second issue, namely; how competitive advantage, which is essential in determining a state's wealth and power, is created and shifts among nation states.[2] This thesis also focuses on the underlying roles of industrialisation and technological change in shaping the international distribution of competitive advantage. Such a conceptualisation helps us better understand changes in the distribution of power and wealth.

Defence and Industrialisation

This section links the competitiveness of states in the international system to the need to maintain a national defence capability (e.g. power) and to promote industrialisation (e.g. wealth). It then explains how competition between states has centred on the development of industries that are militarily and economically strategic; broadly the defence and capital goods industries. While state intervention is critical in the creation of these industries, this section suggests that firms too are crucial determinants of the competitiveness of these industries and of a state's position in the international hierarchy.

In recent years, a number of studies have examined the determinants of international economic competitiveness. In particular, some researchers link the importance of technology in enhancing a state's industrial capabilities to potential competitiveness in key international markets.[3] In one of the most detailed international political economy analyses of the economic competitiveness of states, Cohen and Zysman observe that:

> Technological developments can provoke rapid market shifts ..... Some critical technologies can affect the competitive position of a whole range of industries; and if one nation uses these technologies to gain a lead in a vital product, it can forge an important trade advantage for itself. These are the *strategic transformative industries* .... This reshuffling of market position in a period in which important new strategic transformative sectors are emerging ... can result in new international hierarchies of wealth but also of power.[4] (Italics in original)

The idea that there exists a group of leading or strategic industries, which are critical to sustaining industrialisation and international competitiveness, is a recurring theme in international political economy as evidenced by recent debates regarding the utility of industrial and technology policies to promote global competitiveness in high technology industries.[5] Broadly defined these strategic transformative industries comprise the defence and capital goods sectors.[6] The important relationship between the defence and capital goods industries, in determining a state's hierarchical position in the international system, has been widely discussed and accepted in the literature from international relations and economic history.

The defence industry is clearly essential to a state's military capability and power (and hence "the ability to pursue wealth"). More broadly, however, this industry has also stimulated the development of the capital goods sector, thereby influencing the form and pace of industrialisation itself.[7] For example, Rosenberg has shown how the requirements of the firearms industry shaped the initial development of the sewing-machine, bicycle, machine tools, and later, the motor vehicle industries owing to a process of technological convergence.[8] In his article on the sources of international competitiveness, Chesnais suggests that England's international dominance during the 1800s:

> was due less to its textile industry than to its metallurgical and mechanical industries, the technology these industries incorporated, and also England's military capacity, which allowed the industries to be established.[9]

The capital goods industry has long been recognised for its crucial role in the industrialisation process. Three reasons account for its centripetal role: 1) The capital goods sector contributes the most to manufacturing value added; 2) It has characteristically high intra-industry linkages as well as backward/forward linkages to other industries, including defence; and 3) It generates and diffuses technology and other positive externalities throughout the economy. Not surprisingly then various economists have posited that continued technological learning in the capital goods industry is especially important because of its synergistic effect on an integrated system of industries. Indeed, as Rosenberg has shown, the very "pace of technical advance in the user industry may depend critically upon events in the capital goods sector."[10]

Several studies have documented the strategic significance of the capital goods industry for the production of military goods.[11] In his classic discussion of the sources of military power, Knorr writes, "military potential ... derives from the composition of the accruing capacity for production. Military potential obviously benefits ... from an expansion of the ... capital goods industries...."[12] In another major contribution to international relations, Sen defines a group of industries, the majority of which are classified as capital goods, that are strategic for industrialisation and economic growth.[13] "The dual significance for military self-sufficiency and national economic independence can be held to provide the rationale for the desire [by states] to acquire this group of industries."[14]

It is clear now from this discussion that the international competitiveness of states can be linked to their aspirations and abilities to stay ahead technologically and commercially in key industries associated with the defence and capital goods sectors.[15] Indeed, there is a growing body of research from both the OECD and newly industrialising countries (NICs) that highlights the role of the state in attaining international competitiveness. In general, these studies focus on the effects of government trade, industrial and technology policies on manufacturing competitiveness.[16] Conducted at the level of countries and industries, their empirical analyses of the determinants of competitiveness are often limited to comparative macro/micro economic data on productivity levels, R & D spending, manufacturing value-added, and export growth rates.

Nonetheless, as discussed more fully in the forthcoming literature review, such analyses cannot explain the complex process by which a country and its industries attain or fail to sustain international competitiveness. Many factors underlie the marked differences in performance and competitiveness among industries within a single state and across states. Explanations of international competitiveness from international relations, international political economy and economics have focused on some of these factors such as states, interest groups and technology. These explanations, however, have generally neglected the pivotal role played by firms.

The central argument of this thesis is that the international political and economic competitiveness of a state, and hence its hierarchical position in the international system, is importantly determined by firms. An understanding of firms as well as their interaction with other firms and with the state is crucial to explicating differences in international competitiveness. Thus, a corollary objective of this thesis is to elucidate the determinants of competitiveness at the firm level, in particular, firms' technological, managerial and entrepreneurial capabilities and strategies, i.e., firm behaviour.

Firms obviously differ in their capabilities to innovate. They also vary in terms of their access as well as abilities to absorb and exploit new technologies. As will be shown later in the case studies, these differences in technological capabilities considerably determine a firm's competitiveness in domestic and international markets. In addition, these firm-level differences directly affect a state's industrial development and trade performance. A study by the OECD on the relationship between science, technology and competitiveness saliently observes:

> The international competitiveness of a national economy is built on the competitiveness of the firms which operate within, and export from, its boundaries, and is, to a large extent, an expression of the will to compete and the dynamism of firms, their capacity to invest, to innovate both as a consequence of their own R & D and of successful appropriation of external technologies.[17]

Nevertheless, firms' capabilities and strategies are sensitive to external influences (incentives and penalties), such as factor markets and macroeconomic forces, for example, foreign exchange and interest rates. Consequently, states -- their trade, industrial and technology policies -- help shape the external environment of firms and their behaviour.

In concluding this introductory section let us return to the initial question of how competitive advantage is created and distributed among nation states. As suggested in the discussion above, competition between states has centred on the development of industries that are militarily and economically strategic: the defence and capital goods industries. Although all states are equally motivated to create these key industries, the ability of states to be competitive internationally in these high technology sectors varies tremendously. How this competitiveness is achieved and leads to subsequent shifts in the relative political and economic power of states is importantly decided by two analytically distinct actors: firms and states. In essence, as this thesis will show, international competitiveness can be explained as the outcome of the strategic interaction of firms and states.

Contending Approaches from the Literature

Accompanying the emergence of the newly industrialising countries in the 1980s was the rapid expansion of these states' defence and manufacturing industries. The growth of these industries and their export success in global markets are important developments in the international system. They exemplify both changes in the competitive advantage of states that are engendered by the process of industrialisation, and possible shifts in the bases of power (loosely defined) within the international political economy.

The literature from political science and economics offers various contending explanations for the remarkable growth of the NICs' defence and manufacturing export capabilities. This vast literature can be organised around three distinct analytical questions. First, the fields of international relations and development economics concentrate on describing the motivations, capabilities and implications of defence production in the NICs. Second, scholarship from comparative politics and neoclassical economics attempts to explain the NICs' rise to international economic competitiveness. A third framework derives from the general focus of international political economy on how wealth and power are created and distributed. For example, defence and industrialisation are especially important to mercantilists, who have traditionally been concerned about how the state ensures national military security and economic competitiveness.

As the author will demonstrate in the following detailed literature review, these theoretical approaches are inadequate. None effectively integrates firms into their explanations of the development of defence and manufacturing capabilities by the NICs, nor do they view the process by which export competitiveness is achieved as the outcome of interaction between states and firms.

As argued in this thesis, firms play a crucial role in the acquisition, generation, utilisation, and diffusion of technology, which is essential to the attainment of an arms production capability and international competitiveness. Thus, a more insightful, powerful conceptualisation of the relationship between defence and industrialisation necessarily involves a discussion of firms and their technological capabilities, and how a firm's behaviour is influenced by its strategic interaction with the state. Such a theoretical explanation also helps to explicate the differing levels of defence manufacturing and export performance among the NICs.

International Relations

The link between the NICs' impressive manufactured export performance and these states' burgeoning arms industries has been vaguely conceptualised in the international relations literature by the term "defence (or military) industrialisation".[18] In general, this literature, particularly the subfield of international security studies, has focused on assessing the motivations, capabilities and foreign policy implications of defence industrialisation in the NICs. Development economics has concentrated largely on measuring the particular economic implications (costs) of defence production activities for the broader civilian economy. The author will begin her discussion with a review of the scholarship from international relations.

There are three major strands of the international relations literature, which focus on arms production in the NICs. First, beginning in the early 1980s there was an explosion of largely descriptive, individual country case studies, which hypothesised that defence industrialisation was a function of two basic determinants: motivations and capabilities.[19] Influenced by realist preoccupations with the projection and balance of power in the international system, these authors have emphasised primarily the strategic and political rationales for why the NICs initiated defence industrialising programmes.

Accordingly, the role of threat perception often has been linked to regional arms races. For example, most studies argue that India's massive arms production programme and consequently, its military buildup, are tied to its regional arms race with the Peoples' Republic of China and Pakistan.[20] The twin desires to ensure security of supply and improve self-reliance, in some cases caused by international arms embargoes, are other widely articulated rationales. Taiwan's and Israel's development of indigenous advanced fighter airplanes (the Indigenous Defence Fighter and Lavi) are said to have been prompted by desires for self-sufficiency in view of various U.S. administration refusals to sell these countries sophisticated aircraft.[21] A third set of strategic explanations for defence industrialisation involve regional hegemonic power aspirations. This politico-strategic rationale is closely linked to prestige considerations on the part of those NIC arms producers governed by military regimes. Defence industrialisation, therefore, may serve to fulfill the military's national security role and to enhance its professional image and power abroad. The relatively recent emergence during the 1980s of arms industries in military-led Brazil and Indonesia were attributed to these states' hegemonic aspirations in Latin America and Southeast Asia respectively.[22]

The second strand of the international relations literature attempts to link capabilities -- industrial, technological, financial -- to the long-term viability of defence production and exports by the NICs. In contrast to the consensus that underpins the discussion of the motivations for defence industrialisation, the issue of defining "capabilities" has been far more problematic and the subject of much methodological and conceptual confusion as well as debate. Two schools of thought predominate. On the one hand, writers from the arms trade literature link the growth of NIC defence industrialisation to the provision of security assistance and technology transfer arrangements from foreign suppliers.[23] In their view:

> the development of numerous arms industries ... with export capability or potential came about through the transfer of technology and ... defence production knowledge through license and coproduction arrangements with more advanced industrial suppliers.[24]

Subsequent studies have tried to measure qualitatively as well as quantitatively the extent to which individual NICs depend on various elements (licenses, technical data, designs) of foreign technology transfers.[25]

On the other hand, various studies correlate the process of defence industrialisation in the NICs to these states' growing technological and industrial capabilities.[26] Since defence production is one of the most complex manufacturing activities, requiring extensive industrial inputs from steel, metallurgy, machinery, and electronics, the increase in domestic arms production in the NICs, according one author, "can probably be explained in part by the growing manufacturing sector. Conversely, the desire to produce arms might also have enhanced the propensity to give priority to industrialisation in general and to certain industries in particular."[27]

Rather than flushing out more precisely the linkage between arms production and industrialisation, this literature has focused instead on devising a macrostatistical methodology for measuring a NIC's defence industrial base. Using a variety of economic indicators, such as the share of manufacturing as a percentage of GNP, the number of scientists and technical personnel engaged in R & D, GNP per capita, etc., to comprise "potential defence capacity" (PDC) or the "potential arms production base"

(PAPB), these macrostatistical studies relate the prior existence of a PDC/PAPB to arms production output and exports by the NICs.[28]

A widely cited macrostatistical study by Neuman, for example, finds that:

> the existence of a large military to provide an adequate market, combined with generous national income and a sizeable population to support the necessary industrial infrastructure significantly affect a state's long-term ability to produce major weapons systems....[29]

Neuman as well as others (Wulf, Deger, Peleg, and Kennedy) have then used these indices of PDC to rank order the defence industrialising countries. For instance, according to Deger, "For the top six countries (Israel, India, Brazil, Yugoslavia, South Korea, and Turkey), there seems to be a close connection between the ranks given by actual arms production and the potential capacity of defence manufacturers."[30]

Building upon assessments of defence production and export capabilities of the NICs, the third and final strand of the international relations literature primarily focused on the policy implications -- foreign policy, regional security, conventional arms control -- arising from defence industrialisation in the NICs. At the centre of this literature was a vigorous and often acrimonious debate over the issue of whether or not the emergence of these defence industrialising countries signalled the erosion of an international system characterised by hierarchy and hegemony.

Sparking this debate was the qualitative conclusion by Neuman, in her *International Organisation* article cited above, that Third World arms production (including the NICs), was inconsequential to both the stability of the world order and to the international arms trade. Her assessment was based on the argument that such arms production was technologically deficient in comparison to the arms industries of the advanced industrialised states:

> These developments demonstrate how difficult it will be for Third World countries to change the existing world military-industrial balance ... In light of these developments it is unlikely that LDCs will ever be able to achieve independence from foreign military transfers or mount a significant commercial challenge to the major arms suppliers.[31]

A number of subsequent studies (Schwartz, Louscher and Salomone) have challenged Neuman's questionable statistical methodology and thus her conclusions (Ross & Evans).[32] Writing from the arms trade perspective, several authors have argued that Neuman presents an overly static view of the process of defence industrialisation. In particular, Neuman is criticised for her assumption that arms industries are only the product of general macroeconomic conditions of states and consequently does not link the transfer of foreign weapons technology to the development of defence production capabilities. According to Schwartz, the author of one of the most comprehensive, detailed rebuttals of Neuman:

> It is likely that production capability depends on the technology they have acquired from outside sources. Because much production depends on nonindigenous technology, the level of technology of weapons produced is not necessarily linked to domestic, industrial, technological, and economic capability.[33]

In essence, Schwartz argues that Neuman fails to consider the possibility of advances in defence production capabilities through licenses, technology transfers and coproduction agreements with foreign suppliers. "This is the dynamic Neuman ignored and the technological factor she overlooked."[34] This view has garnered much support, including a recent study by the Office of Technology Assessment (OTA), which found that:

> In 1988, for example, India, Egypt, Indonesia, South Korea, Taiwan and Brazil were producing 43 different major weapons under international licensing agreements ... As a consequence, several of these nations have attained significant defence industrial capacity and have entered the arms export business.[35]

The conclusions from such studies obviously counter Neuman's belief that the impact of the NICs' defence manufacturing and export capabilities on the international system is negligible. According to Ross, for example, "To the extent that Third World's defence-production capabilities contribute to the diffusion of power and the erosion of the post World War II international hierarchy, the expansion of those capabilities would appear to diminish the prospects for world order."[36] This diffusionary perspective is also echoed in the previously cited OTA report. "Increasing proliferation of sophisticated weapons and technological know-how has injected new elements of uncertainty and concern into international relations."[37]

Having completed a detailed overview and evolution of the international relations literature regarding defence industrialisation in the NICs, this author will now demonstrate why this literature is conceptually inadequate because of its failure to integrate the role of firms into analyses of the defence industrialisation process. There are three fundamental criticisms that the author wants to raise in relation to the international relations literature as a whole, and to the concept of defence industrialisation in particular.

The first criticism concerns international relations' analyses of the motivations for NIC arms production, and their near exclusive emphasis on the role of the external, international environment in determining the defence production activities of the NICs. A classic example of this line of argument is provided by Nolan in her study of two NIC defence manufacturers, South Korea and Taiwan:

> it is hard to see certain prominent features of these two small "garrison states" - including the vigorously pursued development of their indigenous military industries - as anything other than adaptations to the changing international environment. The single most important factor of that environment for both states has been their intimate relationship with the United States.[38]

At issue here is the failure to link cause and effect; namely, the international relations literature does not adequately explain or specify how external pressures -- declining foreign military assistance, regional arms races, international arms embargoes -- shape the process of defence industrialisation in the NICs. Often one finds in the literature separate treatments of motivations and overviews of the structure of a country's arms industry, without any intervening discussion of how these *motivations* relate to a NIC's *capability* to manufacture military products.[39] For example, in analysing India's hostile strategic environment, many scholars have consequently linked India's huge arms industry to the regional arms race involving China and Pakistan. However, as the subsequent case study indicates, while India does face external threats to its security, its defence production capabilities are characterised by technological obsolescence, terrible inefficiencies, and huge dependence on foreign suppliers of technology.

Another analytical problem is that while such exogenous factors may have an initial, stimulative effect on NIC defence industrialisation, endogenous, economic (as well as political) factors may be of longer term consequence. Indeed, the international relations literature often neglects the economic incentives that are independently as well as increasingly encouraging arms production by the NICs. One exception is Evans, who, in a previous work, pointed to the importance of integrating economic factors -- foreign exchange earnings derived from arms exports, potential technological spin-offs from defence manufacturing, enhanced labour productivity and training, access to critical foreign technologies -- into international relations analyses.[40]

A final comment is that the preoccupation in international relations with exogenous international systemic factors ignores the crucial, central role of firms. As will be shown in the case studies that follow, the sharp contrast between Brazil's and India's defence production capabilities cannot simply be explained by the impact of their differing strategic environments. Other factors, such as domestic firms' technological strategies and interaction with the state, are the dominant variables.

The second major criticism of the international relations literature on defence industrialisation in the NICs is its lack of any coherent theoretical framework. At present, this literature is characterised by extremely descriptive, individual country case studies. There has been little attempt to organise these case studies under a conceptual rubric, or to offer comparative analysis. In fact, such attempts have been rejected in some IR circles:

> the delineation of general, systemic factor cross-country comparison is not presently a valid approach for understanding defence-industrial production in industrialising states....[I]n the absence of a detailed case study it is impossible to know whether or not countries have enough in common ... to constitute an appropriate group for comparison.[41]

Doubtless, case study methodology may offer a detailed explanation of one country's motivations for and experiences with defence industrialisation, for which the comparative macrostatistical studies mentioned above are unsuited. However, the continued lacuna of comparative approaches in the international relations literature, after nearly a decade of often duplicative case study analyses, reflects a certain theoretical laziness. No where is this laziness more evident than in the very concept of "defence industrialisation"; a subject to which the author now turns.

The term "defence industrialisation" was coined as a shorthand way of conceptually linking the twin processes of defence production and industrialisation occurring in the NICs. In reviewing those studies that base their analyses on "defence industrialisation", this author is unable to locate a single definition or explanation of the concept.[42] This analytical inability to clarify more precisely the relationship between the NICs' growing manufacturing capabilities and their arms production/export activities is the third and most fundamental weakness of the international relations literature.

A primary example of the conceptual haziness over defence industrialisation that prevails in the literature can be found in one of the most well respected studies in the field, *Arms Production in the Third World*. Avoiding the necessity of defining what they mean by defence industrialisation, these authors write, "The link between arms production and civilian production has been firmly established in other studies."[43] Ironically, the two studies to which they refer are the highly criticised macrostatistical works by Neuman, especially, and Wulf, discussed above.[44]

The concept of defence industrialisation thus degenerates into a circular debate. On the one hand, there are those authors (Neuman and Wulf), using macrostatistical indicators, who do not link the increasing internationalisation of the arms industry and, as consequence, argue that the impact of NIC defence industrialisation is negligible. On the other hand, there are those, from the arms trade literature, who correlate defence industrialisation entirely to transfers of foreign technology, ignoring, in the first place, indigenous defence production capabilities. That these two IR-based approaches talk past one another is regrettable; that they do not extend our conceptual understanding of defence industrialisation in the NICs is problematic.

Thus, in summarizing this critique of the international relations literature on defence industrialisation in the NICs, the author reiterates the need to develop a comprehensive theoretical framework; one that incorporates the role played by firms into analyses of defence industrialisation. Such a framework could then provide a better basis for well researched, methodologically sound, comparative studies. These are some of the objectives of this thesis.

Development Economics

The field of development economics has been only tangentially interested in the subject of defence industrialisation in the NICs. Instead, development economists have subsumed the issue of assessing the economic implications stemming from arms production activities, into the broader "guns versus butter" debate.[45] The guns vs. butter literature addresses two interrelated questions: 1) What are the economic *causes* of military expenditure in industrialising countries? and 2) What are the *effects* of such expenditure for growth and development?

A study, which examines the causal relationship of defence and growth, is the highly controversial work of Benoit.[46] Based on a sample of 44 developing countries (including the NICs), and six country case studies, Benoit reaches the surprising finding that defence expenditure overall actually stimulates rather than retards economic growth. This conclusion also is confirmed in his subsequent 1978 study:

> Contrary to my expectations, countries with a heavy defence burden generally had the most rapid rate of growth, and those with the lowest defence burdens tended to show the lowest growth rates.[47]

Additionally, Benoit argues that defence programmes, including arms production activities make "tangible" indirect contributions to the civilian economy through the provision of housing, medical care, education, public infrastructure etc.[48] However, both the precise statistical methodology and his qualitative assessment of the contributions made by military programmes has received substantial criticism in studies conducted by other development economists.[49]

The most substantive study of the wide-ranging effects of military expenditure on growth and development is Deger's *Military Expenditure in Third World Countries*.[50] Her study offers a distinct analytical approach to understanding the guns vs butter tradeoff; one also that specifically examines the economic implications of defence industrialisation in the NICs. Deger argues that it is necessary to include the effect of the mobilisation of resources into quantitative assessments of the impact of defence spending on growth. As military expenditure increases it influences savings, investment (absorptive capacity), and human capital formation -- important economic variables, which have previously been missing in the guns vs. butter debate. On the basis of econometric and empirical estimates, Deger reports that:

> the overall effect of military expenditure is to *reduce* growth rates. If we take all interdependent effects together, an increase in the defence burden [military expenditure] leads to a decrease in the growth rate through a decline in the savings rate, a fall in investment per unit of capital and a reduction in human capital formation.[51]

The implications of these conclusions for Benoit's causal correlation of higher defence spending and growth rates are spelled out by Deger:

> Attention by Benoit, and others criticising his work, has generally focused on allocation based on a *given* production possibility frontier in the short run. This book, however, claims that even in the short run the very act of allocation will tend to shift the output possibilities open to the economy.[52]

Of more direct relevance to this dissertation is Deger's analysis regarding the potential impact of military expenditure on the process of defence industrialisation in the NICs. "It may increase the productivity of capital in civilian industries by adding to effective demand; it may lead to more capital intensive modes of production ... and it may produce through R & D a greater measure of technical progress."[53] Deger observes that while arms production activities on the whole are expected to provide a potential source of spin-off if the domestic industrial base can respond, the extent of these spin-offs is often overstated.

What then can be concluded regarding the potential contributions of the field of development economics to defence industrialisation in the NICs? Clearly this part of the economics literature has been consumed with the question of whether defence spending, and by association, arms production, positively, negatively or ambiguously affects growth and development. Such a normative problem, however, deters as well as sidesteps the thorny task of substantively clarifying the relationship between arms production and industrialisation.

To determine the interrelationship between arms production and industrialisation in the NICs, we need detailed investigations of the nexus between the defence and manufacturing sectors, to which cross-country, macrostatistical analyses are inappropriate methodological tools. As is foreshadowed here, case study analyses of Brazilian and Indian defence industrialisation reveals that India has paid a high societal price -- in terms of lower productivity, duplicative research and manufacturing efforts, larger defence expenditures -- because of the state's failure to integrate broader civilian manufacturing into its autarkic defence production sector. This finding would not have been apparent within the limited guns versus butter, cost-benefit calculus of the development economics approach to defence industrialisation in the NICs.

While the international relations literature tends to describe the growing defence production capabilities of the NICs in isolation from the process of industrialisation, neither neoclassical economics nor comparative politics analyse industrialisation in the NICs with any particular sectoral focus on defence. As mentioned previously, the latter two literatures offer competing explanations of rapid industrialisation in the NICs. Neoclassical economics emphasises the primary role of market forces and the adoption of astute policies by "rational" governments. In contrast, comparative politics focuses on the political bases of industrialisation, delineating the political, historical, ideological, and social factors that have conditioned the NICs' manufactured export performance. However, neoclassical economics and comparative politics have both assigned an overly limited role to the firm and of technology. As a consequence, they analytically fail to capture the complex process by which firms as well as states do or do not achieve international competitiveness.

Neoclassical Economics

Neoclassical economics correlates the NICs' rapid industrialisation and manufactured export performance to the successful application of the theory of comparative advantage with export-led growth strategies. According to comparative advantage-based analyses, the NICs' reliance on market forces to determine factor prices (particularly wage rates) and the removal of trade distortions and biases quickened the pace of industrialisation and exports of labour-intensive manufactured goods.[54] Additionally, the impressive rates of growth achieved by the East Asian NICs (9.4%) in contrast to the Latin American NICs (6.9%) over 1960-83 were used by neoclassical theorists to assert the superiority of export-oriented versus import-substitution industrialisation strategies.[55] This tendency to view industrialisation and external orientation as causally related is rife in neoclassical discussions of the positive effects that exporting activities have had on total factor productivity in the NICs. Balassa et al. and Krueger, for example, suggest that competitive pressures force NIC exporters to improve quality, economise on scarce foreign inputs, reduce production costs, develop economies of scale, and to respond faster to market changes.[56]

Nevertheless, possible neoclassical contributions to explanations of defence industrialisation in the NICs are extremely limited and inadequate primarily for three interconnected reasons. First, they assign an extraordinarily narrow and counterfactual role to the state, to the firm and to technology. The neoclassical economics literature provides a fairly prescriptive description of the process of industrialisation in the NICs, and explains the success or failure of states to implement the correct industrial strategies in terms of the rational/irrational behaviour of policymakers. Little, for instance, contends that, "the success [of the East Asian NICs] is almost entirely due to good policies and the ability of the people..."[57] Underlying this rational choice view, however, is the assumption of a relatively passive role played by the state. According to the neoclassical view, apart from the provision of institutional arrangements such as a legal and monetary system, all the state has to do is to establish "correct" factor prices and to ensure non-discrimination against exports.

Empirical evidence suggests, however, that this conceptualisation of the state is too narrow. Indeed, as is substantiated later in the review of the literature from comparative politics, neoclassical economists have written about the effects of policy on development, but generally have not examined the determinants of particular policy choices; they treat politics as exogenous.[58] In essence much of the neoclassical economics literature has failed to consider the social, political, ideological, and historical conditions in which industrial policy is developed, and thus cannot explain why different industrialisation strategies are chosen, persist and shift among the NICs.

A second, related theoretical weakness is that neoclassical explanations fail to specify the contributions of firms and states to comparative advantage itself. For example, according to one critic:

> the only agents taken into consideration by neo-classical theoreticians are the *countries*. However, these nation-states are reduced to a blueprint or abstraction. They are merely containers of given combinations of factors. Their only reality is to constitute a pretendably insuperable barrier to the movement of productive factors.[59]

In addition, the neoclassical literature offers an essentially uniform explanation for the economic performance of all the Asian NICs. Yet, as Fransman notes, "it is clear that there are radical differences in the extent and forms of government intervention undertaken by each of the four states."[60] There are in fact many country case studies that explicate the specific mechanisms -- R & D support, export incentives, investment capital -- governments use to promote industrialisation in such NICs as South Korea, Hong Kong, Singapore, Taiwan, and Brazil.[61]

A final criticism of the neoclassical economics literature is that its adherence to the theory of comparative advantage precludes a fuller analytic explanation of the role of technology in the industrialisation process in the NICs. Following the work of Hicks, the prevailing conceptualisation is that changes in technology are simply induced by changes in relative factor prices.[62] In the very highly stylised models used in trade theory, "technology" is taken to be freely available to all countries and, within countries, to all firms. Countries simply settle on appropriate levels of capital/labour intensities in accordance with their factor price ratios. Firms in a given industry all have the same production function and select their factor inputs according to those ratios, shifting costlessly along the function as the ratios change.

Fundamentally, however, the neoclassical emphasis on resource endowment, factor prices and the assumption that productivity is exogenously determined suppresses questions about the determinants of technical and productivity change, and hence international competitiveness. At issue here is the limited ability of neoclassical economics to incorporate the role of technology into their explanations of industrialisation and economic growth since technology is assumed to be exogenously determined and the acquisition of technical knowledge unproblematic.[63]

Indeed, writers such as Nelson & Winter increasingly criticised neoclassical economics for its oversimplification of technical change and for its obfuscation of the role of this "large residual" in economic growth:

> What we now know about technical change should not be comforting to an economist who has been holding the hypothesis that technical change can be easily accommodated within an augmented neo-classical model. Nor can the problem here be brushed aside as involving a phenomenon that is "small" relative to those that are well handled by the theory; rather it relates to a phenomenon that all analysts (or virtually all) acknowledge as the central one in economic growth. The tail now wags the dog. And the dog does not fit the tail very well. The neo-classical approach to growth theory has taken us down a smooth road to a dead end.[64]

Indicative of this criticism, is the growing recognition in the economics literature that innovation and technological change have a central role in the industrialisation process in the advanced industrialised countries as well as in the NICs. For example, an increasing number of case studies have begun to highlight the importance of technological innovation for industrial competitiveness in OECD countries.[65] The rapid industrialisation experience of Japan especially, and its successful competition in international trade, has led to an awareness and interest in researching technology development in the NICs and in the Third World generally.[66] Though a growing literature now exists on the economics of technological innovation and industrialisation in the NICs, it has, however, tended to ignore the generation of technology by indigenous firms. There are three principle reasons for this neglect.

The first is economists' long-standing preoccupation with major innovations as the main source of technological progress. Technological change has thus been typically associated with innovations at the global frontier of technology, rather than along the frontier.[67] Since major innovations are assumed to take place in the advanced industrialised countries, neoclassical theory presumes that (to the extent that technological lags are admitted) that the transfer, assimilation and absorption of technology by industrialising countries is automatic and costless.

A second, related reason is the near exclusive focus by both neoclassical and development economics on questions concerning the cost of transferring foreign technology and on the choice of technique. Stewart and James note that, "In the 1960s and 1970s most research on technology [in the industrialising countries] ... was directed at the question of labour or capital intensity of production technique (sometimes described as the "neoclassical" question).[68]

Such a perspective has led various economic analyses of technology and industrialisation in the NICs to concentrate on "the terms of transfer and imperfections in international technology markets, rather than on the efficiency with which the technology is used by the importer."[69] Furthermore, one is asked implicitly to assume that once the patent, design, equipment, process technology has been transferred, firms (buyer and seller) will share the same stock of technical knowledge. But if firms in the neoclassical tradition have equal access and employ the same technologies, why then do some firms in the same sector succeed in manufacturing and others do not?

The result of such theoretical blinders is the tendency by neoclassical as well as some development economists to relegate the NICs to the role of manufacturers and exporters of labour-intensive, low-skill manufacturers, and the recipients of technology (via direct foreign investment/licensing) from the advanced industrialised countries. Hence there is a peculiar parallel between the economics and international relations literature, both of which assign these states to the lowest tier in the international political economy. As Lall pointedly notes of the neoclassical perspective, "There is, in sum, little ... which would lead us to expect indigenous enterprises from developing countries would enter international markets as competitive sellers of fairly broad ranges of technology."[70]

How then can neoclassical economics account for the emergence of the NICs' international competitiveness in what is obviously one of if not the most technologically sophisticated industries in the world: defence production? Clearly then we need to move beyond the conventional neoclassical paradigm and to integrate technology and its generation, use and diffusion by firms into our analyses of how states attain particular industrial competitiveness in global markets. We also need to define how such factors as entrepreneurship, market structure, a state's industrial, trade and technology policies affect firms' behaviour and technological capabilities.

More recent literature from a neo-Schumpeterian tradition has attempted to redress such lacunas in the literature on technology and industrialisation in the NICs.[71] Briefly, this emerging literature has focused on the dynamic process of technological change in the NICs as well as in Third World countries. Two key concepts that underpin such analyses are "technological capability" and "technical/technological change". The former refers to the ability of a firm to transform inputs into outputs; the latter, refers to the introduction of new ways of transforming inputs into outputs.

There are two primary research agendas within this literature. The first describes the nature of technological change and the various factors -- firms, market structures, technologies, government policies -- that affect the acquisition of technological capability in these countries. The consensus from such studies is that regardless of the initial pattern of acquisition, the assimilation and effective utilisation of technology by the industrialising countries is not automatic and costless, rather it involves considerable technological change and local innovation.

Attempts to measure the output of technological change via data analyses of patents, bilbiometrics etc., has led to the second area of research: attempting to compare the technological capability of different countries by examining their technology exports. As mentioned above, technology exports are of particular interest to economists because they exemplify the changes in comparative advantage that accompany the process of industrialisation. As a consequence, much of this literature has sought to analyse what is behind technology exports in the NICs, and more importantly, to devise how firms developed the technological capabilities behind those exports in the first place.[72]

While some of this literature consists of empirical, micro-based, individual firm studies, which do, in fact, explore technology development at the firm level, the absence of any broader comparative theoretical preconception makes the findings of such studies hard to generalise. Lall's work on Indian engineering companies, Da Cruz's study of Brazilian metalworking firms, and Katz's study of select Latin American manufacturing industries, are examples of this approach.[73] As acknowledged by two of the foremost researchers of this field, "The relationship between technological change and industrial development is an area where practical endeavors have outpaced analytical understanding."[74]

The evident failure of neoclassical economics to integrate the role of the state and the factors conditioning its influence into explanations of industrialisation in the NICs ignited rival theories from the political science subfield of comparative politics. In reaction to neoclassical as well as dependency approaches to economic development, the comparative politics literature has framed the issue in terms of explaining why the NICs succeeded in *initiating* industrialisation. Analyses of how the NICs achieved manufactured export competitiveness in the international political economy are couched using a "barrier to entry" framework. As a result, various authors from comparative politics have focused on delineating the political bases of industrialisation.[75]

State activity in the NICs encompasses two distinct roles. First, the state is expected to adjudicate market failures. For example, state intervention in Taiwan, Mexico, and Brazil in the form of creating public sector enterprises in high technology sectors is attributed to the presumed weakness (financial as well as organisational) and inefficiency of local capital. And second, the state is viewed as central to the resolution of collective action problems. The remarkable success of Japan, South Korea, and Taiwan, in contrast to their Latin American counterparts, Brazil and Mexico, is said to be derived from the East Asian states' abilities to resolve conflicting policy goals and coalitional interests.[76]

Common to comparative politics studies of the NICs is the argument that industrialisation requires certain types of domestic political institutions, especially "strong" states, which are sufficiently insulated from domestic interest groups.[77] (Insulation permits the formulation of coherent, cohesive policies and enables effective mediation with foreign capital.)[78] Nevertheless, analyses of how the state influences the process of industrialisation vary considerably. Some scholars emphasise the nature of the political regime, class formation, while others note the importance of the sociological characteristics of the state's policymakers. As the following select overview of the comparative politics literature reveals, few if any of these studies, however, attribute the NICs' emergence and continued manufactured export growth to firm-level factors.

One of the most articulate and elaborate theoretical analyses of the state and industrialisation in the NICs is provided by Haggard.[79] In contrasting the two industrial "growth strategies" -- import substitution and export-led -- Haggard asserts that the "puzzle is to explain why countries adopted the industrial strategies they did, and why they sustained them over time."[80] To answer these questions, Haggard bases his analysis on the role and weight of four independent variables: the international system (e.g. source of external pressure), domestic coalitions, political institutions, and ideas. He then explores the "logic, strengths and weaknesses" of each through a comparative historical analysis of four East Asian and two Latin American NICs. In essence, Haggard, as he has done elsewhere, argues that because the East Asian NICs have enjoyed substantial autonomy from both domestic and international forces, these states have been able to provide and implement the political and economic policies responsible for the success of the export-led industrialisation strategy.

Another subset of the comparative politics literature has used industry-based studies to demonstrate the active role played by the state in initiating and promoting industrialisation, especially in high technology sectors.[81] Work by Grieco on the Indian computer industry and by Adler on the Brazilian as well as Argentine computer and nuclear sectors are particularly representative of statist approaches.[82] Using a bargaining school framework Grieco suggests that the Indian government was able successfully to mold the activities of multinational computer industry to secure stated policy goals.[83] Reviewing the period 1967-80, Grieco finds that India initially made very little progress in attaining its computer goals related to corporate organisation, market structure and technology transfer, but it achieved significant progress in later years. Aiding this success, however, were the technology changes in the international computer industry, combined with changes in the industry's structure, which expanded the Indian state's computer opportunities and therefore its potential bargaining power.

While sympathetic to Grieco's criticism of the dependency school for its deterministic belief that in areas of high technology owned by MNCs, developing countries will fail in any attempt to initiate sectoral-based industrialisation, Adler argues that Grieco's methodology is inadequate. "...case studies of domestic technological and industrial development in one sector may be of limited value in explaining why some developing countries succeed in domestic high-technology projects, while others fail despite their best efforts."[84] In basing his analysis of the contrasting experiences of the Argentine and Brazilian computer and nuclear industries, Adler implicitly differentiates himself from both Haggard and Grieco, when he suggest that one must look beyond the interaction of domestic and international structural factors and to consider the crucial role played by ideological groups:

> success was related to the ideologies of key actors as well as their perception of their country's ability to set and attain technological goals. Ideologically motivated groups of scientists and technocrats -- referred here as guerrillas -- ... were able to affect the decision-making processes of their state institutions.[85]

Adler goes on to note the importance of bureaucratic insulation which shielded these "pragmatic anti-dependent guerrillas" from clientelism and domestic political attack.

Having now selectively surveyed the literature from comparative politics, are there any insights on which we can base our analysis of defence industrialisation in the NICs? From the outset it can be said that though the state is a necessary factor in explaining industrialisation in the NICs, it is not sufficient. The critical point to be made is that the near exclusive focus in the comparative politics literature on entry by the NICs into industrialisation is too static, and leads to the diminution of the role played by firms.

As this author suggests, the further a country or a state moves in the industrialisation process, the more important non-state actors such as firms become. Moreover, there may in fact be an irrevocable trade-off between the need for the state to overcome initial barriers to entry in the industrialisation process such as, the creation of high technology industries (including defence), and the competitiveness of that industry in the long run. Indeed, the implicitly static industry analyses of Grieco and Adler fail to consider the possibility or effects of such a tradeoff. As a consequence their arguments about the power of states and sociological factors to influence the pattern of sectoral investment crumble under the test of time.

For example, Grieco's claim that the Indian government has succeeded in creating an indigenous, competitive and technologically advanced computer industry does not hold up to empirical scrutiny. Recent studies, including those from the Indian government itself, highlight several weaknesses in the organisation, structure and technology base of the country's domestic computer industry: high import intensity, negligible value added, huge technology lags (3-5 years), and uncompetitive domestic prices (on average 2.5 times higher than international prices).[86] Some computer industry analysts have argued further that India's hard core bargaining strategy with the multinationals was tantamount "to hitching our wagons to a particular level of technology without allowing for flexibility or maneouvrability."[87]

Adler's conviction that the Brazilian computer industry derives its longevity and success because of ideologically motivated policymakers also is problematic. By failing to weigh the interests of such non-state actors as Brazil's manufacturing firms, which have been strong opponents of the Brazilian government's sectoral policy (because of higher indirect costs of production), Adler failed to anticipate the power of these economic actors in gaining the recent revocation of the informatics legislation, which has nurtured and protected this industry.

A second critical weakness of the statist approaches is their treatment of firms as exogenous to the process of industrialisation in the NICs. Like their neoclassical counterparts, most comparative politics theorists, if they discuss firms at all, simply treat firms as black boxes -- firms simply take orders from the state. In addition, by limiting analyses primarily to explaining the common factors conditioning the successful adoption of export-led industrialisation strategies by some NICs, comparative politics cannot account for the divergent performances at the sectoral as opposed to the macroeconomic level. Even those studies which are sensitive to this methodological issues, e.g. Adler's comparative study of the Brazilian and Argentine nuclear and informatics industry, treat sectors/industries as homogeneous and monolithic in their preferences and behaviour.

The author concludes her review of comparative politics by suggesting that we need to understand and to incorporate the role of firms into analyses of the industrialisation process. We need explanations for differences between firms in the same sector within the same country and between different countries. As pointed out by business scholars, firms do not merely react to state policies and other factors affecting their external environments. "[M]any have actively sought to create new, internal sources of advantage. As they jockey for position [in international markets], firms often adopt quite different strategies within the same industry."[88] To reiterate my argument, the ability of the state to initiate and more importantly, to *sustain* industrialisation depends upon the technological capabilities and strategies of firms and the cooperation between firms and state to ensure that external economies from any one industrial activity are captured within the national unit.

International Political Economy

As mentioned previously, the literature from international political economy focuses on the questions of how power and wealth are created and whether their redistribution generates conflict or cooperation. The specific relationship between defence and industrialisation is central to political economists', especially mercantilists', preoccupation with how the state derives and ensures national military capabilities (power) and economic competitiveness in international markets (wealth).[89] Research on these related sets of questions has been profoundly influenced by a particular neo-mercantilist conception of international political economy provided by Gilpin:

> Political economy ... means the reciprocal and dynamic interaction in international relations of the pursuit of wealth and the pursuit of power. In the short run, the distribution of power and the nature of the political system are the major determinants of this framework within which wealth is produced and distributed. In the long run, however, shifts in economic efficiency and in the location of economic activity tend to undermine and transform the existing political system.[90]

Although this concept has been quite influential, much of the research based on it is conceptually flawed. As will be shown below, firms play a critical role in this reciprocal interaction between wealth and power in both the advanced and newly industrialising countries. However, the existing literature in international political economy often ignores the role of firms and fails to grasp their significance. Two examples illustrate this failure.

The first is *The Political Economy of International Relations*. In this book, Gilpin refines his definition of international political economy further, emphasising the organisation of the pursuit of power and wealth by states. The essence of this organisation is the interaction between the state and the market:

> The state and the market have tended to displace other forms of political and economic organisation in the modern world because of their efficiency in the production of power and/or wealth ... State and market interact to influence the distribution of power and wealth in international relations.[91]

Gilpin also clearly affirms the impact of strategic industries in spurring inter-state conflict, which is an important element in this author's argument that rivalry between states is based on the competitive development of the strategic defence and capital goods industries. His discussion of this impact, however, continues to emphasise the interaction of states and markets and to disregard the strategic role of firms:

> Embedded in this relationship of state and market ... is the interaction of economic and political change that gives rise to an intense competition among states over the global location of economic activities, especially the so-called commanding heights of modern industry.[92]

In brief, Gilpin argues that states and markets are the actors, and their interaction creates and causes shifts in the distribution of wealth and power.

Gilpin's understanding of the relation between the state and the market seems to be based on an analogy with the neoclassical model of a monopoly. In a monopoly, a single supplier faces a set of consumers that are individually too small to affect the price. Although the monopolist must be concerned with the aggregate of consumers' behaviour, i.e., the demand curve facing the monopolist, there is no strategic interaction between the monopolist and an individual consumer because the behaviour of the latter has no effect on the monopolist. In this setting, the monopolist sets prices and quantities and the consumers act as price takers. In Gilpin's discussion of the relationship between the state and market, the state corresponds to a monopoly supplier that sets governmental policies to which economic actors respond as price or, rather, policy takers.

In Gilpin's theoretical discussion of states and markets, although not in his historical description of, for example the role of multinational corporations, there is no strategic interaction between the state and the economic actors comprising the market. "The market," in Gilpin's words, "is a universe composed mainly of prices and quantities; the autonomous economic agent *responding to price signals* provides the basis of decision."[93] (Italics added by the author for emphasis.) Firms, as strategic actors, play no role in Gilpin's theoretical conceptualisation. The burden of this thesis is, in part, to show that we cannot adequately explain the origins of and the shifts in international competitiveness without treating firms as strategic actors and examining the strategic interaction between firms and the state.

The second example of the failure to integrate the role of the firm is Sen's *The Military Origins of Industrialisation and Trade Rivalry*, which is perhaps the most valuable and extensive treatment from international political economy on the role of the state in ensuring national defence and industrial competitiveness.[94] Since it is the most sophisticated and systematic discussion of this issue, it is useful to summarise Sen's argument briefly.

Using the input-output research of a group of development economists, Sen begins his thesis with two of this group's findings.[95] First, there are similar "structures of production" in different countries at the same stage of economic growth, as measured by per capita income.[96] Second, there exists a group of industries that are essential for industrialisation and economic growth. Sen suggests that this economic phenomenon arises substantially from states' efforts to industrialise in response to the pressures of international competition:

> The state plays a crucial role in fostering and maintaining this pattern of self-sufficient industrial structure. The reason for this is to be found in the competitive relations between states in the international political system. Once the process of industrialisation has reached a significant stage in one country, others are compelled to respond by industrialising themselves....[97]

More specifically Sen argues that the fundamental attributes of industrialisation are importantly predetermined by states' efforts to establish industries for defence and economic self-sufficiency.

He indicates that in a number of latecomer countries, including Japan, Brazil and India, states have assumed a preeminent role in the creation of these industries for a variety of reasons related to market failure and high barriers to entry. Having linked the motivations for state intervention to the desire and necessity to maintain defence capabilities and industrial competitiveness, Sen then considers the effects of government intervention by these latecomer countries on the international system.

The imperative of states to develop strategic industries, which often cannot be supported through domestic consumption alone, leads to the creation of global surplus capacity and ultimately to international trade conflicts. According to Sen:

> The latecomer countries thus unavoidably threaten the established position of firstcomer countries [e.g. United States, Great Britain, Germany etc.]. This threat provokes economic rivalry over markets in the latecomer country itself, in third markets, and in the domestic market of the firstcomer.[98]

Sen's work thus provides an insightful study about the historic sources of contemporary international trade conflict and rivalry deriving from state pursuit of power and wealth, via the formation of strategic defence and capital goods industries.

There is, however, a fundamental weakness in this important contribution because of the author's failure to integrate the role of firms into his analysis. If there are observable structural economic similarities between countries, why then are there subsequent differences between states' defence/industrial capabilities and levels of international competitiveness, given equal motivations and patterns of state intervention? Although Sen outlines the various common policies that latecomer states have used to foster these strategic industries, he does not adequately link such state intervention to the attainment of international competitiveness in these industries. In focusing solely on the motivations and patterns of state intervention across states and not on firms, he cannot explain variance at the national or industry level.

Referring to two of Sen's cases of latecomer countries, India and Brazil, why is it that India's defence and capital goods industries are far less self-sufficient and internationally competitive than Brazil's, particularly when the Indian government has been far more interventionist than the Brazilian state in creating and sustaining these strategic industries? The development of these strategic industries is obviously not merely the outcome of unilateral actions by the state. This critical weakness may stem from Sen's neo-mercantilist focus on the state as the predominant actor in international relations. By leaving out the critical role played by the firm and its strategic interaction with the state, Sen is unable to explain more fully the relationship between defence and industrialisation.

Why Firms Matter: A Conceptual Framework

The preceding review of the literature has illustrated that existing scholarship from political science and economics has generally neglected the role played by firms in defence industrialisation and in the attainment of international competitiveness. This Ph.D. thesis will demonstrate the importance of firms to these processes. It thereby contributes to a better understanding of how firms influence the international distribution of competitive advantage. To meet this objective, the author investigates the development of the defence and capital goods industries by the NICs. As shown above, these industries are critical to the creation and distribution of power and wealth by states. They strongly determine a state's hierarchical position in the international system.

The central task of this thesis is to explain the development of these strategic industries by the NICs, and to account for the variance in their performance and international competitiveness across the NICs. The thesis uses comparative case studies from Brazil and India, two prominent regional political and economic powers, whose industrial bases are similar, though their strategic environments differ markedly.

As indicated in Table 2.1, *Brazil & India: Defence Industrial Indicators*, India's capital goods sector is slightly larger than Brazil's in terms of capital goods as percentage of manufacturing value added, and the number of capital goods establishments.[99]

Table 2.1

Brazil & India: Defence Industrial Indicators

	Brazil	India
Gross Domestic Product (1985) Current U.S. Millions*	188,250.	175,710.
Defence Expenditure/GDP average annual percentage**	2.0%	6.0%
R & D spending as a percent of GNP 1984/1982*	0.7%	0.9%
Capital Goods as a percentage of manufacturing value added (1985)*	25.4%	27.4%
Number of Capital Goods Industries (thousands)***	15.8	18.3
Number of scientists & engineers (thousands)*	32.5	100.1

Source: *Lall
**International Institute for Stategic Studies, *The Military Balance*, London: IISS, various years.
***Chudnovsky et al.

Dramatic differences are evident, however, between the Brazilian and Indian governments' allocation of resources to defence. India well outstrips Brazil in terms of spending on defence and public-sector R & D, and in the size of its scientific-engineering base.

Nevertheless, during the late 1970s and throughout the 1980s Brazil rose to become the leading defence producer and exporter among the newly industrialising countries. India, on the other hand, became the leading arms importer among the industrialising countries and in the Third World.[100] How then did Brazil achieve its position as a leading defence manufacturer and exporter, despite its lack of a strategic threat and comparatively smaller defence industrial base? To explain the relative performance and competitiveness of Brazil's defence industry in contrast to India's, the author provides a general conceptual framework for understanding this contrast. Although this conceptual framework is applied to the cases of Brazil and India, it is equally applicable to other industrialising countries.[101]

Three important dimensions define this conceptual framework. These three dimensions are centripetal to explaining the comparative development and competitiveness of the defence industries in the newly industrialising countries. The first dimension is the technology strategies of the defence and capital goods firms. A firm's technology strategy vitally affects the development of its underlying technological and manufacturing capabilities.[102] Differences in strategies can affect a firm's relative performance within an industry. A technology strategy entails decisions and efforts by a firm to monitor and search for new technologies, to invest in its own R & D capabilities, to choose among different technologies, to absorb, and to adapt these technologies in ways that augment the capabilities of the firm.

The successful development of defence industrial and export capabilities by a firm generally requires a technology strategy that involves all of these activities. For instance, in order to broaden a firm's existing technological capability, it is often necessary to monitor and search for relevant technological innovations internationally. Often, however, firms bypass and neglect this activity with costly results. As discussed later in the case study on India, one of the reasons for the perpetual manufacturing delays and technological obsolescence of India's Advanced Light Helicopter and Light Combat Aircraft projects was the failure of Hindustan Aeronautics to keep abreast of important weapons technologies.

A more critical component of a firm's technology strategy is the ability to choose wisely among different technologies and to select the means for its successful transfer and absorption. Different technologies afford the firm with different opportunities to expand its productivity, performance and competitiveness. Thus, in choosing a particular technology, a firm is affecting its own future technological learning and experience, and, hence its capabilities.

Many defence producers in the NICs often want and choose foreign technologies that are very close to the international technological frontier. In doing so, firms then have to consider how this technology can be effectively transferred through, for example, licensing agreements, coproduction arrangements, training and technical assistance programmes. In selecting how the technology is to be transferred, the firm consciously or unconsciously determines the prospects for its subsequent assimilation and modification. This, in turn, affects the firm's long-term technological and industrial capabilities. As we shall see shortly in the Brazilian case study, Embraer's emergence as a leading manufacturer of small military and commercial aircraft was based on a conscious technology strategy that astutely selected foreign technologies, such as advanced composite material technology, and ensured their transfer and absorption through coproduction, offset and other arrangements with advanced foreign aircraft manufacturers.

The second dimension to the conceptual framework is the ability of a NIC to develop an integrated defence-industrial base, characterised by strong interaction between defence and capital goods firms. The author maintains that the successful performance and competitiveness of some NIC arms producers is based on their tight industry linkages to a highly diversified and specialised capital goods sector. As demonstrated above, the capital goods sector is the locus of technological innovation in an economy.[103] The forward and backward flows between this producing industry and its user industry, the defence sector, are critical to ensuring the rapid inter-sectoral diffusion of related technologies and manufacturing processes. Indeed, without the interaction between the defence and capital goods firms, technological capabilities are likely to remain internalised within a firm, and will not develop sufficiently because the market is too narrow. One example of the beneficial impact of inter-firm linkages on the competitiveness of the Brazil's defence industry involves the capital goods firm, Metal Leve, which produces special alloy pistons for a Brazilian aircraft manufacturer, Embraer. Embraer's initial demand for and technology assistance to Metal Leve enabled the latter to develop the high quality and economies of scale necessary for attaining export competitiveness.

State intervention, particularly its trade, industrial and technology policies is the third and final dimension of the author's conceptual framework. Differences in the extent and form of state intervention affect the relative pace, development and international competitiveness of the NICs' defence industrial capabilities. Such differences may include whether a state's trade policy is more inward or outward oriented; whether its industrial policies are highly regulatory or less interventionist; and whether its technology policy emphasises self-reliance through government-assisted R & D, or relies more on private-sector R & D initiatives.

In choosing among these various policies, a state influences the competitive environment of firms and affects the linkages between capital goods and defence firms. For example, a government's industrial policies can affect the market structure in which firms interact. Differences in the distribution of firm sizes, degrees of vertical integration and market concentration ratios have implications for the rate of technological innovation and diffusion among defence and capital goods firms. For instance, a highly concentrated market structure, dominated by a few, large firms, may preempt opportunities for technological learning and diffusion, which could occur in a more competitive market characterised by an evenly distributed number and sizes of firms.

By regulating the pressure of international competition on firms through, for example, controls on direct foreign investment or the provision of export incentives, a state's trade policy also influences the technological development and competitiveness of its defence and capital goods firms. It is now widely recognised, for example, that exposure to the international market through export activities will have beneficial effects on a firm's continued competitiveness. Indeed, the international, as opposed to the domestic market, forces firms to be more efficient in terms of cost, quality, delivery times, and after-sales service.[104] In sum, where an industrialising country lies along the three dimensions -- firms' technology strategies, the development of an integrated defence-industrial base, and a state's trade, industrial and technology policies -- does much to explain the development and level of international competitiveness of its defence sector.

The Cases of Brazil and India

Having outlined the conceptual framework, the author would like to use it to explain briefly the contrast in Brazil's and India's defence industries. This contrast will be developed at length in the subsequent chapters. As is foreshadowed here, the successful technological development and international competitiveness of Brazil's defence and capital goods firms resulted from these firms' own long-term, cumulative R & D efforts, and from a strategy that emphasised building systematically on foreign technological inputs -- licensing, training programmes abroad, coproduction arrangements.

The success of Brazil's defence industry also derived from strong interindustry linkages with the capital goods sector. As the Brazilian case study will document, one of the reasons for the unusually high inter-industry linkages is that many of the country's capital goods firms diversified into military production beginning in the late 1960s-early 1970s. Reacting to various recessions in the domestic capital goods sector, some Brazilian firms became important defence manufacturers and global exporters. Other smaller capital goods firms converted part of their production lines to supply these larger domestic defence manufacturers. The beneficial effects of these *inter*-sectoral and *intra*-sectoral linkages on Brazilian defence and manufacturing competitiveness are highlighted in Chapter 5. Briefly they include more rapid technological development and diffusion between the capital goods and defence industries, the generation of economies of scale and specialisation, and the promotion of capital goods exports by smaller subcontracting firms because of the international reputation effects enjoyed by their larger suppliers.

In Brazil, the government has limited its involvement in the defence industry. It has generally used its trade, industrial and technology policies to provide the necessary infrastructure which facilitates firm initiatives. The Brazilian government has tried to create a conducive environment that stimulates the technology acquisition and upgrading efforts of defence and capital goods firms by encouraging linkages to its R & D institutes and by financing private-sector R & D. The government has also promoted the development of the capital goods industry and has strengthened linkages between the defence and capital goods firms, via domestic content policies and by subsidising purchases of local capital goods. In addition, the Brazilian government's trade policy of promoting direct foreign investment and exports has induced defence and capital goods firms to employ technologies that are very close to the international frontier.

This issue of competitive pressure is a critical factor explaining the different outcomes in Brazil and India. In effect by applying competitive pressures from domestic as well as international sources, and by subsidising firms' technological efforts, the Brazilian government has incited close competition between firms. Brazilian defence and capital goods firms are thus induced to make large investments in technological learning and in other R & D activities, which, in turn, contribute to these firms' international competitiveness.

By comparison, the failure of India's defence industry to develop indigenously and to achieve at least a modicum of export competitiveness stems from shortcomings in each of the three dimensions. First, Indian firms' technology strategies have not enabled them to generate new or even improve existing technologies, not only because of these firms' limited desire to learn but because of the inefficient use of foreign technologies. In many cases this behaviour by Indian firms was affected by the lack of interaction between the defence and capital goods industries.

Indeed, as evidenced in Chapter 4, the physical and technological linkages between the country's capital goods sector and its defence industries are extremely fragmented, and have lead to the autarkic, duplicative development of each sector. This lack of integration has prevented the defence and capital goods industries from becoming more innovative and efficient through inter-sectoral learning and sharing.

In stark contrast to the Brazilian government's primarily indirect intervention in the defence and capital goods industries, Indian government intervention in these vital industries has been extraordinarily invasive. The Indian government has used various policies to direct the industrial and technological capabilities of its defence and capital goods manufacturers. In particular, the Indian government has emphasised a technology push approach through the development of a massive government science and technology infrastructure. However, as the case study on India will show, this infrastructure is characterised by excessive fragmentation, poor coordination and a high degree of concentration in R & D activities in government laboratories. Furthermore, given the relatively narrow focus on defence-related R & D and the institutional separation of the defence and capital goods industries, potential commercial spillovers have been limited.

The Indian government has sought to protect and insulate its capital goods firms from international market forces by tightly regulating direct foreign investment and imports of foreign technologies. Indeed, of the NICs, the Indian government has had the most restrictive trade policies. The combined effects of these policies have blunted incentives for India's defence and capital goods firms to invest and develop technological capabilities, leading to the structural obsolescence of these industries. This lack of exposure and access to foreign technologies has retarded the growth and exports of the country's defence and manufacturing industries.

Conclusion

In sum, the central question motivating this thesis is: What accounts for the variance in defence-industrial performance and international competitiveness among the newly industrialising countries? The variance that we observe across these states poses two puzzles for existing theoretical approaches, discussed above.

The first puzzle is that international relations theory, particularly the subfield of international security studies, would predict that states facing greater strategic threats would have the most technologically developed and competitive defence production capabilities. However, this is not what we will observe in the cases of Brazil and India. These case studies will show that the causal relationship of a country's external environment on its defence-industrial capabilities is underspecified. For example, Chapter 3 will document how, **in the absence of a strategic threat**, Brazil achieved its position as the leading arms producer and exporter in the NICs. Chapter 4 will reveal why, **in spite of the enormous strategic pressures** -- threat of war with Pakistan and China as well as a regional arms race -- India's defence industry has largely failed to meet those threats.

The variance in the defence-industrial capabilities and competitiveness across the NICs raises yet another theoretical puzzle. International political economy and comparative politics theories suggest that the international context (competitive relations between states) and state power ("strong"/"weak" states) jointly should explain the variance in the industrial and export performance of states' defence industries.[105] In particular, these theories argue that strong states should be relatively more effective in achieving certain economic objectives.[106] But, as Chapter 4 will highlight, the Indian government, a purportedly "strong" state, with many policy instruments at its disposal, has been unable to develop and sustain a competent indigenous defence industry. Clearly this multivariate theoretical explanation, linking state strength to desired industrial outcomes, is also underdetermined.

The author's conceptual framework helps resolve these puzzles by explaining the variance in the NICs' defence industrial capabilities in terms of the three dimensions: 1) the technological strategies of firms; 2) an integrated defence-industrial base characterised by strong interindustry linkages between the defence and capital goods sectors; and 3) government trade, industrial and technology policies. This framework suggests the following hypotheses:

1) The deeper a firm's technology strategy, the more likely that firm will become a competitive manufacturer and exporter. The term "deeper" refers to the ability of the firm to search, select wisely among foreign technologies, to secure their transference and effective absorption, and to investment in its own R & D in ways that augment the future technological capabilities of the firm.

2) The tighter and more structured inter-industry linkages are between the defence and capital goods sector, the more likely the country's defence industry will be technologically capable and export competitive.

3) The more a government's trade, industrial and technology policies act to help stimulate firms' technological efforts and to expose them to pressures from both the domestic and international markets, the more competitive and technologically advanced a country's defence/capital goods firms will be.

To conclude, the author maintains that in applying these three hypotheses to the case studies of Brazil and India, she is successfully able to explain the competitiveness of Brazil's defence industry in contrast to India's.

Endotes

[1]Kenneth Waltz (1979), for example, argues that conflict or war is less likely to occur in an international system characterised by a bipolar distribution of power than in a multipolar system. Robert Gilpin (1981) posits that the process of uneven growth between states leads to hegemonic wars. Robert Keohane (1984) attempts to show how regimes may help international cooperation survive the relative decline of a hegemonic power and the emergence of a more even distribution of power in the international system. Sen (1984) has argued that the industrial rise of latecomer countries, such as Japan and the NICs, unavoidably threatens the established positions of the firstcomer countries (e.g. United States, Germany) provoking economic rivalry and conflict in international markets.

[2]Indeed, understanding the determinants of international economic competitiveness is especially relevant in the 1990s when the very relationship between wealth and power, as traditionally conceived, is being transformed. As the threat of global military conflict recedes, states according to Stopford and Strange, are now competing over the means to create wealth within their territory rather than for power over more territory. "Where [states] used to compete for power as a means to wealth, they now compete more for wealth as a means to power." See John M. Stopford and Susan Strange with John Henley, *Rival States, Rival Firms: Competition for World Market Shares* (Cambridge: Cambridge University Press, 1991), 1.

[3]See G. Dosi, C. Freeman, R.R. Nelson, G. Silverberg, and L. Soete, eds., *Technical Change and Economic Theory* (London: Frances Pinter Publishers, 1988); Jorge Niosi, ed., *Technology and National Competitiveness: Oligopoly, Technological Innovation, and International Competition* (Montreal: McGill-Queen's University Press, 1991); and C. Freeman, *The Economics of Industrial Innovation* (London: Francis Pinter, 1982).

[4]Stephen Cohen and John Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy*, (New York: Basic Books, 1987), 109-110.

[5]Laura D'Andrea Tyson, *Who's Bashing Whom? Trade Conflict in High-Technology Industries* (Washington, D.C.: Institute for International Economics, 1992); W. Sandholtz, M. Borrus and J. Zysman et al., *The Highest Stakes* (New York: Oxford University Press, 1992). For historical treatments see Nathan Rosenberg, *Perspectives on Technology* (Cambridge: Cambridge University Press, 1976); and Gautam Sen, *The Military Origins of Industrialisation and Trade Rivalry* (London: Frances Pinter, 1984).

[6]The term "capital goods" generally refers to the machinery and transport equipment, which enter capital formation. For a specific product breakdown of capital goods one may refer to division 38 of the International Standard Industrial Classification (ISIC) and to section 7 of the Standard International Trade Classification (SITC).

[7]This refers to Sen's (1984) argument that while the impact of military requirements was not the *cause* of industrialisation itself, military needs were "catalytic" in that they were instrumental in stimulating the pace and development of various strategic capital goods industries.

[8]N. Rosenberg, *Perspectives on Technology*, 16. Technological convergence has a two-fold meaning. For instance, industries which manufacture differentiated products can be convergent because of their use of identical or similar types of machinery. Convergence also refers to the manufacturing processes that underlie, for example, the machinery and metal-using sector (e.g. the manufacturing technique of interlocking parts used in the firearms and textile machinery industries).

[9]François Chesnais, "Technological Competitiveness Considered as a Form of Structural Competitiveness," in *Technology and National Competitiveness: Oligopoly, Technological Innovation, and International Competition*, ed., Jorge Niosi (Montreal: McGill-Queen's University Press, 1991), 153.

[10]Rosenberg, 200.

[11]See the classic study Ralph G. Hawtrey, *Economic Aspects of Sovereignty* (London: Longmans, 1952); Klaus Knorr, *Military Power and Potential* (Lexington, MA.: D.C. Heath & Company), 1970; and Sen, *The Military Origins of Industrialisation*. An interesting study of the development of the capital goods industry in relation to military production in Japan is provided by Toshiaki Chokki, "A History of the Machine Tool Industry in Japan," in *Machinery and Economic Development*, ed., Martin Fransman (London: Macmillan Press, 1986). For a timely discussion of the impact of commercial technologies on defence production see Jay Stowsky, "From Spin-Off to Spin-On: Redefining the Military's Role in American Technology Development," in *The Highest Stakes*, eds., W. Sandholtz, M. Borrus and J. Zysman, et al (New York: Oxford University Press, 1992).

[12]Knorr, *Military Power and Potential*, 71.

[13]The industries which comprise the strategic set are: textiles, iron and steel, chemicals, machinery, paper and paper products, and transport equipment. See Sen, *Military Origins of Industrialisation*, 50.

[14]Ibid., 7.

[15]Debate continues, however, over which segments of these industries -- semiconductors, aircraft, motor vehicles, machine tools -- are most vital to ensuring a nation's competitiveness in global markets.

[16]See Sanjaya Lall, *Building Industrial Competitiveness in Developing Countries* (Paris: OECD, 1990); Dieter Ernst and David O'Connor, *Technology and Global Competition: The Challenge for Newly Industrialising Economies* (Paris: OECD, 1989); Stephan Haggard, *Pathways from the Periphery: The Politics of Growth in the Newly Industrialising Countries* (Ithaca: Cornell University Press, 1990); Gary Gereffi and Donald L. Wyman, eds., *Manufacturing Miracles: Paths of Industrialisation in Latin America and East Asia* (Princeton: Princeton University Press, 1990); and Frederic C. Deyo, ed., *The Political Economy of the New Asian Industrialism* (Ithaca: Cornell University Press, 1987).

[17]1983 Report Science, Policy and Technology Committee of the OECD, cited in Chesnais, "Technological Competitiveness Considered as a Form of Structural Competitiveness," in *Technology and National Competitiveness: Oligopoly, Technological Innovation, and International Competition*, ed., Jorge Niosi (Montreal: McGill-Queen's University Press, 1991), 150-51.

[18]See James Everett Katz, ed., *Arms Production in Developing Countries* (Lexington: Lexington Books/D.C. Heath & Company, 1984); James Everett Katz, ed., *The Implications of Third World Military Industrialisation* (Lexington: Lexington Books/D.C. Heath & Company, 1986); Michael Brzoska and Thomas Ohlson, eds., *Arms Production in the Third World* (London: Taylor & Francis, 1986); and Office of Technology Assessment, *The Global Arms Trade* (Washington, D.C.: U.S. Government Printing Office, June 1991).

[19]Ilan Peleg, "Military Production in Third World Countries: A Political Study," in *Threats, Weapons and Foreign Policy*, eds., Pat McGowan and Charles Kegley (Beverely Hills: Sage Publishers, 1980); Michael Moodie, "Defence Industries in the Third World: Patterns and Promises," in *Arms Transfers in the Modern World*, eds., Stephanie G. Neuman and Robert E. Harkavy (New York: Praeger Publishers, 1980); Katz, *Arms Production in Developing Countries*, and Brzoska and Ohlson, *Arms Production in the Third World.*

[20]Raju G.C. Thomas, *Indian Security Policy* (Princeton: Princeton University Press, 1986); Harpreet Mahajan, *Arms Transfers to India, Pakistan and the Third World* (New Delhi: Young Asia Publishers, 1982); and Barry Buzan, Gowher Rizvi, Rosemary Foot, Nancy Jetly, B.A. Robertson, and Anita Inder Singh, *South Asian Insecurity and the Great Powers* (London: Macmillan, 1986).

[21]See Janne E. Nolan, *Military Industry in Taiwan and South Korea* (London: Macmillan, 1986); A. James Gregor, "The Republic of China in Taiwan," in *Implications of Third World Military Industrialisation*, ed., James Everett Katz (Lexington: Lexington Books/D.C. Heath & Company, 1986); A. J. Gregor, R.E. Harkavy and S.G. Neuman, "Taiwan: Dependent Self-Reliance," in *Arms Production in the Third World*, eds., Michael Brzoska and Thomas Ohlson (London: Taylor &

Francis, 1986); and "Israel's Defence Industry: Evolution and Prospects," in *The Global Arms Trade*, Office of Technology Assessment (Washington, D.C.: U.S. Government Printing Office, June 1991).

[22]See Donald A. Weatherbee, "Indonesia: Its Defence Industries Complex," in *Implications of Third World Military Industrialication*," ed., James Everett Katz (Lexington: Lexington Books/D.C. Heath & Company, 1986); Bilveer Singh, "ASEAN Arms Industries: Potentials and Limits," *Comparative Strategy*, Vol. 8, no. 2 (1989); Clovis Brigagão, *O Mercado da Segurança Ensaios Sobre Economia Politica de Defesa* (Rio de Janeiro: Editora Nova Fronteira, 1984); Alexandre de S.C. Barros, "Brazil," in *Arms Production in Developing Countries*, ed., James Everett Katz (Lexington: Lexington Books/D.C. Heath & Company, 1986); and Renato Dagnino, "A Industria de Armamentos Brasileira: Desenvolvimento e Perspectivas," in *O Armamentismo e o Brasil: A Guerra Deles*, eds., Amilcar O Herrera, Pinguelli Rosa, and Renato P. Dagnino (São Paulo: Editora Brasiliense S.A., 1985).

[23]See Andrew J. Pierre, *The Global Politics of Arms Sales* (Princeton: Princeton University Press, 1982); Office of Technology Assessment, *The Global Arms Trade*; and David J. Louscher and Michael D. Salomone, eds., *Marketing Security Assistance: New Perspectives on Arms Sales* (Lexington: Lexington Books, 1987).

[24]David J. Louscher and Michael D. Salomone, "Brazil and South Korea: Two Cases of Security Assistance and Indigenous Production Development," in *Marketing Security Assistance*, 132.

[25]See Ann Naylor Schwarz, "Arms Transfers and the Development of Second-Level Arms Industries," in *Marketing Security Assistance*; and Stephanie G. Neuman, "International Stratification and Third World Military Expenditure," *International Organization* (Winter 1984): 167-197.

[26]Office of Technology Assessment, *The Global Arms Trade*; David Saw, "The Emergence of Third World Aircraft Industry," *Military Technology*, Vol. 4, no. 4 (1988); and Thomas Ohlson, "The Asean Countries: Low-Cost Latecomers," in *Arms Production in the Third World*.

[27]Herbert Wulf, "Arms Production in Third World Countries: Effects of Industrialisation," in *World Armaments and Disarmament 1985 Yearbook*, Stockholm International Peace Research Institute (Stockholm: Almqvist and Wiksell, 1985), 366.

[28]Gavin Kennedy, *The Military in the Third World* (New York: Charles Scribner's Sons, 1974); Herbert Wulf, "The Structure of the Defence Industry," in *The Structure of the Defence Industry*, eds., Nicole Ball and Milton Leitenberg (London: Croom Helm, 1983); Ilan Peleg, "Military Production in Third World Countries;" and Stephanie G. Neuman, "International Stratification and Third World Military Expenditure."

[29]Stephanie G. Neuman, "Third World Arms Production and Global Arms Transfer Systems," in *Arms Production in Developing Countries*, ed., James Everett Katz (Lexington: Lexington Books/D.C. Heath & Company, 1984), 21. This chapter is based on a previous *International Organisation* article, "International Stratification and Third World Military Expenditure" cited above.

[30]Saadet Deger, *Military Expenditure in Third World Countries: The Economic Effects* (London: Routledge & Kegan Paul, 1986), 169.

[31]Neuman, "Third World Arms Production," 28-29.

[32]Louscher and Salomone, *Marketing Security Assistance*; Andrew Ross, "World Order and Arms Production," in *Implications of Third World Military Industrialisation*; and Carol V. Evans, "Reappraising Third World Arms Production," *Survival* (March-April 1986): 99-118.

[33]Ann Naylor Schwartz, "Arms Transfers and the Development of Second-Level Arms Industries," 109.

[34]Ibid.

[35]Office of Technology Assessment, *The Global Arms Trade*, 8.

[36]Ross, "World Order and Arms Production," 284.

[37]Office of Technology Assessment, *The Global Arms Trade*, 17.

[38]Nolan, *Military Expenditure in Taiwan and South Korea*, 120.

[39]See, for example, Katz, *Arms Production in Developing Countries*; Katz, *Implications of Third World Military Industrialisation*; and Ohlson and Brzoska, *Arms Production in the Third World.*

[40]See Evans, "Reappraising Third World Arms Production."

[41]Nolan, *Military Industry in Taiwan and South Korea*, 17.

[42]A prime example is Katz, *Implications of Third World Arms Production.*

[43]Brzoska and Ohlson, *Arms Production in the Third World*, 29.

[44]Ibid, refer to footnote number 3 on page 33.

[45]Emile Benoit, *Defence and Economic Growth in Developing Countries* (Boston: D.C. Heath & Co./Lexington Books, 1973); and Nicole Ball, "Defence and Development: A Critique of the Benoit Study," *Economic Development and Cultural Change*, Vol. 31, no. 3 (April 1983): 507-24. Saadet Deger, *Military Expenditure in Third World Countries: The Economic Effects* (London: Routledge & Kegan Paul, 1986).

[46]Emile Benoit, *Defence and Economic Growth in Developing Countries* (Boston: D.C. Heath & Co./Lexington Books, 1973)

[47]Emile Benoit, "Growth and Defence in Developing Countries," *Economic Development and Cultural Change*, Vol 26, no. 2 (January 1978): 271.

[48]Ibid., 277.

[49]See especially, Nicole Ball, "Defence and Development: A Critique of the Benoit Study," *Economic Development and Cultural Change*, Vol. 31, no. 3 (April 1983): 507-24; and Kenneth Boulding, "Defence Spending: Burden or Boon," *War/Peace Report*, Vol. 13, no. 1 (1974): 19-24; and Deger, *Military Expenditure in Third World Countries*.

[50]Saadet Deger, *Military Expenditure in Third World Countries: The Economic Effects* (London: Routledge & Kegan Paul, 1986).

[51]Deger, 244-45.

[52]Ibid., 190.

[53]Ibid., 195.

[54]See, for example, I.M.D. Little, "The Experience and Causes of Rapid Labour-Intensive Development in Korea, Taiwan Province, Hong Kong, and Singapore; and the Possibilities of Emulation," in *Export-Led Industrialisation and Development*, ed., Eddy Lee (Geneva: International Labour Organisation, 1981); and Bela Balassa, *The Newly Industrialising Countries in the World Economy* (New York: Pergamon Press, 1981).

[55]Statistical data on comparative growth rates is found in Sanjaya Lall, *Building Industrial Competitiveness in Developing Countries* (Paris: OECD, 1990). See James Riedel, "Trade as the Engine of Growth in Developing Countries, Revisited," *The Economic Journal*, 94 (March 1984): 56-73; Anne O. Krueger, *Foreign Trade Regimes and Economic Development: Liberalisation Attempts and Consequences* (Cambridge, MA.: Ballinger Press, 1978). For a critique of the dichotomous view between import-substitution industrialisation and export-led strategies refer to David Evans and Parvin Alizadeh, "Trade, Industrialisation and the Visible Hand," *Journal of Development*

Studies, 21, 1 (1984): 24-46; and Herbert Schmitz, "Industrialisation Strategies in Less Developed Countries: Some Lessons from Historical Experience," *Journal of Development Studies*, 21, 4 (1984): 1-24.

[56]Bela Balassa and Associates, *Development Strategies in Semi-Industrial Economies* (Baltimore: Johns Hopkins University Press, 1982); and Krueger, *Foreign Trade Regimes*.

[57]Little, "The Experiences and Causes of Rapid Labour-Intensive Development," 57.

[58]This point has been made by, for example, by Stephan Haggard, *Pathways from the Periphery: The Politics of Growth in the Newly Industrialising Countries* (Ithaca: Cornell University Press, 1990); and Peter B. Evans, Dietrich Rueshemeyer and Theda Skocpol, eds., *Bringing the State Back In* (New York: Cambridge University Press, 1985).

