LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

Essays in Macro Finance

by

Lorenzo Bretscher

A thesis submitted to the Department of Finance of the London School of Economics and Political Science for the degree of Doctor of Philosophy

April 2018

Acknowledgements

I would like to thank my advisor Christian Julliard for his generous support, patience, guidance and trust. Ever since we have met, Christian took me for what I am, never stopped believing in me and inspired me with his attitude towards both research and life in general. Thank you, Christian!

Moreover, I am deeply grateful to Lukas Schmid and Andrea Tamoni. Thank you for your continuous and invaluable support, help and feedback on research and, most importantly, friendship.

Special thanks also go to my co-authors who have taught me much more than I have ever imagined to learn about economics and finance: Alex Hsu, Aytek Malkhozov, Carlo Rosa and, in particular, Andrea Vedolin.

In addition, I have also benefited from numerous discussions with permanent and visiting faculty members at the Financial Market Group but also the Department of Economics at LSE. I would like to thank Ashwini Agrawal, Ulf Axelson, Mike Burkart, Georgy Chabakauri, Vicente Cunat, Amil Dasgupta, Daniel Ferreira, Wouter Den Haan, Juanita Gonzalez-Uribe, Moqi Groen-Xu, Dirk Jenter, Peter Kondor, Dong Lou, Igor Makarov, Ian Martin, Philippe Mueller, Gianmarco Ottaviano, Daniel Paravisini, Christopher Polk, Dimitri Vayanos and Michela Verardo.

My time at LSE would not have been the same without the many great friends that I have met during my years as a PhD student. In particular, I would like to extend my thanks to the members of my cohort who have made my time at LSE very special and memorable; Bernardo De Oliveira Guerra Ricca, Brandon Yueyang Han, Lukas Kremens, Dimitris Papadimitriou, Malgorzata Ryduchowska, Petar Sabtchevsky and Su Wang. Thank you also to Agnese Carella, Fabrizio Core, Thomas Drechsel, Andreea Englezu, Jesus Gorrin, Friedrich Geiecke, Tengyu Guo, Zongchen Hu, Kilian Huber, Francesco Nicolai, Olga Obishaeva, Paola Pederzoli, Alberto Pellicioli, Michael Punz, Marco Pelosi, Simona Risteska, Matthias Rupprecht, Una Savic, Seyed Seyedan, Karamfil Todorov and Yue Yuan for their friendship and support during all these years.

I would also like to acknowledge the financial support from the London School of Economics and Political Science as well as the Finance Department.

Finally, I am indebted to my family, Laura, Marianne and Martin, for constantly reminding of what is important in life and their continuous support over the years.

Most importantly, I thank my partner, Lena Maria, who was there for me every step of the way. She has been the source of everlasting love, kindness, forgiveness and support

and has never stopped believing in me. Without her, I would never have gotten to where I am today.

Declaration of Authorship

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I warrant that this authorisation does not, to the best of my belief, infringe the rights of any third party.

I declare that my thesis consists of 77'850 words

Statement of conjoint work

I confirm that Chapter 2 and Chapter 3 were jointly co-authored with Andrea Tamoni and Alex Hsu and I contributed 33% of this work.

Abstract

In the first paper of my dissertation I document that industries with low offshoring potential have 7.31% higher stock returns per year compared to industries with high offshoring potential, suggesting that the possibility to offshore affects industry risk. This risk premium is concentrated in manufacturing industries that are exposed to foreign import competition. Put differently, the option to offshore effectively serves as insurance against import competition. A two-country general equilibrium dynamic trade model in which firms have the option to offshore rationalizes the return patterns uncovered in the data: industries with low offshoring potential carry a risk premium that is increasing in foreign import penetration. Within the model, the offshoring channel is economically important and lowers industry risk up to one-third. I find that an increase in trade barriers is associated with a drop in asset prices of model firms. The model thus suggests that the loss in benefits from offshoring outweighs the benefits from lower import competition. Importantly, the model prediction that offshorability is negatively correlated with profit volatility is strongly supported by the data.

In the second paper (co-authored with Andrea Tamoni and Alex Hsu) we study the impact of fiscal policy shocks on bond risk premia. Government spending level shocks generate positive covariance between marginal utility and inflation (term structure level effect) making nominal bonds a poor hedge against consumption risk leading to positive inflation risk premia. Volatility shocks to spending have strong slope effect (steepening) on the yield curve, producing positive nominal term premia. For level and volatility shocks to capital income tax, term structure level effects dominate, delivering negative risk premia. Fluctuations in term premia are entirely driven by volatility shocks. Lastly, fiscal shocks are amplified at the zero lower bound.

The third paper (co-authored with Andrea Tamoni and Alex Hsu) discusses how risk aversion (RA) affects the macroeconomic response to uncertainty shocks. In the data, heightened level of RA during the 2008 crisis amplified the decline of output and investment by roughly 21% and 16%, respectively, at the trough of the recession. The degree of RA determines the impact of second moment shocks in DSGE models featuring stochastic volatility. Ceteris paribus, higher RA leads to stronger responses of macroeconomic variables to uncertainty shocks, making un certainty shocks as economically significant as level shocks. Conversely, elevated RA can amplify or dampen responses to level shocks depending on whether RA exaggerates or attenuates consumption growth expectations.

Contents

List of Figures

List of Tables

Chapter 1

From Local to Global: Offshoring and Asset Prices

Lorenzo Bretscher[1]

1.1 Introduction

> "The typical 'Made in' labels in manufactured goods have become archaic symbols of an old era. These days, most goods are 'Made in the World'."
> Antras (2015)

Over the recent decades, the world economy has seen a gradual dispersion of the production process across borders. Firms increasingly organize their production on a global scale and choose to offshore parts, components, or services to producers in foreign countries. The revolution in information and communication technology (ICT) and the dismantling of trade barriers allow firms to engage in global production networks, or global sourcing strategies, in order to cut costs.[2] For this reason, the choice of production

[1]I would like to thank Veronica Rappoport, Andrea Vedolin, Ulf Axelson, Oliver Boguth (discussant), Harris Dellas, Boyan Jovanovic, Ian Martin, Gianmarco Ottaviano, Christopher Polk, Andreas Rapp (discussant), Alireza Tahbaz-Salehi, Andrea Tamoni, Branko Urosevic, Philip Valta, Alexandre Ziegler (discussant) and, especially, Christian Julliard and Lukas Schmid as well as the seminar participants at LSE, the University of Bern, the University of Warwick, Oxford University, Nova School of Business & Economics, CEMFI, INSEAD, HEC Paris, Boston College, Carnegie Mellon University, the University of Chicago, Imperial College, London Business School, the Swiss Economists Abroad Conference, the Belgrade Young Economist Conference, the Doctoral Tutorial of the European Finance Association and the HEC Paris Finance PhD Workshop for valuable comments. I also thank J. Bradford Jensen for sharing his data on industry tradability. All remaining errors are my own.

[2]In addition to the ICT revolution and lower trade barriers, political developments have led to an increase in the fraction of world population that actively participates in the process of globalization (Antras (2015)).

location is a potentially valuable decision tool at the firm level. However, firms/industries differ in their ability to engage in offshoring due to the nature of their products and tasks involved in the production process. In short, in the era of globalization, the possibility to take a business from local to global has heterogenous implications for the cross-section of industries.

In this paper, I exploit cross-sectional heterogeneity in the ability to offshore to study how the possibility to relocate the production process affects industries' cost of capital. In particular, I focus on industries' ability to offshore the employed labor force and examine whether this is reflected in the cross-section of returns.[3] To this end, I construct a measure of labor offshorability at the industry level. The measure is calculated in two steps. In the first step, using data from the O*NET program of the U.S. Department of Labor, I calculate an offshorability score at the occupation level, as in Acemoglu and Autor (2011).[4] In the second step, I aggregate occupation offshorability scores by industry, weighting them by the product of employment and the wage bill associated with each occupation. The resulting data set covers an average of 331 industries per year during the period 1990 to 2016.[5]

I sort industries in five offshorability quintiles and find that the strategy that is long the low and short the high offshorability quintile portfolios, L-H, yields average annual excess returns of 7.31 percent and a Sharpe ratio of 0.48. This premium is not spanned by well-known risk factors such as Fama and French (2015) and Carhart (1997). Even after controlling for the five factors of Fama and French (2015), L-H generates positive average annual excess returns of 4.18 percent.

Furthermore, I split the sample into manufacturing and service industries. In univariate sorts, the L-H excess return spread in manufacturing is two to three times larger in magnitude compared to services. Moreover, for service industries, the premium is explained by the CAPM and a positive loading on the market. For manufacturing industries, on the other hand, common linear factor models fail to explain the returns generated by L-H. Consistent with this, in annual panel regressions at the firm level, I find that lagged industry offshorability significantly predicts annual excess returns for manufacturing but not for service industries. The results for manufacturing firms are

[3]In a related paper, Donangelo (2014) shows that industries that employ many workers with transferable skills are more exposed to aggregate shocks.

[4]A strand of literature in labor economics studies offshoring of tasks at the occupation level. See, for example, Jensen and Kletzer (2010), Goos and Manning (2007), Goos, Manning, and Salomons (2010), Acemoglu and Autor (2011), and Firpo, Fortin, and Lemieux (2013).

[5]Industries are defined at the three-digit Standard Industry Classification (SIC) from 1990 to 2001 and at the four-digit North American Industry Classification System (NAICS) level thereafter.

economically meaningful: a one standard deviation increase in offshorability is associated with 4% to 5% lower annual excess stock returns. These results are robust to controlling for firm characteristics known to predict excess returns.

A first-order question is what drives the heterogeneity between manufacturing and services. A potential explanation is based on the degree of foreign import competition. While manufacturing industries have seen a sharp increase in foreign competition, mainly from low-wage countries, this is not the case for service industries.[6] I relate my results to foreign import competition in manufacturing industries using conditional double sorts of excess returns on proxies of import competition and offshorability. I find that the L-H premium is monotonically increasing in import competition.[7] The results are robust to different proxies of import competition: First, I use a direct measure of import penetration from low-wage countries defined as the imports from low-wage countries divided by the sum of domestic production and net exports in a given industry (see Bernard, Jensen, and Schott (2006a)). Second, I use industry-specific shipping costs as a proxy for barriers to trade.[8] These results are consistent with the U.S. having a comparative advantage in providing services but not in manufacturing (see also Jensen (2011)).[9]

In a related paper, Barrot, Loualiche, and Sauvagnat (2017) focus on manufacturing industries and document that industries more exposed to foreign competition have higher excess returns. While their work establishes that import competition poses risks for an industry, my findings document that offshoring allows industries to hedge these risks. Intuitively, being able to offshore allows firms to fight import competition from low-wage countries by reducing costs through relocating production. Consistent with this argument, a recent paper by Magyari (2017) shows that offshoring enables U.S. firms to reduce costs and outperform peers that cannot offshore.

To further improve understanding of the mechanism, I embed the option to offshore in a two-country general equilibrium dynamic trade model similar to Ghironi and Melitz (2005) and Barrot, Loualiche, and Sauvagnat (2017) with multiple industries and aggregate risk. I will refer to the two countries as East and West. My model departs from previous work by allowing firms to offshore part of the production, as in Antras

[6]This can be seen from U.S. trade balances. While the trade balance in goods is negative and has decreased sharply over the last 25 years, the trade balance for services is positive and has been stable over time.

[7]In line with this, many recent empirical studies, such as Autor, Dorn, and Hanson (2013, 2016) and Pierce and Schott (2016), stress the importance of imports from low-wage countries for understanding the dynamics in U.S. manufacturing industries.

[8]Shipping costs are calculated as the markup of the Cost-Insurance-Freight value over the Free-on-Board value, as in Bernard, Jensen, and Schott (2006b).

[9]The principle of comparative advantage was first elaborated by Ricardo (1821) and formalized by Heckscher (1919) and Ohlin (1933). They argue that countries have a comparative advantage in activities that are intensive in the use of factors that are relatively abundant in the country.

and Helpman (2004). Moreover, I assume that the East has a comparative cost advantage over the West in performing offshorable labor tasks. As a result, offshoring to the East allows Western firms to reduce production costs and diversify aggregate risks. In addition, firms in both countries can export and sell their products abroad.

The model successfully matches industry- and trade-related moments and generates return patterns qualitatively, in line with the data. First, it generates a return spread between low and high offshorability industries. Second, the spread is increasing in the degree of import penetration. Third, excess returns of multinational companies are higher than for domestic firms. Fourth, industry excess returns are increasing in import penetration.

Asset price movements in the model are governed by shocks to aggregate productivity in each of the two countries. The responses of equilibrium quantities to the two aggregate productivity shocks are related because quantities react to changes in the ratio of aggregate productivity of the two countries: upon arrival of a positive (negative) productivity shock in the East (West), more Eastern firms find it profitable to export, which results in an increase in import penetration and competition in the West. As a result, Western firms experience losses in market share and lower profits. At the same time, offshoring allows Western firms to reduce production costs, which renders them more competitive towards new market entrants. Consequently, industries with a higher offshoring potential have smoother profits and dividends. Put differently, high (low) offshorability industries are less (more) exposed to aggregate productivity shocks in the model. This difference in exposure to aggregate risk results in an L-H return spread in industry excess returns, as observed in the data.

To further validate the model, I test three of its main predictions in the data. First, the model predicts that profit volatility is decreasing in industry offshorability, which is strongly supported by the data: a one standard deviation increase in industry offshorability is associated with an up to 19.7% lower profit volatility for the median firm. Second, the model predicts that the offshorability premium is largest in industries with more price-sensitive consumers. Conditional double sorts of monthly excess returns on U.S. trade elasticities from Broda and Weinstein (2006) and offshorability confirm this prediction in the data: the L-H spread is roughly double in magnitude for industries with high compared to low U.S. trade elasticities. Finally, within the model, low (high) offshorability industries have high (low) covariance with consumption. Consistent with this, I find that the strategy that is long low and short high offshorability industries has a positive and significant consumption beta in the data.

To quantify the importance of the offshorability channel in the model, I study industry moments in absence of offshorable labor tasks. The counterfactual indicates that an industry with no offshorability exhibits substantially higher risk premia (up to 33% or 3.14 percentage points) and lower equity valuations (a reduction of up to 17%). Hence, offshoring is an economically important channel in the model.

Finally, within the context of my model, I examine the consequences of a sudden increase in trade costs on goods shipped from East to West. Alternatively, this could be interpreted as a sudden increase in trade barriers for all goods imported by the West. Intuitively, higher barriers to trade lead to a decrease in import penetration in the model, which reduces industry risk. However, an increase in trade barriers also renders offshoring less valuable, since shipment of intermediate goods becomes more costly. Interestingly, within the model, the loss in benefits from offshoring outweighs the positive effects from lower import penetration. As a result, consumption and asset prices in the West fall.

The rest of the paper is organized as follows. After the literature review, section 1.2 details the data and discusses the construction of the labor offshorability measure. In section 1.3, I discuss the empirical findings. Section 1.4 presents a theoretical model with a calibration. Finally, section 1.5 concludes.

Literature Review

This paper relates to four main strands of literature. First, the paper relates to the literature that studies the interaction between labor and asset prices. Danthine and Donaldson (2002) and Favilukis and Lin (2016) document that operating leverage induced by rigid wages is a quantitatively important channel in matching financial moments in general equilibrium models.[10] More recently, a growing body of papers focus on different forms of labor heterogeneity and the cross-section of stock returns.[11] In particular, Zhang (2016) finds a real option channel for firms that have the possibility to substitute routine-task labor with machines. Moreover, Donangelo (2014) shows that industries with mobile workers are more exposed to aggregate shocks, since mobile workers can walk away for outside options in bad times, making it difficult for capital owners to shift risk to workers. This paper contributes to the literature by studying a new dimension of labor heterogeneity, i.e., whether or not a task can be offshored.

Second, this study relates to the literature on the effects of competition and international trade for asset pricing. Among others Loualiche (2015), Corhay, Kung, and Schmid

[10] Gomes, Jermann, and Schmid (2017) investigate the rigidity of nominal debt, which creates long-term leverage that works in a similar way to operating leverage induced by labor.