[59]Charles-Albert Michalet, *Le Capitalisme Mondial* (Paris: PUF, 1976), 42, cited in François Chesnais, "Technological Competitiveness Considered as a Form of Structural Competitiveness," in *Technology and National Competitiveness: Oligopoly, Technological Innovation, and International Competition*, ed., Jorge Niosi (Montreal: McGill-Queen's University Press, 1991), 142.

[60]Martin Fransman, *Machinery and Economic Development* (London: Macmillan Press, 1986), 159.

[61]Included in this broad literature are: Daniel I. Okimoto, *Between MITI and Market: Japanese Industrial Policy for High Technology* (Stanford: Stanford University Press, 1989); Alice Amsden, *Asia's Next Giant: South Korea and Late Industrialisation* (New York: Oxford University Press, 1989); Gary Gereffi and Donald L. Wyman, ed., *Manufacturing Miracles: Paths of Industrialisation in Latin America and East Asia* (Princeton: Princeton University Press, 1990); and Frederic C. Deyo, ed., *The Political Economy of the New Asian Industrialism* (Ithaca: Cornell University Press, 1987).

[62]John R. Hicks, *The Theory of Wages* (London: Macmillan, 1932). As discussed below, the neoclassical focus on traditional research questions, such as the labour and capital intensity of technology, and the factor substitutability of labour and capital in response to differing factor prices, has tremendously influenced the emerging economics literature on technology and industrialisation in the NICs.

[63]For an interesting discussion of the limitations of neoclassical economic treatments of technology, see G. Dosi, C. Freeman, R.R. Nelson, G. Silverberg, and L. Soete, eds., *Technical Change and Economic Theory* (London: Frances Pinter Publishers, 1988); and Jorge Niosi, ed., *Technology and National Competitiveness*.

[64]R.R. Nelson and S.G. Winter, *An Evolutionary Theory of Economic Change* (Boston: Belknap Press for Harvard University Press, 1982), 204-205.

[65]See Niosi, ed., *Technology and National Competitiveness*; Keith Pavitt, *Technical Innovation and British Economic Performance* (London: Macmillan, 1980); OECD, *Structural Adjustment and Economic Performance* (Paris: OECD, 1987); Stephen Cohen and John Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy*.

[66]Among this vast and growing literature see Martin Fransman and Kenneth King, eds., *Technology Capability in the Third World* (London: Macmillan, 1984); Dieter Ernst and David O'Connor, *Technology and Global Competition: Challenge for the Newly Industrialising Economies* (Paris: OECD, 1989); Sanjaya Lall, *Building Industrial Competitiveness in Developing Countries*; World Bank, *Korea: Managing the Industrial Transition* (Washington, D.C.: The World Bank, 1987); World Bank, *Brazil: Industrial Policies and Manufactured Exports* (Washington, D.C., 1983); Simon Teitel, "Technology Creation in Semi-Industrial Economies," *Journal of Development Economics*, Special Issue: Symposium on Technological Change and Industrial Development, Vol. 16, nos. 1-2 (September-October 1984): 39-61.

[67]See Joseph A. Schumpeter, *Capitalism, Socialism and Democracy*, 3d edition (New York: Harper & Row, 1950) and Angus Maddison, *Phases of Capitalist Development* (New York: Oxford University Press, 1982).

[68]Frances Stewart and Jeffrey James, *The Economics of New Technology in Developing Countries* (London: Frances Pinter, 1982), p. 1.

[69]Sanjaya Lall, *Building Industrial Competitiveness*, p. 18.

[70]Sanjaya Lall, "Technology Learning in the Third World," in *The Economics of New Technology in Developing Countries*, eds., Frances Stewart and Jeffrey James (London: Frances Pinter Publishers, 1982), 158.

[71]See Martin Fransman, *Technology and Economic Development*; Fransman and King, eds., *Technology Capability in the Third World*; Carl Dahlman, Bruce Ross-Larson and Larry E. Westphal, "Managing Technological Development: Lessons from the Newly Industrialising Countries," *World Development*, Vol. 15, no. 6 (1987): 759-775; Simon Teitel, "Towards an Understanding of Technical Change in Semi-Industrialised Countries," *Research Policy*, 10 (1981): 127-47; and Martin Bell, Bruce Ross-Larson and Larry E. Westphal, "Assessing the Performance of Infant Industries," *Journal of Development Economics*, Vol. 16, nos. 1-2 (September-October 1984): 101-28.

[72]See, for example, Carl J. Dahlman and Francisco E. Sercovitch, "Exports of Technology from Semi-Industrial Economies and Local Technological Development,"

Journal of Development Economics, Vol. 16, nos. 1-2 (September-October 1984): 63-99; Sanjaya Lall, "Exports of Technology by Newly Industrialising Countries," *World Development*, Vol. 12, nos. 5-6 (1989); and Sanjaya Lall, *Building Industrial Competitiveness*.

[73]Sanjaya Lall, "India," *World Development*, Vol. 12, nos. 5-6 (1984): 535-65; Helio Nogueira da Cruz, *Mudança Tecnologica no Setor Metal-Mecânico do Brasil: Resultados de Estudos de Casos* (São Paulo: Instituto de Pesquisas Econômicas, Faculdade de Economia e Administração da Universidade de São Paulo, 1985); and Jorge Katz, ed., *Technology Generation in Latin American Manufacturing Industries* (London: Macmillan, 1987).

[74]Simón Teitel and Larry E. Westphal, "Editors' Introduction," *Journal of Development Economics*, Special Issue, Symposium on Technological Change and Industrial Development, Vol. 16, nos. 1-2 (September-October 1984): 1.

[75]See Stephan Haggard, *Pathways from the Periphery: The Politics of Growth in the Newly Industrialising Countries* (Ithaca: Cornell University Press, 1990); Gary Rodan, *The Political Economy of Singapore's Industrialisation: National State and International Capital* (New York: St. Martin's Press, 1989); and David Collier, ed., *The New Authoritarianism in Latin America* (Princeton: Princeton University Press, 1979).

[76]On Taiwan see K.T. Li, "The Growth of Private Industry in the Republic of China," in *The Experience of Dynamic Economic Growth on Taiwan*, ed., K.T. Li (Taipei: Mei Ya Publications, 1976); and Robert Wade and Gordon White, eds., *Developmental States in East Asia* (New York: St. Martin's Press, 1988). On Korea, see Leroy Jones and Il Sakong, *Government, Business and Entrepreneurship in Economic Development: The Korean Case* (Cambridge: Harvard University Press, 1980). For Singapore refer to Gary Rodan, *The Political Economy of Singapore's Industrialisation*; and Linda Y.C. Lim, "Singapore's Success: The Myth of the Free Market Economy," *Asian Survey*, 23 (June 1983). For general reference, see Francis W. Rushing and Carole Ganz Brown, eds., *National Development Policies for Developing High Technology Industries* (Boulder, CO.: Westview Press, 1986).

[77]Chalmers Johnson, *MITI and the Japanese Miracle* (Stanford: Stanford University Press, 1982); Stephan Haggard and Chung-in Moon, "Institutions and Economic Policy: Theory and a Korean Case Study," *World Politics*, 42 (January 1990): 210-32; and Robert Wade and Gordon White, eds., *Developmental States in East Asia*. One of the most extensive treatments of the role of the state in industrialisation is Guillermo O'Donnell's "bureaucratic authoritarian model" in which political repression is viewed as a functional necessity for rapid industrialisation in Latin American NICs. See Guillermo O'Donnell, *Authoritarianism and Corporatism in Latin America* (Princeton: Princeton University Press, 1979). David Collier and others have later

criticised the model for its economic determinism in Collier, ed., *The New Authoritarianism in Latin America.*

[78]According to Haggard, "Three dimensions of the state as an institutional and legal structure bear on the ability of political elites to realise their interests. The first is degree of insulation from societal pressures, which in turn is a function of the institutional arrangements linking state and society. The second is cohesiveness of the decision-making structure itself. The third is instruments that are available to state elites in pursuing their political and substantive goals." *Pathways from the Periphery*, 43-44.

[79]Ibid.

[80]Ibid., 3.

[81]See, for example, Peter B. Evans, *The Alliance of the Multinational, State and Local Capital in Brazil* (Princeton: Princeton University Press, 1983); Gary Gereffi, *The Pharmaceutical Industry and Dependency in the Third World* (Princeton: Princeton University Press, 1983); and Douglas C. Bennett and Kenneth E. Sharpe, *Transnational Corporations versus the State: The Political Economy of the Mexican Automobile Industry* (Princeton: Princeton University Press, 1985).

[82]Joseph M. Grieco, "Between Dependency and Autonomy: India's Experience with the International Computer Industry," *International Organisation*, Vol. 36, no. 3 (Summer 1982): 609-32; and Emanuel Adler, *The Power of Ideology: The Quest for Technological Autonomy in Brazil* (Berkeley, CA.: University of California Press, 1987). For a condensed version of Adler's argument refer to "State Institutions, Ideology, and Autonomous Development: Computers and Nuclear Energy in Argentina and Brazil," *Latin American Research Review*, 23, 9 (1988): 59-90.

[83]According to Grieco these goals included: "First, India should participate in the ownership and control of foreign computer subsidiaries in the country. Second, ... wholly Indian producers should satisfy most of the country's computer needs, with foreign units temporarily supplying only very exotic technologies and large systems. Third, India should have access to and participate in the manufacture of the most advanced systems available internationally." See Joseph Greico, "Between Dependence and Autonomy," 612.

[84]Emanuel Adler, "State Institutions, Ideology, and Autonomous Development," 59.

[85]Ibid., 83.

[86]Government of India, "Report on the Computer Industry" in *Studies in the Structure of the Industrial Economy*, BICP, Ministry of Industry, Government of India

(New Delhi: Government of India Press, 1989). See also Sudha Mahlingam, "Computer Strategy in India: Strategies for Latecomer Entry," *Economic and Political Weekly*, 21 October 1987, 2375-2384.

[87]Confidential interview, with official in Commerce Ministry, Indian embassy, Washington, D.C., November 1992.

[88]John M. Stopford and Susan Strange with John Henley, *Rival States, Rival Firms: Competition for World Market Shares* (Cambridge: Cambridge University Press, 1991), 65-66.

[89]See the classic studies by Eli F. Heckscher, *Mercantilism*, 2 vols (London: George Allen & Unwin, 1935); Friedrich List, *The National System of Political Economy* (New York: Longmans, Green 1904); Jacob Viner, "Power versus Plenty as Objectives of Foreign Policy in the Seventeenth and Eighteenth Centuries," *World Politics*, 1 (1948): 1-29; and Ralph G. Hawtrey, *Economic Aspects of Sovereignty* (London: Longmans, 1952).

[90]Robert Gilpin, *U.S. Power and the Multinational Corporation: The Political Economy of Foreign Direct Investment* (New York: Basic Books, 1975), 43.

[91]Robert Gilpin, *The Political Economy of International Relations* (Princeton: Princeton University Press, 1987), 10-11.

[92]Ibid., 24

[93]Ibid., 10-11.

[94]Gautam Sen, *The Military Origins of Industrialisation and Trade Rivalry* (London: Frances Pinter, 1984).

[95]See the pioneering work on industrialisation using the input-output methodology developed by Hollis B. Chenery and Tsunehiko Watanabe, "International Comparisons of the Structure of Production, *Econometrica*, 26, no. 4 (October 1958): 487-521; K.V. Santhanam and R.H. Patil, "A Study of the Production Structure of the Indian Economy: An International Comparison," *Econometrica*, 40, no. 1 (January 1972): 159-76; and David Simpson and Jinkichi Tsukui, "The Fundamental Structure of Input-Output Tables and International Comparison," *Review of Economics and Statistics*, Vol XLVII, no. 4 (November 1965): 434-446.

[96]These development economists refer to the industrial structure of production in terms of 1) the similarity in growth patterns of countries is observable in terms of the growth patterns of different sectors and manufacturing industries, in relation to GNP per capita; 2) Comparability of a number of structural input-output indicators: a) measure of

backward-forward linkages which connect a single industry to others, b) the degree of triangularisation of the input-output tables, and c) the comparability of the technical coefficients between countries. A later Brazilian study, not included in Sen's book, provides further evidence for the existence of a structure of production. See Paulo Fontenela e Silva, *Aspectos Tecnológicos da Estrutura Industrial Brasileira: Uma Análise de Insumo-Produto* (Rio de Janeiro: BNDES, 1980).

[97]Sen, *The Military Origins of Industrialisation*, 7.

[98]Ibid., 158.

[99]This data should be treated with extreme caution because of the inherent methodological problems involved pertaining to the availability and reliability of relevant economic data collected from developing countries.

[100]Based on 1992 data from the Stockholm International Peace Research Institute.

[101]Of course the power of this conceptual framework ultimately depends on its usefulness in explaining the relative defence-industrial capabilities and export competitiveness in many different countries. Judgements regarding this power must therefore await future research.

[102]For an excellent discussion of the development of technology capabilities in the newly industrialising countries see Carl J. Dahlman, Bruce Ross-Larson and Larry E. Westphal, "Managing Technological Development: Lessons from the Newly Industrialising Countries," *World Development*, Vol. 15, no. 6 (1987): 759-775.

[103]A comparative study that examines the evolution of the capital goods sector in these and other industrialising countries is Daniel Chudnovsky and Masafumi Nagao with the collaboration of Staffan Jacobsson, *Capital Goods Production in the Third World: An Economic Study of Technology Acquisition* (London: Frances Pinter Publishers, 1983). See also Howard Pack, "Fostering the Capital Goods Sector in LDCs," *World Development*, Vol. 9, no. 3 (1981): 227-50.

[104]Martin Fransman, *Machinery and Economic Development*, 32.

[105]The concept of "strong" and "weak" states gained general acceptance in political science as an analytical tool for understanding the ability of government officials to implement particular policies. This conceptualisation was used first to explain divergent national responses and economic policies in the United States, Western Europe and Japan. See, for example, Peter Katzenstein, ed., *Between Power and Plenty* (Madison: University of Wisconsin Press, 1978). More recently, the "strong" state/"weak" state concept has been used to explain why the East Asian NICs successfully pursued export-oriented growth strategies in contrast to the import-substitution

experiences of some Latin American NICs. See Stephan Haggard, *Pathways from the Periphery* (Ithaca: Cornell University Press, 1990).

[106]The comparative politics literature generally defines "strong" states in terms of: 1) the cohesiveness of the state apparatus, 2) the extent to which the state is sufficiently insulated from domestic interest groups, and 3) the degree of autonomy state bureaucracies enjoy from society. Peter Hall extends this conceptualisation by including the capacity of a state to implement policy, if necessary over the objections of key social groups. See Peter Hall, *Governing the Economy: The Politics of State Intervention in Britain and France* (New York: Oxford University Press, 1986), p. 164.

Chapter III

MARKET RATIONALES FOR BRAZILIAN DEFENCE PRODUCTION

During the 1980s Brazil was the world's seventh largest exporter of major weapons and was ranked second, after the Peoples Republic of China, in terms of the value of defence production output and exports among the developing countries. The most prominent purchasers of Brazilian defence equipment include Iraq, Libya, Saudi Arabia, the United Kingdom, and France. Today, some of Brazil's leading defence industries are teetering at the edge of financial collapse, exposed to the recession in the global market for arms and to the vagaries of government policies.

This chapter analyses the emergence and subsequent, recent decline of the Brazilian defence industry. In conjunction, the author delineates the specific relationship that has developed between the country's major defence companies and the Brazilian government, focusing particularly on: Embraer, a mixed private/state-owned aircraft producer; Engesa, a privately owned armoured vehicle manufacturer; and Avibras, a private missile firm. Rather than remain at the vague "country" level of analysis, which is characteristic of the international arms production/trade literature, the chapter's focus is deliberately at the firm as well as sectoral level.

The argument underpinning this chapter is that, contrary to conventional wisdom, the rapid emergence and export success of Brazil's arms industries during the 1980s resulted from firms' own strategies as opposed to government intervention and promotion. However, beginning in 1990 some of the country's defence companies began to experience severe economic contractions, in some cases making them more susceptible and open to government assistance. The reason for the recent shift towards coordination and cooperation in firm-government relations stems from the fact that, having gained international prominence, many of the defence firms are now considered national "strategic" assets by the Brazilian government. These companies' perceived value to the government in Brasilia is measured in terms of their export revenue potential, high technology capability, large and highly skilled, unionized workforce, and huge concentration in the industrial and politically powerful state of São Paulo.

To provide the reader with the necessary empirical background and to delineate diachronically the interaction between the leading defence firms and the Brazilian government, this chapter is divided into three sections. In section one, the author re-examines the conventional political and economic theories, which attempt to explain the emergence of Brazil's defence industries during the late 1960s, and their subsequent remarkable arms export performance. Conventional political explanations of the performance of the Brazilian defence industry emphasise internal, state-centric rationales on the part of the country's military governments. Economists, however, generally attribute externally induced, trade-liberalising factors. Based on her interviews and questionnaire survey data collected from Brazilian capital goods and defence firms, the author proposes an alternative hypothesis. She suggests that Brazilian defence production was initiated because of domestic sectoral conditions; namely, internal cyclical factors within the Brazilian capital goods sector encouraged firms to diversify into military production. A three-stage, econometric model is developed, which exhibits the weak effect of government policies on this process of diversification -- a surprising result given the nature of the "militarised" state.

Section II consists of in-depth, individual, firm case studies from Brazil's four defence sectors: aircraft, armoured vehicles, missiles, and naval craft. Utilising information gained through interviews and company site visits, the author documents how these firms achieved international competitiveness through the pursuit of various strategies related to R&D, new product development and marketing. In the third and final section of this chapter, an assessment is provided of the deleterious impact of the global recession in the arms trade on Brazil's defence firms. Referring to the country's three major defence companies -- Engesa, Embraer and Avibras -- the author details the respective responses to the current trade crisis by these firms and by the Brazilian government.

SECTION I: CONVENTIONAL THEORIES

The conventional wisdom emanating from the political science and strategic studies literature has uniformly emphasised the supposed direct role of successive military governments in creating and promoting the development of an indigenous defence industry in Brazil. Influenced by the vast literature concerning the determinants of military intervention and involvement in Latin American politics, political scientists have argued that Brazil's defence sector was instrumental to the internal political and foreign policy aspirations of the military regime.[1]

The development of defence industries has thus been widely interpreted and linked by some authors to prestige considerations on the part of Brazil's military government and to the need to enhance its political-economic power base. One such characteristic theoretical formulation suggests:

> Motivated by a well-defined, aggressive national development plan, the new military leadership vigorously fostered a Brazilian defence industry as a means not only to upgrade its military capabilities but to assist in the nation's overall socioeconomic development.[2]

Other writers, of a more "bureaucratic-authoritarian" orientation, such as Brazilian Alexandre de S.C. Barros, contend that the motivations for Brazil's defence efforts, "and the idea that it could be implemented realistically, spring from the armed forces' organizational culture...."[3] In particular, several political analysts point to the ideological role of security and development, "*segurança e desenvolvimento*", the national security doctrine, as formulated by Brazil's National War College, the *Escola Superior de Guerra* (ESG). (The ESG is also said to be the responsible state organ, where the military, conservative business leaders and technocrats are jointly trained "to disseminate an ideological orientation as well as ... bureaucratic capabilities."[4]) The core of this "doctrine" proclaims the inseparability of national security from Brazilian social, cultural and economic development (hence the strategic justification for import-substitution industrialisation). As Vargas observes, "The relationship that is established between national security and development derives from the geopolitical commitment to autarky or self-rule...."[5] From this perspective:

> The military becomes the essence or core of the social organism, and the military doctrine of national security links all social practices to the problems of internal and external defence and to infuse the entire civilian existence with this [militarisation].[6]

The indirect effect of the military's ideology of *segurança e desenvolvimento* on the development of Brazil's arms industry is suggested by a number of authors. For example, Franko-Jones extrapolates that "state intervention in the armaments industry, as mandated by segurança e desenvolvimento, reflects a pattern of state activity in Brazilian industry in general."[7] Dagnino suggests that this doctrine "shaped the production decisions of the defence industries because of the armed forces' perceived necessity of autonomous supply of counter-insurgency weapons.[8]

Another set of political explanations relate the growth of the arms industry and its subsequent exports to the international system.[9] These analyses advance the hegemonic aspirations of this South American giant. The concept of "*Brasil grande potencia*" is said to complement the Brazilian military government's perception of its enhanced role in international affairs. Specifically, Brazilian defence production may be seen to augment "that nation's long-time policy goal of maintaining dominance in Latin America and exerting greater influence in Sub-Saharan Africa and the third world in general."[10] For example, the acceleration of the Brazilian Navy's nuclear submarine programme has been attributed to the aftermath of the Falklands/Malvinas Conflict and to the Navy's subsequent concern over extraterritorial powers in the South Atlantic.

The 1977 rupture in relations between the Geisel and Carter administrations is often cited as the immediate impulse behind Brazil's development of an autonomous arms industry. In response to U.S. restrictions on aid because of concern regarding the 1975 nuclear agreement with the Federal Republic of Germany, and purported human rights violations, Brazil's military government cancelled four military agreements with the

United States.[11] According to Fragoso, this break in military cooperation (including purchases of U.S. military equipment), impressed the armed forces with the need for self-sufficiency in arms production and in related industries.[12] In addition, Brazil's subsequent open arms export policy (particularly to Iraq and Libya), has been tied to an explicit attempt by the Foreign Ministry (*Itamaraty*) to pursue a foreign policy, independent of the United States.

Motivations aside, political scientists have then considered what policy mechanisms the state (e.g. military) has used to promote the economic viability of the defence industries. The establishment of the *Grupo Permanente de Mobilização Industrial*, the Permanent Group for Industrial Mobilization, in 1964 is often interpreted as marking the first explicit attempt by the military to develop an extensive defence sector in partnership with private industry. As a result of this association between the industrial federation of São Paulo (FIESP), and the military government, Brigagão writes:

> many sectors of civil industry were converted to the production of arms... Amongst these sectors were: vehicles and automotive, mechanical equipment components, leather and shoes, textiles, aeronautical equipment....[13]

Often influenced by U.S. writings on the "military industrial complex", analysts have also concentrated on the purportedly close interaction of a defence community or "*tripé*", which involves the state, the defence industries and multinational corporations.[14] One example of such cooperation is Brazil's helicopter industry, Helibras, which was until 1988 jointly owned and operated by the regional state of Minas Gerais and the French aerospace company, Aerospatiale. The military is likewise credited for the emergence of the São José dos Campos "military-industrial-research park", where the largest aerospace manufacturing industries have located alongside the government-financed, Air Force-operated, *Centro Tecnológico de Aeronautica* (CTA).

The economic literature clearly has had little interest in determining motivational factors. Instead, economists have concentrated on the question of what accounts for the relative success of Brazil's export performance, especially in terms of high-technology capital goods (inclusive of defence items). Much of this analysis has occurred under the rubric of the import-substitution industrialisation/export-led growth debate.

The dominant explanation emerging from mainstream economics is that Brazil, like other newly industrialising countries, adopted the "right" international trade policies, by liberalising imports, adopting "realistic" exchange rates and providing incentives for exports. Above all, the Brazilian government managed to correct factor prices (often by the military government repressing wage rates) so that manufactured exports reflected underlying comparative advantage. For instance, Tyler attributes Brazil's industrial growth and expansion to a "policy strategy ... of ... fortifying markets and improving the functioning of the price system."[15] In sum, Brazil's industrial expansion and exports is explained by state reliance on market forces and integration into the world economy.

Neither the strategic/political arguments nor the economic rationales, however, satisfactorily explain the impetus behind Brazilian defence production and its distinctive features. The political interpretation, while it attempts to introduce a pluralist view of the "state" (e.g. military, industry and MNCs), is arguably reductionistic. Namely, it presumes that state and defence industry preferences are uniform, and that there exists great homogeneity within the defence sector itself. Such explanations have thus neglected any analysis of firm-level behaviour, and have assumed that government policies affect equally the various industries -- aircraft, shipbuilding, missiles, and armoured vehicles.

In fact, data collected from recent interviews with all the largest defence producers suggests that the Brazilian military facilitated rather than determined the development of Brazilian arms production. First, we would expect the military regime to stimulate the defence industries through the central government budget. As Table 3.1 indicates, Brazilian defence expenditures over the past twenty years are relatively insignificant, averaging 1.3% of GDP per annum (especially when compared to other large Third World weapons producers like India, whose defence expenditure/GDP averaged over five per cent for the same time period.) If we factor out weapons procurement from the budget, which constitutes approximately 28% of total defence expenditures, the figures from Table 3.1 diminish considerably.[16]

Additionally, the lions' share of the procurement budgets over these years has been allocated to the Navy (the nuclear submarine programme), and to weapons imports (such as sophisticated fighter aircraft). Yet, the major defence companies -- in the terms of value of production and exports -- manufacture missiles, armoured vehicles and aircraft. What then accounts for the rise of these industries if the state --- a military one -- is providing neither sufficient capital nor a market for domestically manufactured weapons?

Table 3.1 *BRAZILIAN DEFENCE EXPENDITURE*

Year	Defence Expenditure/ GNP	Defence Expenditure (1985$ mill. and Prices)
1965	2.10	1,628
1966	1.81	2.038
1967	2.40	2.682
1968	2.11	2,646
1969	2.16	2,969
1970	2.00	1,937
1971	2.49	4,007
1972	1.89	3,349
1973	1.68	3,401
1974	1.16	2,560
1975	1.19	2,289
1976	1.13	2,512
1977	1.08	2,556
1978	.91	2,380
1979	.75	2,122
1980	.81	1,625
1981	.57	1,736
1982	.65	2,001
1983	.62	1,886
1984	.50	1,646
1985	.76	2,741
1986	.75	2,725
1987	.50	2,412
1988	.80	1,459
1989	.37	1,180
1990	.9	1,059
1991	.8	1,080

Source: *The Military Balance*, various dates. London: International Institute for Strategic Studies
Latest available defence expenditure figures are provided.

Obviously the export market may be a significant explanatory factor (especially given that the export ratio of the top five firms has been approximately 90%). This factor then leaves open the question of whether the military government used specific economic incentives to encourage defence exports, thereby maintaining the future economic viability of these firms. And, it is at this juncture where the political explanations converge with economic calculations regarding Brazilian export performance of manufactured goods.

As mentioned previously, economists have largely attributed the increase in Brazil's exports during the mid-to-late 1970s to the conducive international trade environment. They also have emphasised the positive effect of liberal trade and industrial policies on Brazilian manufactured exports. However, such analyses have neglected important internal cyclical features affecting the Brazilian capital goods sector: In the years prior to the explosive growth in GNP and exports, industrial capacity in the capital goods sector was heavily underutilised. As Malan & Bonnelli have argued, "An outstanding feature of the industrial sector in Brazil ... was the existence of substantial idle capacity, especially in the manufacturing sector... [This unutilised capacity] was an obvious factor in allowing the subsequent boom."[17] It is this factor that suggests the need for an alternative hypothesis.

An Alternative Hypothesis

The alternative explanation advanced by the author posits that domestic market considerations, rather than broad political motivations explain the tremendous growth in defence output during the last twenty years. Specifically, Brazilian capital goods firms diversified into military production in response to the internal cyclical nature of the sector, especially during the two recessions, 1962-67 and 1980-84. In essence, the emergence of Brazil's defence sector was an unintended consequence of domestic economic fluctuations rather than the result of deliberate manipulation of market mechanisms by the Brazilian military government. Finally, though both political scientists and economists have attributed the development of defence industries, and competitiveness of arms exports to heavy state intervention by the military regime, such explanations appear to be weak, as the model shall demonstrate.

The author would now like to defend this argument using data collected from her interviews with defence manufacturers and from a mail questionnaire survey of randomly selected Brazilian capital goods producers. (Please refer to the appendix for an overview of the research conducted in Brazil and for a brief discussion of the survey methodology.) Before she introduces the model, however, the author would first like to demonstrate the linkage of military diversification to conditions existing within the Brazilian capital goods sector.

The Military-Industrial Nexus: Capital Goods & Defence Diversification

The sub-period 1956-61 was characterised by the acceleration of industrialisation in Brazil and is associated with the increased participation of the multinational corporations in the manufacturing sector. In particular, the expansion of the multinational automotive industry in Brazil during the mid-1950s onwards played a key role in the development (through backward linkage effects) of the domestic capital goods sector. As a Vargas Foundation economist notes, "the setting up of [component] industries facilitated the establishment of part of the capital goods sector particularly in the transport industry."[18] The Kubitschek government aided this process by instituting the Executive Group for the Automotive Industry. According to a study by Gordon and Grommers:

> The essential features ... involved ... the importation of manufacturing equipment and of automotive components for a limited period of years, in return for a firm commitment by the automotive companies for the progressive replacement of imports by Brazilian-made components, backed up by specific plans for the deletion of imports.[19]

Subsequent programmes were developed for shipbuilding, tractors and railway equipment. During the period 1955-64 these programmes helped initiate "the [domestic] production of numerous other capital goods, for example, trucks, buses, agricultural tractors, light planes, and ships."[20] As a result of this intensive import substitution industrialisation, rapid expansion in the capital goods sector occurred. The average growth rate for transport equipment was 25.1% per annum (p.a.), for electrical machinery 20.7% p.a., chemical and pharmaceuticals 14.4%, and metal products 10.4% p.a.[21]

By the mid-1960s, however, domestic capital goods firms were in financial crisis as the recession in Brazil not only had dampened internal demand, but the new military government had introduced a policy of import liberalisation. According to Tadini, "the period comprising 1962-1967 was not one of grand transformations in the structure of the sector, which operated with unutilised capacity, as a function of the economic recession and of an anti-inflationary policy that restrained public investment.[22]

If we refer to Table 3.2, *Physical Production of Select Capital Goods*, the data provides a partial observation of the impact of the recession on the transportation sector. The statistics do show, however, an important phenomenon that affected generally the capital goods sector; namely, a great oscillation in demand. According to Lago, this oscillation had the additional "disastrous effect for firms' profitability and was in part also responsible for the low level of technology of a number of products"[23] Another Brazilian economist, Tavares, notes the rapid drop in rates of capacity utilisation that accompanied this fluctuation in demand for capital goods -- the average was 75 per cent during the 1962-67 recession for capital goods producers. Her research indicates significant diversification amongst domestic capital goods producers in the last years of the recession. "This diversification is not only related to the productive structure of the industry, which is relatively flexible, but also to the instability of demand...."[24]

Two important factors relevant to the movement of capital goods firms into military production emerge from this discussion. The first relates to the timing of diversification and the second, to the diversification amongst producers of transport and machinery equipment. Note that the bulk of defence products, -- aircraft, armoured vehicles, naval vessels etc. -- all fall within the transport category. The questionnaire survey data do indeed reinforce this pattern of military diversification. According to cross tabulations of the data, the following firms all heavily diversified into military production at the end of the recession, or shortly afterwards. Amongst this group, Avibras, Bernardini, Engesa, and Embraer constitute the major Brazilian arms producers (measured in terms of the value of output).

Table 3.2

Physical Production of Select Capital Goods, 1962-67

Year	Trucks	Buses	Ships	Light Aircraft	Tractors
1962	38,743	927	22,740	48	8,826
1963	22,851	1,179	49,150	31	11,018
1964	22,249	2,245	56,680	20	13,302
1965	22,653	2,306	16,620	15	10,804
1966	32,299	2,754	16,340	44	12,709
1967	28,561	3,245	78,380	12	8,868

Source: For trucks, buses and tractors, figures are provided by ANFAVEA, *Indústria Automobilística Brasileira*, Novembro 1972; for shipping data see SUNAMAM, *Superintendencia Nacional da Marinha Mercante*; and for light aircraft information is provided by Neiva, Aerotec and the CTA. Adapted from Luiz A. Corrêa do Lago, Fernando Lopes de Almeida, Beatriz M.F. de Lima, *A Industria Brasileira de Bens de Capital*, Rio de Janeiro: Instituto Brasileira de Economia, Fundação Getúlio Vargas, 1979, p. 136.

Table 3.3: *Diversification into Military Production*

Company	Diversification	Year
Avibras	small aircraft - missiles	1964
Bernardini	bank vaults - tanks	1967
Mecanica Pesada	turbines, engines - naval	1967
Engesa	oil drilling equip - tanks	1968
Embraer	civil - military aircraft	1969

This pattern of diversification is duplicated subsequently during the second recession in Brazil, following the OPEC oil shock of 1979. However, before we turn to a discussion of the effects of the 1980-84 recession on this process of military diversification amongst capital goods producers, we need to understand the pre-existing conditions in the sector. Prior to the recession, the so-called "Brazilian Miracle" of 1968-73 had a paradoxical effect on domestic capital goods producers. As Malan & Bonelli note, the higher rates of production occurring during this period did not entail substantial increases in productive capital and capacity.[25] The continued instability in demand for capital goods also limited investment in the expansion of capacity utilisation.

In an attempt to counteract these trends, the government introduced the Second Development Plan in 1974 (II PND). The Plan's emphasis on public sector investment and a policy of renewed import-substitution had a significant effect on the Brazilian domestic capital goods sector. According to Treblat, public enterprises had been considered a short-cut to industrialisation, "an expediency forced upon policymakers by the absence of a well-financed domestic private sector and by Brazil's reluctance to allow transnational corporations into certain strategic sectors."[26]

The location of the majority of these enterprises in highly capital intensive sectors, such as energy, transportation, and steel, had a two-fold effect on the capital goods sector during this period. First, state enterprises were industries characterised by internal economies of scale, so they could supply the capital goods sector with lower cost intermediate inputs. Second, state enterprises were an important counter-cyclical source of demand for capital goods. For example, Treblat calculates that by the mid-to-late 1970s, the 40 largest public sector firms accounted for between 40-59 per cent of equipment orders from local capital goods producers.[27] However, just as the 1974-79 period witnessed the expansion of the public and capital goods sectors, so did the 1980-84 recession promote severe contraction in both these industries. When in late 1979 the Brazilian government cut investment in the public sector, the impact was acutely felt throughout the manufacturing sector.

This recession was evidenced by declines in manufacturing growth rates; the average annual growth rate fell from 18.1 to 7.1 per cent during the 1980-84 period. The slowdown in the industrial sector was also reflected in the indices of capacity utilisation. Capacity utilisation in the capital goods sector declined from 83% in 1980 to 78% one year later. Transport was severely affected with a fall from 86% to 71% in the same time period. The 1981 economic recession was particularly localised in the industrial sector. Output during 1981 fell substantially in the capital goods industries (18.7%). This underutilisation of capacity was the direct result of investments made during the 1968-73 period, based on the expectations of further expansion of state enterprises.

The questionnaire data indicate that most of the firms, which diversified during the second recession, maintained their original lines of production, but turned to supply the larger, established defence producers with subcomponents. For example, one of the respondents -- an optical goods firm -- diversified in 1982 to supply the "heads-up display" for Embraer's Tucano military trainer aircraft. A company, which produced specialised stamping machinery for the automotive industry, found an additional customer in 1980 -- a tank manufacturer, Engesa. The development of these ancillary industries should be viewed as a response to the huge increase in internal demand by Brazilian defence producers, which was triggered subsequently by the 1980-86 boom in arms exports.

If one cross tabulates those companies that moved into military production, with their respective reasons for diversification, some interesting tentative conclusions may be drawn. Referring to Table 3.4, in terms of the overall reasons for military diversification two explanations dominate: economies of scale and capacity utilisation. Within the transportation sector (aircraft, automotive, shipbuilding, and engines) the same explanations hold, with automotive emphasising capacity utilisation and aircraft emphasising primarily economies of scale. Having established a pattern of military diversification amongst capital goods producers in response to internal demand pressures, one may now turn to the three-stage model, which will test and measure the effects of Brazilian government policies on this movement by firms into defence production.

Table 3.4: ***Reasons For Military Diversification***

Original Product Line	*Reasons for Diversification* 1	2	3	4	5
Flight Control					1
Construction				1	
Electic Power					1
Photographic/Optical	1				
Scientific Equipment					
Aircraft	1	1	3	1	
Railroad			1	1	
Shipbuilding		1	1	2	
Motor Vehicles			2	5	
Electric Wire				1	2
Missile, Radar & Radio	1			2	1
Electr. Ind. Mach.			1		
Machinery (incl. arms)	1		1	1	
Computers	3				1
Spec. Ind. Machinery	1		2		
Metal/Wood Machinery	1			1	
Agricultural Equip.			2		
Engines & Turbines				1	
Metal Products	1	2		4	
Non Ferrous (Alum.)				2	
Iron & Steel	1			2	
Non-Metallic Mineral Prd.		1	1		
Plastic Products				1	
Rubber				1	
Tyres			2	2	
Petroleum Refining		1			
Chemical Products				2	1
Paints & Varnishes			1		
Syn. Fibres & Resins					1
Clothing			1		
Carpets			1		
Textile Goods			1		
Weaving			1		
N=75	11	6	21	30	8

Reasons:

1) Supply new market with new product
2) Procurement policies of our customers
3) Economies of scale -- expand existing line of production to supply new customers
4) Increase capacity utilisation because of sectoral decline
5) Keep up with international technological developments

THE MODEL

Using the questionnaire data set, a three-stage model was constructed to test the previously discussed economic and political factors that analysts commonly assume to have influenced the process of defence industrialisation in Brazil. A set of conditioning variables that constitute the baseline model is first created. Government policy variables are then added individually to the set to permit measurement of their respective effects.

Dependent variables:

a) Diversification;

$$y=(diver=1)$$

Constructed on the basis of a closed-ended question asking if companies had diversified.

b) Diversification into military production and;

$$if(diver=1)\wedge(diverres=1)$$

then

$$y=(divermil=1)$$

This dependent variable is conditional upon diversification, and if firms converted directly into military production and/or retained their main product lines but diversified their markets to supply the armed forces (national and/or foreign) and/or other defence firms.

c) Share of total production devoted to military.

$$y(milsh/divermil=1) = p1mil*(domkt1/100) + p2mil*(domkt2/100) + p3mil*(domkt3/100)$$

Conditional upon military diversification, this dependent variable was constructed on the basis of the company's three main product lines, and the respective percentage that military product represented in total production.

Independent Variables for Baseline Models:

All of the following, with the exception of foreqsh and pink, are dummy variables in which the independent variable equals one for the indicated condition, and zero otherwise.

Privco:	Private company (versus mixed or state-owned);
Intrad:	In-house R&D activity;
Extrad:	External R&D -- usage of industrial, government, military or university research institutions;
Foreqsh:	Percentage of foreign equity participation in the company;
Perstrns:	Hiring of foreign technicians and/or engineers & sending personnel abroad for specialised training;
Expinc:	Increase in world demand for exports;
Pink:	Exports (increase=1, decrease=-1, unchanged=0).

(Variables expinc and pink were constructed as follows. Companies were asked whether their exports had increased/decreased (pink) over the 1977-87 period. Companies were then asked to what did they attribute this movement: changes in world demand (expinc), competitiveness of their product, etc.)

Part I: Baseline Models

Baseline Probit Model for Diversification*

$$Prob(diver=1)=\Phi(z)$$

$$z=(.239+2.815privco-1.683intrad-2.426foreqsh+2.432perstrns-1.464expinc)$$

(2.63) (.64) (2.81) (2.96) (1.96)

Number of Observations = 67

*Note: For this and subsequent models, asymptotic t-values are given in parentheses below the estimated coefficients.

Baseline Probit Model for Diversification Into Military Production

$$Prob(divermil=1/diver=1)=\Phi(z)$$

$$z=(.385+1.929privco-1.683intrad-2.426foreqsh+2.019perstrns-1.465expinc)$$

(2.57) (1.33) (2.94) (3.49) (2.77)

Number of Observations = 50

Baseline Regression Model for Military Share of Production

$$(milsh/divermil=1)=.668+.248extrad-.188intrad-.340foreqsh-.149perstrns+.226pink$$

(2.79) (1.19) (2.09) (1.41) (3.01)

R Squared = .28

Number of Observations = 50

Analysis of the Baseline Models:

Of the five independent variables used in the two probit models, privco and perstrns are positive and highly significant. These results suggest that being a private company, with highly trained personnel (foreign or foreign-trained) increases the probability of firms diversifying or diversifying into military production. Thus, the earlier cited example of state ownership of defence firms, which has been used as a previous political explanation, is not supported by the data.

Foreqsh and expinc, however, are negative and significant. A negative value for foreqsh means that the probability of a firm diversifying/diversifying militarily diminishes as foreign equity increases. The negative coefficients for expinc indicate a negative effect of increasing world demand for exports on diversification/diversification into military production. This latter result conflicts with the externally-induced, international trade rationales advanced by some economists. Yet, it is consistent with the econometric findings of Guimarães, who, using cross-section data from the Brazilian capital goods sector, analyses the effect of industrial structure on export performance. He concludes that the export performance of Brazilian capital goods sector increased/decreased in relation to a decrease/increase in internal demand rather than world demand or export incentives. The results of his study also indicate that exports of intermediate goods (inclusive of capital goods) are sensitive to the level of domestic trade, while exports of final goods responded essentially to export incentives.[28]

The milsh (share of military production) regression substitutes the variables privco (private company) and expinc (increase in world demand for exports) for extrad (external

R&D) and pink (exports), both of which are positive and significant. Extrad is an important finding because it supports the important relationship of Brazilian government, military and university research institutes with those firms engaged in defence-related production. (The centrality of this linkage of government-sponsored R&D activity to private defence firms is explored later in Chapter 5.) Pink also is a crucial explanatory variable because it indicates that military producers are large exporters, which is indeed the case.

Part II: Government Policies

Using the same baseline models for diversification, diversification into military production and military share of production, we now introduce separately individual government policy variables. In the interviews and mail questionnaire surveys, respondents were asked to assess the impact on their firm (positive, negative or no effect) of specific government policies over a ten year period, 1977-87. This period was chosen because it captures the boom period for Brazilian defence exports. A total of twelve policy variables was used in the survey, and four have been excluded from the model either because of their specificity to certain groups, such as multinational corporations, or because of their universal applicability.

Independent Government Policy Variables:

Govsubc: Government subsidies for domestic capital goods purchases. Beginning in 1964, the Special Agency for Industrial Investment (FINAME) of the National Economic Development Bank (BNDES) attempted to stimulate the capital goods sector by providing subsidised financing for the acquisition of domestically produced machinery & equipment.

Govltf: Availability of government long-term financing for investment either through the BNDES or through national/regional banks.

Fisinx: Fiscal incentives to export, including the *crédito prémio* (export tax credit); pre/post-shipment financing for capital goods with long production periods, provided by FINEX (Export Financing Fund), managed by the Bank of Brazil's Foreign Trade division, CACEX.

Govextx: Reduction or exemption on imports of capital goods. The Befiex program allows 70-90% duty and tax reduction on capital goods imports; 50% reduction on imports of raw materials and intermediate products if final products are exported. The transport industries have been heavily favoured by the Befiex system.

Govprm: Government procurement policies for targeted sectors such as informatics (computers) and naval equipment.

Govsubt: Government subsidies for R&D activities provided by the BNDES through its programmes FUNTEC (Scientific and Technology Development Fund) and FINEP (Studies and Projects Financing Agency) to promote domestic technological capabilities at the firm level.

Govdmc: Government domestic content policies i.e. "Law of Similars".

Govtax: Reduction of the IPI (Federal Industrial Product) and ICM (State Value Added) taxes.

Probit Models of Government Policies on Diversification

Policy Variable	Estimated Coefficient	T-Value	Percentage Correctly Predicted
Govsubc	.527	.83	95.5
Govltf	.786	1.03	92.5
Fisinx	.777	1.21	94.0
Govextx	.461	.57	94.0
Govprm	.640	.26	95.4
Govsubt	-.002	.03	94.0
Govdmc	2.208	1.33	94.0
Govtax	.843	1.04	95.5

Probit Models of Government Policies on Diversification into Military Production

Policy Variable	Estimated Coefficient	T-Value	Percentage Correctly Predicted
Govsubc	-.365	1.00	83.6
Govltf	.137	.37	83.6
Fisinx	.134	.41	83.6
Govextx	.711	1.88	82.1
Govprm	-.001	.02	84.6
Govsubt	-.004	.08	83.6
Govdmc	1.813	2.00	86.6
Govtax	-.137	.37	83.6

Regression Models for the Effects of Government Policies on the Military Share of Production

Policy Variable	Estimated Coefficient	T-Value	R Squared
Govsubc	-.015	.25	.35
Govltf	-.080	1.12	.37
Fisinx	-.031	.56	.35
Govextx	.013	.18	.35
Govprm	-.006	.66	.36
Govsubt	-.007	.81	.36
Govdmc	-.020	.29	.35
Govtax	-.020	.30	.36

As the results indicate -- in all three stages: diversification, diversification into military production and military share of total production -- the government policies are usually highly *insignificant*. Only in the diversification into military production probit model do two independent variables show significance: govdmc (domestic content) and govextx (reduction of import duties). At first glance the juxtaposition of these results appears to be contradictory. It may be explained, however, by the effect of these policies on two distinct sub-groups. Domestic content laws would encourage local subcomponent capital goods producers to diversify into military production, while reductions on imports would provide an incentive for larger producers of, for example, transportation equipment, to diversify militarily because of their improved access to and demand for capital goods inputs embodying high technology (for example, specialised composite fibres or computer numerically controlled machine tools).

An interesting and important finding is the poor performance of fisinx (fiscal incentives to export) in each of the three stages. In effect, this result undermines the arguments of Dagnino and Franko-Jones, among others, that the military government directly encouraged exports in order to maintain the long-term viability of defence firms, (given the absence of a domestic market).

Indeed, in unusually candid interviews held at Brazil's Ministry of Foreign Relations, Itamaraty, and at CACEX, Ministry and bank officials said that the government had not formulated any policies towards the Brazilian defence industries and their exports until late 1986, when the arms market was already declining.[29] Only with the impending bankruptcy of Engesa in 1988, brought on by the unconcluded Saudi Arabian Osorio contract, had any direct consultation and coordination occurred between Itamaraty, the Armed Forces' ministries and CACEX. When asked to assess the policymaking process for arms exports sales, one Itamaraty official confessed, "frankly it's a mess."[30]

Part III: Extended Sampling of Military Producers

To verify the findings of the negligible effect of government policies on Brazilian defence producers, a second survey was conducted. This sample, however, consisted only of military producers, which accounts for a lower response rate (20%) than the first survey of capital goods industries (40%). Since this second data set contained known defence firms, the two conditional probit stages -- diversification (diver) and diversification into military production (divermil) -- were dropped. Among the various baseline models run, however, significantly the same milsh (share of military production) baseline model as the original is re-established. This finding should attest to the strengths of the specification of the model and its explanatory power.

$$y(milsh/divermil=1)=.664+.214extrad-.114intrad-.247foreqsh-.167perstrns+.182pinl$$

(3.02) (.73) (1.77) (2.14) (2.79)

n=77

R Squared = .25

Obviously, however, any further analysis of the data on Brazilian defence producers must examine the effects of government policies on particular defence sub-sectors (e.g. aircraft, missiles) since sub-sectors may be more sensitive to the influence of specific government policies.

Using the combined questionnaire data sets, the author created four samples representing the aircraft (AIR), armoured vehicles (ARM), naval (NAV), and missiles & small arms (MSA) industries. Respondents were selected on the basis of either being major weapons producers or manufacturers and suppliers of critical defence-related inputs (engines, turbines, machine tools, etc.)

The equations shown below were estimated with an overall intercept and three of the four industry dummy variables (aircraft, armoured vehicles and naval). Thus, the coefficient for the overall intercept is equal to that of the omitted dummy variable (missiles & small arms), and the coefficients of AIR, ARM and NAV are the respective industry coefficients relative to that for the omitted industry, MSA. Where:

$$milsh = b1I1 + b2I2 + b3I3 + b4I4 + ...conditioningvariables$$

$$I4 = one - I1 - I2 - I3$$

such that

$$y(milsh/divermil=1) = b4one + (b1-b4)I1 + (b2-b4)I2 + (b3-b4)I3$$

Baseline Model for Industry Dummies & Conditioning Variables

$$y(milsh/divermil=1) = 1.14MSA + .05AIR - .28ARM - .149NAV + .241extrad - .511intrad - .211perstrns + .241p$$

(5.74) (.44) (2.57) (1.26) (2.75) (2.51) (2.45) (3.19)

n=46

R Squared = .46

An attempt was then made to determine if government policy effects were significant at the sub-sectoral industry level. Models were fitted to include interactions between each independent policy variable and the four independent industry dummy variables. Only three of the government policy variables showed significance for individual industries. They were government import tax reductions (govextx) for armoured vehicles, government ownership (govmkt) for small arms, and government procurement policies for the naval industry.

In each of these cases, however, the set of industry-government policy interactive variables yielded no significant improvement over the baseline regression or over the baseline plus the government policy variable, constrained to a single coefficient. Importantly, no single policy variable was significant at the five per cent level. Further experiments that pooled the most promising industry-policy interaction sets, two at a time and then three at a time, also failed to reveal any significant pattern.

The Results of the Milsh Baseline Regression with the Inclusion of Government Policy Variables

Policy Variable	Coefficient	T-Value	R Squared
Govtax	-.072	-.90	.47
Govsubc	.041	.75	.46
Govprm	-.124	-1.60	.49
Govdmc	.033	.45	.46
Govmkt	.100	1.42	.48
Govextx	-.476	-.57	.46
Fisinx	-.098	-.18	.46

Conclusion

This first part of Chapter III has developed an alternative explanation for Brazilian defence production and export performance through the use of primary data and a three-stage model. A more interesting and neglected field of research remains however. As evidenced by the previous critique, too much of the literature has thus far focused on the political and economic reasons that pushed Brazil and other Third World countries into military production. Not enough attention has been paid to the question of how and why Brazilian companies successfully broke into such a competitive global market. These are the questions that have stimulated the second part of this chapter: an analysis of firm-level behaviour, using case studies from Brazil's major defence companies.

Section II: Case Studies of Brazilian Defence Firms

Firm-level case studies are provided in this section from Brazil's four major defence sectors: aircraft, armoured vehicles, missiles, and naval craft. Each of the case studies is based on the author's extensive site visits and interviews with corporate management, engineers and marketing representatives. Utilising this information, she provides a detailed overview of these individual companies and their product lines, documenting the various strategies -- R&D, subcontraction, coproduction etc. -- these firms have pursued to develop new products and markets. These case studies also serve as a fascinating account of the successes and failures these high-technology, start-up companies have experienced in the process of breaking into such an internationally competitive, high barrier-to-entry industry.

Empresa Brasileira de Aeronautica S.A. (Embraer)

"Nowadays at every 50 seconds, there is a Brazilian-made aircraft taking off somewhere in the world, carrying passengers and freight in its mission to produce wealth and find out opportunities, offering its contribution for a better world we all wish for." (Embraer corporate video)

Embraer is headquartered in São José dos Campos, 80 km from the industrial city of São Paulo. Its main production facilities cover an area of 230,000 square meters. The company in 1993 employs approximately 9,000 people, of whom 2,000 are technicians and 1,200 are engineers. Seventy-four per cent of Embraer's work force is employed in production. Since its foundation in 1969, the company has produced and delivered over 4,500 aircraft to civil and military customers in 47 countries worldwide.[31] (Please refer to Table 3.5 for a breakdown of Embraer's corporate structure and a listing of aircraft manufactured and delivered to date.)

The rise of Embraer, from a fledgling Third World company of 595 employees in 1970, to the world's fifth largest aircraft manufacturer has been charted by industry observers and defence academicians alike. Analyses of Embraer's development are divided between narrow political and economic explanations. On the one hand, some observers, such as Dagnino, a well-known Brazilian political scientist, contend that Embraer's "functional logic is that of a State enterprise" and "its functional dynamics is molded ultimately by strategic military conditions."[32]

> This means that, as it happens in the central countries in similar sectors, cost and investment limits are ... secondary in the decision making process. It is pointless to attempt to fit its actions and projects by a strictly entrepreneurial-commercial criteria.[33]

Contraposed to this interpretation, are rational actor explanations. Embraer's "feat can only be explained ... [because] ... it decided from the beginning that it would try to sell high-technology products to industrialized nations. It learned to identify a need, develop a product and market it successfully."[34]

These analyses, however, are not theoretically integrative: They abstract the interests of the state, the firm, and the military from the effects of markets at both domestic and international levels. They also tend not to incorporate the centrality of technological development to such a strategic industry.

Table 3.5: *Embraer's Subsidiaries and Products*

1) *Indústria Aeronáutica Neiva*, Botucatu, São Paulo

In 1981 Embraer acquired Neiva and is now the sole stockholder. Neiva produces most of the Piper-licensed small, light aircraft. It also manufactures the indigenously designed EMB-201, Ipanema agriculture plane. The company employs approximately 530 people.

2) *Embraer Divisão Equipamentos* (EDE), São José dos Campos

Embraer's equipment division which produces mechanical and hydraulic systems, as well as weapons pylons and landing gear for the Tucano and AMX military aircraft. EDE's workforce consists of 365 employees.

3) *Embraer Aircraft Corporation*, USA & *Aviation Internationale*, France

These subsidiaries provide sales and technical support for the company's clients located in the U.S, Europe, Australasia and the Middle East. Workforce consists of 135 employees.

4) *Orbita Sistemas Aeroespacias*, São José dos Campos

Embraer's participation in this recently formed missile consortia is 40%. It will be expected to provide the design, manufacture and marketing of a range of guided missiles and rockets.

Production History of Embraer until November 1991

Aircraft		Quantity
EMB-110	Bandeirante	495
EMB-120	Brasilia	245
EMB-121	Xingu	106
EMB-312	Tucano	416
EMB-326GB	Xavante	182
EMB-201	Ipanema	678
EMB-400	Urupema	10
EMB-710	Carioca	288
EMB-711	Corisco	499
EMB-712	Tupi	144
EMB-720	Minuano	285
EMB-721	Sertanejo	205
EMB-810	Seneca	786
EMB-820	Navajo	137
EMB-821	Caraja	33

This schism reinforces the need for a theoretical framework, which is based on the interaction between the interests and objectives of the state and its related agencies (the Brazilian Air Force, the CTA), with the behaviour of the firm, Embraer. The conceptualisation offered by this author suggests that state involvement through fiscal and technology policies accounts for the initial development of Brazil's aircraft industry: first by providing the front-end capital for the creation of Embraer and by assuming initial procurement orders; and second, by facilitating and encouraging technology transfers from foreign companies and domestic research centres to the aircraft industry. Though many political scientists attribute *a priori* national security motivations for Embraer's establishment, this writer contends that the nature of aircraft production itself (substantial barriers to entry), and its international strategic role determined state participation.

Indeed, the evolution of Brazil's aircraft industry has been conditioned largely by Embraer's concern for profitability and technological learning. Specifically, Embraer has developed using four concomitant approaches:

1) The commitment to indigenous design and manufacture;

2) Joint ventures with foreign aircraft producers to acquire and upgrade technological capabilities;

3) Carefully phased introduction of domestic components;

4) Product development balanced between military and civil domestic/export markets.

Although the origins of Brazil's aircraft industry may be traced back to the 1940s, the creation of Embraer dates to 1962, when the CTA became interested in designing and manufacturing planes for regional air transport.[35] The results of the efforts on the part of the CTA's *Instituto de Pesquisas e Desenvolvimento* (IPD) and the Institute's *Departamento de Aeronaves* (DAR) was the initiation in June 1965 of Projeto IPD-6504: the *Bandeirante* aircraft. (*Bandeirante* refers to the early Portuguese pioneers in Brazil).

After consultations with many São Paulo-based industries, which were either unwilling or unable for financial reasons to invest in the manufacture of the Bandeirante, the CTA approached the Ministries of Finance, Industry and Commerce, and Planning for a solution. The result was the creation in 1969 of a mixed, state-privately owned company, Embraer, according to Decreto-Lei no. 770, and an initial financing scheme (Portaria 52 GB), authorised by the Finance Ministry. This latter law enacted in 1970 allowed for a one per cent deduction on corporate income tax with the purchase of Embraer shares. In 1988 there are approximately 226,506 shareholders without direct vote, representing 92.9 percent of the capital ($330 million).[36] The government, through the Air Force, retains control through its possession of 51 per cent of the voting shares. (Interestingly, the largest private shareholder in Embraer is the transnational automotive conglomerate, Autolatina -- a joint venture between Volkswagen and Ford).

The Brazilian government stimulated demand for Embraer-produced aircraft by financing both the Air Force's purchase of 80 EMB-110 Bandeirantes, and the licensed production of 112 EMB-326 Xavantes with Italy's Aermacchi. Subsequently, the Agricultural Ministry placed an order with Embraer for an indigenously designed and manufactured agricultural dust/spray crop aircraft, the Ipanema.

Indirectly, the Brazilian government provided exogenous research and development capabilities through its funding of such research institutions as the CTA, whose mandate includes linking aeronautical research to industrial applications. (For example, the United States' NASA programme, the British Royal Aircraft Establishment, and India's Defence Research Development Organisation all assume the same function.) The transfer of the Bandeirante project to Embraer from the CTA included not only the transfer of disembodied technology and manufacturing "know how", but the movement of highly trained engineers from the aeronautical engineering institute, *Instituto Technologico de Aeronautica*, ITA, who had been associated with the Bandeirante project. Such a transfer was also complemented by the activities of the *Instituto do Actividades Especiais* (IAE), and the Industrial Support Institute, IFI, whose functions are to link and transfer research and development to industrial applications by qualifying domestic component suppliers.

Three planes -- the Bandeirante, the Tucano and the Brasilia -- have marked Embraer's indigenous technological advance. As mentioned previously, the Bandeirante was developed at the CTA in response to the general aviation needs of a small passenger and freight aircraft, which could operate on the short and often unpaved airstrips characteristic of the country's interior. The CTA, in conjunction with Embraer, also decided to equip the Bandeirante with a more economical turbo-prop rather than a jet engine because the latter was considered too ambitious a project.

Throughout the initial 1970s, the Bandeirante underwent many design and engineering changes, (stretching the aircraft from eight to 19 passengers) at the request of its domestic customer, the Brazilian Air Force, and foreign clients. Though the EMB-110 is primarily configured as a 19-seat aircraft for regional passenger and cargo transport, its design is enormously flexible. For example, using the same airframe, the Bandeirante can be deployed for air drop, search and rescue, maritime surveillance, and ambulance missions.

The export success of the Bandeirante stemmed not only from its design flexibility but Embraer's strategy of market segmentation and price competitiveness. For instance, despite its intermediate-level, the Bandeirante was exported to developed as well as Third World countries. By 1975 many U.S. and European airline companies were feeling the pinch of higher oil prices, and the EMB-110 turbo-prop was far cheaper to use than conventional small jets for feeder airlines. At the same time, Third World countries sought the Bandeirante for precisely the reasons it had been built for the Brazilian market, and because of the plane's low maintenance costs. In 1990, 500 units had been produced and were operating in 24 countries, primarily in the United States (over 147 units are in operation), and within Brazil itself.[37]

However, because of the intermediate-level and small size of the Bandeirante, many other newly industrialising counties began to produce similar aircraft and compete for Embraer's market niche. As a consequence, the export market success during the mid-1970s onwards depended very much on price competitiveness. According to Table 3.6, *Embraer's Position in the Medium-Commuterliner Market*, in the 20 passenger airliner category, the best price on offer in 1984 amounted to $2.1 million for Brazil's Bandeirante.[38]

The success of the Bandeirante enabled Embraer to establish an international reputation in the commuter airline market -- a base from which it was well placed to

Table 3.6

Embraer's Position in the Medium-Commuterliner Market

Aircraft	Company/Country	First Flight	Price U.S. Mill. (1984)
212 Aviocar	CASA (Spain)	1971	2.40
Bandeirante	Embraer (Brazil)	1968	2.10
330	Shorts (UK)	1974	3.30
Dash 8	DHC (Canada)	1983	5.20
340	Saab-Fairchild (Sweden/US)	1983	5.30
Brasilia	Embraer (Brazil)	1983	4.70
360	Shorts	1981	4.10

Source: *Flight International*, September 1, 1984, p. 412

introduce its new product, the EMB-120, Brasilia. (Brasilia, the capital of the country, is built in the shape of an airplane.) The Brasilia was specifically designed to take advantage of the changes in the U.S. airline market, brought on by deregulation and the subsequent demand for new aircraft caused by the growth of the commuter and regional airlines. Indeed the design of the Brasilia, a 30-seat passenger, pressurized, twin turboprop airliner -- was heavily influenced by interactions with potential U.S. customers.[39]

U.S. and European carriers presently flying the Brasilia include: Texas Air Corp, Britt Airway, Air Midwest; in France, Air Littoral; in the United Kingdom, Delta Air transport; and in Germany, Deutsche Luftverkehrsgesellschaft.[40] The two principal attractions of the Brasilia are its performance (its 300 km cruising speed makes the Brasilia the fastest in its class), and its price and financing package. In 1984 prices the Brasilia cost $4.82 million and could be financed at 7.5% to 8% for 8-9 years with 15 per cent down.[41] In addition to civil sales, 26 Brasilias have been bought by the Brazilian Air Force for search and rescue and airborne early warning missions.

The development of the Tucano turboprop fighter trainer, Embraer's first indigenously designed military aircraft enabled the company both to satisfy the domestic requirements of the Air Force, and to target a substantial export market niche. With a low price tag of $1.9 million, and over 600 aircraft sold worldwide, the Tucano has become the sales leader in the lucrative military turboprop trainer field. The Tucano also was the first military sale to a NATO country by a Brazilian company. In 1985, the British Royal Air Force selected the Tucano over established domestic and European competitors, such as the British Aerospace Hawk and the Swiss Pilatus PC-9. In 1992 France reached an agreement with Embraer for the purchase of 80 Tucano aircraft.

Licensed and Collaborative Programmes

Embraer has used licensed production and international collaboration arrangements to develop the company's technological capabilities and to offset the risks and investment costs of new production programmes. Among these various joint ventures, the Piper agreement, the AMX and the CBA programmes best illustrate this strategy.

In the mid-1970s, Brazil was the largest single export market for U.S. general aviation aircraft. The Brazilian government's concern over the country's deteriorating balance of payments, and interest on the part of Embraer in the series production techniques of light planes led to an agreement with the U.S. Piper Aircraft Corporation in 1974. While Piper was responsible for the transfer of technology and technical assistance in the areas of manufacturing, materials handling and quality control, it gained a marketing stronghold in Brazil and Latin America because Piper's other competitors, Beach and Cessna, were largely excluded because of subsequent trade barriers on imports of light aircraft. (The custom duties on foreign-built aircraft were raised from seven to 50 per cent.)

In a report which assessed the impact of technology transfers by U.S. companies on the American manufacturing competitiveness, Baranson observes:

> Brazil is not unique amongst the more industrialised of the developing countries in its desire to develop an indigenous aircraft industry. It is perhaps unique, though, in its professional approach to that end. Its strategy of effectively closing entry to its markets for all but the foreign firm prepared to share front-end technology, to impart sophisticated design

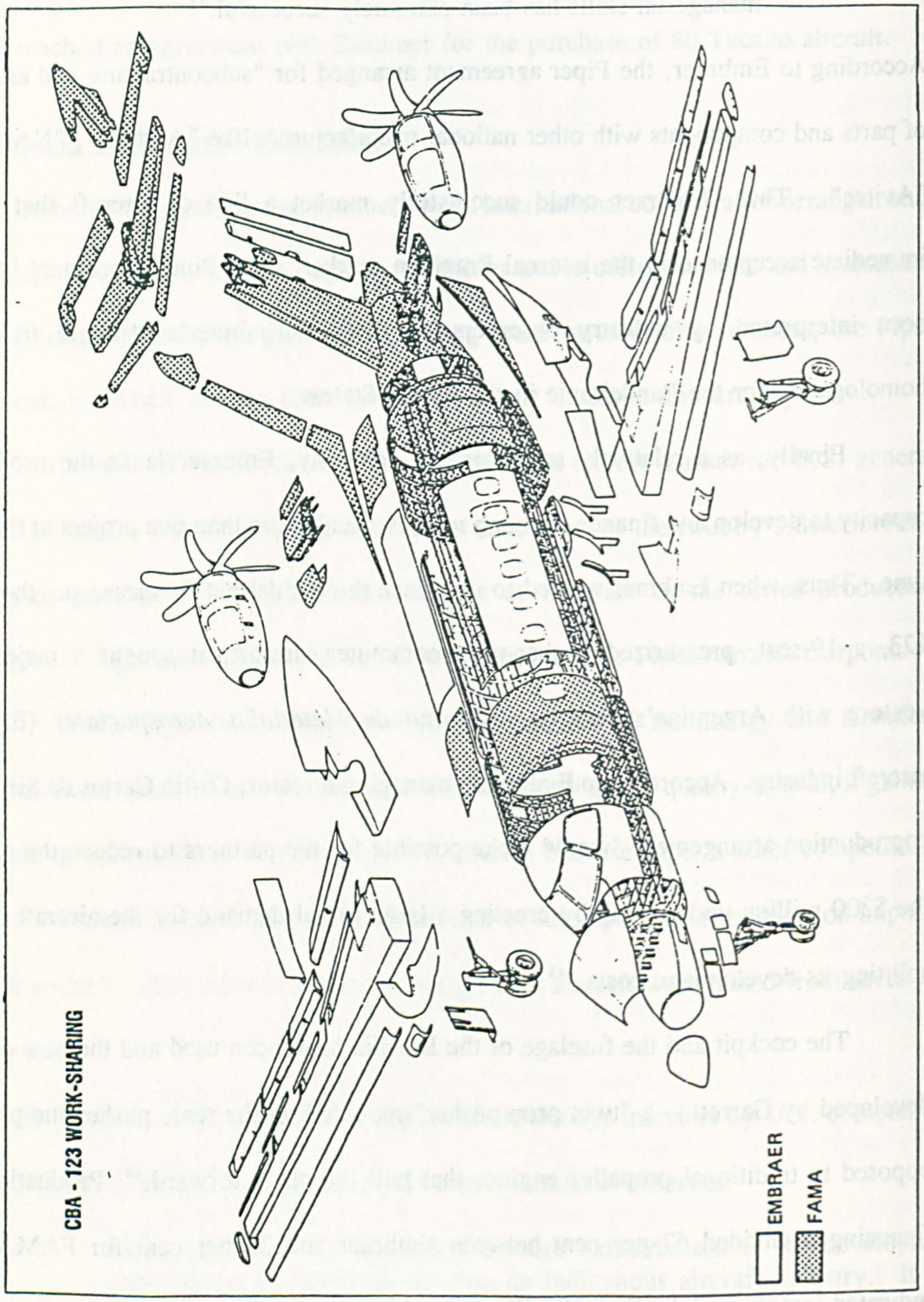
> and engineering capabilities, and to instruct Brazilian nationals in managerial skills has been extremely successful.[42]

According to Embraer, the Piper agreement arranged for "subcontracting and assembly of parts and components with other national manufacturers like "Aerotec", "Neiva" and "Avitec". Thus, Embraer could successfully market a line of aircraft that gained immediate acceptance in the internal Brazilian market. The Piper agreement has also been interpreted by industry observers as part of Embraer's struggle to secure homologation for the Bandeirante in the United States.

Finally, as a relatively small aircraft company, Embraer lacks the production capacity to develop and finance (through reinvestment) more than one project at the same time. Thus, when Embraer wanted to introduce the Bandeirante's successor, the CBA-123, a 19-seat, pressurized pusher-prop commuter aircraft, it sought a major joint venture with Argentina's *Fabrica Argentina de Materiales Aerospaciales* (FAMA), aircraft industry. According to Embraer's managing director, Ozilio Carlos da Silva, this coproduction arrangement "would make possible for the partners to reduce the risks of the $300 million undertaking by creating a large initial demand for the aircraft and by splitting its development costs."[43]

The cockpit and the fuselage of the Brasilia have been used and the new engine, developed by Garrett -- a "twin-prop pusher" mounted on the rear, pushes the plane as opposed to traditional propeller engines that pull the plane forward.[44] Production and financing is divided 67 per cent between Embraer and 33 per cent for FAMA. As indicated in Figure 3.1, *CBA-123 Work-Sharing*, the Brazilian company is responsible for the manufacture of: the cockpit, forward fuselage, section II of the fuselage center

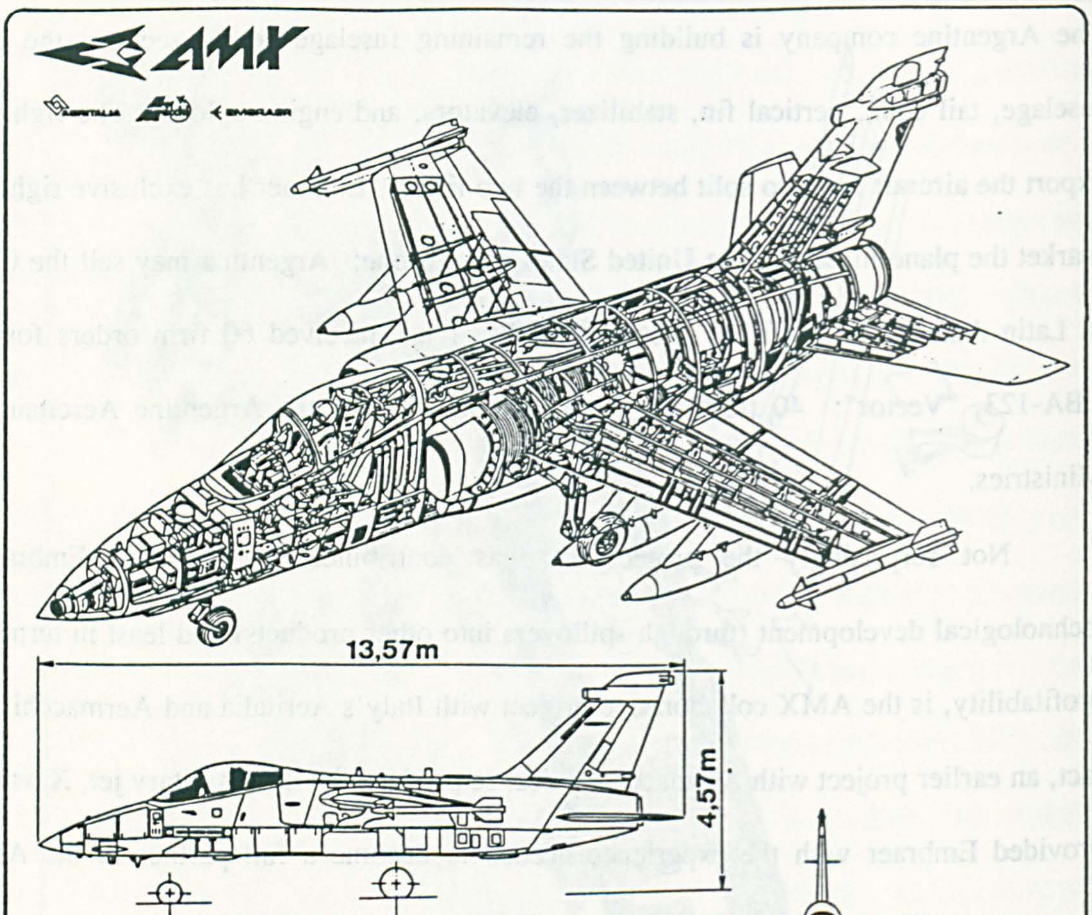
Figure 3.1



section, wings, flaps, aileron, ground spoilers, spoilerone, engine nacelles, and rudders. The Argentine company is building the remaining fuselage center section, the rear fuselage, tail cone, vertical fin, stabilizer, elevators, and engine pylons. The rights to export the aircraft are also split between the two firms: Embraer has exclusive rights to market the plane in Brazil, the United States and Europe; Argentina may sell the CBA in Latin America and Africa. To date, Embraer has received 60 firm orders for the CBA-123, "Vector"; 40 from the Brazilian and 20 from the Argentine Aeronautical Ministries.

Not surprisingly the project that has contributed the most to Embraer's technological development (through spillovers into other products) and least in terms of profitability, is the AMX collaborative project with Italy's Aeritalia and Aermacchi. In fact, an earlier project with Aermacchi to license produce the light military jet, Xavante, provided Embraer with the experience needed to become a full partner in the AMX programme. The Brazilian company has a 29.7 per cent share in the programme, while the shares of Aeritalia and Aermacchi are 46.5 and 23.8 per cent respectively. Production is divided accordingly: Aeritalia assembles the aircraft, and produces the fuselage center section, fin, and various systems for the AMX's front section and components for the wing and empennage. Aermacchi is responsible for the front and rear fuselage sections. Embraer contributes the wings, empennage, wing pylons, external fuel tanks, and landing gear for the AMX. (Figure 3.2, provides an illustration of the AMX.) The Brazilian Air Force will receive a total order of 79 AMXs to replace the aging Xavantes, and Italy's Air Force will take the remaining 187. At present no firm

Figure 3.2


AMX
13,57m
4,57m
4,74m
2,15m
8,88m
12,56m
DESENHO EM CORTE
E TRÊS VISTAS
CUT-AWAY &
THREE-VIEW DRAWING

export orders have been secured for this subsonic tactical support aircraft, despite its lower price tag of $10 million in relation to its competitors.

The AMX and Brasilia programmes have required considerable investments -- an estimated $42 million in industrial capacity and composite materials technology. (An agreement for the transfer of a advanced materials technology and handling was previously signed between Embraer and the U.S. helicopter manufacturer, Sikorsky.) The surfaces and wings of these aircraft are constructed using such composite materials as carbon fibre, Kevlar and Nomex (honeycomb). As many as twenty to thirty layers of carbon fibre are used in the production of structures and are heated inside an air vacuum oven called an autoclave to 130-150 degrees centigrade. This "oven", which is 50 meters long and 405 meters wide, is the second largest autoclave in the world. These aircraft also have required extensive investments in CAD-CAM technology, in which many of the aircraft parts are manufactured using highly sophisticated numerically controlled machine tools, some of which cost close to two million dollars. As one Embraer official wryly commented "The only thing these machines don't do is pay the bills."[45]

Following the pattern of the automotive industry, the aircraft industry also is becoming more interdependent and internationalised, despite its domestic strategic value. Embraer has become a subcontractor to other aircraft industries, and has been obliged increasingly to negotiate offset contracts for its exports. The president of Embraer, Ozires Silva, argues that offsets are central to ensuring foreign contracts, particularly in the advanced industrialised countries, where rationalisation of defence-related industries has had important employment ramifications. Silva likened offsets to driving a herd of cattle across piranha-infested rivers in central Brazil. "You send one cow across as a sacrifice to distract the piranha. You lose that one, but the rest get across safely."[46] This willingness to provide offsets was an important factor securing the sale of the Tucano to the British Royal Air Force. Thirty per cent of the aircraft (the wings, landing gear and canopy) is made in Brazil, 60 per cent is fabricated under license from Embraer by Short Brothers in Northern Ireland. (Not surprising Short Brothers later received a royal award because the company was able to secure employment and create an additional 800 new jobs with the Tucano project.) The modifications of the RAF's Tucano, including a more powerful engine and stronger undercarriage, required such significant re-engineering by Embraer that the RAF version is commonly referred to as the "Super Tucano".[47] The Tucano has also been license produced by Egypt, though Embraer produced and shipped all of the parts to Egypt for assembly.

Subcontraction activities have provided the company with another avenue for technological development. Beginning in the early 1970s, Embraer produced parts (vertical tail assemblies and pylons) for Northrop's Tiger F-5E aircraft, which were exported to the United States. Embraer gained considerable know-how in the areas of metal/metal bonding, which was subsequently used in the production of the Bandeirante, Xingu, Brasilia, and Tucano aircraft. Embraer has also transferred its metal/metal bonding technology to the Brazilian automotive manufacturing sector.