[11] See, among others, Gourio (2007), Ochoa (2013), Eisfeldt and Papanikolaou (2013), Belo, Lin, Li, and Zhao (2015), Kuehn, Simutin, and Wang (2017), Donangelo, Gourio, Kehrig, and Palacios (2016) and Tuzel and Zhang (2017)

(2017) and Bustamante and Donangelo (2016) show that the risk of entry is priced in the cross-section of expected returns. In a recent and closely related paper, Barrot, Loualiche, and Sauvagnat (2017) focus on risks associated with import competition and find that firms more exposed to import competition command a sizeable positive risk premium. Furthermore, Fillat and Garetto (2015) document that multinational firms exhibit higher excess returns than purely domestic firms. This is rationalized in a model in which selling abroad is a source of risk exposure to firms: following a negative shock, multinationals are reluctant to exit the foreign market because they would forgo the sunk cost they paid to enter. While their model shows how firms' revenues relate to risk in multinationals, my paper focuses on the relation between firm risk and labor costs.

Third, a recent line of research studies the consequences of the surge in international trade over the last decades at the establishment and firm level. Among others, Autor, Dorn, and Hanson (2013) and Pierce and Schott (2016) show that U.S. manufacturing establishments more exposed to growing imports from China in their output markets exhibit a sharper decline in employment relative to the less exposed ones.[12] Other studies use tariff cuts to instrument for import competition and find that it affects firms' capital structure (Xu (2012) and Valta (2012)) and capital budgeting decisions (Bloom, Draca, and Van Reenen (2015) and Frésard and Valta (2016)). My paper complements this literature by studying asset pricing implications instead of firm quantities. I find that offshoring allows firms to allocate resources more efficiently and lowers risks associated with foreign import competition.[13] Therefore, my paper also contributes to the growing body of empirical trade literature that documents that manufacturing firms have benefited from offshoring. Hummels, Jørgensen, Munch, and Xiang (2016), Chen and Steinwender (2016) and Bloom, Draca, and Van Reenen (2015) document that offshoring fosters firms' productivity and innovation activity. Magyari (2017) shows that offshoring enables U.S. firms to reduce their costs. She also finds that firms that are able to offshore actually increase their total firm-level employment both in manufacturing and headquarter service jobs.[14]

Fourth, this paper relates to the literature that examines the relationship between firm and plant organization and performance. Empirically, Atalay, Hortaçsu, and Syverson (2013) examine the domestic sourcing by U.S. plants, and Ramondo, Rappoport, and Ruhl (2016) study foreign sourcing by U.S. multinational firms. These papers show that firms and plants tend to source a large share of their material inputs from third-party

[12]See also Autor, Dorn, and Hanson (2016), Acemoglu, Autor, Dorn, Hanson, and Price (2016), Amiti, Dai, Feenstra, and Romalis (2016).

[13]Related papers show that firms suffer less from import competition if they have larger cash holdings (Frésard (2010)) or higher R&D expenses (Hombert and Matray (2017)).

[14]Compared to other related papers, Magyari (2017) focuses on employment at the firm level rather than at the establishment level.

suppliers. My paper documents how sourcing decisions affect asset prices. Theoretically, Antras and Helpman (2004) formulate a model in which firms decide whether to integrate the production of intermediate inputs or outsource them with incomplete contracts. Both decision can either take place domestically or abroad. More recently, Antras, Fort, and Tintelnot (2016) develop a quantifiable multi-country sourcing model in which global sourcing decisions interact through the firm's cost function, and Bernard, Jensen, Redding, and Schott (2016) present a theoretical framework that allows firms to decide simultaneously on the set of production locations, export markets, input sources, products to export, and inputs to import. In contrast, my model focuses on the interaction of offshoring and industry risk. To do so, I incorporate the possibility to offshore into a dynamic trade model with multiple industries, as in Ghironi and Melitz (2005), Chaney (2008) and Barrot, Loualiche, and Sauvagnat (2017).[15]

1.2 Data

In this section, I first outline the data and the method to construct a measure of labor offshorability at the occupation level and the industry level. Second, I discuss the financial and accounting as well as international trade data used in the empirical analysis.

1.2.1 Measuring Labor Offshorability

As a first step, I calculate a measure of offshorability at the occupation level. To do so, I follow the recent literature in labor economics and use data from the U.S. Department of Labor's O*NET program on the task content of occupations.[16, 17] This program classifies occupations according to the Standard Occupational Classification (SOC) system and has information on 772 different occupations.[18] O*NET contains information about the tools and technology, knowledge, skills, work values, education, experience and training needed for a given occupation.[19] I follow Acemoglu and Autor (2011) and Blinder (2009) and calculate an offshorability score at the occupation level.

[15] Melitz (2003) and Bernard, Jensen, Eaton, and Kortum (2003) also allow for firm heterogeneity and heterogenous gains from trade.

[16] For papers that rely on the O*NET data base, see, among others, Jensen and Kletzer (2010), Goos and Manning (2007), Goos, Manning, and Salomons (2010), Firpo, Fortin, and Lemieux (2013), and Acemoglu and Autor (2011).

[17] I use O*NET 20.3, available from https://www.onetonline.org/

[18] Some of the 772 occupations are further detailed into narrower occupation definitions. The total number of more-detailed occupations in O*NET is 954.

[19] The O*NET content model organizes these data into six broad categories: worker characteristics, worker requirements, experience requirements, occupational requirements, labor market characteristics, and occupation-specific information.

Acemoglu and Autor (2011) argue that an occupation that requires substantial face-to-face interaction and needs to be carried out on site is unlikely to be offshored. To capture this notion of offshorability, they focus on seven individual occupational characteristics, which are tabulated in Panel A of table 1.18. Compared with alternative occupation offshorability scores (see Firpo, Fortin, and Lemieux (2013), for example), Acemoglu and Autor (2011) base their calculations on fewer occupation characteristics to mitigate a high correlation with the routine-task content of an occupation.[20]

[Insert Table 1.18 here.]

The O*NET database organizes characteristics in work activities or work context (see column 3 of Panel A in table 1.18). For work activities, O*NET provides information on "importance" and "level". I follow Blinder (2009) and assign a Cobb-Douglas weight of two-thirds to "importance" and one-third to "level" to calculate a weighted sum for work activities.[21] Since there is no "importance" score for work context characteristics, I simply multiply the relative frequency by the level.[22] Thus, the offshorability score for occupation j, off_j, is defined as

$$off_j = \frac{1}{\sum_{l=1}^{A} I_{jl}^{\frac{2}{3}} \times L_{jl}^{\frac{1}{3}} + \sum_{m=1}^{C} F_{jm} \times L_{jm}} \tag{1.1}$$

where A is the number of work activities, I_{jl} is the importance and L_{jl} is the level of a given work activity in occupation j, C is the number of work context elements, F_{jm} is the frequency and L_{jm} is the level of a given work context in occupation j.[23] Finally, I take the inverse to obtain a score that is increasing in an occupation's offshorability.[24]

In a second step, I aggregate the occupation offshorability scores at the industry level using industry-level occupation data from the Occupational Employment Statistics (OES) program of the BLS. This data set contains information on the number of employees in a given occupation, industry and year. The data set is based on surveys that track employment across occupations and industries in approximately 200,000 establishments

[20] As a robustness check, I also calculate occupation offshorability according to Firpo, Fortin, and Lemieux (2013). They base their calculations on 16 different occupation characteristics, which are organized into three categories: face-to-face contact, on-site and decision-making. The characteristics are tabulated in an online appendix. The results of the paper remain qualitatively the same when the measure of Firpo, Fortin, and Lemieux (2013) is employed and are available upon request.

[21] The results are robust to different Cobb-Douglas weights. For example, taking simple averages between importance and level scores does not change any of the results in the paper.

[22] For example, the level of the work context element "frequency of decision-making" is a number between one and five: 1 = never; 2 = once a year or more but not every month; 3 = once a month or more but not every week; 4 = once a week or more but not every day; or 5 = every day.

[23] Note that importance and level scores are all rescaled to be between zero and one. Relative frequencies F_{jm} lie, by definition, between zero and one.

[24] The occupation offshorability for Acemoglu and Autor (2011) ranges between one-sixth and one.

every six months over three-year cycles, representing roughly 62% of non-farm employment in the U.S. Each industry in the sample was surveyed every three years until 1995 and every year from 1997 onwards. For the period before 1997, I follow Donangelo (2014) and use the same industry data for three consecutive years to ensure continuous coverage of the full set of industries. For example, the data used in 1992 combine survey information from 1990, 1991, and 1992. Unfortunately, the OES did not conduct a survey in 1996. To avoid a gap, I follow Ochoa (2013) and Donangelo (2014) and rely on survey information from the years 1993, 1994, and 1995.

The data set employs the OES taxonomy with 258 broad occupation definitions before 1999, the 2000 Standard Occupational Classification (SOC) system with 444 broad occupations between 1999 and 2009, and the 2010 SOC afterwards. To merge the occupation level offshorability with the OES data set, I bridge different occupational codes using the crosswalk provided by the National Crosswalk Service Center. Industries are classified using three-digit Standard Industrial Classification (SIC) codes until 2001 and four-digit North American Industry Classification System (NAICS) codes thereafter.[25]

The OES/BLS data set also includes estimates of wages since 1997. For the 1990 to 1996 period, I use estimates of wages from the BLS/U.S. Census Current Population Survey (CPS) obtained from the Integrated Public Use Microdata Series of the Minnesota Population Center.[26] I aggregate the occupation level offshorability measure, off_j, by industry, weighting by the wage expense associated with each occupation:

$$OFF_{i,t} = \sum_j off_j \times \frac{emp_{i,j,t} \times wage_{i,j,t}}{\sum_j emp_{i,j,t} \times wage_{i,j,t}} \tag{1.2}$$

where $emp_{i,j,t}$ is the employment in industry i, occupation j and year t, and $wage_{i,j,t}$ measures the annual wage paid to workers. Using wages at this stage is consistent with placing more weight on occupations with greater impact on cash flows.[27] Lastly, $OFF_{i,t}$ is standardized in each year, i.e., the cross-sectional mean and standard deviation of the offshorability measure are set to zero and one, respectively. The resulting data set covers the years 1990 to 2016, with an average of 331 industries.

[25] While the OES data set is designed to create detailed cross-sectional employment and wage estimates for the U.S. by industry, because of changes in the occupational classification, it might be challenging to exploit its time series variation. For this reason, I focus predominantly on cross-sectional analyses of the data.

[26] These data are available from https://www.ipums.org/. For more information, see King, Ruggles, Alexander, Flood, Genadek, Schroeder, Trampe, and Vick (2010)

[27] I also test for robustness of the empirical analysis by using an industry measure of offshorability that does not rely on wages, i.e.,

$$OFF^{\star}_{i,t} = \sum_j off_j \times \frac{emp_{i,j,t}}{\sum_j emp_{i,j,t}}.$$

The results remain qualitatively unchanged and are available upon request.

1.2.2 Financial and Accounting Data

For the empirical analysis, I use monthly stock returns from the Center for Research in Security Prices (CRSP) and annual accounting information from the CRSP/COMPUSAT Merged Annual Industrial Files. The sample of firms includes all NYSE-, AMEX-, and NASDAQ-listed securities that are identified by CRSP as ordinary common shares (with share codes 10 and 11) for the period between January 1990 and December 2016. I follow the literature and exclude regulated (SIC codes between 4900 and 4999) and financial (SIC codes between 6000 and 6999) firms from the sample. I also exclude observations with negative or missing sales, book assets and observations with missing industry classification codes. Firm-level accounting variables are winsorized at the 1% level in every sample year to reduce the influence of possible outliers. All nominal variables are expressed in year-2009 USD.[28] I also use historical segment data from COMPUSTAT to classify firms in multinationals and domestic firms as in Fillat and Garetto (2015). Finally, I use COMPUSTAT quarterly to calculate the volatility of sales and profits, as in Minton and Schrand (1999). A detailed overview of the variable definitions can be found in the online appendix.

1.2.3 International Trade Data

I use product-level U.S. import and export data for the period 1989 to 2015 from Peter Schott's website. For every year, I obtain the value of imports as well as a proxy for shipping costs at the product level that can be aggregated to the industry level. I follow Hummels (2007) and approximate shipping costs with freight costs, i.e., the markup of the Cost-Insurance Freight value over Free-on-Board value. Moreover, I use data on US trade elasticities at the product level from Broda and Weinstein (2006). Finally, data on U.S. trade balances are from the Bureau of Economic Analysis.

1.3 Empirical Evidence

In this section, I present the empirical results of the paper. First, I examine the validity of the offshorability measures. Second, I report that average portfolio excess returns are decreasing in offshorability. Third, I show that the premium that can be earned by going long low and short high offhsorability industries is concentrated in manufacturing industries and is not explained by a wide range of linear asset pricing models. Finally, I

[28]I use the GDP deflator (NIPA table 1.1.9, line 1) and the price index for non-residential private fixed investment (NIPA Table 5.3.4, line 2) to convert nominal into real variables.

offer further empirical evidence that links the offshorability premium to the recent surge in foreign import competition from low-wage countries.

1.3.1 Validity and Summary Statistics of Labor Offshorability

I start by examining whether the measures discussed in section 1.2 deliver reasonable rankings of occupations and industries in terms of offshorability. Panels B and C of table 1.18 report the top and bottom ten occupations by offshorability. Occupations with high offshorability are not restricted with respect to location or immediacy to the final consumer. Conversely, occupations at the bottom are either closely related to the location, such as "tree trimming", or to customers, such as "dentists". Unfortunately, off_j is, by construction, constant throughout time. Therefore, occupation offshorability is unable to capture how technological progress has affected the offshorability of individual occupations.[29] To the extent that technological progress has affected offshorability symmetrically across occupations, this is not a concern for my cross-sectional analysis.

In contrast, industry offshorability inherits some time variation from the changes in the occupation-industry composition of the U.S. labor force. To gain a better sense of the time-variation in $OFF_{i,t}$, I examine the industry rankings for manufacturing and services industries separately.[30] Table 1.2 reports the top and bottom ten industries by offshoring potential in the years 1992 and 2015 (Panels A and B) and the transition probabilities (Panel C) between offshorability quintiles for manufacturing industries.[31] In 1992, the top industries are predominantly apparel industries, whereas the bottom industries are related to mining and construction. The 2015 rankings reveal that there is not much variation over time during the sample period. In fact, even though industries are now classified according to the NAICS system, the top and bottom ten are similar to 1992.[32]

Another way to examine the persistence of $OFF_{i,t}$ over time is to look at transition probabilities. I do so by sorting industries into quintiles of offshorability each year and calculating the transition probabilities across quintiles. Panel C of table 1.2 reports the one- and five-year transition probabilities.[33] For industries in the top or bottom

[29] Several authors note that recent technological advances have substantially increased the offshorability of occupations. See, among others, Antras (2015) for manufacturing occupations and Jensen (2011) for service industry occupations.

[30] Manufacturing industries contain all industries with SIC codes between 2011 and 3999 and NAICS codes between 311111 and 339999, respectively. Conversely, service industries encompass all industries that are not classified as manufacturing industries.

[31] An analogous table with industry rankings for the full sample can be found in an online appendix.

[32] Note that the industries with NAICS code 3341xx correspond to SIC industry 3570, which ranks 18th in 1992.

[33] I calculate transition probabilities for the period 1991 to 2001 (SIC codes) and 2002 to 2016 (NAICS codes) separately and report the average of the two. The transition probabilities are very similar for the two subsamples.

quintiles of labor offshorability, the probability of being in the same quintile the next year (in five years) is close to 90% (80%). For the middle quintiles, the persistence is slightly lower, approximately 75%, over one year and 60% over five years. To sum up, industry offshorability is very persistent over time, consistent with offshoring being a slow-moving response to changes in the economic environment.

[Insert Tables 1.2 and 1.3 here.]

Table 1.3 reports analogous industry rankings and transition probabilities for service industries. I find that legal and financial services and computer software programming are high in offshorability, whereas mining, labor unions and other personal services are not.[34] Overall, the findings are very much in line with those for manufacturing. Again, the top and bottom ten industries in 1992 and 2015 suggest that $OFF_{i,t}$ does not exhibit much variation over time. The transition probabilities in Panel C confirm this impression. The probability of remaining in the same quintile over the next year (next five years) ranges between 83% and 91% (61% and 82%). Moreover, there are only very few changes, other than to the neighboring quintile, even over five years.

Next, I examine how offshorability correlates with other labor- and trade-related variables. Panel A of table 1.4 reports correlations at the occupation level. Interestingly, off_j is positively and significantly related to skill (correlation coefficient of .31), which is driven by the large number of service occupations that are both offshorable and skill-intense.[35] This is in line with Jensen (2011), Blinder (2009) and Amiti and Wei (2009), who discuss that recent advances in communication technologies increasingly allow for the offshoring of service jobs. Importantly, the correlation between offshorability and routine-task occupations is statistically indistinguishable from zero (correlation coefficient of .04). Hence, occupation level offshorability does not solely capture occupations that can be substituted with machines. This is consistent with Zhang (2016), who finds an insignificant empirical correlation coefficient of -.02 between offshorability and routine-task labor at the firm level. In panel B, I report the overlap in occupations that rank in the top tercile for the different measures. I find that the percentage overlap is close to 33%, which is what one would expect in case of no correlation. This suggests that there is little correlation in the highest-ranked occupations across measures.

[Insert Table 1.4 here.]

[34] Related to this finding, Alan Blinder writes in *Foreign Affairs* in 2006 that "...changing trade patterns will keep most personal-service jobs at home while many jobs producing goods and impersonal services migrate to the developing world...".

[35] Examples of such occupations include legal support workers or paralegals, computer programmers, and radiologists.

Panel C reports time-series averages of annual Spearman rank sum correlations of different variables at the industry level both for manufacturing and services. The correlation with skill is positive and significant for both manufacturing and service industries. While the point estimate for manufacturing is very similar to that at the occupation level (.29), it is slightly higher for services (.44). The correlation with routine is statistically indistinguishable from zero for both sectors (the point estimates are .10 for manufacturing and .14 for services). Interestingly, the correlation with the labor mobility measure of Donangelo (2014) is negative (-.22) and weakly statistically significant for manufacturing and is positive (.11) but insignificant for services. The weak relationship with labor mobility is not surprising. Labor mobility is intended to capture the transferability of occupation-specific skills across industries, which is conceptually very different from offshorability.

Furthermore, I find that the correlation coefficient with product tradability from Jensen (2011) is positive (.13) but insignificant for manufacturing and positive and highly statistically significant for services (.23).[36] The insignificant correlation coefficient in manufacturing is not surprising. While offshorability captures the "tradability" of the labor force, the measure by Jensen (2011) captures the tradability of the product.

Finally, I also analyze the relation between $OFF_{i,t}$ and industry shipping costs, a variable often employed in studies of international trade. I document a negative and weakly significant correlation coefficient (-0.16) between offshorability and shipping costs paid by importers for manufacturing industries. For services, the lack of import data makes it impossible to calculate shipping costs at the industry level.

1.3.2 Portfolio Analysis

1.3.2.1 Offshorability Portfolios and Excess Returns

To study the characteristics of sample industries and realized excess returns, I construct five offshorability portfolios. For each sample year, I assign industry offshorability in the previous year to individual stocks. I then obtain monthly industry returns by value-weighting monthly stock returns. Again, industries are defined at the 3-digit SIC level between 1990 and 2001 and at the 4-digit NAICS level between 2002 and 2016. In every year, at the end of June, I sort industry returns into five portfolios based on industry offshorability quintiles. Finally, industry returns within each offshorability portfolio are either equal- or value-weighted. To obtain value-weighted portfolio returns, I use an industry's market capitalization as a weight. In what follows, in the interest of brevity,

[36] I thank J. Bradford Jensen for sharing his data on industry tradability. Jensen (2011) measures of industry tradability are based on geographic concentration/dispersion of production.

I refer to industry excess returns simply as excess returns. Panel A of table 1.5 reports the equal- and value-weighted excess returns of the five portfolios. L (H) stands for the portfolio consisting of industries with low (high) offshorability, and L-H refers to the strategy that is long L and short H.

[Insert Table 1.5 here.]

Industries with low offshorability have average equal-weighted (value-weighted) monthly excess returns that are .61% (.80%) higher compared to high offshorability industries. The magnitude of the spread is economically meaningful: 7.31% (9.64%) per year for equal-weighted (value-weighted) returns with an annualized Sharpe ratio of .48 (.47). I also consider unlevered equity returns to ensure that the results are not driven by leverage. I follow Donangelo (2014) and Zhang (2016) and calculate unlevered stock returns as

$$r_{i,y,m}^{unlevered} = r_{y,m}^{f} + (r_{i,y,m} - r_{y,m}^{f}) \times (1 - lev_{i,y-1})$$

where $r_{i,y,m}$ denotes the monthly stock return of firm i over month m of year y, $r_{y,m}^{f}$ denotes the one-month risk-free rate in month m of year y, and $lev_{i,y-1}$ denotes the leverage ratio, defined as the book value of debt over the sum of book value of debt plus the market value of equity at the end of year $y-1$ for firm i. The unlevered excess returns (.51% equal-weighted and .73% value-weighted) and corresponding Sharpe ratios (.46 equal-weighted and .43 value-weighted) are slightly lower in magnitude.

Despite the relatively short sample period, t-tests using Newey-West standard errors confirm that the L-H spread is statistically significant both in equal- and value-weighted portfolios. Notably, the results are slightly stronger for value-weighted returns. While traditional t-tests only compare returns of the L and H portfolios, the "monotonic relationship (MR)" test by Patton and Timmermann (2010) tests for monotonicity in returns relying on information from all five portfolios. Next to the L-H spread in table 1.5, I report in parentheses the p-value from the MR test, which considers all possible adjacent pairs of portfolio returns. The bootstrapped p-value is studentized, as advocated by Hansen (2005) and Romano and Wolf (2005). The p-values indicate that the null hypothesis of non-monotonic portfolio returns is rejected both for equal- and value-weighted returns.

To test whether the L-H spread reflects industries' exposure to risk factors irrespective of the ability to relocate production, I estimate linear factor regression models. Panels B and C of table 1.5 report time-series regressions across the five offshorability portfolios for the four- and five-factor models of Carhart (1997) and Fama and French

(2015).[37] Even after controlling for the various factors, the estimated alphas show a nearly (one exception) strictly monotonic pattern for both equal- and value-weighted returns.[38] Moreover, the alpha of the L-H portfolio remains statistically significant in three out of four specifications. L-H loads positively on SMB in all specifications. Moreover, for equal-weighted portfolios, L-H is positively related to HML. Even though the magnitude of the L-H alpha is smaller than the spread in univariate portfolio sorts, it is economically meaningful: the annualized alphas range between 3.82% and 6.49%, with Sharpe ratios from .35 to .41.

1.3.2.2 Offshorability premium: Manufacturing vs Service Industries

Due to limited data availability, most empirical papers that study the effects of offshoring focus on U.S. manufacturing firms or European data.[39] Hence, having a measure of offshorability both for manufacturing and services industries, it is interesting to see how the results differ among these two broad sectors. To this end, I first split the sample into manufacturing and services and then conditionally sort industries into five offshorability portfolios, as discussed above.[40]

Table 1.6 reports univariate portfolio sorts and CAPM regression results for manufacturing (Panel A) and services (Panel B). The univariate sorts show that portfolio excess returns are decreasing in offshorability in both sectors, which suggests that the relocation of production is a desirable option in manufacturing and service industries. This is consistent with Jensen and Kletzer (2010), Blinder (2009) and Amiti and Wei (2009), among others, who discuss the increasing importance of offshoring in service industries.

However, the annualized mean excess return of L-H in manufacturing is two to three times the magnitude of that in services: 12.37% versus 6.66% for equal-weighted levered returns and 12.43% versus 4.15% for equal-weighted unlevered returns. This is also true for value-weighted excess returns. Hence, having the option to offshore seems to affect the risk profile of manufacturing and services industries differently. This conclusion finds further support in sector-specific CAPM regression results. For manufacturing, the L-H strategy is not spanned by the market, and the resulting alphas are highly statistically and economically significant. For services, on the other hand, the alphas are insignificant

[37] The risk-free rate and the market, size, value, momentum, profitability and investment factors are obtained from Kenneth French's website.

[38] The results are very similar for the unconditional CAPM, the conditional CAPM and the three-factor model of Fama and French (1992). The corresponding regressions are tabulated in an online appendix.

[39] See Harrison and McMillan (2011) and Ebenstein, Harrison, McMillan, and Phillips (2014) for studies on U.S. data and Hummels, Jørgensen, Munch, and Xiang (2016) for a study with Danish data.

[40] Manufacturing includes all industries with SIC codes between 2011 and 3999 and NAICS codes between 311111 and 339999. Conversely, services encompass all industries that are not classified as manufacturing.

and are only roughly one-third in magnitude compared to manufacturing. In short, while differential exposures to the market across the five offshorability portfolios explain the offshorability spread in services, this is not the case in manufacturing.[41]

[Insert Tables 1.6 and 1.7 here.]

Panel C of table 1.6 shows portfolio characteristics of the five portfolios in manufacturing and services, respectively. For manufacturing, firms with low offshorability tend to be large, have a low book to market ratio, low market leverage and low labor intensity compared to high offshorability firms. For services, on the other hand, the five portfolios show no clear patterns in terms of book to market ratio and market leverage.

As a more restrictive test of the offshorability premium in manufacturing, I employ the four- and five-factor models by Carhart (1997) and Fama and French (2015), respectively. The results are reported in table 1.7. The alpha of the L-H strategy remains highly statistically and economically significant across all specifications: the annualized alphas range between 8.05% and 9.94% with Sharpe ratios from .55 to .81. Moreover, L-H positively loads on size and momentum.

To gain an idea of the performance of L-H in each sector over time, I plot the evolution of a one USD investment on a log-scale in the left panel figure 1.1. The figure plots L-H separately for manufacturing and service industries along the market, size and value. Both L-H portfolios significantly outperform the size and value strategies over the period from July 1991 until June 2016.

[Insert Table 1.8 and Figure 1.1 here.]

Interestingly, the L-H strategy in manufacturing does not generally correlate strongly with the market except during the financial crisis, when both investments lose value. The right panel of figure 1.1 plots the realized equal-weighted excess returns of the L-H strategy in manufacturing along with average monthly excess returns for the first and second half of the sample period. The two averages are similar in magnitude (1.19% during 1991 and 2004 and 0.86% during 2004 and 2016), which suggests that the L-H strategy delivers a stable return over time.

To further investigate the offshorability premium in manufacturing, I report portfolio sorts for different time subsamples in table 1.8. The sample is split into four subsamples - one for each decade plus one that excludes the financial crisis. The offshorability

[41] These results also hold for the three-factor model of Fama and French (1992): the L-H for manufacturing loads positively on size, and the L-H for services loads positively on the market and size. The corresponding results are tabulated in an online appendix.

premium is, with one exception, positive and significant in all subsamples. This is true both for equal- and value-weighted portfolios. For most subsamples, the premium is significant at the 10% level due to the relatively small sample size and the corresponding loss of statistical power. Moreover, the MR-test rejects the null hypothesis of non-monotonic portfolio returns for all but the most recent subsample that runs from 2010:01 to 2016:06.[42]

In a next step, I investigate the predictive power of offshorability in the cross-section of returns. To do so, I run annual panel regressions at the firm level. The regressions are of the following form:

$$r_{i,t} = a + b_{j,t} + c * OFF_{i,t-1} + d * controls_{i,t-1} + \epsilon_{i,t}, \quad (1.3)$$

where $r_{i,t}$ is the firm's i annual stock return, a is a constant term, $b_{j,t}$ is an industry×year fixed effect, $OFF_{i,t-1}$ is lagged labor offshorability and $controls_{i,t-1}$ are lagged firm-level characteristics.[43] I include firm size, book-to-market ratio, market leverage ratio, hiring rate, investment rate, one-year lagged stock return, operating leverage, and profitability to control for characteristics known to predict expected excess returns. Standard errors are clustered at the firm and year level.

Table 1.9 reports the regression results for manufacturing in Panel A and services in Panel B. All variables are standardized with mean zero and variance one, which makes the coefficients directly comparable. For manufacturing, the coefficient of offshorability is negative and statistically significant across all specifications. Moreover, the coefficients are only marginally affected by adding control variables individually (compare regression specifications (1) to (9)), which is reassuring.[44] The estimated slopes range from -4.64 to -5.06 and are economically meaningful: a one standard deviation increase in offshorability is associated with a 4% - 5% lower annual excess stock return.

[Insert Table 1.9 here.]

Regression specification (10) includes all control variables at once, which results in a reduction in sample size. Nevertheless, the coefficient on OFF_{t-1} stays negative and

[42] In a robustness test, I test whether the results are driven by the time variation in the $OFF_{i,t}$ measure. I find that keeping industry offshorability fixed over time (i.e., fixing it to the first observation for each industry classification period) results in very similar full and subsample results. The corresponding results are tabulated in an online appendix.

[43] Note that offshorability is measured at the industry level only. Hence, firms in a given industry and year share the same offshorability.

[44] I run similar monthly panel regressions following Belo, Lin, Li, and Zhao (2015) and find that the results are nearly identical. The results are available upon request.

highly statistically significant.[45] For services, the coefficients on offshorability are negative throughout all specifications. However, the coefficients are statistically significant only in two regression specifications, which suggests that for services, OFF_{t-1} does not have much predictive power once controlled for other firm characteristics. This is consistent with the findings of table 1.6.

1.3.3 Manufacturing Industries and the Surge in International Trade

Technological advances such as the revolution in information and communication technologies and the dismantling of trade barriers have contributed to an increase in international trade activity over the recent past. The left panel of figure 1.2 shows that the ratio of imports to U.S. Gross Domestic Product (GDP) has increased by a factor of 1.5 over the sample period. Interestingly, this increase in imports/GDP is mostly due to imports from low-wage countries, which have increased by a factor of 4.5 since 1990. By contrast, high-wage country imports have increased by a factor of 1.2 only.[46] These growth patterns are illustrative of the change in the composition of U.S. imports, consistent with the principle of comparative advantage first elaborated by Ricardo (1821) and continued by Heckscher (1919) and Ohlin (1933).[47] They argue that countries have a comparative advantage in activities that are intensive in the use of factors that are relatively abundant in the country. As a result, countries that have an abundance of low-cost labor have an advantage in producing labor-intense products, and countries with an abundance of skilled labor specialize in skill-intense products.

[Insert Figure 1.2 here.]

Another way of illustrating the change in the composition of U.S. imports is to look at the trade balances for goods and services separately, as reported in the right panel of figure 1.2. While the trade balance in goods has decreased sharply over the last 25 years, the trade balance in services has been positive and slightly increasing since 1960. Hence, the United States is a net exporter in services.[48] Consistent with this, Jensen (2011) argues that providing services is consistent with the U.S.'s comparative advantage. On the other hand, international specialization has led to fierce import competition in manufacturing

[45]These results are robust to various industry definitions. The corresponding results are tabulated in an online appendix.

[46]I follow Bernard, Jensen, and Schott (2006a) and label a country as low-wage in year t if its GDP per capita is less than 5% of the GDP per capita of the U.S. A list of countries that were classified as low-wage in every year of the sample period can be found in an online appendix.

[47]The figure that plots value shares of imports instead of real value of imports looks nearly identical. The corresponding figure can be found in the online appendix of the paper.