A recent subcontraction arrangement involves the manufacture by Embraer of 207 advanced composite external wings for McDonnell-Douglas' new MD-11 wide-bodied trijet. For this program Embraer developed the tooling and complete detailed design of three outboard flaps, which are fabricated using carbon epoxy fibre material, and are among the largest composite structures on the MD-11, measuring 8.9 meters long. In interviews held at the U.S. company's Long Beach facilities, various supplier managers for the MD-11 emphasised that access to Embraer's expertise in composite material technology was a key factor in McDonnell-Douglas' decision to outsource this critical part of the aircraft.[49] Included in this subcontraction arrangement was a technical exchange programme for the training of Embraer engineers at McDonnell-Douglas. Over this three-year programme, Embraer sent its aeronautical designers and engineers on a one-year rotational basis to work alongside their Douglas counterparts on the new MD-80 project. The Brazilian company also benefitted from its subcontractor relations with McDonnell-Douglas in the areas of quality-control, programme management, and advanced material technology and processes.

Embraer's Promotion of Linkages to the Capital Goods Sector

Many industry analysts have argued that Embraer is nothing more than a final assembler of largely imported aircraft parts. This focus on nationalisation indexes of Embraer's products, however, obscures the essential decision by Embraer *not* to integrate vertically its entire production process. As an Embraer Equipment Division (EDE) representative pointed out, "From the day of its conception Embraer was willing to deal pragmatically with its industrial and technological limits."[50] Embraer has concentrated its efforts on design, and systems engineering and integration. Both Embraer and the

CTA's Industrial Support Institute have encouraged the development, through backward linkage effects of local aircraft component suppliers.

As stated above, the IFI played an early complementary role by qualifying local suppliers for Embraer. Since an agreement in the early 1970s between the United States' FAA, and Brazil's CTA over reciprocal homologation of aircraft, the IFI's focus has shifted. The Institute's activities now largely centre around certification of indigenously produced aircraft. With the growing demand for large series of parts brought on by the Tucano and Piper production requirements, Embraer established its own National Industrial Directorate, and its equipment subsidiary, the EDE.

Since aircraft are characterised by batch production and manufactured for customers' specific requirements, economies of scale become an important determinant in parts production. In addition, because of the research and development costs, the industry is structured by highly specialised subtier manufacturers. For example, only a few companies in the world supply composite materials and engines for aircraft. As a result, Embraer has concentrated on systems integration of subcomponents supplied by local capital goods producers, major international suppliers, and in some cases, by the domestically-based transnational corporations. Thus, Embraer has turned its reliance on imports (avionics and engines) induced by customer specifications into a marketing advantage. A procurement director explains:

> If we can buy cheaper with the quality, then we buy outside...because...it is a very, very expensive industry. Six point four million dollars for the price of our Brasilia. And each of its buyers chooses its own avionics -- Let's take radar. For example, Americans want King radar, the British buy Ferranti. Same for avionics. Eighty per cent choose Collins...very dependable equipment. Our airframes use aluminum with special alloys.

> We buy that from Alcoa here in Brazil but through their company in the United States, sometimes from Kaiser in West Germany. Not yet economically feasible to make special aluminum here in Brazil -- there are no economies of scale. Good technology is available in Brazil but not a sufficient market.[51]

Such pragmatism is also reflected in Embraer's decision not to rush into the production of its own engines (especially jet) and avionics. In keeping with its technology policy, Embraer instead has sought phased development encouraging the nationalisation of those products. The AMX programme has provided Embraer with the experience in building jet turbines. The company, in association with a Brazilian firm, Celma (an experienced engine maintenance company), and jointly with Britain's Rolls Royce might begin series production of jet engines in the late-1990s.

The nationalisation indexes in 1978 for Embraer aircraft were as follows: 80% for the Ipanema, 75% Bandeirante, 70% Xavante, and about 40% for the licensed Piper series. In 1991, the indexes for the Brasilia and Tucano are slightly lower (67%) because of the imports of composite materials and avionics. At the same time, a local supplier network has been built up as part of Embraer's policy to increase the participation of local firms in the manufacture of aircraft. (Table 3.7 provides a listing of Embraer's major domestic suppliers.)

When asked about these links to Brazilian industry, the managing director of Embraer's EDE said that the company supplies the technology, training and quality control methods to these industries, and subcontracts about two-thirds of its production to approximately 350 Brazilian firms. He warned, however, that:

> One should see Embraer as an aeronautical industry from the Third World and Brazil's economic situation. Problems with subcontractors are not

Table 3.7

Embraer's Domestic Suppliers

FIRM	PRODUCT
PIRELLI	Tanks
ABC SISTEMAS	Navigation Control Panel Radio Altimeter Navigation Fixing Selector Flight Director Selector Navigation Mode Weapon Aiming Selector Interface Unit BC/MC IFU Control Panel Electronic Flight Control System Central Suppression Unit Bus Controller/Main Computer TV/IR Map Display System IFF Radio Set
ELEBRA	Air Data Computer Flap and Slat - ECU
AEROELETRÔNICA	Horizontal Situation Indicator (HSI) GCU/CTA Standby Attitude Heading Reference (SAHR) V/UHF System Armament T-27
ENGETRÔNICA	VIR-130 DME-42 ADF-60 Radios T-27
ELETROMETAL ACOS FINOS S/A	Ferrous and Non-ferrous Metals
CIBA GEIGY QUIMICA S/A	Resins, Hardeners, Catalyzers
ARTEFATOS ELÉCTRICOS E MECÂNICOS DE AERONÁUTICA LTDA.	Brackets and Fasteners
NAKATA S/A IND. COM.	Shock Absorbers
D.F. VASCONCELOS S/A	Optical Equipment

> related to quality because of Embraer's high standards, but of delays...The economy is more a concern than technology.[52]

Moreover, the reputation that Embraer has achieved in the international market has opened doors for exports from the Brazilian airplane parts industry.

Brazil's economy with its $120 billion debt, and its concomitant need for exports is precisely why Embraer has so heavily favoured development of products that are attractive to its export customers. In addition, Embraer avoided the mistake that India, Taiwan and other industrialising countries have made in building aircraft industries by relying almost exclusively on domestic military procurement. The company has maintained a balance between military and civil aircraft production from the start. In 1987, for example, Embraer exported $320 million, which represented 68.1% of the total value of production. (International sales were divided 33.4% for military and 67.6% for civil aircraft.) Out of the 31.9% that constituted domestic sales, the civil market accounted for 25.7%.

When asked whether Embraer would gravitate further towards military production because of the Tucano's popularity, Embraer's managing director, Ozilio Silva responded negatively, "The trade in military aircraft appears to be in decline. The competition is very large. The costs of aircraft are very high."[53] In fact, Silva acknowledged that Embraer had not wanted to build the AMX fighter aircraft because of the plane's high costs of production and insufficient export market, but was pressured to do so by the Brazilian Air Force. Instead, Embraer has sought to develop dual purpose aircraft. For example, both the Bandeirante and the Brasilia have civil (e.g. commuter) and military derivatives (search & rescue, reconnaissance, maritime patrol). Table 3.8, *Embraer's*

Table 3.8

A Breakdown of Embraer's Aircraft Production

Production Breakdown of Embraer	% of Net Income
Heavy Planes (1)	57.1
Light Planes (2)	6.7
AM-X	20.2
Service	0.9
Parts	9.4
Other	5.7

1. Heavy planes include the Bandeirante, Brasília, Xingu, and Tucano programmes.
2. Light planes include the *Piper* line of aircraft and the agricultural plane, the Ipanema.

Aircraft Production Breakdown, shows the distribution of Embraer's military and civil aircraft production as a percentage of net income.

Engenheiros Especializados S.A. (Engesa)

A few years ago, television viewers saw the Colombian army storm the justice ministry in an attempt to dislodge terrorists, who were holding several judges hostage. Visible were several Cascavel armoured cars, part of a fleet of 100 purchased in 1981 from one of Brazil's leading arms export companies, Engesa.

Founded in 1958 by its current owner and president, José Luis Whitaker Ribeiro, the São Paulo-based company manufactured oil drilling equipment, and its own "boomerang/bogie" rear suspension system, which enabled the company's trucks and other heavy vehicles to deliver equipment to remote oilfields. Engesa's first military contract, worth $70 thousand, was with the U.S. Army to refit its two-ton trucks with the "bogie" suspension system.[54] One year later, the Brazilian Army also sought Engesa's automotive expertise. "It was 1968, a year of serious recession for us and for Brazil, and the Army required an inexpensive source to modify 100 four-wheel drive trucks."[55] Two years later, Whitaker had built a prototype armoured car, hoping to sell it to the Brazilian Army. Despite the Army's interest as well as the Marine's requirement for development of an amphibious armoured car, neither service's procurement budget could sustain the initial purchases of these vehicles (the Cascavel and Urutu respectively). Thus began Engesa's search for lucrative export markets. After disguising his armoured car as an ambulance, (because the military government, officials at CACEX and Itamaraty refused to permit its export), Whitaker sent a prototype to

Libya, where in 1974 Engesa secured its first export contract for 200 Cascavels and Urutus.

The story behind Engesa's meteoric rise from an obscure equipment and transport producer to a world leading armoured vehicle manufacturer attests to strong private entrepreneurship, product development through linkage to the Brazilian and transnational transport industries, and to government/university research centres, as well as international marketing abilities. Before we examine these explanations, however, it is important to appreciate the initial constraints that Engesa faced in the development of its armoured car industry. These problems can be summarized as follows:

(1) Customers

- No tradition as purchasers of Brazilian military equipment;
- Unknown product reputation;
- Foreign militaries were often not well prepared or knowledgeable in terms of establishing technical requirements for weapons systems.

(2) Export Market

- Lack of familiarity with these countries;
- No long-standing tradition as weapons manufacturer;
- Lack of knowledge about potential competitors;
- Great distance from high technology centres in the United States and Europe, which hindered keeping abreast of technological developments.

(3) Suppliers

- Reluctance on the part of foreign suppliers, which greatly reduced Engesa's bargaining power;
- Unfavourable payment conditions (hard currency payments in advance of sales);

- Production scales for specialised items like guns and optronics were often incompatible with domestic supplier market conditions;

- Short delivery times.

(4) Government

- Not yet prepared to have a significant defence industry in Brazil;

- Technical/Commercial/Diplomatic support unavailable;

- Extremely limited domestic defence procurement budget;

- Non availability of credit programmes or lines of credit through CACEX;

(5) Resources

- Few experienced professionals;

- Difficulties in importing necessary computer hardware and software, especially CAD-CAM technologies because of the Brazilian government's Informatics policies.

(6) Foreign Politics

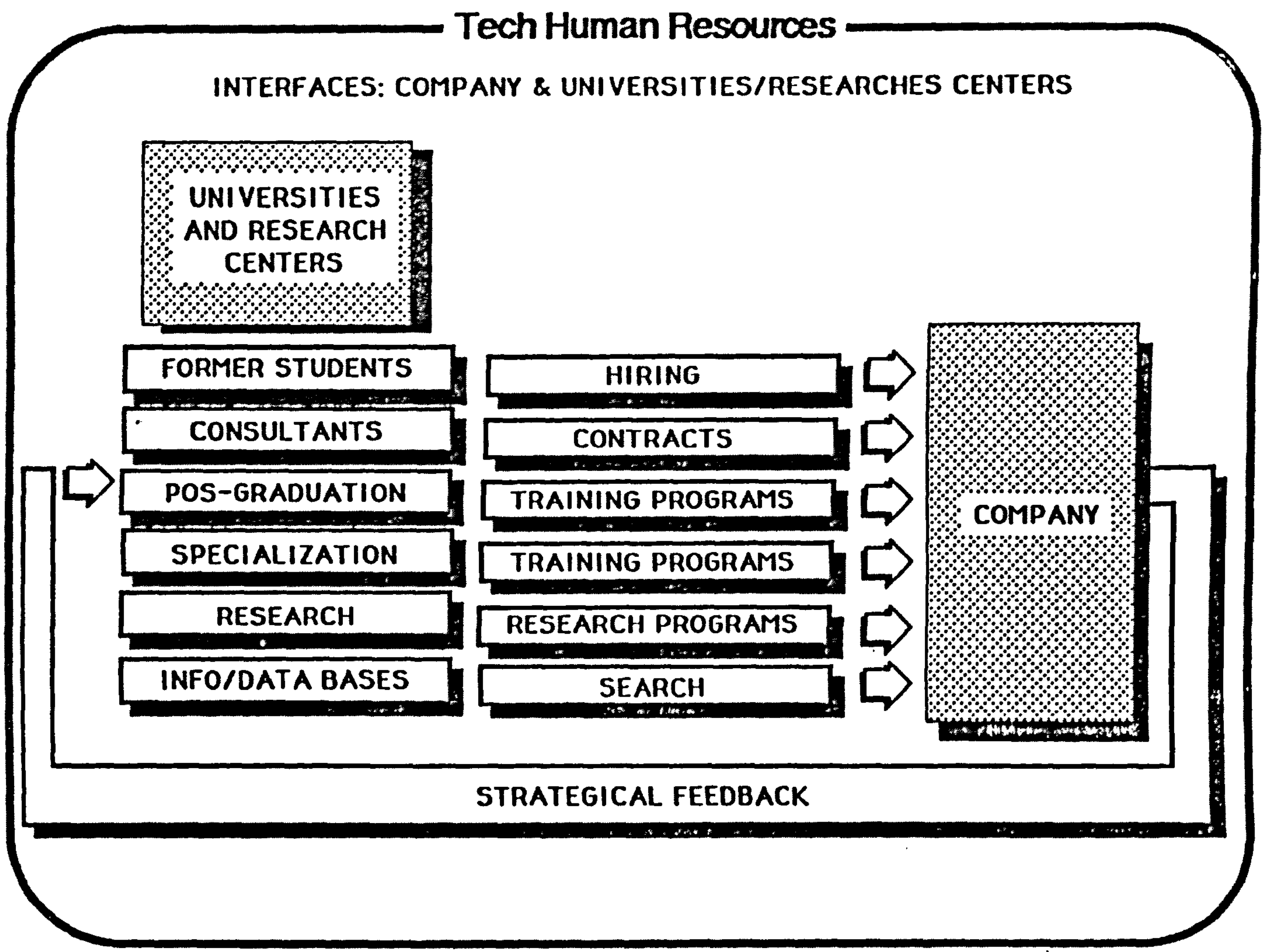
- Restrictions imposed on exports of weapons to such pariahs as South Africa and Taiwan by the developed countries.[56]

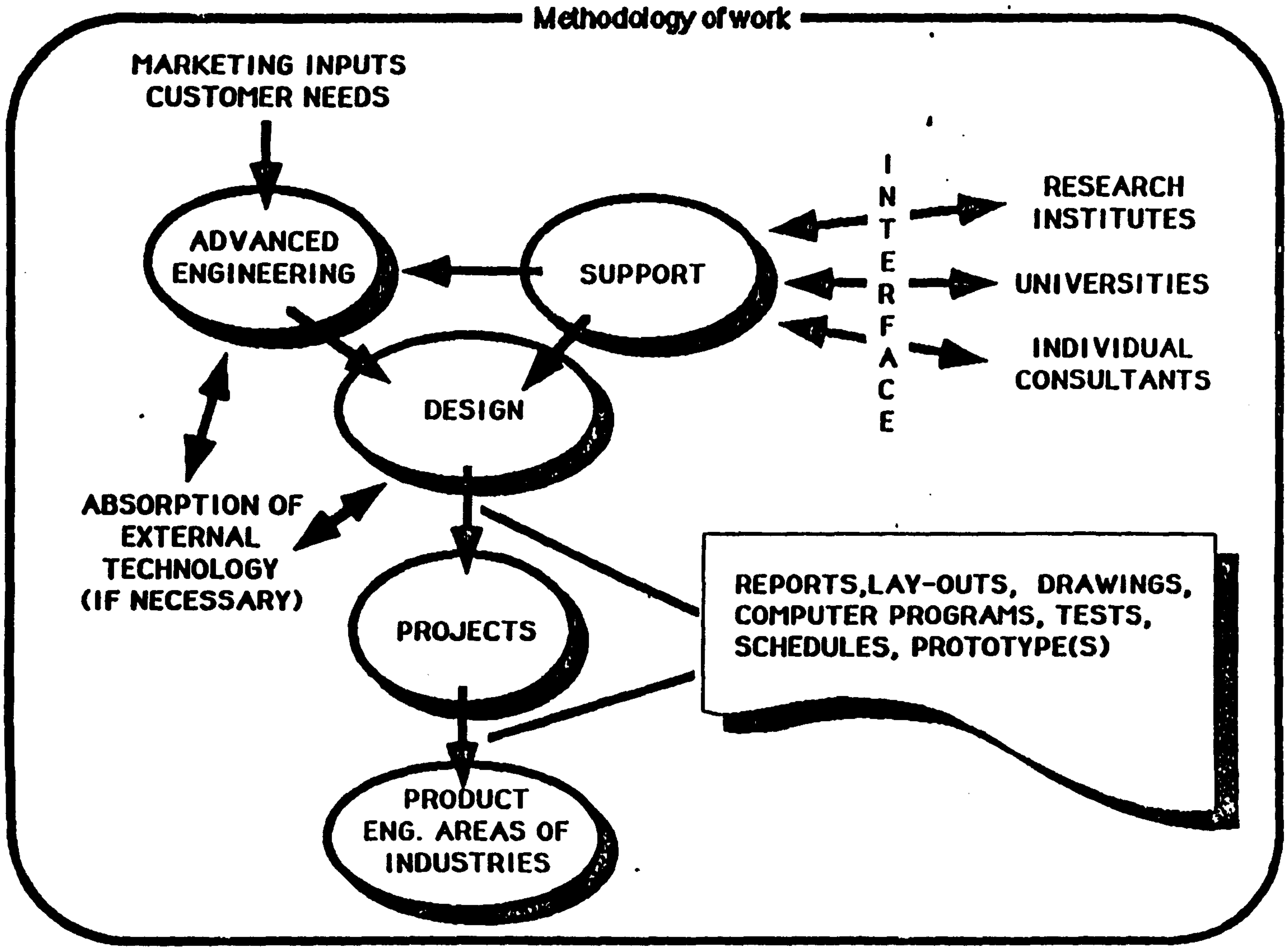
When asked by this author what factors then explained Engesa's success, despite these considerable barriers to entry, company officials were quick to respond. They emphasised carefully phased product development, assisted by heavy investments in research and development, especially in engineering and technical resources; a procurement policy that entailed partnerships with domestic and foreign suppliers; and a marketing/sales strategy, which targeted market niches for intermediate-level weapons systems.[57] As each of these explanations also provide insights into firm-level behaviour, the author will address them individually.

First, in terms of product development, all of Engesa's armoured fighting vehicles (AFVs) and armoured personnel carriers (APCs) share the same characteristics: simple and flexible design concepts, low cost, good performance and reliability, easy use and maintenance. These characteristics also explain the major selling points of Engesa's products to its Third World customers.

Second, the company's strong engineering and technical base is reinforced through linkages to other military, industrial and university centres: the *Instituto de Engenharia, Centro Tecnico do Exercito* (CTE_x), INPE, IPT etc. The following Chart 3.2, *Tech/Human Resources*, provided by Engesa, illustrates the company's interfaces with Brazil's universities and research centres. Not only has Engesa tapped into available technological developments throughout the related metallurgical, electronics and chemical industries, this form of technology sharing also provides a way of selecting highly trained and educated future employees.

In addition, the company's technical director maintained that there were significant efficiencies gained by having both civil and military R & D projects carried out under one department at the same time. (For example, maximised utility of expensive CAD/CAM systems, and fast response to sales and marketing requests).[58] In terms of product engineering, one Engesa engineer said that because of the specialised, customer-specific requirements inherent in the company's products, they often had to incorporate design changes within short periods of time.[59] (Refer to Chart 3.3, *Methodology of Work*, which details the design and production process.) As a result, flexibility in design and systems integration are heavily emphasised. This requirement often has entailed


Tech Human Resources
INTERFACES: COMPANY & UNIVERSITIES/RESEARCHES CENTERS
UNIVERSITIES AND RESEARCH CENTERS
FORMER STUDENTS
CONSULTANTS
POS-GRADUATION
SPECIALIZATION
RESEARCH
INFO/DATA BASES
HIRING
CONTRACTS
TRAINING PROGRAMS
TRAINING PROGRAMS
RESEARCH PROGRAMS
SEARCH
COMPANY
STRATEGICAL FEEDBACK


Methodology of work
MARKETING INPUTS
CUSTOMER NEEDS
ADVANCED ENGINEERING
SUPPORT
INTERFACE
RESEARCH INSTITUTES
UNIVERSITIES
INDIVIDUAL CONSULTANTS
DESIGN
ABSORPTION OF EXTERNAL TECHNOLOGY (IF NECESSARY)
PROJECTS
REPORTS,LAY-OUTS, DRAWINGS, COMPUTER PROGRAMS, TESTS, SCHEDULES, PROTOTYPE(S)
PRODUCT ENG. AREAS OF INDUSTRIES

adaptations and modifications of transferred technology and reverse engineering. Finally, the company has invested heavily in human resource development for its employees. Such a policy includes incentives to undertake post-graduate programmes in the sciences and in business administration, as well as in-house language training.

Engesa's international cost competitiveness strategy is based not only on cheaper wage rates (relative to the advanced industrialised countries), but on its procurement policy. Central to this policy is the company's "make or buy" decisionmaking process and its relations with external suppliers. According to company officials, this "make or buy" decision is made on the basis of whether the input is: of strategic value (e.g. must have the capability to manufacture); classified or sensitive (e.g. armour); domestic resource availability; and production scale. Engesa has particular difficulties with foreign suppliers because of the excessive time needed to secure import permits from CACEX, and because of Itamaraty's refusal to supply end-user certificates on Brazilian defence exports.

However, company sources say they have been able to develop close relations with many foreign suppliers, as many of these military-related manufacturers need to export given their own countries' shrinking domestic weapons procurement budgets. Engesa's four strategies for securing reliable suppliers are: 1) "make suppliers become partners" (by encouraging the supplier to share the risks involved in product development); 2) "for strategic items assure possibility of technology transfer"; 3) "make losers become winners"; and 4) "seek companies that have branches in Brazil" An example of these two latter strategies is the company's search and acquisition of

German MWM engines (which lost a bid to supply the German Leopard II), for the Osorio main battle tank project.[60]

Obviously Engesa's sales and marketing strategy is pivotal in helping to explain Brazil's remarkable success in becoming among the world's ten leading defence exporters during the 1980s. The company had to overcome the many barriers to entry in the highly competitive international arms market; not least of which includes lack of export financing (such as that provided by the United States' Foreign Military Sales Assistance Program), and lack of military and government sales support.

The director of Engesa's sales and marketing attributes the company's success in export markets to the fact that the company's teams are extraordinarily well prepared. "They have assessed the competition and its capabilities, they know Engesa's product capabilities thoroughly, and team members are interoperable in terms of their technical and financial backgrounds."[61] Another important corollary to this marketing strategy has been the establishment of commercial offices in the United States as well as in Europe. From these vantage points, Engesa can be closer to technology centres and to its foreign suppliers. A related factor is the company's renowned after-sales support, in terms of guaranteed access to spare parts, training for the crew, and maintenance (including on the front line during the Iran-Iraq war).

Many analysts, however, rightly note that Engesa can take advantage of the country's non-aligned position in the international system and its affinity with other Third World countries. As Engesa's superintendent for marketing explained:

> We are a Third World country, we understand each other....We are not like the United States or France who sell and forget a customer. And we

> are not like the Russians, when they make a sale, they arrive with 500 engineers and technicians and start interfering in domestic politics. We make a straight commercial deal....[62]

In 1982-83 Engesa embarked on a programme of diversification back into the civilian automotive sector because its assessment of future military markets looked bleak. For reasons that will become apparent later, Engesa opted to acquire industries for this purpose rather than restructure through conversion planning. In 1983 Engesa purchased FNV, an automotive company, and bought from the Brazilian capital goods magnate, Bardella, its electric motors/subway transport division. (These acquisitions were made with the belief that investments in Brazil's urban public transport sector would be forthcoming.) In addition, Engesa entered into a joint venture with the Dutch MNC, Philips, forming Engetronica to manufacture and supply the expanding telecommunications business. (See Table 3.9, *Engesa's Corporate Structure*, for an overview of Engesa's subsidiary portfolio and its product lines.) By late 1984, however, Engesa was experiencing severe financial difficulties as a result of its failed diversification strategy. According to corporate officials, the problems centered around the rapidity of the expansion, little cash flow, no product familiarity, and lack of overall capability to manage these very different companies.[63]

During the same period, Saudi Arabia expressed interest in Engesa developing a main battle tank for its army. The timing of the Saudi contract for the initial research and development phase was fortuitous for Engesa. Though Engesa was by now an established weapons exporter, it faced new entrants -- both domestic and foreign -- in its traditional product lines and markets. Simultaneously, the life cycle of its main product

Table 3.9: ***Engesa's Corporate Structure in 1989***[1]

Engesa has eight major subsidiaries, which including its São Jose dos Campos headquarters, are based primarily in the state of São Paulo, as well as in Salvador.

1. Engex S.A.: *Equipamentos Especializados*

Specialised equipment and parts manufacturer for the petroleum (Petrobras), transportation (GM), mining, agriculture, and forestry industries.

2. Engesa Química S.A.:

Engesa is the majority stockholder in this joint venture with the state-owned ammunition company, Imbel. Engeq produces ammunition for Engesa's armoured personnel carriers' 90 and 105mm guns. Other important customers include the Brazilian armed forces, Imbel and the armed services of foreign countries.

3. Engelectrica S.A. *Engesa Equipmamentos Elétricos*

Engesa's electrical motor manufacturing division. It produces generators, motors and "no-break" equipment for the company's military vehicles and for other civilian applications.

4. Engesa Eletrônica S.A.

A joint venture between Engesa (70% stockholder) and Inbraphil, the Philips Brazilian subsidiary. This division manufactures the fire control, optronics and communication systems for Engesa's APCs, as well as the Osorio. It also produces under license telecommunications equipment, avionics for Embraer and computer network hardware for IBM.

5. Engexo Exportadora S.A.

A trading company, which is responsible for the marketing and sale of Engesa's and other Brazilian companies' defence exports.

6. Aerobrasil

Controls and undertakes "door-to-door" delivery of Engesa's military equipment with its company-leased Boeing 707 and 727 aircraft.

7. FNV Veiculos & Equipamentos

Traditional producer of railway carriages, buses, agricultural and forestry vehicles, as well as specialised trucks.

8. Orbita Sistemas Aeroespaciais

Engesa is a partner is this missile consortium along with Embraer, Imbel and other defence-related firms for the production of various air-to-air and surface-to-surface missiles.

Engesa's Production Breakdown[2]

	Percentage of Net Revenue
External Trade	**70.6%**
Military Products:	69.2%
Armoured Cars Jeeps and Trucks Spare Parts	
Civilian Products:	1.4%
Kits	
Domestic Trade	**29.4%**
Military Products:	10.7%
Armoured Cars Trucks and Jeeps Spare Parts	
Civilian Products:	18.7%
Tractors Jeeps Spare Parts Service Other	

[1]Since March 1990, when Engesa filed for bankruptcy protection, the company has undergone a major restructuring effort. Various subsidiaries have been sold off, for example, *Engetrônica* was sold to Moddata, or have been closed down entirely (Aerobrasil)

[2]These figures are based on 1989 data provided from the *Comissão Valores Mobilários*. They are for Engesa only and do not include the production activities of any of its subsidiaries.

lines was in decline, and the company's customers were requesting more sophisticated weapons. Thus, the decision to proceed with the development of a MBT as well as to enter into partnership with two other defence-related companies, Orbita and Helibras, was viewed as a means to upgrade and diversify Engesa's military market position.

The Osorio MBT programme encapsulates Engesa's approach to developing new weapons systems. First, following the Saudi requirement for a light main battle tank, the company conducted a market feasibility study of other Third World countries, where bridges and roads could not support the 60-ton MBTs such as the United States' M-1 A-1 or the French AMX. Second, Engesa then searched for the best available armour, engines, suspension system, electronics, and gears. In keeping with its strategy of finding suppliers who would share the development costs, Engesa succeeded in attracting many foreign suppliers because the Osorio programme represented the only real new tank development project in the 1980s-90s. For example, Dunlop, supplier to the British Challenger I MBT, was willing to provide the Osorio's hydropneumatic suspension system (which keeps the tank lower on the ground versus the more conventionally used torsion bar suspension system). Within Brazil, Engesa could rely once more on the transnational automotive industry, particularly German MNCs to supply the smaller 85 km/hr engine (MWM) and the gear box (ZF).

Indeed, due to Engesa's engineering strength in systems integration, the configuration of the Osorio is unlike any other MBT on the international market; not only because of its recent conception and incorporation of new technologies, but because of its flexibility in taking account various export customer demand and needs. (In contrast, U.S. and British defence firms have to tailor their products to suit the specific requirements of the domestic armed services.) This flexibility in design and options (guns, type of petrol, engines) is also reflected in the speed of the development process: It took only five years for Engesa to develop and test two prototypes of the Osorio.

The development of this main battle tank also reflects the inherent difficulties of a Third World-based company in moving up the high-technology ladder to the production of more advanced weapons systems. First, the financial resources required have been enormous. Since Saudi Arabia gave the go-ahead for prototype production of the Osorio in 1985, Engesa proceeded to spend $60 million in research and development and prototype development. It was widely rumoured that Saudi Arabia had provided financial assistance for the initial R&D costs. When asked whether such reports were accurate, company officials said that they had not been able to "recover" the money previously offered. "After five years all Saudi Arabia provided was lodging and terrible food."[64] However, Engesa said it was able to secure some government funding for research and development from FINEP (approximately four million), and technical assistance from the army's CTE_x.

Should the Saudi contract ever be finalised, the production budget will entail an additional $30 million investment, much of which Engesa expects to raise on the São Paulo stock market, *Bovespa*. Production of the Osorio will require drastic changes in production and assembly methods, new plant design and expansion, as well as the introduction and use of specialised materials and machining processes. Engesa argues that such an investment in new materials and process technology will have significant spillovers for its other military (APCs and AFVs) and civilian lines.

Aside from financial constraints related to production costs, there are numerous other complications involved in the sales and marketing of the MBT. First, by the mid-1980s several developed countries, primarily the United States, became concerned about Engesa's sales volume and customers (Iraq, Libya and Saudi Arabia). Additionally, the Osorio programme represented a distinct move to enter the high technology end of the international arms export market, which had been long dominated by the established U.S., Soviet and French firms. These concerns led the United States, in particular, to attempt to thwart the Saudi sale by restricting technology transfers of U.S. suppliers to Engesa.[65] For a period of over a year, the Osorio's larger engine supplied by a Detroit-based company was affected by the U.S. curb on its export. When asked whether such restrictions could seriously impair the Osorio and future programmes, a company official responded:

> They [the United States] did this kind of thing...but we ended up having the engine. The version of the engine that we import, we have a kind of agreement with [the company] and it is characterised for a civilian application.[66]

In addition, because the Osorio was in direct competition for the Saudi contract with the U.S. M1 Abrams, British Challenger and the French AMX-40, Engesa required greater diplomatic support and export financing from the respective government ministries, Itamaraty and CACEX. While Britain sent its then Prime Minister Thatcher to Saudi Arabia, Engesa could only pressure Brasilia to dispatch the Army Minister Leonidas. The Minister's presence did not impress the Saudis since Brazil's own army did not possess the Osorio because it could not afford the MBT's $2.2 million price tag. (However, the Army Minister was only too happy to help secure the Osorio contract for Engesa, because of a kickback arrangement: for every twenty Osorios Engesa sold, the Army would be able to purchase one at reduced cost.)

Despite an announcement in August 1989 by the Saudi government to buy 318 Osorios (renamed Al Fahd, the leopard), the contract worth $7.2 billion has yet to be finalised.[67] Subsequently, Engesa was forced to sell its highly profitable subsidiaries, FNV and Engetronica, because of the company's extremely severe cash flow.[68] The effect of these sales was to leave the company in the perverse situation of being even further defence dependent. In April 1990 after a 3,000 man layoff Engesa filed for bankruptcy protection, as its then liabilities were more than double the highest valuation of its assets.

Aviões Brasileiros (Avibras)

Avibras is a privately owned, low-profile, missile company.[69] It is located at the centre of aerospace activities in Brazil, in the city of São José dos Campos in the state of São Paulo. Of the major Brazilian defence firms, Avibras has intentionally retained the greatest autonomy from government agencies and from the Brazilian armed forces.

Avibras was established in 1961 by João Verdi Carvalho Leite, an ITA graduate, initially to manufacture aircraft. The only two aircraft (trainers) ever manufactured were never homologated by the CTA, since the two prototypes and the manufacturing facilities were destroyed by a fire. This disaster, as well as the creation of Embraer, persuaded the founders of Avibras to shift to the field of military high technology, mainly rockets, missiles, bombs, as well as chemicals (solid propellant and explosives), and electronics. Avibras' military production programmes have placed the company at the forefront of rocket and missile production in the Third World.

In cooperation with the CTA's Institute for Space Activities and the National Institute for Space Research, the company's first aerospace project involved the development of an experimental satellite launch vehicle for meteorological purposes, the Sonda I and II. Avibras concentrated on the development of the motor and its solid propellant. In addition to these space-related activities, Avibras has developed meteorological radars, antennas and their associated ground stations for satellite communication (Brasilsat and Intelsat) for the Brazilian civilian market.

In the 1980s the company's turnover grew from under \$7 million per year with about 500 employees, to well over \$100 million per year and over 5,500 employees, reaching \$1.2 billion from 1981 to the beginning of 1988. Out of this total, exports alone accounted for \$1 billion. Indeed, of Brazil's defence firms, Avibras has consistently been the largest exporter. However, Avibras' turnover dropped sharply in 1988 to under \$30 million, with no revenues in 1989 and 1990. It recovered to about \$70 million in 1991 and remained the same in 1992.

Avibras' export success was achieved by spotting and developing a market niche for a new defence product, the internationally renowned Astros II System. This product was a key factor explaining the subsequent success of the company. Avibras' first client, Iraq, played a vital role in the growth and development of Avibras, by signing a contract and releasing a large down payment of about \$100 million out of a \$500 million contract to a then very small, relatively unknown company, to supply a sophisticated rocket system that was still on paper. The Iraqi contract included the technology transfer of the Astros II system, and the supply of 11 Astros II batteries, 60,000 SS30, 4,000 SS40 and 1,200 SS60 rockets. The technology transfer was never completed, and only 1,000 SS40 and none of the SS60 were delivered. The contract was breached at this point and no more deliveries or payments were made after 1987, leaving 25% of the contract outstanding.

The Iraqi contract enabled the company to develop the Astros system and to build the manufacturing facilities. The development of the Astros system was achieved through massive investments in R&D, manufacturing, and human resources. During the peak years, about 400 engineers and 400 technicians were employed by the company, out of 5,500 employees. This team consisted of some of the best Brazilian as well as foreign scientists, engineers and technicians in the field.

Saudi Arabia has been Avibras' largest client. Between 1986 and 1988 the country received 12 Astros II batteries and 30,000 SS30s. A second contract signed at the end of 1990 consisted of a shipment of 5,000 SS30, 4,000 SS40 and 600 SS60 rockets that were delivered just before the Gulf War. Additional rockets and technical support are currently under contract. Qatar has one Astros battery and a small amount of rockets. Brazil has one battery and a small supply of rockets as well. Contrary to what has been published, Libya has never received any arms shipments from Avibras -- a contract was negotiated in 1983 but never came into force. Other potential clients that have strongly considered the purchase of the Astros II system include Iran, (which has wanted a license to produce the system), Thailand, Venezuela, and Angola.

Major Products

The major product developments of the company are:

1. Astros System

The Astros II consists of 127mm (SS30), 180mm (SS40) and 300mm (SS60) rockets, which are able to reach targets from 9km to 70km, carrying a 30kg high-explosive warhead, 24 subammunition of cluster or antipersonnel bombs, and 60 subammunition of cluster or antipersonnel bombs. The firing is done using an armoured launching vehicle (LMU), supported by a reammunition armoured vehicle (RMD), and a fire control unit (UCF). A later version of the Astros system included a command and control vehicle and a maintenance workshop vehicle. A battery of Astros IIs consists of: six launchers, three reammunition vehicles and one fire control unit, and is able to fire four containers per launcher in 20 seconds. Avibras provides complete logistical support and training for the system, which has been successfully battlefield proven by both Iraq and Saudi Arabia.

2. Flying Intruders at Low Altitude (FILA)

This system was specified and ordered by the Brazilian Army, with an initial order of 13 units and a future order, that never materialized, of 150 units. Only nine units were delivered and the contract was breached. At this point 70% of the FILA's components can be manufactured in Brazil. The system is a technology transfer and license agreement between Avibras and a Swiss company, Contraves, based on the

Skyguard technology.[70] This joint development project required the development of software, logistics, field and laboratories tests, maintenance, manuals, and client training. The project involved more than 200 people over a four-year period, with an extensive training program both at Contraves in Switzerland, and in Brazil for Avibras' engineers, programmers, technicians, and mechanics.

3. FOG-MP

This system consists of a fibre optic-guided missile with a ten kilometer range, hand-guided via a television camera in the nose of the missile. The FOG-MP barely made its first and only prototype flight, lacking further R&D. Avibras needs an additional U.S. $50 million to conclude the developmental stage since none of the manufacturing problems have been solved due to a lack of suppliers for most items. Procurement of sensitive components, such as laser diodes, micro cameras and guidance systems, will be difficult since they are available only outside of Brazil. The project is managed by Avibras Fibras Opticas (AFO), a subsidiary of Avibras.

4. SBAT 70

This sidewinder or ground-to-ground rocket can be supplied, but international market prices are so competitive that Avibras has virtually given up its production, and any further development of this rocket.

5. Inertial Navigation System (Sis Nav)

A land navigation system prototype and its gyro has been developed and tested. Whether the company could, in the short run, produce the gyros and miniaturized systems to be used in missiles, is doubtful. To date the only application for this system is for offshore oil rig drilling guidance. This technology was initially developed at CTA-INPE over a ten-year period. For two of these years a select group of engineers worked at Litton in the United States and with other companies in France, Germany and Japan.[71]

6. SS300 and Barracuda

These two projects, a medium-range missile (SS300) and a naval version of the Astros II (Barracuda), never went beyond the prototype stage. Further investment in R&D would only occur if a firm order was received from a client.

7. Antennas

Avibras Fibras Opticas is also responsible for the 10m diameter telecommunication antennas, which were designed to be transported and assembled in the jungle without any special support or equipment. This subsidiary is also the major supplier of telecommunications antennas for Embratel used on telephone, television, data transmittal through satellite (Brasilsat and Intelsat). Special antennas and systems for private data transmission are being developed and Itaú, a major Brazilian bank, has signed a purchase contract worth over $5 million. In addition, AFO produces home satellite TV reception antennas.

The Development of a Supplier Network

Underpinning Avibras' systems integration capability were decisions pertaining whether to produce components in house (because of the need to avoid loss of control over know how for sensitive components and because of difficulties in finding a reliable source of supply), or whether to source parts to local as well as foreign suppliers. As a consequence, Avibras has established very strong bonds with its specialised suppliers including:

Mechanical Parts of the Rockets

From the design and specification stages, Avibras worked together with various suppliers to develop the production capability of needed components. The most sensitive items were the flow forming of motors and ogives. Production technology was secured through a joint R&D effort with the then West German suppliers of the flow forming equipment and the West German mechanical workshops that developed and produced the preforms. Afterwards, Avibras found local suppliers for the raw materials and mechanical components.

Solid Propellent

The formula was developed by the company and of all the materials required, only one item, Ammonium Perclorate, still is a critical import item. Avibras has had to depend on U.S. (KerrMcgee and Pepcon) and French (SNPE) suppliers, since a Brazilian facility (in Lorena, São Paulo) has been incapable of producing the propellent in sufficient quantities and quality.[72] As for Hidroxil Terminated Polibutadien Resin, a local supplier, Petroflex (a former subsidiary of Petrobras now privatised) is producing in quantities and quality needed.

Explosives

Explosives for war heads and subammunition, including the raw material, are locally produced by Imbel and ICI's Explo.

Electronics and Telecommunications

Dependence on foreign suppliers is enormous both for systems such as the firing control unit (Contraves), radios (Plessey and Racal), navigation systems (Teldix), special computers (CDC of Canada), and electronic components (integrated circuits, relays, connectors, capacitors, cabling). Most of the material is imported from the United States or from Europe. There are no local sources or any foreseen development of them, so that even if some of the equipment and boards could be assembled locally, most of the components would have to be imported.

Vehicles

The vehicles for the Astros system are designed and manufactured by Tectran, a subsidiary of Avibras, using a special German Mercedes Benz 6x6 chassis. Tectran also manufactures the launching platform (which is the most critical item) as well as the cabling, and assembles all instrumentation and accessories. Except for the chassis, which could be replaced only with a costly, redesigned adaption to a locally produced, Scania Vabis 6x6 chassis, all other items can be supplied domestically.

According to a former company manager, four factors greatly affected Avibras' successful development of these suppliers. The first factor was the capability and willingness of local capital goods firms to supply the larger Brazilian defence companies because of the various recessions in their industry. In conjunction, many local suppliers felt a certain national pride in supplying a domestic, high technology company such as Avibras. Third, most of Avibras' domestic and foreign suppliers are small-to-medium sized companies, which permits efficient and flexible transactions. A final factor is that cost concerns are not critical to Avibras' procurement policy since the markup on many of its products (the Astros) is as much as forty per cent. (Indeed, in terms of Avibras' procurement policy, cost factors are weighted fourth, behind safety, quality, and delivery time.)

All these military projects have been financed by Avibras from its revenues. R&D has usually received the highest funding priority. Equipment, materials, components, training, consulting, travelling, have also been readily available (until recently). Salaries at Avibras are among the highest in the country, sometimes matching U.S. and European standards, and have attracted experienced personnel from various aerospace agencies and other companies, including those from abroad.

During the late 1980s, when there were no outstanding contracts and deliveries, Avibras turned to local and foreign banks for loans of over $250 million to guarantee payment of salaries, fixed costs and R&D. Considerable effort was made to keep all R&D personnel. An important factor helping Avibras retain its R&D teams, was that its engineers and technicians were not easily absorbed by the commercial, manufacturing sector because of their high specialisation and salaries.

In the first days of 1990, with debts piling up, no new orders at hand and 4,000 employees on a paid leave without salaries for months, Avibras filed for bankruptcy protection, *concordata*. The terms of the *concordata* allowed the company to repay 40% of its debt obligations within one year and the remaining balance within two years, with 12% p.a. interest and no monetary correction. Since inflation ran very high in 1990 and 1991, the total amount repaid was less than eight per cent of the original value, meaning the company was "pardoned" on about U.S. $350 million on debts owed to banks (Loyds, Banco do Amazonia, BCN) and suppliers. The *concordata* has severely hurt small and medium suppliers locally and abroad since over U.S. $50 million is still owed them.

D.F. Vasconcelos

Established in 1941, D.F. Vasconcelos (DFV) is Brazil's sole industrial precision optics manufacturer, and one of the country's oldest defence producers.[73] The history of this company, as told by the founder himself -- a German expatriate, and former prisoner of war in England -- is characteristic of the experience of small private capital goods firms. Mr. Vasconcelos' first project was to supply the Brazilian army with rangefinders for coastal artillery, aiming circles and binoculars. A few years later in 1943 Vasconcelos was called by the War Department to start an optical factory in São Paulo, and to go to the United States for specialised education (at George Washington University), and to buy the necessary equipment and technology (Brazil was entitled to this technology as a recipient under the Lend Lease Act).

Since those years, the company has diversified several times, as highlighted by Table 3.10, *D.F. Vasconcelos' Production Breakdown*. Because of its excellent die casting facility, especially with aluminum, DFV produced carburetors in the 1950s for

Table 3.10

D.F. Vasconcelos Production Breakdown

BREAKDOWN OF PRODUCTION	PERCENT OF NET INCOME
Professional Optical Equipment	28.5
Consumer Optical Equipment	17.5
Defence Material	18.3
Optical and Mechanical Components	19.4
Exports	15.2
Miscellaneous	1.1
TOTAL	**100.0**

1) Professional Optical Equipment includes medical and hospital instruments.

2) Consumer Optical Equipment includes binoculars, eyeglasses, telescopes, etc.

3) Defence Equipment includes gun sights, periscopes, air-to-ground missiles, cluster bombs, night vision equipment.

Bendix, a multinational automotive company. With the oil crisis of the 1970s and the recession in the transport sector, DFV sold the division to Fiat and returned to the manufacture of optical equipment, especially medical and defence equipment, and more recently, robotics.[74] With a reduced base of 750 employees from a high during the automotive boom of 2,000, DFV now concentrates its optics production in civil lines (binoculars and telescopes, camera lenses for a German company, Agfa)

D.F. Vasconcelos also produces defence optical equipment for sale to the Brazilian armed forces and abroad. Additionally, the company is an important subcontractor to three other Brazilian defence firms: Embraer, Engesa and Bernardini. (Refer to Table 3.11, *D.F. Vasconcelos' Principal Clients*, for a complete listing.) For example, DFV developed and produces the heads up displays used in Embraer's Xavante, Tucano, and Brasilia aircraft. Using transferred technology through a joint venture agreement with Pilkington Glass of the United Kingdom, DFV has manufactured and provided periscopes and night vision/laser equipment for tanks and armoured vehicles (Osorio and Tamoyo as well as Jararaca, Urutu, Cascavel). Other products include: collimeters for motors, lenses for guns, stethoscopes for aerial photography, timing fuzes and mechanical devices for 37mm and 70mm unguided rockets, 40mm anti-aircraft gun using electronic radar etc. Given its expertise in high precision optics, D.F. Vasconcelos was contracted by the CTA during the mid-1980s for the research and development of an infra-red seeker/guidance system for an air-to-air missile, the Piranha. However, in 1987 D.F. Vasconcelos was forced to abandon the prototype development of the Piranha. The CTA had held up funding and the company could no longer afford to continue the

Table 3.11

D. F. Vasconcelos' Principal Clients

Defence Equipment	Armed Forces
	ENGESA - Engenheiros Especializados S/A
	EMBRAER - Empresa Brasileira de Aeronautica
Professional & Consumer Optical Equipment	Fotoptica Ltda.
	Casa Anglo Brasileira S/A
	Cinotica S.A.
	Mesbla S/A
	Comaci Hospitalar e Científica Ltda.
	Coday - Importação e Comercio Ltda.
	Hospital das Clinicas da Faculdade de Mecicina da Universidade de Sao Paulo
Optical and Mechanical Components	Xerox do Brasil S/A
	Nashua do Brasil S/A
	IBM do Brasil Com. Ind. Ltda.
	Kodak Brasil Com. Ind. Ltda.
	MECAF - Mecanica Fina Ltda.
	3 M do Brasil Ltda.
	Micronal Aparelhos de Precisão

project and support the R & D staff out of its current operating expenses. The CTA then forced D.F. Vasconcelos to transfer its team and research to a newly created missile company, Orbita.

Orbita

The creation of Orbita, an association of five aerospace-related companies, in 1986 revealed underlying conflicts of interest among Brazil's leading defence producers. This association consists of Engesa and Embraer, each with 40 per cent participation; the remainder divided among three companies Esca, an aerospace company interested primarily in air traffic control and radar systems with 11 per cent; Imbel, the Brazilian Army's ammunition and propellant factory with five per cent participation; and Parcom -- the splinter group that left D.F. Vasconcelos in 1989 at four per cent.[75] The company, which is expected to have its own facilities on Embraer's land in São José dos Campos, is largely a paper company, as none of its three main missile projects -- the air-to-air missile (MAA-1) Piranha for the AMX aircraft; the surface-to-air missile (MSA-31); and the anti-tank MSS.12 have proceeded beyond the prototype development phase.

According to an Orbita video provided by Engesa, Orbita will have the following company inputs: 1) Engesa, using its engineering and marketing strengths, is to be responsible for vehicles, warhead, ammunition, fire-control systems, and electronics. Engesa has already contributed to the development of the anti-tank missile through its division Engemissile, which was absorbed by Orbita. This division had been working on the development of the anti-tank missile in conjunction with Italy's OTO Melara; 2) Embraer contributes its background in project engineering, CAD/CAM designing, composite materials technology, avionics, aerodynamics, and systems integration; 3) ESCA is providing its expertise in flight control systems, communications, systems engineering, and applicative software; 4) IMBEL supplies propellants and explosives; and finally 5) Parcom contributes its knowledge of infra-red guidance technology derived from the initial development at DFV of the air-to-air Piranha missile. Conspicuously absent from this group obviously is Avibras.

Engesa's initiative in forming Orbita to compete with Avibras can be attributed to two motivations. First, enmity had existed between Leite of Avibras and Whitaker of Engesa because of the latter's desire to undermine Avibras' missile business. Second Engesa had a progressive interest in developing missiles to complement its military vehicle platforms.

NAVAL

The Brazilian shipbuilding industry was initiated during the 1950s, aided by the activities of the *Grupo Executivo da Industria de Construção Naval*, and fiscal incentives provided by the Brazilian government.[76] Today, Brazil's shipbuilding industry consists of eight firms, though four dominate the sector. They include: *Arsenal de Marinha do Rio de Janeiro* (AMRJ), the state-owned shipyard, which is the main national supplier to the Brazilian Navy; Verolme, a private Brazilian company (formerly Dutch owned however), which is Brazil's largest shipyard, located in Jacuecanga, near Angra dos Reis in the state of Rio de Janeiro; Ishibras, a company 90 per cent owned by the Japanese conglomerate, Ishikawajima-Harima Heavy Industries Co. Ltd.; and MacLaren, another smaller, privately-owned Brazilian shipyard based in Niteroi at the Ilha de Conceição.

During the 1970s, the shipbuilding industry's share in exports of capital goods was very low, on average less than ten per cent of total production was exported. By 1983, however, the industry had exported nearly half of its total production, as indicated in Table 3.12, *Sectoral Exports of Specialised Capital Goods.*

Brazilian Navy Defence Production Programmes

Despite the presence of an extensive commercial shipbuilding sector, the Navy, in contrast to the experiences of Brazil's Air Force and Army, has been slow to involve the private sector in defence production activities. Some naval observers attribute the growing obsolescence and excessive concentration of naval assets (ships, office and production facilities in Rio de Janeiro) to this reluctance. As one Brazilian naval captain observed, "The bitter reality is that the present Navy cannot control even small selected South Atlantic areas and has painful difficulties patrolling even for a short time, the entire Brazilian coast."[77] When asked what accounts for the Navy's different perspective from its fellow services, Admiral Mario Cesar Flores observed that the Navy is more internationally oriented and the Navy is very dispersed in its research and development activities, which are not widely connected to industry.[78] For example, the Navy uses the Federal University of Rio, University of Campinas for electronics, University of São Paulo for nuclear-related technologies. The Navy also has a strong tradition of sending personnel abroad to U.S. universities, such as MIT and Caltech for specialised programmes.

The approximately 49,000 man Navy operates roughly 110 ships, of which 37 serve in the fleet. The remainder serve in support roles. Most of the vessels have been

Table 3.12:

Sectoral Exports of Specialized Capital Goods

(percentage of production)

	Subsector	1981	1982	1983	1984	1985
1)	Heating & Cooling Equipment[1]	5.1	3.8	5.3	4.5	10.2
2)	Mechanical	33.0	21.3	38.6	41.3	47.8
	2.1 - Machines[2]	25.7	13.1	29.8	35.8	38.8
	2.2 - Industrial Equipment	7.3	8.2	8.8	5.5	9.0
3)	Components & Materials	7.2	6.2	8.4	8.2	8.1
4)	Metal Structures	5.5	7.5	19.8	22.1	9.0
5)	Electrical Equipment	14.1	12.5	17.8	22.3	16.3
6)	Railroad	19.4	11.3	19.1	11.7	8.2
7)	Naval	17.4	34.2	49.9	17.3	30.6

Source: Partbank/Zanini

[1]Excludes tabulations

[2]Excludes diesel motors

scheduled for decommissioning within the decade, though owing to budgetary constraints modernisation and replacement programmes have been considerably delayed.[79] For instance during the 1986-87 period the Brazilian Navy was allocated only $72 million for new construction programmes.

In addition, a breakdown of the Navy's budget reveals that only 21 per cent is allocated for procurement; six per cent for research and development; and the remainder for personnel costs. The pattern of procurement has been to use the Navy's IP_qM (Instituto de Pesquisas de Marinha) and invest in the conception of the project, and then transfer it to the Navy's own AMRJ shipyard.[80] (IP_qM projects include sonar, acoustics, electronic equipment, missile technology, gyroscope guidance and the submarine propulsion programme.) Two programmes, in particular, are reflective of this approach: The corvette and nuclear submarine programmes.

Corvette Programme

In order to complement and eventually replace the Navy's aging fleet of World War II vintage destroyers, the Navy established a requirement for the indigenous design and construction of 12 corvettes. Preliminary design work began in 1978 at the Navy's *Diretoria de Engenharia Naval* (DEN) and construction of the first four were authorised in 1984. Because of the pressures of time, and limited facilities at the Navy's own shipyard, it was decided that two of the Inhauma class corvettes would be built by AMRJ, the remaining two by Brazil's leading private shipbuilder, Verolme. Approximately 65 per cent of the value of the corvette is locally produced and subcontracted by other Brazilian defence-related firms: its steel superstructure, anti-ship missile "Barracuda," as well as the anti-air defence system (similar to the ground Fila version), are to be provided by Avibras; the 40mm gun is being produced under license from Bofors by CBV; and Helibras is to provide the Aerospatiale licensed-produced helicopters. The propulsion and fire-control systems and sonar are imported.[81]

Nuclear Submarine Programme

Although the primary role of the Brazilian Navy is sea control, Brazil's investment in its submarine programme has been interpreted to project offensive power, and to serve as a deterrent. The main roles of the Brazilian submarines are to attack enemy naval forces, to blockade enemy harbours with mines, and to attack sealines of communication. The submarines also could be deployed defensively to control such choke points as the Rio-Santos-Vitoria area. The Navy has begun replacement of four U.S. Guppy-class units with West German Type 1400-class submarines. The leading ship, the Tupi, was built in West Germany and is already in service. An additional three have been constructed at AMRJ with supervision from the Ferrostaal/ Ingeniear Kontor Lubeck/HDW (Howaldswerke) consortium.

Some local subcontracting also has been undertaken. For example, the special metal used for construction of the pressurised hulls is being provided by a former state-owned steel company, Usiminas. The hull is to be manufactured by Nuclep, a division of the state-owned nuclear company, Nuclebras. Some of the São Paulo-based MNCs are also engaged in the project. Siemens, for example, is providing the electric motors. However, as the director of Naval procurement argued, the $70 million investment in research and development costs makes it difficult to justify indigenisation of some components, especially communications equipment. The problem according to Admiral Flores, is not one of absorbing or developing technology, but one of finance. "Our biggest enemy," Flores remarked, "is the Brazilian economy."[82]

Brazil's own nuclear-powered submarine programme has been the central development project of the Navy, and best reflects the division of labour between the activities of the Navy and private industry. Using the facilities of Copesp and Aramar, the Navy has concentrated on the technology and systems development for the propulsion system, not on the production of the submarine itself.[83] Copesp's primary role is to develop the propulsion system in coordination with Aramar. The latter Institute will develop, nationalise and certify components, equipment and conventional naval systems, in particular those currently imported for steamships. Aramar also has been involved in the construction of a compact nuclear reactor that could make viable the nuclear propulsion system. The Navy's procurement division will be responsible for the submarine production programme, and for targeting local private sector involvement.

When asked why this division of labour was established, Copesp's director, Admiral Orthon Pinheira da Silva, responded:

> Two reasons: First to fulfill the needs of the Navy. Second, because the applicability of this technology for the civilian nuclear energy programme, which because of bureaucratic politics has prevented the development in Brazil of a good civilian nuclear energy programme."[84]

The Navy wanted to avoid such political entanglements at the state level, and to develop the technology quietly, without international scrutinisation. In fact, this latter concern has proved well-founded, as the United States has been anxious about the spillover potential of the submarine programme on Brazil's nuclear weapons capability. Washington has impeded the export of any material related to the programme, so the system for the fuel cycle, for example, has been developed indigenously.

What then accounts for the relative success of the naval submarine propulsion programme? As Admiral da Silva explained, "the technology was available in Brazil, the only problem was how to find it. The management of the programme has been more of a challenge than a technical one."[85] According to him six reasons suffice:

1) Definition of a long-run programme;

2) Accounting system "center of costs";

3) Step-by-step development;

4) Ensuring safety of systems -- for example waste disposal;

5) Funding secure though at low levels;

6) Participation of highly trained and qualified personnel on the project with linkages to universities and other R & D centres such as IPEN (Nuclear Energy Research Institute).

Work on the nuclear-powered submarine has progressed relatively quickly. The zero-power reactor, which serves as a test lab, is in operation, as is the primary circuit of pressurized water to cool the reactor core. The construction of a test compartment reproducing the submarine's propulsion model is underway, and the submarine's reactor, Renap I is to operate fully within the next five years.[86] Despite these advances the first NAC submarine is not expected to enter service before the year 2005.

Verolme

Founded in 1959 as a subsidiary to a Dutch shipbuilding company, *Verolme Vergnide Scheepsvefen*, the company was acquired in 1983 by a group of Brazilians and is now 100 per cent nationally and privately owned. As of 1989 Verolme had produced 92 ships of various kinds. It is Brazil's leading shipbuilding firm as detailed in Table 3.13, Verolme's Sectoral Position. Verolme's installations include three construction docks with a capacity of 30 thousand, 150 thousand, and 60 thousand DWT, one dry dock for the construction and repair of platforms and large quantity of cranes and heavy moving equipment.

Table 3.13: *Verolme's Sectoral Position*

(in 1987 CZ$ Millions)

Firm	Social Capital	Net Equity	Perm. Assets	Gross Revenue
Verolme	1,806.0	5.896.3	9,817.2	5.589.3
Ishi	841.8	3,998.0	6,160.2	4.435.3
Caneco	240.0	2,415.4	2.623.8	2,280.4
Mauá	532.8	4,322.7	5.420.2	2,097.8

Source: *Comissão de Valores Mobiliários*

Verolme's former owner and president, Peter Landsberg, had begun to diversify the company's manufacturing activities to offset the effects of the 1980s' recession in the capital goods sector, and in the international shipbuilding market.[87] Verolme expanded its lines of production in two important ways. The first diversification efforts concentrated on supplying Brazil's expanding petroleum sector. For example, Verolme is now a major producer of semi-submerged and self-raising oil rig platforms and other kinds of equipment for oil exploration and petroleum production. Indeed, according to Table 3.14, *Verolme's Principal Clients*, Petrobras now accounts for 28 per cent of Verolme's total production. Another line of civil diversification is the construction of dredges under license from a Dutch company, Industrieele Handels Coombinatie - IHC. In addition, Verolme is investing in the production of specialised vehicles to combat fire for use at airports and in industry.

A second strategy was to take advantage of the Brazilian Navy's new policy of subcontracting surface ship work to local private shipbuilding companies. Because of Verolme's substantial industrial capacity and technical know-how, the company was contracted by the Navy in 1985 to build two frigates of the "Almirante Inhauma class" as part of the Navy's frigate programme. (The Navy's own shipyard, AMRJ, is constructing two also; a total production of 12 units is expected.)

As a result of the frigate contract Verolme invested heavily in expanding its shipbuilding installations. One of the principal investments for the frigate programme was the installation of a covered platform with a capacity of 600 deadweight tons. Verolme also sought to improve its efficiency by investing in the areas of automation and data processing, and by installing a system of information integration with IBM 4341 computers. These investments involved nearly $15 million.[88] The results of such investments have been partially realised already: Verolme in 1989 had already completed

Table 3.14

Verolme's Principal Clients

Domestic

- Vale do Rio Doce Navegação S.A. - DOCENAVE
- McDermott Shipyard
- Petróleo Brasileiro S.A. - PETROBRÁS
- Odebrecht Perfurações Ltda. - OPL
- Cia. de Navegação Lloyd Brasileiro S.A.
- Marinha do Brasil
- Montreal Engenharia S.A.
- Cia. de Navegaçào Marítima Netumar
- Cia. de Navegação do Amazonas
- H. Dantas Comércio Navegação e Indústrias Ltda.
- S.P. Light
- Cia. Brasileira de Dragagem - CBD

Foreign

- Canadian Steamship Lines - CSL
- Seamar Shipping Corporation
- Aramco Overseas Company
- Salem/Nang Fung
- Gokal
- Medway Maritime inc.
- Seamaster Shipping Inc.
- Seacloul Maritime Inc.
- Firefly Maritime Inc.
- Harpoon Maritime Inc.
- Mundial Maritime Inc.
- Hadron Shipping Inc.
- McDermott Shipyard

Ship Repair

- Frota Nacional de Petroleiros - FRONAPE
- Petróleo Brasileiro S.A. - PETROBRÁS
- Vale do Rio Doce Navegação - DOCENAVE
- Odebrecht Perfurações Ltda.
- Montreal Engenharia S.A.
- Brasil Offshore Ltda.
- Transportes Fluviais e Marítimos S.A.
- Minerações Brasileiras Reunidas S.A.

1987 Breakdown of Verolme's Major Clients

• Petrobrás	27.7%	• C.S.L. (Canada)	10.5%
• Docenave	26.6%	• Marinha	8.8%
• Odebrecht	4.8%	• Reparos/Outros	5.9%
• Seamar	15.7%		

construction of one of the two frigates-- approximately two years ahead of the Navy's own frigate construction programme at AMRJ. Verolme would like to bid on the future Navy contract for construction of its nuclear-powered submarines. However, such a contract would require at least a $12 million investment for Verolme, and it is still unclear whether the Navy will subcontract construction.

Verolme's third strategy has been to export. In keeping with trends in the Brazilian shipbuilding sector as a whole, Verolme exported to the United States and to Australia during the 1981-83 period when the company exported eight ships and four platforms. Since that time Verolme has exported on average over 40% of its total production. The company also sees the potential for an export market for the frigates. These Brazilian 2,000 ton ships have more armour than other competing 3,000 ton frigates and are equipped with helicopter anti-submarine warfare capabilities, sophisticated anti-air and anti-ship missiles, and a 4.5m gun. Potential export for these frigates are various Third World nations, especially in East Asia and in Latin America.

SECTION III: THE BUBBLE BURSTS

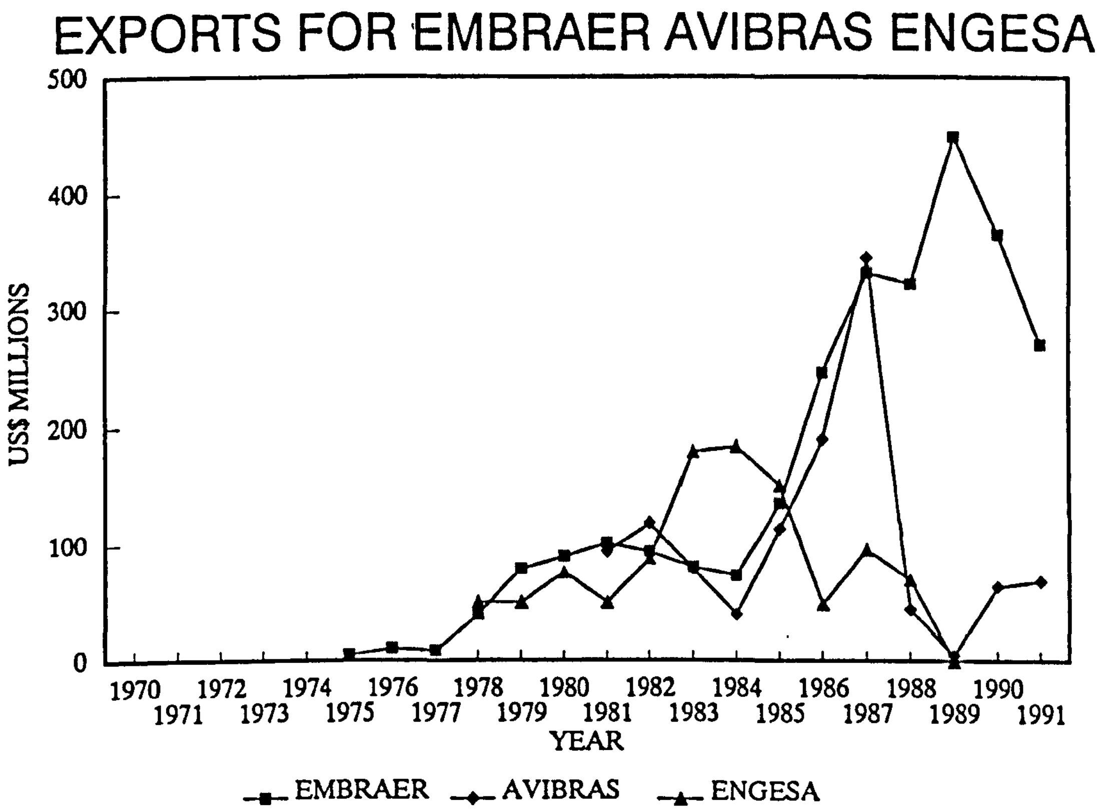
At the end of 1988, a succession of adverse factors began to have their effect on the Brazilian defence industry, as evidenced in Table 3.15, *The Financial Crisis in the Brazilian Defence Sector*. As indicated in Figure 3.3, *Exports for Embraer, Avibras and Engesa*, faced with declining international markets for their aerospace and armoured products, the country's three leading firms -- Engesa, Embraer and Avibras -- initiated major downsizing and debt restructuring programs. At the peak of arms trade boom these three firms employed 24 thousand scientists, engineers, highly skilled technicians

Table 3.15: ***The Financial Crisis in the Brazilian Defence Sector***

	Liquid Operational Receipts			**Net Profit Before Tax**			**Net Profit Per Share**			**Total Debts**		
Firm	**86**	**87**	**88**	**86**	**87**	**88**	**86**	**87**	**88**	**86**	**87**	**88**
Embraer	114.71	159.86	174.51	4.18	2.19	76.07	6.9%	1.9%	-64.2%	67.5%	77.0%	78.6
Avibras	63.98	120.14	NA	6.78	926.	70.00	26.5%	2.1%	NA	81.8%	58.9%	NA
Engesa	38.71	35.44	22.49	-306.	-14.61	-35.18	5.8%	-173.0%	-77.6%	94.3%	107.2%	138.1
Helibras	2.57	3.43	NA	382.	-7.21	NA	75.0%	110.2%	NA	94.3%	149.6%	NA
D.F.Vasconcelos	3.95	2.83	2.94	459.	-1.27	88.	15.0%	-58.9%	2.4%	36.7%	47.3%	33.2%
Bernardini	1.78	1.99	1.98	-76.	-149.	91.	-1.3%	-2.0%	0.5%	18.4%	12.6%	22.2%
Orbita	--	565	1.07	--	275	-3.80	--	9.3%	-213.6%	--	62.9%	130.3%

Source: *Quem é Quem na Economia Brasileira, da Editora Visão*, 1989.

Figure 3.3


EXPORTS FOR EMBRAER AVIBRAS ENGESA
500
400
300
200
100
0
US$ MILLIONS
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991
YEAR
EMBRAER
AVIBRAS
ENGESA

and management. Today a small fraction of that labour force remains -- some 8,000. In response to the financial crisis and the pressure from trade unions, the Brazilian government has relied primarily on the country's banking system to provide short-term liquidity for these cash-starved firms. In general, however, the Brazilian government has yet to devise a coherent industrial policy, struggling to secure only temporary, ad-hoc measures to alleviate the crisis. There is some evidence that two of these firms -- Embraer and Avibras -- will succeed in diversifying further into other commercial transport and telecommunications industries.

Engesa

Engenheiros Especializados S.A. was the first of Brazil's defence firms to show signs of financial fatigue. Operating at tremendous losses since 1986, Engesa filed for bankruptcy protection, "*concordata*," on 21 March 1990. Since that time, Engesa's economic viability and future have been hamstrung; the subject of a complex political battle involving the country's legal system, important financial institutions (the Brazilian National Treasury and the National Development Bank), the Congress, labour unions, the Army Ministry, as well as foreign creditors. A brief review of Engesa's tortured concordata process reveals a broader, fundamental division in Brazilian politics over whether this and other defence-related companies should be treated as national "strategic" assets, thus meriting major government-assisted bailouts in the form of debt cancellation and capital injections.

At the center of this controversy are the terms and conditions for the repayment of Engesa's estimated $450 million total debt. This figure includes the company's debts of some $178 million owed to the National Treasury (back taxes), Bank of Brazil, Banco Real, and the National Economic Development Bank, as well as its residual debts -- $40 million in back salaries to 410 former unionised employees and $2 million to JEC Marconi of Great Britain for reimbursement of costs incurred in the development of components for the Osorio main battle tank.[89] Although the judge, presiding over the concordata, has insisted in demanding the monetary correction of these debts (due to Brazil's rampant inflation), nevertheless, the total amount repaid to date adds up to only 0.3% of the original total.[90]

This outcome was achieved by the Brazilian Army and the government applying pressure on the larger financial creditors, particularly the Bank of Brazil and Banco Real, "convincing" them to issue letters to the judge with their agreement to renounce "voluntarily" or postpone the debts owed to them.[91] As a result, 42% of Engesa's debts have been cancelled. The Congress has subsequently initiated an investigation into the concordata's proceedings, challenging the Army's rescue operation of Engesa and the use of public funds to revive the moribund firm in the name of the national interest.[92]

In April 1992 an agreement was reached between Engesa's owner, José Whitaker, and the Brazilian banks over the company's future. The official document, the *Protocolo de Intenções e Procedimentos*, calls for Engesa's remaining assets and facilities to be handed over to Imbel, a small arms and ordnance manufacturer, partly owned by the Army Ministry. Imbel is to hold a 20% share of Engesa and to sell the remaining shares to other Brazilian firms not yet identified.[93] The Minister of the Army, Carlos Tinoco, justified the "statisation" of Engesa arguing that, "The country is not able to run the risk of having a traditional arms industry in the hands of foreigners."[94]

Indeed, Engesa's owner, Whitaker, had been actively engaged in negotiations with foreign firms, including British Aerospace, which wanted to use Engesa's production and design facilities to build a military version of the Land Rover jeep. According to one inside source at Engesa, the tentative agreement with BA, began to jeopardise the Army's interest in and influence over the future of Engesa.[95]

Embraer

The economic collapse of Engesa is an extreme case highlighting the vulnerabilities that some private defence, export-oriented firms face during recessions in the global arms trade. The current situation for Empresa Brasileira Aeronautica (Embraer), Brazil's mixed state/privately-owned aircraft company, is far more complex, given the Air Force's long-standing interest in the company.

In the case of Embraer, the company's precarious economic position stems from the impact of recessions and declining markets for both its military and commercial aerospace products. According to Embraer's financial director, Manoel de Oliveira, "the world recession has affected our principal client, the United States."[96] The acute financial crisis for many U.S. airline carriers has stalled deliveries in 1992 of nearly 33 Brasilia aircraft -- Embraer's leading export product, which has recently accounted for 50% of the company's sales revenue. In conjunction with declining commercial export sales, Embraer has incurred a 35% drop in procurement orders by the Brazilian Air Force for its AMX subsonic military fighter due to federal budgetary constraints. As

Table 3.16, *Embraer's Financial Balance, 1991-92*, indicates, there have been additional, longer-term financial problems affecting the company's continued viability.

Table 3.16

EMBRAER'S FINANCIAL BALANCE 1991-1992

Short term debts:	U.S. $250 million
Medium/long term debts:	U.S. $650 million
Estimated Income 1991:	U.S. $500 million
Estimated Losses 1991:	U.S. $200 million
Total liability after 1991:	U.S. $1,100 million
Estimated Total Assets:	U.S. $1,000 million

The first difficulty is the non-existence of financing for Embraer's export sales from either Brazilian or foreign banks.[97] Second, Embraer lacks the necessary funding for the finalisation of its two commercial projects -- the Brazilian/Argentine CBA-123 "Vector" (19 seat twin turboprop commuter aircraft), and the Brasilia's successor, the EMB-145, a 45-seat regional jet. In the case of the EMB-145, Embraer estimates that it will require some U.S. $300 million to manufacture and commercialise the aircraft.[98]

Embraer is responding to this dire economic outlook with a five-pronged approach. First, company executives have downsized the labour force by 30%, announcing in May 1992 the dismissal of about 2,500 employees. This reduction is the second since 1990, when approximately 4,000 Embraer employees were cut from a total workforce of nearly 13,000.[34] A second response has been to restructure Embraer's short-term debts. The relending of U.S. $407 million by the Bank of Brazil at reduced interest rates and with a five-year amortisation grace period will save the company $50 million annually.[100]

Embraer's third strategy is to secure exports for its existing aircraft products. In early 1993 the company had guaranteed contracts in its portfolio of nearly one billion dollars for the next five years. These contracts include: the sale of 80 EMB-312 Tucano trainer fighter aircraft to the French Air Force, worth $200 million; 241 firm orders for the Brasilia; and about 250 pre-orders for the EMB-145 regional jet. Looking to secure a five billion dollar contract to supply an estimated 765 Super Tucano trainers for the U.S. Navy and Air Force Joint Primary Aircraft Training System (JPATS), Embraer has established a strategic alliance with the Northrop Corporation of the United States.[101]

A fourth approach to ensuring the aircraft company's longer term viability is to diversify into other commercial markets. A noteworthy example is Embraer's equipment division's recent successful bid to supply anti-lock braking systems (ABS) to various domestic and multinational transport manufacturers. EDE already produces 150-200 ABS per year for various Embraer aircraft, and has adopted the technology and converted its ABS production line to supply 5,000 units a year for heavy trucks and buses. The ABS supplied by EDE is so competitive that some foreign transport manufacturers, including General Motors and Scania, estimate a 20% savings in operational and maintenance costs for the lifetime of the vehicle.[102]

By far the most politically controversial and economically problematic solution to Embraer's future is the Brazilian government's desire to privatise fully the aerospace company. Initiated in 1991 by the Collor Administration, the privatisation scheme calls for a reduction in the Brazilian Air Force's voting shares from its current 51% to only 20%, and for the sale of the remaining shares -- 30% to a group of Brazilian investors, 10% to Embraer employees, and 40% to foreign investors, preferably an aerospace company. The latter group of investors would be allowed to manage and run the company. The selling price for Embraer is understandably low -- U.S. $200 million -- given the company's outstanding sizeable liabilities, and it is anticipated that the BNDES, which has been in charge of the country's privatisation program, will accept external debt bonds by interested foreign investors. The original date for the privatisation of Embraer, set for August 1992, was first postponed, and has been suspended by the new Brazilian President, Itamar Franco. Prospects for the future privatisation of the aircraft company remain extremely uncertain due to a number of legal and political obstacles discussed below.

At present, Embraer is in the midst of a complex legal struggle to prevent the company from slipping into private ownership before formal privatisation occurs. This extraordinary situation has resulted from the floating of debentures in 1989 to draw additional capital into the company. According to corporate law, holders of these debentures are now entitled to convert them into preferred shares since Embraer has not issued dividends in over three years.[103] If the debentures are converted into preferred shares, the ratio of preferred to ordinary shares would reach 80%, exceeding the two-thirds ratio established under Brazilian federal law. To restore the correct ratio between the ordinary and preferred shares, the excess should be transformed into ordinary shares with voting rights. Such a transformation, however, would result in the private sector-held ordinary shares exceeding the 49% limit established by the company, and Embraer would thus slip out of state control. (According to the law which created Embraer, the Brazilian government, via the Air Force, is to hold a majority -- 51% -- of the ordinary shares with voting rights.) In the meantime, Embraer is negotiating with the holders of the debentures in the hopes of buying back the excess preferred shares, and thereby maintaining state control of the company before privatisation is reinitiated.[104] Since Embraer does not have the necessary Cr $252 billion with which to repurchase the shares, the Air Force has been pressuring the Brazilian government to inject the necessary capital.