[48]In fact, the United States is the global leader in business service exports. The OECD reports that the United States accounts for approximately 22 percent of the OECD total.

industries.[49] In fact, many recent empirical studies stress the importance of international trade for understanding the dynamics in U.S. manufacturing industries. In particular, the rise in import penetration from low-wage countries has been emphasized as the key driving force of the decrease in manufacturing employment (see, among others, Autor, Dorn, and Hanson (2013, 2016), Pierce and Schott (2016)).[50]

Motivated by this evidence, I examine how my results relate to import competition from low-wage countries. I follow Bernard, Jensen, and Schott (2006a) and calculate import penetration from low-wage countries at the industry level. Panel A of table 1.10 reports conditional double sorts on import penetration and offshorability.[51] Indeed, the L-H spread is monotonically increasing with import penetration both for equal- and value-weighted returns. This finding is consistent with the interpretation that the ability to relocate production is most valuable in industries that are exposed to fierce import competition from low-wage countries.[52]

[Insert Tables 1.10 and 1.11 here.]

I also run cross-sectional return predictability regressions conditional on import penetration being lower (higher) than the median, which allows me to control for various firm characteristics. The results are reported in Panel B. Consistent with the double sorts, I find that coefficients on offshorability are negative and significant only for firms in industries with high import penetration. Moreover, the absolute values of the estimated coefficients on OFF_{t-1} are double the magnitude for high compared to low import penetration industries.

A potential concern is that realized U.S. imports from low-wage countries may be correlated with industry import demand shocks. To mitigate this concern, I instrument for import competition with industries' average shipping costs paid on imports, which serves as a proxy for barriers to trade. In the data, industries with low shipping costs are associated with high imports and exports. Panel A of table 1.11 reports average returns of conditional double sorts on shipping costs and offshorability. The L-H spread is monotonically decreasing with shipping costs, consistent with the findings in table 1.10.

[49]The increase in imports is either due to new market entrants or imports of intermediate production inputs. Antras (2015) reports that between 2000 and 2011, close to 50% of imports were intra-firm transactions, i.e., either intermediate production inputs or final goods manufactured entirely abroad. The other half of imports were either third-party intermediate goods or final products of foreign competitors. Hence, the surge of imports from low-wage countries over the past 25 years brought cheaper intermediate production inputs but also more fierce competition to the U.S.

[50]While US total imports as a share of GDP have increased from 4.19% to 15.48% since 1960, US manufacturing employment as a percent share of nonagricultural employment has fallen from 28.43% to 8.69%. A corresponding figure can be found in the online appendix.

[51]I first sort on import penetration and then on offshorability.

[52]The results are very similar for double sorts on offshorability and import penetration from China, as reported in an online appendix.

Panel B tabulates the results of conditional panel regressions. Offshorability negatively predicts firms' annual excess returns only in industries with lower-than-median shipping costs.

Barrot, Loualiche, and Sauvagnat (2017) document that industries with low shipping costs face higher import competition and have higher excess returns. This premium originates from the risk of displacement of least efficient firms triggered by import competition. Given that the offshorability premium is increasing in import penetration from low-wage countries and decreasing in shipping costs, my findings suggest that offshoring helps protect industries from foreign competition. In particular, being able to offshore allows firms to reduce their labor costs upon increases in competition. This argument is consistent with Magyari (2017), who finds that offshoring enables US firms to reduce costs and outperform peers that cannot offshore.

Table 1.4 shows that offshorability is slightly negatively related to shipping cost. Hence, one might be concerned whether sorting on offshorability is similar to sorting on shipping costs. To mitigate this concern, I replicate the findings of Barrot, Loualiche, and Sauvagnat (2017) for my sample period and control for the return of the portfolio that is long firms in low shipping cost industries and short firms in high shipping cost industries (henceforth, SC). The explanatory power of SC is very limited. In fact, neither the monotonic relationship in the offshorability portfolio alphas nor the highly statistically significant alpha of the L-H portfolio is impaired.[53]

Approximately half of the manufacturing firms in my sample are multinational companies that have sales in at least one country other than the United States. Fillat and Garetto (2015) have documented that multinational firms experience higher stock returns compared to domestic firms. To understand how their results relate to mine, I first split the sample into multinational and domestic manufacturing firms and then conditionally sort them into five offshorability portfolios in each subsample. The results are reported in panel A of table 1.12.

[Insert Table 1.12 here.]

In line with Fillat and Garetto (2015), I find that equal-weighted excess returns for multinationals are higher than for domestic firms. Moreover, the L-H spread is positive, significant and of very similar magnitude for both groups. This suggests that sorting on offshorability is different from sorting on a firm's location of sales. In addition, the non-monotonicity of portfolio excess returns can only be rejected for firms with multinational

[53]In a first step, I replicate the findings of Barrot, Loualiche, and Sauvagnat (2017). Despite different sample periods, the resulting portfolio sorts look very similar to those in their paper. Portfolio sorts and the regression results are reported in the online appendix of this paper.

operations. Panel B confirms that even after controlling for other firm characteristics, offhsorability negatively predicts future annual excess returns both for multinational and domestic firms.

Finally, given the large number of multinationals in manufacturing industries, another potential concern is that L-H is related to differential foreign exchange exposures across industries. To address this, I estimate three two-factor models including the U.S. market excess return and either the dollar factor, the carry factor (both from Verdelhan (2017)) or the excess return of high interest rate currencies minus low interest rate currencies (from Lustig, Roussanov, and Verdelhan (2011)). I find that the three factors related to foreign exchange are insignificant in most specifications. Moreover, the L-H alphas are positive and statistically different from zero in all specifications. The corresponding results are tabulated in an online appendix.

1.4 Model

In this section, I develop a two-country dynamic general equilibrium trade model with multiple industries that are heterogenous in their ability to offshore.

The model builds on existing work on trade models with aggregate risk by Ghironi and Melitz (2005) and Barrot, Loualiche, and Sauvagnat (2017), who also focus on asset prices. To discuss my empirical results through the lens of the model, I additionally embed firm-level offshoring, as in Antras and Helpman (2004), in the model. Consequently, firms not only decide whether or not to export but also where to produce their goods.

The model features two countries, West and East. To distinguish between the two countries, quantities that refer to the East are labeled with a $\star$. Each country is inhabited by a continuum of homogenous households and two industrial sectors that are spanned by $S + 1$ industries. The first sector consists of one industry and a single homogenous good, and the corresponding sector quantities are labeled with a 0. The second sector encompasses S industries, which each consist of a continuum of differentiated goods that are produced by a continuum of firms.

1.4.1 Demand Side: The Households Problem

Homogenous households have the following Epstein-Zin preferences over the consumption stream $\{C_t\}$:

$$U_t = \left\{(1-\beta)\, C_t^{\frac{1-\gamma}{\nu}} + \beta \left(\mathbb{E}_t\left[U_{t+1}^{1-\gamma}\right]\right)^{\frac{1}{\nu}}\right\}^{\frac{\nu}{1-\gamma}}$$

where C_t is an aggregate consumption index, β is the subjective time discount factor, γ is the coefficient of risk aversion, ψ is the elasticity of intertemporal substitution and $\nu \equiv \frac{1-\gamma}{1-1/\psi}$ is a parameter defined for notational convenience. Each period, households derive utility from consuming goods in $S+1$ industries. C_t is given by the following aggregator:

$$C_t = c_{0,t}^{1-a_0} \left[\sum_s \delta_s^{\frac{1}{\theta}} \left(\int_{\Omega_{s,t}} c_{s,t}(\varphi)^{\frac{\sigma_s - 1}{\sigma_s}} d\varphi \right)^{\frac{\sigma_s}{\sigma_s - 1} \frac{\theta - 1}{\theta}} \right]^{\frac{\theta}{\theta - 1} a_0},$$

where $c_{0,t}$ and $1-a_0$ denote, respectively, the consumption and the expenditure share in the homogenous good sector; $c_{s,t}(\varphi)$ denotes the consumption of differentiated good variety φ in industry s; δ_s is an industry taste parameter (where $\sum_s \delta_s = 1$); θ is the elasticity of substitution between industries; σ_s is the elasticity of substitution among good varieties within industry s; and $\Omega_{s,t}$ is the set of firms that sell their goods at time t in industry s in the West.

The aggregation over industry-specific consumption and over varieties is based on constant elasticity of substitution with elasticities θ and σ_s, respectively. This results in Dixit and Stiglitz (1977) demand schedules at both the industry and the product level. Detailed derivations can be found in appendix 1.8.4 of the paper.

Finally, households obtain revenues L_t from inelastic labor supply and from ownership of firms, resulting in the following budget constraint:[54]

$$\sum_s \int_{\Omega_{s,t}} p_{s,t}(\varphi) c_{s,t}(\varphi) d\varphi \leq L_t + \Pi_t,$$

with Π_t being profits from firm ownership.[55] In what follows, I suppress the time index t for ease of notation.

1.4.2 Supply Side: Firms' Production and Organizational Decision

Homogenous good sector - The homogenous good 0 is produced under constant returns to scale (CRS) and a production function that is linear in labor.[56] Moreover,

[54] Wages in each country are equal to the numeraire and are set to 1 as discussed below.

[55] Households can have ownership both in Eastern and Western firms, as will become clear in the section on asset prices below. Alternatively, one can think of households owning a share in a world mutual fund that redistributes profits of firms from the two countries, as discussed in Barrot, Loualiche, and Sauvagnat (2017).

[56] In other words, one unit of labor produces one unit of good 0. Because of the CRS technology, there are no profits to be distributed from sector 0.

the good is freely traded across countries. Its price is used as a numeraire in each country and is set to one.[57]

Differentiated goods sector - This sector encompasses S industries that each consist of a continuum of differentiated goods that are produced by a continuum of monopolistically competitive firms. Each firm produces a different product variety, φ. Intuitively, firms possess a product variety-specific blueprint that determines their idiosyncratic productivity. In what follows, φ not only serves as an identifier of product variety but also stands for idiosyncratic productivity. Following Antras and Helpman (2004), I model firms' production function as a Cobb-Douglas function that aggregates two tasks: non-offshorable **h**eadquarter tasks, $h(\varphi)$, and **o**ffshorable tasks, $o(\varphi)$:[58]

$$y_s(\varphi) = A \left[\frac{h_s(\varphi)}{\alpha_s}\right]^{\alpha_s} \left[\frac{o_s(\varphi)}{1-\alpha_s}\right]^{1-\alpha_s},$$

where $y_s(\varphi)$ is the amount of product variety φ produced in industry s, A is aggregate productivity and α_s is the headquarter-intensity in industry s. Importantly, $1 - \alpha_s$ measures to what extent a firm can offshore its production. Since α_s is identical for all firms in industry s, firm offshorability is identical to industry offshorability in the model. Furthermore, I assume that aggregate productivity follows an autoregressive process of order one in each country:

$$a_t = \rho_a a_{t-1} + \epsilon_t^a \qquad a_t^\star = \rho_{a^\star} a_{t-1}^\star + \epsilon_t^{a^\star},$$

where a_t ($a_t^\star$) is the logarithm of A_t ($A_t^\star$), $\epsilon_t^a \sim N\left(0, \sigma_a^2\right)$ $\left(\epsilon_t^{a^\star} \sim N\left(0, \sigma_{a^\star}^2\right)\right)$ and $cov\left(\epsilon_t^a, \epsilon_t^{a^\star}\right) = 0$.

Production is costly. Firms are subject to production costs as well as fixed organizational costs. The total production costs consist of wages or salaries paid for time actually worked, w, and other labor costs, c, such as payments to pension plans, unemployment insurance fees, legal costs and accruals for possible severance payments. I assume that other labor costs are proportional to the amount of labor hired such that the marginal costs of labor equals $w + c$. I further assume that any unit of labor can be employed either as headquarter or offshorable tasks. In other words, within a country, there is no separation of the labor force. For clarity of exposition, in what follows, I will be explicit about the total costs associated with one unit of headquarter and offshorable labor employed in industry s. I call them $w_{h,s}$ and $w_{o,s}$, respectively.

[57]Consequently, wages are equal to one in both countries.

[58]The task-specific technology is linear in labor: for every unit of labor, each task produces φ units of task-specific output.

Throughout the paper, I further assume that the East has a comparative cost advantage in offshorable labor over the West. In particular, I assume that $c > c^\star$. That is, within the context of the model, the East can be associated with a low-wage country such as China and the West with a highly developed economy such as the U.S. Intuitively, the wedge $c - c^\star$ can be interpreted as differences in unemployment benefits and other social insurances, strength of labor unions and severance payments across the two countries. This cost wedge provides an incentive to Western firms to offshore and, as such, is a key ingredient for the model to generate results consistent with the empirical evidence.

Given the comparative cost advantage of the East over the West, firms decide on their organizational strategy along two dimensions. First, they decide whether to produce domestically or offshore part of their production. Second, they choose whether to sell their output only domestically or, alternatively, both on the domestic and export market. In what follows, I detail the optimal sorting of firms into the different strategies.

Domestic Production vs Offshoring

Firms operate in monopolistically competitive industries and set their prices at a markup over marginal costs. The monopolistic competition markup $\frac{\sigma_s}{\sigma_s - 1}$ is determined by the elasticity of substitution among product varieties within an industry, σ_s.[59] Hence, the price set by firms that produce domestically is given by

$$p_{s,D}(\varphi) = \frac{\sigma_s}{\sigma_s - 1} \frac{(w_{h,s})^{\alpha_s} (w_{o,s})^{1-\alpha_s}}{A\varphi},$$

where $w_{h,s}$ ($w_{o,s}$) are total wage costs for headquarter (offshorable) tasks. Firm profits in industry s are defined as the difference between sales and total costs, $\Gamma_{s,D}(y_{s,D}(\varphi), \varphi)$:

$$\begin{aligned}
\pi_{s,D}(\varphi) &= p_{s,D}(\varphi) y_{s,D}(\varphi) - \Gamma_{s,D}(y_{s,D}(\varphi), \varphi) \\
&= \frac{1}{\sigma_s} p_{s,D}(\varphi) \left[\frac{p_{s,D}(\varphi)}{P_s} \right]^{-\sigma_s} C_s \\
&= B_s \left((w_{h,s})^{\alpha_s} (w_{o,s})^{1-\alpha_s} \right)^{1-\sigma_s} (A\varphi)^{\sigma_s - 1},
\end{aligned}$$

where $B_s = \frac{1}{\sigma_s} \left[\frac{\sigma_s}{\sigma_s - 1} \right]^{1-\sigma_s} P_s^{\sigma_s} C_s$. Without loss of generality, fixed organizational costs for a purely domestic firm are set to 0.[60] Consequently, all firms in an industry are productive, since domestic production is profitable for all values of φ.

[59] The higher the σ_s, the lower the markup $\frac{\sigma_s}{\sigma_s - 1}$.

[60] Alternatively, I could set the fixed costs for domestic production to a value different from zero. Consequently, firms with sufficiently low idiosyncratic productivity would decide to shut down production entirely. In the absence of fixed costs for domestic production, fixed costs of offshoring, f_O, can be interpreted as the excess cost of offshoring in comparison to domestic production.

Firms decide whether or not to offshore tasks of type o. On the one hand, firms that offshore can benefit from potentially lower total production costs and from risk diversification.[61] On the other hand, offshoring is costly due to trade costs, $\tau^\star$, and per-period fixed organizational costs of offshoring, f_O. [62]

Trade costs are often associated with the costs of transporting intermediate inputs across countries. Alternatively, $\tau^\star$ can be interpreted more broadly to reflect other technological barriers related to international fragmentation, such as language barriers, communication or search costs.