A final factor complicating the prospects for the privatisation of Embraer is the lack of a political consensus not only between the trade unions, which are opposed to privatisation, and the aircraft company itself, but within the Brazilian Congress and at the executive level as well. Among labour's most vocal and powerful opponents of Embraer's privatisation are Antonio Donizetti Ferreira, President of the Metallurgical Union, and Edmundo Carlos de Carvalho, President of the Federal Workers Union in the Areas of Science and Technology. Donizetti deplores the selling of Embraer for the price of a "banana", suggesting that the government should direct investment to the firm. Such funding "exemplifies ... the rest of the world where private aeronautical firms are, in the last instance, helped by federal governments."[105] Leading congressional opposition to the proposed partial sale of Embraer to foreign investors are Aldo Rebelo and Ernesto Gradella. They argue that:

> In the first case, the firm is of strategic value...and is the center of technological capability in the country; in the second case, there is the risk that Embraer will be transformed into a mere secondary industry that would furnish parts for the prime manufacturers [e.g. Boeing and Airbus].[106]

Such views have gained the support of Brazil's new, more nationalist-oriented President Franco, who has suspended privatisation plans pending further congressional and financial inquiries.

Avibras

The future of Avibras has been positively affected by an abnormal inventory of Astros' rockets available for delivery just before the Gulf War, and the decision by Saudi Arabian Army to place a large order of rockets for their system. With those deliveries in 1990, and additional ones for the following two years, Avibras has been able to pay off its *concordata* in part by trimming the work force to about 800 people.

Avibras is making enormous efforts to generate new export sales of the Astros II System. Such exports are the only way the company will likely experience renewed growth and gain significant capital inflows. Since the international arms market is less receptive and much more competitive today, Avibras will have to rely on business from traditional clients and perhaps from some African countries (Angola and Mozambique). As for other, new military products, there is no clear market niche for any of them today. It is also likely that the company will expand its activities outside of Brazil, in order to find better R&D and production sites both for Avibras' existing products as well new ones. Already Portugal has been considered as a possible location for the manufacture of ultralight leisure airplanes.

Another factor affecting the company's improved chances of survival is its recent move to diversify into the civilian market. Avibras is providing a range of services and products to the commercial market, using facilities, equipment and technological expertise gained from its military experience. Such "conversion" activities include: technology transfer of electrophoretic painting (used for rocket motors) to General Motors and Ericsson; high precision machining and milling; soldering of different metals by explosion (cladeamento); quality control methods; humidity insulation resins; and special vehicles, such as "Locotractor" (a truck with regular rubber wheels and steel wheels used at railroad terminals to push railway cars), and tractors manufactured by Tectran.

The company has invested R&D in these commercial areas, and expects to develop more civil products and services. The target is to reach a 50% turnover from this market. This task has already proven difficult, since some attempts to diversify commercially have failure largely because of the high cost structure of the company. In order to reduce the 1991 figure of 95% revenue dependence on military products, Avibras will have to initiate further major cost reduction measures.

Conclusion

In this Brazilian case study chapter, the author has shown that the development and international competitiveness of the country's arms industry derived largely from firm-level initiatives. The author substantiates her hypothesis for Brazilian military production, demonstrating that domestic market factors in the capital goods sector, rather than state-centric explanations, induced firms to diversify into defence production. This hypothesis is verified by the author using a three-stage econometric model based on her survey data of Brazilian defence and capital goods firms.

In section II, the author provided in-depth, firm-level case studies from Brazil's aircraft, armoured vehicle, missile, and naval industries. In each of the case studies, the author delineated the respective strategies these defence firms adopted to augment their technological capabilities and competitiveness in international markets. A number of common strategies emerge from the firm case studies. They include: the use of exports to stimulate the firm's product development and improvement; collaboration with foreign manufacturers through licensing, coproduction and training activities; and conscious efforts by defence firms to develop and retain linkages with the local capital goods industries. These strategies are discussed at greater length in Chapter 5.

The author now turns to the case study on India to understand why the country's defence industries, in contrast to Brazil's, have not succeeded in attaining the technological and manufacturing capabilities necessary for international competitiveness.

Endnotes

[1]For a thorough review and analysis of various theories of Latin American military behaviour, see George Philip, *The Military in South American Politics* (London: Croom Helm, 1985).

[2]William Perry and Juan Carlos Weiss, "Brazil," in *The Implications of Third World Military Production*, ed., James Everett Katz (Lexington: Lexington Books, 1986): 6.

[3]Alexandre de S.C. Barros, "Brazil," in *Arms Production in Developing Countries*, ed., James Everett Katz (Lexington: Lexington Books, 1984): 76.

[4]Peter Locke, "Brazil: Arms for Export," in *Arms Production in Developing Countries*, eds., Michael Brzoska and Thomas Ohlson (London: Taylor & Francis, 1986): 81.

[5]See ESG. *Manual Basico* (ESG: Rio de Janeiro, 1976).

[6] Augusto Vargas, *Militarisation and the International Arms Race in Latin America*, (Boulder: Westview Press, 1985): 22.

[7]Patrice Franko-Jones, "Public-Private Partnership: Lesson from the Brazilian Armaments Industry," *Journal of Interamerican Studies and World Affairs* (Winter 1987-88): 47.

[8]See Renato Dagnino, "A Industria de Armamentos Brasileira: Desenvolvimento e Perspectivas," in *O Armamentismo e o Brasil: A Guerra Deles*, eds., Amilcar O. Herrera, Pinguelli Rosa, and Renato P. Dagnino, et al (São Paulo: Editora Brasiliense S.A., 1985), 70-105.

[9]Ethan B. Kapstein, "The Brazilian Defence Industry and the International System," *Olin Institute in National Security and Economics Working Paper*, (Cambridge: Center for International Affairs, Harvard University, November 1989).

[10]Michael Moodie, "Defence Industries in the Third World: Problems and Promises." in *Arms Transfers in the Modern World*, eds., Stephanie G. Neuman & Robert E. Harkavy (New York: Praeger, 1979), 298

[11]For details see Clovis Brigagão, "Brazil's Military Industry: A Discussion of Recent Developments," *Latin American Research Unit Working Paper #27* (Toronto, December 1979), 24.

[12]José Luis Ribero Fragoso, "As Reformulaçoes na Politica Externa Brasileira nos Anos 70," *Estudos Afro-Asiaticos*, N5 (1981): 41-53.

[13]Clovis Brigagão, *0 Mercado de Segurança: Ensaio Sobre Economia Política da Defesa* (Rio de Janeiro: Editora Nova Fronteira, 1984), 40.

[14]Peter B. Evans, "The Military, the Multinationals and the "Miracle": The Political Economy of the "Brazilian Model" of Development," *Studies in Comparative International Development*, 9, 3 (Fall 1974): 26-45.

[15]William Tyler, "Brazilian Industrialisation and Industrial Policies: A Survey," *World Development*, 4, 10/11 (1976): 863-882.

[16]This estimate was provided during interviews with the various armed forces ministries during August 1988.

[17]Pedro S. Malan and Regis Bonelli, "The Brazilian Economy in the Seventies: Old and New Development," *World Development*, 5, nos. 1-2 (1977): 22.

[18]Translated from Fernando Lopes de Almeida, *A Expansão da Industria de Bens de Capital* (Rio de Janeiro: Fundação Getúlio Vargas, 1983), 12.

[19]Lincoln Gordon & Engelbert L. Grommers, *United States Manufacturing Investment in Brazil* (Boston: Harvard University, 1962), 48.

[20]Almeida, 14.

[21]World Bank, *Brazil: Industrial Policies and Manufactured Exports*, (Washington, D.C.: World Bank, 1983), 3.

[22]Venilton Tadini, *O Setor de Bens de Capital sob Encomenda: Análise do Desenvolvimento Recente (1974/83)* (São Paulo: Universidade de São Paulo, 1986), 25.

[23]Luiz A. Correa Lago, et al., *A Indústria Brasileira de Bens de Capital* (Rio de Janeiro: Fundação Getúlio Vargas, 1979), 137.

[24]Tavares, 86.

[25]Malan & Bonelli, 28.

[26]Thomas J. Treblat, *Brazil's State-Owned Enterprises: A Case Study of the State as Entrepreneur* (Cambridge: Cambridge University Press, 1983), 116.

[27]Treblat, 136.

[28]Edson P. Guimarães, "Uma Nota Sobre a Influencia da Estrutura Industrial na Exportação de Manufaturados Brasileiros," *Revista Brasileira da Economia*, 38, 1 (Jan/Mar 1984): 95.

[29]The creation of the *Politica Nacional de Exportação de Material de Emprego Militar* (PNEMEN) provided the policy mechanism beginning in 1986 to derive an arms export policy and to secure the cooperation among the various financial, diplomatic and military agencies. Its members, which meet on an ad-hoc basis, include: CACEX, the Ministry of Industrial Development, the Ministry of Finance, the Brazilian Defence Council, Itamaraty, and the President of the Republic (any export involving more than $50 thousand must be authorised by the President as mandated by the constitution). Any one of these six consultative bodies has veto power.

In interviews with management from all of Brazil's major defence firms, company officials uniformly said that they undertook their own marketing efforts with minimal involvement from Itamaraty, and that they had been able to circumvent the PNEMEN by characterising exports of defence equipment as civilian.

[30]Interview with an Itamaraty official responsible for reviewing and assessing potential political impacts stemming from Brazilian exports abroad in Brasília, August 1989.

[31]This analysis of Embraer is based extensively on the author's site visits in 1988, 1989, 1991 and interviews with various Embraer corporate officials, engineers and technicians.

[32]Renato P. Dagnino, "A Indústria de Armamentos Brasileira: Desenvolvimento e Perspectivas," in *O Armamentismo e o Brasil: A Guerra Deles*, eds., Amilcar O. Herrera, Pinguelli Rosa, and Renato P. Dagnino, et al (São Paulo: Editora Brasiliense S.A., 1985).

[33]Ibid.

[34]Alan Riding, "Success on a Wing and Some Flair: Brazil's State Aircraft Firm is Landing Big Contracts," *The New York Times*, 13 November 1987, F1, F19.

[35]For an early history of aircraft production in Brazil, see Ozires Silva, "O Voo da Embraer," *Revista Brasileira de Technologia*, 13, 1 (Janeiro/Marco 1982): 20-30.

[36]Information provided by Mr. Arnolde Wolde of the Commissão de Valores Mobilizãção, Rio de Janeiro, November 1988.

[37]Embraer company information.

[38] *Flight International*, 1 September 1984, p. 412., cited in Daniel Todd and Jamie Simpson, *The World Aircraft Industry* (London: Croom Helm, 1986).

[39] David Velupillai, "Brasilia: Embraer's New Commuter," *Flight International*, 30 January 1983, 254-269.

[40] Embraer company data.

[41] Embraer interview at São José dos Campos, November 1988. See also David North, "EMB-120 Entering Crowded Market," *Aviation Week & Space Technology*, 1 August 1983, 31.

[42] Jack Baranson, "International Transfers of Industrial Technology by U.S. Firms and their Implications for the U.S. Economy," Vol. 1, Report Prepared for the Office of Foreign Economic Research, International Labor Affairs Bureau, U.S. Department of Labor (Washington, D.C.: Developing World Industry and Technology, December 1976.)

[43] Interview with Ozires Silva at Embraer, São José dos Campos, November 1988.

[44] Embraer Begins Marketing New Emb-123 Version," *Aviation Week and Space Technology*, 13 October 1986, 126.

[45] Tour of Embraer facility with Irénio de Faro, Chief Press Relations Officer, November 1988.

[46] Interview with former president of Embraer, November 1988.

[47] Interview with Irénio de Faro, November 1988.

[48] Embraer press release, 4 September 1988.

[49] Interviews with Wayne W. Wilson, General Manager, Diane L. Falconer, Senior Specialist Subcontract Negotiator, and Michael E. Hanson, Business Unit Manager of the MD-11 Supplier Management, at McDonnell-Douglas, Long Beach, CA. March 1992.

[50] Interview with Thomas D. Laurentius, at Embraer's Divisão Equipamentos, São José dos Campos, November 1988.

[51] Interview at Embraer, November 1988.

[52] Interview with Thomas D. Laurentius, Embraer, November 1988.

[53]Interview with Ozires Silva, Embraer, November 1988.

[54]Interview with Arthur Santos of Construtora Mendes Junior, Rio de Janeiro, October 1988.

[55]Interview with Technical Director of Engesa, Eduardo Fernando, São Paulo, August 1989.

[56]Much of the above and proceeding analysis is based on site visits and interviews with various Engesa corporate managers and engineers from 1988-1991.

[57]Ibid.

[58]Ibid.

[59]Ibid.

[60]Ibid.

[61]Interview with Marketing Director of Engesa, Vito di Grassi at Engesa, November 1988.

[62]Interview with Engesa's Technical Director, Eduardo Fernandes, August 1989.

[63]Interviews held at FNV, August 1989.

[64]Confidential interview with Engesa representative, August 1989.

[65]Interview with Colonel John Post, U.S. Embassy, Brasilia, August 1989.

[66]Confidential interview with Engesa representative, August 1989.

[67]Robert Godoy, "Tanque pode render ate U.S. 7 Bilhões," *O Estado de São Paulo*, 25 Agosto 1989, 11.

[68]For details of these sales see, *Gazeta Mercantfl*, 25 Agosto 1989, 31; and *O Estado de São Paulo*, 25 Agosto 1989, 12.

[69]The following discussion of Avibras is based on company data and interviews with various Avibras representatives beginning in November on 1988-92.

[70]Some additional features include a second radar (KA band - Ericsson) added to the X band radar, attached to two 35 mm guns. It can detect, identify, prioritise targets, aim, order, and track the shooting of targets as low as 20 meters from the ground. The

extremely high cost of the system (twice the cost of Skyguard) made it unaffordable, and Avibras still has four semi-assembled units in stock.

[71]Initially, Litton Italy had an offset agreement with the CTA: in exchange for Embraer's choice of the Litton navigation system for the AMX, the CTA would receive the underlying technology related to that specific system. However, this technology transfer agreement was never finalised. A technology transfer was then proposed by the French company, SNPE, but was considered inadequate by Avibras. Avibras tried to receive the technology from a U.S. firm, Incosin, but was blocked by American authorities, who would not allow the assembled gyros to be exported. These gyros were eventually supplied by another U.S. company, Condor Pacific, and with those gyros, Avibras assembled the first inertial navigation system. At the end of 1989, the company managed, with consultations from a well known expert on gyros to make the gyro and inertial navigation system at the prototype level.

[72]Information derived from interviews with D.F. Vasconcelos at the company in São Paulo, November 1988.

[73]Full rocket production requires approximately 2,200 tons/year, and the nominal plant capacity of the Brazilian facility is approximately 400 tons/year.

[74]D.F. Vasconcelos diversified into medical equipment because of investment by the Brazilian government in health, medical research, hospital construction, and education.

[75]Interview with representative of Orbita, Mr. Vito di Grassi, at Engesa corporate headquarters, November 1988.

[76]For this programme see Klaus Wolff-Casado Revuelta, "El Programma de Construccion Naval de la Marina del Brasil," *Technologia Militar*, no. 3 (1988).

[77]Interview with naval official, Naval Ministry, Brasília, August 1989.

[78]Interview with Admiral Mario Cesar Flores, Naval Ministry, Brasilia, August 1989.

[79]For a concise overview of Brazil's naval capabilities see Eduardo Italo Pesce, "Brazil's Navy Must Wait," *Proceedings* (March 1987): 134-138.

[80]For specifics see Ronaldo S. Olive, "AMRJ Shipbuilding Programmes," *Jane's Defence Review*, Vol. 4, no. 8 (1983): 739-745.

[81]Interview with Peter Landsberg of *Verolme*, Rio de Janeiro, November 1988.

[82]Interview with Admiral Flores, Brasília, August 1989.

[83]Interview at Copesp with Admiral Orthon Pinheiro da Silva, São Paulo, August 1989.

[84]Ibid.

[85]Ibid.

[86]*Latin American Regional Reports, Brazil*, 1 June 1989, 4-5.

[87]Interview with Peter Landsberg at Verolme corporate headquarters, Rio de Janeiro, November 1988.

[88]Data provided by the Comissão de Valores Mobiliários, Rio de Janeiro.

[89]Carlos Lovizzaro, "Engesa vai complementar pagamento da concordata," *Gazeta Mercantil*, 3 April 1992, 31.

[90]See Carlos Lovizzaro, "Juiz alonga prazo da concordata da Engesa," *Gazeta Mercantíl*, 23 March 1992, 49; and "Engesa deposita parte da dívida," *Gazeta Mercantíl*, 3 April 1992.

[91]Carlos Lovizzaro, "Credores retardam a moratória da Engesa," *Gazeta Mercantíl*, 29 July 1992.

[92]Eliana Simonetti, "Com Dinheiro do Povo," *Veja*, 8 April 1992, 78. See also Joâo Domingos, "Negócios de Exercito com Engesa são Questionados," *O Estado de São Paulo*, 3 April 1992.

[93]Simonetti, "Con Dinheiro do Povo."

[94]Ibid., 79.

[95]Ibid.

[96]Carlos Lovizzaro, "Recessão nos EUA Influi no Prejuízo de U.S. $235 Milhões da Embraer," *Gazeta Mercantíl*, 2 April 1992.

[97]In July 1991, FINEX announced the creation of a Program for Export Financing (PROEX). However, the Brazilian government has directed few financial resources to sustain this ambitious programme.

[98]Carlos Lovizzaro, "Contratos de $U.S. 1 Bilhões," *Gazeta Mercantíl*, 2 April 1992.

[99]"Embraer Demite 30% dos Empragados e Ozires Culpa a Falta de Contratos," *Vale do Paraíba*, 26 May 1992, 3.

[100]Lovizzaro, "Recessão nos EUA."

[101]See "Embraer Acerta Participação em Concorrência nos EUA," *Vale do Paraíba*, 21 May 1992, 5; and Barbara Opall, "4 Teams Bet Jets Fill Bill U.S. Top Pick for Joint Trainers," *Defence News*, 1-7 March 1993, 14. Among the competitors bidding to supply the hotly contested JPATS contract are: the Argentine FAMA's Pampa-2000 teamed with Vought Aircraft; the Italian Gruppo Agusta's S211 teamed with Grumman, the Swiss PC-9 Pilatus teamed with Beech Aircraft; Germany's Deutsche Aerospace's Fan Ranger, teamed with Rockwell; and the Italian Aermacchi's T-Bird II, teamed with Lockheed Corporation.

[102]Virginia Silveira, "Divisão da Embraer quer Lançar Freios ABS para Veículos Pesados em 93," *Gazeta Mercantíl*, 13 October 1992.

[103]"Edital para Avaliação da Empresa sai no dia 13," *Vale do Paraíba*, 6 June 1992, 5.

[104]"Suspensa Venda de Açoes da Embraer nas Bolsas," *Jornal do Tarde*, 2 May 1992.

[105]"Embraer Demite 30% dos Empregados."

[106]Ibid.

Chapter IV

INDIA: THE COSTS OF STRIVING FOR SELF-SUFFICIENCY

SECTION I: THE STRATEGIC RATIONALE

India's development of a defence production programme over the past forty years has been motivated by strategic factors. Three complementary explanations are commonly advanced by defence analysts; namely: 1) the triangular arms race in South Asia, 2) superpower involvement in the region, and 3) India's own hegemonic aspirations. Let us examine each of these explanations in turn.

The most widely held explanation in the international relations literature suggests that India's defence capabilities have been largely conditioned by the continued arms build-up by its two main neighbours, the Peoples Republic of China and Pakistan. Since the country's independence, India has fought four wars with its neighbours: three with Pakistan in 1948, 1965 and 1971, and one with China in 1962. Indeed, as indicated in Table 4.1, *South Asia's Military Balance,* India's military expenditure (as measured in constant 1985 dollars) is among the largest of the region's nations. It doubled from $4.09 billion in 1980-81 to nearly eight billion dollars in 1991-92.

The Indian government's experience of a U.S. arms embargo during the 1965 war also provided the Ministry of Defence with the basis for its policy of self-reliance in defence production. Such a strategic rationale can be found in the 1964-65 Ministry of Defence (MoD) annual report:

> Weapons and equipment best suited for our conditions are not available in any one country; nor is it possible to ensure a steady supply of such

Table 4.1

SOUTH ASIA'S MILITARY BALANCE

Expenditure & Armed Forces

	Defence Expenditure (constant 1985 $millions)		**Percent GDP**		**Armed Forces** (thousands)[1]
	1985-86	1991-92	1985-86	1991-92	1991-92
China	10,615	12,025	3.6	3.2	3,030.
India	6,263	7,990	3.0	2.9	1,265.
Pakistan	2,076	3,014	6.9	7.0	580.

[1]Excludes reserve and paramilitary forces.

Source: *The Military Balance, 1992-93*. London: The International Institute for Strategic Studies, 1992

> weapons and equipment from the respective countries of origin in the case of our being involved in hostilities. Therefore, it becomes a basic necessity to establish manufacturing capabilities.[1]

More recent, regional developments -- the cementing of military cooperation between China and Pakistan, and an increasingly pro-active PRC in terms of that country's military modernisation programme and high visibility arms exports (e.g. CSS-11 and East Wind missiles to Saudi Arabia) -- have magnified India's threat perceptions, and are specifically linked to India's development of an intermediate-range, ballistic missile programme.

A second interpretation for India's expanded defence, especially its naval capability, relates to the presence and subsequent introduction of sophisticated arms to the region by the two superpowers during the 1980s: the United States in the Persian Gulf during the Iran-Iraq war, as well as following the more recent Iraqi invasion of Kuwait, and the 1979 Soviet invasion of Afghanistan. This primarily "defensive" rationale is one that the Indian government and defence community emphasize:

> India's arms acquisitions have been to balance the Chinese and Pakistani arms build-up [and to maintain] an equilibrium with its neighbours who possess more sophisticated weaponry ... India's arms acquisitions have been made not with a view to become a military power but sufficiently well equipped to protect its political and economic interests and its long borders and coastline.[2]

Thus, as a consequence of Pakistan's receipt of $1.6 billion in U.S. military assistance (1982-87), including the acquisition of F-16 fighter aircraft and Harpoon anti-ship missiles, Indian officials argue that they had no choice other than to accept a Soviet offer of an estimated $1.74 billion arms transfer package (1988-93).[3] This agreement included the Indian licensed production of the Soviet T-72 tank, MiG-23 interceptors and the MiG-29 Fulcrum. Throughout this period Pakistan ranked fourth (after Israel, Egypt and Turkey) among the beneficiaries of U.S. foreign military sales credits, while India became the second largest recipient of Soviet arms deliveries to the Third World.[4]

The debate over which South Asian state initiated the arms re-action race blurs, however, a more uncomfortable third proposition. India's neighbours, including Australia, have suggested that the country's defence production programme and arms imports are providing the military basis for India's hegemonic aspirations in the subcontinent.[5] The recent reorientation of the Indian Navy has been cited as evidence of India's regional ambitions in the Indian Ocean. According to one analyst:

> The original sea control/shore defence orientation which largely emphasised preserving the integrity of India's coastal waters against a Pakistani threat, has steadily given way to an assertive naval orientation...[The new strategic posture includes]... the defence of sea lanes and the preservation of zones of influence, where the emphasis has shifted from a specifically shoreline defence to a portmanteau conception labelled "defence of the nation's maritime interests".[6]

Such a conception has been interpreted by naval analysts to include the defence of India's coastline and seaborne trade, as well as its broader economic and foreign policy interests in the Indian Ocean.

To meet these new naval requirements, India has relied principally on weapons purchased from the Soviet Union and Western Europe. The acquisition of the British aircraft carrier, Viraat, formerly the HMS Hermes, has been complemented by an inventory of naval aircraft -- Sea Harriers, Tu-142 maritime reconnaissance aircraft, Dornier 228 light patrol aircraft, as well as a number of anti-submarine warfare helicopters, including Sea Kings, KA-27s/25s. Reportedly, India is also seeking collaboration with European shipbuilding companies to build a third aircraft carrier. In addition, India's naval fleet has been greatly expanded by recent deliveries of Soviet Kashin II destroyers, Foxtrot, Kilos and one Charlie I nuclear-powered submarine. (A new 704-acre submarine dockyard has been built with Soviet assistance at Vishakaputnam, headquarters of the Indian submarine fleet.)[7]

Various defence analysts point to the impact of India's enhanced naval and air capabilities on two of the Indian Ocean's six island states: the Maldives and Sri Lanka. In November 1988 Indian forces surgically suppressed a coup against the Maldivian government of President Gayoom, and India has continued to intervene in the Sri Lankan government's attempt to suppress the Tamil separatist guerilla war. Further away in the Bay of Bengal, Indonesia has begun construction of a large naval base on Sumatra reportedly in response to the Jakartan government's concern over India's future politico-military intentions.

Given these broad strategic objectives and willingness to commit a substantial proportion of the country's economic resources to their obtainment, the Indian government has established the largest state-owned military-industrial-research sector (MIRS) in the Third World. In the next section the author discusses the organisation and extent of India's defence production capabilities.

The Indian Military Industrial Research Sector

Indigenous defence production in India dates from 1801 when the East India Company established the Gun Carriage Agency near Calcutta. At the time of India's independence from Britain in 1947, the country's defence sector consisted of 15 ordnance factories and one clothing factory. It was not until some fifteen years later, however, that the Indian government began to invest heavily in the development of a defence-industrial capability. The reason for this massive expansion is aptly summarised in a later report of the Ministry of Defence:

> The main thrust of the Defence production effort is towards the twin objectives of modernisation of arms and equipment and achievement of progressive self-reliance and self-sufficiency ... the conflicts of 1965 and 1971 highlighted the need for defence preparedness, self-sufficiency and growing self-reliance in the field of defence equipment.[8]

Evidence of this commitment may be found in Table 4.2, *Volume of Arms Production in India*. Indian central government expenditure for defence production rose sharply following the Indo-Pakistani 1971 war. At present India's defence sector consists of eight state-owned defence industries or defence public sector undertakings (DPSUs), thirty-three ordnance factories, and thirty-four research-development laboratories and establishments.

Before proceeding with an overview of this MIRS, a brief discussion outlining the political organisation of this structure is useful. Such a discussion will serve as a backdrop to the thesis's central argument that India's relatively unsuccessful experience in indigenous defence production (in comparison to Brazil's) has been hindered by government policies that tend to dampen firm-level incentives.

The political economy foundation for the Indian government's socialist emphasis on self-reliance and self-sufficiency, and on the state's role in the industrialisation process, is articulated in the 1948 and 1956 Industrial Policy Resolutions. For example,

Table 4.2

Volume of Arms Production in India

(Values in U.S. current dollars) *

Year	Ordnance Factories	Public Sector Undertakings	Total
1963 —— 64	212.8	62.8	275.6
1967 —— 68	121.1	119.5	240.6
1970 —— 71	164.0	214.7	378.7
1973 —— 74	235.1	310.6	545.7
1977 —— 78	624.7	487.3	1,112.0
1978 —— 79	672.8	524.2	1,197.0
1979 —— 80	738.9	618.3	1,357.2
1980 —— 81	853.7	617.4	1,471.1
1981 —— 82	908.8	953.5	1,862.3
1982 —— 83	918.6	1,209.4	2,128.0
1983 —— 84	1,006.9	1,404.8	2,411.7
1984 —— 85	1,025.5	1,483.8	2,509.3
1985 —— 86	1,071.1	1,444.9	2,516.0
1988 —— 89	———	1,370.7	———

*Included in these figures is the civilian part of production, which amounts on average to 30 per cent of total production.

Source: Government of India. Ministry of Defence, *Annual Report*, various issues. Rupee conversion rates are from International Monetary Fund, *International Financial Statistical Yearbook, 1989.*

the industrial policies enunciated by the newly formed Nehru government in 1948 "envisage a mixed economy with an overall responsibility of the government for planned development of industries and their regulation in the national interest."[9] As a result of these policies, India's economy was divided into three discrete categories: 1) Schedule A industries", which were the exclusive preserve of the state. Located in this public sector were and continue to be the arms, ammunition and other defence-related equipment factories, atomic energy, mining, iron and steel, heavy equipment industries, and the industries related to communications, railway, aircraft, and shipbuilding; 2) The joint sector or "Schedule B industries", which included minerals, machine tools, road and sea transport, and many intermediate products; 3) Lastly, private firms, which as originally conceived were expected to supplement the state-owned sectors. As a consequence of this industrial structure, the Indian arms industry does not subscribe to the archetypical British and U.S. model, in which the defence sector is dominated by private firms competing for contracts provided by the defence services, with the substantial overview and funding approval by various parliamentary/congressional committees.

With respect to the organisation of defence in India, due to constitutional and legislative limitations, the three services, Army, Air Force and Navy operate independently and outside the Ministry of Defence. More specifically, the Ministry of Defence has no direct financial control over the three services and thus serves only as a coordinating agency. Parliamentary involvement in the defence policy and budget process is relatively weak since there is no formal defence committee in the Lok Sabha (the lower house of parliament). As a result of these weak institutional linkages, critics argue that defence policymaking is highly centralised at the prime minister level and is characterised by secrecy and extraordinarily poor coordination, particularly in relation to the weapons procurement process. These issues are taken up later in the chapter.

The Ministry of Defence itself is divided into three departments: Defence, Defence Production and Supplies (DDPS), and Defence Research and Development. The DDPS was created in 1962 to expand the defence production base and to coordinate with and meet the equipment requirements of the armed forces. Under the administration of the DDPS are eight public sector undertakings and thirty-six ordnance factories. The ordnance factories produce a wide variety of basic items such as small arms and ammunition, explosives, clothing, and bridging equipment for the country's defence services, primarily the army, with a small proportion of production allocated to the paramilitary forces and the civil police. The ordnance factories produce more than 40 per cent of all the goods and services in the military industrial research sector, and employ approximately 60 per cent of all workers.

The majority of the defence public sector undertakings were established by the Indian government to meet the defence requirements for major sophisticated weapons systems in aircraft, armour, electronics, and special alloy fields -- areas which excluded private sector participation (e.g., Schedule A industries). A few defence sector units, particularly in the shipbuilding sector, were originally located in the private sector, and were subsequently acquired by the Ministry of Defence.

The eight defence public sector units are:

1) Hindustan Aeronautics Ltd. (HAL);
2) Bharat Electronics Ltd. (BEL);
3) Bharat Earthmovers Ltd. (BEML);
4) Magazon Dock Ltd. (MDL);
5) Garden Reach Shipbuilders and Engineers Ltd. (GRSE);
6) Goa Shipyard (GSL);
7) Bharat Dynamics Ltd. (BDL);
8) Mishra Dhatu Nigam Ltd. (MIDHANI).

Prior to 1986 there were nine dpsus. The ninth, Praga Machine Tools Ltd., was transferred that year to the Ministry of Industry.

The oldest, largest and most prominent state firm is Hindustan Aeronautics Ltd., whose main aerospace production factories are located in Bangalore and Nasik, though a further ten facilities are spread throughout six Indian states.[10] It was established in 1940 by Messerswalchand Hirachand and the government of Mysore as a private company and was acquired two years later by the Government of India for the overhaul and repair of the large allied fleet operating in India and the South East Asia command. HAL is responsible for the manufacture and overhaul of aircraft and helicopters as well as the related engines and accessories. More recently, HAL has begun to provide supplies of machined parts and assemblies for civil passenger aircraft manufactured abroad. These include parts for Airbus A-320 under-carriage doors for Aerospatiale.

Bharat Electronics Ltd., was created in 1954 and is now India's second largest defence firm. It has production facilities in Bangalore, Ghaziabad and Pune. Seventy per cent of BEL's production (radio, radar and electronics equipment) is for the armed forces; the remaining 30 per cent is destined for the civil market (TV broadcasting equipment and satellite receiver terminals). The third state-owned defence company is

Bharat Earthmovers Ltd., which was created in 1964 with the transfer of the Rail Coach Factory from HAL. Its main products include railway coaches and earth moving equipment, including tractors, dumpers and bulldozers, for primary use in the civilian sector and in India's power and steel plants as well as mines. BEML is the largest exporter of the eight state-owned defence companies.

India's naval sector consists of three shipyards: Magazon Docks, Goa Shipyards and Garden Reach Shipyards. Established in 1774 and acquired by the Ministry of Defence in 1960, Magazon Docks Ltd., is India's preeminent shipyard, which is capable of building warships such as frigates and submarines, in addition to cargo and passenger ships. In 1966 MDL began producing under U.K. license six Leander frigates. From 1978-88 MDL produced a series of indigenously designed Godavari frigates. The latter 3,000 ton frigate is the only ship of its kind in the world that can carry two helicopters and support an anti-submarine warfare role. At present MDL is building two diesel-powered submarines under license from West Germany's Howaldtswerke Deutsche Werft Ag (HDW). Approximately sixty per cent of the yard's production is in the civil sector, with specialisation on ship repair and construction of off-shore oil platforms, floating docks and cranes.

Goa Shipyard Ltd was started as a Portuguese company in 1957 for the purpose of providing repair facilities for barges. It was acquired in 1964 and became a subsidiary of Magazon Docks in 1967. It specialises in ship repair and engineering work.

Located in eastern India in Calcutta, Garden Reach Shipyards has been engaged in ship repair and engineering activities since 1884. It was acquired by the Government of India in 1960, and despite severe financial losses, GRSE continues to manufacture air compressors, turbine pumps, diesel engines, and generators. Garden Reach Shipyards has manufactured fast patrol craft and inshore patrol vessels for the Coast Guard. Two-thirds of its production is for the civil sector.

Two relatively smaller defence firms were created recently for the production of missiles and specialised high grade, super alloys. Incorporated in 1970 at Hyderabad, Bharat Dynamics Ltd., has produced under license from West European companies the Euromissile and Aerospatiale's SS-11-81. In recognition of India's growing dependency on imported specialised steels and super alloys for the nuclear, aerospace and armour industries, Mishra Dhatu Nigam was established in 1973. It has received foreign assistance from France (Creusot Loire and Perchiney-Ugine Kuhlman), and from West Germany (Krupp) in the area of process technology.[11] Beginning in 1987-88, Midhani began production of nine different types of Soviet grade alloys used in the licensed manufacture of some Soviet MiG engines.

These defence production units are responsible for the design, development and production of all major weapons categories: advanced jet fighters as well as various trainer aircraft and helicopters, main battle tanks, frigates, diesel-powered submarines, missiles, and electronic and communications equipment. Table 4.3, *India's State-Owned Defence Industries*, provides a breakdown of production, profitability, exports, and employment by the defence public sector units. The defence production units (combined dpsus and ordnance) are the second largest industrial sector in India, and comprise the largest proportion of India's state-owned capital goods industries. They are estimated

Table 4.3

INDIA'S STATE-OWNED DEFENCE INDUSTRIES

(1988-1989)

Public Sector Defence Firms	*Production*	*Profits (before tax)*	*Exports*	*Employment*
Hindustan Aeronautics	457.3	26.3	00.76	43,833
Bharat Electronics	274.6	19.8	00.67	19,266
Bharat Earth Movers	360.9	33.5	28.90	16,151
Magazon Docks	167.7	-23.2	-----	14,355
Goa Shipyards	11.9	-.72	00.03	2,091
Garden Reach Shipyards	53.0	-.64	-----	10,427
Bharat Dynamics	26.8	2.8	-----	1,798
Midhani	18.5	.22	-----	1,507

Note: Data, except employment, is measured in current U.S. millions.

to consume approximately 20 per cent of the country's machine tool production, and 30 per cent of all steel and related alloy output. Employment in the defence sector amounts to five per cent of total private and public sector employment.

Created in 1965 and merged in 1985 with the Department of Defence Production, the Department of Defence Supplies' (DDS) purpose is to "mobilise indigenous capacities within the Civil sector for meeting defence requirements, especially those items which were being imported."[12] While this latter Department has been the locus for private sector participation in defence production, in general such participation has been limited to the DDS' procurement of spares and components of a "non-sensitive nature". More recently, however, the DDS has been given the task of developing stronger links with Indian private industry -- a development that is discussed in greater detail later in this chapter.

Defence Research and Development

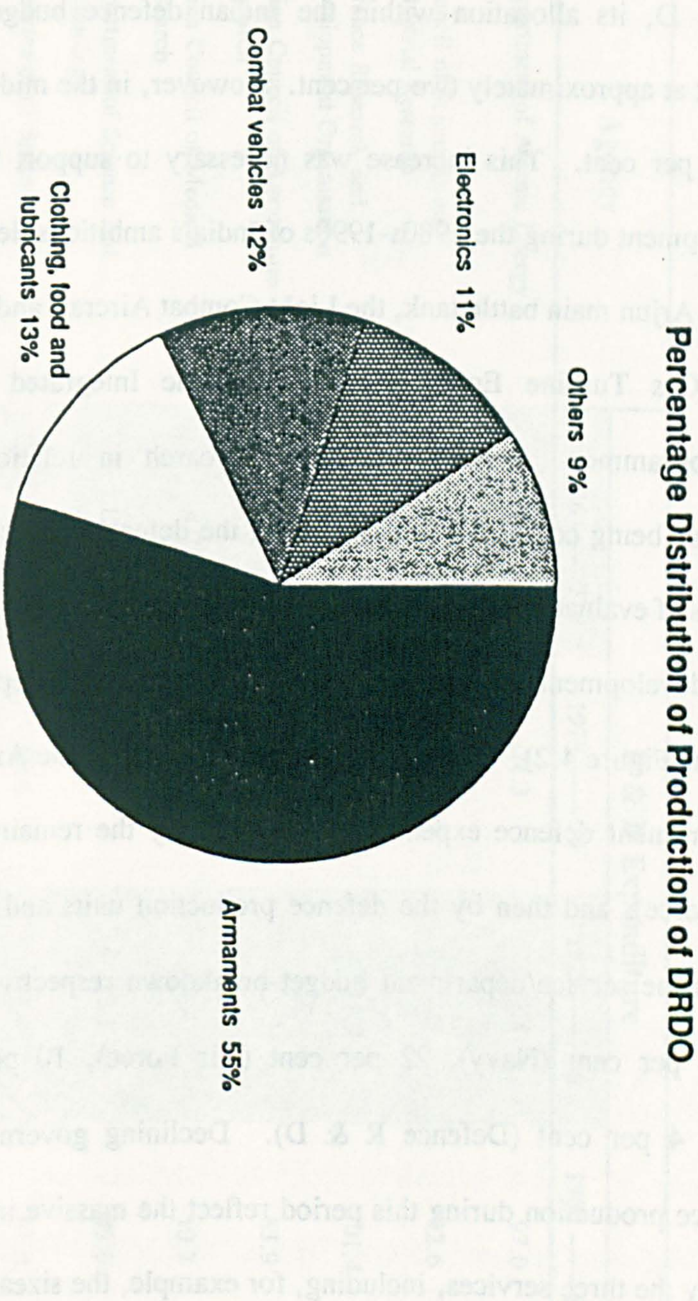
Subsequent to the establishment of the Department of Defence Production, the Ministry of Defence began to invest in a defence research and development base, recognizing that the high obsolescence rate of most weapons necessitated the development and introduction of new technologies and scientific innovations. As a former defence minister, Mr. R. Venkaturaman indicated, "Defence has become increasingly a part of technological regeneration .... In that context the aim of self-reliance becomes more and more relevant."[13]

To secure greater self-sufficiency in defence production, and to spur indigenisation of imported foreign components and technologies, the Defence Research and Development Organisation (DRDO) was established as the MOD's third arm in 1958. In large part the creation of the DRDO dovetailed with the Indian government's interest (as articulated in the 1958 Scientific Industrial Policy Resolution) in establishing a state-sponsored infrastructure for research and development activities as well as for the purpose of training "scientific and technical personnel in the fields of science and education, agriculture, industry and defence."[14]

As a result of such prioritization, the DRDO was formed by the amalgamation of the Defence Science Organisation and the Technical Development Establishment. Functioning as a central coordinating agency for the execution of defence-related research, the DRDO at present operates 42 major laboratories and employs approximately 25,000 people, of whom 6,000 are scientists and highly trained engineers.[15] As indicated in Figure 4.1, *Percentage Distribution of Production of DRDO*, the activities of the DRDO entail basic as well as applied research, design and development in the defence-related fields of aeronautics, combat vehicles, naval technology, missiles and rockets, and metallurgy. Among the main DRDO laboratories engaged in such research activities are the Combat Vehicle Research and Development Establishment (CVRDE) at Avadi, the Gas Turbine Research Establishment (GTRE), the Aeronautical Development Establishment (ADE) in Banagalore, and the Naval Physical Oceanography Laboratory at Cochin (NPOL).[16]

Despite the central importance of the DRDO's activities to these indigenous defence production efforts, expenditure on defence R&D, though enormous in comparison to the expenditure of other science-related government agencies, is relatively

Figure 4.1


Percentage Distribution of Production of DRDO
Others 9%
Electronics 11%
Combat vehicles 12%
Clothing, food and lubricants 13%
Armaments 55%

insignificant in terms of its percentage of the total military budget. For example, as indicated in Table 4.4, *R & D Expenditures by Major Government Scientific Agencies*, while the DRDO has received the largest proportion (20 per cent) of central government funding for R & D, its allocation within the Indian defence budget has remained relatively constant at approximately two per cent. However, in the mid-1980s it jumped to just over four per cent. This increase was necessary to support the simultaneous design and development during the 1980s-1990s of India's ambitious defence production programmes: the Arjun main battle tank, the Light Combat Aircraft and Advanced Light Helicopter, the Gas Turbine Engine Project, and the Integrated Guided Missile Development Programme. Additional military research in relation to the above programmes is also being conducted within each of the defence public sector units.

One means of evaluating Indian government investment in defence production and in research and development is provided by the MoD's Service/Department Defence Budget Allocation (Figure 4.2). As illustrated by this bar chart, the Army is the largest recipient of government defence expenditure, followed by the remaining two services (Navy and Air Force), and then by the defence production units and defence R & D. During the 1980s the service/department budget breakdown respectively was: 50 per cent (Army), 14 per cent (Navy), 22 per cent (Air Force), 10 per cent (Defence Production), and 4 per cent (Defence R & D). Declining government outlays for indigenous defence production during this period reflect the massive increase in foreign arms purchases by the three services, including, for example, the sizeable hard currency

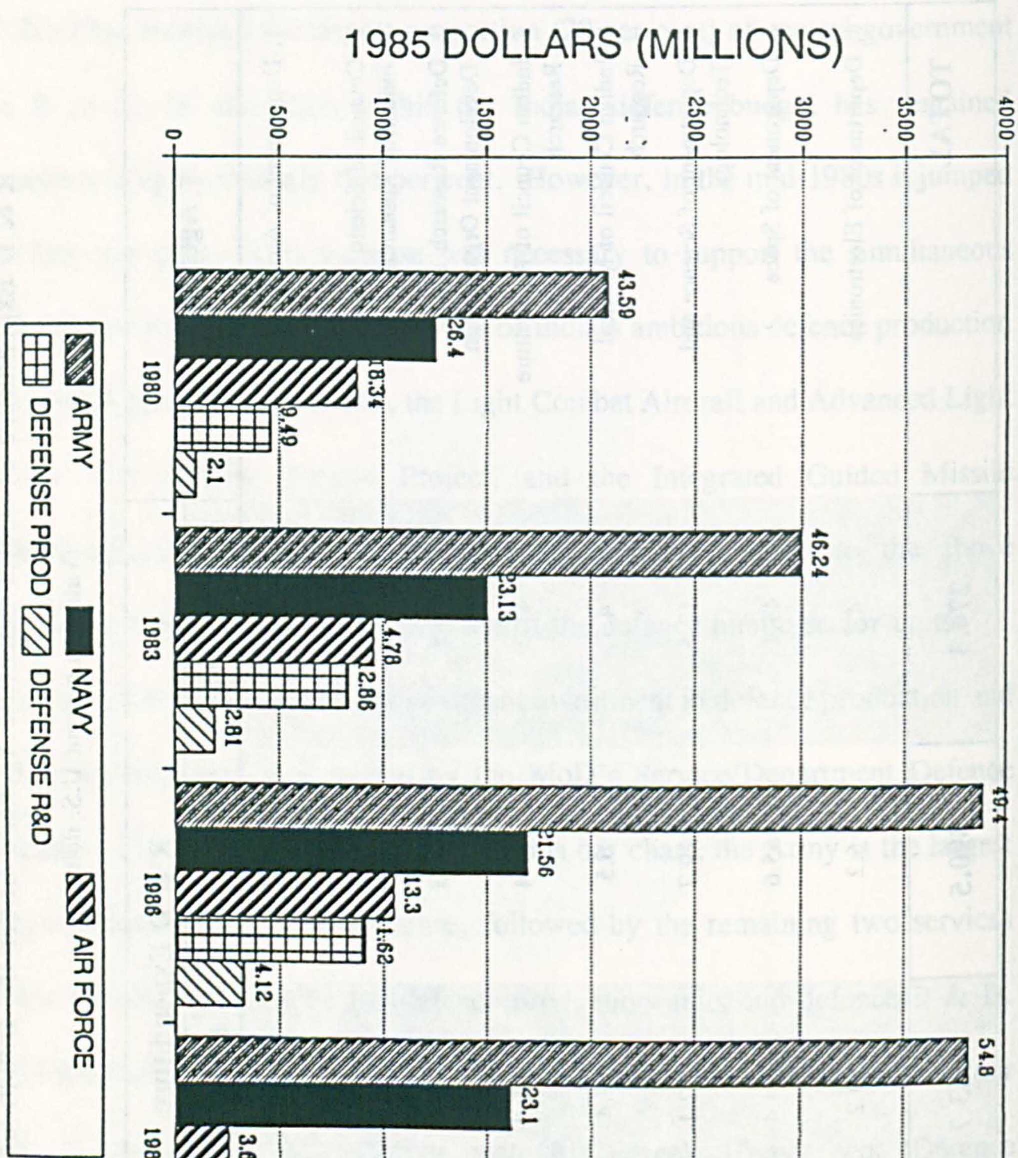
Table 4.4

R & D Expenditure by Major Scientific Agencies Under the Indian Government

(Values in current U.S. dollars)

Agency	R & D Expenditure			
	1976 — 77	1978 — 79	1979 — 80	1980 — 81
1. Department of Atomic Energy	65.1	74.3	83.4	97.0
2. Council of Scientific and Industrial Research	46.1	68.3	72.9	92.6
3. Defence Research and Development Organisation	56.5	81.5	118.9	101.4
4. Indian Council of Agriculture Research	41.3	68.4	95.3	83.9
5. Indian Council of Medical Research	4.7	6.5	7.4	10.7
6. Department of Science and Technology	12.5	29.7	32.1	45.0
7. Department of Space	43.4	55.6	54.4	67.0
8. Department of Electronics	4.7	6.2	9.2	5.5
TOTAL	**274.3**	**390.5**	**363.7**	**503.1**

Figure 4.2: India's Defence Budget Allocation



expenditures on Mirage-2000 and Jaguar aircraft for the Air Force, in addition to HDW submarines, Sea King helicopters, and the Viraat aircraft carrier for the Navy.

A more comprehensive breakdown is provided by the Defence Service Estimates. Lakshmir, in his major study of trends in India's defence expenditures, reports that during the 1980s, budget allocation broke down as follows: pay and allowances accounted for 31 per cent, stores 32 per cent, ordnance factories nearly 14 per cent, and R & D only 2.1 per cent.[17] On this basis, Lakshmir reports that expenditure on stores increased by more than three times in constant prices from 1962-63 to 1984-85. He attributes this increase to the Indian government's belated recognition of the needs to acquire modern weapons (reflected by increasing expenditures on stores), to gear up the domestic production of weapons (by increasing ordnance factory expenditures), and to modify existing weapons technology (by augmenting allocations towards research and development). "...Of this," Lakshmir writes, "the first one, namely acquisition of weapons is very important."[18]

SECTION II: INDIA'S DEFENCE PRODUCTION PROGRAMMES

Successive Indian governments have expended considerable effort towards achieving a high degree of self-sufficiency in the indigenous production of advanced weapons systems and the development of defence-related technologies. Perversely, this obsessiveness on self-reliance and technological autarky has necessitated extensive reliance on licensed production as well as arms imports principally from the former Soviet Union and West European sources.

The relative failure of India's defence industry stems from many factors. First, unlike Brazil, India failed to adopt an intermediate strategy for armament research, development and production. Second, although the breadth of India's defence R & D establishment -- the DRDO and its associated laboratories -- is impressive, many of its programmes have been overly ambitious and out-of-step with the manufacturing capabilities of the defence production units. Third, when projects are handed over to the defence units for development, they take an inordinate time at both the conceptual-design and prototype-production stages. The result is that by the time a weapon system sees fruition, the equipment is so obsolete that India's armed forces do not want it. Delays in production and a subsequent aversion to indigenously produced equipment have led to the sevices' preference for imports of foreign weapons systems.

This cycle of failed production in defence is discussed below, drawing on the specific firm-level experiences in the armour and aircraft sectors. Much of the case study material that is provided in this section is derived from archival research in the Lok Sabha library and supplemented by interviews conducted with various defence ministry officials, as well as with industry engineers and scientists in India's defence and capital goods sectors.

Indigenous Defence Production

Successful indigenous production in India's aerospace and armour industries has often been severely hampered by the delays encountered in moving from the design/prototype to full production stages. As the cases of the Vijayanta and Arjun main battle tank as well as the Advanced Light Helicopter and Light Combat Aircraft programmes illustrate, delays in indigenous production have become endemic, leading invariably to the induction of critical foreign sub-assemblies and components in the prototype phase, and eventually to off-the-shelf purchases of foreign equipment.

Armour

Though India's Combat Vehicles Research Development Establishment (CVRDE) successfully manufactured the Vijayanta tank under U.K. license (a modified Vickers Chieftain tank), its production took ten years, and the Indian army had to import Soviet T-55 MBTs because of the resulting perceived strategic vulnerability. At present, the Nasik ordnance factory is in the process of modernising the Soviet T-55s. These tanks are being upgunned with the indigenously produced Royal Ordnance 105 mm gun, and with an advanced Tank Fire Control System, which Bharat Electronics initially developed for the Vijayanta.

Ironically, the indigenous design and production of the Arjun MBT has been similarly delayed. Initiated in 1980 by the Defence Research and Design Organisation's CVRDE, the MBT-80 Arjun is still in the development phase because of problems related to its power plant. The power plant is still undergoing tests at the Gas Turbine Research Establishment. Owing to this problem, the Arjun prototypes have been fitted in the meantime with imported German 1,200 hp MTU engines coupled with ZF transmissions. Persistent and serious delays in this programme led to the MoD's decision to seek a license-production agreement with the former Soviet Union for the manufacture of the Soviet T-72 tank as an interim measure.

In addition, indigenous defence production in this sector has been severely affected by the weak defence organisation structure: namely, the tremendous lack of communication and coordination between the Army and the Ministry of Defence, the defence production units and the R & D labs over the services' procurement requirements. One important example is the development by Bharat Earth Movers of a heavy duty truck for the Army. When the Army issued in 1978-79 a General Staff Quality Requirement (GSQR) for 95 heavy vehicles, BEML began development and production of the vehicles in 1980-81 without having any specific consultations with the Army. At the same time, the Ministry of Defence did not direct the Army to provide its exact performance requirements and specifications for these vehicles. In the meantime, the Army was permitted and proceeded in 1983 to import 45 vehicles.

Although the prototype of the BEML vehicle was transferred to the Army for their evaluation and trials in 1984, by 1988 the Army had yet to finish its evaluation of the vehicle. BEML was not surprisingly concerned that such a delay would result in the technological obsolescence of its vehicle (because of a later need for a more fuel efficient engine), and losses to the company because of the anticipated low volume (due to the Army's previous imports).[19]

One can well argue that this extensive lack of communication between the MOD, the user (Army), and defence industry (BEML) is in fact institutionalised within the MoD procurement structure. Justifying its lack of effective coordination in the BEML heavy vehicle fiasco, the MoD explained:

> The practice in the Defence Ministry is that whenever the users are thinking of a new equipment...they interact with Defence R and D and *in*

> *some cases, with potential manufacturers also* .... About the responsibility for design and development. There is a separate mechanism as to who will be entrusted with the job. It may be Defence R & D [the DRDO]; it may be Defence public sector undertaking; it may be any other laboratory in the country which may be entrusted with that job....[20] (italics added for emphasis.)

Aerospace

Hindustan Aeronautics' first aerospace project was the development of the HF-24 Marut fighter during the later 1950-60s. HAL was able to design and eventually fabricate the airframe but had not considered the inclusion of a suitable aeroengine. By the time an imported engine (an Orpheus 703) was modified and fitted, the plane was technologically obsolete. Since the plane could not attain the supersonic Mach-2 speed required by the Air Force only 145 of an initial target of 214 aircraft were manufactured. When members of the Committee on Public Undertakings reviewed the HF-24 project in 1970, they concluded:

> the complexities of producing a sophisticated aircraft like the HF-24 had not been properly visualized either by the German engineers or HAL. The Committee are unable to understand as to what were the factors that contributed to the formulation of such unrealistic targets. The lack of experience in production planning must have been all too apparent to the management when they formulated such optimistic estimates initially....Perhaps the only alternative open to HAL would be to enter into collaborative agreements with other countries to manufacture tried and proven designs.[21]

Continued disruptions and the lack of engineering and quality control expertise resulted in the cancellation of the Marut's successor and trainer version, the HF-25, Ajeet. A retired HAL engineer provided a similarly gloomy account:

> The Marut project best exemplifies what is wrong with our aircraft industry. Rather than waiting to establish a strong foundation for the

> country's aircraft industry, HAL pushed ahead and tried to develop a modern combat aircraft comparable to any in the West. Yet in the 1950s and 1960s we simply did not have the necessary design experience, nor the infrastructure in terms of a diversified supplier base in metals and electronics and aeroengines to even begin the project.[22]

Unfortunately the learning-by-doing experience that HAL accumulated as a result of the Marut/Ajeet failures were not internalized. Similar divergences between design and production are being encountered, thus hindering progress on the two current, major aircraft production projects: the Advanced Light Helicopter (ALH) and the Light Combat Aircraft (LCA).

<u>Advanced Light Helicopter</u>

India's first indigenous helicopter programme was mooted initially in 1969 upon the recommendation of the C. Subramaniam Committee on Aeronautics. The Advanced Light Helicopter was planned as a high-tech replacement for the licensed-produced Cheetah and Chetak helicopters in service with the Indian Air Force (IAF), with different versions for the Navy, Army and civilian use. The ALH was expected to be unique because of its three special features: heat resistance, light weight and crashworthiness. Twenty-two years later, however, HAL has yet to begin production of the ALH. Moreover, its intended customers, particularly the Indian Army and Navy, are unlikely to make any sizeable purchases because they have already imported Soviet and West European helicopters. When it is delivered to the services in the late 1990s, the ALH will be neither advanced nor light. Table 4.5, *The Advanced Light Helicopter Programme*, below charts the design and production problems that HAL has incurred in its development of the ALH.[23]

Table 4.5: Overview of the Advanced Light Helicopter Programme

1969	A high-level committee headed by former Defence Minister C. Subramanim recommends that India should develop an Advanced Light Helicopter.
1971	India enters into a ten-year agreement with Aerospatiale of France for the design of a single-engined ALH. The first prototype is scheduled to fly in 1982. One of the important factors in entering into an agreement with the French aerospace company was that in 1962 HAL had begun licensed production of Aerospatiale's Alouette III helicopters.
1977	The Indian Air Force changes its Air Staff Requirement to a twin-engined configuration and recommends that the ALH project be suitably modified, despite the fact that HAL had nearly completed a single-engine design.
1979	The IAF proposal is sanctioned by the MoD and HAL searches for another foreign collaborator. The cost of development of the project has escalated from Rs. 23.04 crore in 1972 to Rs 37.50 crore in 1979.
1981	The agreement with Aerospatiale is terminated and the Indian government is forced to pay cancellation fees of approximately four million U.S. dollars. The single-engine helicopter design, which was ready, goes to waste. In the intervening period of uncertainty a large number of engineers leave HAL in disgust.
1984	A seven-year collaboration agreement worth 89.7 million DM for the ALH project is signed with MBB of West Germany. Decision delays arise because of serious differences among HAL designers over the choice of collaborator. Work on the ALH project starts all over again from scratch.
1984-93	Disputes break out between HAL and MBB designers over the technical specifications of the aircraft. Because of the heavier weight of the MBB design, important indigenous avionics equipment (altimeters and sonars) developed by Bharat Electronics are replaced with lighter, imported equipment. Additionally, HAL's design for the retractable landing gear is replaced by MBB with skids, which save 160 kg, but lower the survivability of the aircraft from 95 per cent to well below 50 per cent.[24]

The Advanced Light Helicopter case study raises two important issues -- one old and one new -- relating to India's troubled defence production record. The first problem is the poor liaison between the Ministry of Defence, Air Force Headquarters and Hindustan Aeronautics in the ALH project. As witnessed in the previous examples of the Arjun MBT programme and BEML's development of a heavy truck for the Army, this problem appears to be endemic in the Indian arms industry, and has led to critical outside reviews. For instance, a former HAL insider, writing in the Deccan Herald, a Bangalore-based newspaper, wrote a scathing commentary on the mid-stream switching of the ALH design from a one- to a two-engine design:

> Here the pertinent point arises. In spite of so many Air Force officers holding key positions in the HAL and so much made of the...liaison with the IAF, how is it possible that an activity on which lakhs and crores are spent gets rendered useless?[25]

This issue was subsequently raised in the Lok Sabha by the Public Accounts Committee's investigation of the ALH project. When asked whether there had existed any continuous interaction between the HAL and the Indian Air Force, a representative of the Air Headquarters stated:

> Whenever the HAL feels that they have something new, they write to us about that. In fact, the twin engine concept was started by HAL. That kind of dialogue is always there. When we have looked for a new system, we have a direct liaison with the Defence R & D and through them, such a liaison exists with HAL. When HAL meetings take place, the minutes get transmitted to us. *But at the conceptual stage we do not have any direct dialogue with HAL.*[26]
> (Italics added for emphasis.)

What was further troubling to the Committee was the issue of why the Air Force opted for a single engine helicopter in 1970, a decision they were later obliged to reverse, when twin-engined helicopters were deployed in the early 1960s. The committee was left with the impression that "the Ministry and the Air Headquarters have not been keeping themselves abreast concurrently of the latest technology in other countries."[27]

A second issue raised by the above case study pertains to the difficulties many defence industrialising countries experience in establishing design capabilities and in investing in the requisite human capital. As pointed out in the previous chapter, an important ingredient to the success of defence producing firms in Brazil was the heavy investments in research and development as well as in the education and training of personnel by those firms. Though Indian defence production units have made some investment in human capital, such investments have not translated into successful production. HAL's chairman explains the problem:

> India, in fact, did not have any helicopter design and development capability. The conscious design to set up such capability means educating people, training them, finding them from abroad also and getting a team of very highly skilled and competent engineers together. In this period of 5-6 years, we did grow from zero to a strength of about 68 trained competent engineers who were ready for a take off....But again because of the lack of continuing projects, the design group has languished [because of the exit of HAL engineers]. It languishes if a project which we start upon, does not get realised. To that extent there is discontinuity in the aircraft design....What we are suffering from in the design field is that we could do with more projects of increasing complexity...*so that what we learn from one is utilised in the more complex one and succeeding...ones.*[28]
> (Italics added for emphasis.)

Light Combat Aircraft

In an important and recent departure from its role as an assembler of foreign-manufactured aircraft (following the fold-up of the Marut HF-24 project) HAL, in collaboration with the DRDO, the Council for Industrial and Scientific Research and several universities, embarked in 1980 on an ambitious indigenous programme to design, develop and produce a light combat aircraft (LCA) for the Indian Air Force requirements of the 1990s. The LCA is primarily an air superiority fighter with a secondary close support role and some interdiction capacity. It will not only replace the Service's aging MiG-21s, but has been touted by Indian defence officials to outperform the U.S. F-16s acquired by Pakistan.

In an attempt to rectify and prevent the previous lack of communication and interaction between the services, defence research and production, the Aeronautical Development Agency (ADA) was set up to fund, manage, monitor, and coordinate the work of the various agencies involved in the LCA project. Additionally, the ADA and the Indian Government each commissioned feasibility studies from MBB and Dornier in West Germany, British Aerospace in the United Kingdom, and Marcel Dassault in France on the basis of specific performance requirements provided by the Indian Air Force. Upon completion of the independent studies, a feasibility report, incorporating the studies' findings, was finalised in 1983.

Despite such a promising start, the LCA project quickly ran into difficulties following the resignations in 1986 of the LCA's two top managers -- the ADA's director general, Dr. S. R. Valluri, and its chief designer (as well as former managing director of HAL), Dr. R. Mahindra. Their resignations were prompted by frustrated and repeated attempts to establish and secure institutional linkages between the R&D units designing the LCA and the production units, which were to manufacture the airframe, engines and subsystems for the aircraft. As Dr. Valluri reiterated, "My basic problem was that the ADA's writ did not run beyond the four walls of its office..."[29] Because of its lack of authority and consequent need to secure broad consensus, the ADA became, "more encumbered with bureaucratic red tape. In a sense, design was being dictated from Delhi instead of being left to the designers to worry about."[30]

The vacuum created by the departures of Valluri and Mahindra further weakened the ADA's ability to run the project. Like the ALH, the LCA has subsequently undergone substantial changes, including the mid-stream switching of foreign design consultants from MBB to Dassault, and the Air Force's additional request of a beyond-visual-range capability, which will increase the weight of the aircraft by four tons. In addition, the LCA's engines, avionics and radar are to be imported. For example, the U.S. government has permitted General Electric to supply seven F404 engines to power the LCA prototypes. These engines will eventually be replaced by the indigenously designed and manufactured GTX-35 gas turbine engine. Various U.S. companies -- Allied Signal, BASF, Litton, and Honeywell -- are providing the LCA's composite materials, flight control and fly-by-wire technologies.[31] Indian defence industry analysts have cynically suggested that "the only thing Indian on the LCA will be the coconut that is broken over the prototype in accordance with Indian tradition."[32]

The latter two indigenous aircraft production programmes follow a remarkably similar cyclical pattern of failure. Nayar aptly characterizes this pattern:

> Firstly, [there was] the failure of the local aeronautics industry to meet the requirements of the airforce. This resulted in good measure from the lack of adequate investment in R&D. In part, however, it was the result of the lack of confidence by the IAF in HAL's products....This lack of confidence in HAL had arisen out of the IAF laying down excessively stringent aircraft specifications, perhaps deliberately, far beyond the

> existent capabilities of HAL to meet, which then took too long to deliver, with the result that the planes were usually obsolete when handed over to the IAF. As a consequence...the IAF...then felt free to press for foreign merchandise.[33]

Nayar suggests that this pattern of failure incited a shift into licensed production of weapons systems in collaboration with foreign suppliers.

The Indian Missile Program

The Defence Research Development Organisation and its Defence R & D Laboratory (DRDL) have been responsible for the steady progress in India's ballistic missile programme. Under the Integrated Guided Missile Development Program (IGMDP), the DRDO has produced and tested a series of missiles: the medium-range surface-to-air missile, Akash; the medium-range surface-to-surface missile, Prithvi, which has a potential range of 250 km and can carry a nuclear payload; the surface-to-air missile, Trishul; and an anti-tank missile, Nag. However, the apex of the DRDO's missile programme is the development of the intermediate-range ballistic missile, Agni.[34]

With the Agni's successful May 1989 test flight, India became the first Third World nation to develop an intermediate-range ballistic missile that was largely derived from its sister, civilian space programme. The Agni, in fact, is a byproduct of India's Integrated Guided Missile Development Program (IGMDP). Initiated in 1983 with Rs. 780 crore funding for a ten-year period, the IGMDP focuses on providing the three wings of the armed forces with a range of tactical missiles.[35]

Both the low-level, surface-to-air missile (SAM), Trishul, and a battlefield-support, surface-to-surface missile (SSM), Prithvi, have been flight tested and acquisition orders have been placed by the Indian army. The defence public sector undertaking, Bharat Dynamics Ltd., is expected to begin manufacturing these missiles in late 1993. Similarly, a third-generation, anti-tank missile, Nag, and a medium-range, air-defense SAM, the Akash, are undergoing development tests.

At the centre of the Integrated Guided Missile Development Program is the intermediate-range ballistic missile, the Agni. The Agni carries a one-ton payload and can easily reach targets in Pakistan. This missile is also capable of reaching China's southern cities; carrying a half-ton nuclear or conventional weapon, the Agni could also hit Beijing to the northeast.

The success of India's missile programme, in contrast to its aircraft and main battle tank programs, is indicative of what the country's defence sector can achieve when realistic targets are set and when a programme is fully supported within the Defence Research Development Organisation (DRDO) establishment and by the armed services. The IGMDP derives from the ongoing collaborative endeavors of the scientists of the DRDO and the Indian Space Research Organisation, as well as 30 other research centres, laboratories, universities, and defence public sector units. The Hyderabad-based Defence Research Development Laboratory (DRDL) is the nodal agency for the IGMDP. The director of the DRDL is Dr. A.P.J. Abdul Kalam, who is also de facto operational head of the IGDMP. He is supported by Dr. V.S. Arunuchalam, Director-General of the Defence Research Development Organisation in Delhi. The project director for the Agni is R.N. Agarwal.

The purpose of the IGMDP is to design a series of missiles using common subsystems and technologies, many of which were derived from the satellite launch vehicle programme, the SLV-3. By integrating simultaneous development of its five missile projects, and in consultation with all three of the armed services, the IGDMP has avoided the delays and duplication that have characterized the Light Combat Aircraft, Advanced Light Helicopter and Main Battle Tank programs. Additionally, basic research funding has been channelled to technology directorates that are at work in the broad areas of propulsion, inertial navigation systems (for the Prithvi and Agni especially), infra-red thermal imaging and millimetric wave guidance systems (for the Nag), advanced composites, and special steel/aluminum forming techniques for missile structures. For example, a few miles to the south of the DRDL is the Research Centre, Imrat, which is a vast complex recently constructed for the testing and calibration of missile components, guidance, control and navigation systems. Comproc, an advanced composite materials test and production facility is now on line for work on carbon and glass fibres, which the missiles will require for outerspace and re-entry conditions.

A critical component to the success of the IGMDP has been the access to crucial foreign technologies and assistance through India's sister space programme.[36] The United States has given a license for the Combined Accelerated Vibration Climatic Test System used to test the impact of heat and vibration on re-entry vehicle components. It also transferred, as part of a larger mid-1980s technology agreement, electro-optical instrumentation for the National Testing Range in Baliapal, Orissa. The equipment was used to track the Agni's test flight. In 1988, the United States agreed to supply an advanced ring laser gyroscope to guide the Light Combat Aircraft. It is not clear what will prevent India from using it in the Agni's strap-down inertial navigation and closed-loop guidance system.

France has also provided much-needed technology in the area of liquid propulsion. The training Indian scientists received from France's *Société Europeène de Propulsion* for the Indian version of the Viking rocket motor (used for the European Space Agency's Arianne Satellite Launcher) has been applied to the Prithvi and Agni launch stages.

Perhaps the largest source of critical foreign technologies for the IGMDP has been the joint German-Indian guidance programme, which began in the mid-1970s. West Germany, via the state aerospace agency, *Deutsche Forschungsanstalt fur Lufthart und Raumfuhrt e.V.* (DRL), provided India with three indispensable missile technologies:

1) Guidance technology for the closed loop system for India's Advanced Space Launch Vehicle (SLV-3), Polar Space Launch Vehicle (PSLV) and the Agni. (The Agni serves in a configuration of six boosters as the first phase rocket for the PSLV. In turn, the Agni boosters are adaptations of the first stage of the SLV-3.)

2) Rocket testing. In 1974-75 the DLR tested a model of India's first stage of the SLV-3 in its wind tunnel at Cologne-Portz. It has also provided technical assistance for the construction of rocket test facilities in India, furnishing a complete design facility and training Indian engineers in high-altitude testing. The Agni's liquid fuel second stage was probably tested at this completed facility.

3) Advanced composite materials fabrication and handling. Beginning in the mid-1970s, Indian scientists received on-the-job training in composites at DLR's Stuttgart and Braunschweig sites. Such training has enabled the Indians to make rocket nozzles and nose cones as well as the domestically developed heat shield for the Agni.

While Indian government officials have maintained that the IGMDP is built around the deployment of conventional munitions (e.g. fuel air-explosives), given the production capability of India's parallel nuclear programme, a nuclear-armed Agni is a likely outcome.

Licensed Production & Arms Imports

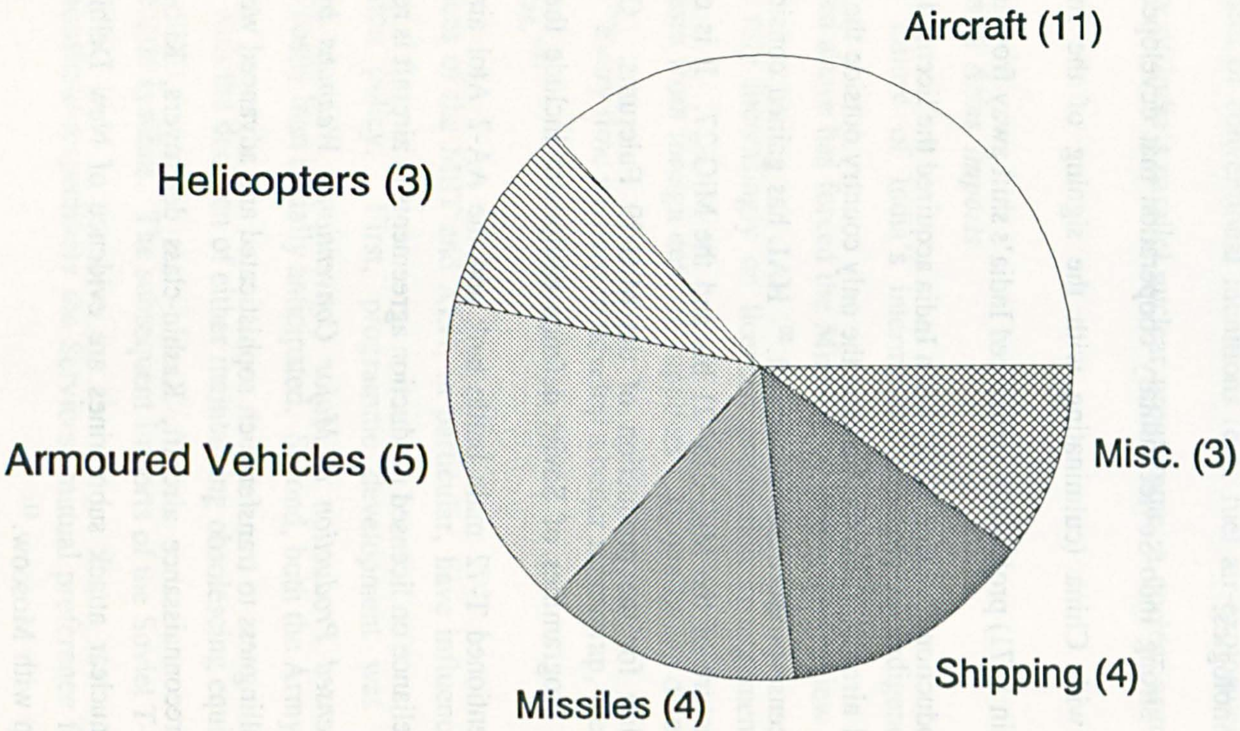
The general failure of India's intermittent attempts at indigenous defence production as outlined above has forced the Ministry of Defence to review its policy of self-reliance and to rely increasingly on licensed production arrangements with and outright arms purchases from foreign defence suppliers. As one Indian defence scientist has wryly observed, "Every time we need to develop a better mousetrap, the country has to import a bigger cat."[37]

The experiences of the MBT and ALH, in particular, have influenced this shift in defence production policy. First, programme development was slower and extraordinarily more costly than initially anticipated. Second, both the Army and the Air Force were then left with the decision of either maintaining obsolescing equipment or of importing foreign weapon systems. The subsequent imports of the Soviet T-72 tank and MiG-25 aircraft demonstrate respectively the Services' mutual preference for the latter avenue.

Licensed production of defence systems is recognised by Indian defence planners as a compromise production solution for political and technical reasons.[38] On the one hand, India's armed forces are assured of faster deliveries of proven foreign weapons systems. On the other hand, licensed production is expected to provide the defence production units with greater learning opportunities through transfers and access to foreign technologies.

The strong Indo-Soviet military cooperation that developed in the wake of the 1962 war with China (culminating with the signing of the Indo-Soviet Treaty of Friendship in 1971) profoundly influenced India's shift away from indigenous to licensed defence production.[39] Since 1962, when India acquired the licensed production rights for the MiG-21 aircraft, India has become the only country outside the former Warsaw Pact states to license-produce Soviet aircraft.[40] HAL has gained considerable experience in the manufacture of the MiG-21s/-21 bis and the MiG-27. It is currently readying its Nasik facility for the production of the MiG-29 Fulcrums. Other Indian licensed production programmes of Soviet defence equipment include the manufacture of the already mentioned T-72 main battle tank and the AA-2 Atol air-to-air missile. The extensive reliance on licensed production agreements in aircraft is reflected in Figure 4.3, *Indian Licensed Production of Major Conventional Weapons by Type*. The Soviet Union's willingness to transfer such sophisticated and advanced weapons systems as Tu-142 Bear reconnaissance aircraft, Kashin-class destroyers, Kilo-class as well as the Charlie I nuclear attack submarines are evidence of New Delhi's historic privileged relationship with Moscow.[41]

Figure 4-3: Indian Licensed Production of Major Weapons by Type, 1970-90



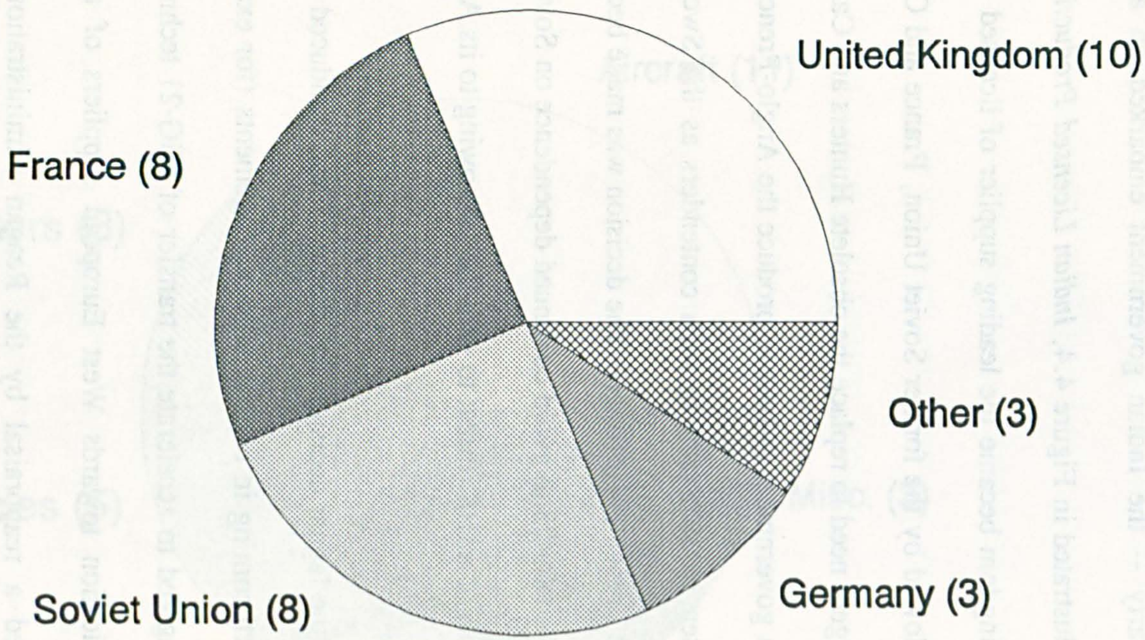
Office of Technology Assessment. *The Global Arms Trade.* Data from Stockholm International Peace Research Institute, *SIPRI World Armament and Disarmament Yearbooks, 1970-90.*

With the 1977 election to power of the Janata Party -- a coalition that included parties critical of India's relationship with the USSR developed by Indira Gandhi's National Congress Party -- the Indian government embarked on a policy of arms diversification. As illustrated in Figure 4.4, *Indian Licensed Production by Country of Origin,* the United Kingdom became the leading supplier of licensed weapons systems during the 1980s, followed by the former Soviet Union, France and Germany.