As in Antras and Helpman (2004), fixed organizational costs, f_O, can be interpreted as the joint management cost of final and intermediate goods production, such as supervision, quality control, accounting, and marketing, which depend on the organizational form and location of production. These costs are expressed in units of effective labor. I assume that firms hire workers from their respective domestic labor markets to cover these fixed costs. Hence, profits with offshoring are equal to

$$\pi_{s,O}(\varphi) \quad = \quad B_s \left((w_{h,s})^{\alpha_s} (w^\star_{o,s}\tau^\star)^{1-\alpha_s}\right)^{1-\sigma_s} \left(A^{\alpha_s} \left(A^\star\right)^{1-\alpha_s} \varphi\right)^{\sigma_s-1} - \frac{f_O}{A}.$$

Profit-maximizing firms in industry s decide to offshore whenever profits from doing so are larger than profits from domestic production, $\pi_{s,O}(\varphi) \geq \pi_{s,D}(\varphi)$. $\varphi_{s,O}$ is defined as the idiosyncratic productivity level for which the profits from the two strategies are equalized, such that $\pi_{s,O}(\varphi_{s,O}) = \pi_{s,D}(\varphi_{s,O})$:

$$\varphi_{s,O} = \left[\frac{f_O\,(A)^{-1}}{B_s\left[\left[(w_{h,s})^{\alpha_s}\left(w^\star_{o,s}\tau^\star\right)^{1-\alpha_s}\right]^{1-\sigma_s}\left[A^{\alpha_s}\left(A^\star\right)^{1-\alpha_s}\right]^{\sigma_s-1} - \left[(w_{h,s})^{\alpha_s}\left(w_{o,s}\right)^{1-\alpha_s}\right]^{1-\sigma_s} A^{\sigma_s-1}\right]}\right]^{\frac{1}{\sigma_s-1}}$$

$\varphi_{s,O}$ is decreasing in $A^\star$ and $w_{o,s}$, since $\sigma_s \geq 1$. In other words, the stronger the comparative advantage of the East over the West, the more Western firms decide to offshore. Regardless of the organizational decision, firm profits are monotonically increasing in φ. This can be seen from figure 1.3, which plots profits of different organizational strategies against idiosyncratic productivity both for Western firms (left panel) and Eastern firms (right panel). Western firm profits from offshoring are negative for low values of φ due

[61] More formally, the total costs of producing y units of a final good of variety φ associated with **D**omestic sourcing and **O**ffshoring can be written as

$$\Gamma_{s,D}(y_{s,D}(\varphi),\varphi) \quad = \quad \frac{y_{s,D}(\varphi)}{A\varphi}(w_{h,s})^{\alpha_s}(w_{o,s})^{1-\alpha_s}$$
$$\Gamma_{s,O}(y_{s,O}(\varphi),\varphi) \quad = \quad \frac{f_O}{A} + \frac{y_{s,O}(\varphi)}{A^{\alpha_s}\left(A^\star\right)^{1-\alpha_s}\varphi}(w_{h,s})^{\alpha_s}(w^\star_{o,s}\tau^\star)^{1-\alpha_s}$$

[62] Notation: $\tau^\star$ labels trade costs for shipments from East to West and τ labels trade costs for shipments from West to East.

to the fixed organizational costs. However, profits from offshoring grow significantly with higher φ, which eventually leads to higher profits compared to domestic production. Consequently, all firms with idiosyncratic productivity larger than $\varphi_{s,O}$ decide to offshore. This implies that large and productive firms offshore. In contrast, Eastern firms abstain from offshoring, since domestic production is more cost-efficient (lower production costs and no trade costs on intermediate inputs). This aspect of the model is discussed in more detail in appendix 1.8.4.3.

[Insert Figure 1.3 here.]

Decision to Export

In addition to choosing the location of production, firms decide whether or not to export. Similar to offshoring, exporting is costly and involves variable trade costs, τ, and per-period fixed costs, f_X . Firms choose to export whenever profits from doing so are positive, $\pi_{s,X} \geq 0$. However, the decision to export also depends on the location of production. Consequently, the productivity cutoff for domestic producers is different from the cutoff for firms that offshore.

The cutoff level for firms that produce **domestically** is defined as [63]

$$\varphi_{s,X,D} = \left[\frac{f_X (A)^{-1}}{B_s^\star \left[\tau (w_{h,s})^{\alpha_s} (w_{o,s})^{1-\alpha_s} \right]^{1-\sigma_s} A^{\sigma_s - 1}} \right]^{\frac{1}{\sigma_s - 1}}.$$

Profit maximization implies that all domestically producing firms in the West with idiosyncratic productivity higher than $\varphi_{s,X,D}$ engage in exporting.

In contrast, firms that **offshore** decide to export whenever their productivity level is higher than [64]

$$\varphi_{s,X,O} = \left[\frac{f_X (A)^{-1}}{B_s^\star \left[\tau (w_{h,s})^{\alpha_s} \left(w_{o,s}^\star \tau^\star \right)^{1-\alpha_s} \right]^{1-\sigma_s} \left[A^{\alpha_s} (A^\star)^{1-\alpha_s} \right]^{\sigma_s - 1}} \right]^{\frac{1}{\sigma_s - 1}}.$$

[63] Note that the corresponding profit expression is equal to

$$\pi_{s,X,D}(\varphi) = B_s^\star \left(\tau (w_{h,s})^{\alpha_s} (w_{o,s})^{1-\alpha_s} \right)^{1-\sigma_s} (A\varphi)^{\sigma_s - 1} - \frac{f_X}{A}.$$

[64] Corresponding profits are equal to

$$\pi_{s,X,O}(\varphi) = B_s^\star \left(\tau (w_{h,s})^{\alpha_s} (w_{o,s}^\star \tau^\star)^{1-\alpha_s} \right)^{1-\sigma_s} \left(A^{\alpha_s} (A^\star)^{1-\alpha_s} \varphi \right)^{\sigma_s - 1} - \frac{f_X}{A}.$$

As above, all Western firms that engage in offshoring with idiosyncratic productivity higher than $\varphi_{s,X,O}$ decide to export. Importantly, this productivity cutoff is valid only for firms that offshore. Hence, the fixed costs of offshoring f_O need not be considered again.

Allowing firms to choose the production location and decide whether or not to export is realistic but increases complexity substantially. In fact, the decision to offshore might affect the decision to export and vice versa. Hence, to ensure tractability, I rule out equilibria in which in a given country, firms that produce only domestically and export and firms that offshore and export co-exist.[65] One way to prevent co-existence is to ensure that only firms that offfshore engage in exporting. This can be induced by large-enough fixed costs of exporting, f_X. In particular, it is sufficient that $\varphi_{s,X,O} > \varphi_{s,O}$ holds period by period.[66] This case is illustrated in the left panel of figure 1.3. $\varphi_{s,X,O}$ is indeed larger than $\varphi_{s,O}$ in this specific equilibrium of the model. As a result, only Western firms that engage in offshoring also export. For the East, the problem is much simpler. Since all firms produce domestically, the relevant cut-off productivity that separates exporters from non-exporters is $\varphi^{\star}_{s,X,D}$.

1.4.3 Aggregation

In what follows, I follow Ghironi and Melitz (2005) and assume that firm productivity is distributed according to a Pareto distribution with lower bound φ_{min} and shape parameter $\kappa_s > \sigma_s - 1 : G(\varphi) = 1 - \left(\frac{\varphi_{min}}{\varphi}\right)^{\kappa_s}$. The assumption of a Pareto distribution for productivity induces a size distribution of firms that is also Pareto, which fits well the empirical distribution. The parameter κ_s relates industry output to the cross-section of firms, where high values are associated with more homogenous industries in the sense that more output is concentrated among the smallest and least-productive firms.

Quantities

As in Melitz (2003) and Ghironi and Melitz (2005), it is enough to track the mass and the average productivity for firms that choose the same strategy. In essence, the model is isomorphic to one in which firms within a strategy group all have a productivity

[65] Antras, Fort, and Tintelnot (2016) multi-country sourcing model, in which global sourcing decisions interact through the firm's cost function, and Bernard, Jensen, Redding, and Schott (2016) present a theoretical framework that allows firms to decide simultaneously on the set of production locations, export markets, input sources, products to export, and inputs to import.

[66] To be precise, a large f_X lowers the probability of co-existence to a very small number but does not strictly rule it out. Therefore, when simulating the model, I check ex post that $\varphi_{s,X,O} > \varphi_{s,O}$ holds period by period for all industries s. More details on the computation approach when solving the model can be found in an online appendix.

equal to the average productivity of the group. Put differently, the average productivity levels per group summarize all information on the productivity distribution relevant for macroeconomic variables.

First, I calculate the fraction of firms in industry s that engage in domestic production, $\zeta_{s,D}$, and offshoring, $\zeta_{s,O}$. Moreover, $\zeta_{s,X,O}$ and $\zeta^{\star}_{s,X,D}$ stand for the fractions of firms that export in the West and East, respectively. These quantities are determined by the cutoff productivity levels and the shape of the Pareto distribution, as detailed in appendices 1.8.4.2 and 1.8.4.3.

Second, I derive average productivity levels for the different groups: 1) $\bar{\varphi}_{s,D}$, for purely domestic Western firms; 2) $\bar{\varphi}_{s,O}$, for Western firms that offshore; 3) $\bar{\varphi}_{s,X,O}$, for Western firms that offshore and export; 4) $\bar{\varphi}^{\star}_{s,D}$, for purely domestic Estern firms; and 5) $\bar{\varphi}^{\star}_{s,X,D}$, for Eastern firms that produce domestically and export. These quantities can be calculated as simple conditional averages for the Pareto distribution. Again, detailed derivations can be found in appendices 1.8.4.2 and 1.8.4.3.

Industry Profits and Prices

Industry-wide profits and price indices can now be calculated using probability masses and average productivity levels. Industry profits are simply given by the sum of the profits made on the domestic and exporting markets. Therefore, industry profits in the West are given by

$$\Pi_s = N_s \left[\zeta_{s,D}\pi_{s,D}(\bar{\varphi}_{s,D}) + \zeta_{s,O}\pi_{s,O}(\bar{\varphi}_{s,O}) + \zeta_{s,X,O}\pi_{s,X,O}(\bar{\varphi}_{s,X,O})\right]$$

and industry profits in the East are given by

$$\Pi^{\star}_s = N^{\star}_s \left[\pi^{\star}_{s,D}(\bar{\varphi}^{\star}_{s,D}) + \zeta^{\star}_{s,X,D}\pi^{\star}_{s,X,D}(\bar{\varphi}^{\star}_{s,X,D})\right],$$

where N_s ($N^{\star}_s$) is the total mass of firms in the West (East) exogenously set to match the size of the economy.

Finally, the industry price indices in the two countries are equal to

$$P_s = \left[N_s \left[\zeta_{s,D}p_{s,D}(\bar{\varphi}_{s,D})^{1-\sigma_s} + \zeta_{s,O}p_{s,O}(\bar{\varphi}_{s,O})^{1-\sigma_s}\right] + N^{\star}_s\zeta^{\star}_{s,X,D}\left(p^{\star}_{s,X,D}(\bar{\varphi}^{\star}_{s,X,D})\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}},$$

in the West, and

$$P^{\star}_s = \left[N^{\star}_s p^{\star}_{s,D}(\bar{\varphi}^{\star}_{s,D})^{1-\sigma_s} + N_s\zeta_{s,X,O}p_{s,X,O}(\bar{\varphi}_{s,X,O})^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}},$$

in the East.

1.4.4 Equilibrium

In equilibrium, the aggregate budget constraint of the representative household is given in terms of the aggregate price index P, composite consumption C, labor income L and revenues from Western and Eastern industries, Π_s and $\Pi_s^\star$:

$$PC \leq L + \sum_s \Pi_s + \chi \left[\frac{N_s}{N_s + N_s^\star} \Pi_s^\star - \frac{N_s^\star}{N_s + N_s^\star} \Pi_s \right].$$

The exogenous parameter $\chi \in [0, 1]$ controls the level of risk sharing across countries in the economy. This formulation embeds both the case of no risk-sharing and perfect or full risk-sharing. Without risk-sharing, $\chi = 0$, households only receive dividends from domestic firms: $\Pi_{no} = \sum_s \Pi_s$. In comparison, with full risk-sharing, $\chi = 1$, households receive a share of total world profits that is proportional to their capital endowments: $\Pi_{full} = \sum_s \frac{N_s}{N_s + N_s^\star} (\Pi_s + \Pi_s^\star)$. Consequently, dividends paid to households are a convex combination of Π_{no} and Π_{full}.

The model is solved with time-invariant mass of firms in each industry. Moreover, the model abstracts from capital or investment. As a result, firms can adjust their production solely by deciding either to offshore or export. The equilibrium is defined as a collection of prices $(p_{s,D}, p_{s,O}, p_{s,X,O}, p_{s,X,D}, P_s, P_T, P)$, output $(y_s(\varphi))$, consumption $(c_s(\varphi))$ and labor demand $(l_s(\varphi))$ such that each firm maximizes profit, consumers maximize their utility, and goods and labor markets clear.

1.4.5 Asset Pricing

Since the representative household in the West holds Western firms, the firms are priced using her stochastic discount factor (SDF). Therefore, I derive the Euler equation from the portfolio problem faced by the representative household. She maximizes her continuation utility over the consumption stream $\{C_t\}$ subject to her budget constraint. Because there is no capital and investment in the model, firms pay out dividends that are equal to their profits, $\pi_{s,t}(\varphi)$.

$$\max \left\{ (1-\beta) C_t^{\frac{1-\gamma}{\nu}} + \beta \left(\mathbb{E}_t \left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1}{\nu}} \right\}^{\frac{\nu}{1-\gamma}}$$

$$\text{s.t. } P_t C_t + \sum_s \int_{\Omega_s} x_{s,t+1}(\varphi) \upsilon_{s,t}(\varphi) d\varphi \leq L + \sum_s \int_{\Omega_s} x_{s,t}(\varphi) \left[\upsilon_{s,t}(\varphi) + \pi_{s,t}(\varphi) \right] d\varphi$$

where $x_{s,t}(\varphi)$ is the investment in the firm in industry s of variety φ and $\upsilon_{s,t}(\varphi)$ is the corresponding firm valuation.

The resulting Euler equation reads as follows:

$$\upsilon_{s,t} = \mathbb{E}_t \left[M_{t,t+1} \left(\upsilon_{s,t+1}(\varphi) + \pi_{s,t+1}(\varphi) \right) \right],$$

where $M_{t,t+1} = \beta^{\nu} \Delta C_t^{-\frac{\nu}{\psi}} R_{c,t}^{\nu-1}$ is the stochastic discount factor (SDF) and $R_{c,t}$ is the return on the consumption claim.

1.4.6 Calibration

To calibrate my model, I associate the West with the United States and the East with China. Moreover, where possible, I calibrate the model using parameters from the literature, as reported in table 1.13. In particular, I use elasticities across industries from Loualiche (2015) and across goods from Broda and Weinstein (2006). The firm distribution is governed by the parameter κ_s, which is set to 3.4, as in Ghironi and Melitz (2005). The industry taste parameter δ_s is equal to 0.5. Hence, households do not have a preference for a certain industry.

[Insert Table 1.13 here.]

Wage costs other than pay for time in the West, c, are chosen to match the empirical counterpart in the United States. According to the Bureau of Labor Statistics (BLS), 24.35% of the total wage costs in manufacturing accounted for social insurance payments and 8.92% for directly paid benefits.[67] Hence, 33.27% of the total wage bill consisted of payments other than wages and salaries for time actually worked. To reflect this in the model, I calibrate c to 0.32 and $c^{\star}$ to 0, assuming absence of social insurance costs in the East.

L and $L^{\star}$ are determined by the ratio of the working age population in the U.S. and China. The Federal Reserve Bank of St. Louis reports a working age population of 205 millions by the end of 2015 in the U.S. and 1'004 million in China. The mass of firms in each country, N_s and $N_s^{\star}$, is chosen to match the ratio of the market capitalization in the U.S. and China. The World Bank states the total market capitalization of listed domestic companies in 2015 as 25.068 trillion USD in the U.S. and 8.19 trillion USD in China. To match the ratio between the two, I calculate the model-implied ratio of the sum of market values of all firms in the West and East, respectively.

[67] Directly paid benefits are primarily pay for leave time, bonuses, and pay in kind.

The headquarter intensities of the two industries, α_s, are set to 0.55 and 0.95, respectively. This implies that a high (low) offshorability industry has an offshoring potential of 45% (5%) and that the average offshoring potential in the model economy is 25%. For comparison, the OECD estimates that close to 20% of jobs in OECD countries are offshorable, while Blinder's (2009) estimates for the U.S. lie between 22% and 29%.[68]

Variable trade cost and fixed cost parameters are set to the values in Ghironi and Melitz (2005) and Barrot, Loualiche, and Sauvagnat (2017), respectively. The subjective discount factor is 0.99, and the intertemporal elasticity of substitution is 1.5, as in Bansal and Yaron (2004a). I calibrate the risk aversion parameter to match the U.S. equity premium. Finally, parameters related to aggregate productivity in the West (East) are chosen to reflect GDP in the U.S. (Chinese imports to the U.S.), as in Barrot, Loualiche, and Sauvagnat (2017).