The MoD's urgent need to replace the obsolete Hunters and Canberras led to the decision by the Janata government to license produce the Anglo-French Jaguar aircraft. The Jaguar was chosen in 1978 among such contenders as the Swedish Viggen, the Soviet Mig-23 and the French F-1 Mirage. The decision was made because the first two had been ruled out: the Mig-23 to avoid continued dependence on Soviet arms supplies; and the Viggen because of a U.S. threat to veto the sale owing to its American-designed engine.

The impact of the Jaguar decision was ironic. First, it induced the former Soviet Union to be more forthcoming in coproduction arrangements (for example, the Soviet Union subsequently agreed to accelerate the transfer of MiG-21 technology to India.)[42] Second, the diversification towards West European suppliers of arms and related technologies prompted a reappraisal by the Reagan administration of U.S.-Indian relations.[43] The eventual signing of a Memorandum of Understanding in 1985 between the Gandhi/Reagan governments encouraged U.S. cooperation and responsiveness to India's request for technology transfers and supplies of critical components for the LCA project, thus marking a significant departure in the previously strained Indo-U.S.

Figure 4-4: Indian Licensed Production by Country of Origin



Office of Technology Assessment. *The Global Arms Trade.* Data from Stockholm International Peace Reseach Institute, *SIPRI World Armament and Disarmament Yearbooks, 1970-90.*

relationship.[44] The former Soviet Union sought to counter such intrusion into its strong defence relationship with India by offering to integrate the LCA's characteristics into the yet undeveloped MiG-35 aircraft.

Though the Indian government's effort to diversify licensed production has been successful, the country's defence producing firms have experienced mixed results with these manufacturing collaboration arrangements. According to MoD officials and firm managers, the most positive benefit derived from licensed production agreements has been the firms' enhanced bargaining power with potential foreign defence contractors. While acknowledging that their stronger ability to secure financial and technological concessions from foreign suppliers has been importantly aided by their leverage in the highly competitive international arms market of the 1980s, Indian defence planners also say their favourable negotiating position resulted from their own increased technical capabilities. They point out that in contrast to the MoD's experience in the late 1960s, when the MoD was rebuffed by Western suppliers in its attempt to purchase high performance aircraft, French, British and German defence industries were now not only willing to allow licensed manufacturing but were also willing to share the technology and development plans related to their next generation weapons systems.

In this respect, successive licensed production of sophisticated weapons systems, particularly with the MiG series, has clearly augmented Indian defence firms' capabilities.[45] However, licensed production has not guaranteed the transition to indigenous design and production. Several Indian defence analysts argue that with the ready availability of Soviet weapons, both off-the-shelf and licensed-produced, the need to become self-sufficient has been removed. (The successful development of India's missile programme is cited as a counter example of this argument.) Nor has licensed production in India necessarily led to the desired substantial savings in foreign exchange as compared to off-the-shelf purchases. An early SIPRI study found that the costs of licensed produced aircraft in India were on average 168 per cent higher than the cost of importing the same aircraft. The main reasons for the higher prices involved in licensed production were large material costs, inefficient use of labour, and escalating prices of imported components. (See Table 4.6, *Costs of Locally Produced and Imported Aircraft in India*.)

Indian defence firms also have encountered a new form of dependence with licensed production agreements. For example, several naval defence firms cited instances in which their production schedules of Leander and Nilgiri class frigates were behind schedule because of late deliveries of crucial spares and assemblies by their foreign suppliers. As one Air Force lieutenant colonel complained:

> Our increased dependence on the Russian equipment is causing much headache. Many of our MiG aircraft were...out of action for some time because the Russians delayed in making fresh supplies of brake pads for the braking gear...[and because] certain parts of MiG including the engines have still to be sent to Russia for overhaul, and major maintenance and repairs.[46]

The non-availability of specifications and drawings from military equipment collaborators has caused additional delays because the designs have to be evolved by reverse engineering techniques and proved by extensive prototype trials.

Table 4.6

Costs of Locally Produced and Imported Aircraft in India

($U.S. Thousand)

	A Total Production Cost	B Cost of importing equivalent aircraft	A/B (%)
HJT-16 Kiran (basic jet trainer)	340	200	170
MIG-21 (supersonic fighter)	1,520	830	183
HF-24 Mark I (supersonic fighter)	940	600	157
Alouette (helicopter)	270	170	159
HS-748 (transport) [a]	1,490	1,000	149
Gnat (fighter)	380	200	190

Source: Stockholm International Peace Research Institute, *The Arms Trade with the Third World*, Uppsala, 1971, p. 731

More importantly, however, licensed production by India's defence sector has undermined efforts to maintain indigenous research and design capabilities. A senior scientist at the National Aeronautic Laboratory complained that:

> The main problem in India is that licensed production has become so much a way of life....If you take the Jaguar programme and you do not take an indigenous R&D programme, what are laboratories like this got to do? Every time you buy an aircraft from outside you make these laboratories an exercise in futility.[47]

The example of the Jaguar aircraft was similarly used by a HAL engineer to explain why HAL's attempt to indigenise further component production has been frustrated after the aircraft company had already assembled nearly 80 of the fighters, "...[C]an we build a Jaguar aircraft today? You must have certain capabilities, a certain base, certain technologies, then you can go onwards. You cannot develop Jaguar aircraft with bullock cart technology."[48] When asked why the situation had been allowed to prevail, the NAL scientist said:

> The reason is simple: there is a complimentarity of interests between the ...public sector undertaking...and the government bureaucracy whose security lies in licensed production because then they don't have to take responsibility for failure. With Jaguar a [Defence] secretary can sign the contract because he knows it is a proven aircraft.[49]

The result of India's forty-year period of experimentation with indigenous and licensed defence production is that neither the goals of self-sufficiency nor self-reliance have been achieved. Rather, the weapons procurement system has generated national political controversy over bribes paid by foreign defence companies to the Ministry of Defence and high-ranking Indian government officials. Indeed, charges of corruption and cover-up in the HDW and Bofors defence procurement scandals precipitated the resignation of former Prime Minister Rajiv Gandhi and his own party's defeat in a national election.[50] Additionally, funding for indigenous defence programmes -- the LCA, ALH, MBT -- has been severely reduced because of the budgetary constraints imposed by the massive importation of arms during the 1980s, and because the original requirements, which these indigenous weapons systems were intended to meet, are no longer a priority. A final irony is that according to Table 4.7, in 1990 India did succeed in becoming the Third World's largest importer of arms.

Defence Exports

Despite its status as one of the largest arms producers in the developing world, India has not been a major exporter of weapons. Official estimates of defence export sales average annually less than $10 million. Included in these estimates, however, are sales of civilian equipment produced by the defence production units. (For example, the sale of earthmoving equipment to some Mid East states is listed in Indian government statistics as an arms export.) Thus, the actual total value of India's arms exports is negligible.

Arms exports have remained and will continue to be low for four major reasons. The first explanation is production delays and poor product reputation. As evidenced above, most of India's major defence production programmes have not proceeded beyond the prototype phase, and the technologies employed face extremely high obsolescence rates. Not surprisingly, the major buyers of India's arms are other even less developed countries such as Bangladesh, Uganda, Ghana, Togo, Nigeria, and Ethiopia.

Table 4.7

The Leading Importers of Major Weapons, 1985—89

The countries are ranked according to 1985-89 aggregate imports. Figures are in U.S. $millions, at constant 1985 prices.

Importers	1985	1986	1987	1988	1989
Third World					
1. India	1,876	3,683	4,585	3,383	3,819
2. Iraq	2,871	2,447	4,247	2,005	418
3. Saudi Arabia	1,447	2,395	1,956	1,770	1,196
4. Syria	1,690	1,508	1,169	1,172	336
5. Egypt	1,282	1,665	2,347	348	152
6. North Korea	977	876	487	1,383	1,553
7. Afghanistan	82	611	687	939	2,289
8. Angola	694	975	1,135	890	24
9. Libya	969	1,359	294	65	499
10. Taiwan	664	866	640	513	263
11. Iran	710	746	685	538	261
12. Pakistan	675	616	467	467	694
13. South Korea	388	267	597	934	607
14. Israel	193	466	1,629	327	93
15. Thailand	305	74	644	510	330
Others	5,753	5,026	4,601	4,012	3,893
Total	20,576	23,580	26,170	19,256	16,427

Source: Stockholm International Peace Research Institute, *1990 Yearbook*.

Second, arms exports have been prevented by third party restrictions contained in licensed production agreements. For instance, Hindustan Aeronautics has wanted to offset some of its production costs by supplying locally manufactured MiG components to countries that deploy these aircraft such as Egypt, Syria and Iraq. The former Soviet Union has prevented such transactions.

A third reason for India's low level of exports is the Indian government's concern not to jeopardize its acclaimed non-aligned status. In 1987 India refused to sell MiG-21s to Zimbabwe because it did not want to become embroiled in the Southern African conflict. A final factor is that the Indian government lacks an effective international defence export marketing agency. Only recently, in late 1989, was a high-level committee established within the Department of Defence Production and Supplies to promote Indian arms exports. Such government action, however, has not resulted in any increased sales of weapons primarily for the reasons outlined above.

SECTION III: BRIDGING THE DEFENCE-INDUSTRIAL DIVIDE

> The country has achieved a degree of self-sufficiency in small arms, ammunition and military software. We have a long way to go before we can call ourselves self-sufficient or self-reliant in this field. Our present efforts in the production of armament are essentially of the assembly variety. This is not something to be ashamed of if we have imported technology for the construction of frigates, aircraft and tanks. It constitutes a necessary first step towards greater indigenisation. Higher inputs in R&D are needed. Since budgetary allocations for R&D are scarce, the horizontal overlapping between the work of the public and private sector in this sphere should be curbed. In our quest for self-sufficiency in defence production the total exclusion of the private sector should be eliminated, as unless this is done we would have unutilised a large segment of the nation's resources both in terms of manpower and funds.[51]
> Jaswant Sing MP (1984)

Since the 1970s, India's defence production programmes have been the subject of much intergovernmental and outside critical review. Most explanations for the poor performance of the defence public sector undertakings have focused on such conventional factors as inadequate funding and poor ministerial coordination.[52] As a consequence, reform measures, which have redressed inefficiencies within the defence public sector units, have centered on ad-hoc, institutional solutions. Few defence analysts have concentrated on an important underlying structural economic constraint, namely, the continued government-legislated separation and autarkic development of India's private capital goods industry from the defence sector.

Several vocal defence analysts have argued that the Indian government needs to adopt a truly integrated approach to defence and economic development. As pointed out by one analyst:

> It has to be appreciated that the two [defence and economic development] are not mutually exclusive -- in fact, one reinforces the other. A healthy economy with a broad industrial base, resulting from development and continuously expanding, strengthens defence capability. Similarly a strong defence protects the gains of development from external aggression.[53]

Ideological, political and institutional constraints, however, have impeded the adoption in India of a Brazilian model of private sector-led defence industrial diversification. Consideration by the Indian government of the potential complementary and dynamic role of the private capital goods industries in augmenting the production capabilities of the defence sector has been missing. Moreover, an understanding that the integration of the capital goods and defence sectors would encourage both to become more innovative and efficient in the areas of production, research and development has been also lacking.[54]

Instead, a narrow bridge, namely "ancillarisation", has been instituted to link the Indian capital goods industries with the defence sector. Ancillarisation is intended specifically to integrate India's small-scale capital goods producers in the defence production process through component purchases. The decision to adopt this more narrow solution has been shaped by the view that despite the poor record of Indian defence production, achievements in the defence sector are expected to provide technological spin-offs to India's private industrial sector thereby fostering broad industrial growth.

This view has been especially prominent in the Lok Sabha. In a recommendation to Hindustan Aeronautics written by the Committee on Public Undertakings in 1968, one finds early evidence of the imitative behaviour that Sen ascribes to latecomer countries such as India in their efforts to establish "strategic industries":

> The Committee understands that in some of the Western countries ...the demands of aviation have led to the development of materials with high strength/weight properties often coupled with resistance to high temperatures. These have found applications in other branches of engineering. The hydraulic systems of aircraft were developed during the Second World War but now find use in tractors, earth moving equipment etc. Similarly the aviation industry provided an initial impetus to electronics, radar and radio. Most of the modern developments in this field have arisen from aviation demand. The experience of the foreign countries would suggest that the fruits of research which can be utilised by other industries in India should be made available to them.[55]

Aside from the perceived benefits of spin-offs from the military sector, some limited form of private sector participation has been expected to alleviate the chronic underutilisation of capacity in the Indian capital goods industries. Severe foreign exchange constraints have been another sizeable factor favouring ancillarisation versus full liberalisation. According to a senior Department of Defence Supplies official:

> 85 per cent of India's defence needs are being imported...In an adverse balance of payments situation, the country can ill afford this. By involving the private sector, which will supplement the efforts of the ordnance factories, we are only trying to hasten the process of indigenisation and ease the foreign exchange situation in the long run as well."[56]

However, confining the private industrial sector to manufacturing only elementary products and intermediate components and spare parts has not only led to mutual antipathy between the two sectors, but has also widened the defence industrial divide. Since the 1970s, ancillarisation of defence production has proceeded at a snail's pace, with both the defence and private sectors blaming each other for the lack of progress and limited interaction. Private industry has argued that the Indian government and the defence ministry have not provided the necessary incentives to encourage their involvement. "What prevents realistic private sector participation is a total lack of planning," says Baba Kalyani of Bharat Forge, a small private company that supplies approximately twenty per cent of its annual output to the defence sector.[57] In particular, the absence of long-term contracts that would permit generation of economies of scale to sustain production has been cited by various capital goods firms as a major factor dampening their participation and investment in production facilities for defence.[58]

A recent example was reported in *Business India*. The case involved Ruston & Hornsby (India) Ltd., a company that was contracted by the MoD to re-engine two East European military vehicles: Kolos Tatra 814 tank transporter and the Topaz armoured personnel carrier. After three years of field testing by the Army of the re-designed engines, the company experienced considerable difficulty recouping its investment in product development. Recalling this experience, the company's general manager bitterly complained, "If the government expects active private sector participation it must ensure that firms are assured adequate return on investment within a reasonable time frame, besides assuring business on a continuing basis."[59] Multi-sourcing is another defence procurement practice that Indian firms object to because it unnecessarily limits capacity utilisation. A director of Indian Seamless Metal Tubes, a company that provides rifle barrels and shell casings to the ordnance factories admitted that, "[t]he system of periodic purchase by issuing tenders doesn't really justify sustained investment in R&D."[60]

Interestingly, further criticism of the defence sector's reluctance to involve private industry participation was provided by a former Defence Secretary, P.V.R. Rao:

> [A] factor which bedevils the situation regarding the harnessing of civil industrial capacity for defence needs is the attitude of the Government ordnance factories...There [is] the nagging fear in the management that once the private sector developed its capacity, the ordnance factories may have to concentrate on the more difficult items and would not be able to produce a good annual report; besides in later lean years, the competition or the pressures for orders by the private sector may leave the ordnance factories without adequate work.[61]

In cases where defence production units have been conscientiously trying to develop private sector component suppliers, economies of scale difficulties and quality considerations impose barriers to entry for some Indian manufacturing firms. As one public sector defence firm, Bharat Earth Movers Ltd., explained:

> The industries like the forging industry on whom we depend, the steel foundries etc. are essentially first targeted to the automotive industry which has got a recurring and higher quantity of demand. Our

> requirements are of larger sizes, smaller quantities, higher degree of specification.[62]

When such requirements are not met by the private manufacturing sector, defence firms have had to integrate vertically all those facilities, leading to significant inefficiencies and duplicative efforts. For example, BEML's attempt to establish a captive foundry as well as a hydraulic shop resulted in delays of over ten years. In the interim, BEML had to resort to massive, outside purchases, and its facilities were faced with chronic underutilisation of capacity. Nevertheless, the defence ministry's criticism of poor quality is refuted by several private sector companies. Baba Kalyani of Bharat Forge counterargues, "If we can make complex forgings for nuclear reactors, there is no reason why we cannot make gun barrels...While military items have to meet the most stringent standards, the fact is that the engineering requirements of some components required by defence can at times be fairly pedestrian."[63]

Within India there is little recognition that continued vertical integration of production within the defence public sector units has had the perverse effect of denying an important means of "learning by others", and of preventing greater specialisation within the Indian capital goods sector. In his massive study of technology development in India, Nayar acknowledges that India's state-owned defence industries continue to be isolated technologically from the civil-industrial sector because, "economic and technical spin-offs from the military-industrial complex do not carry into the industrial economy as a whole but rather remain quarantined not only within the public sector but within its individual units."[64]

In the mid-1980s the Indian government recognised that ancillarisation of its defence industries had neither led to increased indigenisation levels (and hence improved savings of foreign exchange) nor to the technological regeneration of the depressed capital goods sector. Indeed the MoD's Secretary of Defence Production acknowledged that the country's:

> defence industrial effort cannot function as an island of high technology without an *interactive* relationship with the country's civil industry. The former has to depend for its raw material requirements, intermediate products and common user components on the civil industrial sector. Ultimately the degree of indigenisation of our advanced integrated weapon systems depends upon the extent to which the country produces sophisticated steel and other alloys, forgings and castings, basic electronic components, etc. This calls for integrated approach to industrial planning in defence and civil sectors.[65] (Italics added for emphasis.)

Rather than revamping the country's industrial policy in a way that would allow the full integration of the private, capital goods sector into the armaments industry, the Indian government has decided simply to strengthen the existing institutional mechanism within the Department of Defence Production and Supplies that already linked private industry to the defence sector. To provide for closer and continuous interaction between the public defence sector and private industry, a two-tier institutional mechanism was created in 1985 comprising an apex body headed by the Secretary of Defence Production and Supplies, and four functional groups.[66] The apex body, which meets annually, is responsible for major policy issues (e.g., implementation of the phased programme for off-loading low technology items), and the functional groups are responsible for identifying civil industrial sources for the manufacture of specific defence items of a "non-sensitive nature".

The results of this new bridging mechanism have been marginal. Instead of increasing private sector industrial participation, capital goods producers' input into defence production actually declined. In 1988-89, the latest year for which data was obtainable, private sector production for defence was Rs. 134 crore.[67] This figure in fact represented a 40 per cent reduction in the value of private sector supplies from the peak year in 1986-87 of Rs. 277 crore. Nevertheless, some of the dpsus have intensified their own ancillarisation programmes. Bharat Electronics, for example, constructed a 20-unit industrial estate to foster the ancillary and small-scale industry supply of parts, components and subassemblies.

A few of India's larger capital goods producing "houses" -- the Tatas, Birlas, Dunlops, and Kirloskars among others -- are becoming involved in defence manufacturing, particularly in the defence transport area. The main battle tank programme is a case in point. Kirloskar Cummins and Kirloskar Pneumatics are designing components for the engine and suspension systems. Mico Bosch is providing the tank's fuel pump and Dunlop is supplying the rubber pads for the wheels. The computer has been manufactured by BEL and NELCO.

Despite the continued, though limited, participation of the private sector in defence production, criticism remains. Some Indian defence economists argue that this new institutional set-up, established within the Department of Defence Production and Supplies, has succeeded only in creating one more institutional bottleneck, limiting effective interaction between private sector capital goods suppliers and the defence public sector units. "[T]he intervention of a third authority acts only as a hindrance in a programme which requires close and continuous cooperation between the ordnance factories and the manufacturers."[68]

More fundamental, are the criticisms raised by K. Subrahmanyam in an influential IDSA article.[69] The fact that India was the only country in the world that attempted to develop a combat aircraft industry without developing an adequate civil aeronautical industry he attributes to the continued compartmentalisation of defence and civil industrial demands. Paradoxically, however, Subramanyam implicitly suggests that the simple integration of India's industrial sector with defence will not necessarily lead to greater self-sufficiency or self-reliance.

> The defence industrial sector cannot function as a high performance island in a sea of dependent technologies in civil industries. Self reliance in defence involves a large and efficient R&D base and ability to transform the results of R&D into economic industrial mass production. Twenty-five years after the second five year plan our industrial economy is by and large a licensed one. Our civil industry is yet to design on its own a motor cycle or a passenger car.[70]

Arguably, the weak link between India's defence and civil industries is its inefficient and stagnant capital goods sector. Hence, simply strengthening the linkages between the capital goods and defence sectors may not correct the poor technological and manufacturing performance of the country's arms industry.

The Defence/Capital Goods Nexus

The development of an independent arms industry and a diversified capital goods sector has been central as well as indispensable to India's strategy of self-reliant, import-substitution industrialisation. According to one Indian advisor:

> A strong industrial house, especially its capital goods component, and along with that an independent arms industry are the *sine qua non* of national independence, and, for underdeveloped countries necessarily become the first order objectives of national economic policy.[71]

Despite the achievement of a relatively self-sufficient, diversified industrial base, India's capital goods sector has been marked by persistent stagnation since the mid-1960s. The steep decline in the growth of the capital goods sector from 19.6 per cent per annum during 1960-65 to a mere 2.6 per cent between 1966-75 substantially reflects the early stagnation in industrial output.[72] This section briefly discusses the economic stagnation of this vital sector and some of its causes.

The poor performance of India's capital goods sector is indicated by low productivity levels, and a depressed growth rate of value added in industry. With regard to the second indicator, Table 4.8, *Growth Rates of Sub-Periods and Tests of Deceleration Use Based and Input Based Classification*, shows that the growth rate of value added in the industrial sector declined overall from approximately eight per cent per annum in the 1959/60 - 1965/66 period to 5.7 per cent in the latter 1966/67 - 1979/80 period. The deceleration was heavily concentrated in the capital and intermediate goods sectors.

Accompanying the substantial slowing down of real growth in the capital goods sector from 1966 onwards was the pronounced decline of growth in the machinery and transport equipment sectors, which various economists argue had disastrous backward linkage effects to the basic goods industries. As indicated in Table 4.9, *Value Added in Selected Capital Goods Industries, Fifth Year Plan*, in real terms, value added decreased

Table 4.8

Growth Rates of Sub-periods and Tests of Deceleration [a] — Use Based and Input-based Classificiation

(1950-60 to 1965-66; Period I: 1966-67 to 1978-79: Period II)

	Value Added		*Value of Output*	
	I	*II*	*I*	*II*
(A) Use-based classification				
Total	8.0	5.7	8.8c	6.5c
(1) Basic Goods	11.0	6.0	12.2c	7.2c
(2) Intermediate Goods	5.7	4.4[b]	9.4	7.3
(3) Capital Goods	15.4	6.8	15.8	6.1
(4) Consumer Goods	4.7	5.6[b]	5.9	6.2b
(a) Durables	11.5	11.5[b]	12.3	12.6b
(b) Non-durables	4.2	4.9[b]	5.7	5.7b
(b) Input-based classification				
(1) Agro-based	3.7	4.1[b]	5.9	5.1[b]
(2) Metal-based	14.1	6.6	14.6	7.1
(3) Chemical-based	8.2	8.4[b]	11.3	11.2[b]

Notes: (a) The figures show an antilogarithm of the relevant regression coefficient minus 1, where the equation estimated is of the form Log y = a + a'D + bt + b'Dt.

All data are in 1970-71 prices.

(b) Statistically not significantly different from the growth rate of the earlier period.

(c) Excluding electricity and gas.

Source: I.J. Ahluwalia, *Industrial Growth in India*, 1985.

Table 4.9

Value Added in Selected Capital Goods Industries——Average Annual Real Growth Rates in Percentages at Constant 1960 Prices

Period	*All Machinery and Equipment*	*Machine Tools*	*Chemical Equipment*	*All Other Mechanical Machinery*	*Heavy Electricals*	*All Other Electrical Machinery*	*Transport Equipment*	*Professional and Scientific Instruments*
1960-1978	6.7	9.9	31.7	10.8	(1960-76) 18.0	13.0	2.6	13.3
Third FYP 1961-1965	12.7	28.7	37.9	20.1	23.9	15.0	8.7	0
Annual Plans 1966-68	0.2	—14.2	—15.6	—2.6	7.4	3.6	0.2	4.5
Fourth FYP 1969-73	13.8	19.6	132.0	10.7	29.6	17.4	9.6	34.3
Fifth FYP 1974-78	—1.9	—0.5	10.3	8.5	6.3	15.9	—9.0	12.6

Sources:
1. National Accounts Statistics, various years
2. Statistical Abstract of India, 1979, Tables 167 and 168, pp. 407.
3. "Wholesale Price Statistics, India 1947-78", H.L. Chandok, Pub by Economic and Scientific Research Foundation, New Delhi, October, 1978.
4. Census of Indian Manufacturing Industries, for period up to 1960.
5. The Annual Survey of Industries (summary results for the census sector and factory sector) all volumes covering the period up to 1978-79 (the period volume was published in 1983, and contains the latest published figures of 1983).
6. Monthly Statistics of the Production of Selected Industries. All issues published up to 1983 (covering the periods up to 1980).
7. Statistical Abstract of India, all volumes published up to 1983 (covering the periods up to 1980).
8. Monthly Abstracts of Statistics, published by the Central Statistical Organisation, and the Department of Statistics of the Ministry f Planning, Government of India, New Dehli.
9. Profiles of Indian Industries, Economic Intelligence Service Centre for Monitoring the Indian Economy, Bombay.

Cited in, I.J. Ajluwalia, *Industrial Growth in India*, 1985, p.466.

for the transport and machine tools industries, both of which had negative growth rates of -9.0 and -5.0 per cent respectively.

Closely paralleling the recessionary experiences of Brazil's capital goods sector, the demand for Indian capital goods industries as measured by gross output also experienced similar fluctuations. Table 4.10, *Gross Output in Selected Indian Capital Goods Industries*, documents the instability of demand for Indian capital goods and reinforces the particularly severe impact on the machine tool and transport industries. While the machine tool sector's average annual real growth rate declined from 12 per cent (1969-74) to 0.4 per cent (1974-78), transport decelerated even faster from 25.4 per cent in 1969-73 to -6.0 per cent in 1974-78.[73]

An examination of industrial output data for the 1980s, provided by Kelkar and Kumar, reflects a distinct shift away from the metal-based and machine-building industries. They find that the growth rate of the machine tool sector's output, excluding airconditioners and refrigeration, declined to 5.47% annually over the period 1981/82-1988/89, while that of the metal products was reduced even further to 3.95% over the same time period.[74] The acceleration in the industrial sector during the 1980s instead was led by the chemicals, petrochemicals and allied industries. Another interesting feature of India's industrial performance is revealed by looking at the relative growth rates of industrial output when classified by end-user categories. During this period the fastest growing segment was the consumer durables whose output increased at 14.7 per cent annually.[75]

Table 4.10

Gross Output in Selected Capital Goods Industries——Average Annual Growth Rates in Percentages at Constant 1960 Prices

Period	*All Machinery and Equipment*	*Machine Tools*	*Chemical Equipment*	*All Other Mechanical Machinery*	*Heavy Electricals*	*All Other Electrical Machinery*	*Transport Equipment*	*Professional and Scientific Instruments*
1960-1978	8.0	10.5	34.7	12.1	(1960-76) 17.7	14.2	3.3	13.7
Third FYP 1961-1965	15.4	29.6	45.4	18.3	26.5	17.2	12.4	11.2
Annual Plans 1966-68	4.8	1.4	9.9	7.1	15.6	9.8	1.3	8.9
Fourth FYP 1969-73	9.3	12.0	(1969-71) 110.0	8.3	18.7	12.8	25.4	16.1
Fifth FYP 1974-78	2.5	0.4	(1975-78) 5.9	1.2	(1974-76) 8.0	22.3	——6.0	23.2

1. Census of Indian Manufacturing Industries, for period up to 1960

2. The Annual Survey of Industries (summary results for the census sector and factory sector) all volumes covering the period up to 1978-79 (the period volume was published in 1983, and contains the latest published figures of 1983).

3. Monthly Statistics of the Production of Selected Industries. All issues published up to 1983 (covering the periods up to 1980).

4. Statistical Abstract of India, all volumes published up to 1983 (covering the periods up to 1980).

5. Monthly Abstracts of Statistics, published by the Central Statistical Organisation, and the Department of Statistics of the Ministry f Planning, Government of India, New Dehli.

6. Profiles of Indian Industries, Economic Intelligence Service Centre for Monitoring the Indian Economy, Bombay.

Source: I.J. Ajluwalia, *Industrial Growth in India*, 1985, p.452.

This gap between India's potential and actual industrial performance (given its large domestic market, resource base and well developed scientific and technical manpower) continues to be the focus of much scholarly debate.[76] Perhaps the most widely accepted explanation for the country's industrial stagnation is the inefficiency argument.[77] According to this theory, the state has developed a stranglehold on the industrial sector. The slow growth of the capital goods sector is the inevitable result of the Indian government's import-substitution trade and industrial policies. "Nearly all the elements of the industrial policy regime -- ranging from...investment, capacity creation, technology choice, prices [and] foreign collaboration...have had a growth choking effect."[78] In addition, the long duration of India's import-substitution strategy has perversely encouraged the development of a high cost, obsolescent industrial structure, sheltered from foreign competition -- critical factors that have rendered India's few exports uncompetitive.

Indeed, India's industrial policies have played a pervasive role in shaping the development of its defence and capital goods sectors. The Indian government's industrial policies have been traditionally devised and implemented with the aim of influencing the pattern of sectoral investment down to the individual firm-product level. The net effect, however, has resulted in reduced domestic competition and the limited ability of firms to improve their performance. Specifically, for example, firms have limited flexibility in choosing plant location and size, obtaining foreign technology, altering product lines, and reducing their workforces.

The broad objectives of the government's industrial policy are articulated in the various Industrial Policy Resolutions (1948, 1956 and 1973) and Statements (1980 & 1984). Primary amongst these objectives are:

1) Public sector participation in the defence and heavy industries

As discussed previously, public sector control of the "commanding heights" of India's economy has been an integral part of the country's development strategy. Certain sectors, infrastructure and defence especially, are reserved exclusively for the public sector. In addition to reservation policies, the public sector enterprises enjoy preferential licensing, purchase and financing arrangements from the government.

The overall financial performance of the public sector enterprises has been extremely poor. Political interference in the day-to-day functioning of public sector enterprises, overstaffing, labour undiscipline, as well as over-cautious top-heavy bureaucratic management practices, are blamed for the public sector's chronic inefficiency. As evidenced by the recent introduction of reforms in the defence sector, the infusion of private-sector values and integration into the public sector has been seriously considered to be an important solution. As a chairman of a parliamentary committee remarked:

> For a message from one of the public-sector steel plants to reach Krishnamarthy [then chairman of the Steel Authority of India] could take weeks...But Russi Modi [long-serving chief of the private sector Tata Iron and Steel Co.] is only a phone call away from anybody on the shop floor. They say the dinosaur went extinct because it took nearly three minutes for nerve impulses to travel from its tail to its brain....[79]

2) Controls on Large or Dominant Firms

The Monopolies and Restrictive Trade Practices Act (MRTP) was implemented in 1970 in an effort to regulate entry and growth of India's largest private capital goods firms or "houses", thereby limiting the concentration of economic power, and to check practices that restrict competition. This industrial policy severely limits the market entrance or expansion of MRTP firms (defined in 1990 as enterprises or interconnected firms that possess assets of or over Rs one billion or a dominant market share of 25 per cent or more). For example, between 1982 and 1984, the approval rate of industrial license applications involving MRTP clearances was roughly half that of companies in general (40-50 per cent), and the application processing time was also longer, taking as much as two or more years in half of the cases.[80]

3) Promotion of Small-Scale Industry

The promotion of small scale industry takes a number of forms: a) reservation of products for exclusive manufacture by small scale capital goods firms, b) exemption from licensing, c) exemption from corporate tax and preferential excise and sales tax rates, d) exemption from many labour regulations, c) preferential access to domestic and imported raw materials, and f) purchase support through government procurement for small-scale industry products.[81] Since small-scale firms are defined strictly, that is limited to investments in machinery and equipment not exceeding U.S. $272,000 or $350,000, these conditions create a powerful incentive to remain small. According to one Indian economist, "the panoply of privileges creates a small enterprise economy within the economy which is entirely exempt from competition from medium sized and large firms, and which cannot benefit from economies of scale."[82] It also reinforces the high cost structure of Indian industry.

Since the 1991 economic liberalisation programme initiated by Prime Minister Rao, the government has sought to reduce these controls and regulations on industrial growth.[83] This domestic liberalisation package included various measures: 1) delicensing of many product groups (e.g., automotive ancillaries, machine tools), with the exception of industries pertaining to security, strategic, environmental and social concerns; 2) Reduction in the number of industries reserved for the public sector from 17 to eight (the defence industries will continue to remain in the state sector); 3) raising the asset threshold for MRTP companies, thereby enabling more firms to operate without restriction of the Act); 4) increasing the ceiling asset size for small-scale firms and some reduction in the product reserve list; and 5) liberalisation of capital goods imports.

Generally, such industrial policy reforms are intended to lower some of the institutionally created barriers to entry in a number of industries, thereby increasing the opportunity for greater domestic competition. In addition, the scaling up of firm sizes will permit greater economies of scope as well as scale, and consequently a better chance for attaining international competitiveness. Finally, such reforms are expected to provide firms with more discretion in corporate planning, without continued reference to governmental machinery.

Conclusion

This case study chapter has outlined the paradoxical character of India's defence-industrial capabilities. In comparison to Brazil, the Indian government has actively intervened through direct ownership and other industrial policies to establish and promote its arms industry. While the government has succeeded in creating the largest and broadest military industrial research complex among the NICs, it has largely failed in its objective of indigenous and self-sustaining arms production.

A number of factors were highlighted in this chapter which explain this failure. From the beginning, the emphasis on self-sufficiency precluded strong collaborative partnerships with experienced foreign defence manufacturers, thereby denying an important learning opportunity for India's defence firms. As a consequence, Indian firms have not been able to use foreign technologies effectively to augment their own nascent technological capabilities, and to build systematically on those capabilities. Additionally, Indian defence firms have set unrealistic weapons production targets, given their insufficient technological and manufacturing experience and lack of contact with the country's capital goods firms. As intimated throughout the chapter, the cycle of failed indigenous production and, hence, continued reliance on licensed production and arms imports, is the result of such firm-level shortcomings. It is also due to injudicious government policies, particularly those that have led to the stagnation of the capital goods sector, and to the fragmented linkages between this sector and the defence industry. The interaction between India's defence and capital goods firms and the state is now examined in Chapter 5.

Endnotes

[1]*Ministry of Defence Annual Report, 1964-65* (New Delhi: Ministry of Defence, 1965), 50-51.

[2]Harpreet Mahajan, *Arms Transfers to India, Pakistan and the Third World* (New Delhi: Young Asia Publications, 1982), 213.

[3]Dilip Mukerjee, "Hi-Tech Players in a Dangerous Game of Catch," *Far Eastern Economic Review*, 9 June 1988.

[4]See Robert G. Wirsing, "The Arms Race in South Asia: Implications for the United States," *Asian Survey*, Vol. XXV, no. 3 (March 1985): 265-91.

[5]Ross H. Munro, "Superpower Rising," *Time* (International Edition), 3 April 1989, 13.

[6]Ashley J. Tellis, "India's Naval Expansion: Reflections on History and Strategy," *Comparative Strategy*, Vol. 6, no. 2 (1987): 192-93.

[7]Some observers suggest that these recent variegated acquisitions will enable the Indian Navy to structure surface strike groups for offensive purposes, and that its submarine force architecture will prove an effective solution to India's sea denial capabilities. As Naval Chief Admiral Jayant G. Nadkarni admitted in 1988, the Indian strategy is "not only to ensure that the sea areas of importance to us are controlled by us, but to deny them to our adversary. For this the primary weapons would be submarines." See Brahma Chellaney, "India Bolsters its Naval Forces," *Christian Science Monitor*, 22 January 1988, 1, 32.

[8]*Ministry of Defence Annual Report, 1974-75* (New Delhi: Ministry of Defence, 1975), 49.

[9]*India: A Reference Manual, 1976* (New Delhi: Government of India Publications Division, 1976), 25.

[10]For a history of Hindustan Aeronautics Ltd., see Ram Nath Singh, *All About Weapons: From Arrow to Missiles* (Patna: Ghintamani Prakashan Publishers, 1979).

[11]See Office of Technology Assessment, "The Defense Industry of India," in *The Global Arms Trade* (Washington, D.C.: U.S. Government Printing Office, June 1991).

[12]*Ministry of Defence Annual Report, 1986-87* (New Delhi: Ministry of Defence, 1987), 25.

[13]See P. Sharma, "Towards Self-Reliance in Defence," *The Defence Review 1984*, 257-62.

[14]Lt. Col. Sharma, "Defence Production in India," *Institute for Defence Studies & Analysis (IDSA) Journal*, Vol. X, no. 4 (April-June 1978): 322.

[15]Y. Lakshmir, *Trends in India's Defence Expenditure* (New Delhi: ABC Publishing House, 1989), 64.

[16]P. Sharma, "Towards Self-Reliance in Defence," 262.

[17]Lakshmir, *Trends in India's Defence Expenditure*, 56.

[18]Ibid., 59.

[19]India, Parliament, Committee on Public Undertakings, *Bharat Earth Movers Ltd.*, Ministry of Defence, Department of Defence Production and Supplies, 1987-88, Eighth Lok Sabha (New Delhi: Lok Sabha Secretariat, 1988), 87.

[20]Ibid., 41.

[21]Committee on Public Undertakings, 1969-70, Sixtieth Report, *Action Taken by Government on the Recommendation Contained in the Eighth Report of the Committee on Public Undertakings on Hindustan Aeronautics Ltd., Ministry of Defence, Department of Defence Production*, Fourth Lok Sabha (New Delhi: Lok Sabha Secretariat), 1970, 26.

[22]Interview.

[23]From 76th Report, Public Accounts Committee, 1981-82, *Development of a Helicopter*, Ministry of Defence, Seventh Lok Sabha (New Delhi: Lok Sabha Secretariat, March 1983).

[24]Srinivasa Prasad, "Designed Delays," *India Today*, 15 September 1986, 78-79.

[25]S. Sapru, "Inside HAL Today," *Deccan Herald* (Bangalore), 11 March 1979, 6.

[26]Public Accounts Committee, *Development of a Helicopter*, 27.

[27]Ibid., 36.

[28]Ibid., 25.

[29]Cited in Ramidan Singh, "Trouble Before Take Off," *India Today*, 31 January 1986, 77.

[30]Ibid.

[31]Sandanada Mukerjee, "India's New Relationship with USA," *Jane's Defence Weekly*, 28 October 1989, 912.

[32]Amit Gupta, "India's Mixed Performance," *Defence & Diplomacy*, Vol. 7, no. 5 (May 1987): 44-49.

[33]Baldev Raj Nayar, *India's Quest for Technological Independence: The Results*, Volume 2 (New Delhi: Lancers Publishers, 1983), 502.

[34]*Ministry of Defence Annual Report, 1988-89* (New Delhi: Ministry of Defence, 1989), 39.

[35]See article in *Frontine*, "Agni: importance, implications," 10-23 June 1989, 4-16.

[36]See Gary Milhollin, "India's Missiles -- With a Little help from Our Friends," *The Bulletin of Atomic Scientists*, Vol. 45, no. 9 (November 1989): 31-35.

[37]Gowrishankar Sundaram, Mike Howarth and Hormuz Mama, "India: Indigenous Programme Flourish Amid Defence Modernisation," *International Defence Review*, Vol. 19, no 4 (1986): 436.

[38]Interview at the Ministry of Defence, New Delhi, 1989.

[39]See Robert Horn, *Soviet-Indian Relations: Issues and Influence* (New York: Praeger Publishers, 1982); and Rajan Menon, *Soviet Power and the Third World* (New Haven: Yale Press, 1986).

[40]For a discussion of why the MiG-21 was chosen over the objections of the Indian Air Force, see A. L. Saigal, ed., *Memoirs of Air Vice Marshall Harjinder Singh, Birth of an Air Force* (New Delhi: Palit & Palit, 1977).

[41]Various analysts have suggested that while the Soviet Union has benefitted from the influence derived from the arms relationship with India (e.g., India's expressed neutrality over the USSR's 1979 invasion of Afghanistan), India, too, has found licensing and purchases of Soviet arms useful. Three reasons have been advanced by Western and Indian analysts. The first, is the price factor. The USSR has accepted deferred payments in rupees and provides extremely generous credit at only 2.24% interest rates,

repayable over 12-17 years. A second reason for Indo-Soviet arms collaboration is that since the Soviets believed in modular weapons development, in which models were upgraded rather than completely redesigned, existing Indian production lines merely had to be adapted for the next generation. The need to establish separate production lines and invest in the construction of new production facilities is thus removed. The Soviet Union's willingness to conduct barter trade -- arms exports for import of Indian exports of raw materials and commodities -- is cited as the third and final factor. Increasingly, though, Indo-Soviet arms cooperation was criticised because of the latter's reluctance to transfer process technologies needed to indigenise important components (special alloys and metals for MiG engines), and to allow exports of Soviet licensed defence equipment to third countries. For an analysis of Soviet-Indo relations see Jyotirmoy Banerjee, "Moscow's Indian Alliance," *Problems of Communism*, 36 (January/February 1987): 1-12, and Robert G. Wirsing, "The Arms Race in South Asia: Implications for the United States," *Asian Survey*, XXV, 3 (March 1985): 265-91. See also: Michael T. Klare, *American Arms Supermarket* (Austin, TX: University of Texas Press, 1984), 220; S. Nihal Singh, "Why India Goes to Moscow for Arms," *Asian Survey*, Vol XXIV, no. 7 (July 1984): 710; and Salamat Ali, "Cheap but at a Price," *Far Eastern Economic Review*, 7 March 1985, 35.

[42]See Robbin F. Laird, *Soviet Arms Trade with the Non Communist Third World in the 1970's and 1980's* (Washington, D.C.: Wharton Econometric Forcasting Associates, 1983).

[43]For an in-depth review of what prompted a reappraisal by the Reagan Administration of U.S.-Indo relations, see Dilip Mukerjee, "U.S. Weaponry for India," *Asian Survey*, XXVII, no. 6 (June 1987): 595-614.

[46]Some observers believe that if the United States establishes a firm foothold in India's defence production programme, it may pursue the twin objective of extending U.S. influence and providing export opportunities for American defence companies, thereby reducing India's dependence on the Soviet Union. See Nayan Chandra, "A New Indian Summer," *Far Eastern Economic Review*, 25 February 1988, 34.

[45]See Raju G.C. Thomas, "India," in *Arms Production in Developing Countries*, ed. James Everett Katz (Lexington, MA: D.C. Heath & Company, 1984).

[46]Cited in Sharma, "Defence Production in India," 341.

[47]Cited in Nayar, *India's Quest for Technological Independence*, 359-60.

[48]Ibid., 187-88.

[49]Ibid.

[50]For details see Prabha Chawla, "The HDW Deal: The Scandal Surfaces," *India Today*, 15 March 1990, 32-35, and "The Gun That Can Kill at Four Year's Range," *The Economist*, 9 September 1989, 35-36, and Inderjit Badhwar & Ramindar Singh, "Bofors: Getting Away," *India Today*, 15 September 1989, 22-23.

[51]Sharma, *The Defence Review 1984*, 262.

[52]Raju G. C. Thomas, *Indian Security Policy* (Princeton: Princeton University Press, 1986).

[53]K. Subramanyam, "Problems of Defence Industrialisation in India," *IDSA Journal*, 13, no. 3 (January-March 1981): 363-377.

[54]Rajesh Agarwal, *Defence Production in India* (New Delhi: Birla Institute of Scientific Research, 1978), 53.

[55]Refer back to Gautam Sen, *The Military Origins of Industrialisation and International Trade Rivalry* (London: Frances Pinter Press, Ltd., 1984), and the Committee on Public Undertakings, 1969-70, Sixtieth Report, *Action Taken by Government on the Committee on Public Undertakings (Fourth Lok Sabha) on Hindustan Aeronautics Ltd., Ministry of Defence, (Department of Defence Production)*, Fourth Lok Sabha (New Delhi: Lok Sabha Secretariat), 1970, 27.

[56]Kingshuk Nag, "Arms and the Businessmen," *Business India*, 25 June-8 July 1990, 87.

[57]Ibid., 88.

[58]P.K. S. Namboodiri, "Planning for Defence," *Eastern Economist* (Delhi), Vol. 76, no. 4 (23 January 1981, Annual Number): 283-85.

[59]Nag, "Arms and the Businessmen," 88.

[60]Ibid.

[61]P.V.R. Rao, *Defence Without Drift* (Bombay: Popular Prakashan, 1970), 241.

[62]Committee on Public Undertakings, *Bharat Earth Movers Ltd.*, 6

[63]Paranjoy Guha Thakarta, "Peripheral Vision," *India Today*, 28 February 1989, 97.

[64]Nayar, *India's Quest for Technological Independence*, 495.

[65]*Ministry of Defence Annual Report, 1979-80,* 28.

[66]These groups are: vehicles, engineering, electronics and instrumentation, lubricants, chemicals, textiles, and general stores (clothing etc.). *Ministry of Defence Annual Report, 1986-87,* 25.

[67]Guha, "Peripheral Vision," 96.

[68]Rao, *Defence Without Drift*, 241.

[69]See Subramanyam, "Problems of Defence Industrialisation in India," 372.

[70]Ibid.

[71]Nayar, *India's Quest for Technological Independence*, 87.

[72]Vijay Kelkar and Rajiv Kumar, "Industrial Growth in the Eighties: Emerging Policy Issues," *Economic and Political Weekly*, 27 January 1990, 209-222.

[73]In examining the structural retrogression of India's machine tool industry, Matthews finds that this industry made negative profits for almost half the years during the country's most important phase of development, 1960-74. See Ron Matthews, "Technological Dynamism in India and Japan: The Case of Machine-Tool Manufacture," in *Technological Development in China, India and Japan*, eds., Erik Baark and Andrew Jamison (London: Macmillan, 1986), 168-69; and S.L. Shetty, "Structural Retrogression in the Indian Economy Since the Mid-Sixties," *Economic and Political Weekly*, February 1978, Annual Number, 14-18.

[74]Kelkar and Kumar, "Industrial Growth in the Eighties," 211.

[75]Ibid., 212. This shift in consumption-led growth of the 1980s-1990s, in contrast to the investment-led growth of the earlier 1960-65 period, has engendered much debate and criticism among Indian planners and economists.

[76]For a succinct overview of the debate see V.S. Mahajan, ed., *Studies in the Industrial Economy of India. Vol. I,* (New Delhi: Deep & Deep Publications, 1987).

[77]One of the major proponents of this argument is Isher Judge Ahluwalia, *Industrial Growth in India: Stagnation Since the Mid-Sixties* (New Delhi: Oxford University Press, 1985). In this classic study of industrial growth in India, Ahluwalia identifies several important factors responsible for the poor performance of the capital goods sector: 1) the slow growth in per capita incomes in the agricultural sector, which subsequently limited demand for industrial products; 2) underinvestment in and poor management of the infrastructure sectors such as power, steel and the railways.

[78]Srinivasan's characterisation in *Studies in Industrial Economy of India*, 199. J. Bhagwati and T.N. Srinivasan, *Foreign Trade Regimes and Economic Development: India* (New York: Columbia University Press for the National Bureau of Economic Research, 1975).

[79]Lincoln Kaye, "India's Dinosaur Legacy," *Far Eastern Economic Review*, 14 January 1988, 57.

[80]World Bank, *India: An Industrialising Country in Transition* (Washington, D.C.: World Bank, 1989), 87.

[81]Ibid., 88.

[82]Ashok V. Desai, "Technology Acquisition and Application: Interpretations of the Indian Experience," in *The Indian Economy: Recent Development and Future Prospects*, eds., Robert E.B. Lucas and Gustav F. Papanek (Boulder: Westview Press, 1988), 175.

[83]Embassy of India, Commerce Wing, "New Economic Policies of the Government," mimeo, June 1992.

Chapter V

THE STRATEGIC INTERACTION OF FIRMS AND STATES

Introduction

The preceding case studies starkly reveal significant contrasts in the performance of Brazil's and India's defence and manufacturing industries. As this author suggested in Chapter 2, a useful theoretical explanation for this difference is one that elucidates the determinants of firms' technological capabilities, and how the state, through its critical ability to shape the external environment in which firms operate, asserts itself as a major influence on firm behaviour. This chapter explores the strategic interaction of firm behaviour and government policies, drawing upon and integrating the previous Brazilian and Indian case study chapters.

Before we analyse how the strategic interaction of firms and states has conditioned the Brazilian and Indian experiences, it would be useful at this juncture to summarise and highlight the main findings of the case study chapters. Though much of the material in the latter two chapters is intended to provide the reader with a detailed knowledge of the evolutionary development of Brazil's and India's defence and capital goods industries, the case studies also yield interesting preliminary insights regarding the roles of firms and governments in the process of defence industrialisation.

Clearly India's heavy emphasis on technological self-reliance has led to the emergence of a very large and relatively sophisticated defence sector. Nevertheless, these public sector industries coexist with private manufacturing industries, both of which are highly inefficient and technologically lagging behind the world frontier. As argued in this chapter, the development of these industries and low export levels have been largely conditioned by industrial, trade policy-induced constraints. While the Indian government has actively promoted the technological development of its defence and capital goods producing firms, via a science and technology policy, the overall impact on Indian firm R & D behaviour is limited because firms do not invest in improving their technological capabilities largely because of a lack of competitive pressure. This important finding will be developed later in this chapter using a game theoretic framework.

By contrast the Brazilian case study chapter shows that the successful emergence and international competitiveness of the defence industries was an almost accidental by-product of the manufacturing and R & D activities of the capital goods firms. In particular, Brazilian firms consciously targeted and combined foreign and local sources of technology in ways that progressively contributed to the technological sophistication of their products and exports. The impact of the Brazilian state in shaping a conducive environment for its firms has been limited to its technology and trade policies. Indeed, as argued earlier, the development of Brazil's defence firms has been neither fully independent of government policies, nor have they evolved primarily as a consequence of such direct government intervention.

Four preliminary observations emerge from the above discussion:

First, successful technological development requires access to foreign elements of technology. As the case study of the Brazilian aircraft industry, Embraer, indicates, the complementary use of foreign technology, via licensing and coproduction arrangements, permitted the early establishment of internationally competitive products, which has not been possible under India's more autarkic strategy.

Second, the very ability to search, select, assimilate, adapt, and master foreign technologies depends on a firm's own conscious efforts. As will be discussed later in this chapter, Brazilian firms are far more innovative and competitive than their Indian counterparts because their technology strategies provide for longer-term learning.

Third, capital goods and defence exports may themselves facilitate technological development. The closer a firm's product is to the world frontier, the more likely that firm will be under pressure to invest in keeping up with technological developments and upgrading its products to suit customers' demands in a world market. Recognition of the potential technological benefits deriving from exports was an important component of Embraer's and Engesa's development strategies.

A final observation emerges from comparing the Indian and Brazilian case study chapters. Considerable technological effort occurs regardless of the policy environment. However, there appear to be important differences in the nature and direction of the technology that is undertaken.[1] As mentioned previously, under India's relatively more protectionist regime of import substitution, firms' R & D efforts concentrated on substituting imports -- raw materials, components, technology -- which could have been obtained more readily and cheaply from abroad. In Brazil's more competitive environment, which includes an export orientation and encouragement of direct foreign investment, there has been greater pressure on local Brazilian firms to reduce costs, upgrade quality, and keep up with global technology changes. *Thus, contrary to what* *many development economists presumed, India's import-substitution strategy has perpetuated dependence on foreign technology, while in Brazil, its greater export orientation has lead to much more substantial autonomy.*

Embedded in each of these findings are complex issues concerning the inter-relationship between firms' technology strategies and the role of states in shaping the external environment in which firms operate. On the basis of this brief, comparative analysis of the Brazilian and Indian case studies, let us now delineate the influence of the Brazilian and Indian governments' trade and technology policies on firms' technology strategies.

SECTION I: HOW STATE POLICIES AFFECT THE EXTERNAL ENVIRONMENT OF FIRMS

Trade Policies

Brazil

A central differentiating feature of Brazil's industrialisation is its impressive manufactured export performance. As Table 5.1 indicates, *Exports of Capital Goods, 1961-1979*, beginning in the 1970s, Brazil became a leading exporter of manufactured goods. One of the most striking characteristics of the country's export composition is the very high share of capital goods and defence products -- the largest among Argentina, India, Korea, and Mexico.

Indeed the total value of Brazilian manufactured exports including defence has experienced substantial growth since 1965. Moreover, Brazilian firms have enjoyed an impressive record of both product differentiation as well as market diversification. In

TABLE 5.1: EXPORTS OF BRAZILIAN CAPITAL GOODS, 1961-1979
(ISIC 38, US$ million)

ISIC CODE	Subsector	1962	1965	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Annual Growth 1965-1970	1970-1979
381	Metal Products	0.3	1.4	3.2	9.9	11.6	18.8	25.0	43.0	61.8	50.3	78.7	109.3	134.8	47.6	24.5
3811	Cutlery, Hand Tools	0.0	0.8	2.4	6.8	6.7	11.1	12.9	22.7	32.8	23.0	33.0	45.1	63.2		28.2
3812	Metal Furniture	0.0	0.0	0.1	0.1	0.3	0.5	1.1	2.0	2.8	2.3	2.7	4.9	4.0		48.2
3813	Structural Metal Products	0.2	0.2	0.2	0.3	1.6	2.1	3.3	2.9	7.6	6.0	8.7	14.1	27.0		49.7
3819	Metal Products, n.e.c	0.1	0.4	0.5	2.7	3.0	5.1	7.7	15.4	18.6	19.0	34.3	45.2	40.6		40.5
382	Non-Electrical Machinery	2.7	16.8	33.2	63.7	76.1	98.4	129.0	251.3	366.6	326.8	473.0	636.0	864.4	30.5	34.9
3821	Engines and Turbines	0.0	0.1	0.0	0.3	0.9	2.0	1.5	4.8	17.6	13.7	33.0	36.1	41.6		76.5
3822	Agricultural Machinery	0.0	0.4	0.5	1.4	1.4	2.3	6.9	17.1	24.5	17.2	48.6	63.9	90.2		64.7
3823	Metal and Wood Working Machinery	0.3	2.5	3.1	5.7	5.3	8.3	6.7	12.9	19.6	15.6	17.2	32.9	60.2		27.9
3824	Special Industrial Machinery	1.0	4.4	7.4	14.1	18.3	23.6	26.8	48.0	72.9	80.0	114.2	153.2	210.6		36.1
3825	Office Machinery	0.1	0.3	13.6	28.3	27.6	31.6	42.5	97.4	109.9	82.8	116.6	130.0	155.8		23.5
3829	Machinery, n.e.c.	1.3	6.3	8.6	13.9	22.6	30.6	44.6	71.1	122.1	117.5	143.4	219.9	306.0		39.5
383	Electrical Machinery	0.5	4.4	5.9	16.5	27.9	38.6	83.4	182.2	162.9	196.1	286.0	315.8	340.7	30.8	41.0
3831	Industrial Machinery	0.0	1.2	1.8	5.6	9.0	12.7	15.8	45.2	53.1	58.1	79.5	89.9	100.1		39.9
3832	Radio, Television, Comm. Equipment	0.3	1.6	2.9	7.9	12.8	19.2	58.0	118.3	85.5	113.7	168.0	180.8	180.3		43.1
3833	Electrical Appliances	0.0	0.2	0.2	0.4	0.7	1.0	1.9	4.4	5.7	4.7	7.3	7.8	13.5		43.1
3839	Electrical Equipment, n.e.c.	0.2	1.4	1.0	2.6	5.4	5.7	7.7	14.3	18.6	19.6	31.2	37.3	46.8		46.1
384	Transport Equipment	8.7	8.0	4.4	14.9	30.7	81.0	94.0	215.3	373.7	443.2	636.8	984.2	1,247.7	13.1	62.1
3841	Ships, Ship repairs	0.0	4.0	0.1	2.8	11.5	23.7	21.4	13.7	43.1	68.0	116.9	209.1	261.5		56.4
3842	Railroad Equipment	0.8	0.0	0.0	0.2	0.8	0.4	1.7	3.2	5.4	6.5	10.4	22.3	25.2		72.6
3843	Motor Vehicles	5.3	3.8	1.5	11.1	15.2	53.7	66.7	172.8	290.9	318.1	428.2	624.6	781.3		62.3
3844	Motorcycles, Bicycles	0.2	0.0	0.0	0.1	0.3	0.9	1.9	4.7	5.8	5.0	11.3	15.0	15.5		72.3
3845	Aircraft	2.4	0.2	2.8	0.7	2.9	2.3	2.3	20.8	28.4	45.5	69.9	113.1	164.0		84.9
3849	Transport, n.e.c.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2		49.3
385	Scientific, Other Equipment	0.2	0.5	0.3	0.9	2.3	2.9	4.7	10.9	19.8	16.1	23.9	41.8	64.7	12.5	56.1
3851	Scientific, Measuring Equipment	0.2	0.5	0.3	0.6	1.7	2.0	2.9	5.9	9.2	9.4	17.7	29.0	31.7		53.7
3852	Photographic, Optical Goods	0.0	0.0	0.0	0.3	0.5	0.5	1.2	3.9	5.2	4.9	3.9	9.8	28.6		59.3
3853	Watches, Clocks	0.0	0.0	0.0	0.0	0.1	0.4	0.6	1.1	5.4	1.8	2.3	3.0	4.4		60.0
38	Total	12.4	31.1	47.0	105.9	148.6	239.7	336.1	702.7	984.8	1,032.5	1,498.4	2,087.1	2,652.3	26.8	44.2

Source: World Bank/UN Data Bank

1964 primary product exports accounted for a full 85 per cent of Brazil's exports, with coffee alone accounting for over 50 per cent. By 1978, the share of agricultural exports had declined (coffee only accounted for 18 per cent of total exports). The share of manufactured products in total exports rose from about 18 per cent in 1965 to 57 per cent in 1980.[2] According to World Bank figures, the average annual growth rate from 1965 to 1980 was 27.9% in current U.S. dollar terms.[3] According to CACEX data the biggest exporting group was the transport sector, accounting for 42 per cent of exports in the sample. The prominence of military producers as leading capital goods exporters is reinforced in Table 5.2, *Brazil's Leading Exporters*.

An important element in Brazil's strong manufactured export performance has been the diversification of export markets. Like the other NICs, Brazil has been a strong exporter to both the industrialised and developing countries. Chudnovsky finds that "developing countries as main destination for Brazilian exports of capital goods declined their participation from 70 per cent in 1970 to 56 per cent in 1984."[4] He also notes that there were a few products, mostly exported to the South in 1973-75, that were shifted to the North after 1980-82. They included aircraft, electric measuring control equipment, piston engines, statistical machines, and transistors. These five leading capital goods exports to the North accounted for 73 per cent of the value of such exports, reflecting a high degree of concentration. In recent years Brazil's competitive position in manufactured exports has been overtaken by the East Asian NICs. However, significant exceptions to the overall decline include such technologically sophisticated areas as aircraft, missiles, telecommunications equipment, and optical equipment.[5]

Table 5.2

Brazil's Largest Exporters of Non-Food Manufactured Products, 1979
(U.S. Millions)

Firm	Main Product	Exports 1979
1. Petrobras	Gasoline	323.8
2. Volkswagen	Motor Vehicles	213.3
3. Interbrás	Alcohol	133.2
4. General Motors	Motors	128.4
5. Mercedes Benz	Trucks	126.9
6. Ford	Motor	116.7
7. Philco	Trucks	111.7
8. Fiat	Motors	93.3
9. IBM	Office Equipment	92.4
10. Siderurgia Nacional	Steel Sheets	89.6
11. Siderurgia Paulista	Steel Slides	78.4
12. Metal Mineraço	Iron	75.8
13. COBEC	Cast Iron	73.5
14. Saab	Trucks	71.5
15. Aracruz Cellulose	Pulp	68.8
16. Embraer*	Aviation Equipment	68.5
17. Comex	Trucks	64.4
18. First Diesel	CED Cars	59.9
19. Cellulose, Nipo	Cellulose	56.4
20. Comp. Navegação	Freight Ships	49.3
21. Verolme Estal.*	Freight Ships	47.9
22. Engesa*	Amoured Vehicles	47.2
23. Caterpillar	Earthmoving Equipment	42.5
24. Engexco*	Optical Instruments	41.4
25. Pirelli	Car Types	34.1

*Brazilian military manufacturer

Source: CACEX.

Cross-tabulated data from the author's survey reflect both the increase in capital intensity of Brazilian manufactured exports, as well as export market diversification. What is interesting to note from Table 5.3, *Destination of Brazilian Capital Goods Exports*, is that the leading capital goods exports are machinery, fabricated metal products (including small arms, ammunition, heavy ordnance and tanks), aircraft, and iron/steel basic products. Reflecting this concentration of manufactured exports are two regions that are disproportionately important as markets for Brazilian manufactured exports. The main destinations for capital goods exports are Central/Latin America and the United States/Canada. In terms of defence exports, Europe and Latin America predominate for aircraft, the Middle East/Persian Gulf for missiles and tanks (Iran-Iraq war), and Latin America for naval exports. This penetration by successful exporters of defence and capital goods producers into the markets of the industrialised countries is an important new trend. However, except for firms such as Embraer, Avibras and Metal Leve, which have found market niches for their products, most domestic firms have entered the export market at the lower end as producers of low-cost final products or as subcontractors to larger domestic and foreign capital goods manufacturers.

In analysing the respective roles of the firm and the state in the technological development of the capital goods and defence sectors, it is important to assess to what extent the export behaviour of Brazilian firms can be attributed directly to government trade policies, namely the provision of export incentives, and/or to the technological strategies of defence and capital goods firms. The econometric model based on the author's survey data, presented in the Brazilian case study chapter, indicated the

Table 5.3 : Destination of Brazilian Capital Goods Exports

Product Frequency by Region							
PRODUCT	USA/ CANADA	EUROPE	JAPAN	CENTRAL/ LAT AM	MID-EAST/ PERSIAN GULF	AUSTR./ NEW ZEALAND	TOTAL
Basic Industrial Goods	1	0	0	1	0	0	2
Chemical Products	1	0	0	2	1	0	4
Petroleum Refining Products	1	1	1	2	1	0	6
Paints, Varnishes & Lacquers	1	0	0	3	3	0	7
Rubber Products	2	1	0	2	1	0	6
Iron & Steel Products	5	4	3	4	1	4	21
Non-ferrous Metal Basic Industrial Products	3	3	0	2	0	1	9
Structural Metal Products	1	0	0	1	1	0	3
Fabricated Metal Products	5	5	2	9	2	2	25
Metal/Wood Machinery	1	1	0	1	1	1	5
Special Industrial Machinery & Equipment	1	0	0	2	3	0	6
Office, Computing & Accounting Machinery	1	1	0	2	1	0	5
Machinery and Equipment	7	6	0	8	7	2	30
Electrical Industrial Machinery	2	1	0	3	2	0	8
Radio & Television & Commmunication Equipment	2	0	0	4	1	1	8
Electrical Apparatus & Supplies	2	2	0	3	0	0	7
Ship Building & Repair	1	0	0	4	3	1	9
Railroad	0	0	0	2	1	0	3
Motor Vehicles	6	2	0	8	5	1	22
Aircraft	4	3	0	8	2	1	18
Scientific Equipment	0	0	0	1	0	0	1
Photographic & Optical Goods	2	2	0	2	0	0	6
Electric Lights & Power Generation	0	0	0	1	0	0	1
Construction	0	0	0	1	0	0	1
TOTAL	49	32	6	76	36	14	213

negligible effect of government export promotion policies on defence producing firms. However, international trade economists have tried to demonstrate the linkage of these policies to Brazil's broader manufactured export performance.

Since the early 1980s the Brazilian government has tried to increase the export orientation of the industrial sector primarily because of the balance-of-payments considerations deriving from the effects of the OPEC oil schocks in the 1970s-1980s, and the country's estimated $120 billion external debt. A system of fiscal and financial export incentives has been used to compensate for variations in the real exchange rate and to target specific subsectors, for example, the multinational automotive industry. As Tadini notes:

> Government support becomes indispensable, through a consistent and stable policy, that aims to provide the sector with the necessary instruments for the promotion of its products in international trade. This policy would like to have as its objective reducing the difficulties and minimising the high costs of finding new markets that confront firms when they act in isolation.[6]

Tyler's work reveals that the most direct and widely used are fiscal incentives to export. Using his stratification such major incentives include:

1) Exemptions or reductions in the federal and state industrial product and value added taxes (IPI) and (ICM) respectively;

2) Export tax credit *(Credito Premio)*;

3) Income tax exemptions for profits earned from exports;

4) Drawback provisions allowing duty-free import of materials used to produce finished export products -- e.g. Befiex system.[7]

The Central Bank of Brasil, through CACEX, also provides two programmes for financing manufactured exports. The Fund for Export Financing (FINEX) offers pre-and post-shipment export financing. Through Resolution 674 of the Central Bank, CACEX also gives certificates entitling export manufacturing firms to receive financing for their working capital requirements as a percentage of the value of their exports.[8]

Two important studies, however, one by the World Bank, which focuses on the competitiveness of Brazil's capital goods industries, and the other by Tyler, who assesses Brazil's export performance in general, suggest that these incentives by themselves have not been sufficiently strong to explain the growth of capital goods exports.[9] Referring to the 1970s, the World Bank argues that while export incentives were important to export sales, their magnitude only offset the effects of the overvalued cruzeiro, which would favour domestic sales over exports. Tyler expands this point further by suggesting a slight anti-export bias, which is evidenced "through a comparison of the protection afforded to the domestic market and the subsidisation provided for export production."[10] Both studies conclude that the development of Brazilian capital goods exports was made possible by increased productivity and competitiveness. Teubal, in his study of leading capital goods producing firms concurs that the Brazilian government's export policies do not provide an adequate explanation of the industry's international competitiveness. Rather, he suggests that an important technological learning or "capacitation effect", together with enhanced firm reputation, underlies the increased productivity and exports from the Brazilian capital goods sector.[11]

The author's survey data does suggest that the competitiveness of individual firms and buoyant demands of the world market, rather than export incentives, increased export activity. Out of a sample of 94 defence and capital goods producers, 54 firms were significant exporters over the 1977-1989 period, and out of that latter total, only four companies indicated that their exports had declined. Table 5.4, *Reasons for Increased Capital Goods Exports*, reveals the sectoral location of Brazilian firms' exports and the firms' reasons as to what accounts for their success in international markets. Over 50 per cent of these exporting firms emphasised the expansion in world demand for their products, 35 per cent suggested their product reputation, while less than one per cent attributed their foreign sales to government export incentives.

What then can be concluded from this section on the effect of the Brazilian government's trade policies on the competitiveness of the country's firms? Obscured behind the debate on the causal linkage between the provision of export promotion policies and increases in manufactured export activity is a more fundamental point. The Brazilian government's export orientation has been a powerful force for broader industrial and technological development. Clearly the incentives and signals the government provides are an environmental stimulus for Brazilian firms. During an interview with the author, a high-level government official in the Brazilian Ministry of Planning acknowledged this point. "The examples of the arms industries and aeronautics speak eloquently for themselves in this sense. The competition from foreign trade demands permanent technological updating."[12] However, export orientation by itself is not enough to promote or sustain technological deepening or rapid export growth. Indeed the same government official cited the definition of realistic and viable objectives by Brazil's high technology firms as another important firm-level factor:

> The decision to manufacture aircraft according to international market demands, and to invest in technology development for this market segment

Table 5.4: ***Reasons for Increased Capital Goods Exports***

Sector	*Increase in World Demand*	*Government Export Incentives*	*Product Reputation*
Photographic & Optical	1		1
Aircraft	2	1	1
Motor Vehicles	2/M*		2/2M
Shipping	1	1	1
Electrical Apparatus	M		M
Missiles & Communication	1		M
Electric Ind. Machinery			M
Machinery & Equipment	1/2M		2
Office & Computing Equip.	1		
Special Ind. Machinery	M		1
Metal/Wood Machinery	1		1/M
Fabricated Metal Products	3/M		1
Non-Ferrous Metal Products	M		
Iron & Steel Basic Products	2		1
Paints & Varnishes	1	M	1
Petroleum Refining	2M		
Chemical Products	1		
Synthetic Fibres & Resins	1		
Fertilizers	1		M
Total	19/9M	2/M	12/7M

* Note: M indicates a multinational firm.

> was one of the reasons for the accomplishments of Embraer. The same is valid in the case of Engesa.[13]

In sum, it appears that the Brazilian government in part promoted exports because they are considered to be an important means of acquiring access to additional world technologies, not only because of the benefits of participating in international markets, but also because such participation requires Brazilian firms to broaden and deepen their technological capabilities. As we shall see in the following section, India's trade policies have been far more restrictive towards imports of technology. Furthermore, India has not made very effective use of exports to broaden its technology base.

India

> "I believe, as a practical proposition, that it is better to have a second-rate thing made in our country than to have to rely on the first-rate thing that we have to import...." (Nehru)[14]

A crucial element of the Indian government's industrialisation strategy has been the pursuit of import-substitution policies. The original basis for this strategy rested on the perceived need to protect India's infant manufacturing industries and on pessimism about the prospects for export. India's import-substitution policies during the 1970s have been extensively analysed by Bhagwati and Desai (1970) and, later, Bhagwati & Srinivisan (1975).[15] According to these authors some of the major characteristics of the import control system included:

a) Protection was granted to industries often in complete disregard for the relative costs or quality of domestic versus foreign production. "[T]he general incentives to reduce costs and to maintain quality cannot but have been reduced by the sheltered markets provided by policies of automatic protection and strict control over domestic entry;"[16]

b) In order to obtain imported goods, the twin principles of "essentiality" and "indigenous non-availability" had to be met. In addition, the system of actual user (import) licensing on a "fair share basis" meant that efficient capital goods firms could not expand by competing away scarce imports from less efficient ones;[17]

c) The phased manufacturing program prevented imports of all parts and components that were targeted for indigenisation;

d) There are strict controls on direct foreign investment through the Foreign Exchange Regulation Act (FERA) of 1974. Under FERA rules, foreign shareholding cannot exceed 40 per cent of total equity. Shares of up to 74 per cent are permitted if investment is located in high technology industry that has been targeted by the Indian government for development. As a result of these relatively unattractive conditions, few foreign firms have been interested in investing in the country. The effects of India's control on direct foreign investment (DFI) versus Brazil's more open policy are illustrated by comparing stocks of DFI and as a percentage of GDP. In 1984 the stock of DFI in India was approximately $1.5 billion compared to Brazil's $24.6 billion. Direct foreign investment as a percentage of GDP was only 0.6% in India in contrast to Brazil's 13.1%.[18]

The effects of import-substitution policies in discriminating against exports has been extensively analysed in the literature.[19] As mentioned earlier, the emphasis on import substitution in the 1960s partly stemmed from the belief in self-reliance by Indian economic planners in the face of a perceived external demand constraint. However, as Table 5.5, *India's Share in World Exports*, indicates, India's exports since the 1960s have grown more slowly than world trade, leading to a decline in its share of world exports. As an Indian oversight committee on trade policy observed:

> It is particularly disturbing that India's share in world trade declined at a time when developing countries as a group were actually able to increase their share. This ... suggests that we did not make full use of available trade opportunities in the past.[20]

Table 5.6, *Export Performance of Selected Countries*, compares India's manufactured export performance since 1970 with other Latin American and East Asian NICs, as well as with China. As illustrated, the dramatic effect of shifts towards export-oriented policies by these latter countries is shown in the dollar value growth rates of their exports. Although Indian manufactured exports grew at a relatively constant rate between 1974-78, mainly as a result of the improvement in the real exchange rate for exports (brought about by the devaluation of the rupee), by 1980 growth slowed down markedly.

This deceleration spurred various official governmental reviews of India's trade policy and created renewed interest in introducing export incentives. The findings of the 1980 Tandon Committee on Export Strategy were particularly influential in shaping the government's export reform policy:

> A trade regime in which there is significant reliance upon tariffs and licensing affords substantial effective protection to domestic producers in import-competing lines while exports receive no comparable protection. In fact since this type of protection raises the general cost-structure of industry, exports actually suffer from negative effective protection.[21]

Table 5.5

SHARE OF INDIA'S EXPORT IN GLOBAL EXPORTS OF MANUFACTURED GOODS
(U.S. $ million)

Year (1)	Indian Export (2)	World Export (3)	Indian Export as Per Cent of World Export (4)
1970	2,026	315,100	0.64
1975	4,355	875,500	0.50
1980	8,378	2,002,000	0.42
1981	8,373	1,976,733	0.42
1982	8,807	1,845,641	0.48
1983	8,713	1,811,600	0.48
1984	9,874	1,904,600	0.52
1985	8,750	1,923,400	0.45
1986	9,178	2,113,600	0.43

Source: DGCI and UN Trade Statistics. Cited in V. Kelkar & R. Kumar, "Industrial Growth in the Eighties: Emerging Policy Issues," *Economic and Political Weekly*, 27 January 1990, p. 215

Table 5.6

Export Performance of Selected Countries Since 1970
(in U.S. $ billion at current exchange rates)

	1970	1975	1980	1984[a]
Argentina	1.77	2.96	8.02	8.11
Brazil	2.74	8.67	20.13	27.00
China	2.31	7.69	18.27	24.98
Hong Kong	2.51	6.02	19.72	28.32
India	2.03	4.36	8.38	9.46
Malaysia	1.69	3.83	12.95	16.49
Mexico	1.31	2.99	15.30	24.33
South Korea	0.84	15.06	17.51	p29.25

[a] The figures for 1984 are obtained from IMF *International Financial Statistics*, 1986.

Source: UNCTAD *Handbook of Interational Trade and Development Statistics*, 1985. (New York: United Nations). Cited in D. Nayyar, "India's Export Performance, 1970-85." In *The Indian Economy*, R. Lucas & G. Papanek (eds), 1988, p. 245.

Thus, in an effort to offset the higher production costs and other disadvantages of exporting from a highly protected and controlled economy, the Indian government has used numerous, complex incentives to assist exporters of manufactured capital goods. According to Nayyar, India's export promotion policies perform two basic roles: "First ... to provide compensation for disincentives implicit in domestic economic policies and, second, ... to provide an incentive for product and market development."[22] Principal government measures include: 1) the duty-drawback system, which reimburses exporters for the higher prices of foreign and domestic inputs; 2) free trade zones and bonded manufacturing; 3) incentives for and assistance with export marketing; 4) cash compensatory support (reimbursement for indirect and local taxes); 5) profit tax and export credit subsidies; and 6) subsidies on domestic raw materials. However, judging from the poor export performance between 1978-90, these measures have been largely ineffective.

A number of studies have analysed the impact of India's import-substitution trade policy, with its particular emphasis on self-sufficiency, on Indian firms' export capabilities. Several (including the same author) have reached conflicting conclusions. Lall, in a 1982 study, argued that India's import-substitution policies were responsible for the development of the country's broad and deep technological industrial base. Linking that base to exports by Indian firms led him to conclude that India was ahead in terms of both the diversity and complexity of technology exports, followed at some distance by Argentina, with Korea, Mexico and Brazil occupying the middle ground.[23]

A consensus has emerged, however, which reaches the opposite conclusion of Lall's assessment. In a study for the World Bank, Dahlman and Sercovitch compare the local development and exports of technology in Argentina, Brazil, India, Korea, and Mexico. They find that the composition of India's technological exports largely consists of technical services rather than products, and that the destination of most of these exports are to other developing countries as they are based on appropriate technological needs and experience.[24]

Other researchers support Dahlman and Sercovitch's findings, arguing that India's extended period of import-substitution and technological protection for its infant industries has saddled the economy with large areas of outdated technologies, an inefficient industrial structure, and products which can only find limited markets in lesser developed countries.[25] Even Lall is forced to acknowledge in a later study that India's:

> best firms find markets for their accumulated technology in some Third World countries, but these are small (and shrinking) markets: technology exports and technological development can co-exist with growing technological backwardness .... The export...to lesser industrialised countries should not conceal the fact that many ... are too obsolete to be beneficial to the exporting country itself.[26]

The combined effects of the Indian government's anti-export, self-reliance biases have blunted incentives for firms to invest and develop technological capabilities, and thereby have retarded the growth and exports of the country's defence and manufacturing firms, largely because of their lack of exposure to foreign technologies and markets, as well as competitors. The specific consequences are elaborated by Lall:

> While stimulating efforts to indigenise production ... *such a regime encourages firms to remain at a plateau of technological capability.* Since the market they serve is protected ... against imports of more advanced

> products (and against entry by foreign investors), it is easier and profitable to rest at the technological level they reach initially. Internal competition could, in principle, provide a spur to innovation.[27]

An outstanding example of how such barriers to trade and technology lead to both under-investment in technological development and much wasteful, duplicative manufacture of products that could be obtained more cheaply abroad, is the Indian automotive industry. This industry still produces a 1950s' vintage car at what amounts to twice the cost of a modern Japanese import. Only with the introduction of competitive pressures introduced by a recent joint venture between the Indian government and a Japanese car maker have the two traditional local firms sought to improve their cars by seeking foreign licenses and technical agreements. Even so newer cars are still more expensive compared to imports and of poorer quality because the technology of India's machine tools and other automotive inputs is way behind other countries such as South Korea, Brazil and Taiwan. According to Gumaste, one conspicuous input which is missing in the Indian automotive industry is the lack of exposure to international levels of technology. "Over protection from international competition and technology is the principal factor behind the technological obsolescence of Indian industry."[28]

The largely negative impact of the Indian government's trade policies on Indian defence and capital goods firms is an important factor in understanding why Brazilian firms have outperformed their Indian counterparts (as measured by the technological sophistication of Indian defence and manufactured products and exports). This comparative assessment is developed further in the following discussion of Brazil's and India's technology policies.

Technology Policies

Both Brazil and India have promoted broadly based scientific technology policies to stimulate the development of their defence and capital goods industries. However, different strategies were adopted by the governments, leading to contrasting results. India's massive science and technology "push" strategy has met with little success, partly because of the organisation of its "infratechnology" system itself (ivory tower research divorced from production, insufficient attention to the needs of industry, over-regulation of technology imports), and partly due to the stifling emphasis on self-reliance.

By contrast, the Brazilian government has relied on a more indirect technology strategy. It has tried to create a conducive environment that stimulates the technology acquisition and upgrading efforts of firms by providing specialised technical services, research and development support, and by encouraging direct links between the users (defence firms) and producers of capital goods. The country has also relied on foreign investment as a source of both technology and capital. In contrast to India and other NICs, Brazil's policy towards direct foreign investment has been extremely open. Indeed, in comparison with India and Korea, Brazil also has sustained the largest absolute inflows of foreign technology (patents, licenses and technical assistance) and capital goods.

Let us now turn to a more detailed, comparative assessment of how Brazil's and India's technology policies have shaped the environment of their respective capital goods and defence firms. As will be discussed, the nature of the relationship between a government's technology policy and its industries crucially affects the production, dissemination and utilisation of domestic technologies as well as the adaptation and modification of foreign technologies.

Brazil

> A policy of science and technology that distinguishes between *autonomy* (the capacity to decide with independence), and *self-sufficiency* (capacity to produce in the form of autarky). Our goal must be autonomy.... It is super ingenuous that Brazil has the power to advance on all technology fronts simultaneously ... The rigorous selection of technologies for priority areas is an equally essential strategy for countries that, like Brazil, are deficient in technology development.[29]

(A high-ranking minister responsible for Brazilian science and technology affairs)

In Brazil, technology absorption and development policies have been promoted by various state agencies largely out of an awareness of the strategic importance of technology for political and economic autonomy, rather than as an appendage to an export-led industrialisation policy. The coupling of an explicit technology policy, with implicit technological consequences of industrial and trade policies, has led to the expansion of exports of Brazilian manufactured goods incorporating relatively high technologies.

Using an implicit market failure approach to explain the role of the Brazilian government in facilitating technology development, various analysts have described institutional-based technology policies. Analysts, such as Dahlman and Adler concur that the facilitating role of the Brazilian government centres around three broad policies: 1) The development of a science and technology infrastructure; 2) The encouragement of indigenous technological capabilities at the firm level; and 3) The stimulation of demand for local technology.[30] A brief review of these policies will reinforce the survey-based econometric finding that diversification among capital goods producers into defence production was aided indirectly by government-sponsored research and development activities.

1. Development of a Science and Technology Infrastructure

The most important supply-side government policy has been the creation of Brazil's physical and human R & D infrastructure. Since the 1920s various governments have established such research institutions as the Technology Research Institute (IPT) in São Paulo, and the National Institute of Technology (INT) in Rio de Janeiro, as well as the National Research Council (CNP_q). The importance of the CNP_q is evidenced by its multiplicity of roles: the formulation and execution of science and technology policies; inter-ministry coordination of S & T issues; and the promotion of research and training at the university level.[31]

The principal instrument for the implementation of science and technology policy has been the National Fund for Scientific and Technological Development (FNDCT) and, under its control, the National System of Scientific and Technological Development (SNDCT). Since the creation of the SNDCT, four Basic Plans have been issued, covering the periods 1973-76, 1975-79 1980-85, and 1985-90. The first plan promoted an increase in the volume of resources for science and technology by strengthening the FNDCT and other financial mechanisms. The 1975-79 plan aimed at broadening the supply of science and technology and reinforcing the technological capabilities of national firms. The third and fourth plans reflect a reorientation in Brazil's science and technology policy, reducing the previous emphasis on highly specific activities and programmes to the idea of "emerging potential" technologies. (e.g., biotechnology, artificial intelligence etc.).[32]

The relationship of the first two plans for science and technology demonstrate two essential underlying factors: 1) A pattern of informal cooperation among various state institutions: financial agencies of the Secretariat of Planning, BNDES & FINEP, the military ministries, private Brazilian firms, and academic research institutions; and 2) An inherent technology strategy of relying initially on licensing while investing simultaneously substantial resources in research and development, local design activities, and improvement of manufacturing technology for Brazilian state and private enterprises.

Two programmes, initiated by the Ministry of Aeronautics and the Ministry of the Army demonstrate the state's interest in linking the capital goods sector to defence production. In PBDCT 73/74 the Ministry of the Army established a priority for the research and development of armoured vehicles.

> Based on the experience acquired by some industries [Engesa and Bernardini] in Brazil, in the production of heavy tanks and tractors, for military and civilian purposes, the Army is going to promote, in cooperation with the automotive industry, the development of armoured vehicles...as well as turrets, armaments and armour materials. The joint effort carried on by the Army and the Brazilian industry will make it possible to obtain armoured equipment, suitable for military purposes without need for resorting to the acquiring of technology from abroad.[33]

This cooperation with the automotive industry led to various collaborative efforts during the mid-to-late 1970s between the army and domestic private firms. Biselli, a São Paulo-based company, diversified its production line of chassis for heavy duty trucks for army vehicles and tank transporters. Gurgel, a manufacturer of all-terrain vehicles, began to produce jeeps for the Army. The Institute for Military Engineering's design for a versatile vehicle capable of being landed by a parachute resulted in the prototype development by a Rio-based company, Jamy.[34]

The Air Ministry's programme contained in the PNDCT concentrates on research and development of aircraft and aeronautical equipment. The Ministry states that it intends to make the country technologically self-sufficient in relation to the materials considered basic to the aerospace industry by providing "R & D assistance, standardising aircraft and mechanical, electronic equipment....The research ...is concentrated on aircraft and gliders, aircraft propulsion systems and engine systems, engineering, electronic equipment and non/metallic materials used in the aeronautical industry."[35]

The research institutes attached to the Brazilian armed forces are another vital link between science and technology policies at the federal level and domestic private industry. On the "push" side these centres direct industrial research and development in relation to the broad science and technology planning objectives, or in terms of their own specific requirements. On the "pull" side, however, the military research centres are receptive to the needs of Brazilian defence-related companies (e.g., quality control and materials testing).

The CTA has received broad financial cooperation from FUNTEC, FINEP and the CNP_q, and of all the military R & D centres has the closest links to its respective industry, Embraer.[36] As mentioned in the previous case study, Embraer's creation and success owes much to the initial Bandeirante project developed at the CTA, and to the availability of highly trained personnel from the ITA. Both the CTA and IFI have been instrumental in the technological upgrading of the aircraft industry and its suppliers from the local capital goods sector, through their technology assessment of quality control, testing and inspection activities. As Colonel Sergio Valle, former director of the Department of Aeronautical Engineering at the CTA observed, "the purpose of the CTA as regards the country as a whole is to use this infrastructure of personnel...means and techniques in other sectors, such as the capital goods industry and engineering services."[37] This view is also widely shared by the Army, and to a lesser extent the Navy's military research institutes.

The Army has had the oldest science and technology policy. Its research and development institutes comprise the Army Technological Centre (CTE$_x$), the *Instituto de Engenharia Militar* (IME), and the IPT, among various others. Its research institutes have had a looser relationship with the domestic armoured vehicle industries. The *Veículo Blindado Brasileiro* (VBB) prototype was created at the IPT and the engineers who worked on the project were later hired by Engesa -- the product of their efforts was the armoured car, the Urutu. However, as indicated in the II PND, and by the case study of Engesa's development of the Osorio MBT, industry has often wagged the tail of the Army. Instead, these institutes have concentrated on broad technology related to communications, electronics, metallurgy, and electrical & mechanical engineering, and have coordinated with the Institute for Aeronautical Research (IPA) and the Army Research and Development Institute (IPD) in missile-related, aerospace research.[38]

The Navy has been slow to develop extensive links with Brazil's large shipbuilding industry. As the naval case study illustrates, while industry has participated in the recent corvette project, with the assistance of the Institute for Military Research and the Navy's CP_qM, the nuclear submarine programme has been kept largely within the Naval institutes Copesp/Aramar and its shipyard, AMRJ.

2. <u>Firm-Level R & D</u>

To support indigenous technology capabilities at the firm level, the Brazilian state has provided subsidised financing through the BNDES' agencies, Scientific and Technical Development Fund (FUNTEC) and FINEP. Since its creation in 1964, FUNTEC has concentrated on funding education and applied technological research, as well as on strengthening local, autonomous industrial technological development, mainly through the Subprogramme on the Demand and Utilisation of Technology. In particular, FUNTEC has minimised risks for those Brazilian defence and capital goods firms interested in technological innovation, and has then tried to support the diffusion of technological development acquired or undertaken in industry. Two important defence-related companies, Embraer and Engesa have been recipients of FUNTEC financing: Engesa for the development of a forestry tractor and Embraer for the design and construction of electronic components for aircraft.[39]

Working in tandem with FUNTEC is FINEP, whose own financing activities have been directed towards priority areas in the capital goods sector. FINEP's programmes include: subsidised financing for consulting, feasibility, product development, and management studies. It has also used risk-sharing instruments and, to a lesser extent, equity participation to foster national firms' technological activities. According to Adler, FINEP's financing activities have been targeted to the needs of small to mid-sized capital goods firms rather than large companies. "...[I]t financed 83 percent of total support cost for technological development of national enterprises in 1973 and 86 percent in 1978."[40] In the period 1973-89, FINEP subcontracted 1,761 technological support operations valued at U.S. $810 million.[41]

The programme that supports local private technological development activities is ADTEN. The main activities financed through this programme are: R & D for new products and processes in agriculture, industry and health; research related to adapting imported technologies; purchase and absorption of imported technological packages; and the establishment of quality control and R & D centres.[42] Together these programmes' funding of R & D project support, especially in the early stages of the development of Brazil's high technology industries, helped to support the infrastructure necessary for successful innovative capabilities at the firm level.

As revealed in the three-stage model, the Brazilian government's policy of protecting the local capital goods sector through the "Law of Similars" was an important variable in explaining the movement by capital goods firms into defence production. In conjunction, the government, again through the BNDES, has promoted the demand for local technology in the form of incentives to purchase domestically produced machinery and equipment. An important instrument is FINAME (Agencia Especial de Financiamento Industrial). This agency provides competitive, flexible financing for the production and commercialisation of domestically manufactured heavy equipment and for the development of advanced industrial technologies.

A separate study links technology exports from Brazilian capital goods firms to these firms' reliance on government financing for research and development as well as these firms' use of technology institutes and centres. The author of this study found that "of over 80 locally-owned technology exporting companies, 44 (or 55%) benefitted from financial support from the government to carry out R & D projects (in many cases in association with domestic scientific and technical institutions)."[43] Thus, the Brazilian state has acted to guarantee and widen the domestic market for local capital goods firms, especially for the more complex products, by reducing the risks associated with technological development, adoption and diffusion.

The Brazilian government has recognised the risk aversion of local firms to purchase domestically supplied products and technologies because the net benefits to be gained from adopting new technologies or goods embodying those technologies are uncertain. In some cases local sources of technology may be more expensive than foreign ones, in other cases firms may be willing to pay more for foreign technology or products rather than risk using an untried local source. By subsidising purchases of domestically developed technologies, the Brazilian government has enabled local technology suppliers to gain experience, thereby allowing them to lower costs and generate necessary economies of scale.

India

> In a country of India's size and endowments, self-reliance is inescapable and must be at the very heart of technological development. (Government of India)[44]

> Without enhancing its scientific and technological capacity, India could not be economically and politically independent. (Nehru)[45]

Unquestionably, the Indian government's technology policies have had a significant influence -- both at the firm and sectoral levels -- on the pace, development and structure of growth of the country's defence and capital goods industries. In contrast to the Brazilian government's primarily indirect role in promoting the technological development of these two interrelated industries, the Indian government's intervention in these sectors has been extraordinarily invasive. As was explored in the preceding chapter, the Brazilian government has used various incentives both to spur firms to upgrade their technological capabilities through learning-by-doing, and to ensure technological diffusion throughout the defence and capital goods sectors through learning-from-others. By ensuring such diffusion, the state deliberately stimulates technological development through competition between and cooperation among Brazilian firms.

The Indian government, however, has adopted a narrowly conceived technology push approach that uses highly regulatory mechanisms to direct the technological capabilities of the defence and manufacturing sectors. There are three major objectives of the Indian government's technology policies:

> (1) the creation of a massive scientific infrastructure through the expansion of the educational system and the strengthening of government research institutions;
>
> (2) the promotion of "self-reliant" indigenous technological capability in the strategic defence-industrial sectors;
>
> (3) the control over Indian firms' access to foreign technologies, through restrictions on direct foreign investments (FERA) and transfers of technology.

A discussion of the largely negative impact of all three objectives on the technological capabilities of Indian defence and capital goods firms is now developed.

1. Scientific Infrastructure

The establishment of an extensive scientific infrastructure, consisting of specialised research and development laboratories as well as consultancy, engineering and design organisations has been central to the Indian government's "technology push" approach. The Indian government also has expanded the stock of human capital through heavy investments in science-related higher education. The purpose of the laboratories and institutes is to generate applied technologies in the areas of defence, manufacturing and agriculture, which can be transferred to and utilised by industry. Defence-related research in the aerospace, nuclear energy and space areas is organised by the Defence Research Development Organisation and constitutes the largest proportion of government R&D (See Table 5.7, *Distribution of Indian Government Spending on Sciences and Technology*). Industrial research, however, is coordinated by the Council of Scientific and Industrial Research (CSIR) and its commercialisation arm, the National Research Development Corporation (NRDC), and by the Department of Science and Technology (DST).

Established in 1942, the CSIR's primary function is to assist both public and private sector industry in technology development, updating, indigenisation, energy conservation etc. The CSIR also conducts R&D in its 33 laboratories in areas of national, "strategic" priority -- aeronautics, microelectronics, biotechnology, information technology -- which the Indian government considers vital to national security and to the economic growth of the country.[46] To promote the utilisation of the CSIR's research by

Table 5.7

Distribution of Indian Government Spending on Sciences and Technology

	IN %
CSIR	16.2
DST	11.8
Industrial Research	15.0
• Heavy Industry	4.5
• Mining and Metal Woking	4.4
• Other	6.1
Food Industry	15.0
Atomic Energy	15.1
Aeronautics and Space	11.0
Social Programmes (family planning, health, education, ...)	7.8
Transportation and Communications	8.1
TOTAL	**100.0**
TOTAL IN 10^9 Rs	**15.68**

industry and to act as a link between the research organizations and industry, the NRDC was established in 1953.[47]

The DST was established in 1970 with the principal responsibilities of promoting new areas of science and technology, undertaking or financing research, design and development in the universities and private sector, and supporting and coordinating national research institutions and scientific bodies. Since 1974, the DST, along with the Directorate General of Technical Development, has been charged with promoting indigenous technology in the private sector. Specifically related to the promotion of the technological development of India's capital goods sector, the latter organization's Monitoring Division has been involved in assisting productivity improvements, modernisation of plants and facilitating standardisation within the sector. A breakdown of the research and development activities within this massive scientific infrastructure reveals heavy sectoral concentration. Aggregated and broken down by Government Ministries, the Ministry of Defence dominates, accounting for 27 per cent of total government (central and state) R&D expenditures, followed by Heavy Industries (25 per cent), Petroleum (19%), Communications (14%), and Chemicals and Fertilizers (8%).[48]

Despite the Indian government's sustained efforts to develop technology capability through promoting the utilisation of government research, on the whole these attempts have failed. As Nayar concludes, "The pattern ... was one of the laboratories under government auspices carrying out research...isolated from the production system....For this reason there was abundant criticism about the lack of linkage between scientific research and the productive system [industry]."[49] According to one estimation, the contribution of government research to industrial output during the 1970s-early 1980s was less than one per cent.[50]

Subsequent studies on the extent of utilisation of government research by industry in the mid-1980s confirm the lack of effective linkages between the R&D institutes and industry. Using NRDC data, Alam and Langrish found that "out of a total of 2,015 processes referred [to the NRDC by the labs] up to 1978, only 44 per cent were licensed to industry of which only 18 per cent were reported to have gone into production."[51] Their sample indicates that 85 percent of the licensed processes were not put into production. Various analyses have reasoned that the alienation between government R&D and private sector industry continues because of institutional failures (e.g., poor bureaucratic communication and coordination) and because of the undue influence of "self-reliant" objectives of the kind of R&D undertaken by the government laboratories. As one eminent science planner observed:

> That we have not made much progress in growth of technological self-reliance in spite of the significant amounts of money being spent on science and technology is a measure of the alienation that exists between R&D and industry, and a reflection on the implementation of an avowed policy.[52]

In relation to the first set of analyses, researchers have been divided over the extent and kinds of institutional linkages. Attributing the underutilisation of government-sponsored R&D to the need to strengthen links between industry (including defence) and the government laboratories, Valluri suggests: "There does not seem to be a reliable mechanism in the concerned government departments to monitor the progress towards technological self-reliance."[53] In particular, the poor communication and coordination between the Ministry of Defence, the research organisations and defence production firms have been singled out. A Secretary of Defence Production and Supplies admitted this institutional failure in testimony to a review conducted by the Indian Parliament's Committee on Public Undertakings:

> We in this Ministry have not evolved any special mechanism for monitoring R and D projects of defence public sector undertakings. I concede that this is an area where we need an improvement over what we have been doing in the past.[54]

Nevertheless, other analysts of India's technology policies argue that what is needed is not further institutionalisation, but decentralisation. Citing the NRDC as an illustration, Chakrabati has argued that it has imposed only another "new organisational and procedural barrier between research institutes and potential users."[55]

Analysts have also criticised the Indian government's bias towards basic and adaptive R&D due to its obsession on self-reliant technology. "Funding for research institutions has been expected to form a sheet-anchor for the growth of an indigenous technology base, as distinct from an industrial manufacturing base," observed one former defence research official.[56] Desai, too, has long argued that:

> India has an important asset in the form of national laboratories which should be used, not for import substitution in technology as at present, nor for facilitating the indigenisation of imported technologies as captive R&D used by firms but to support the large-scale, long-range cooperative R&D by industries.[57]

This sentiment is also shared by critics of India's poor defence production record. "The country,"suggests Bajpai:

> should avoid the sentimental error of carrying out R&D in areas where the technology is available for ready purchase, or of duplicating the effort in areas which have been covered elsewhere....In the name of self-reliance

> avoidable but precious effort is at present being devoted in our research establishments to reinventing wheels.[58]

Finally, there are the promising and interesting research findings of Alam and Langrish, who suggest that the failure to transfer government-sponsored technologies to industry derives in part from poor incentive structures within the CSIR/NRDC bureaucracies (e.g., low salaries and royalty payments for these scientists), but primarily from the skewed size distribution of Indian private sector firms.[59] Their study found that while small firms had considerable interest in government research, the technology transferred from the government labs often required further development and these firms lacked the necessary technical and marketing resources to produce and/or market the product successfully. Though large Indian firms were likely to possess such resources, they expressed little interest in government R&D because of their preference for proven imported technologies.

2. Private Sector R&D

In recognition of these collective criticisms, the Indian government, beginning in the mid-1970s, encouraged private industry to undertake its own R&D. The direct incentives included tax concessions, foreign exchange allowances and the relaxation of some licensing requirements. For instance, private sector R&D units recognised by the DST receive a fiscal concession in which 125 per cent tax write-off is available for all capital and revenue expenditures incurred in research and development. Other incentives include liberalising imports of certain capital goods and raw materials for R&D, and special investment allowances for firms utilising R&D transferred through the national laboratories.

Data provided by the DST indicates that private sector R&D activity has expanded in response to these incentives. In 1950 there were only 13 R&D units in the private industrial sector. By the mid-1980s, however, there were an estimated 816 "recognised" R&D facilities.[60] According to data compiled by the DST, private industry outspends the public sector in respect to total industrial R&D expenditure by a small amount (Rs 236.75 crore as against 235.76 crore 1984-85).[61] The main areas of private sector R&D are in the chemicals, electrical equipment, pharmaceutical, and transportation industries.[62] Using DST data, Lall reports that there is a close correlation between firm size and R&D spending amongst private firms. R&D spending "declines consistently with firm size, though at the very tail end this is slightly reversed, presumably because of high R&D spending by some small electronics firms."[63]

None of these broad indicators, however, reflect the nature and quality of research and development activity by Indian capital goods and defence firms. In a separate study of the Indian government's technology policies, Alam concluded that the qualitative effect of government incentives in directly promoting indigenous research and development capabilities by Indian firms has been marginal. "While these incentives may encourage firms to set up R&D departments and to even take up preliminary research activities," Alam states that, "they are rarely responsible for making a firm technologically dynamic."[64] Furthermore, Alam, among others, has pointed out that there is a serious upward bias created by the DST incentive structure. For example, the R & D tax incentives only encourage firms to report expenses incurred in other activity as R&D figures and to inflate generally their R&D expenditures and not the achievements of R&D.[65]

Two separate studies report that the increase in private firm-level R&D has occurred largely as a consequence of the poor reputation of the government laboratories. The government has largely failed in its efforts to turn its laboratories into "engines" of technological advance. Desai writes, "When forced to go to them, Indian firms have preferred to increase their own R & D effort."[66] Furthermore, despite government incentives to support technological development at the firm level, "large sectors of Indian industry have fallen behind advances in technology abroad, and show technological incompetence."[67]

3. Technology Import Policy

In contrast to Brazil, the Indian government's technology import policies are exceedingly restrictive. The motivations underlying these policies are three-fold: to conserve foreign exchange, to promote self-reliance, and to control or direct foreign technologies in strategic defence and industrial sectors. There are six major policy mechanisms the Indian government employs to regulate transfers of foreign technologies.

First, to lower the cost of foreign technologies for Indian firms, the government prescribes royalty payment ceilings for various industries. Currently, the computation of royalty payments is determined by the net selling price, which is calculated by deducting the cost of imported components and components brought out in India. Thus, royalty payments are normally restricted to three to five per cent of sales and subject to a 40 per cent income tax, leaving between 1.5 to 2 per cent for the foreign collaborator -- hardly attractive or competitive by international standards.[68] (Royalty rates of five to ten per cent net of tax are the norm for international technology contracts.)

Second, the government imposes restrictions on the duration of collaboration agreements. In an attempt to induce faster technological adoption by Indian firms, the standard duration of these contracts was lowered from ten to five years. This time period, however, is widely considered inadequate for the successful transfer of complex technologies.

Third, technology transfer agreements, which limit the potential of Indian firms to export, are prohibited. This government policy has negatively affected both the supply of technology and its quality without having significantly increased the possibility of exports.[69] A fourth mechanism is the ban on the use of a supplier's trademark in the domestic market. Fifth, various government laws have weakened the protection of international patents.

Lastly, even when foreign technology collaboration agreements meet all these conditions, they are subject to a lengthy review and approval process: first by the Technology Evaluation Committee -- composed of members of the DGTD, the DST, the CSIR, and NRDC -- and then by the concerned government department. Evidence of the veto power of the latter is provided by Lall. He maintains that the "extremely nationalistic Department of Electronics has been able to so restrict technology inflows as to set Indian electronics firms back by over a decade in a very fast-moving technology."[70]

The broader impact of India's restrictive technology import policies is suggested by various researchers.[71] The conventional view is that while such mechanisms have led a number of India's larger industrial firms to buy technology skillfully, these policies, nevertheless, tend to discourage major research and development activity related to design capability or process innovations. In addition, such import restrictions have led to the gradual technological obsolescence of some sectors of Indian industry because the technology payment restrictions prevent Indian firms from obtaining technology in its full breadth and depth, and from keeping abreast of world technology.

One example is India's public sector steel industry, which employs technology that is at least three decades old.[72] This technological obsolescence is acknowledged as a major deterrent to the potential competitiveness of India's defence and manufactured exports. Ahluwalia succinctly comments:

> The restrictive policy toward import of technology implied inadequate access to the latest technology [and] ...led to a major and widening technological gap in India relative to the rest of the world. This not only prevented upgradation of the quality of domestic production, thereby reducing the competitiveness of Indian exports in the world markets, but also led to inefficient use of raw materials, particularly energy, with its wide-ranging impact on the cost-structure in the economy.[73]

In essence, rather than achieving self-reliance in defence and capital goods production, the government's defensive policy of restricting imports of technology has contributed to the technological dependence and stagnation of Indian firms. Lall argues that India's technological promotion policies have been pushed too far. Pointing to the example of Japan, he notes that:

> after all, Japan continued to import massive amounts of technology while fostering its own R & D and absorptive efforts. It did not attempt "self-

> reliance" in all technologies at all costs - its main concern was to get its manufacturing industries up to competitive world standards and then to use its accumulated knowledge to establish leadership in selected areas. Its interventionist regime was geared to economic efficiency, which India's patently is not.[74]

While the successful experience of Brazilian firms highlights the importance of combining transfers of foreign technologies with in-house R&D and learning-by-doing activities, Indian firms have yet to adopt such a longer-term integrated approach, and thereby develop stable, smooth learning trajectories. Indeed, as a former Chairman of HAL acknowledged, "...we are not making the investments necessary to keep technology current....If today we import technology but do not make the investments that...are needed to develop from this foundation forward...then we are going to be in a sterile situation of repeated imports of technology."[75] Recognition of such costs explains why India has finally begun to liberalise its policies on technology imports, thereby providing industries, such as transport, machine tools, computers, and electronics, access to more advanced foreign technologies.

Impact of Indian Government's Technology Policy on Firms

As this author argues, the intersection of the Indian government's technology import policy and strategic firm behaviour jointly have constrained technological development as well as diffusion. The two most pernicious effects of the Indian government's technology import policy relate to the relatively low price paid for technology through royalty payments and the short duration of collaboration agreements. Bell & Scott-Kemmis conclude that both effects have prevented Indian firms from obtaining foreign technology in its full breadth and depth and from keeping abreast of world technology.[76]

Contrary to the common view that foreign suppliers deliberately limit the technological content of collaboration agreements by minimising the knowledge and expertise they make available, are the findings provided by these two researchers. In their discussion with British technology suppliers to Indian firms, Bell & Scott-Kemmis found that:

> almost 75 per cent stated they would have been willing to broaden the initial provision of information and know how... Furthermore, over 50 per cent of the suppliers would also have been willing to assist their Indian partners develop their own capacities to undertake technological improvement activities....In both these cases, the great majority of suppliers emphasised that they would have provided such technological assistance if the level of payment had been higher to recuperate the costs involved and that this was the only significant condition.[77]

This finding is reinforced by recent studies conducted by Alam, Cooper and the Cabinet Secretariat of the Government of India.[78] These studies underscore the fact that government restrictions on payments of transfers of foreign technologies have severely constrained the technological content as measured by the older age of the technology transferred and by the limited provision of training/technical assistance.

A number of Indian firms agree that government restrictions generally limit their ability to obtain necessary technological assistance. According to a senior manager in an electronics product firm:

> We find that some suppliers are fairly willing to provide more comprehensive know-how but they want extra payment for that. This is a problem because of the government restrictions on what can be paid, so acquiring more training, more assistance and more comprehensive technology is difficult....If firms want to pay more to acquire more they

> either find another channel of payment, try to convince the supplier to accept less, find trade-offs on other issues, or give up.[79]

A report by the Economic Administration's Reforms Commission regarding the effect of government policies (including trade and industrial) on technology development and acquisition also criticised the low royalty payment restriction.

> In the prevailing environment of controls and clearances...[Indian firms] try and operate within these norms and guidelines so as to obtain speedy clearances and get ahead with their projects, making such compromises in regard to quality or other considerations as necessary. Besides...the regulation of capacity...through industrial licensing and the restrictive attitude to imports protect the Indian entrepreneurs from the rigours of competition, and quality is not a condition of survival. This results in an acquiescence in and a perpetuation of low level and out-moded technologies.[80]

Evidence of the technological content/royalty payment trade-off is provided by an UNCTAD study of 20 of India's leading capital goods firms.[81] An examination of the age pattern of imported designs transferred to the sample firms under foreign licensing is indicated in Table 5.8, *Age of Designs Imported Under Collaboration.* In 53 per cent of the collaboration agreements, designs were introduced into the Indian market more than nine years after their introduction into the world market. Very few designs reflected more recent technology (e.g., only 12 per cent involved the supply of designs between one and five years).

A number of scholars have suggested that the government's policy of limiting the duration of collaboration agreements has had an additional deleterious impact on the technological capabilities of Indian firms. One negative effect is that it limits the benefits of foreign collaboration to Indian firms. The five-year duration may be too short for many firms to absorb and "unpackage" the technology, as well as to begin production.

Table 5.8

Age of Designs Imported Under Collaboration by the Sample Firms

Age in years	Machine tools I				Equipment for process industry II				Electrical equipment III				Total for complex capital goods (I+II+III)			
	DT	FT	FC	Total	DT	FT	FC	Total	DT	FT	FC	Total	DT	FT	FC	Total
1—5	1	—	1	2	—	—	—	—	2	—	1	3	3 (12.5)	— (—)	2 (20.0)	5 (11.6)
6—8	2	1	2	5	2	1	—	3	4	1	2	7	8 (33.3)	3 (33.3)	4 (40.0)	15 (34.9)
9 above	5	1	1	7	4	4	—	8	4	1	3	8	13 (54.2)	6 (66.7)	4 (40.0)	23 (53.5)
Total No. of agreements	8	2	4	14	6	5	—	11	10	2	6	18	24 (100.0)	9 (100.0)	10 (100.0)	43 (100.0)

DT = Domestic firm with technical collaboration.

FT = Foreign minority joint ventures.

FO = Foreign-controlled joint ventures (including subsidiaries of foreign firms).

Source: UNCTAD. *Technology Issues in the Capital Goods Sector: A Case Study of Leading Machinery Products in India, 1983.*

Given such time constraints, Indian firms are forced to narrow the extent of their technology transfer agreements.

Section II: The Firm

The previous section discussed how the Brazilian and Indian governments' trade and technology policies have shaped, via inducements and restrictions, the environment of their defence and capital goods firms. It is difficult, however, to relate these firms' technology activities, observed in the case studies, entirely to the governments' application of specific, direct promotion policies and instruments. Rather, the comparative case studies point to the relative ineffectiveness of such policies and instruments. The survey-based, econometric model in the Brazilian case study chapter found that government policies had a marginal impact on the technological development and subsequent export success of the major defence/capital goods firms. Indeed, the conclusion drawn from the chapter is that Brazilian firms benefitted from the *absence of (restrictive) government policies*. In the India chapter, one is confronted by a dismal record of manufacturing failures in the defence and commercial sectors, despite the government's promotion of extensive science and technology policies.

What then accounts for the competitiveness of Brazilian firms or the poorer performance of Indian enterprises? As argued in the introduction to this chapter, firm-level technological capabilities and strategies are important determinants of international competitiveness. As acknowledge by an OECD study, "No amount of national provision of physical or human resources or political support will lead to competitiveness and dynamic growth if the firms concerned cannot bring the package together in the form of viable capabilities."[82]

To understand more clearly the factors affecting Brazil's and India's divergent experiences, we need to focus our analysis at the level of the firm, and to examine comparatively Brazilian and Indian firms' respective efforts and strategies to develop technological capabilities. Indeed, various studies from the literature on industrialisation and technology development have argued that the poorer industrial performance of some NICs is due to the absence of sustained efforts by firms to acquire and use the capabilities necessary for continuous technological development. For example, according to Bell:

> the accumulation of technological capabilities is not accomplished through costless, automatic learning-by-doing ... [it] takes *conscious* efforts to develop a technological strategy, to invest in resources for technological changes, and progressively to accumulate technological capability. (Italics added for emphasis.)[83]

It is equally important to understand why a firm chooses a particular technology and what factors affect firms' abilities to choose in the first place. Thus, a necessary corollary to the analysis of the divergent performances of Brazilian and Indian firms must describe the firms' environment, particularly in terms of competitive pressures, and explain how the environment influences the technological behaviour of the firm.

In an attempt to elucidate the complex strategic interaction between a firm's behaviour and the government policies that condition its environment, this section is divided into three parts. The first assesses comparatively the technological efforts and strategies of Brazilian and Indian firms. The second analyses how environmental variables, such as firm size, degree of vertical integration, low product specialisation, and market concentration influence the efforts by Brazilian and Indian firms to develop an indigenous technological capability. In the final part, the author, borrowing from the game theoretic literature, describes the strategic interaction between rival firm behaviour and government policies. This discussion provides the basis for understanding why Indian defence and capital goods firms are technologically both dependent and stagnant in comparison to their Brazilian counterparts.

Firm-Level Strategies Towards Technological Development

As the case studies illustrated, both Brazilian and Indian firms have relied heavily on inputs of foreign technology, primarily via licensing activities. However, one is led to the conclusion that Brazil's firms, such as Embraer, Engesa and Avibras, have been far more effective than, for example, India's Hindustan Aeronautics, in ensuring that foreign technologies contribute to the development of indigenous manufacturing and design capabilities. Clearly the technological efforts made and strategies pursued by Brazilian firms to adapt, assimilate, and improve the technology transferred are important explanatory factors. As is argued in this section, the successful technological development of Brazil's defence and capital goods firms resulted from these firms' own long-term strategic efforts to build systematically on foreign technological inputs -- licensing, coproduction arrangements -- and on their own accumulated research and development experiences. To ascertain the importance of technology strategy on firms' competitiveness, let us now turn to Brazilian and Indian firms' contrasting approaches towards technological development.

An immediate factor that differentiates Brazilian and Indian firms is their respective motivations for utilising license agreements as a means to augment their technological capabilities. A major study of the capital goods industries of various developing countries reported that Indian firms have used licensing agreements "at an early stage or even at the time of the establishment of the firm, as in the case of some leading firms in India."[84] By comparison, "in the case of the Brazilian domestic firms, the practice of concluding licensing arrangements relating to the manufacture of mostly complex capital goods started relatively late in their lives, on average twenty-three years after their foundation...."[85]

Various other studies reinforce this divergent licensing strategy between Brazilian and Indian firms. For example, an UNCTAD study of India's leading manufacturing enterprises found that an Indian firm tends to pursue, "a static strategy of rapid diversification under foreign licensing to maximise short-run profits, rather than a dynamic strategy of increasing its market share...through product innovations based on its own development of design capabilities.[86] The author in her interviews with Indian capital goods firms also found that licensing was used as defensive measure to prevent loss of market share or entry by a potential competitor via rival pre-emption (A firm strategy that is discussed at length in Section III). Teubal's study of a few select Brazilian capital goods firms provides an interesting contrast to Indian firm licensing behaviour. He maintains that Brazilian firms consider foreign licensing and other "know-how" agreements to be a useful, and in some cases, a necessary condition for diversification and shifting into more complex, but technologically related product lines.[87]

That Brazilian firms have clearly focused on assimilating foreign technologies purchased at each stage, building on them and progressively moving assistance to higher and more specific levels is extraordinarily important because such a technology strategy actually conditions the successful use of a license. In other words, the accumulated technological capacity of a firm seeking or implementing a license decisively affects the outcome of its use. It can affect, for example: a) whether and the extent to which technological problems are correctly defined and anticipated; b) the appropriateness of the choice of technology and the supplier; and c) the negotiation of and conditions for the agreement.[88] Whether or not adaptive efforts will follow the acquisition of a license, however, depends on firms' efforts, particularly research and development activities. (Obviously firms' own technological efforts may be influenced in part by government incentive (or disincentive) structures.) We shall now address these themes returning to the Brazilian and Indian case studies.

Brazil

Despite the varying experiences of the firms surveyed by the author, Brazilian capital goods and defence producers shared broad strategies towards the development and integration of both domestic and imported technologies within the firm. The impact of these shared approaches, taken as a whole, may explain the relationship of increasing technological content with the expansion of Brazilian manufactured and defence exports.

As revealed in Table 5.9, *Firm Strategies to Augment Technological Capability*, Brazilian firms have commonly used seven strategies to enhance their technological capabilities. These include:

Table 5.9:

FIRM STRATEGIES TO AUGMENT TECHNOLOGICAL CAPACITY

SECTOR	INTERNAL R&D	IMPORT EQUIP.	FOREIGN ASSIST.	TRAINING ABROAD	GOVT/MILI R&D	LICENSING CO PROD.	MNC TECH TRANSFER
Construction	1	1	1	1	1		
Photographic & Optical	1			1	1	1	
Scientific Instruction	1					1	
Aircraft	6	3	3	5	9	4	
Motor Vehicle	5	5	1	5	2	2	1
Railroad	1	1		1			
Ship Building	4	2	1	3	1	3	
Electrical Apparatus	3	3	1	4	2	1	
Missile & Communication	5	4	2	4	2	1	
Electrical Ind. Machinery	1	1	1			1	1
Machinery & Arms	8	8	4	3	4	3	
Office & Computing	4	3		4	3	2	1
Spec. Ind. Machinery	2	3	1	2	2	2	1
Metal/Wood Machinery	2	2		1	1	1	
Agricultural Machinery	1	2		1	1	1	
Engines & Turbines	1	1	1	1	1	1	
Fabricated Metal Products	12	5	1	5	3	4	
Non-ferrous Metal Products	4	4	3	3	3	1	1
Iron & Steel Products	3	3	2	4	3	1	
Non-metallic Menierals	2	2	1	2	2	2	
Plastic Products	1						
Rubber Products	1	1		1		1	
Tyres	3	2		1	2		
Petroleum Refining	1			1			
Chemical Production	5	4	3	3	1	1	1
Paints & Varnishes	2	1		1		1	
Synthetic Fibres & Resins	1			1		1	
Pesticides/Fertilizer	1	1		1			1
Clothing	1	1		1			1
Carpets & Rugs	1						
Textile Goods		1		1			
Spinning/Weaving	1						1
Total	85	64	26	61	44	35	9

(1) Internal research and development activities;

(2) Use of imported capital goods;

(3) Hiring of foreign personnel;

(4) Use of specialised training and educational programmes for their employees;

(5) Use of government, military or university research institutes;

(6) Licensing and coproduction arrangements;

(7) TNC technology transfers to Brazilian subsidiaries.

Though ten per cent of the firms surveyed relied on technology transfers from their parent transnational corporations, since this strategy does not apply to wholly Brazilian-owned firms, we will leave it aside, and concentrate on the remaining six strategies.

By far the most widely used means of technology development was internal research and development activities: 84 out of the sample's 94 firms were engaged in their own research and development. The sectors, which were most actively engaged in R & D were communications equipment (5), fabricated metal products (12), automotive (5), aircraft (5), and missiles/small arms (7). Of the 65 firms that relied on imports of capital goods, the missiles/small arms (8), and automotive (5) were most prominent. A total of 59 companies considered the hiring of highly skilled Brazilians as well as the sending of personnel abroad for specialised training to be important means of increasing technological development. Of these firms, aircraft (5) and automotive (5) dominated. Fourth on the list was reliance on external research and development institutes with 41 firms, of which the leader was the aircraft industry (9), followed by missiles/small arms (4).

Thirty-four firms used licensing/coproduction arrangements. The sectoral leader again was aircraft (4), then split equally (three each) between shipping, missiles and metal products. Finally, the hiring of foreign personnel was a strategy employed by 26 firms, of which missiles (4), aircraft (3), chemical products (3), and non-ferrous metals (3), accounted for half of the responses. By combining these strategies into three distinct groups a clearer, integrated approach towards technological development at the firm level emerges.

The first is the encouragement of active technology absorption by means of a pragmatic approach that assimilates foreign and domestic technology sources: licensing and coproduction activities in conjunction with in-house research and development. Erber has called this strategy of combining indigenous R & D and reliance on foreign technology through licensing, "walking on two legs".[89] His research on the Brazilian capital goods industry indicates that one of the legs -- licensing activities -- has proven to be extremely beneficial in a number of important ways. First, by relying on a tried product through licensing for part of its product range, the firm diminishes the technical and economic uncertainties inherent in new product development. It can then concentrate on its own products, "reducing the overall risk of failure...." to the firm.[90] This approach reflects the strategy of Embraer in the AMX programme.

Second, if a firm has an independent technological capability, it can apply the designs, skills and fabrication technology (know-how and know-why) transferred via licensing to other manufacturing areas. A final advantage of licensing may be the reduction of delivery times. As Erber notes, "[t]he development of designs is a very time-consuming process ... especially when the product is new for the enterprise and more so in the case of capital goods subject to high performance requirements."[91] The same is particularly true for defence products and such an approach is best represented by Engesa's strategy of partnership with its key foreign and domestic suppliers.

The mail questionnaire survey responses also provide important information in understanding the reasons why Brazil's defence and capital goods producers have used licensing to augment their technological capacities. Table 5.10, *Reasons for Licensing*, outlines the technical and commercial reasons for licensing and coproduction as measured by the frequency of responses by the sample firms. Two dominant complementary explanations emerge for licensing: The first -- in terms of its high response frequency -- is procurement specifications by firms' customers. One may recall that for custom-built capital goods, especially in the defence and transportation sectors, customers will have special requirements, e.g., engines and avionics for aircraft, optronics, engines and guns for tanks. Furthermore, in some markets, licensing may be a *sine qua non* for entry, e.g., imposed by the customer due to high performance and reliability requirements or because of traditional links with some suppliers.

The second reason for licensing is a technical one, namely licensing amongst this sample has been most often used to acquire designs. Licensing for acquiring technical assistance or because of competitive pressures related to the structure of the industry, or threats posed by other suppliers are other explanations. Together these four reasons account for 78 per cent of the basis for licensing activities by Brazilian firms.

Table 5.10

Reasons For Licensing

	Technical					Commercial	
Firm's Product	Design	Technical Assistance	Quality	Fabrication Technology	Customer Specs.	Market Comptn.	Time Factor
Air Transport Services	1				1		
Photographic & Optical	1	1	1	1			
Scientific Instruments		1			1		
Aircraft	3	2	1		2	1	
Motor Vehicles	1	3	1		2	3	
Railroad	1	1			1		
Ship Building	3	1		1	1	1	1
Electrical Apparatus	2			2		2	
Missile &	4	2		1	3	2	2
Machinery & Arms	2	4			3		3
Office & Computing	2	1	1		1	1	
Spec. Ind. Machinery	1	1			1	1	
Metal/Wood Machinery	2		2		2	2	
Fabricated Metal Prod.	3	2			3	1	2
Non-ferrous Metals		1			1		
Non-metallic Minerals				3	3	2	
Rubber	1				1	1	
Chemical Products	1				1	1	
Paints & Varnishes	1			3	4	1	
Spinning/Weaving				1			
Total	29	20	6	12	31	19	8

This corporate strategy of combining licensing with a firm's own investment in internal R & D capability is aptly reflected in the following quotation from a leading Brazilian capital goods producer:

> We ought to draw the benefit of large international R & D investment, choosing that technology that helps us to solve our difficulties; at the same time, we have got to invest ... in the development of our own technology, mainly in those areas most favourable to us. This way we shall improve our bargaining power *vis-a-vis* our foreign partners, placing ourselves on an equal footing; in a position to exchange technology rather than to rely on foreign technology.[92]

The second strategy that Brazilian defence and capital goods producing firms have used to enhance their technological capabilities, and hence competitiveness, is the usage of what Dahlman labels "specialised technological agents" -- research institutes, information centres, consulting engineering firms, universities.[93] As Dahlman argues, the information flows between producing firms and specialised technological agents are often extraordinarily important because, "[u]nlike competing firms, whose interest is to limit diffusion, the interest of the specialised technological agents is to carry out diffusion."[94]

In the Brazilian case study chapter, firms' usage of the domestic and technological infrastructure, particularly the research and development institutes of the armed forces (the CTA, CTE_x) has been very high. Indeed, the regression model, found in Chapter 3, reinforces the importance of access to these specialized technological agents among all military producers as well as those of the defence subsectors. The aircraft and missile industries, as theorised earlier, have the strongest links to the CTA and affiliated centres. Eighty-six per cent of the surveyed firms in the aircraft-related industries and 83 per cent of missile-related companies said that they relied on the CTA as a means to upgrade their technological capabilities. The army and naval subsectors had the least strong links to their respective military research institutes, in part reflecting lower levels of technology inherent in manufacturing these goods, and because of the broader and more diversified linkages to the automotive and other transport industries. About 41 per cent of the armoured car/tank subsector relied on research and development centres provided by the CTE_x and INPE, and 40 per cent of the naval industries actively sought the participation of the IP_qM. The proximity of these technological agents is an important source for the information flows needed by firms for adaptations and innovations in manufacturing products as well as in new investments. The linkage between Brazilian firms and research centres has crucially aided these firms' capabilities and international competitiveness because of the lowered information search costs for firms -- a point that is developed shortly.

A third strategy pursued by Brazil's defence and capital goods firms is heavy investment in human capital formation, either by hiring specialised foreign personnel or primarily by providing employees with specialised education and training programmes, through universities and technical colleges in Brazil as well as overseas. As Bell notes, firms need not accumulate technological capacity only by creating it. If the skills and knowledge are not available within the firm, they "may be acquired through the simple mechanism of hiring the people who embody those resources."[95] Again, the proximity of the graduate aerospace institute, ITA, has been an important source both for training as well as hiring purposes of some Brazilian firms. For example, during Avibras' peak production period, approximately 55 per cent of its engineers and technicians were former ITA graduates.[96] Similar studies involving machinery producing firms in Brazil and Argentina indicate that hiring readily available human resources was an important component in these firms' learning processes.[97]

In terms of training, the case studies demonstrate that all of Brazil's leading defence firms have used extensive training programmes for their personnel, often in conjunction with licensing and coproduction arrangements. Close examination of a number of other studies suggests that various kinds of formalised training were often far more important as sources of technological capacity than were forms of doing-based learning. For example, Dahlman emphasises the importance of the massive technology training efforts undertaken by the Usiminas steel company in Brazil. Even during the earliest investment stage, when Brazilian engineers were allocated to work alongside their Japanese counterparts, there was also extensive training in Japan.

This technology strategy involved a more active and explicit training approach than one in which learning was "passively" acquired through mere participation. Although various kinds of "doing" played some role in augmenting the technological capacity of the firms involved, the effort made to undertake explicit training was probably much more significant. The explicit investment in the acquisition of technological capabilities by Brazil's defence and capital goods firms can now be dramatically contrasted with the experiences of Indian firms.

India

Unlike the positive experience with foreign licensing of Brazilian firms, only rarely has the technological content of these agreements made significant additions to the technological bases of India's defence and capital goods firms. Three important factors help explain Indian firms' poorer technology acquisition and development strategies.

The first relates to an earlier discussion regarding Indian firms' defensive use of licensing either through rapid diversification or rival pre-emption. Both cases suggest that firms' accumulated technology experiences and capabilities may be relatively shallow and limited. A major survey of both British and Indian firm managers and engineers involved in technological collaboration agreements confirms this picture of limited technological dynamism.[98] For example, approximately 50 per cent of the British suppliers interviewed in this study considered that their Indian partners had not acquired the capacity to manufacture a new or improved product. In almost all of these cases considered to have been relative or complete failures, the suppliers indicated the limited technical and managerial capabilities of their Indian partners.

Successful collaboration, on the other hand, was invariably related to prior learning experiences of Indian firms. Accordingly, many of the foreign suppliers emphasised the importance and need for a close and extended relationship with the Indian firms in order to transfer successfully the know-how and know-why which could contribute to these firms' capacities to pursue trajectories of continuous technical change. However, because of the limited duration and possibility of renewal of these collaboration agreements, such vital technology flows were effectively blocked.

A second issue pertains to Indian firms' choices of technologies. The technology selected will affect a firm's potential ability to adapt the technology to local conditions, to modify it to sustain productivity improvements, and to move closer to the international technology frontier. Teece's conceptualisation of "path dependency" is useful in the above context:

> A firm's core business ... stems from the underlying natural trajectory embedded in the firm's knowledge base ....Hence, a firm's initial point of entry in a technological regime, and the trajectories/paths which are initially selected, will define in large measure the kinds of competencies in certain areas.[99]

The consequences of path dependency are well demonstrated in the case studies of Indian defence firms. In choosing to acquire the very latest in foreign high technologies, presumably to attain an equal footing with the advanced Western countries (the Light Combat Aircraft and the Advanced Light Helicopter projects for example), Indian firms were locked into a situation of continuously receding from the frontier as it advanced. In contrast, by selecting technologies behind the frontier (turbo-powered aircraft), Brazilian firms were able to open technological "black boxes" in ways that led to their progressive development.

A third factor explaining why the technological content of many foreign licensing agreements are both narrow and shallow is that Indian importing firms' strategies and efforts towards foreign technology acquisition are similarly narrow and shallow. Evidence of such firm-level failure is reported by Bell and Scott-Kemmis:

> the primary reason for ineffective absorption appeared not to be the inherent difficulty of absorption. The problem appeared to be largely a result of inadequate *efforts* to absorb the technology .... The immediate

> reason ...seemed to lie within the firms themselves and associated with the firms' approaches to commercial and technological development.[100]

The survey conducted by these two researchers found that in over half of the collaboration agreements examined, the Indian partner's objective did not extend beyond acquiring the capability to carry out basic manufacturing activities. The objective of developing capacities for improving the imported technology appeared to have had some influence on the technological content in only 20 per cent of the cases.[101]

An UNCTAD study of leading Indian capital goods manufacturers, including some defence firms, provides concrete evidence for this negative assessment of Indian firms' efforts. As indicated in Table 5.11, *Elements of Technology Transferred Under Licensing*, Indian capital goods firms, like their Brazilian counterparts, sought licensing agreements as a means to secure designs -- over fifty per cent. Yet, compared to Brazil's capital goods and defence firms, very little emphasis was paid by Indian firms to other equally important and complementary means of improving their technological capabilities. A prominent Indian economist, Bagchi, concurs with this assessment, observing that, "the experience of such countries as Japan and South Korea and the example of exceptional enterprises in India indicate, successful absorption of borrowed technology *requires substantial in-house expenditure on research and development and adoptive engineering*."[102] Referring specifically to the defence sector, one Indian defence official has written:

> Manufacture of a product under license from abroad does not make us self-generating. This practice is more in the nature of an intravenous drip for a sick patient. Unless it is accompanied by other relevant treatment, the patient may be doomed to die....It is only when we understand the

Table 5.11: Elements of Technology Transferred Under Licensing Agreements of Sample Firms

Elements	Machine tools I				Equipment for process industry II				Electrical equipment III				Total for complex capital goods (I+II+III)			
	DT	FT	FC	Total	DT	FT	FC	Total	DT	FT	FC	Total	DT	FT	FC	Total
A. No. of firms	2	1	2	5	3	1	—	4	1	1	2	4	6	3	4	13
B. No. of collaboration	8	2	4	14	8	3	—	11	10	2	6	18	26	7	10	43
C. <u>Elements of Technology</u>:																
1. Design (basic)	8	2	4	14	8	3	—	11	10	2	6	18	23	7	10	40
2. Design methodology	5	2	4	11	5	3	—	8	9	2	6	17	19	7	10	36
3. Detailed design	2	1	2	5	1	1	—	2	1	—	2	3	5	2	4	11
4. Technical assistance	6	1	4	11	1	—	—	1	5	1	4	10	12	2	8	22
5. Patents	5	1	3	9	3	2	—	5	6	2	5	13	14	5	8	27
6. Trademark	—	—	1	1	—	—	—	—	1	—	—	1	—	—	2	2
7. Personnel training	6	1	2	9	3	2	—	5	8	2	5	15	17	5	7	29
8. Others	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	32	8	20	60	21	11	—	32	40	9	28	77	90	28	49	167
Average number of elements in each collaboration	4	4	5	4	3	4	—	3	4	5	5	4	3	31	41	4

DT = Domestic firm with technical collaboration.
FT = Foreign minority joint ventures.
FO = Foreign-controlled joint ventures (including Indian subsidiaries of foreign firms).

Source: UNCTAD. *Technology Issues in the Capital Goods Sector: A Case Study of Leading Machinery Products in India, 1983.*

> scientific, technical, engineering and design principles that we can claim to have imported the latest technologies.[103]

While Brazilian firms clearly assigned a high priority to the training and hiring of specialised personnel, Indian firms have made relatively little use of licensing agreements to secure technical assistance through sending personnel abroad for training. Referring back to Table 5.11, only 13 per cent of licensing agreements included arrangements for technical assistance, and only 17 per cent incorporated specialised personnel training. Bell & Scott-Kemmis found that neither British technicians' visits to India nor Indian visits to technology suppliers were included in half the technology collaboration agreements. Access to laboratories and design offices of the British suppliers was also rarely included. This narrow technology acquisition pattern by Indian firms was noted by one U.K. engineering firm:

> The Indian government and many Indian firms are on the wrong track. You would think that they would be trying to maximise technology transfer and building a basis for development into the future. But what they do is negotiate the price for technology to such a low level that suppliers do not really transfer technology at all. The Indians often don't concern themselves with what is technology transfer but just focus on price. Through this agreement (the Indian partner) will not have the capacity to develop this technology....At present they don't get technology transfer, just designs.[104]

Another area in which Indian firms are comparatively weaker than their Brazilian counterparts is their neglect of the importance of learning through informal searching.[105] One study of the more successful NICs indicates, "The acquisition of technological capability...comes from conscious efforts to monitor what is being done, to try new things, to keep track of developments throughout the world...."[106] One reason why Indian firms bypass this step, in essence failing to search for better technological solutions, is that the costs, particularly for India's many small-sized capital goods firms are too great. As we have seen in the case of Brazil, these costs can be reduced if firms turn to specialised technological agents that are able to capture economies of scale in their searches and are knowledgeable about what technologies will work in local conditions. Unfortunately, the characteristic fragmentation and poor coordination between India's massive technostructure and the country's defence and manufacturing firms often preclude such diffusion of information.

In summarising this comparison of Brazilian and Indian firms' technological strategies, one can begin to separate the effect of firms' own strategies from the impact of governments' trade and technology policies. The relative technological performance and export success of Brazilian defence and manufacturing firms was not an automatic outcome of government promotion policies. Rather, it resulted from these firms' conscious efforts to identify what they needed from the acquisition of foreign technology, and from efforts to absorb and complement that technology with their own related R & D activity. In a significant number of instances, however, such efforts to acquire additional technological capabilities seem to have been induced by the need to respond to stimuli and demand for technical change; hence the importance of a firm's external environment.

In India, too, it appears that the overall impact of technology policies may have been limited for two interrelated reasons. As discussed above, most Indian firms do not select appropriate technology strategies that would enable them to improve and even generate new technology, not only because of limited learning and accumulated experience, but more importantly on account of a lack of competitive pressure. To quote two Indian firm managers:

> 1) The market in India is not that sophisticated. Our economy is really very patchy....There are many areas where technology is about 10 years behind the developed countries. But firms don't accept this, they don't accept the need to change and to learn.[107]
>
> 2) There is very little pressure for technological excellence and little incentive for technical change. Our customers are not demanding and our markets are not competitive.[108]

In conclusion, the development of a firm's technological capability lies at the centre of successful manufacturing as well as exports, and of the ability of a firm to adapt and generate new technologies. A firm's technological and manufacturing capabilities are the result of a strategy that emphasises investment in learning by the firm itself. However, a firm's technology strategy is also influenced by external competitive influences, a subject to which we will now turn.

The External Environment of a Firm

In the vast literature on technological innovation and diffusion, many different variables have been adduced to explain the competitive influences that affect the strategic behaviour of firms. Among the most important to be studied and of relevance to our comparative analysis of Brazilian and Indian firm technology behaviour are firm size, vertical integration and market concentration. These variables are not mutually exclusive and often overlap; they may also be conditioned by government policies. As indicated shortly, an important element in the explanation of the weaker performance of India's defence and capital goods firms is that the government's industrial, trade and technology policies have molded the external economic environment of its firms in ways that do not provide the necessary incentive structure conducive to innovation.

1. Size Distribution and Diversification

According to the Schumpeterian hypothesis tested in the literature from industrial organisation, large-sized firms are expected to be more innovative because of their ability to finance R&D and other resources related to new product development and marketing.[109] By comparison, small-sized firms usually cannot afford this internal division of labour. Table 5.12 provides a breakdown of firm size by manufacturing output in Brazil and India.

As discussed in an earlier chapter, Indian industrial policies are skewed towards the creation of high barriers to entry and growth for large firms (MRTP legislation), and towards the promotion of small-scale industries. Table 5.12 reflects this size distribution among Indian firms, which is peculiar because of the noticeable absence of middle-sized firms. Such skewedness has only reinforced the pattern of weak firm technological competitiveness. It has also resulted in undue vertical integration and low product specialisation among Indian firms. The larger sized firms often operate under monopolistic conditions and therefore lack incentives to undertake R & D to improve their products while a great number of firms are too small to utilise either adaptive or innovative technology effectively.

The effects of MRTP and industrial licensing controls (e.g., caps on plant capacity) have encouraged horizontal integration. Large firms tend to establish subsidiaries for new product lines rather than to diversify within product categories in

Table 5.12

Manufacturing Output by Firm Size

Firm Size (Number of Workers)	India [1] (1982/83)	Brazil [2] (1986/87)
0 — 49	12.7%	6.0%
50 — 99	7.1%	7.0%
100 — 199	7.7%	13.0%
200 — 499	15.0%	34.0%
500 — 999	13.0%	12.0%
1,000 — 1,999	15.5%	16.0%
2,000 — 4,999	12.7%	12.0%
5,000 — above	16.3%	10.0%

[1] Data derived from *Annual Survey of Industries*, 1982/83, cited by World Bank, India, 1989, p. 98.

[2] Data provided by Banco Nacional de Desenvolvimento Economico e Social, Rio de Janeiro, Brazil

an existing manufacturing facility or company.[110] Lall argues that the impact of the Indian government's industrial policies on such diversification is largely negative because they:

> Induce large industrial firms to diversify into completely unrelated activities which are assigned priority in the relevant Plans, where they have no technological advantage or experience, and so spread resources very thinly and induce a lack of specialisation. This holds down the absolute size of the undertakings in many industries to tiny scales by international standards, and so prevents firms from launching R & D efforts on scales that allow for the absorption of new technologies.[111]

This discussion of diversification highlights important differences between the performance of Brazilian and Indian defence and capital goods firms, in spite of the fact that both countries' capital goods sectors were faced with unstable demand and low rates of capacity utilisation. First, India's capital goods firms have pursued a policy of defensive diversification, in some cases because of the constraints imposed by government policies, and in others to gain simple monopolistic advantage. In stark contrast, Brazil's capital goods firms diversified into defence in response to domestic sectoral conditions as well as international trade demands, and successfully entered the highly competitive international arms market on the basis of product and cost advantages.

Second, in India the absence of a large cohort of mid-sized capital goods firms, as well as product reservations and protection from international competition for both large and small firms, are indicators in and of themselves of intentionally restrictive competitive policies. The combined effects of these policies have weakened the incentives for India's small-scale capital goods firms to undertake R & D activity or to improve their existing technologies. The experience of some Indian defence production units with ancillary production by small-scale capital goods producers has been poor product quality, lack of standardisation and quality control. In many cases poor product reputation has encouraged the further vertical integration of the public sector defence production units to the detriment of developing extensive, private-sector subcontraction networks. Indeed, as Chudnovsky et al., confirm, the relatively high degree of vertical integration of the leading producers of capital goods in India is not only reflected in the fact that the size distribution is biased in the direction of large firms, but also in the small proportion of their total costs which is accounted for by subcontraction work.[112]

2. Vertical Integration

Many analysts of technology change in both the advanced and newly industrialising countries have suggested that there are distinctive institutional and organisational choices that affect the quality and level of a state's indigenous technology capability. For instance, Ranis observes that one of these choices is reflected by the debate regarding subcontraction as opposed to more vertically integrated firms within an industry.[113] He, like other theorists of industrial organisation, point to the significance and potential applicability of the Japanese model. Industrial subcontracting in Japan is used widely as a means of generating efficiencies in the manufacturing production process and in enforcing quality standards.

The author's data collected from a sample of Brazilian capital goods firms indicate the occurrence of a fair degree of subcontracting, though its occurrence is demonstrably linked to the size of the company (as measured by employment and value of output). In interviews with the major defence producers in Brazil, company executives consistently emphasised a policy of promoting inter-industry linkages through industrial subcontracting activities. In some instances, this subcontraction policy was motivated by a strategy of reducing dependence on foreign suppliers. In other cases, firms indicated cost considerations, the government's domestic content laws, and its financing programme for the purchase of domestic capital goods as reasons for industrial subcontraction.

As indicated in the Brazilian chapter, particularly in the case study of the aircraft industry, Brazil's predominantly medium-sized, defence-related firms have subcontraction arrangements with other medium and smaller specialised capital goods producers. The most notable example is that of Embraer, which along with the CTA's IFI, has transferred technology to improve and ensure the quality of its many suppliers, most of which have been accustomed to working for the less stringent technological requirements of the automotive industry. Moreover, a small number of these suppliers have become significant exporters in their own right, as a result of their affiliation with such an internationally recognised company.

One of these firms interviewed was Metal Leve, a medium-sized, private company that began producing ball bearings and pistons for the local automotive subsidiaries of the TNCs in the 1950s, and later for the international aircraft industry.[114] Beginning in 1968, Metal Leve diversified its product range by investing in quality control, and gained experience in the manufacture of aircraft pistons for Pratt & Whitney engines used in Embraer aircraft. Today it is the sole manufacturer of aircraft pistons for general aviation, producing exclusively for Teledyne-Continental and Lycoming. The export ratio of the company's products rose from eight per cent in 1970 to approximately 50 per cent in 1992 (18 per cent is direct export sales, the remaining is intrafirm trading arrangements via the Brazilian-based automotive TNCs). Estimated total annual export sales are $45 million. When asked about the sources of its comparative advantage in both domestic and international markets, Metal Leve's marketing director said that the company competes on price, quality and delivery. "Timing is especially important in the automotive sector because of assembly schedules, quality is most important in aircraft because of reliability."[115]

Metal Leve's success also has been based on a technology strategy that includes the effective absorption of imported technology through intense training in-house and at the technology suppliers' facilities and the systematic adoption of transferred technology to local conditions. In 1979, with financial assistance from FINEP (a $2.2 million loan), Metal Leve established its own R & D centre, which has been involved in broader research related to CAD/CAM, mechanical physics and metallurgy, particularly advanced bonding technology for aluminum, metal and composites. The centre employs approximately 300 people. Reflecting its emphasis on the importance of export markets, as a source not only of technical information but of continuous pressure to improve performance from its automotive customers, in 1989 Metal Leve set up the Advanced Technology Centre in Ann Arbor, Michigan as an extension of its São Paulo R & D facility.

As this brief case study of Metal Leve indicates, subcontraction arrangements have stimulated the further development and diversification of the Brazilian capital goods sector. In particular such arrangements have led to improved and faster adoption rates of technology, and have generated greater specialisation and the achievement, in some cases, of international scale economies. However, it is important to stress that the necessary prerequisite for such a learning process through subcontraction is the pre-existence of a diversified and complex industrial structure. What distinguishes the Brazilian case from the Indian experience is that within Brazil's diversified capital goods sector, there has been the strong and long-lasting interaction between both public and private sector firms engaged in the production of machinery and transport equipment and the defence-related industries.

By contrast, subcontraction to ancillary firms is underdeveloped in India, accounting for only an estimated ten per cent of total manufactured production (as compared to rates of at least forty per cent and higher for the Brazilian defence/capital goods firms).[116] Rather, "ancillarisation" is used by Indian defence/MRTP firms as a defensive strategy for releasing internal capacity and for cutting production costs due especially to excise taxes and higher prices of intermediate goods. In this regard these larger firms can take advantage of the small-scale industries' low "infrastructure costs", since small firms may lay off labour without government approval and are exempt from both minimum wage and employee benefit payments.[117]

The correspondingly high degree of vertical integration among India's defence and capital goods firms means that these firms are denied important "learning from others" opportunities. In his seminal work, *Perspectives on Technology*, Rosenberg acknowledges that in the capital goods sector especially, a major inducement for technological change derives from demands imposed by one firm on its suppliers.[118] For example, the technological performance of Brazilian defence and capital goods firms was raised through these firms' efforts to improve product quality, materials application, and process technology (Embraer and Metal Leve). These efforts were stimulated by the firms' domestic as well as international environments. Thus changes introduced or required by customers (e.g., Embraer's redesign and production changes of its Tucano trainer fighter for Britain's Royal Air Force), suppliers and competitors (particularly in international markets) were crucial sources of threats, opportunities and ideas -- competitive incentives very much lacking in India's protected industrial milieu.

This low level of subcontraction has also meant that the growth of India's defence and capital goods manufacturers has been significantly hindered by the absence of such a network of producers. As Pack has observed of these technologically related sectors, "[a] principal requirement of the entire mechanical-engineering sector is the development of a subcontracting network."[119] In his extensive study of the Indian automotive industry, Gumaste argues that the development of the transport sector has been similarly impeded by the absence of an extensive subcomponent network:

> It would be futile to expect a flower to bloom in a desert. We cannot expect our automobile industry to produce vehicles of a world standard unless our technological upgradation and modernisation takes place in all the upstream industries. Technological development in an import restricted economy is a cumulative process...One cannot expect high levels of technology in one industry unless all other industries are also technologically up-to-date.[120]

Two important concluding caveats derive from the discussion of firm size and vertical integration. First, as Schumpeter pointed out, admittedly large firms may be a necessary condition for building up those technological capabilities where complexity or risk create significant economies of scale and scope. The case is stronger in industrialising countries, such as India, where the deficiencies of supplier networks create the need to internalise functions that would be external to firms in more industrially advanced countries. Second, as the Brazilian case study demonstrates, relative largeness can be counterbalanced by competitive inducements to innovation and efficiency either through domestic market pressures and/or by international trade pressures.

In the case of India, however, its firms have been denied sources and incentives for important learning through investment in improved technological capabilities because of a lack of such competitive pressures. As is discussed next, the issue of competition assumes special significance in the Indian context since the government's trade and industrial policies, coupled with extremely low levels of domestic competition, mean that competitive pressures have been very limited.

3. Market Concentration

As Table 5.13, *Product Concentration in Selected Capital Goods Industries*, indicates, the defence-related, transport and heavy equipment industries in India are highly concentrated. Despite the implementation of various industrial policies to control large, dominant firms, production of capital goods, including some defence equipment, is highly concentrated in only a few firms. Concentration ratios are also high in India's machine tool sector, in which the top three firms account for over 75 per cent of the value of production, and the public sector enterprise, Hindustan Machine Tool, accounts for 60 per cent of total sectoral output.[121]

Table 5.13

Product Concentration (Monopoly) in Selected Capital Goods

	1980	
	No. of units	Degree of Concentration
Non-Electric Machinery		
• Boilers and steam generating plants	16	H
• Textile machinery	248	N
• Earth-moving machinery:	19	H
• Metallurgical Machinery	20	H
• Chemical & Pharmaceutical Machinery	77	N
• Mining Machinery	11	M
• Refrigeration & Airconditioning	20	L
Transport Equipment:		
• Trucks and Buses	7	H
• Jeeps	1	H
• Passenger Cars	4	H
• Scooters	13	H
• Motorcycles	4	H
• Railway Wagons	13	L
• Mopeds	8	H
• Diesel engines (vehicular)	6	L

Degree of concentration is defined by the extent of share of top three enterprises in the production (or sale) as given below:

H: High concentration — 67 per cent or more
M: Medium concentration — 60 per cent or more
L: Low concentration — 50 per cent or more
N: Nil concentration — below 50 per cent

Source: *Market and Market Shares for 200 Industrial Products*. Bombay: Centre for Monitoring Indian Economy, August 1980. Cited in UNCTAD, 1988. p. 17.

Four-firm concentration ratios are also high in such intermediate goods industries as basic metals, synthetic fibres and paper products. To a substantial degree these relatively high market concentration levels are attributable to the effects of government licensing policies, which as discussed above confine production of certain products to different size classes of firms. In many segments of Indian industry characterized by high four-firm concentration ratios (particularly transport), the average change in an individual firm's market share was well below five per cent annually.[122]

India's highly concentrated industrial market structure also raises important implications for firm-level R & D activity. Such a market structure, following Schumpeterian-based arguments, should insulate dominant firms from competitive pressures and thus enable them to appropriate the "fruits" of their innovations. However, as indicated by the relatively poor performance of India's defence and capital goods industries, the presence of market power with concentration has allowed Indian firms to reap profits without necessarily being innovative. This is because Indian industry has been highly protected, which means, that although appropriating the rewards from R & D is not difficult, there has been no pressure to undertake technological change.

Government policies have been the key determinant of the degree of competitive pressure and therefore of the technological strategies and efforts of many Indian firms. As a result, private sector R & D has been directed at complying with local use regulations rather than aimed at overall improvement in production or efficiency. In an interview conducted by Bell & Scott-Kemmis with a consumer electronics producer, the latter explained:

> The Indian market is very traditional and in this context product change is risky. Many firms are used to receiving high [profit] margins but they are often not used to and not willing to make significant development efforts. They often just copy products which are successful on the Indian market rather than trying something new. This will only change when our markets change through greater competition.[123]

In essence, Indian firms are induced to opt for the stability of market shares through satisficing behaviour. Only when competition is introduced have Indian firms countered with and intensified technological improvements. For example, according to studies conducted by Morehouse and Laroia, only when India's oligopolistic tractor industry was threatened by Punjab Tractors' (PTL) successful entry and introduction into the market of an indigenous tractor was there a qualitative shift in the established firms' attitudes towards R and D.[124] In this competitive situation, the technological strength of PTL was a positive factor in its manufacturing success and in inducing other companies to improve their engines and models.

Many Indian firms prefer, however, to use licensing of foreign technology as a means to secure rapid market entry or product improvement rather than to innovate through indigenous research and development. As will be investigated in Section III, given the combined effects of 1) Indian firms' own technological strategies, 2) concentrated market structure, and 3) government policies, there seems to be little positive incentive to induce firms to increase their technological capabilities via licensing. In other words, Indian firms are, in fact, behaving rationally as they respond to the above effects. Let us now turn to a formal discussion of this interaction between the state and firm using a game-theoretic framework.

SECTION III: A GAME THEORETIC APPROACH: R&D PATENT RACES

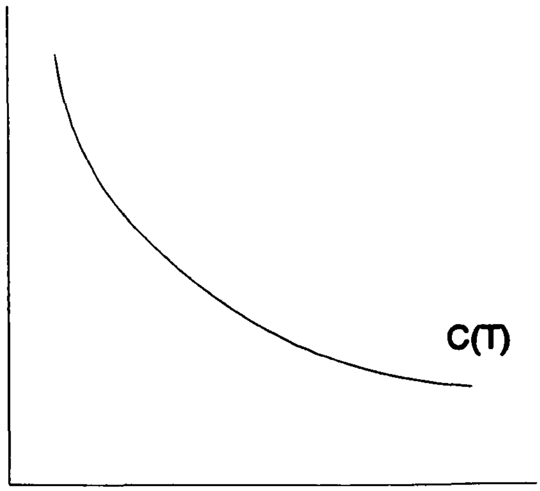
In the preceding two sections, the writer has delineated a comparative analysis of government policies and firm strategies in Brazil and India. Section I concentrated on describing the institutional arrangements and incentives these two governments employ to promote technological growth and change in the context of defence industrialisation. Section II focused on the firms themselves -- contrasting Brazilian and Indian firms' choices and pursuits of technological strategies, and their respective external economic environments. In this final, brief section, the author uses a game theoretic framework to illustrate formally how the interaction between government policies and external environment affects firm technology behaviour.

The industrial organisation literature offers many game theoretic models that analyse the incentives for technological innovation, adoption and diffusion among firms in relation to market structure and strategic firm behaviour.[125] In particular, these models investigate the opposing effects of monopoly power and competition upon a firm's incentive to engage in innovative activity. Some of this game theoretic literature is especially applicable to the comparative analysis of Brazilian and Indian firm behaviour. The first are deterministic models of patent races. The most influential one was developed by Gilbert and Newbery (1982). The second are "memoryless" patent race models of Dasgupta & Stiglitz (1980), Lee & Wilde (1980), Loury (1979), and Reinganum (1983a) (1983b). A third line of game theoretic research, which incorporates the effects of learning into patent races, is associated with Fudenberg, Gilbert, Stiglitz, and Tirole (1983).

To understand the applicability of these models to the analysis of Brazilian and Indian firms, the author will first describe in simplified terms the assumptions underpinning these models. Subsequently, the author will then tie various attributes of these patent race models to the technology behaviour of Brazilian and Indian firms.