1.4.7 Model Mechanism

Consumption Response - To examine what drives asset prices in the model, it is necessary to understand how aggregate consumption and the SDF respond to aggregate productivity shocks in the model.

The elasticity of consumption in the West to a productivity shock in the East, $\eta^{\star}(C)$[69], is

$$\eta^{\star}(C) = \underbrace{-\eta^{\star}(P)}_{\text{price effect}} + \underbrace{\frac{\Pi}{L+\Pi}\eta^{\star}(\Pi)}_{\text{wealth effect}} \tag{1.4}$$

The elasticity consists of a price and a wealth effect. As will be discussed later, the elasticity of the price index with respect to $A^{\star}$ is negative. As a result, the sign of the first term is unambiguously positive. On the other hand, the sign of the wealth effect depends on the degree of international risk sharing. With full risk-sharing, the wealth effect is positive, as is the elasticity of consumption with respect to a foreign productivity shock: Western households benefit from (1) lower domestic prices due to increases in imports and (2) higher capital income due to higher world profits.

However, with a sufficiently high degree of home bias in capital income (low χ), the wealth effect is negative and dominates the positive price effect. As an illustration, the first row of figure 1.4 plots impulse response functions of consumption for different values of χ. In the baseline parametrization, $\chi < 0.75$ is sufficient to generate a negative

[68]The OECD also reports the offshoring potential for NACE 2-digit industries. For the year 2003, the numbers lie between 79.5% and 1.8%.

[69]Notation: $\eta(X) = \frac{\partial \log X}{\partial \log A}$ and $\eta^{\star}(X) = \frac{\partial \log X}{\partial \log A^{\star}}$.

consumption response. $\chi = 0.75$ implies that Western households overweigh their investments in domestic firms by 18.62% compared to domestic firms' share of the world market. Hence, a fairly moderate home bias is sufficient to generate a negative elasticity of consumption with respect to a positive productivity shock in the East. In comparison, Coeurdacier and Rey (2012) empirically find a home bias for equity investments of 44.6% in the U.S. in 2008.[70] To simplify the exposition, I impose no international risk sharing (i.e., $\chi = 0$) in my benchmark specification; I then discuss the implications thereof.

[Insert Figures 1.4 and 1.5 here.]

The elasticity of consumption to productivity shocks in the West looks identical to equation 1.4. For shocks to A, however, the elasticity of consumption is unambiguously positive. In particular, both price and wealth effect carry a positive sign.

In what follows, I separately discuss how shocks to $A^{\star}$ and A affect the equilibrium. The discussion mostly focuses on the West as the main country of interest and starts with the analysis of aggregate productivity shocks in the East.

Shocks to $A^{\star}$ - To facilitate the discussion, figure 1.4 plots impulse response functions of model quantities to a positive one standard deviation shock to $A^{\star}$ in the absence of risk sharing. As discussed, consumption in the West (East) decreases (increases) upon arrival of a shock. Moreover, due to higher productivity, more Eastern firms find it profitable to export, which results in an increase in import penetration. Higher import penetration in turn leads to an increase in product variety, a decrease in industry prices and a loss in market share and profits of Western firms.

Higher productivity in the East, however, also renders offshoring more attractive. Doing so allows firms to lower costs, which goes hand in hand with a larger market share and higher profits. Hence, offshoring effectively acts as partial insurance against adverse consequences associated with foreign productivity shocks.

The response of the fraction of firms that offshore is more pronounced in high offshorability industries. The reason is simple: in the model, industries with higher offshoring potential are able to replace more workers/tasks, which results in a larger cost reduction and makes it more likely for firms to overcome the fixed costs of offshoring. As a result, profits drop less in industries with high offshorability.

[70] For further empirical evidence of home bias in the U.S., see, among others, French and Poterba (1991) and Coval and Moskowitz (1999); and for rational explanations of the home bias puzzle, see, for example, Glassman and Riddick (2001), Ahearne, Griever, and Warnock (2004), Nieuwerburgh and Veldkamp (2009) and Bretscher, Julliard, and Rosa (2016).

What does this mean for asset prices? The heterogenous response of industry profits maps into differential asset price and excess return dynamics across industries. The last row plots the response of the SDF, asset prices and excess returns for the case of no and full risk sharing, respectively. Consistent with the consumption response in the first row, the SDF increases under no risk sharing but decreases with full risk sharing. However, the qualitative response of asset prices and returns is not altered by the degree of risk sharing. In both cases, the responses are negative and more pronounced for the low offshorability industry.

Shocks to A - Figure 1.5 plots the impulse responses to a *negative* one standard deviation shock to A. I plot the responses to a negative productivity shock to facilitate comparison with the impulse response functions after a shock to $A^{\star}$. Upon arrival of the shock, Western consumption drops, which affects firms through a decrease in product demand. Moreover, because the production function of Eastern firms that export to the West is not directly affected by shocks to A, their productivity and, hence, their prices remain unchanged. This gives Eastern exporters a competitive advantage over Western firms whenever a negative shock to A happens. As a result, Western firms lose market share to these exporters.

As above, offshoring presents itself as a valuable alternative in order to mitigate the adverse consequences of the shock. Again, offshoring results in a larger cost reduction for high compared to low offshorability industries. Consequently, the response of the fraction of firms that offshore is more pronounced in high offshorability industries, which ultimately leads to smoother industry profits. Asset prices and excess returns follow from industry profits and look very similar to figure 1.4 (not shown).

To sum up, the ability to offshore protects industries against losses associated with import competition. Differences in offshorability across industries contribute to a spread in excess returns similar to the L-H spread observed in the data.

1.4.8 Model Simulation Results

To quantify the model and investigate the contribution of the two productivity shocks, I calculate moments from simulated data. As discussed in section 1.4.6, I target the ratios of market capitalization and working age populations in the U.S. and China as well as the average import competition from China to discipline my calibration exercise. In particular, matching these moments constrains the choice of parameters N_s, $N_s^{\star}$, L, $L^{\star}$ and $f_X^{\star}$. The model matches the targeted moments well, as can be seen in panel A of table 1.14.

[Insert Table 1.14 here.]

Panel B of the same table reports model-implied macro moments. Similar to Barrot, Loualiche, and Sauvagnat (2017), aggregate consumption is too volatile in the model. While the mean of the risk-free rate is close to the data, the model implied standard deviation is too low. Interestingly, the model-implied U.S. labor share aligns quite well with the data. The Bureau of Labor Statistics reports a labor share of 58.4% as of the third quarter in 2016. In comparison, the model-implied labor share is 60.54%.

The moments of industry quantities are reported separately for high and low offshorability industries in panel C. The level of import penetration is slightly higher in the industry with low offshoring potential. Intuitively, because Eastern firms face less resistance upon entering in this industry, it is optimal to do so to a higher extent in equilibrium. Moreover, import penetration is more volatile because the response to productivity shocks is more pronounced, as can be seen from figures 1.4 and 1.5. For industry profits, the standard deviation and covariance with aggregate productivity shocks and consumption are decreasing in offshorability. In other words, the possibility to offshore allows firms to smooth their profits, which renders them less exposed to shocks.

Panel D of table 1.14 reports moments of model asset prices and excess returns. The model-implied annualized market risk premium is 4.52%.[71] Since the model does not feature financial leverage, this is the unlevered risk premium. To make the model premium comparable to the data, I calculate the model-implied levered market risk premium assuming a leverage ratio equal to the sample median of 23.8%. The model market risk premium of 5.93% is quantitatively in line with the annualized excess return of the S&P 500 of 5.72% during the sample period. As in the data, model excess returns are lower for high compared to low offshorability industries. The levered (unlevered) annualized L-H spread between the two model industries is equal to 3.82% (2.91%), which is clearly lower than the risk-adjusted annualized spread of 8.05% for manufacturing industries in the data. I will discuss different reasons for the relatively low L-H spread in the model in section 1.4.10. This section will also discuss how the magnitude of the spread depends on model parameters and endogenous model quantities.

$$\eta^{\star}\left(\Pi^{X}\right) = \underbrace{-\sigma_s\left[1+\frac{\kappa_s-(\sigma_s-1)}{\sigma_s-1}\right]\left[-\eta^{\star}\left(P_s^{\star}\right)\right]}_{\text{price effect}} + \underbrace{\left[1+\frac{\kappa_s-(\sigma_s-1)}{\sigma_s-1}\right]\eta^{\star}\left(C_s^{\star}\right)}_{\text{demand effect}} + \underbrace{(1-\alpha_s)\,\kappa_s}_{\text{productivity effect}} \tag{1.5}$$

Within the model, it is possible to separate the domestic profits from profits from exporting. Equation 1.5 shows the elasticity of profits from exporting with respect to a

[71] I calculate the model market risk premium as the value-weighted excess return across industries.

productivity shock in the East, $A^\star$. The elasticity consists of three parts: (1) price effect (negative): the industry price index, $P_s^\star$, decreases and causes a loss in market share and profits; (2) demand effect (positive): demand increases and leads to an increase in profits; (3) productivity effect (positive): since all exporters also offshore, productivity shocks in the offshoring country directly affect profits through gains in productivity. Hence, the elasticity of export profits is negative whenever the price effect dominates.

Panel D of table 1.14 shows that profits from exporting are riskier than total industry profits, which results in higher excess returns for exporters compared to the industry as a whole. Intuitively, all exporters have exercised their offshoring option, which leaves them unable to smooth profits going forward. Consequently, the model implies that multinational firms whose profits stem from domestic and exporting markets exhibit higher excess returns than purely domestic firms. This is consistent with the empirical evidence in Fillat and Garetto (2015).

To quantify the contribution of the two productivity shocks, I simulate the model with just one stochastic productivity process at a time. Panel A of table 1.15 reports simulated moments in the model economy for industry profits and excess returns. In the model, 89% of the L-H spread is due to shocks to $A^\star$, while only 11% is due to shocks to A.

[Insert Table 1.15 here.]

In an extension discussed in section 1.8.4.4 of the appendix, I introduce international bond trading to the model, as in Ghironi and Melitz (2005). Not surprisingly, the standard deviation of consumption decreases compared to the baseline model, as bonds allow households to smooth their consumption intertemporally. As a result, the overall risk premium is lower. Importantly, however, the L-H spread is unaffected by the introduction of international bond trading. Since risk-free bonds are a state independent savings technology, trading them does not help mitigate state-specific risks.[72]

1.4.9 Testable Model Implications

The model delivers several predictions that can be tested in the data. Within the model, the possibility to offshore allows firms and industries to lower their exposure to aggregate productivity shocks. As a result, profits are less volatile for high compared to low offshorability industries. To test this model implication, I calculate profit and sales volatility as in Minton and Schrand (1999) and regress these volatilities on lagged offshorability, other firm controls (Tobin's Q, leverage and investment) and year fixed

[72]Relevant moments of simulated data of the model with international bond trading are reported in table 1.28 of the appendix.

effects.[73] Standard errors are clustered at the year and firm level. The regression results are tabulated in Panel B of table 1.15.

Consistent with the theory, the coefficients on $OFF_{i,t-x}$ for profit volatility are negative and highly statistically and economically significant both for one- and five-year lags. Interestingly, the coefficient on $OFF_{i,t-5}$ is double the magnitude of the coefficient on the first lag. A one standard deviation increase in industry offshorability is associated with an 8.9% (one-year lag) to 19.7% (five-year lag) decrease in the profit volatility for the median firm. Regression coefficients for several lags with 90% and 95% confidence bands are plotted in figure 1.6. I find that the coefficient on $OFF_{i,t-x}$ is monotonically increasing in magnitude with the horizon. This is consistent with offshoring being a process that takes time to be fully incorporated.

[Insert Figure 1.6 here.]

The results for sales volatility are very similar as for profit volatility. While the coefficients on $OFF_{i,t-x}$ are negative in all specifications, they are statistically different from zero at a 90% (95%) confidence level only for horizons larger or equal to three (four) years. Intuitively, offshoring allows for a cost reduction that affects profits with higher immediacy than sales.

Furthermore, the model allows one to form predictions about the cross-sectional dispersion of the L-H premium. Households become more price-sensitive when the elasticity of substitution among product varieties, σ_s, increases. Put differently, in industries with high elasticities, all else being equal, the drop in Western firms' market share is more pronounced upon arrival of an adverse productivity shock - both in low and high offshorability industries. This can be seen from the elasticity of domestic profits with respect to a productivity shock in the East:

$$\begin{aligned}\eta^{\star}\left(\Pi^{D}\right) &= \underbrace{-\left(\sigma_s-\theta\right)\left(-\eta^{\star}\left(P_s\right)\right)}_{\text{competition effect}} + \underbrace{\eta^{\star}\left(C_s\right)+\frac{1-a_0-\theta}{a_0}\left(-\eta^{\star}\left(P\right)\right)}_{\text{expenditure effect}} + \\ &\left[\underbrace{\kappa_s\frac{\zeta_{s,O}\left(\pi_{s,O}-\pi_{s,D}\right)}{\Pi^{D}}}_{\text{relative benefits from offshoring}} \underbrace{-\left(\sigma_s-1\right)\frac{\zeta_{s,D}\pi_{s,D}\Phi+\zeta_{s,O}\pi_{s,O}}{\Pi^{D}}}_{\text{industry composition effect}}\right]\left(-\eta^{\star}\left(\varphi_{s,O}\right)\right) + \\ &\underbrace{\frac{\zeta_{s,O}\pi_{s,O}}{\Pi^{D}}\left(\sigma_s-1\right)\left(1-\alpha_s\right)}_{\text{productivity gain from offshoring}},\end{aligned} \tag{1.6}$$

[73] I adapt the methodology proposed by Minton and Schrand (1999) to calculate cash flow volatility both for profit and sales volatility.

where $\Phi > 0$ and $\frac{\partial \Phi}{\partial \varphi_{s,O}} > 0$.[74] Irrespective of an industry's offshorability, the elasticity is more negative with higher σ_s because the *competition effect* is amplified. Competition leads to a decrease in industry prices, which results in a decrease in market share. Moreover, the effect of an increase in σ_s depends on the industry equilibrium in the West (*industry composition effect*). A higher elasticity of substitution harms firms that have already offshored. These firms cannot decrease costs further, and their profits are adversely affected by increases in competition.[75]

Lastly, *productivity gains from offshoring* increase the elasticity of domestic profits with respect to a productivity shock in the East. Intuitively, firms that offshore benefit from positive productivity shocks in the offshoring country. As a result, this productivity effect shows up in the elasticity of profits. Interestingly, the productivity gain is multiplied by the term $(\sigma_s - 1)$, which implies that being able to offshore is more valuable when the elasticity of substitution is high. Hence, a testable implication of the model is that excess return spreads between high and low offshorability industries are larger in industries with high elasticity of substitution with respect to imported goods.

[Insert Table 1.16 here.]

To test this implication in the data, I use U.S. trade elasticities estimated by Broda and Weinstein (2006) from 1990 to 2001. Table 1.16 reports average returns for double sorts on offshorability and U.S. trade elasticities. The results are consistent with the model. The L-H spread is increasing in trade elasticities. In fact, for low elasticity industries, the spread is no longer statistically significant.

Finally, the model implies that the covariance of industry excess returns with consumption is decreasing in offshorability. In other words, low (high) offshorability industry excess returns have a high (low) covariance with domestic consumption. To test this model implication, I calculate consumption betas for offshorability portfolios both in the model and in the data. It is well known that differences in the covariance of returns and contemporaneous consumption growth do not explain the expected returns observed in the U.S. stock market.[76] However, Parker and Julliard (2005) show that considering the ultimate risk to consumption, defined as the covariance of quarterly portfolio returns and consumption growth over the quarter of the return and many following quarters, can

[74] φ is defined as follows:

$$\Phi = \frac{\varphi_{s,min}^{\kappa_s}}{\sigma_s - 1} \left[\frac{\varphi_{s,O}^{\sigma_s - \kappa_s} \left[\kappa_s - (\sigma_s - 1)\right]}{\varphi_{s,min}^{\sigma_s - 1} - \varphi_{s,min}^{\kappa_s} \frac{1}{\varphi_{s,O}^{\kappa_s - (\sigma_s - 1)}}} - \frac{\kappa_s}{\varphi_{s,O}^{\kappa_s} - \varphi_{s,min}^{\kappa_s}} \right]$$

[75] Note that σ_s is multiplied by the share of profits that come from companies that offshore.