1. A Deterministic Model

Gilbert and Newbery use a stylised, deterministic model to examine the question of whether an incumbent monopolist, faced with a potential entrant who competes for a patentable innovation, would have less incentive to innovate than the potential entrant. Their model is based on the assumption that the date of innovation is a deterministic function of research and development expenditure. The more one spends on R & D, the earlier the date of innovation or discovery. "In its simplest representation, the date of invention, *T*, is a deterministic function of the time path of expenditures. The present value of an optimal expenditure path defines a cost function *C(T)*, that is a decreasing function of the invention date."[126] Figure 5.1 below provides a useful representation of Gilbert & Newbery's deterministic assumption.



The issue then is who is willing to pay more for the innovation: the monopolist or the potential entrant? Gilbert and Newbery show that the "efficiency effect" implies that the monopolist would be willing to pay more than a potential entrant, especially if the innovation is "non-drastic". The "efficiency effect", as Tirole explains, presumes " ... that in a homogenous-good industry, a monopolist does not make less profit than two noncolluding duopolists."[127] In essence, a monopolist could divide itself into two parts and mimic the R & D activities of its two rival competitors. To express this "efficiency effect", symbolically:

> Let Π_m be the monopolist's profits (excluding the purchase price of the innovation), if it remains a monopolist and buys the innovation;
>
> Π_{me} is the monopolist's profit if there is entry, e.g., if the competitor purchases the innovation and shares the market with the monopolist; and

Π_e represents the entrant's profits (also excluding the purchase costs associated with the innovation):

Then, the efficiency effect can be represented as:

$$\Pi_m \geq \Pi_{me} + \Pi_e$$

The efficiency effect implies:

$$\Pi_m > \Pi_e$$

Namely, the profits the monopolist will secure by innovating and remaining a monopolist exceed the profits the potential entrant will obtain if it innovates. In brief, the monopolist is willing to pay a higher price for the innovation than the entrant. Given the deterministic relation Gilbert and Newbery assume, whereby the more a firm spends on R & D advances the date of innovation, the monopolist will be the first to innovate, secure the patent and preempt the would-be entrant, thereby deterring entry. In effect, the patent race becomes an auction. The innovation and patent are being auctioned off, and they will go to the firm willing to pay the highest price -- the monopolist.[128]

While the efficiency effect in the Gilbert & Newbery model implies that the monopolist will preempt a potential entrant by securing the patent, this effect does not necessarily lead to the adoption or implementation of the patented technology by the monopolist. Indeed, the monopolist may want to obtain property rights, via the patent, on a technology or product innovation even though the firm will make no use of it. As Gilbert & Newbery note:

> A firm with monopoly power has an incentive to maintain its monopoly power by patenting new technologies before potential competitors and that this activity can lead to patents that are neither used nor licensed to others (sometimes called "sleeping patents").[129]

This behaviour, which is known as "shelving", may occur as a consequence of the preemptive behaviour by the monopolist. In some cases, the possibility of shelving may even strengthen the incentive for preemption by the monopolist.

Gilbert and Newbery's model provides two examples of shelving.[130] First, shelving may occur if the patent relates to a product technology that is not superior to that of the monopolist. Second, a similar situation arises when a patented substitute product is not sufficiently differentiated from the monopoly's existing product to warrant incurring the costs associated with introducing the new product to the market. In both instances, the monopoly's payoff to exploiting the patent, given that the potential entrant can no longer threaten to exploit the innovation, is too small to overcome the costs of adopting the new innovation. The sole purpose of acquiring the patent then is to eliminate the potential entrant's threat.

Having described the possibility of shelving behaviour by firms, let us now analyse the factors influencing the firm's decision of whether or not to exploit the innovation. Arrow observes that with patent protection, a firm's incentive to invest in research and development is less under monopolistic than under more competitive conditions.[131] The reason, Arrow explains, is that the monopolist gains less from innovating than a competitive firm because the monopolist "replaces" itself, whereas the competitive firm becomes a monopolist. This property has been subsequently labelled the "replacement effect".

Teece has used the "replacement effect" in his study of technology and market structure.[132] He argues that vertically integrated firms often have specialised investments in place, and that since the primary role for vertical integration is to protect specialised assets from recontracting hazards, vertically integrated firms are likely to have a higher proportion of their asset base dedicated to particular technologies. He concludes, "[t]hus a monopolist which is vertically integrated and has assets specialised to the old technology may indeed delay the commercialisation of new technology if it is confident that it does not face competitive threats."[133]

2. "Memoryless" Patent Race Models

As outlined previously, what drives Gilbert & Newbery's model explaining the persistence of monopoly is its deterministic stylisation of the research and development process. However, in reality, the innovation process is characterised by considerable uncertainty. Various game theorists have attempted to model the importance of uncertainty in relation to patent races.[134] In these patent race models, a firm's probability of successfully innovating and obtaining a patent at a point in time depends only on the firm's current research and development expenditure and not on its past expenses (i.e., a firm's accumulated technological experience), hence the term "memoryless". According to these highly stylised models, firms compete vigorously until the innovation is secured via a patent.

Reinganum (1983b) similarly addresses the question of the effect of current monopoly profit upon an incumbent firm's incentive to invest in R & D in the context of a memoryless, stochastic racing model.[135] This model was devised to compare the results with those of Gilbert and Newbery. As we found in the Gilbert & Newbery deterministic model, the incentive to preempt dominates, e.g., an incumbent monopolist has a greater incentive to preempt than does the challenger. However, when the date of rival discovery is drawn from a continuous distribution as in Reinganum's stochastic racing model, concern for preemption is much less acute. Her model shows that which of the two firms -- the incumbent monopolist or the potential entrant -- spends more on R & D, and thereby innovates first, depends on the two effects identified above in the deterministic model; namely, the "efficiency effect" and the "replacement effect". Reinganum demonstrates that either of the two effects may dominate.

Let us first consider the case of a drastic innovation. For drastic innovations the preemption incentive is the same for both firms. Since the winner *de facto* becomes a monopolist, there is no dissipation of monopoly rent, i.e., there is no efficiency effect; hence the replacement effect will dominate. According to Reinganum, "when the first successful innovator captures a high share of the post-innovation market, then in a Nash equilibrium the incumbent firm invests less than does the potential entrant....[Hence] the incumbent is less likely to be the innovator than the challenger."[136]

The intuition behind why the replacement effect dominates in the case of drastic innovations is straightforward: when the innovation is uncertain, the incumbent firm receives profits before the successful innovation. The innovation period is of random length, but is stochastically shorter the more the incumbent (or challenger) invests. The incumbent has less incentive than the challenger to shorten the period of its incumbency (or to "replace" itself).

Second, let us now consider cases for less superior or "non-drastic" innovations. According to Tirole, "in order to eliminate the replacement effect, it is sufficient to choose an R & D technology in which the amounts committed per unit of time are considerable, so the probability of discovery per unit of time is high."[137] Hence, in the case of non-drastic innovations, innovation is more readily achieved earlier, and the monopolist is much more concerned with the possibility of innovation by the entrant -- the efficiency effect -- than with the date of its own "replacement"."[138] Thus, Reinganum shows that for a non-drastic innovation the monopolist will likely persist because it has a higher probability of securing the patent.

3. "Leapfrogging" Patent Race Models

Gilbert & Newbery's deterministic model, as well as Reinganum's "memoryless" patent race model are both limited depictions of the innovation process. The stylisations of the R & D process in these models are not sufficiently rich to capture the important role played by factors central to firms' innovative capabilities. These factors include accumulated R & D experience through various forms of learning (learning-by-doing, learning-by-searching etc.), the ability to monitor and respond to rivals' R & D efforts, and simple luck.

Recall, for example, Reinganum's 1983 work on a memoryless patent race model described above. In this model a firm's probability of discovery during the next interval is a stochastic function of what amount of expenditure a firm devotes to R & D at that point in time. While Reinganum introduces a limited form of uncertainty into the innovation process, the role of a firm's past R & D expenses, i.e., experience or learning, has no effect on its current likelihood of discovery. Indeed, experience is not a factor in her model, nor in Gilbert & Newbery's. Fudenberg, Gilbert, Stiglitz, and Tirole develop a very useful and more realistic patent race model because they attempt to formalise firms' R & D experience and/or learning effects. The underlying assumption of their paper is that a firm's probability of making a patentable discovery during any short interval depends not only on current research and development expenditure, as in the "memoryless" models, but on the firm's accumulated technological experience to date -- its "stock" of experience.

The Fudenberg et al., paper examines when patent races will be characterized by vigorous competition and when they will "degenerate" into monopoly. Under certain conditions, a firm may be able to prevent the entry of its competitors by virtue of being a marginally earlier entrant into the race -- a result which they label "ϵ-preemption".[139] The authors demonstrate that what determines whether races are characterised by ϵ-preemption or competition depends on whether a firm, which is behind in the race (as measured by the expected time remaining until discovery if both firms incur the same costs), can "leapfrog" the leader; that is, accumulate more experience and jump ahead in the race.

Tirole provides the necessary intuition behind the ϵ-preemption result and the possibility of leapfrogging found in the Fudenberg et al., model.[140] He uses the analogy of a foot race between two runners, both of whom are equally good, and prefer to run at a slower pace rather than exhaust themselves by running faster. The leader has eyes in the back of its head and can monitor whether the follower is catching up. Since the leader can always adjust its speed to the follower's, there is no point for this lagging rival to speed up. If the follower did, the leader would be certain to see this and speed up too. The lagging rival would be running harder but with no better chance of catching up. Forseeing this result, the follower has no incentive to increase its speed. Indeed, if a firm is only slightly, i.e., "ϵ", behind in accumulated experience, it has no incentive to continue the race and drops out, leaving the other firm to invest and innovate. As long as the leader has eyes in the back of its head, that is, can monitor the other firm, so that there is no chance that it will be leapfrogged, the race goes to the leader, who proceeds at the slower pace.

Now, suppose that the runners race on tracks separated by a wall with holes in it, allowing the competitors periodically to check their relative positions. The leader can no longer afford to run at a slow pace; if it did, the follower unobserved could run faster and leapfrog the leader. Thus, competition is engendered in this race due to the imperfect monitoring (lags in information) of rival firms' R & D investment activities.

Fudenberg et al., provide two patent race models, which demonstrate how leapfrogging can occur. The first is a multistage patent race. Likening the race to separate research and development activities, Fudenberg et al., offer a two-stage, fixed intensity model, in which a firm must complete the first stage -- make a preliminary discovery -- before proceeding to the second stage -- progress towards a patentable innovation -- with the rewards going to the winner of the race.[141] In this two-stage race, the winner of the patent race can leapfrog the leader by making the preliminary discovery first.

Leapfrogging occurs in this model because the probability of success is a stochastic function of R & D effort. Completion of the first stage is a random event, and by being lucky in the first stage, a firm with less experience could leapfrog a more experienced rival.[142] Preemption occurs at the date of the preliminary discovery, but it is not ϵ-preemption in that neither firm drops out of the race at the very start if the other firm has slightly more experience. The possibility of leapfrogging is thus shown to generate competition. As Tirole succinctly observes of the Fudenberg et al., multistage patent race, "Competition is most intense when firms are even. When the lagging firm draws even, both firms intensify their research effort. The leader tends to invest more in R & D than the follower."[143]

Using a deterministic patent race model inspired by Gilbert & Newbery's work, Fudenberg et al., provide another example of how leapfrogging may occur if firms have only imperfect information about the R & D activities of their competitors. This second possibility of the follower leapfrogging the leader arises via information and/or response lags (firms observe their rivals' R & D efforts, but with some delay). Information lags occur because within the current time period, each firm must choose its R & D effort without knowing what rival firms are doing. Fudenberg et al., explain, "[i]n this case a firm may leapfrog not because the success probability is stochastic, but because it can make progress toward invention without revealing its progress to a more experienced competitor."[144] The authors again find that if a firm is behind by a sufficiently large amount, it drops out of the race, allowing the remaining, lead firm to proceed with its research and development at a slower monopoly pace.

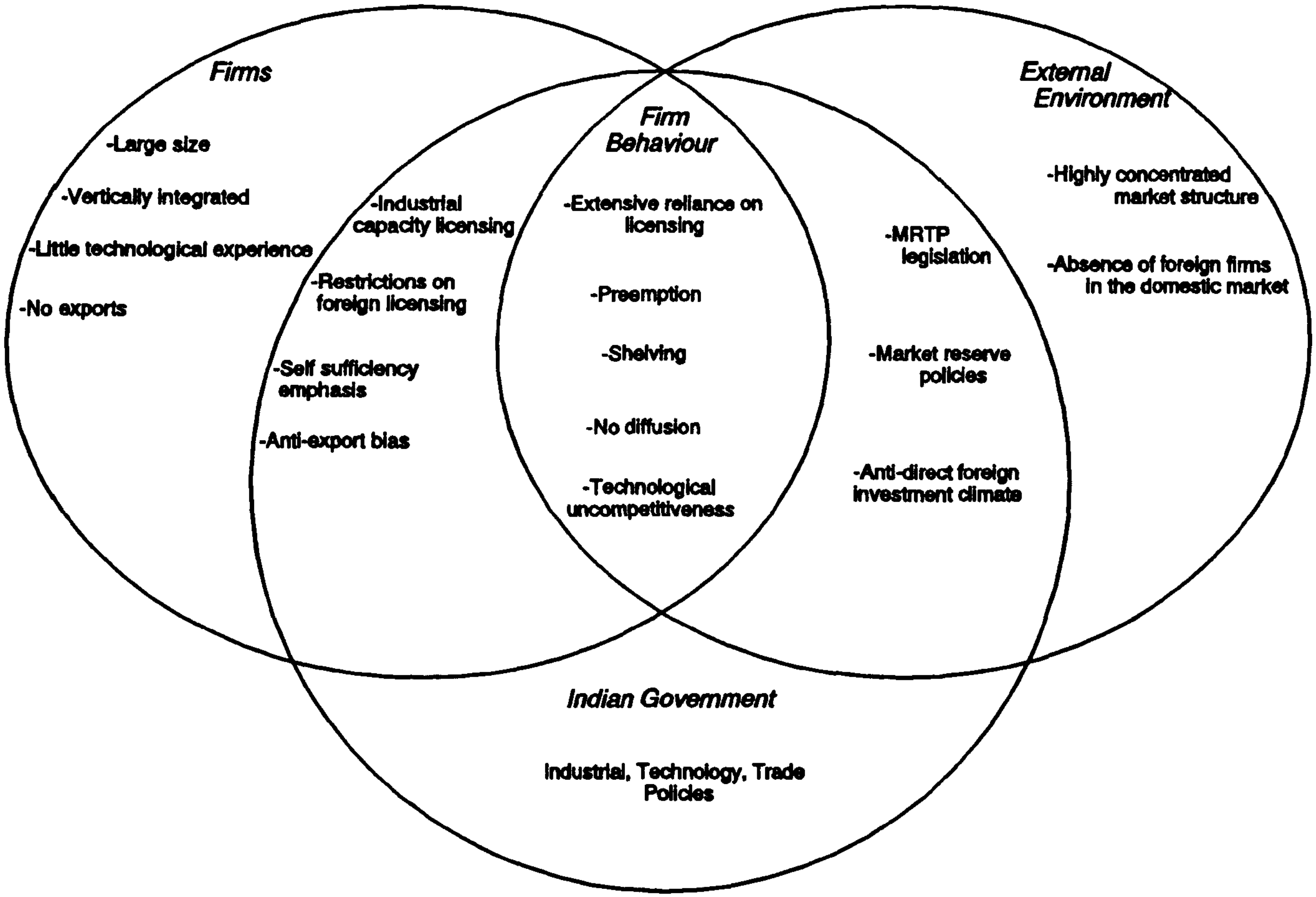
To conclude this first part, the author has described the "deterministic", "memoryless" and "leapfrogging" game-theoretic models, and has briefly discussed their conceptual evolution and linkage. In the next part, she will demonstrate the potential relevance of these patent race models to an explanation of the contrasting technology behaviour as well as strategies of Indian and Brazilian firms.

Application of Game Theoretic Models to Indian and Brazilian Firm Behaviour

Despite the simplicity of the stylisations of the technological innovation process underlying these models, two of them -- the "deterministic" and "leapfrogging" games -- elucidate respectively Indian and Brazilian firm behaviour. Let us start with the Gilbert & Newbery deterministic model as applied to the Indian case study. To illustrate the applicability of their game-theoretic model, let us first recapitulate the technology strategies and environments of Indian firms. Throughout this discussion the reader may refer to Figure 5.2, *India: The Strategic Interaction of Firms and Government.*

As discussed in the case study chapter and in Section II above, though Indian defence and capital goods firms rely extensively on foreign licensing, they invest little in complementary technological activities, such as research and development and learning-by-searching. In many cases, the Indian government's industrial, trade and technology policies have unintentionally encouraged the emergence of a highly concentrated market structure, consisting of a few, huge, vertically integrated firms. The combined effects of firms' narrow technology strategies and external environment has limited the adoption of new technologies as well as their diffusion.

Figure 5.2: India: The Strategic Interaction of Firms and Government



As suggested earlier, Gilbert & Newbery's stylisation of a patent race is a poor representation of innovation because they assume a deterministic relationship between R & D expenditure and the time of innovation. In this deterministic setting, which firm innovates first reduces to which firm is willing to pay more for the innovation. In effect, the innovation is auctioned off to the firm willing to pay the most for it. Although a weak model of patent races, Gilbert & Newbery's model is a much better representation of the technology licensing process in India. In the Indian licensing context, the issue is which firm is willing to pay more to secure the foreign license.

Paralleling the outcome of their deterministic model, one may then expect to find similar strategic behaviour among Indian firms; namely, that the country's monopolistic firms would be willing to pay more to acquire foreign licenses. Since these firms will expend more for the license there will also be preemption. The tendency for India's monopolistic firms to preempt rivals from acquiring foreign licenses has, in fact, been confirmed by a recent study that examined the relationship of firm size to imports of foreign technology. The study, which is based on questionnaires and interviews, found that larger firms both paid substantially more and obtained an absolutely higher proportion of licenses than other sized firms.[145]

An additional factor related to the preemptive licensing behaviour of Indian firms is that some firms will strategically seek shallow and/or narrowly focused technology transfer agreements. If the agreement is complex, for example, that is, contains training and other forms of technology acquisition, the license is likely to take a long time getting through the Indian government's approval process. There is then the risk that the license may be denied by the government, or that the foreign supplier may become impatient and loose interest and seek a rival Indian partner.

By granting only one foreign license for a particular technology to a single firm, the Indian government, in effect provides the recipient firm with monopoly power and hence allows for shelving. The rationale behind the Indian government's policy of granting the Indian licensee with exclusive market access is to prevent the foreign licensor from setting up a subsidiary in the country for the duration of the agreement. Additionally, the Indian government wants to prevent any one foreign technology supplier from dominating the market.[146]

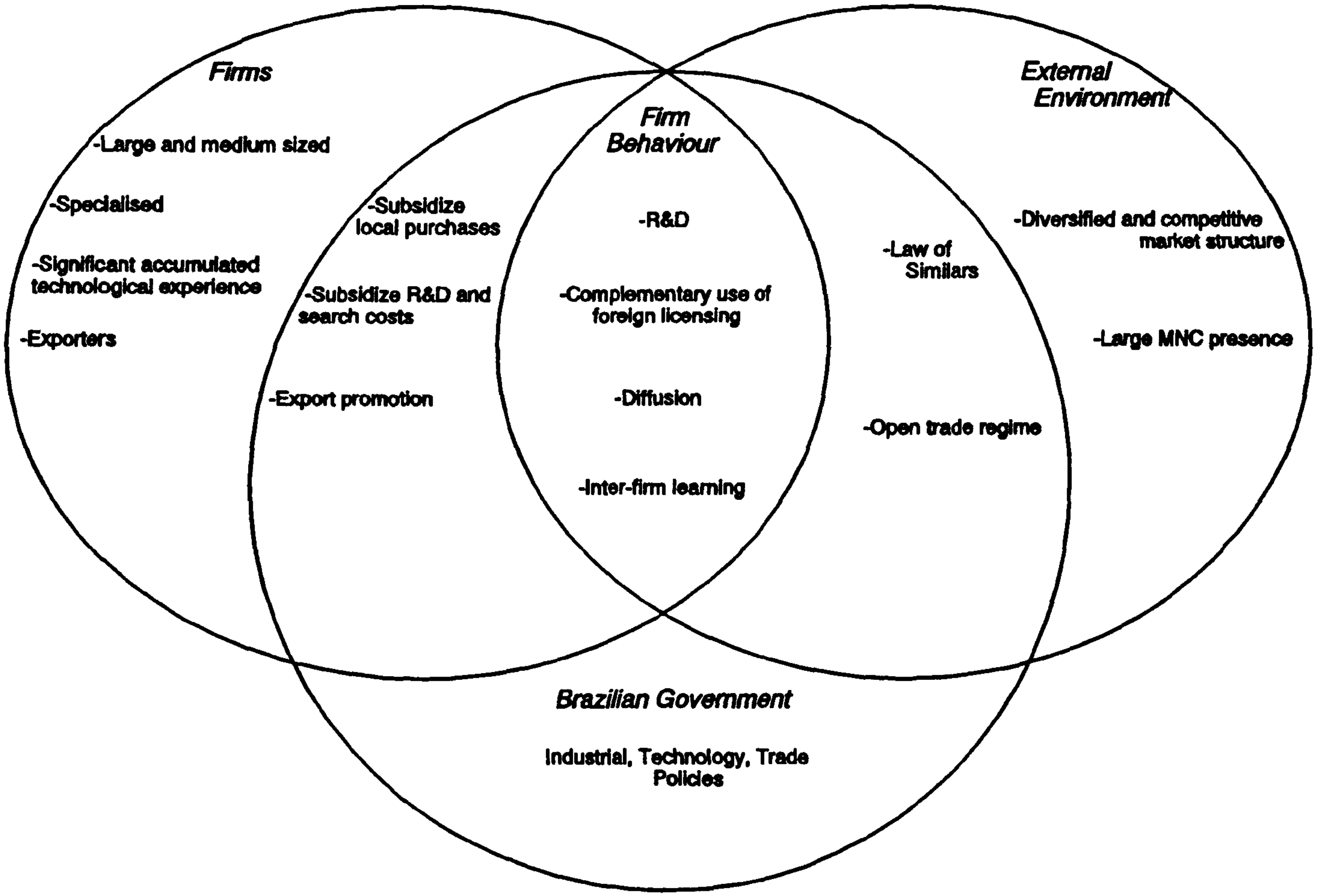
Due to the replacement effect outlined in the Gilbert & Newbery deterministic model, there will be strategic shelving of technology by Indian firms if there is a single license. Indeed, as discussed above, foreign licensors to Indian firms found that these firms tended to sit on the acquired technology, denying its potential diffusion. This shelving behaviour was also observed by Indian bureaucrats in the commerce ministry. In an interview with this author, one bureaucrat acknowledged, "Very few of India's MRTP firms do anything with the technology they import. Even though many are extremely profitable, they won't invest much in complementary R & D."[147]

What would happen, for example, were the Indian government to allow multiple licensing between foreign suppliers and Indian firms? The strategic behaviour of Indian firms might shift. Initially a firm might successfully preempt a rival from obtaining a highly sought after foreign technology. Later, however, the firm would be more likely to exploit the technology contained in the license because of the fear that if it did not make use of the superior technology, a rival could profit by exploiting a licensed technology that was less superior.

The tendency towards preemption and technology shelving by Indian firms has led to the structural uncompetitiveness of the country's economy. First, such behaviour has contributed to the continued obsolescence of the country's technological base. Limiting technology acquisition via foreign licensing to securing and obtaining licenses that incorporate relatively older technologies, only reinforces path dependent development. As hypothesized earlier, large, vertically integrated firms will have a greater commitment to old technology because of the significant technology-specific investments they have made upstream and downstream. Second, since adoption and diffusion of new technologies is thwarted because of shelving, few externalities are generated in terms of inter-firm learning through subcontraction arrangements. Preemption and shelving thus also buttress India's highly concentrated market structure.

In stark contrast to India, Brazil's more competitive domestic and trade environments have stimulated the adoption, development and exploitation of foreign as well as domestic technologies by its defence and capital goods firms. Learning by doing and the accumulation of experience are central features of R & D in Brazil. In these respects, the Fudenberg et al., "leapfrogging" model may be a better representation of the strategic incentives that inform Brazilian firm behaviour. Throughout this discussion please refer to Figure 5.3, *Brazil: The Strategic Interaction of Firms and Government.*

Figure 5.3: Brazil: The Strategic Interaction of Firms and Government



Recall the earlier argument that Brazilian firms have accumulated more technological expertise than their Indian counterparts. This difference was explained by the fact that Brazilian companies consciously expended considerable effort to accumulate and improve their technological capabilities through research and development activities, subcontraction, specialised employee training assistance, and searching. While Brazilian firms also sought foreign licenses, they tended to use licenses to help upgrade and complement their *existing* technological capabilities, rather than as Indian firms tended to do -- use licenses strategically to bar substitute products from entering the market.

The Brazilian government's technology policies have encouraged indirectly the technological learning and search activities of Brazilian firms, and have supported inter-firm diffusion of technology. First, the provision of financial project and R & D feasibility assistance to Brazilian firms, via FINEP programmes, has certainly lowered the costs entailed in searching for new technologies as well as reduced the uncertainties involved in their adoption. Second, the funding or encouragement of the work of specialised technological agents, for example, Brazil's universities and the R & D centres of the military, has encouraged the diffusion of technology among firms, thereby reducing the potential for shelving. A direct application of the Fudenberg et al., model is now offered.

One may recollect from the discussion of Fudenberg et al., that the possibility of leapfrogging the leader in a patent race induces competition and intensifies R & D activity. For example, their multistage patent race model demonstrates that the closer firms are to each other, the fiercer the competition, and the more firms will invest in research and development in the hope of obtaining the patent first. One of the perhaps unintended consequences of the Brazilian government's trade and technology policies is that such broad policies have engendered close competitive relations between the country's domestic firms. For instance, the government's trade policies of promoting direct foreign investment and exports by Brazilian firms has pressured domestic firms to employ competitive technologies that are very close to the international frontier. By allowing for relatively open competitive foreign licensing and collaboration arrangements, Brazilian firms are induced to exploit these technologies earlier and at faster rates of adoption than their Indian counterparts, who are motivated to shelve.

In effect, by applying competitive pressures from domestic as well as international sources, and subsidizing firms' technological efforts, the Brazilian government has induced firms to race at relatively close distances. We can thus explain the larger investments in learning and in R & D-related activities by Brazilian firms, which in turn have contributed overall to these firms' international competitiveness.

Conclusion

This chapter has integrated the previous case studies on the Brazilian and Indian defence industries and has provided a comparative assessment. As outlined in Chapter 2, the variation in technological and manufacturing capabilities as well as in international competitiveness of these two countries' arms industries can be explained in terms of firm strategies, as well as the strategic interaction among firms and the state. Accordingly, this chapter has delineated and contrasted Brazilian and Indian firms' technology strategies. It has also outlined the trade and technology policies of the Brazilian and

Indian governments. The author has then analysed the differing and separate effect of these policies on Brazilian and Indian firm behaviour. As evidenced by the game theoretic discussion above, the interaction between the defence and capital goods firms and the state in Brazil provided a conducive and competitive environment in which firms could pursue strategies that augmented their capabilities and competitiveness in the global arms market. In contrast, the interaction between the Indian government and the defence/capital goods firms stultified competitive inducements for firms to develop dynamic technological and export capabilities.

Endnotes

[1]This point is made by Carl Dahlman and Francisco Sercovitch, "Local Development and Exports of Technology," *World Bank Staff Working Papers, No. 667*, (Washington, D.C.: The World Bank,1984), 43.

[2]World Bank, *Industrial Policies and Manufacturing Exports* (Washington, D.C.: The World Bank, 1983), 23.

[3]Ibid., 27.

[4]Daniel Chudnovsky, *South-South Trade in Capital Goods: The Latin American Experience*, Texta para Discussão N. 57 (Rio de Janeiro: Universidade Federal de Rio de Janeiro, Instituto de Economia Industrial, Outubro, 1984), 23.

[5]See J. Tavares de Araujo, L. Haguenauer, and J. Borco Machado, "Protecão Competitivade e Desempenho Exportador da Economia Brasileira nos Anos 80," *Revista Brasileira de Comércio Exterior*, Vol. 5, no. 26 (Novembro-Decembro 1989).

[6]Venilton Tadini, *O Setor de Bens de Capital Sob Encomenda: Análise do Desenvolvimento Recente (1974/83)* (São Paulo: Departamento de Economia, Universidade de São Paulo, Faculdade de Economia e Administração, 1986), 107.

[7]See William G. Tyler, *The Brazilian Industrial Economy* (Lexington: Lexington Books, 1981).

[8]See World Bank, page 65 for details.

[9]These studies are respectively: The World Bank, *Brazil: Protection and Competitiveness of the Capital Goods Producing Industries*, Report No. 2488 (Washington, D.C.: The World Bank, 1980), and William G. Tyler, *Advanced Developing Countries as Export Competitors in Third World Markets: The Brazilian Experience* (Washington, D.C.: CSIS, 1980).

[10]Tyler, *Advanced Developing Countries*, 56-57.

[11]Morris Teubal, "The Role of Technological Learning in the Exports of Manufactured Goods: The Case Study of Selected Capital Goods in Brazil," *World Development*, Vol. 12, no. 8 (1984): 854.

[12]Interview with official from Brazil's Ministry of Planning, Brasilia, August 1989.

[13]Ibid.

[14]Cited in Lorne E. Kavic, *India's Quest for Security* (Berkeley: University of California Press, 1967), 107.

[15]J.N. Bhagwati and Padma Desai, *India: Planning for Industrialisation: Industrialisation and Trade Policies Since 1951* (New Delhi: Oxford University Press, 1970); and J.N. Bhagwati and T.N. Srinivisan, *Foreign Trade Regimes and Economic Development: India* (New York: Columbia University Press, 1975).

[16]Bhagwati & Srinivisan, 226.

[17]Isher Judge Ahluwalia, *Industrial Growth in India: Stagnation Since the Mid-Sixties* (New Delhi: Oxford University Press, 1985), 114.

[18]Sanjaya Lall, *Building Industrial Competitiveness in Developing Countries* (Paris: OECD, 1990), 57.

[19]See Martin Wolf, *India's Exports* (New York: Oxford University Press for the World Bank, 1982); Depak Nayyar, *India's Exports and Export Policies* (Cambridge: Cambridge University Press, 1976); and Government of India, Ministry of Commerce, *Report of the Committee on Trade Policies* (New Delhi: Government of India, December 1984).

[20]Cited in Ahluwalia, 116.

[21]Ibid., 115-116.

[22]Depak Nayyar, "India's Export Performance, 1970-85: Underlying Factors and Constraints," in *The Indian Economy*, eds., Robert E.B. Lucas and Gustav F. Papanek (Boulder: Westview Press, 1988), 225.

[23]See Sanjaya Lall, *Developing Countries as Exporters of Technology: A First Look at the Indian Experience* (London: Macmillan, 1982).

[24]C. Dahlman and F. Sercovitch, 47.

[25]See, for example, Ashok V. Desai, ed., *Technology Absorption in Indian Industry* (New Delhi: Wiley Eastern Ltd., 1988).

[26]Cited in Dahlman and Sercovitch, 45.

[27]Lall, "India," 555.

[28]See V.M. Gumaste, *Technology Self Reliance in the Automobile and Ancillary Industries of India* (Madras: Institute for Financial Management and Research, 1988), 109.

[29]Confidential interview with a high-ranking minister responsible for science and technology affairs, Brasilia, August 1989.

[30]Carl Dahlman, "Foreign Technology and Indigenous Technological Capability in Brazil," In *Technology Capability in the Third World*, eds. Martin Fransman and Kenneth King (London: Macmillan Press, 1984). See also Emanuel Adler, *The Power of Ideology: The Quest for Technological Autonomy in Argentina and Brazil* (Berkeley: University of California Berkeley Press, 1987).

[31]For a thorough review of these research institutions see Adler, page 163.

[32]See I PBDCT, *Plano Básico de Desenvolvimento Científico e Technológico, 1973-74* (Brasilia: Presidência da Republica, 1973); and II PBDCT, *Plano Básico de Desenvolvimento Científico e Technológico, 1975-1977* (Brasília: Presidência da Republica, 1975).

[33]See I PBDCT, *Plano Básico de Desenvolvimento Científico e Technológico, 1973-74*, 68-69.

[34]Company interviews. See also Roberto Pereira de Andrade and José de Souza Fernandes, *Veículos Militares Brasileiros* (São Paulo: Aquarius, 1983).

[35]I PBDCT 1973-74, 72.

[36]Interview with CTA officials, São José dos Campos, November 1988.

[37]Ibid.

[38]See *II PBCDT, 1975-1977.*

[39]World Bank, *Brazil: Industrial Policies and Manufacturing Exports*, 230.

[40]Adler, 195.

[41]Carl J. Dahlman and Claudio R. Frischtak, *National Systems Supporting Technical Advance in Industry: The Brazilian Experience*, World Bank Industry and Energy Department Working Paper Industry Series Paper No. 32 (Washington, D.C.: The World Bank, June 1990), 14.

[42]World Bank, *Brazil: Industrial Policies and Manufacturing Exports*, 103.

[43]Francisco Sercovitch, "Brazil," *World Development*, Vol. 12, no. 5/6 (1984): 594.

[44]*Government of India 1983 Technology Policy Statement* cited in Gumaste, 8.

[45]Cited by Thomas Owen Eisemon, "Insular and Open Strategies for Enhancing Scientific and Technological Capacities: Indian Educational Expansion and its Implications for African Countries," in *Technological Capability in the Third World*, eds., Martin Fransman and Kenneth King (London: Macmillan, 1984), 269.

[46]A. Rahman, *Science and Technology in India* (New Delhi: National Institute of Science, Technology and Development Studies, February 1984), 41.

[47]Ghayar Alam and John Langrish, "Government Research and its Utilisation by Industry: The Case of Industrial Civil Research in India," *Research Policy*, 13 (1984): 56.

[48]Data derived from "Industrial R&D Expenditures by Public Sector - Ministry - Department - State - Government-Wise During 1980-81," in A. Rahman, *Science and Technology in India*, 192.

[49]Baldev Raj Nayar, *India's Quest for Technological Independence* (New Delhi: Lancers Publishers, 1983), 327.

[50]Ashok V. Desai, "The Origin and Direction of Industrial R&D in India," *Research Policy*, 8 (1980): 91.

[51]Alam and Langrish, "Government Research and its Utilisation by Industry," 55.

[52]S. R. Valluri, "Management of R and D Institutions and Self-Reliance," *Economic and Political Weekly*, 25 August 1990, M111.

[53]Ibid., M112.

[54]India, Parliament, Committee on Public Undertakings, *Bharat Earth Movers Ltd.*, Ministry of Defence, Department of Defence Production and Supplies, 1987-88. Eighth Lok Sabha (New Delhi: Lok Sabha Secretariat, 1987), 38.

[55]Cited in Diana Crane, "Technological Innovation in Developing Countries: A Review of the Literature," *Research Policy*, Vol. 6, no. 4 (October 1977): 390.

[56]Valluri, "Management of R and D Institutions and Self-Reliance," M111.

[57]Ashok V. Desai, "Technology Acquisition and Application: Interpretations of the Indian Experience," in *The Indian Economy: Recent Developments and Future Prospects*, eds., Robert E.B. Lucas and Gustav F. Papanek (Boulder: Westview Press, 1988), 177.

[58]U.S. Bajpai, ed., *India's Security: The Politico-Strategic Environment* (New Delhi: Lancers Publishers, 1983), 64.

[59]Alam and Langrish, "Government Research and its Utilisation by Industry," 57.

[60]Nayar, *India's Quest for Technological Independence*, 328.

[61]*India Weekly*, 7-13 August 1987.

[62]Ibid.

[63]Sanjaya Lall, "India's Technology Capability: Effects of Trade, Industrial, Science and Technology Policies," in *Technological Capability in the Third World*, eds., Martin Fransman and Kenneth King (London: Methuen, 1984), 234-35.

[64]Ghayur Alam, "India's Technology Policy: Its Influence on Technology Imports and Technology Development," in *Technology Absorption in Indian Industry*, ed., Ashok V. Desai (New Delhi: Wiley Eastern Ltd., 1988), 153.

[65]Ibid.

[66]See Ashok V. Desai, "Origin and Direction of Industrial R & D in India," *Research Policy*, 9 (1980): 74-96; "The Slow Rate of Industrialization: A Second Look," *Economic and Political Weekly*, Vol. 19, nos. 31-33 (1984), 1267-1272; and "Technological Performance in Indian Industry: The Influence of Market Structure and Policies," in *Technology Absorption in Indian Industry*, ed., Ashok V. Desai (New Delhi: Wiley Eastern Ltd., 1988), 26.

[67]Ibid.

[68]Keya Sarkar, "Machine Tool Industry: Gearing Up -- With a Little Help from Japan," *Business India*, 23 September - 6 October 1985, 87.

[69]Alam, "India's Technology Policy," 146.

[70]Lall, "India's Technology Capability," 236.

[71]See, for example, R.M. Bell and D. Scott-Kemmis, "Indo-British Technical Collaboration Since the Early 1970s - Change, Diversity and Forgone Opportunities," Science Policy Research Unit mimeo (Brighton: University of Sussex, 1984).

[72]World Bank, *India: An Industrialising Country in Transition* (Washington, D.C.: The World Bank, 1989), 86.

[73]Ahluwalia, *Industrial Growth in India*, 162-63.

[74]Lall, "India," 562-63.

[75]Government of India, Public Accounts Committee, 1981-82 (Seventh Lok Sabha) *Development of a Helicopter*, Ministry of Defence (New Delhi: Lok Sabha Secretariat, March 1983), 26.

[76]See Don Scott-Kemmis and Martin Bell, "Technological Dynamism and Technological Content of Collaboration: Are Indian Firms Missing Opportunities?" in *Technology Absorption in Indian Industry*, ed., Ashok V. Desai (New Delhi: Wiley Eastern Ltd., 1988).

[77]Ibid., 89.

[78]See Alam, "India's Technology Policy," and Charles Cooper, "Supply and Demand Factors in Indian Technology Imports: A Case Study," both in *Technology Absorption in Indian Industry*. Refer also to Economic Administration Reforms Commission, Report No. 20, *Technology Development and Acquisition* (New Delhi: Cabinet Secretariat, Rashtrapati Bhavan, 1983).

[79]Scott-Kemmis & Bell, "Technological Dynamism," 94-95.

[80]Economic Administration Reforms Commission, Report No. 20, *Technology Development and Acquisition*, 26.

[81]See UNCTAD's study, *Technology Issues in the Capital Goods Sector: A Case Study of Leading Machinery Producers in India* (New York: United Nations, 1983).

[82]Sanjaya Lall, *Building Industrial Competitiveness in Developing Countries* (Paris: OECD, 1990), 61.

[83]Martin Bell, Bruce Ross-Larson and Larry E. Westphal, "Assessing the Performance of Infant Industries," *Journal of Development Economics*, Vol. 16, nos. 1-2 (September-October 1984): 123-24.

[84]D. Chudnovsky, Ma Nagao, and S. Jacobsson, *Capital Goods Production in the Third World* (London: Francis Pinter Publishers, 1983), 110.

[85]Ibid.

[86]UNCTAD, *Technology Issues in the Capital Goods Sector*, 121.

[87]Teubal, 861.

[88]Chudnovsky *et al.*, 66.

[89]F.S. Erber, *Technology Development and State Intervention: A Study of Brazilian Capital Goods Industry*, unpublished Ph.D. dissertation (Brighton: University of Sussex, 1978).

[90]Ibid., 95.

[91]Ibid., 93.

[92]Sercovitch, 594.

[93]Carl Dahlman, Bruce Ross-Larson, and Larry Westphal, "Managing Technological Development: Lessons from the Newly Industrialising Countries," *World Development*, Vol. 15, no. 6 (1987): 772.

[94]Ibid.

[95]R.M. Bell, ""Learning" and the Accumulation of Industrial Technological Capacity in Developing Countries," in *Technology Capability in the Third World*, eds., Martin Fransman and Kenneth King (London: Macmillan, 1984), 197.

[96]Interview with Avibras employee, São José dos Campos, Brazil, August 1989.

[97]See H.N. Da Cruz and N.B. Da Silva, "Mudança Technológica no Setor Metal Mecânico: Relatório Parcial, Parte II," mimeo, IDB/ECLA/IDRC Research Programme on Scientific and Technological Development in Latin America (São Paulo: Fundação Instituto de Pesquisas Economicas, 1981); and Carl Dahlman, *A Microeconomic Approach to Technical Change: The Evolution of the USIMINAS Steel Firm in Brazil*, unpublished Ph.D. dissertation (New Haven: Yale University, 1979).

[98]See R.M. Bell and D. Scott-Kemmis, *Indo-British Technological Collaborations Since the Early 1970s: Change, Diversity and Forgone Opportunities*, 5 vols (Brighton, U.K.: Science Policy Research Unit, University of Sussex, 1985).

[99]See David J. Teece, "Technological Change and the Nature of the Firm," in *Technical Change and Economic Theory*, eds., Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete (London: Pinter Publishers, 1988), 264-65.

[100]D. Scott-Kemmis and M. Bell, "Technological Dynamism and Technological Content of Collaboration," 97-99.

[101]Ibid., 91.

[102]Amiya Bagchi, "The Economic Impact of Trust and Confidence," *Far Eastern Economic Review*, 30 May 1985, 78-79. Also cited in Eddie J. Girdner, "Economic Liberalisation in India: The New Electronics Policy," *Asian Survey*, XXVII, no. 11 (November 1987): 1188-1204.

[103]Valluri, "Management of R and D Institutions and Self-Reliance," M111.

[104]D. Scott-Kemmis and M. Bell, "Technological Dynamism and Technological Content of Collaboration," 94.

[105]See R.R. Nelson and S.G. Winter, *An Evolutionary Theory of Economic Change* (Boston: Belknap Press for Harvard University Press, 1982).

[106]Dahlman, et al, "Managing Technology Development," 754.

[107]Bell and Scott-Kemmis, "Technological Dynamism," 72.

[108]Ibid., 73

[109]For a useful review of the literature, see Stephen Davies and Bruce Lyons with Huw Dixon and Paul Geroski, *Economics of Industrial Organisation* (London: Longman Group, U.K., Ltd., 1988).

[110]See Kripa Shankar, "Characteristics of Diversification in Indian Industry," *Economic and Political Weekly*, 3 June 1989, 1250.

[111]Sanjaya Lall, "India's Technology Capability," 231.

[112]Chudnovsky, et al., 139.

[113]Gustav Ranis, "Determinants and Consequences of Indigenous Technological Activity," in *Technological Capability in the Third World*, eds., Martin Fransman and Kenneth King (London: Macmillan Press, Ltd, 1984), 102.

[114]The following discussion is based on company data and an interview with Gustavo Frank, Marketing Director for Metal Leve, São Paulo, November 1988.

[115]Ibid.

[116]Chudnovsky, et al., 138.

[117]Bharat Bhusan, "Ancillarisation: A New Production Strategy," *Business India*, 16-29 January 1984, 88.

[118]Nathan Rosenberg, *Perspectives on Technology* (Cambridge: Cambridge University Press, 1976.)

[119]Howard Pack, "Fostering the Capital Goods Sector in LDCs," *World Development*, Vol. 9, no. 3 (1981): 232.

[120]Gumaste, 109.

[121]Keya Sarkar, "Machine Tools Industry: Gearing Up with a Little Help from Japan," *Business India*, 23 September - 6 October 1985, 88.

[122]World Bank, *India: An Industrialising Country*, 105.

[123]Bell and Scott-Kemmis, 92.

[124]See Ward Morehouse, "Technology and Enterprise Performance in the Indian Tractor Industry: Does Self-Reliance Measure Up?" *Economic and Political Weekly*, 20 December 1980, 2139-52; and V.K. Laroia, "Case Study of Swaraj Tractors," paper presented at a UNIDO-ICRIER Workshop on Management and Technological Change, ICRIER, New Delhi, 1988, which is cited in Kathuria, M120.

[125]See, for example: P. Dasgupta & J. Stiglitz, "Uncertainty, Industrial Structure, and the Speed of R & D," *Bell Journal of Economics*, 11 (1980): 1-25; D. Fudenberg & J. Tirole, "Preemption and Rent Equalisation in the Adoption of New Technology." *Review of Economic Studies*, 52 (1985): 383-401; D. Fudenberg, R. Gilbert, J. Stiglitz, and J. Tirole, "Preemption, Leapfrogging, and Competition in Patent Races," *European Economic Review*, 22 (1983): 3-31; R. Gilbert & D. Newbery, "Preemptive Patenting and the Persistence of Monopoly," *American Economic Review*, 74 (1982): 514-526; C. Harris & J. Vickers, "Racing with Uncertainty," *Review of Economic Studies*, 54 (1987): 1-22; T. Lee & L. Wilde, "Market Structure and Innovation: A Reformulation," *Quarterly Journal of Economics*, 194 (1980): 429-436; G.C. Loury, "Market Structure and Innovation," *Quarterly Journal of Economics*, 93 (1979): 395-410; J.F. Reinganum, "On the Diffusion of a New Technology: A Game Theoretic Approach," *Review of Economic Studies*, 48 (1981a): 395-405; -- "Market Structure and the Diffusion of New

Technology," *Bell Journal of Economics*, 12 (1981b): 618-624. -- "A Dynamic Game of R & D: Patent Protection and Competitive Behaviour," *Econometrica*, 50 (1982): 671-688; -- "Technology Adoption under Imperfect Information," *Bell Journal of Economics*, 14 (1983a): 57-69; and -- "Uncertain Innovation and the Persistence of Monopoly," *American Economic Review*, 73 (1983b): 741-48.

[126]Gilbert & Newbery, 515.

[127]Jean Tirole, *The Theory of Industrial Organisation* (Cambridge: MIT Press, 1989), 393.

[128]I would like to acknowledge the invaluable comments provided by Dr. Robert Powell, U.C., Berkeley, regarding the Gilbert & Newbery deterministic model.

[129]Gilbert & Newbery, 514.

[130]Gilbert & Newbery, 518.

[131]See Kenneth Arrow, "Economic Welfare and the Allocation of Resources for Inventions," in *The Rate and Direction of Inventive Activity*, ed., R. Nelson (Princeton: Princeton University Press, 1962).

[132]See David J. Teece, "Technological Change and the Nature of the Firm," In *Technical Change and Economic Theory*, eds., Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete (London: Pinter Publishers, 1988).

[133]Teece, 275.

[134]See P. Dasgupta & J. Stiglitz (1980); T. Lee & L. Wilde (1980); G.C. Loury (1979); and J. Reinganum (1982).

[135]See Reinganum (1983b).

[136]Reinganum (1983b), 741.

[137]Tirole, 396.

[138]Ibid.

[139]Fudenberg, et al., 3.

[140]Tirole, 398.

[141]Fudenberg, et al., 10.

[142]Ibid., 14.

[143]Tirole, 399.

[144]Fudenberg, et al., 14.

[145]Cited in Sanjay Kathuria, "Market Structure and Innovation: A Survey of Empirical Studies of Shumpeterian Hypotheses for Developed Countries and India," *Economic and Political Weekly*, 26 August 1989, M113-M124.

[146]The Indian government's licensing policies are currently under review as part of the country's broader economic liberalisation programme initiated in 1991.

[147]Interview, Ministry of Commerce, Indian Embassy, Washington, D.C. February 1991.

Chapter VI

CONCLUSION

This chapter concludes the thesis and is divided into four sections. First, the author returns to the research questions posed in the introductory chapters concerning defence industrialisation in the NICs. She reconsiders the broad objectives of the thesis and briefly summarises her argument. In the second section, the author re-examines the three hypotheses of her conceptual framework introduced in Chapter 2 regarding: 1) firms' technology strategies, 2) an integrated defence-industrial base, and 3) government trade, industrial and technology policies. She argues that these hypotheses *interactively* account for the variance in Brazil's and India's defence industrial capabilities and export competitiveness. In section three, the author revisits her critical analysis in Chapter 2 of the relevant scholarship on defence industrialisation in the NICs from international relations, international political economy, comparative politics as well as development and neoclassical economics. Drawing on the empirical findings of the Brazilian and Indian case studies, she discusses the limitations of political science and economics-based theoretical explanations. The inadequacy of these explanations is traced to their failure to incorporate the pivotal role played by firms. In the fourth and final section of this chapter, the author briefly outlines some of the important theoretical implications as well as limitations of her own work, and suggests avenues for future research.

The Argument in Brief

This thesis has broadly addressed an issue central to both international relations and economics; namely, how competitive advantage, which is essential in determining a state's power and wealth, is created and distributed among nation states. Competitive advantage in this thesis has been defined in terms of a country's possession of two industries that are militarily and economically strategic -- the defence and capital goods industries. Though all states are motivated to develop and sustain these critical industries, the ability of states to be competitive internationally in these high technology sectors varies enormously. In particular, the thesis has focused on the growth of the newly industrialising countries' defence and manufacturing industries during the 1970s and 1980s and their potential export success in global markets. The objective of the thesis has been to explain how these countries derived their defence-industrial capabilities, and what accounted for the variance in capabilities and export competitiveness among the NICs.

As evidenced in Chapter 2, much of the literature on the emergence of the NICs in the international political economy has concentrated largely on the state. This thesis has demonstrated that firms also play important roles in explaining the development of a state's defence industrial capability and competitiveness, and, consequently, its position in the international system. The author has employed comparative case studies from two newly industrialising countries, Brazil and India. She has shown that the interaction between firms and states determines the development of and variance in these two countries' capabilities and international competitiveness. In brief, she explains that the successful performance and competitiveness of Brazil's defence industries, in marked contrast to India's, resulted from Brazilian firms' deep and complex technology strategies, tight inter-industry linkages between defence and capital goods firms, and government policies that stimulated and reinforced technological innovation and diffusion at the firm level.

The Conceptual Framework

In an attempt to integrate the roles played by firms and states in the defence industrialisation process of the NICs, the author constructed a conceptual framework consisting of three dimensions. In this second section, the author re-examines this framework and her research design in light of the case study findings. Before doing so, however, it is useful to remind the reader that although each of the three dimensions of the framework provide a direct and separate means for comparing Brazil and India, these dimensions are, in fact, meant to be treated *interdependently*. It is only by exploring the *interactive* effects of state policies, linkages between the capital goods and defence firms, and firms' technology strategies that one can account for the variance between Brazil's and India's arms industries.

Firms' Technology Strategies

The first dimension of the author's conceptual framework is the technology strategies of defence and capital goods firms. As discussed in Chapter 2, a technology strategy entails decisions and conscious efforts by a firm to monitor new technologies, to absorb and adapt these technologies, and to invest in its own R & D capability. The author hypothesised that differences in the technology strategies of firms (whether they were sufficiently "deep" or not) would account for a firm's relative performance and competitiveness domestically and internationally within an industry. Consequently, a primary objective of the author's survey research and company site visits in Brazil and India was to explore and define the technology strategies of defence and capital goods firms. Thus, the contrast between Brazilian and Indian firms' technology strategies led the author to anticipate that Brazil's defence industry would be more capable and competitive because the technology strategies of Brazilian firms appeared to be more complex, involving most if not all of the activities described above.

In Chapter 3, the author showed that the successful technological development and international competitiveness of Brazilian defence companies (Embraer, Engesa, Avibras, D.F. Vasconcelos etc.) resulted in large part from these firms' technology strategies of making long-term cumulative R & D efforts and building systematically on foreign technological inputs -- licensing, coproduction, technical training arrangements. Further investigation of Brazilian defence and capital goods firms' technology strategies and comparative assessments with Indian firms occurred in Chapter 5. The author's survey research found that three common traits marked Brazilian firms' successful technology strategies.

The first was the active search, transference and absorption of both foreign and domestic technologies. The second was the use of "specialised technological agents" -- universities, research institutes, consulting engineering firms -- by Brazilian defence and capital goods firms to enhance their own in-house technological capabilities. The third approach pursued by Brazilian firms was heavy investments in human capital formation, by hiring foreign personnel or by providing company employees with specialised training and educational programmes in Brazil and abroad. This three-pronged technology strategy reduced overall risks, lowered information search costs and shortened production-to-market times. It also ensured that foreign technology sources *reinforced* rather than *replaced* Brazilian defence and capital goods firms' technology strategies -- a critical factor explaining the relative competitiveness of the Brazilian arms industry in comparison to India's.

The explicit investment in the acquisition of technology capabilities by Brazilian firms was dramatically contrasted with the experience of Indian firms. The Indian case study, particularly the review of the Light Combat Aircraft and Advanced Light Helicopter defence production programmes, projected a picture of limited indigenous technological capability and extreme reliance by firms on all types of foreign technology assistance. The author linked this evident lack of competitiveness of India's defence industry in part to the shortcomings of the technology strategies devised by the country's defence and capital goods firms.

In Chapter 5 three important factors were identified that helped to explain Indian firms' inadequate technology acquisition and development strategies. The first related to the lack of consistent and sufficient investments in in-house R & D activities. The second factor was that, as a consequence of these firms' limited technical experience, Indian defence and capital goods firms often made poor, uninformed technology selections. This shortcoming stemmed from these firms' overestimation of their own technological absorption capabilities and underestimation of what was required to secure the successful transference of imported technologies. Indeed, the third factor, the narrow technology acquisition approaches of Indian firms, accounted for this underestimation.

Compared to Brazilian firms, Indian companies attached little importance, and thus expended little effort in absorbing, adapting and using foreign technologies to upgrade their existing R & D capabilities. For example, the reader learned that most technology transfer agreements with foreign suppliers did not include any technical training assistance, company site visits, or the hiring of specialised personnel. It was also evident that Indian firms' technology strategies generally had not enabled them to generate new or even improve existing technology, not only *because of their limited capability to learn but because of the inefficient use of foreign technologies*. Hence, the first dimension of the author's conceptual framework -- the technology strategies of defence and capital goods firms -- provided one of the pieces to the larger puzzle of why India failed to develop a largely indigenous defence industry, capable of achieving a modicum of export competitiveness.

An Integrated Defence-Industrial Base

The second dimension of the author's conceptual framework is the degree of integration of a country's defence-industrial base. The author hypothesised that the relatively successful performance and competitiveness of some NIC arms producers, in contrast to others, was based on having a highly integrated and diversified defence-industrial base, characterised by strong linkages between defence and capital goods firms. Thus in researching and contrasting the defence-industrial bases of Brazil and India, the author investigated the extent of the linkages, particularly in the form of subcontraction activity, between these two technologically strategic sectors. She also delineated some structural factors -- firm-size, vertical integration and market concentration -- that conditioned these linkages. As evidenced in Chapter 5, in several instances the linkages between the defence and capital goods sectors were affected by government policies -- the third and last dimension, which will be discussed below.

The author's survey research in Chapter 3 provided clear evidence of unusually strong inter-industry linkages between Brazil's defence and capital goods firms. Reacting to recessions in the Brazilian capital goods sector, many of these firms diversified into military production, later becoming sizeable arms exporters. A number of smaller capital goods firms, as well as foreign multinational corporations based in Brazil, converted part of their production lines to supply these larger, domestic defence companies.

The beneficial effects of these inter-industry linkages on the competitiveness of the Brazilian defence and capital goods firms was discussed in Chapter 5. They included more rapid technological development and diffusion between the capital goods and defence industries. For example, many important defence exporters, such as Embraer and Engesa, actively promoted and strengthened subcontraction arrangements with smaller capital goods firms, transferring various technologies and manufacturing know-how in order to improve and ensure the quality of their suppliers. This diffusion of technology, as well as the promotion of capital goods sales abroad through the export activities of Brazilian arms producers, enabled many local capital goods firms to generate important economies of scale and specialisation.

In stark contrast to Brazil's integrated defence-industrial base, Chapter 4 showed that the linkages between India's defence and capital goods firms were extremely weak and fragmented. Ideological, institutional and economic factors had constrained the development in India of a truly integrated defence-industrial base. Two factors were particularly detrimental and reinforced the autarkic development of each sector. The first was the government's legislated separation of the state-owned defence industries from the country's largely private capital goods sector. The second was that the defence and capital goods firms were both reluctant to implement the Indian government's ancillarisation policy, which was intended to encourage private sector subcontraction by the state-owned defence firms. On the one hand, this government directive threatened the inefficient, vertically integrated defence firms, which resisted the ancillarisation policy, arguing that the private capital goods sector was incapable of producing defence items of the necessary high quality and standards. On the other hand, the ancillarisation programme failed to attract private sector participation because it did not ensure that defence firms would provide long-term procurement orders of sufficient scale. As evidenced in Chapters 4 and 5, the continued lack of integration between India's defence and capital goods firms prevented these industries from becoming more competitive and innovative through inter-sectoral learning and sharing.

Government Policies

State intervention, particularly government technology, industrial and trade policies, is the third dimension of the author's conceptual framework. The author hypothesised that differences in the extent and form of state intervention would also account for the variance in the pace, development and international competitiveness of the NICs' defence industrial capabilities. On this basis, she argued that the more a government's policies acted to stimulate pressures from both domestic and international market forces, the more technologically advanced and export competitive a country's defence industries would be.

In Chapter 5, the author compared the trade, industrial and technology policies of the Brazilian and Indian governments. The differences in these countries' policies were striking. In Brazil, for example, the government did not have a coherent, well formulated set of technology, industrial and trade policies targeted towards the arms industry. To the contrary, as investigated in Chapter 3, the Brazilian government's involvement was extremely limited. Its' technology, industrial and trade policies indirectly shaped a conducive environment that facilitated firm-level initiatives. For instance, the Brazilian government's technology policies helped to stimulate the technology acquisition and upgrading efforts of defence and capital goods firms by supporting government-related R & D institutes and universities, and by lowering the cost for private-sector R & D activity. The Brazilian government's industrial policies -- domestic content laws and subsidised purchases of local capital goods -- spurred the development and broadening of the capital goods industry through subcontraction arrangements, thereby strengthening linkages between the defence and capital goods sectors. Finally, the government's open trade policies of promoting direct foreign investment and exports encouraged Brazilian defence and capital goods firms to reduce costs, to upgrade product quality and service, and to keep abreast of global technological innovations.

By contrast, the defence-industrial policies of the Indian government were very articulate and highly specific. It used numerous technology, industrial and trade policies to direct as well as regulate the activities of its defence and capital goods industries. Such policies, however, had tremendous, negative unintended consequences for the viability of India's defence industry and has led to the perverse situation of the Indian government having to rely extensively on foreign licensed arms production and imports.

In terms of technology policies, the Indian government promoted technological self-reliance in defence production, primarily through the establishment of a massive government science and technology infrastructure. Nevertheless, as indicated by Indian defence firms' sad record of production, this infrastructure was often characterised by excessive fragmentation, poor inter-ministerial coordination and a high degree of R & D concentrated in isolated government laboratories.

As discussed in Chapter 4, the Indian government's industrial policies legislated the autarkic separation and development of the public defence sector from the private capital goods industries. Thus, given the relatively narrow focus on defence-related R & D and the institutional separation of the defence and capital goods industries, potential inter-industry technological spillovers were prevented. Lastly, the government's inward trade policy of import substitution protected and insulated India's defence and capital goods industries from international market forces, by discouraging direct foreign investment and by tightly regulating imports of foreign technologies. As a consequence, Indian firms not only had limited exposure and access to foreign technologies, but were denied important sources of competitive pressure.

In summarising the third dimension of the thesis' conceptual framework, it is important to emphasise the often unintended consequences of governmental policies. India tried to develop a competitive defence sector, but the unintended outcome of its trade, industrial and technology policies was precisely the opposite. This is what Chapter 5, particularly the game theoretic analysis of the Indian government's foreign technology licensing policy, revealed. The discussion of the Gilbert & Newbery deterministic model showed that the combined effects of the Indian government's trade, industrial and technology policies ironically induced many of the country's defence and capital goods firms strategically to preempt rivals from acquiring foreign licenses. By granting only one foreign license for a particular technology to a single dominant firm, the Indian government unintentionally provided the recipient firm with monopoly power, which then enabled the firm to shelve the technology and thus deny possibilities for its diffusion. Consequently, Indian defence and capital goods firms were neither induced to use up-to-date technologies nor to share those technologies through subcontracting arrangements with other firms. Hence, by looking at the strategic interaction of firms and the state, the technological obsolescence of Indian industry became more understandable.

In contrast to India, the indirect effects of the Brazilian government's broad technology, industrial and trade policies incited close competition as well as collaboration between defence and capital goods firms. This was demonstrated using the Fudenberg, Gilbert, Stiglitz, and Tirole "leapfrogging" model. Thus, the unintended effect of these government policies was to induce Brazilian firms to invest in improving their technological capabilities, which, in turn, contributed to their overall export competitiveness.

Bringing the Firm In

In this section the author returns to her criticisms, raised in Chapter 2, of political science and economics for their failure to integrate firms into their theoretical explanations of defence industrialisation in the NICs. Drawing on her research findings, the author discusses the analytical impact of firms on the main schools of thought, paying particular attention to the theoretical implications for international relations, international political economy, and comparative politics. Indeed, one of the important contributions of this Ph.D thesis is that it provides a number of counter-intuitive findings that challenge some of the IR, IPE and comparative politics precepts.

Political Science

Starting with the scholarship from international relations, the author argued that this literature could not adequately explain defence industrialisation, in particular, the variance in defence production capabilities among the NICs. There are two principal reasons for this failure. First, international relations almost exclusively emphasises the role of the external strategic environment in determining the defence production activities of the NICs, and second, the international relations' literature on defence production in the NICs lacks a conceptual framework. Underlying such theoretical inadequacies is the neglect to consider and incorporate the crucial role of firms.

Regarding the first criticism, the author suggested earlier that the observable variance in the NICs' defence industrial capabilities and export competitiveness posed a puzzle for international relations theory. Due to the presumed linkages between motivations and capability, IR theory predicts that states facing greater strategic threats would have the most technologically advanced and competitive defence production capabilities. Paradoxically, however, this is not what we observed in the Brazilian and Indian case studies.

As the Brazilian chapter showed, the Brazilian arms industry succeeded in becoming the leading arms producer and exporter among the NICs, in the **absence of a strategic threat**. This case study demonstrated the importance of examining firms' motivations and strategies, as opposed only to states'. As evidenced in Chapter 3, the emergence of Brazil's defence industries could not be explained in terms of industry simply responding to the military government, which, in turn was influenced by some strategic threat. Rather, on the basis of her interviews and survey research, the author found that firms diversified from capital goods into defence production because of market conditions -- recession in the Brazilian capital goods sector and a buoyant demand for arms by the Persian Gulf and Mid East states.

In stark contrast, the Indian case study, Chapter 4, revealed why, **in spite of serious strategic pressures** such as the threat of war with Pakistan and China, a regional arms race, and hegemonic aspirations, India's defence industry has been largely incapable of meeting the country's security needs. Given the stronger motivation on the part of the Indian government (in contrast to Brazil), the IR literature predicts that India would have a more advanced defence industry. Yet, the country does not. Why then do we see industry failure in India?

The Indian case study and the comparative analysis of Chapter 5 provided answers to this particular puzzle. These chapters offered important insights into the reasons for this failure at the level of firms; for instance, the overestimation by the Indian arms industries of their technological and manufacturing capabilities, their lack of contact with capital goods suppliers, their shallow technology strategies etc. These chapters also highlighted the negative impact of Indian government policies on these firms, particularly the lack of competitive market pressures to induce these firms to invest in and diffuse technology. In sum, both the Brazilian and Indian case studies show that the influence of a country's external environment on its defence-industrial capability is underspecified because firms are not treated as intervening variables between motivations and capabilities.

Returning to the second criticism of international relations, especially the subfield of international security studies, the author found the literature on defence industrialisation lacking both theoretical and comparative frameworks. In particular, the literature was characterised either by **individual** country case studies or by macrostatistical surveys, neither of which conceptually clarified the relationship between defence production and industrialisation in the NICs. The thesis fills these theoretical and methodological lacunas by providing a conceptual framework of defence industrialisation -- one that incorporates firms, links defence-industrial activities in an economy, and examines government policies -- in a comparative analysis of two of the

NICs' largest defence manufacturers. It is hoped that this framework and research design has extended not only our understanding of defence industrialisation in these two NICs, but can offer a basis for future comparative studies.

The variance in Brazil's and India's defence-industrial capabilities and competitiveness, which emerged clearly from the case study chapters, also poses a theoretical puzzle for both international political economy and comparative politics. As indicated in Chapter 2, particularly in the works by Sen, Gilpin and Haggard, international political economy and comparative politics theories suggest that the international system (characterised by anarchy and inter-state competition) and state power ("strong"/"weak" states) jointly should explain the variance in the industrial and export performance of states' defence industries. These theories argue that strong states are relatively more effective in achieving certain industrial objectives because of their ability to devise and implement necessary policy instruments. Nevertheless, as the reader learned from Chapters 4 and 5, the Indian government, a purportedly "strong" state, with many policy instruments at its disposal, has been unable to secure the development of an indigenous, technologically competitive defence industry. Why then do even "strong" states have difficulties in obtaining their objectives?

The author's research suggests a fundamental weakness underpinning international political economy and comparative politics theories: Their assumption that industry success or failure derives from the relative strength of states is obviously underdetermined. Both the Brazilian and Indian case studies, as well as Chapter 5, *The Strategic Interaction of Firms and States*, show that analyses confined to examining state policies present a partial and sometimes misleading image of the capacity of governments to achieve economic objectives. For example, in the case of Brazil, the author demonstrated that the success of the country's arms industries was not the result of direct state intervention, via trade and industrial policies on the part of a "strong" military government. Rather, these defence firms achieved global competitiveness on their own, using various technology and manufacturing strategies that emphasised coproduction, licensing, and technical assistance arrangements, often with foreign defence companies.

In the contrasting case of India, the reader witnessed tremendous state intervention and support for the country's defence industries through direct state ownership, regulation of foreign technology transfers, and government procurement, among many other policies. Yet, such state intervention failed to secure the objective of a relatively technologically self-sufficient defence industry, capable of producing an array of indigenous aerospace, armour and naval equipment.

Thus, as documented throughout this thesis, the ability of Brazilian and Indian government officials to attain viable, competitive defence industries depended as much upon what was outside the state, namely firms -- the importance of well-conceived technology strategies, and tight inter-firm linkages between the defence and capital goods sectors -- as what was inside the state (i.e. government policies and the ability to implement them). In short, this thesis has shown that theories from international relations, international political economy and comparative politics need to be extended to incorporate the potential contributions of firms.

Economics

As discussed in Chapter 2, there is a tendency by both neoclassical and development economics to relegate the NICs to being manufacturers and exporters of simple, low-cost, labour-intensive products. The puzzle raised by this caricature is how can neoclassical and development economics account for the NICs' development and, in some cases, international competitiveness in what is obviously one of the most technologically sophisticated industries in the world: defence production? The author argued that in order to solve this puzzle, economics had to move beyond the conventional neoclassical paradigm and to integrate the roles played by technology, firms and states.

For example, the author's microstudies of Brazilian and Indian defence firms, as well as the discussion in Chapter 5 of the strategic interaction of firms and states, raised a number of insightful findings regarding technology, its use by firms, and the impact of government policies on its development and diffusion. In Brazil, the reader learned that defence firms, such as Embraer, Engesa and Avibras, invested heavily in R & D activities as a central means of enhancing their international competitiveness. The survey findings revealed that many of these companies shared broad technology strategies which emphasised the successful development and assimilation of both indigenous and imported technologies. Such firm-level initiatives were complemented by the Brazilian government's financial support of several military-related R & D institutes (the CTA, CTE_x and CP_qM).

By contrast, the author's research in India found that technology development in the defence sector was characterised by high levels of obsolescence and extreme dependence on foreign technology suppliers. By focusing on the inefficient transfer and use of these foreign technologies, for example in the Light Combat Aircraft and Advanced Light Helicopter programmes, which in some cases was attributed to perverse Indian government licensing policies, the author could explain why India's defence-industrial capabilities were relatively underdeveloped in comparison to Brazil's.

The central criticism raised by the author concerning analyses of defence industrialisation in the NICs from development economics was a methodological one. The author's comparative case study approach has provided a far richer account of the relationship between arms production and industrialisation in the NICs than that offered by the macrostatistical studies of development economics. The author's research has shown that the trade-off between defence production and growth is both more complex and ambiguous than the guns versus butter calculus suggests.

For instance, the case study on India revealed that the country has been paying an enormous societal price in terms of lower productivity, duplicative research and manufacturing efforts, and large defence expenditures because of the Indian government's failure to integrate private capital goods firms into its autarkic defence sector. By comparison, it could be argued that the cost of Brazil's arms industry to the economy has been much lower, because of the substantially less government fiscal support for this industry and because of the export revenues generated by the defence firms. Even the economic impact of the recent restructuring of the Brazilian defence industry has been minimal because of the latitude and ability of these primarily private-sector firms to diversify back into capital goods production.

This concludes the author's analysis of the implications of her research findings for theories of defence industrialisation in the NICs offered by international relations, international political economy, comparative politics, neoclassical and development economics. In brief, this thesis has demonstrated that the apparent dichotomy between the market-led approaches of economics and the "statist"-oriented explanations of political science is illusory. Individually, neither fully captures the development of and variance in the defence industrial capabilities and export competitiveness of the NICs.

Future Research

This thesis on defence industrialisation in the NICs has important theoretical implications regarding the way we view states and firms in the international system. In this final section, the author reflects upon her own analytic treatment of these two important actors. Recognising some of the limitations in this thesis, which stem in part from her conceptualisation of states and firms, the author discusses how such limitations can be mitigated through future research. She begins this discussion by addressing the fundamental issue of the role of the state in shaping the arena in which firms interact. The author then turns to the issue of firm behaviour -- in particular, what factors, internal to the firm, condition the adoption of certain technology strategies.

Contending Images of the State

A crucial finding that emerges from the thesis (see Chapter 5) is that the arena in which firms interact profoundly affects outcomes; i.e. Brazilian defence firms' superior technological and export performance in comparison to Indian firms. The author described some *aspects* -- government policies and market structures -- of the arena in which firms operate. But how does one think about the *origins* of this arena? What factors shape this arena in the first place?

In evoking the Brazilian and Indian case studies, two different views emerge regarding the determinants of this arena. Each view derives from a particular conceptualisation of the state. The first view holds that the state can choose the arena in which firms operate. Government policies derive soley from state preferences, they do not evolve from the strategic interaction with other non-state actors. The state, in this view, is a unitary actor and, in the domestic realm, is an omnipotent one. The state stands outside the arena in which firms interact. Indeed, the state creates this arena. This image of the state underpins much of international relations theory.

This view of the state leads to specific kinds of research questions. In particular, what are the consequences of different government choices, i.e. policies, on the arena and, ultimately, on the behaviour of firms. This thesis, especially its game theoretic discussion of Indian firms' licensing behaviour, directly addresses this question. It neatly illustrates the often unintended consequences of various government trade, technology and industrial policies on the arena of Brazilian and Indian firms. The prevalence of important but unintended consequences demonstrates how difficult it is for a state to obtain its desired outcomes, even if the state were sufficiently strong that it could specify the arena in which firms interact.

In the second view, the arena is determined by the strategic interaction among competing actors. Government policies are the resultant of a political process. In this view, the state is not a unitary actor. It no longer stands outside the arena but is one actor in a larger arena. This image of the state is central to comparative politics. Comparative politics, however, emphasises the interplay and structural relations between primarily political actors -- bureaucracies, political parties and interest groups, social classes etc. An important contribution of this thesis has been to demonstrate that firms too are important actors in this process.

What is underdeveloped in this thesis, however, is a clearer discussion of how firms participate in this process. To address this limitation, the author needs to return to her firm-level case studies in Brazil and India. There she must draw out more precisely the strategic interaction between firms and other domestic as well as foreign actors -- government ministries, armed forces, key entrepreneurs, trade unions, the United States and the former Soviet Union to name a few -- out of which the arena is formed and shifts. Whether such interactions share any systematic properties across these and other disparate cases remains to be seen. These are important areas for future research and will help clarify the respective roles of states and firms in the process of defence industrialisation in the NICs.

Inside the Firm

Two areas for future research arise from the author's conceptualisation of firms. Both relate to the author's unintentional "black boxing" of the firm. First, despite the author's extensive use of firm-level case studies, there is a tendency to treat firms as homogeneous in their preferences and behaviour. This limitation stems from constraints imposed by the author's comparative cross-national, inter-industry research design. To draw an effective comparision between the technological and export capabilities of the Brazilian and Indian defence industries, the author first had to search for and aggragate similarities in the technology strategies of Brazilian firms and Indian firms respectively. Only by aggragating individual firm behaviour to the sectoral level could the author then observe systematic cross-national industry differences from which to make generalisable conclusions.

One possible area for future research would be to tease out the *intra-industry* differences within either the Brazilian or the Indian defence sectors. For instance, why is it that India's missile programme has largely succeeded when the country's aircraft, naval and armour programmes have stagnated? To analyse this particular question, the author could use her existing firm data base and employ a comparative *inter-firm* research design.

The second area for future research pertains to the question: Where do firms' technology strategies come from? In particular, what are the possible factors, internal to the firm such as ownership characteristics, labour-management practices, firm structure, that might condition the selection and adoption of a particular technology strategy, i.e. firm behaviour? The thesis does not directly address these important and related questions. Though the literature from economics on the determinants of firm behaviour is growing -- for example, transaction cost, principal agent and other institutional theories -- the application of these theories to empirical studies is still in its infancy.* Whether such theories can successfully explain the selection of particular technology strategies by firms is a potential area for further research.

Admittedly these issues regarding the conceptualisation of the state and firm constitute weaknesses and important agendas for future research. Nevertheless, only by exposing the reader to the broader theme that firms matter, can we now begin to ask another set of questions, such as the ones posed above. The author has succeeded in the first task, the second lies ahead of her.

---

*Works that examine firms as economic institutions include: Alfred Chandler, *The Visible Hand* (Cambridge: Harvard University Press, 1977); B. Holmstron and J. Tirole, "The Theory of the Firm," In *Handbook of Industrial Organisation*, R. Schmalensee and R. Willig, eds (Amsterdam: North Holland, 1989); and Oliver O. Williamson, *The Economic Institutions of Capitalism* (New York: Free Press, 1985).

Appendix

A Note on Sources and Methods

A central task of this thesis was to relate differences in the international competitiveness of countries to the strategic interaction between firms and states. Using case studies from two newly industrialising countries, the author was interested in explaining what accounted for the contrasting performance and international competitiveness of Brazil's and India's defence industries. Her particular objective was to study whether national competitiveness in international markets was linked to firm-level factors.

To examine the determinants of international competitiveness at the firm level, it was necessary to conduct fieldwork in Brazil and India for two reasons. First, what published information exists on Brazilian and Indian defence firms is generally only available in country. Second, and more importantly, the information available in the public domain even in Brazil and India is insufficient to examine the development of defence capabilities and export competitiveness by these countries' firms due to the militarily sensitive nature of the industry involved.

This research consisted of interviews and a questionnaire survey in Brazil and India. In both countries she interviewed individuals from defence and capital goods firms (corporate managers as well as engineers), the armed forces, as well as officials from various government ministries related to finance, industry, trade, and science and technology. These interviews provided the author with detailed information about the technological and export capabilities of individual firms and about how government policies affect the defence and capital goods industries.

However, it was necessary to rely on more quantitative, econometric methods, based on mail questionnaire survey data, in order to draw broad comparisons among Brazilian and Indian firms regarding their technological capabilities, export competitiveness and interaction with the state. To obtain this data, the author developed sample questionnaires and tested them on a small population of firms in both countries. From the outset, the author was concerned about viability of survey research methods because questionnaire surveys have not been widely applied in the developing world. Indeed, the sample survey in India met with such extremely low response rates that the plan for a broader survey had to be abandoned. Instead, the author had to rely extensively on interviews, company site visits and archival research in the Lok Sabha parliamentary library.