[76] See, among others, Mankiw and Shapiro (1986), Breeden, Gibbons, and Litzenberger (1989), Campbell (1996), Cochrane (1996), and Lettau and Ludvigson (2001)

largely explain the cross-sectional pattern of expected portfolio returns. Ultimate consumption risk is likely to be a better measure of the true risk of an asset if consumption is slow to adjust to returns. Alternatively, Brainard, Nelson, and Shapiro (1991) and Bandi and Tamoni (2017) show that measuring both portfolio returns and consumption growth at a lower than quarterly frequency improves the performance of the consumption CAPM (CCAPM). Given that my model does not feature a slow adjustment of consumption to returns, I follow the latter approach and calculate portfolio returns and consumption growth over four and eight quarters both in the model and in the data.[77]

[Insert Table 1.17 here.]

Panel A of table 1.17 reports the regression results for the simulated data. As discussed above, the consumption beta is higher for low compared to high offshorability industries. As a result, L-H has a positive and significant consumption exposure in the model. The R^2 is close to one, since the CCAPM holds within the model. Panel B reports corresponding regressions for my sample of manufacturing industries. Consistent with the model, the consumption beta is positive and significant for the L-H portfolio for four-, six- and eight-quarter returns. This is true both for equal- and value-weighted returns.

1.4.10 Comparative Statics and Model Counterfactuals

This section explores the role of model parameters using comparative statics analyses and discusses model counterfactuals. First, I explore comparative statics with respect to differences in headquarter intensity across industries. Figure 1.7 shows that the model L-H premium is increasing in the difference in headquarter intensity of low and high offshorability industries, $\alpha_L - \alpha_H$. An increase in the difference in headquarter intensity across industries maps into an increase in the difference in offshoring potential across industries (i.e., $\alpha_L - \alpha_H = (1 - \alpha_H) - (1 - \alpha_L)$). Hence, a larger difference in offshoring potential implies a larger difference in industry risk premia.

[Insert Figures 1.7 and 1.8 here.]

Second, the left panel of figure 1.8 plots annualized industry returns for different values of risk aversion, γ. The L-H spread is increasing in risk aversion. To generate returns in line with market returns over the sample period, a relatively high risk aversion coefficient of

[77]See Lynch (1996), Marshall and Parekh (1999) and Gabaix and Laibson (2002) for models that implement slow or delayed adjustment of consumption.

roughly 80 is needed.[78] The right panel of figure 1.8 plots the returns of the two industries for different levels of import penetration.[79] In line with the findings of Barrot, Loualiche, and Sauvagnat (2017), returns in both industries are increasing in import penetration. Importantly, the model-implied L-H spread is increasing in import penetration. This is consistent with the excess return double sorts from tables 1.10 and 1.11. Moreover, the figure shows that import penetration is a quantitatively important driver of the L-H spread: an increase in import penetration from 6.26% (benchmark calibration) to 11.12% leads to an increase in the levered L-H spread from 3.82% to 5.73%. This is intuitive, given that offshoring protects industries against foreign import competition. Consequently, a reason for the relatively low model L-H spread compared to the data is that the calibration only accounts for import penetration from China. In fact, over the sample period, the average import penetration from all countries is equal to 24.95%. Therefore, allowing for a higher level of import penetration could help in matching the L-H spread.

Having established that import competition drives returns, one might wonder whether the L-H spread is predominantly driven by the difference in the level of import penetration across the two industries (see panel C of table 1.14). To explore this possibility, I simulate the model such that both industries have the same mean of import penetration. To do so, I slightly increase the mass of Eastern firms in the high offshorability industry. Panel C of table 1.15 reports the results. Industry excess returns slightly increase because overall import penetration has increased. Moreover, the levered L-H spread decreases slightly from 3.82% to 3.45%. Hence, the difference in equilibrium means of import penetration across industries matters, but it only accounts for 9.7% of the L-H spread in the benchmark calibration. Therefore, the model-implied L-H spread cannot be explained by differences in import penetration across industries.

Next, I explore the quantitative importance of the offshorability channel within the model. To do so, I simulate the baseline model and set the offshorability in both industries to zero, i.e., $(1-\alpha_s)=0$. Consequently, firms can no longer offshore. Moreover, by setting $(1-\alpha_s)=0$, the two industries become identical to each other, since differences in headquarter intensity are the only source of industry heterogeneity. Panel C of table 1.15 reports the moments for valuations and excess returns. In comparison with the baseline low (high) offshorability industry, the excess returns are 2.65 (5.27) percentage points higher. This remarkable increase in risk premium is due to a higher exposure of firm profits to aggregate shocks. To further assess the importance of the channel in absence of industry heterogeneity, I compare the no offshorability case with

[78] For comparison, the annualized return (excess return) of the S&P 500 over the sample period is equal to 8.25% (5.72%).

[79] Average import penetration is defined as $IP = \left[\sum_s \eta_s IP_s^{1-\theta}\right]^{\frac{1}{1-\theta}}$, where IP_s is the import penetration of a single industry.

a counterfactual in which both industries have an offshorability of 20%, $(1-\alpha_s) = 0.2$ (not shown): offshoring allows the industry risk premium to be lowered by 33% or 3.14 percentage points. Moreover, higher implied discount rates result in 17% lower equity valuations in the model without offshoring. To sum up, the offshoring channel is economically important in the model. Being able to offshore significantly lowers the risk of an industry, which manifests in lower excess returns and higher equity valuations.

Furthermore, I use the model to explore the response to a sudden increase in trade costs when shipping goods from East to West. This could be interpreted as the introduction of a new tax in the West on all imported goods. To do so, I simply replace the trade cost parameter, $\tau^\star$, with an autoregressive process of order one with the mean equal to 1.1 and a persistence of .95. This allows me to generate impulse response functions for model variables upon a shock in trade costs, as shown in figure 1.9. The figure shows responses after a one percent increase in $\tau^\star$. In the model, an increase in trade costs leads to lower import penetration from Eastern firms, which reduces the risk for Western industries. However, higher trade costs also render offshoring less attractive, since shipment of intermediate goods is more costly. Consistent with this, figure 1.9 shows that both import penetration and the fraction of firms that offshore fall upon an increase in $\tau^\star$. Interestingly, the asset prices of Western firms also decrease in the model. Hence, the reduction in the benefits from offshoring outweigh the positive effects from lower import penetration. Consistent with this, asset prices drop more for the high compared to low offshorability industry.

[Insert Figures 1.9 and 1.10 here.]

Finally, I explore through the lens of the model what would happen if the comparative cost advantage of the East over the West were to fade away. This is an important counterfactual, given that hourly manufacturing wages in China have risen by an average of 12% per year since 2001.[80] In particular, I assume that the comparative cost advantage of the East decreases to half of its initial magnitude. Figure 1.10 reports impulse responses to a positive productivity shock in the East, $A^\star$, for the benchmark and the low comparative cost advantage economies. As the comparative advantage becomes smaller, the East loses its relative cost competitiveness over the West. This leads to lower import penetration and exposure of Western firms to aggregate productivity shocks in the East. As a result, industry profits and asset prices drop less compared to the benchmark economy, and the unconditional risk premium is lower. Importantly, the L-H spread is also

[80] See the article "A tightening grip" in the Economist from March 12, 2015.

smaller, with a low comparative advantage.[81] Intuitively, offshoring provides insurance against a risk that is less severe compared to the benchmark economy.

1.5 Conclusion

This paper studies how the possibility to relocate production affects industries' cost of capital. Using a new measure of offshorability at the industry level, I find that industries with low offshoring potential carry an annualized 7.31 percent risk premium over industries with high offshoring potential. This suggests that the option to offshore is an important driver of industry risk. The offshorability premium for services is only half that of manufacturing. For manufacturing industries, traditional factor models fail to explain the offshorability premium. For service industries, on the other hand, the premium is explained by the CAPM and a positive loading on the U.S. market.

An explanation based on the recent surge in international trade and specialization is consistent with various return patterns in the data. Intuitively, being able to reduce production costs through offshoring allows firms to compete against foreign competitors from low-wage countries. Consistent with this, double sorts of monthly excess returns on industry import penetration from low-wage countries and offshorability show that the offshorability premium is increasing in import penetration from low-wage countries.

A two-country general equilibrium trade model that embeds the option to offshore is able to rationalize a number of stylized facts: (1) there is a positive excess return spread between low and high offshorability industries; (2) the offshorability spread is increasing in import penetration; (3) excess returns for multinational companies are higher than for domestic firms; and (4) industry excess returns are increasing in import penetration. Moreover, within the model, counterfactuals indicate that the offshorability channel is economically important, as it allows industries to lower risk premia by 33% and increase equity valuations by 17%.

Importantly, three main model predictions are strongly supported by the data. First, the model predicts a negative relationship between offshorability and profit volatility. In the data, a one standard deviation increase in industry offshorability is associated with an up to 19.7% lower profit volatility for the median firm. Second, the model predicts that the offshorability premium is the largest in industries that have high elasticities of substitution with respect to imported goods. Double sorts of monthly industry excess returns on U.S. trade elasticities and offshorability confirm this prediction. Finally, within the model, low (high) offshorability industries have high (low) covariance with

[81] The annualized market risk premium and the L-H spread in the low comparative advantage economy are equal to 4.54% and 2.52%, respectively.

consumption. Consistent with this, I find that the strategy which is long low and short high offshorability industries has a positive and significant consumption beta in the data.

Finally, the model implies that a sudden tax increase on all imported goods results in a decrease in consumption and asset prices. Put differently, losing access to international specialization and offshoring benefits outweighs the benefits from lower import competition.

1.6 Tables

TABLE 1.1: **Occupation Tasks that define Offshorability**

Panel A tabulates the tasks used to calculate occupation offshorability by Acemoglu and Autor (2011). The acronyms *WA* and *WC* in the third column stand for work activity and work context. Panels B and C report the top and bottom ten occupations by offshorability, off_j.

Panel A: Acemoglu and Autor (2011)		
4.C.1.a.2.l	Face-to-Face Discussions	WC
4.A.4.a.5	Assisting and Caring for Others	WA
4.A.4.a.8	Performing for or Working Directly with the Public	WA
4.A.1.b.2	Inspecting Equipment, Structures, or Material	WA
4.A.3.a.2	Handling and Moving Objects	WA
4.A.3.b.4	Repairing and Maintaining Mechanical Equipment (*0.5)	WA
4.A.3.b.5	Repairing and Maintaining Electronic Equipment (*0.5)	WA

Panel B: Top Ten Occupations by Offshorability		
SOC	Occupation Title	off_j
31-9094	Medical Transcriptionists	0.50
41-9041	Telemarketers	0.48
43-4011	Brokerage Clerks	0.47
51-6021	Pressers, Textile, Garment, and Related Materials	0.46
15-2041	Statisticians	0.45
43-3031	Bookkeeping, Accounting, and Auditing Clerks	0.45
43-9022	Word Processors and Typists	0.45
51-6031	Sewing Machine Operators	0.44
15-2099	Legal Support Workers	0.44
15-1131	Computer Programmers	0.44

Panel C: Bottom Ten Occupations by Offshorability		
SOC	Occupation Title	off_j
37-3013	Tree Trimmers and Pruners	0.26
47-4021	Elevator Installers and Repairers	0.26
29-1151	Nurse Anesthetists	0.26
29-1021	Dentists	0.26
47-5013	Service Unit Operators, Oil, Gas, and Mining	0.26
29-1024	Prosthodontists	0.25
29-2041	Emergency Medical Technicians and Paramedics	0.25
33-1021	Firefighters	0.25
49-9051	Electrical Power-Line Installers and Repairers	0.25
49-9095	Manufactured Building and Mobile Home Installers	0.24

Table 1.2: **Most Offshorable and Non-Offshorable Manufacturing Industries**

Panels A and B tabulate the top and bottom ten manufacturing industries in terms of their offshoring potential, $OFF_{i,t}$. Industries are defined at the three-digit SIC level until 2001 and at the four-digit NAICS level thereafter. Manufacturing encompasses industries with SIC codes between 2011 and 3999 and NAICS codes between 311111 and 339999. Panel C reports industry transition probabilities (in percent), e.g., the probabilities that an industry in the highest offshorability quintile in year t will be in the second highest offshorability quintile in years $t+1$ and $t+5$.

Panel A: 1992 - Top and Bottom Ten Manufacturing Industries by Offshorability

SIC	Industry Title	$OFF_{i,t}$	SIC	Industry Title	$OFF_{i,t}$
2310	Men's and Boys' Suits, Coats, and Overcoats	2.85	3730	Ship and Boat Building and Repairing	-1.43
2320	Men's and Boys' Furnishings, Work Clothing	2.58	2450	Wood Buildings and Mobile Homes	-1.51
2360	Girls', Children's, and Infants' Outerwear	2.56	2110	Cigarettes	-1.52
2330	Women's, Misses', and Juniors' Outerwear	2.35	2430	Millwork, Veneer, Plywood, and Structural Wood	-1.63
2340	Women's, Misses', and Children's Undergarments	2.17	3530	Construction, Mining, and Materials Handling	-1.88
2350	Hats, Caps, and Millinery	2.05	3860	Photographic Equipment and Supplies	-2.09
3150	Leather Gloves and Mittens	1.94	2530	Public Buildings and Related Furniture	-2.13
2370	Fur Goods	1.77	3820	Analytical, Optical, Measuring, and Controlling	-2.32
2380	Miscellaneous Apparel and Accessories	1.75	3760	Guided Missiles and Space Vehicles and Parts	-2.50
3010	Tires and Inner Tubes	1.39	3810	Navigation, Aeronautical, and Nautical Systems	-2.95

Panel B: 2015 - Top and Bottom Ten Manufacturing Industries by Offshorability

NAICS	Industry Title	$OFF_{i,t}$	NAICS	Industry Title	$OFF_{i,t}$
334100	Computer and Peripheral Equipment Manufacturing	2.59	311400	Fruits and Vegetables and Specialty Food	-0.84
334200	Communications Equipment Manufacturing	2.46	331300	Alumina and Aluminum Production	-0.85
334600	Manufacturing Magnetic and Optical Media	2.28	336600	Ship and Boat Building	-0.88
334400	Semiconductors and Other Electronic Components	2.16	321200	Veneer, Plywood, and Engineered Wood Products	-1.12
333300	Commercial and Service Industry Machinery	1.50	321100	Sawmills and Wood Preservation	-1.23
315200	Cut and Sew Apparel Manufacturing	1.47	336100	Motor Vehicle Manufacturing	-1.28
315900	Apparel Accessories and Other Apparel	1.32	327300	Cement and Concrete Product Manufacturing	-1.33
316900	Other Leather and Allied Products	1.24	331100	Iron and Steel Mills and Ferroalloy Manufacturing	-1.38
314900	Other Textile Product Mills	1.10	322100	Pulp, Paper, and Paperboard Mills	-1.38
316200	Footwear Manufacturing	1.01	327400	Lime and Gypsum Product Manufacturing	-1.43

Panel C: Manufacturing Transition Probabilities

	year t+1				
year t	Q1(t+1)	Q2(t+1)	Q3(t+1)	Q4(t+1)	Q5(t+1)
Q1(t)	86%	11%	2%	1%	0%
Q2(t)	13%	73%	12%	3%	1%
Q3(t)	2%	12%	72%	12%	1%
Q4(t)	1%	3%	13%	78%	6%
Q5(t)	1%	1%	1%	7%	90%

	year t+5				
year t+5	Q1(t+5)	Q2(t+5)	Q3(t+5)	Q4(t+5)	Q5(t+5)
Q1(t)	76%	17%	3%	3%	1%
Q2(t)	17%	61%	17%	5%	1%
Q3(t)	2%	19%	59%	18%	2%
Q4(t)	2%	5%	20%	65%	7%
Q5(t)	3%	1%	2%	9%	85%

TABLE 1.3: **Most Offshorable and Non-Offshorable Services Industries**

Panels A and B tabulate the top and bottom ten service industries in terms of their offshoring potential, $OFF_{i,t}$. Industries are defined at the three-digit SIC level until 2001 and at the four-digit NAICS level thereafter. Services encompasses industries with SIC codes below 2011 and above 3999 and NAICS codes below 311111 and above 339999, respectively. Panel C reports industry transition probabilities (in percent), e.g., the probability that an industry in the highest offshorability quintile in year t will be in the second highest offshorability quintile in year $t+1$ and $t+5$.