In Brazil, the questionnaire met with much more success and was subsequently sent to approximately 500 of the country's defence and capital goods firms. The questionnaire surveyed a broad cross-section of Brazil's manufacturing sectors to establish whether and what kinds of linkages existed between the capital goods and defence firms. Specifically, the author needed to collect the data necessary to test her hypothesis that many Brazilian capital goods producers diversified their product lines into defence, and later supplied the expanding global arms trade of the 1980s. The author also wanted to gauge the ability of these firms to use foreign technologies effectively.

All of the major Brazilian defence companies were surveyed, since the omission of any one firm in such a small population might introduce some bias. The remaining firms were randomly selected from various annual listings of capital goods producers. The response rate to this international mail questionnaire survey was a surprising 40 per cent -- overwhelming by even domestic survey standards. The Brazilian survey is included in this appendix with its English translation.

Using the data from the mail questionnaire, the author constructed a three-stage econometric model, which consisted of two probit and one ordinary least squares regression equations, to test whether and how the diversification by Brazilian firms into military production was affected by various government policies. The three-stage model and a discussion of the results are found in Chapter 3. Both the questionnaire data and the econometric results enabled the author to conclude that the relative success of Brazil's arm industry during the 1970s-1980s was attributable to a particular firm-government interaction that stimulated the indigenous technological sophistication and international competitiveness of Brazilian defence manufacturers.

QUESTIONÁRIO

Gostaria de começar fazendo-lhe perguntas gerais sobre o tipo e o tamanho de sua companhia.

1. Qual é sua posição na firma? ______________________________

____

2. Ano de fundação da firma? ______________________________

____

3. Tipo de companhia:

Privada __________ Pública __________ Mista __________

4. Qual é a participação estrangeira no patrimônio da firma, representada como porcentagem das ações?

Nenhuma __________
Abaixo de 20% __________
De 20% a 50% __________
Acima de 50% __________

5. Número total de empregados: em 1977 __________

em 1987 __________

Gostaria de saber o que sua companhia produz e quais os mercados para seus bens e/ou serviços, tanto domésticos como internacionais.

6. Quais são suas principais linhas de produtos?

Produto #1 ______________________________

Produto #2 ______________________________

Produto #3 ______________________________

7. Houve uma mudança significativa ou diversificação em qualquer das linhas de produtos desde a criação da firma?

Sim __________ Nao __________

7a. Se hove, quando e qual foi a mudança? ______________________________

____

____

____

7b. Quais as razões para a mudança? ______________________________

____

____

8. Valor total da produção em cruzeiros/cruzados para:

1977 ____________________ 1987 ____________________

9. Qual é a participação de cada um dos principais produtos da firma no mercado doméstico? (Expresse-a por favor, como porcentagem.)

Produto #1 _________ Produto #2 _________ Produto #3 _________

10. Quais são os principais fregueses de seus principais produtos no Brasil? (Se possível, especifique, por favor, o nome da firma.)

Para o produto #1:

Firmas particulares ____________________
Empresas públicas ____________________
Multinacionais ____________________
Outras firmas ____________________

Para o produto #2:

Firmas particulares ____________________
Empresas públicas ____________________
Multinacionais ____________________
Outras firmas ____________________

Para o produto #3:

Firmas particulares ____________________
Empresas públicas ____________________
Multinacionais ____________________
Outras firmas ____________________

11. Valor das exportações em cruzeiros/cruzados dos principais produtos:

	1977	1987
Produto #1	__________	__________
Produto #2	__________	__________
Produto #3	__________	__________

12. Caso as exportações da firma tenham aumentado ou diminuído significativamente durante os dez últimos anos, quais foram as principais razões para a flutuação?

____

____

13. Destino da exportação dos principais produtos?

Produto #1 ____________________
Produto #2 ____________________
Produto #3 ____________________

No próximo grupo de qüestoes, gostaria de saber como sua companhia desenvolveu suas linhas de produtos. Interesso-me, especialmente, nas fontes e espécies de technolgias que sua firma ou divisão tenha utilizado.

14. Que meios foram utilizados para criar ou aumentar sua capacidade de produção?

Pesquisa e desenvolvimento dentro da própria empresa ______________________________

____

Importação de bens de capital estrangeiros, tais como máquinas operatrizes ______________

____

Contratação de projetistas estrangeiros ______________________________________

____

Envio de pessoal ao estrangeiro ____

Uso de serviços de pesquisa governamental (Especifique, por favor)

____

____

Acordos de concessões ____

Outros meios ____

____

15. Caso sua firma tenha importado várias tecnologias, inclusive esboços e componentes, houve necessidade de qualquer modificação na tecnologia receibida? Por exemplo:

Adaptação de materiais locais aos modelos estrangeiros ____________________________

____

Introdução de equipamento estrangeiro às linhas de produção

____

Economia de materiais importados escassos ____________________________________

____

Outras necessidades? ____

16. Sua firma utilizou qualquer tipo de acordos de concessão?

Sim ______________ Não ______________

16a. Se utilizou, para que produto/produtos? ___________________________________

____

____

16b. Quais foram as principais razões tecnicas para a concessão?

Obtenção do esboço do produto ____

____

Assistência tecnica ____

Outras razòes ____

16c. Quais foram as principais razões comerciais?

Políticas de compra de seus fregueses ______
Necessidade de competir com firmas já possuidoras de tal technologia ______

______

Outras razões ______

______

______

17. Quais são os seus principais concessores? ______

______

______

18. Sua firma está envolvida em qualquer tipo de acordos de subcontratação?
Sim ______ Não ______

18a. Se estiver, com quem? (Se possível, forneça o nome da firma envolvida, por favor.)

Multinacional ______
Empresa privada ______
Empresa pública ______
Outra firma ______

Finalmente, gostaria de saber qual é a sua avaliação do efeito das politícas e das regulamentações do governo federal sobre sua firma.

19. Como as políticas ou as regulamentações governamentais afetaram sua companhia? (Seja específico, por favor.)

Financiamento subsidiado para a aquisição de bens de capital ______

______

Isenção de tarifas e impostos sobre as importações ______

______

Financiamento subsidiado para estimular e fortalecer as capacidades technológicas da firma

______

Incentivos fiscais para a exportação ______

______

Outros ______

______

19a. Fazendo um balanço, que tipo de impacto econômico estas políticas produziram:

Positivo (Especifique, por favor) ______

______

Negativo (Especifique, por favor) ______

______

Brazil Questionnaire - (English translation)

I would like to start by asking you some general questions concerning the type and size of your company.

1. What is your position in the firm? ______________________________

____

2. Year of foundation of the firm? ______________________________

____

3. Type of Company:

Private __________ Public __________ Mixed __________

4. What is the foreign equity participation in percentage of shares?

None __________
Under 20% __________
20-50% __________
Over 50% __________

5. Total number of employees: in 1977 __________

in 1987 __________

I am interested to know what your company produces, and what your markets are -- both domestic and international -- for your goods and/or services.

6. What are your main product lines?

Product #1 ______________________________

Product #2 ______________________________

Product #3 ______________________________

7. Has there been significant change of divervification in any of your product lines since the creation of the firm?

Yes __________ No __________ When __________

7a. If yes, what was the change? ______________________________

____

____

____

7b. What were the reasons for the change? ______________________________

____

8. Total value of production in cruzeiros/cruzados for:

1977 ____________________ 1987 ____________________

9. What is the domestic market share, for each of the firm's main products? (Please express as a percentage.)

Product #1 __________ Product #2 __________ Product #3 __________

10. Who are the principal customers for your main products in Brazil? (If possible, could you please specify the name of the firm.)

For product #1:

Private firms ____________________
Public enterprises ____________________
Multinationals ____________________
Other firms ____________________

For product #2:

Private firms ____________________
Public enterprises ____________________
Multinationals ____________________
Other firms ____________________

For product #3:

Private firms ____________________
Public enterprises ____________________
Multinationals ____________________
Other firms ____________________

11. Value of exports in cruzeiros/cruzados for main products:

	1977	1987
Product #1	__________	__________
Product #2	__________	__________
Product #3	__________	__________

12. If the firm's exports have increased or decreased significantly over the past ten years, what have been the main reasons for the fluctuation? ____________________

____

____

13. Destination of export for main products?

Product #1 ____________________
Product #2 ____________________
Product #3 ____________________

In this next series of questions, I would like to know how your company has developed its product lines. In particular, I am interested in the sources and kinds of technologies your firm or division has utilised.

14. What means have been used to create or augment your production capacity?

Internal research and development ______________________________

____

Importation of foreign capital goods, such as machine tools ____________________

____

Hiring foreign personnel, such as consultants ______________________________

____

Sending personnel abroad ______________________________________

Use of local industrial, university research or government research institutes. (Please specify)

____

____

Other methods ____

____

15. If your firm has imported various technologies, including designs and components, have you had to make any changes in the technology received? For example:

Adaptation of local materials to foreign designs ______________________________

____

Introduction of foreign equipment to production lines

____

Economise scarce imported materials ______________________________

____

Other necessities? ____

16. Has your firm used any licensing agreements?

Yes ____________ No ____________

16a. If yes, for which product/s? ______________________________

____

16b. What are the main technical reasons for licensing?

Obtaining product design ______________________________________

____

Technical assistence ____

Other reasons ____

16c. What were the major commercial reasons?

Procurement policies of your customers ______________________________
The need to compete with firms already possessing such technology ____________________

Other reasons ____

17. Who are your major licensors? ______________________________

18. Is the firm engaged in any subcontracting arrangements?
Yes __________ No __________

18a. If yes, with whom? (<u>If possble, could you please provide the name of the firm involved</u>.)

Multinational ______________________________
Private firm ______________________________
Public enterprise ______________________________
Other firm ______________________________

Finally, I would like your assessment of the effects of federal government policies or regulations on your business.

19. How have government policies or regulations affected your company? (<u>Please be specific</u>.)

Subsidised financing for purchase of capital goods ________________________

Exemption from duties and taxes on imports ________________________

Subsidised financing to stimulate and strengthen your firm's technological capabilities

Fiscal incentives to export ______________________________

Other ____

19a. On balance, what kind of economic impact have these policies had on your firm:

Positive (Be specific, please) ______________________________

Negative (Be specific, please) ______________________________

BIBLIOGRAPHY

Books and Monographs

Achen, Christopher H. *Interpreting and Using Regression*. Sage University Paper series on Quantitative Applications in the Social Sciences, No. 07-029. Beverly Hills: Sage Publishers, Inc., 1982.

Adler, Emanuel. *The Power of Ideology: The Quest for Technological Autonomy in Argentina and Brazil*. Berkeley: University of California Press, 1987.

AEROESP Industry Register 1987. São José dos Campos: CTA, 1987.

Agarwal, Rajesh K. *Defence Production and Development*. New Delhi: Arnold-Heinemann Publishers, 1978.

Ahluwalia, Isher Judge. *Industrial Growth in India: Stagnation Since the Mid-Sixties. New Delhi: Oxford University Press*, 1985.

Almeida, Fernandes Lopes de. *A Expansão de Indústria de Bens de Capital: Fatores Determinantes*. Rio de Janeiro: Fundação Getúlio Vargas, 1983.

Amsden, Alice. *Asia's Next Giant: South Korea and Late Industrialisation*. New York: Oxford University Press, 1989.

Andrade, Robert Pereira da, and Jose de Souza Fernandes. *Veículos Militares Brasileiros*. São Paulo: Aquarius, 1983.

Anuário Aerospacial Brasileiro. São Paulo: Aviação em Revista Ed., 1983.

Arrow, Kenneth. "Economic Welfare and the Allocation of Resources for Inventions." In *The Rate and Direction of Inventive Activity*, ed. R. Nelson. Princeton: Princeton University Press for the National Bureau of Economic Research, 1962.

Associação Brasileira da Indústria de Máquinas e Equipamentos. *Bens de Produção Mecânicos: Sinopse Statistica - Brasil - 1981*. São Paulo: Associação Brasileira da Indústria de Maquinas e Equipamentos, Sindicato Interstadual da Indústria de Máquinas e Equipamentos, 1982.

Azar, Edward and Chung-In Moon, eds. *National Security in the Third World: The Management of Internal and External Threats*. Aldershot, Hants. U.K.: Edward Elgar Publishers Ltd., 1988.

Bajpai, U.S., ed. *India's Security: The Politico-Strategic Environment*. New Delhi: Lancers Publishers, 1983.

Balassa, Bela. *The Newly Industrialising Countries in the World Economy*. New York: Pergamon Press, 1981.

Ball, Nicole. *Third World Security Expenditures: A Statistical Compendium*. Stockholm: Swedish National Defence Research Institute, 1983.

Ball, Nicole, and Milton Leitenberg. eds. *The Structure of the Defence Industry: An International Survey*. New York: St. Martin's Press, 1983.

Banco InterAmerican de Desenvolvimento. *Progresso Socio-Economico na America Latina*. Relatorio de 1988. Parte especial: Ciencia e Tecnologia. Washington, D.C.: BID, 1988.

Baranson, Jack. "International Transfers of Industrial Technology by U.S. Firms and their Implications for the U.S. Economy." Vol. 1. Report prepared for the Office of Foreign Economic Research, International Labor Affairs Bureau, U.S. Department of Labor. Washington, D.C.: Developing World Industry and Technology, December 1976.

Bell, R.M., and D. Scott-Kemmis. *Indo-British Technological Collaborations Since the Early 1970s: Change, Diversity and Forgone Opportunities*. 5 Vols. Brighton, U.K.: Science Policy Research Unit, University of Sussex, 1985.

Bennett, Douglas C., and Kenneth E. Sharpe. *Transnational Corporations versus the State: The Political Economy of the Mexican Automobile Industry*. Princeton: Princeton University Press, 1985

Benoit, Emile. *Defence and Economic Growth in Developing Countries*. Lexington, MA.: D.C. Heath & Co., 1973.

Bergsman, Joel. *Brazil: Industrialisation and Trade Policies*. London: Oxford University Press, 1970.

Bhagavan, M.R. "Capital Goods Sector in India: Past and Present Trends and Future Prospects." In *Studies in Industrial Economy of India*, ed. V. S. Mahajan. New Delhi: Deep & Deep Publishers, 1987.

Bhagwati, J. N., and Padma Desai. India: *Planning for Industrialisation: Industrialisation and Trade Policies Since 1951*. New Delhi: Oxford University Press, 1970.

Bhagwati, J. N., and T.N. Srinivasan. *Foreign Trade Regimes and Economic Development: India*. New York: Columbia University Press, 1975.

Bhargava, G.S. "India's Security in the 1980s." *Adelphi Papers* No. 125. London: International Institute for Strategic Studies, Summer 1976.

Blalock, Hubert M. *Social Statistics*. New York: McGraw-Hill Book Company, Inc., 1960.

Bond, Jennifer Sue, and R. Naguraja Rao. *Governmental Organisation and Planning for Science and Technology in Brazil*. Vol. 1. Cambridge, MA.: Center for Policy Alternatives, Massachusetts Institute of Technology, April 1976.

Brazilian Defence Directory 1987. São Paulo: Aviação, 1987.

Brigagao, Clovis. "Brazil's Military Industry: A Discussion of Recent Developments." *Latin American Research Unit Working Paper*. No. 27. Toronto: Latin American Research Unit, December 1979.

----. *O Mercado da Segurança: Ensaios Sobre Economia Politica da Defesa*. Rio de Janeiro: Editora Nova Fronteira, 1984.

----. "A Cultura dos Riscos: Conforto & Segurança." In *O Armamentismo e o Brasil: A Guerra Deles*, eds. Amilcar O Herrera, Pinguelli Rosa, and Renato P. Dagnino, et al. São Paulo: Editora Brasilliense S.A., 1985.

Brumer, Sara. *Estrutura, Conduta e Desempenho de Mercado da Indústria*. Porto Alegra: Fundação da Economia e Estatistica, 1981.

Bruneau, Thomas C., and Philippe Faucher, eds. *Authoritarian Capitalism: Brazil's Contemporary Economic and Political Development*. Boulder, CO.: Westview Press, Inc., 1981.

Brzoska, Michael, and Thomas Ohlson, eds. *Arms Production in the Third World*. London: Taylor & Francis, 1986.

----. eds. *Arms Transfers to the Third World, 1971-85*. Oxford: Oxford University Press for SIPRI, 1987.

Bulmer-Thomas, V. *Input-Output Analysis in Developing Countries*. Chichester: John Wiley & Sons, Ltd., 1982.

Buzan, Barry, Gowher Rizvi, Rosemary Foot, Nancy Jetly, B.A. Robertson, and Anita Inder Singh. *South Asian Insecurity and the Great Powers*. London: Macmillan, 1986.

Campbell, A., and G. Katona. "The Sample Survey." In *Research Methods in the Behavioral Sciences,* eds L. Festinger and D. Katz. New York: Holt, Rinehart and Winston, 1953.

Campbell, Donald T., and Julian C. Stanley. *Experimental and Quasi-Experimental Designs for Research*. Chicago: Rand McNally & Company. Eighth printing, 1972.

Castella, P. *La Production Indienne de Biens d'Equipement et le Developpement Industriel de l'Inde Depuis 1950*. Paris: O.R.S.T.O.M., 1977.

Castro, Claudio de Moura. *E Possivel uma Tecnologia "Made in Brazil"?* São Paulo: Promocet, 1986. Issued by Secretaria de Industria, Comercio, Ciencia e Technologia.

---. *High Technology in Intermediate Countries?: The Case of Brazil*. Rio de Janeiro: Instituto de Planejemento Econômico e Social, June 1983.

Castro Andrade, Regis de. "Brazil: The Economics of Savage Capitalism." In *The Struggle for Development: National Strategies in an International Context*, eds. M. Bienefeld, and M. Godfrey. London: John Wiley & Sons, Ltd., 1982.

Chenery, Hollis. *Structural Change and Development Policy*. New York: Oxford University Press for the World Bank, 1979.

Chudnovsky, Daniel. *South-South Trade in Capital Goods: The Latin American Experience*. Texto para Discussao N. 57. Rio de Janeiro: Universidade Federal do Rio de Janeiro, Instituto de Economia Industrial, Outobro 1984.

Chudnovsky, D., Ma Nagao, and S. Jacobsson. *Capital Goods Production in the Third World*. London: Francis Pinter Publishers, 1983.

Cohen, Stephen, and John Zysman. *Manufacturing Matters: The Myth of the Post-Industrial Economy*. New York: Basic Books, 1987.

Collier, David, ed. *The New Authoritarianism in Latin America*. Princeton: Princeton University Press, 1979.

Cruz, Helio Nogueira da. *Mudança Tecnológica no Setor Metal-Mecânico do Brasil: Resultados de Estudos de Casos*. São Paulo: Instituto de Pesquisas Econômicas, Faculdade de Economia e Administração da Universidade de São Paulo, 1985.

Dagnino, Renato P. "A Indústria de Armamentos Brasileira: Desenvolvimento e Perspectivas." In *O Armamentismo e o Brasil: A Guerra Deles*, eds. Amilcar O. Herrera, Pinguelli Rosa, and Renato P. Dagnino, et al. São Paulo: Editora Brasilliense S.A., 1985.

Dahlman, Carl, and Francisco Sercovich. "Local Development and Exports of Technology." *World Bank Staff Working Papers*, No. 667, Washington, D.C.: The World Bank.

Dahlman, Carl J., and Claudio R. Frischtak. *National Systems Supporting Technical Advance in Industry: The Brazilian Experience*. Washington, D.C.: World Bank, Industry and Energy Department Working Paper, Industry Series Paper No. 32, PRE, June 1990.

Davies, Stephen, and Bruce Lyons with Huw Dixon and Paul Geroski. *Economics of Industrial Organisation*. London: Longman Group U.K. Ltd., 1988.

Defence Review Annual. New Delhi: Nu Tech Photolithographers, various years.

Deger, Sadat. *Military Expenditure in the Third World Countries: The Economic Effects*. London: Routledge & Kegan Paul, 1986.

Desai, Ashok V., ed. *Technology Absorption in Indian Industry*. New Delhi: Wiley Eastern Ltd., 1988.

Deyo, Frederic C., ed. *The Political Economy of the New Asian Industrialism*. Ithaca: Cornell University Press, 1987.

Dosi, Giovanni, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete. *Technical Change and Economic Theory*. London: Frances Pinter Publishers, 1988.

Enos, J., and W.H. Park. *The Adaption and Diffusion of Imported Technology in the Case of Korea*. London: Croom Helm, 1987.

Ernst, Dieter, and David O'Connor. *Technology and Global Competition: The Challenge for the Newly Industrialising Economies*. Paris: OECD, 1989.

Evans, Peter. *Dependent Development: The Alliance of Multinational, State and Local Capital in Brazil*. Princeton, NJ.: Princeton University Press, 1979.

Evans, Peter, Dietrich Rueshemeyer, and Theda Skocpol, eds. *Bringing the State Back In*. New York: Cambridge University Press, 1985.

Feit, Edward. *The Armed Bureaucrats: Military-Administrative Regimes and Political Development*. Boston: Houghton and Mifflin, 1973.

Fransman, Martin. *Technology and Economic Development*. Great Britain: Wheatsheaf Books Ltd., 1986.

----. ed. *Machinery and Economic Development*. London: Macmillan Press, 1986.

Fransman, Martin, and Kenneth King, eds. *Technological Capability in the Third World*. London: Macmillan Press, Ltd., 1984.

Freeman, Christopher. *The Economics of Industrial Innovation*. London: Frances Pinter, 1982.

Furtado, Celso. *Análise do "Modelo" Brasileiro*. Rio de Janeiro: Editora Civilizaçao Brasileira, 1982.

Gereffi, Gary. *The Pharmaceutical Industry and Dependency in the Third World*. Princeton: Princeton University Press, 1983.

Gereffi, Gary, and Donald L. Wyman, eds. *Manufacturing Miracles: Paths of Industrialisation in Latin America and East Asia*. Princeton: Princeton University Press, 1990.

Gershenkron, Alexander. *Economic Backwardness in Historical Perspective, A Book of Essays*. Cambridge, MA.: Belknap Press of Harvard University Press, 1962.

Gilks, Anne, and Gerald Segal. *China and the Arms Trade*. London: Croom Helm, 1985.

Gill, Sucha Singh. *Political Economy of Indo-Soviet Relations 1947-80*. New Delhi: Rajesh Publications, 1983.

Gilpin, Robert. *The Political Economy of International Relations*. Princeton: Princeton University Press, 1987.

----. *War and Change in World Politics*. New York: Cambridge University Press, 1981.

Gordon, Lincoln, and Engelbert L. Grommers. *United States Manufacturing Investment in Brazil.* Boston: Graduate School of Business Administration, Harvard University, 1962.

Guimarães, Eduardo Augusto. *The Activities of Brazilian Firms Abroad.* Texto para Discussao N. 50. Rio de Janeiro: Universidade Federal do Rio de Janeiro, Instituto de Economia Industrial, Julho de 1984.

Guimarães, Eduardo Augusto, Jose Tavares de Araujo Filho, and Fabio Erber. *A Politica Cientifica e Tecnologica.* Rio de Janeiro: Jorge Zaher Editor, 1985.

Gumaste, V.M. *Technology Self-Reliance in the Automobile and Ancillary Industries of India.* Madras: Institute for Financial Management and Research, 1988.

Haggard, Stephan. *Pathways from the Periphery: The Politics of Growth in the Newly Industrialising Countries.* Ithaca: Cornell University Press, 1990

Hall, Peter. *Governing the Economy: The Politics of State Intervention in Britain and France.* New York: Oxford University Press, 1986.

Harkavy, Robert E. *Arms Trade and the International Systems.* Cambridge, MA.: Ballinger Publishing Co., 1975.

Hawtrey, Ralph G. *Economic Aspects of Sovereignty.* London: Longman, 1952.

Hayes, Margaret Daly. *Brazil and the South Atlantic: Changing Perspectives on an Emerging Issue.* Washington, D.C.: Center of Brazilian Studies, School of Advanced International Studies, The Johns Hopkins University, 1981.

Heckscher, Eli F. *Mercantilism.* 2 vols. London: George Allen & Unwin, 1935.

Herrera, Amilcar O., et al. *O Armamentismo e o Brasil: A Guerra Deles.* São Paulo: Brasiliense. 1985.

Hirschman, Albert O. *National Power and the Structure of Foreign Trade.* Berkeley: University of California Press, 1945.

Hirschman, Albert O. *The Strategy of Economic Development.* New Haven: Yale University Press, 1958.

Hogarth, R.M., ed. *Question Framing and Response Consistency.* San Francisco: Jossey-Bass, 1982.

Horn, Robert C. *Soviet-Indian Relations: Issues and Influence*. New York: Praeger Publishers, 1982.

Huq, M.M., and C.C. Pendergust. *Machine Tool Production in Developing Countries*. Edinburgh: Scottish Academic Press, 1983.

Johnson, Chalmers. *MITI and the Japanese Miracle*. Stanford: Stanford University Press, 1982.

Johnson, Harry G., ed. *Economic Nationalism in Old and New States*. Chicago: University of Chicago Press, 1967.

Johnson, John J., ed. *The Role of the Military in Underdeveloped Countries*. Princeton: Princeton University Press, 1962.

Jones, Leroy, and Il Sakong. *Government, Business and Entrepreneurship in Economic Development: The Korean Case*. Cambridge: Harvard University Press, 1980.

Kaldor, Mary. "The Military in Third World Development." In *Disarmament and World Development*, ed. Richard Jolly. Oxford: Pergamon Press, 1978.

Kamien, Morton I., and Nancy L. Schwartz. *Market Structure and Innovation*. Cambridge: Cambridge University Press, 1982.

Katz, James Everett, ed. *Arms Production in Developing Countries*. Lexington, MA.: D.C. Heath & Company, 1984.

----. *The Implications of Third World Military Industrialisation*. Lexington, MA.: Lexington Books/D.C. Heath & Company, 1986.

Katz, Jorge, ed. *Technology Generation in Latin American Manufacturing Industries*. London: Macmillan, 1987.

Katzenstein, Peter, ed. *Between Power and Plenty*. Madison: University of Wisconsin Press, 1978.

Kennedy, Gavin. *The Military in the Third World*. New York: Charles Scribner's Sons, 1974.

----. *Defence Economics*. London: Duckworth and Company, Ltd., 1983.

Keohane, Robert. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton: Princeton University Press, 1984.

Kirkpatrick, C.H., N. Lee, and F.I. Nixson. *Industrial Structure and Policy in Less Developed Countries*. London: George Allen & Unwin, Ltd., 1984.

Kish, Leslie. *Survey Sampling*. New York: Wiley, 1965.

----. "Selection of the Sample." In *Research Methods in the Behavioral Sciences*, eds. Leon Festinger and Daniel Katz. New York: Holt, Rinehart and Winston, 1953.

----. "Some Statistical Problems in Research Design." In *The Quantitative Analysis of Social Problems*, ed. E. Tufte. Reading, MA.: Addison-Wesley Publishing Company, 1970.

Kolodziej, Edward A., and Robert E. Harkavy, eds. *Security Policies of Developing Countries*. Lexington, MA.: D.C. Heath & Company, 1982.

Klare, Michael T. *American Arms Supermarket*. Austin: University of Texas Press, 1984.

Knorr, Klaus. *Military Power and Potential*. Lexington, MA.: D.C. Heath & Company, 1970.

Krueger, Anne O. *Foreign Trade Regimes and Economic Development: Liberalisation Attempts and Consequences*. Cambridge, MA.: Ballinger Press, 1978.

Lago, Luiz A. Correa do, Fernandes Lopes de Almeida, and Beatriz M.F. de Lima. *A Indústria Brasileira de Bens de Capital*. Rio de Janeiro: Fundação Getulio Vargas, Instituto Brasileiro de Economia, 1979.

Laird, Robbin F. *Soviet Arms Trade with the Non-Communist Third World in the 1970's and 1980's*. Washington, D.C.: Wharton Econometric Forecasting Associates, 1983.

Lakshmir, Y. *Trends in India's Defence Expenditure*. New Delhi: ABC Publishing House, 1988.

Lall, Sanjaya. *Building Industrial Competitiveness in Developing Countries*. Paris: OECD, 1990.

----. *Multinationals, Technology and Exports*. London: Macmillan Press, Ltd., 1985.

----. *Developing Countries as Exporters of Technology: A First Look at the Indian Experience*. London: Macmillan Press, Ltd., 1982.

Leff, Nathaniel H. *The Brazilian Capital Goods Industry: 1929-64*. Cambridge, MA.: Harvard University Press, 1968.

Lewis-Beck, Michael S. *Applied Regression: An Introduction*. Sage University Paper Series on Quantitative Applications in the Social Sciences, No. 07-022. Beverely Hills: Sage Publications, Inc., 1980.

List, Friedrich. *The National System of Political Economy*. New York: Longmans, Green, 1904.

Louscher, David J., and Michael D. Salomone, eds. *Marketing Security Assistance: New Perspectives on Arms Sales*. Lexington: Lexington Books, 1987.

----. *Technology Transfer and U.S. Security Assistance*. Boulder, CO.: Westview Press, 1987.

Lucas, Robert E. B., and Gustav F. Papanek, eds. *The Indian Economy: Recent Developments and Future Prospects*. Boulder: Westview Press, Inc., 1988.

Maddison, Angus. *Phases of Capitalist Development*. Oxford: Oxford University Press, 1982.

Mahajan, Harpreet. *Arms Transfers to India, Pakistan and the Third World*. New Delhi: Young Asia Publications, 1982.

Mascarenhas, R.C. *Technology Transfer and Development: India's Hindustan Machine Tools Company*. Boulder, CO.: Westview Press, 1982.

Matthews, Ron. "Technological Dynamism in India and Japan: The Case of Machine-Tool Manufacture." In *Technological Development in China, India and Japan: Cultural Perspectives*, eds. Erik Baark and Andrew Jamison. London: Macmillan, 1986.

McDonough, Peter. *Power and Ideology in Brazil*. Princeton: Princeton University Press, 1981.

Menon, Rajan. *Soviet Power and the Third World*. New Haven: Yale University Press, 1986.

Michalet, Charles-Albert. *Le Capitalisme Mondial*. Paris: PUF, 1976.

Mitra, Jayati Datta. "The Capital Goods Sector in LDCs: A Case for State Intervention?" *World Bank Staff Working Paper. No. 343*. Washington, D.C.: The World Bank, 1979.

Moodie, Michael. "Defence Industries in the Third World: Patterns and Promises." In *Arms Transfers in the Modern World*, eds. Stephanie G. Neuman and Robert E. Harkavy. New York: Praeger Publishers, 1980.

Mowery, David C., ed. *International Collaborative Ventures in U.S. Manufacturing*. Cambridge: Ballinger Publishers, 1988.

Mowery, David C., and Nathan Rosenbergy, eds. *Technology and the Pursuit of Economic Growth*. Cambridge: Cambridge University Press, 1989.

Mullins, A.F. *Born Arming: Development and Military Power in New States*. Stanford University Press, 1987.

Myers, David J. "Brazil." In *Security Policies of Developing Countries*, eds. Edward A. Kolodziej and Robert E. Harkavy. Lexington, MA.: Lexington Books/D.C. Heath and Company, 1982.

Nanda, B.R., ed. *Science and Technology in India*. New Delhi: Vikas Publishing House, 1977.

Nayar, Baldev Raj. *Policy Foundation and Policy Change. Vol. 1, India's Quest for Technological Independence*. New Delhi: Lancers Publishers, 1983.

----. *The Results. Vol. 2, India's Quest for Technological Independence*. New Delhi: Lancers Publishers, 1983.

Nayyar, Deepak. *India's Exports and Export Policies*. Cambridge: Cambridge University Press, 1976.

Nelson, R. R., and S. G. Winter. *An Evolutionary Theory of Economic Change*. Boston: Belknap Press for Harvard University Press, 1982.

Neuman, Stephanie G., ed. *Defence Planning in Less-Industrialised States*. Lexington, MA.: Lexington Books/D.C. Heath and Company, 1984.

Neuman, Stephanie G., and Robert E. Harkavy, eds. *Arms Transfers in the Modern World*. New York: Praeger Publishers, 1979.

Nieves, Renato Baumann, and Helson C. Braga. *O Sistema Brasileiro de Financiamento as Exportações*. Rio de Janeiro: Institute de Planejamento Economico e Social/Instituto de Pesquisas Monografia N. 34, 1986.

Niosi, Jorge., ed. *Technology and National Competitiveness*. Montreal: McGill-Queen's University Press, 1991.

Nolan, Janne E. *Military Industry in Taiwan and South Korea*. London: Macmillan Press, Ltd., 1986.

O'Donnell, Guillermo. *Authoritarianism and Corporatism in Latin America*. Princeton: Princeton University Press, 1979.

Okimoto, Daniel. *Between MITI and Market: Japanese Industrial Policy for High Technology*. Stanford: Stanford University Press, 1989.

Organisation for Economic Cooperation and Development. *Committee for Scientific and Technological Policy, Science, Technology and Competitiveness*. Paris: OECD/STP, 1984

Ostrom, Charles W. "Time Series Analysis: Regression Techniques." *Sage University Paper Series on Quantitative Applications in the Social Sciences*, No. 07-001. Beverely Hills: Sage Publications, Inc., 1978.

Payne, S.L. *The Art of Asking Questions*. Princeton: University of Princeton Press, 1951.

Peleg, Ilan. "Military Production in Third World Countries: A Political Study." In *Threats, Weapons and Foreign Policy*, eds. Pat McGowan and Charles Kegley. Beverley Hills, CA.: Sage Publishers, 1980.

Pierre, Andrew J. *The Global Politics of Arms Sales*. Princeton: Princeton University Press, 1982.

Rahman, A. *Science and Technology in India*. New Delhi: National Institute of Science, Technology and Development Studies, February 1984.

Ram, V. Sri, N. Sharma, and K.K.P. Nair. *Performance of Public Sector Undertakings*. New Delhi: Economic and Scientific Research Foundation, 1976.

Rama Rao, R. *Self Reliance and Security: Role of Defence Production*. New Delhi: Radiant Publishers 1984.

Ramamurti, Ravi. *State-Owned Enterprises in High Technology: Studies in India and Brazil*. New York: Praeger Publishers, 1987.

Rao, P. V. R. *Defence Without Drift*. Bombay: Popular Prakashan, 1970.

Rizvi, Hasan Askari. *South Asia and India Military Buildup*. Lahore: Progressive Publishers, 1973.

Rodan, Garry. *The Political Economy of Singapore's Industrialisation: National State and International Capital.* New York: St. Martin's Press, 1989.

Rosenberg, Nathan. *Perspectives on Technology.* Cambridge: Cambridge University Press, 1976.

Rosenberg, Nathan, and Claudio Frischtak, eds. *International Technology Transfer.* New York: Praeger Publishers, 1985.

Rushing, Francis W., and Carole Ganz Brown, eds. *National Development Policies for Developing High Technology Industries.* Boulder: Westview Press, 1986.

Sadar Patel Institute of Economic and Social Research. *Technology Issues in the Capital Goods Sector: A Case Study of Leading Machinery.* Ahmedabad, India: Sadar Patel Institute, September, 1983.

Saigal, A.L., ed. *Memoirs of Air Vice Marshal Harjinder Singh, Birth of an Air Force.* New Delhi: Palit & Palit, 1977.

Sandholtz, Wayne, Michael Borrus and John Zysman et al., *The Highest Stakes.* New York: Oxford University Press, 1992.

Sarin, H.C. *Defence and Development.* New Delhi: United Service Institution of India, 1979.

Savasini, José Augusto Arantes. *Export Promotion: The Case of Brazil.* New York: Praeger Publishers, 1978.

Schumpeter, Joseph. *Capitalism, Socialism and Democracy.* 3d edition. London: New York: Harper & Row, 1950.

Sciberras, E., and B.D. Payne. *Machine Tool Industry: Technical Change and International Competitiveness.* Harlow, Essex (U.K.): Longman Group Ltd., 1985.

Sen, Gautam. *The Military Origins of Industrialisation and International Trade Rivalry.* London: Frances Pinter, Ltd., 1984.

Silva, Marcos Eugénio da. *Innovãçoa Tecnológica: Un Estudo do Casa.* São Paulo: Instituto de Pesquisas Econômicas, 1984.

Silva, Paulo Fontenela e. *Aspetos Tecnologicos da Estrutura Industrial Brasileira: Uma Analise de Insumo-Produto.* Rio de Janeiro: BNDES, 1980.

Singh, Ram Nath. *All About Weapons: From Arrow to Missiles*. Patna: Ghintamani Prakashan Publishers, 1979.

Stepan, Alfred. *Rethinking Military Politics: Brazil and the Southern Cone*. Princeton: Princeton University Press, 1987.

Stewart, Francis. *Technology and Underdevelopment*. London: Macmillan, 1977.

Stewart, Francis, and Jeffrey James, eds. *The Economics of New Technology in Developing Countries*. London: Frances Pinter, 1982.

Stockholm International Peace Research Institute (SIPRI). *Arms Trade and the Third World*. Stockholm: Almqvist and Wiksell, 1971.

----. *World Armaments and Disarmaments*. Stockholm: Almqvist and Wiksell, various dates.

Stopford, John, and Susan Strange with John Henley. *Rival States, Rival Firms: Competition for World Market Shares*. Cambridge: Cambridge University Press, 1991.

Tadini, Venilton. *O Setor de Bens de Capital sob Encomenda: Analise do Desenvolvimento Recente (1974/83)*. São Paulo: Departmento de Economia, Universidade de São Paulo, Faculdade de Economia e Administração, 1986.

Tavares, José. *Indústria Belica Brasileira: O Homen Dinante da Sua Destruiçao*. Brasilia: Camara dos Deputados, Centro de Documentação e Informação, Coordenação de Publicaçoes, 1983.

Thomas, Raju G.C. *Indian Security Policy*. Princeton: Princeton University Press, 1986.

----. *The Defence of India*. New Delhi: Macmillan Company of India Ltd., 1978.

Thomas, Richard. *India's Emergence as an Industrial Power: Middle Eastern Contracts*. London: C. Hurst for the Royal Institute of International Affairs, 1982.

Tirman, John, ed. *The Militarisation of High Technology*. Cambridge, MA.: Ballinger Publishing Company, 1984.

Tirole, Jean. *The Theory of Industrial Organisation*. Cambridge: MIT Press, 1988.

Todd, Daniel, and Jamie Simpson. *The World Aircraft Industry.* London: Croom Helm, 1986.

Trabasso, T. "The Importance of Context in Understanding Discourse." In *Question Framing and Response Consistency*, ed. R.M. Hogarth. San Francisco: Jossey-Bass, 1982.

Treblat, Thomas J. *Brazil's State-Owned Enterprises: A Case Study of the State as Entrepreneur.* Cambridge: Cambridge University Press, 1983.

Tuomi, Helena, and Raimo Väyrynen. *Militarisation and Arms Production.* London: Croom Helm, 1983.

Tyler, W.G. *The Brazilian Industrial Economy.* Lexington: Lexington Books/D.C. Heath, 1981.

----. *Advanced Developing Countries as Export Competitors in Third World Markets: The Brazilian Experience.* Washington, D.C.: Centre for Strategic and International Studies, Georgetown University, 1980.

Tyson, Laura D'Andrea. *Who's Bashing Whom? Trade Conflict in High-Technology Industries.* Washington, D.C.: Institute for International Economics, 1992.

United Nations Conference on Trade and Development (UNCTAD). *Technology Issues in the Capital Goods Sector: A Case Study of Leading Machinery Producers in India.* New York: United Nations, 1983.

United Nations Industrial Development Organisation. *Industrial Priorities in Developing Countries.* New York: United Nations, 1979.

Varas, Augusto. *Militarisation and the International Arms Race in Latin America.* Boulder, CO.: Westview Press, Inc., 1985.

Vernon, Raymond, ed. *The Technology Factor in International Trade.* New York: Columbia University Press for the National Bureau of Economic Research, 1970.

Versiani, Flàvio Rabelo, and Vânia Lomônaco Bastos. *The Brazilian Machine-Tool Industry: Patterns of Technological Transfer and the Role of the Government.* Brasilia: Universidade de Brasilia, Instituto de Ciências Humanas, Departmento da Economia, June 1976.

Wade, Robert, and Gordon White, eds. *Developmental States in East Asia.* New York: St. Martin's Press, 1988.

Waltz, Kenneth. *Theory of International Relations*. Reading, MA.: Addison Wesley, 1979.

Warwick, D.P., and S. Osherson. *Comparitive Research Methods*. Englewood Cliffs, NJ: Prentice-Hall, 1973.

Watanabe, Susumu, ed. *Technology, Marketing and Industrialisation: Linkages Between Large and Small Enterprises*. New Delhi: Macmillan Press, 1983.

Wolf, Martin. *India's Exports*. New York: Oxford University Press, 1982.

World Bank. *Brazil: Industrial Policies and Manufacturing Exports*. Washington, D.C.: World Bank, 1983.

----. *India: An Industrialising Country in Transition*. Washington, D.C.: The World Bank, 1989.

----. *India: Recent Developments and Medium-Term Issues*. Washington, D.C.: World Bank, 1989.

----. *Korea: Managing the Industrial Transition*. Washington, D.C.: The World Bank, 1987.

Articles

Adler, Emanuel. "State Institutions, Ideology, and Autonomous Development: Computers and Nuclear Energy in Argentina and Brazil." *Latin American Research Review*. 23, 9 (1988): 59-90.

Alam, Ghayur. "Government Research and its Utilisation by Industry: The Case of Industrial Civil Research in India." *Research Policy* 13 (1984): 55-61.

Albrecht, Ulrich, Dieter Ernst, Peter Lock, and Herbert Wulf. "Armaments and Underdevelopment." *Bulletin of Peace Proposals*. Vol. 5, no. 2 (1974): 173-85.

Ames, Barry. "Military and Society in Latin America." *Latin American Research Review*. 23, 2 (1988): 157-69.

Amsden, Alice H. "The Industry Characteristics of Intra-Third World Trade in Manufactures." *Economic Development and Cultural Change*. 29, no. 1 (October 1980): 1-19.

----. "The Division of Labour is Limited by the Rate of Growth of the Market: The Taiwan Machine Tool Industry in the 1970s." *Cambridge Journal of Economics*. 9 (1985): 271-84.

Arnold, Walter. "Science & Technology Development in Taiwan and South Korea." *Asian Survey*. Vol. 28, no. 4 April 1988: 437-450.

Bacha, Edmar L. "Issues and Evidence on Recent Brazilian Economic Growth." *World Development*. 5, nos. 1-2 (1977): 47-67.

Baer, Werner. "The Brazilian Boom 1968-72: An Explanation and Interpretation." *World Development*. 1, no. 8 (August 1973): 1-15.

Baer, W., Kerstenetzky, I., and A. Villela. "The Changing Role of the State in the Brazilian Economy." *World Development*. 1, no. 11: 23-34.

Ball, Nicole. "Defence and Development: A Critique of the Benoit Study." *Economic Development and Cultural Change*, Vol. 31, no. 3 (April 1983): 507-24.

Banerjee, Jtotirmoy. "Moscow's Indian Alliance." *Problems of Communism*. 36 (January February 1987): 1-12.

Baumann, Renato, and Helson C. Braga. "Export Financing in LDCs: The Role of Subsidies for Export Performance in Brazil." *World Development*. 16, 7 (July 1988): 821-33.

Bell, Martin, Bruce Ross-Larson, and Larry E. Westphal, "Assessing the Performance of Infant Industries," *Journal of Development Economics*, Vol. 16, nos. 1-2 (September-October 1984): 101-28.

Benoit, Emile. "Growth and Defence in Developing Countries." *Economic Development and Cultural Change*. Vol. 26, no. 2 (January 1978).

Bhagavantam, S. "Organisation, Management and Progress of Defence Research and Development." *Indian Journal of Public Administration*. 15, no. 3 (July-September 1969): 395-403.

Boulding, Kenneth. "Defence Spending: Burden or Boon." *War/Peace Report*. Vol. 13, no. 1 (1974): 19-24.

Bratersky, M. V., and S.I. Lunyov. "India at the End of the Century: Transformation into an Asian Regional Power." *Asian Survey*. Vol XXX, No. 10 (October 1990): 927-942.

Chenery, Hollis B., and Tsunehiko Watanabe. "International Comparisons of the Structure of Production." *Econometrica*. 26, no. 4 (October 1958): 487-521.

Coelho, Edmundo Campos. "Forcas Armadas: O Ordem das Prioridades." *Politica e Estrategia*. 5, 2 (Abr/Jun 1987): 224-34.

Crane, Diane. "Technological Innovation in Developing Countries: A Review of the Literature." *Research Policy* 6, no. 4 (October 1977): 374-95.

Dahlman, Carl F., Bruce Ross-Larson, and Larry E. Westphal. "Managing Technological Development: Lessons from the Newly Industrialising Countries." *World Development*. Vol. 15, no. 6 (1987): 759-775.

Dahlman, Carl J., and Francisco C. Sercovich. "Exports of Technology from Semi-Industrial Economies and Local Technological Development." *Journal of Development Economics*. Special Issue: Symposium on Technological Change and Industrial Development, 15, nos. 1-2 (September-October 1984): 63-99.

Davidson, B.J.G. "Indian Aerospace -- Closing the Technology Gap." *Interavia*. 27 (November 1972): 1237-39.

Defence and Foreign Affairs Digest. "Brazil: Material Chief Comments on Policy." Vol. 6, no. 2 (1978).

The Defence Review. "Towards Self-Reliance in Defence." (1984): 257-62.

Desai, Ashok V. "The Origin and Direction of Industrial R & D India." *Research Policy*. 8 (1980): 74-96.

----. "India's Technological Capability: An Analysis of its Achievements and Limits." *Research Policy*. 13 (1984): 303-10.

----. "Market Structure and Technology: Their Interdependence in Indian Industry." *Research Policy*. 14, no. 3 (June 1985): 161-70.

Elkin, Jerrold F. "The Indian Air Force of the 1980s: Modern Clout in Southwest Asia." *Air University Review*. 35, no. 6 (September-October 1984): 88-95.

Erber, Fábio Stefano. "Desenvolvimento Tecnologico e Intervenção do Estado: Um Confronto Entre A Experiencia Brasileira e a dos Paises Capitalistas Centrais." *Revista de Administração Publica*. 14, no. 4 (October-December 1980): 10-72.

Evans, David, and Parvin Alizadeh. "Trade, Industrialisation, and Visible Hand." *The Journal of Development Studies.* 21, no. 1 (October 1984):22-46.

Evans, Peter B. "The Military, the Multinationals and the 'Miracle': The Political Economy of the "Brazilian Model" of Development." *Studies in Comparative International Development.* 9, no. 3 (Fall 1974): 26-45.

----. "Multinationals, State-Owned Corporations and the Transformation of Imperialism: A Brazilian Case Study." *Economic Development and Cultural Change.* 26, no. 1 (October 1976): 43-64.

Foss, Christopher F. "Engesa -- The First Ten Years of Armoured Vehicles Production." *Defence* (December 1980).

Fragoso, João Luiz Ribeiro. "As Reformulaçães na Politica Externa Brasileira nos Anos 70." *Estudos Afro-Asiaticos.* N. 5 (1981): 41-53.

Fransman, Martin. "Promoting Technological Capability in the Capital Goods Sector: The Case of Singapore." *Research Policy* 13 (1984): 33-54.

Fudenberg, Drew, Richard Gilbert, Joseph Stiglitz, and Jean Tirole. "Preemption, Leapfrogging and Competition in Patent Races." *European Economic Review.* 22 (1983): 3-31.

Fudenberg, Drew, and Jean Tirole. "Preemption and Rent Equalisation in the Adoption of New Technology." *Review of Economic Studies.* 52 (1985): 383-401.

Gilbert, Richard and David Newberry. "Preemptive Patenting and the Persistence of Monopoly." *American Economic Review.* 72 (1982): 514-526.

Girdner, Eddie J. "Economic Liberalisation in India: The New Electronics Policy." *Asian Survey.* Vol. 27, no. 11 (November 1987): 1188-1204.

Gowrishankar, Sundaram, Mike Howarth, and Hormuz Mama. *International Defence Review.* "India: Indigenous Programs Flourish Amid Defence Modernisation." 19, no. 4 (1986): 435-44.

Grieco, Joseph M. "Between Dependency and Autonomy: India's Experience with the International Computer Industry." *International Organisation* 36, no. 3 (Summer 1982): 609-32.

Guimarães, Edson P. "Uma Nota sobre a Influencia da Estrutura Industrial na Exportaçõa de Manufaturados Brasileiros." *Revista Brasileira de Economia.* 38, 1 (Jan/Mar 1984): 95-110.

Gupta, Amit. "India's Mixed Performance." *Defence & Diplomacy*. Vol. 7, no. 5 (May 1987): 44-49.

----. "The Indian Arms Industry: A Lumbering Giant?" *Asian Survey*. Vol. XXX, No. 9 (September 1990): 846-861.

Harris, C., and J. Vickers. "Racing with Uncertainty." *Review of Economic Studies*. 54 (1987): 1-22.

Hirschman, Albert O. "The Political Economy of Import-Substituting Industrialisation in Latin America." *The Quarterly Journal of Economics*. 82, no. 1 (February 1968): 1-32.

Horowitz, Irving Louis, and Ellen Kay Triumberger. "State Power and Military Nationalism in Latin America." *Comparative Politics*. 8 (January 1976): 223-44.

Howarth, H.M.F. "Brazil's Defence Industry: Ambitious and Growing Fast." *International Defence Review*. 18, no. 9 (1985): 1413-27

Hudson, Rexford A. "The Brazilian Way to Technological Independence: Foreign Joint Ventures and the Aircraft Industry." *Inter American Economic Affairs*. 37, no. 2 (Autumn 1983): 23-43.

Ikenberry, John G. "The State and Strategies of International Adjustment." *World Politics*. 39: 53-77.

Interavia. "Embraer is Confident about its Future: Chairman Ozires Talks to Interavia." 9 (1983): 997.

Katz, Jorge M. "Domestic Technological Innovations and Dynamic Comparative Advantage." *Journal of Development Economics*. 16, nos. 1-2 (September-October 1984): 13-37.

Kolodziej, Edward, and Robert E. Harkavy. "Developing States and the International Security System." *Journal of International Affairs*. 34, 1 (Spring/Summer 1980): 59-87.

Lall, Sanjaya. "India." *World Development*. 12, no. 516 (1984): 535-65.

Lim, Linda Y.C. "Singapore's Success: The Myth of the Free Market Economy." *Asian Survey*. 23 (June 1983).

Liu, Paul K.C., Ying-Chuan Liu, and Hiu-Lin Wu. "New Technologies, Industry, and Trade -- The Taiwan Experience." *Industry of Free China*. vo. 72, no. 4

(October 1989): 23-35 and *Industry of Free China* vol. 72, no. 5 (November 1989): 7-24.

Macedo, Ubiratan Borges de. "A Escola Superior de Guerra, Sua Ideologia e Transito para a Democracia." *Politica e Estrategia* 6, 2 (Abr/Jun 1988): 215-222.

Majeed, Akhtar. "Indian Security Perspectives in the 1990s." *Asian Survey*. Vol. XXX, No. 11 (November 1990): 1084-1098.

Malan, Pedro S., and Regis Bonelli. "The Brazilian Economy in the Seventies: Old and New Developments." *World Development*. 5, nos. 1-2 (1977): 19-45.

Mama, Hormuz P. "Space as a Spur for National Development in India." *Space Markets and Satellite Technology*. 4 (Winter 1987): 188-96.

Manrique, Gabriel G. "Intra-Industry Trade Between Developed and Developing Countries: The United States and the NICs." *The Journal of Developing Areas*. Vol. 21, no. 4 (July 1987): 481-94.

Menon, Commodore K. R. "Third World Navies React." *Proceedings of the U.S. Naval Institute*. March 1989.

Milhollin, Gary. "India's Missiles -- With a Little Help From our Friends." *The Bulletin of Atomic Scientists*. Vol. 45, no. 9 (November 1989): 31-35.

Morehouse, Ward. "Technology and Enterprise Performance in the Indian Tractor Industry: Does Self-Reliance Measure Up?" *Economic and Political Weekly*. Vol. 15, no. 51 (20 December 1980): 2139-52.

Mowery, David, and Nathan Rosenberg. "The Influence of Market Demand upon Innovation: A Critical Review of Some Recent Empirical Studies." *Research Policy* 8 (1979): 102-53.

Mukerjee, Dilip. "Indo-Soviet Economic Ties." *Problems of Communism*. 36 (January-February 1987): 13-24.

----. "U.S. Weaponry for India." *Asian Survey*. 27, no. 6 (June 1987): 595-614.

----. "India and the Soviet Union." *The Washington Quarterly*. Vol. 9 (Spring 1986): 109-122.

Neuman, Stephanie. "International Stratification and Third World Military Expenditure." *International Organisation* (Winter 1984): 167-97.

Nolan, Janne E. "Ballistic Missile in the Third World -- The Limits to Non-Proliferation." *Arms Control Today*. Vol. 19, no. 9 (November 1989): 9-14.

Olive, Ronaldo S. "Bandeirante: Success Story of Brazil's Young Aircraft Industry." *Interavia*. 29 (August 1974): 749-50.

----. "AMRJ Shipbuilding Programmes." *Janes's Defence Review*. Vol. 4, No. 8 (1983).

Pack, Howard. "Fostering the Capital Goods Sector in LDCs." *World Development*. 9, no. 3 (1981): 227-50.

Pavitt, Keith. "Patterns of Technical Change: Towards a Taxonomy and a Theory." *Research Policy*. 13, 6 (1984): 343-74.

Peirera, Antonio Carlos. "Aspectos Totalizantes da Doutrina de Seguranca Nacional." *Politica e Estrategia* 6, 2 (Abr/Jun 1988): 252-271.

Peirera Roberto. "Os Helicopteros de Helibrás." *Tecnologia e Defesa*. No. 3 (Maio 1983): 40-41.

Reinganum, Jennifer F. "Dynamic Games of Innovation." *Journal of Economic Theory*. 25 (1981): 21-41.

----. "Market Structure and the Diffusion of New Technology." *The Bell Journal of Economics*. 12, 2 (Autumn 1981): 618-624.

----. "On the Diffusion of New Technology: A Game Theoretic Approach." *Review of Economic Studies*. XLVIII (3) No. 153 (1981):395-405.

----. "Uncertain Innovation and the Persistence of Monopoly." *American Economic Review*. 83, 4 (September 1983): 741-748.

----. Innovation and Industry Evolution." *Quarterly Journal of Economics*. 100 (1985): 81-100.

Rek, Bron. "The New Supercommuters Prepare to Attack the US Market." *Interavia*. 7 (1983): 717-20.

Revista Brasileiro Tecnológico. "Politica, Estado e Desenvolvimento Tecnológico." Brasilia, 14, no. 3 (Mai-Jun 1983): 4-17.

Reidel, James. "Trade as the Engine of Growth in Developing Countries, Revisited." *The Economic Journal*. 94 (March 1984): 56-73.

Riedel, James, Chris Hall, and Roger Grawe. "Determinants of Indian Export Performance in the 1970s." *Weltwirtschaftliches Archiv.* Vol. 120, no. 1 (1984):40-63.

Santhanam, K.V., and R.H. Patil. "A Study of the Production Structure of the Indian Economy: An International Comparison." *Econometrica.* 40, no. 1 (January 1972): 159-176.

Saw, David. "The Emergence of the Third World Aircraft Industry." *Military Technology.* Vol. 4, no. 4 1988.

Schmitz, Hubert. "Industrialisation Strategies in Less Developed Countries: Some Lessons of Historical Experience." *The Journal of Development Studies.* 21, no. 1 (October 1984): 1-21.

Selcher, Wayne A. "The National Security Doctrine and Policies of the Brazilian Government." *Parameters.* 7, no. 1 (1977).

Sercovich, Francisco. "Brazil, in Special Issue: Exports of Technology by Newly Industrialising Countries." *World Development.* 12, no. 516: 575-99.

Sharma, Gautam. "Defence Production in India." *IDSA Journal.* 10, no. 4 (April-June 1978): 322-346.

Sharma, P. "Towards Self-Reliance in Defence." *The Defence Review 1984*: 257-262.

Singh, Bilveer. "ASEAN's Arms Industries: Potentials and Limits." *Comparative Strategy.* Vol. 8, no. 2, 1989: 249-264.

Singh, Pushpindar. "1984-85 Annual Report of the Indian Defence Ministry." *Asian Defence Journal.* (July 1985): 64-67.

Singh, S. Nihal. "Why India Goes to Moscow for Arms." *Asian Survey.* 24, no. 7 (July 1984): 707-20.

Silva, Ozires. "O Vôo da Embraer." *Revista Brasileira de Tecnologia.* 13, numero 1 (Janeiro/Março 1982): 20-30.

Simpson, David, and Jinkichi Tsukui. "The Fundamental Structure of Input-Output Tables and International Comparison." *Review of Economics and Statistics.* Vol XLVII, no. 4 (November 1965): 434-446.

Smith, Ron. "Military Expenditure and Capitalism." *Cambridge Journal of Economics.* 1, no. 1 (1977): 61-76.

Smith, Ron, Anthony Humm, and Jacques Fontanel. "The Economics of Exporting Arms." *Birkbeck College Discussion Paper.* No. 164 November 1984).

Souza, José Fernandes de. "Biselli." *Tecnológia e Defesa.* No. 3 (Maio 1983): 6.

----. "Entrevista: Gurgel: Jipes em Todo o Mundo." *Tecnológia e Defesa.* No. 8 (1983): 34-35.

----. "Pierelli: Centro de Pesquisas." *Tecnológia e Defesa.* No. 8 (1983): 39-40.

Subrahmanyam, K. "Problems of Defence Industrialisation in India." *IDSA Journal.* 13, no. 3 (January-March 1981): 363-377.

Taylor, Trevor. "Defence Industries in International Relations," *Review of International Studies.* Vol. 1, 1990

Teitel, Simon. "Towards an Understanding of Technical Change in Semi-Industrialised Countries." *Research Policy* 10 (1981): 127-47.

----. "Technology Creation in Semi-Industrial Economies." *Journal of Development Economics.* Special Issue: Symposium on Technological Change and Industrial Development. 16, nos. 1-2 (September-October 1984): 39-61.

----. "Science and Technology Indicators, Country Size and Economic Development: An International Comparison." *World Development.* 15, no. 9 (September 1987): 1222-35.

Teitel, Simon, and Francisco Sercovitch. "Latin America." *World Development.* 12, no. 5-6: 645-60.

Tellis, Ashley J. "India's Naval Expansion: Reflections on History and Strategy." *Comparative Strategy.* Vol. 6, no. 2, 1987.

----. "The Air Balance in the Indian Subcontinent: Trends, Constants and Contexts." *Defence Analysis.* Vol. 2, no. 4 (December 1986): 263-89.

Teubal, Morris. "The Role of Technological Learning in the Exports of Manufactured Goods: The Case of Selected Capital Goods in Brazil." *World Development.* 12, no. 8 (1984): 849-65.

Topik, Steven. "The Evolution of the Economic Role of the Brazilian State, 1889-1930." *Journal of Latin American Studies.* 11, no. 2 (1979): 325-342.

Tyler, W.G. "Brazilian Industrialisation and Industrial Policies: A Survey." *World Development*. 4, nos. 10-11 (October-November 1976): 863-82.

Viner, Jacob. "Power versus Plenty as Objectives of Foreign Policy in the Seventeenth and Eighteenth Centuries." *World Politics*. 1 (1948): 1-29.

Williams, John Hoyt. "Brazil's Arms Industry on the Move." *Armed Forces Journal International* (December 1984): 106-112.

----. "Brazilian Weapons." *National Defence*. 71 (September 1986): 57-64.

Wionczek, Miguel S. "Growth of Military Industries in Developing Countries: Impact on the Process of Underdevelopment." *Bulletin of Peace Proposals*. 17, no. 7 (1986): 47-58.

Wirsing, Robert G. "The Arms Race in South Asia: Implications for the United States." *Asian Survey*. 25, no. 3 (March 1985): 265-291.

Wolff, Klaus. "The Brazilian Defence Industry: Partners or Competitors to the Established Western Defence Industries." *Military Technology*. 9, no. 10 (October 1985): 92-119.

Government Publications

Brazil

Banco Nacional Desenvolvimento e Social (BNDES). *Annual Reports 1987, 1988.*

----. *Siderugia Brasileira: Questoes e Perspectivas*. Textos para Discussão N. 5. Rio de Janeiro: Area de Planejamento, Departamento de Estudos, Janeiro de 1987.

----. *Sintese do Plano de Acao 1987.*

----. *O Capital Estrangeiro na Industria Brasileira: Atualidade e Perspectivas.* Estudos BNDES No. 10 . Rio de Janeiro: BNDES, Area de Planejamento, Departamento de Estudos, 1988.

----. *Questoes Relativas a Competitividade da Indústria de Bens de Capital: Bens de Caital sob Encomenda e Maquinas-Ferramenta.* Estudos No. 8. Area de Planejamento, Departamento de Estudos, Junho 1988.

----. *Programa Economico*. Vol. 18, Setembro de 1988.

----. *Plano Estrategico 1988/90.*

I PBDCT. Plano Basico de Desenvolvimento Científico e Tecnológico, 1973/1974. Brasilia: Presidência da República, 1973.

II PBDCT. Plano Basico de Desenvolvimennto Científico e Tecnológico, 1975/1977. Brasilia: Presidência da República, 1975.

Government of Brazil. *Regulamento do Imposto e Renda*. Decreito 85.450, de 4.12.88. São Paulo: Editora Reserche Tributairie, 1988. p. 866.

----. LEX - *Coletenea e Legislança e Jurisprudencia*. Lex Editora S.A. Vol. XLVIII - 1984, pagina 534.

India

Economic Administration Reforms Commission. *EARC Report No. 20. Technology Development and Acquisition*. New Delhi: Cabinet Secretariat, 7 June 1983.

Ministry of Defence. *MOD Annual Reports*. (various years). New Delhi: Ministry of Defence.

India (Republic) Parliament. Public Accounts Committee. *Epitome of the Reports of the Central Committee of Public Accounts From 1977-1978 to 1978-1979. (Sixth Lok Sabha) and of the Government Orders thereon with an Index.* New Delhi: Comptroller and Auditor General of India, 16 February 1983.

----. Public Accounts Committee. Sixty-Sixth Report, Public Accounts Committee (1981-82) (Seventh Lok Sabha). *Redundancy in Materials Procured for the Manufacture of an Aircraft*. Ministry of Defence, New Delhi: Lok Sabha Secretariat, December 1981.

----. Eighty-seventh Report, Public Accounts Committee, 1981-82. (Seventh Lok Sabha) *Replacement of Basic Trainer*. Ministry of Defence. New Delhi: Lok Sabha Secretariat, March 1982.

----. Ninety-eigth Report, Public Accounts Committee, 1981-82. (Seventh Lok Sabha) *Wasteful Expenditure on Procurement of Imported Aircraft Spares and Infructurous Expenditure on Procurement of Defective Ammunition*. Ministry of

Defence, [Action Taken on 37th Report (Seventh Lok Sabha)] New Delhi: Lok Sabha Secretariat, April 1982.

----. Seventy-Sixth Report, Public Accounts Committee, 1981-82. (Seventh Lok Sabha) *Development of a Helicopter.* Ministry of Defence, New Delhi: Lok Sabha Secretariat, March 1983.

----. Committee on Public Undertakings. *Action Taken by Government on the Recommendations contained in the hundred and twenty-fourth Report of the Estimates Committee. [Second Lok Sabha]; Hindustan Aircraft Ltd.*, Bangalore. New Delhi: Lok Sabha Secretariat, 1966.

----. Committee on Public Undertakings, 1968-69. (Fourth Lok Sabha) *Forty-Second Report, Magazon Dock Ltd., Bombay*, Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, April 1969.

----. Committee on Public Undertakings, 1968-69. (Fourth Lok Sabha) *Twenty-fifth Report, Praga Tools Ltd.* Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, February 1969.

----. Committee on Public Undertakings. *Praga Tools Ltd.* Fourth Lok Sabha. Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, 1969.

----. Committee on Public Undertakings, 1969-70. *Action Taken by Government on the Recommendations Contained in the Twenty-fifth Report of the Committee on Public Undertakings (Fourth Lok Sabha) on Praga Tools Ltd.* Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, January 1970.

----. Committee on Public Undertakings, 1969-70. (Fourth Lok Sabha) *Sixtieth Report.* Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, February 1970.

----. Committee on Public Undertakings. *Action Taken by Government on the Recommendations Contained in the Eighth Report of the Committee on Public Undertakings (Fourth Lok Sabha) on Hindustan Aeronautics, Ltd.*, Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, 1970.

----. Committee on Public Undertakings, 1971-71. (Fifth Lok Sabha) *Third Report. Bharat Electronics Ltd., Bangalore.* Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, November 1971.

----. Committee on Public Undertakings, 1971-72. (Fifth Lok Sabha) *Second Report. Bharat Earth Movers Ltd.* Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, September 1971.

----. Committee on Public Undertakings. *Action taken by Government on the recommendations contained in the eigth Report of the Committee on Public Undertakings (Fourth Lok Sabha) on Hindustan Aeronautics Ltd.* Ministry of Defence, Department of Defence Production. New Delhi: Lok Sabha Secretariat, 1970.

----. Committee on Public Undertakings (1974-75) *Fifty-Eighth Report, Hindustan Machine Tools Ltd.* Ministry of Industry and Civil Supplies, Department of Heavy Industry. New Delhi: Lok Sabha Secretariat, February 1975.

----. Committee on Public Undertakings, 1985-86. *Ninth Report on Bharat Electronics.* Ministry of Defence, Department of Defence Production and Supplies. (Eighth Lok Sabha) New Delhi: Lok Sabha Secretariat, 1986.

----. Committee on Public Undertakings. *Bharat Earth Movers Limited.* Ministry of Defence, Department of Defence Production and Supplies, 1987-88. (Eigth Lok Sabha) New Delhi: Lok Sabha Secretariat, 1988.

----. Committee on Public Undertakings. Thirteenth Report on Bharat Electronics Ltd.: *Capacity Utilisation, Production & Pricing, Research and Development.* Ministry of Defence, Department of Defence Production & Supplies, 1986-87 (Eighth Lok Sabha) New Delhi: Lok Sabha Secretariat, 1986.

----. Committeee on Public Undertakings. *Bharat Electronics Limited: Capacity Utilisation, Production & Pricing, Research and Development.* Ministry of Defence, Department of Defence Production & Supplies, 1987-88 (Eighth Lok Sabha) NewDelhi: Lok Sabha Secretariat, 1987.

United States

Executive Office of the President, Office of Management and Budget. *Standard Industrial Classification Manual 1987.* Springfield, VA.: National Technical Information Service, 1987.

U.S. Congress, Joint Economic Committee. *The Machine Tool Industry and the Defence Industrial Base.* Hearing before the Joint Economic Committee, Congress of the United States, Ninety-eighth Congress, first session, 7 June 1983. Washington, D.C.: Government Printing Office, 1983.

U.S. Congress, Office of Technology Assessment. *The Global Arms Trade.* Washington, D.C.: U.S. Government Printing Office, 1991.

Newspapers

Aerospace Daily. "France Reported to Have Ordered 41 Embraer Xingu Trainers." 26 January 1981, 118.

AsiaWeek. "Singapore Shoots for the Sky." Vol 14, no. 11 (11 March 1988), 50-1.

Aviation Week and Space Technology. "Avibras Seeks Better Balance of Domestic, Export Business." 25 June 1984, 209.

----. "Brazilian Export Policy Sparks Criticism." 21 June 1982, 60.

----. "Nations Building Industrial Bases with Cooperative Production Efforts." 23 June 1985, 323-324.

Bhushan, Bharat. "Ancillarisation: A New Production Strategy." *Business India.* (16-29 January 1984, 76-89.

Brown, David A. "India's Aircraft Industry Grows." *Aviation Week and Space Technology.* 17 Janauray 1985, 14-16.

----. "India Identifies Large Market for Advanced Light Helicopter." 19 May 1986, 69,71.

----. "India Nearing Full Production of Soviet MiG-27m Fighter." 28 April 1986, 22.

----. "India Seeks European Technical Aid for Light Combat Aircraft." 17 June 1985, 61-63.

Business Week. "Brazil: The Aircraft Industry Irks U.S. Competitors." 11 October 1976, 45.

Chanda, Nayan. "The Third World Race for Ballistic Missiles." *Far Eastern Economic Review.* 2 June 1988.

Chawla, Prabhu. "The Scandal Surfaces." *Business India.* 15 March 1990, 32-35.

Chellaney, Brahma. "India Bolsters its Naval Forces." *Christian Science Monitor.* 22 January 1988, 1 & 32.

Cockburn, Robert "Third World Holds Its Own with the West's Majors." in Aviation (I), The International Herald Tribune. 30 May 1985, 7.

Diehl, Jackson. "Brazilian Industrialists Oppose Government." *The Washington Post.* 1 May 1984, A21.

Defesa. (bimonthly irregular), São Paulo.

Everett, Martin G. "Brazil's Fledgling Arms Industry Making a Hit with Weapons-Hungry Third World Armies." *The Wall Street Journal.* 4 January 1985, 14, 18.

Fialka, John J. "Space Research Fuels Arms Proliferation: Indian Missile Suggests U.S., West German Parenthood." *The Wall Street Journal.* 6 July 1989, A8.

Financial Times (London). "Brazil: Limits of Finance." 1 September 1988.

Foreign Broadcast Information Service. (various dates).

Foster, Richard. "Strong Success in Sales to the Third World." *Financial Times.* 20 December 1985, 6.

Frontline. "Agni: Importance, Implications." 10-23 June 1989, 4-16.

Ghatt. V. V. "On Competitive Impulses and Public Enterprise Performance." *Economic and Political Weekly.* 27 May 1989, M-50-54.

Godoy, Roberto. "Tanque pode render ate U.S. 7 Bilhoes." *O Estado do São Paulo.* 22 August 1989, 11.

Goodsell, James Nelson. "Brazil Cashiers Military Government, But Cashes in on Arms Sales." *The Christian Science Monitor.* 14 January 1985, 11.

Graham, Bradley. "Brazil Arms Industry Competes Worldwide." *The Washington Post.* 2 November 1986, D1.

Gupta, Ruchira. "HDW Deal: In Hot Pursuit." *Business India.* 19 March-1 April 1990, 85-86.

Hellyner, Paul. "Brazil's Increased Arms Sales Include Iraq-Iran Deals." *Jane's Defence Week.* 23 June 1984.

House, Richard. "Saudi Arabians, Brazilians Agree to Manufacture Weapons Jointly." *The Wall Street Journal.* 12 October 1984, 2F.

----. "Taking on the Big Guns." *South*. November 1985.

India Weekly. "Another Long-Range Missile Developed." 17 July 1987, 10.

Ingrassia, Lawrence. "The Arms Business: World Weapons Sales Slow, Competition by Suppliers Heats Up." *The Wall Street Journal*. 30 May 1984, 1, 20.

International Businessweek. "Brazil: A Third World Plane Maker Targets the RAF." 18 June 1984

International Herald Tribune. "Aviation: High World Sales Bring Problems." 7 September 1982, 7s, 11-12s.

Johnson, Henry. "Arms Industry Rivals Chief Export Sectors." *International Herald Tribune*. 7 September 1982, 8s.

Johnstone, Bob. "Taiwan's Hi-Tech Hothouse." *Far Eastern Economic Review*. 31 August 1989

----. "Hi-Tech Dilemma." *Far Eastern Economic Review*. May 15 1985.

Karp, Aaron. "Defusing the Third World Missile Threat." *The Wall Street Journal*. 21 June 1988.

Kathuria, Sanjay. "Market Structure and Innovation: A Survey of Empirical Studies of Schumpeterian Hypotheses for Developed Countries and India." *Economic and Political Weekly*. 26 August 1989, M-113-M124.

Kaye, Lincoln. "India's Dinosaur Legacy." *Far Eastern Economic Review*. 14 January 1988, 56-58.

Kelkar, Vijay, and Rajiv Kumar. "Industrial Growth in the Eighties: Emerging Policy Issues." *Economic and Political Weekly*. 27 January 1990, 209-222.

Kepp, Michael. "Brazil Finds Success as Arms Maker, but No-Sales Strings Sales Policy Irritates U.S." *The Sun* (Baltimore). 10 March 1988, p. 2A.

Latin America Weekly Report. WR-84-09, "Concern over Tucano Sale." WR-84-22 (8 June 1984), 11

----. "Orders Come in for Osorio Tank." WR-84-49 (14 December 1984), 9.

Latin American Regional Reports: Brazil. "U.S. Objects to Deal on French Missile Know-How. 23 November 1989.

Mahalingam, Sudha. "Computer Strategy in India: Strategies for Late-Comer Entry." *Economic and Political Weekly*. 21 October 1989: 2375-2384.

Margolis, Mac. "Brazil Plans to Resume Weapons Sales to Libya." *The Washington Post*. 28 January 1988, A22.

Mukerjee, Dilip. "Hi-Tech Players in a Dangerous Game of Catch." *Far Eastern Economic Review*. 9 June 1988.

Munro, Ross H. "Superpower Rivalry." *Time* (International Edition). 3 April 1989.

Nag, Kingshuk. "Defence Production: Arms and the Businessman." *Business India*. 25 June-8 July 1990, 87-88.

Nag, Kingshuk, and Rajiv Shirali. "Why We Can't Afford War." *Business India*. 14-27 May 1990, 46-52.

Namboodiri, P.K.S. "Planning for Defence." *Eastern Economist*. (New Delhi) 23 January 1981, 283-5.

Reddy, Amulya Kumar N. "Basis of the Japanese "Miracle": Lessons for India." *Economic and Political Weekly*. 24 June 1972, 1241-45.

Riding, Alan. "Brazil's Burgeoning Arms Industry." *The New York Times*. 3 November 1985.

Sarkar, Keya. "Machine Tool Industry: Gearing Up -- With a Little Help from Japan." *Business India*. 23 September-6 October 1985, 82-88.

Satyanarayana, P.V. "Machine Tools: Narrowing the Technology Gap." *Business India*. 5-18 March 1979, 50-58.

Shankar, Kripa. "Characteristics of Diversification in Indian Industry." *Economic and Political Weekly*. 3 June 1989, 1241-1251.

South. "The Missile Race Hots Up" August 1989.

Stevenson, Richard W. "No Longer the Only Game in Town." *The New York Times*. 4 December 1988, F1, F7.

Subrahmanyam, K. "Chinese Missiles and Indian Security," *Times of India* quoted in *India Weekly*. 22 April 1988, 10.

The Sunday Calcutta Statesman. "First Batch of MIg-29s." 4 January 1987, 1, 9.

Valluri. S. R. "Management of R and D Institutions and Self-Reliance." *Economic and Political Weekly*. 25 August 1990, M-111-M114.

Veja. "Cientista das Arabias" 3 October 1990, 48-50.

Velupillai, David. "Brasilia: Embraer's New Commuter." *Flight International*. 30 July 1983, 254-69.

Weintraub, Richard M. "India Tests Mid-Range Agni Missile." *The Washington Post* 23 May 1989, A1, A21.

Weisman, Steven R. "U.S. to Sell High-Tech Equipment to India for Arms-Upgrading Plan." *The New York Times*. 1 October 1986.

Unpublished Materials

Erber, F.S. *Technology Development and State Intervention: A Study of the Brazilian Capital Goods Industry*. Ph.D. diss., University of Sussex, U.K., 1978.

Lima, Paulo de Torso Flecha de. *"Notas: O Quadro Internacional."* Mimeo presented to the University of São Paulo, November 1988.