Panel A: 1992 - Top and Bottom Ten Services Industries by Offshorability

SIC	Industry Title	$OFF_{i,t}$	SIC	Industry Title	$OFF_{i,t}$
8110	Legal Services	3.47	4740	Rental of Railroad Cars	-2.29
6220	Commodity Contracts Brokers and Dealers	2.65	8650	Political Organizations	-2.43
8720	Accounting, Auditing, and Bookkeeping Services	2.38	1010	Iron Ores	-2.49
6210	Security Brokers, Dealers, and Flotation Companies	2.23	1230	Anthracite Mining	-2.52
5120	Drugs, Drug Proprietaries, and Druggists' Sundries	2.09	8730	Research, Development, and Testing Services	-2.53
6060	Credit Unions	1.60	4970	Irrigation Systems	-2.56
6140	Personal Credit Institutions	1.46	8230	Libraries	-2.78
6030	Savings Institutions	1.41	8620	Professional Membership Organizations	-2.78
7290	Miscellaneous Personal Services	1.40	8610	Business Associations	-3.30
7370	Computer Programming and Data Processing	1.37	8630	Labor Unions and Similar Labor Organizations	-3.32

Panel B: 2015 - Top and Bottom Ten Services Industries by Offshorability

NAICS	Industry Title	$OFF_{i,t}$	NAICS	Industry Title	$OFF_{i,t}$
511200	Software Publishers	3.18	622100	General Medical and Surgical Hospitals	-1.23
541200	Accounting, Bookkeeping, and Payroll Services	2.85	623100	Nursing Care Facilities (Skilled Nursing Facilities)	-1.25
519100	Other Information Services	2.85	483200	Inland Water Transportation	-1.25
541500	Computer Systems Design and Related Services	2.49	212100	Coal Mining	-1.29
523100	Commodity Contracts Intermediation and Brokerage	2.41	481200	Nonscheduled Air Transportation	-1.31
525900	Other Investment Pools and Funds	2.39	485100	Urban Transit Systems	-1.38
541100	Legal Services	2.12	485200	Interurban and Rural Bus Transportation	-1.43
523900	Other Financial Investment Activities	2.05	621900	Other Ambulatory Health Care Services	-1.43
518200	Data Processing, Hosting, and Related Services	2.04	487900	Scenic and Sightseeing Transportation, Other	-1.54
525100	Insurance and Employee Benefit Funds	1.93	621200	Offices of Dentists	-1.93

Panel C: Transition Probabilities Services

	year t+1				
year t	Q1(t+1)	Q2(t+1)	Q3(t+1)	Q4(t+1)	Q5(t+1)
Q1(t)	90%	6%	1%	1%	1%
Q2(t)	7%	83%	7%	1%	1%
Q3(t)	2%	8%	83%	6%	1%
Q4(t)	1%	1%	6%	86%	5%
Q5(t)	0%	1%	2%	6%	91%

	year t+5				
year t+5	Q1(t+5)	Q2(t+5)	Q3(t+5)	Q4(t+5)	Q5(t+5)
Q1(t)	79%	11%	3%	3%	3%
Q2(t)	14%	63%	15%	6%	2%
Q3(t)	3%	18%	61%	16%	2%
Q4(t)	4%	4%	18%	64%	10%
Q5(t)	1%	2%	4%	11%	82%

TABLE 1.4: **Correlations**

This table reports correlation coefficients of offshorability with various labor-related variables. Panel A reports the coefficients for correlations at the occupation level. *off* is occupation-level offshorability; $\mathbb{1}_{\{off_j > off_{p66}\}}$ is a variable that is equal to *off* if an occupation ranks in the top tercile in terms of offshorability and zero otherwise; *skill* is the job zone measure from O*NET; and *routine* equals the routine-task content score of an occupation calculated with O*NET task-level data, as in Acemoglu and Autor (2011). Panel B reports the percentage overlap in occupations within the top tercile for the different measures. For example, an overlap of 50% means that half of the top tercile tasks are identical for two variables. Finally, Panel C reports the time-series averages of annual Spearman rank sum correlations of different variables at the industry level, both for manufacturing and services. The sample period is 1990-2016. The aggregation to the industry level for *Skill* and *Routine* is discussed in detail in the appendix. *Mobility* is the industry-level labor mobility measure from Donangelo (2014), which is available between 1990 and 2011. *SC* is shipping costs paid by importers. Shipping costs are obtained at the product-level for all U.S. manufacturing imports and then aggregated at the 3-digit SIC and 4-digit NAICS industry levels, as in Barrot, Loualiche, and Sauvagnat (2017). U.S. trade data are only available for manufacturing industries. *Tradability* is final product tradability per industry from Jensen (2011), which is available at the 4-digit NAICS level. This restricts the sample period to 2002 to 2016. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%.

Panel A: Correlation at the Occupation Level

	off_j	$\mathbb{1}_{\{off_j > off_{p66}\}}$	Skill	Routine
off_j	1			
$\mathbb{1}_{\{off_j > off_{p66}\}}$	0.79***	1		
Skill	0.31***	0.33***	1	
Routine	0.04	-0.02	-0.67***	1

Panel B: Overlap in Top 33% Occupations per Measure

	# Occ	# Top 33%	# Overlap	%-Overlap
off vs skill	772	259	113	43.63%
off vs routine	772	257	86	33.46%

Panel C: Correlation at Industry Level

	Skill	Routine	Mobility	SC	Tradability
Manufacturing:					
Corr($OFF_{i,t}$,)	0.29**	0.10	-0.22*	-0.16*	0.13
Services:					
Corr($OFF_{i,t}$,)	0.44***	0.14	0.11	NaN	0.23***

Table 1.5: **All Industries: Univariate Sorts and Four- and Five-Factor Models**

Panel A reports mean excess monthly levered and unlevered returns and corresponding Sharpe Ratios. L-H stands for an investment strategy that is long the portfolio of firms with low offshorability (L) and short the portfolio of firms with high offshorability (H). Values in parentheses next to the L-H mean excess returns correspond to the p-values of the "monotonic relationship (MR)" test by Patton and Timmermann (2010). Panel B (C) reports Carhart (1997) four- (Fama and French (2015) five-) factor model regression results both for equal-weighted (columns 2-8) and value-weighted (columns 10-16) portfolio returns. Monthly α estimates are expressed in percent. $Offshorability$ is lagged by 18 months. Returns are at a monthly frequency. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers returns from July 1991 to June 2016.

	Equal-Weighted Returns						Value-Weighted Returns					
	L	2	3	4	H	L-H	L	2	3	4	H	L-H
Panel A: Portfolio Sorts												
Levered Ret.	1.061***	0.893***	0.712***	0.398	0.452	0.609** (0.07)	1.059***	0.814***	0.586***	0.434	0.255	0.804* (0.00)
Sharpe Ratio	0.69	0.60	0.51	0.27	0.35	0.48	0.73	0.64	0.49	0.30	0.18	0.47
Unlevered Ret.	0.824***	0.655***	0.573***	0.297	0.318	0.506* (0.04)	0.895***	0.628***	0.463**	0.341	0.165	0.730** (0.01)
Sharpe Ratio	0.69	0.57	0.52	0.24	0.29	0.46	0.71	0.60	0.47	0.26	0.13	0.43
Panel B: Carhart (1997) Four-Factor												
Alpha (%)	0.261**	0.093	0.068	-0.263**	-0.057	0.318	0.372***	0.212	0.102	0.054	-0.062	0.434*
	(0.12)	(0.11)	(0.12)	(0.12)	(0.15)	(0.21)	(0.15)	(0.13)	(0.13)	(0.16)	(0.16)	(0.26)
MKT Beta	1.010***	1.015***	0.951***	0.989***	0.846***	0.163**	0.929***	0.938***	0.874***	0.852***	0.901***	0.028
	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.08)	(0.08)	(0.06)	(0.04)	(0.06)	(0.06)	(0.13)
SMB Beta	0.624***	0.470***	0.272***	0.406***	0.227***	0.397***	0.283***	-0.072	-0.200***	0.091*	-0.071	0.354***
	(0.04)	(0.08)	(0.07)	(0.09)	(0.10)	(0.10)	(0.06)	(0.04)	(0.06)	(0.05)	(0.08)	(0.12)
HML Beta	0.239***	0.365***	0.227***	0.185***	-0.032	0.271***	-0.038	0.113*	0.081	-0.166*	-0.328***	0.291*
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.10)	(0.09)	(0.07)	(0.05)	(0.09)	(0.08)	(0.16)
UMD Beta	-0.048	-0.064	-0.123***	-0.173***	-0.133***	0.085	0.117***	0.000	-0.082*	-0.226***	-0.265***	0.382***
	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.10)
R^2 (%)	89.22	87.44	85.70	86.71	75.48	22.09	70.23	76.54	77.98	73.89	77.25	19.41
Panel C: Fama and French (2015) Five-Factor												
Alpha (%)	0.081	-0.193**	-0.206	-0.466***	-0.269*	0.350*	0.370**	0.046	-0.061	-0.031	-0.171	0.541*
	(0.12)	(0.09)	(0.13)	(0.14)	(0.15)	(0.21)	(0.17)	(0.13)	(0.12)	(0.17)	(0.18)	(0.31)
MKT Beta	1.108***	1.172***	1.098***	1.094***	0.958***	0.150**	0.937***	1.031***	0.960***	0.885***	0.947***	-0.010
	(0.04)	(0.04)	(0.05)	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.05)	(0.07)	(0.08)	(0.12)
SMB Beta	0.706***	0.613***	0.345***	0.450***	0.285***	0.421***	0.370***	0.036	-0.204***	-0.062	-0.152*	0.522***
	(0.04)	(0.05)	(0.06)	(0.07)	(0.08)	(0.10)	(0.07)	(0.04)	(0.06)	(0.08)	(0.09)	(0.15)
HML Beta	0.163***	0.237***	0.142**	0.250***	-0.031	0.195*	-0.150*	-0.001	-0.004	-0.054	-0.107	-0.043
	(0.06)	(0.05)	(0.06)	(0.08)	(0.07)	0.100	(0.08)	(0.06)	(0.08)	(0.08)	(0.10)	0.148
RMW Beta	0.272***	0.464***	0.293***	0.177*	0.221*	0.051	0.212	0.329***	0.074	-0.326***	-0.167	0.379
	(0.06)	(0.06)	(0.07)	(0.10)	(0.11)	0.151	(0.13)	(0.08)	(0.08)	(0.13)	(0.14)	0.231
CMA Beta	0.035	0.042	0.104	-0.129	-0.041	0.076	0.026	0.047	0.216	0.139	-0.190	0.216
	(0.07)	(0.06)	(0.10)	(0.13)	(0.12)	(0.16)	(0.15)	(0.11)	(0.11)	(0.17)	(0.18)	(0.30)
R^2 (%)	90.13	90.54	85.83	84.95	74.56	20.64	69.69	78.84	77.70	71.56	71.80	8.07

Table 1.6: **Manufacturing vs Services Industries**

Panel A (B) reports mean excess monthly levered and unlevered returns as well as CAPM regression results for the sample of manufacturing (services) industries. L-H stands for an investment strategy that is long the portfolio of firms with low offshorability (L) and short the portfolio of firms with high offshorability (H). Values in parentheses next to the L-H mean that excess returns correspond to the p-values of the "monotonic relationship (MR)" test by Patton and Timmermann (2010). Monthly α estimates are expressed in percent. $Offshorability$ is lagged by 18 months. Returns are at a monthly frequency. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. Panel C reports portfolio characteristics for manufacturing and services industries separately. *Size* is the time-series average of annual portfolio means of the market capitalization (logarithm); *# Employees* is the number of employees as reported in Compustat; *Book to Market* is defined as the book value (item CEQ) of equity divided by the market value of equity (item CSHO × item PRCC_F); *Leverage* is total debt (item DLC + item DLTT) divided by the sum of total debt and market value of equity; *Labor Intensity* is a firm's labor intensity defined as the logarithm of the ratio of the number of employees divided by gross property, plant and investment (PPEGT). The sample covers returns from July 1991 to June 2016.

	Equal-Weighted Returns						Value-Weighted Returns					
	L	2	3	4	H	L-H	L	2	3	4	H	L-H
Panel A: Manufacturing - Portfolio Sorts & CAPM Regressions												
Levered Ret.	1.134***	0.949***	0.945***	0.387	0.103	1.031*** (0.01)	1.257***	0.614***	0.737***	0.466	0.045	1.212*** (0.16)
	(0.34)	(0.31)	(0.29)	(0.33)	(0.27)	(0.44)	(0.32)	(0.26)	(0.22)	(0.34)	(0.29)	(0.43)
Unlevered Ret.	0.905***	0.719***	0.776***	0.276	-0.131	1.036*** (0.06)	1.117***	0.441**	0.620***	0.378	-0.003	1.120*** (0.22)
	(0.27)	(0.24)	(0.24)	(0.30)	(0.24)	(0.36)	(0.28)	(0.21)	(0.19)	(0.31)	(0.27)	(0.39)
Alpha (%)	0.420**	0.293*	0.355**	-0.306*	-0.424***	0.844***	0.649***	0.112	0.341**	-0.256	-0.503***	1.152***
	(0.19)	(0.18)	(0.16)	(0.18)	(0.16)	(0.23)	(0.21)	(0.17)	(0.16)	(0.19)	(0.19)	(0.34)
MKT Beta	1.119***	1.026***	0.924***	1.085***	0.826***	0.293***	0.953***	0.787***	0.619***	1.130***	0.858***	0.095
	(0.06)	(0.06)	(0.04)	(0.05)	(0.03)	(0.06)	(0.06)	(0.05)	(0.04)	(0.07)	(0.07)	(0.10)
R^2 (%)	71.02	70.61	68.83	71.52	62.20	10.03	55.50	61.84	48.72	65.16	59.45	0.22
Panel B: Services - Portfolio Sorts & CAPM Regressions												
Levered Ret.	1.010***	0.818***	0.468	0.640*	0.455	0.555* (0.27)	0.991***	0.577**	0.538*	0.444	0.513*	0.478* (0.06)
	(0.35)	(0.33)	(0.34)	(0.33)	(0.28)	(0.33)	(0.33)	(0.30)	(0.32)	(0.33)	(0.28)	(0.30)
Unlevered Ret.	0.751***	0.568**	0.309	0.462*	0.405	0.346 (0.37)	0.746***	0.437*	0.366	0.298	0.412	0.334 (0.15)
	(0.28)	(0.25)	(0.25)	(0.27)	(0.26)	(0.38)	(0.28)	(0.23)	(0.24)	(0.29)	(0.26)	(0.38)
Alpha (%)	0.305	0.146	-0.259*	-0.010	-0.058	0.363	0.324*	-0.028	-0.096	-0.256	0.014	0.310
	(0.20)	(0.19)	(0.16)	(0.20)	(0.19)	(0.25)	(0.20)	(0.16)	(0.20)	(0.18)	(0.19)	(0.27)
MKT Beta	1.105***	1.053***	1.139***	1.018***	0.803***	0.301***	1.046***	0.947***	0.993***	1.095***	0.781***	0.264***
	(0.06)	(0.06)	(0.04)	(0.05)	(0.05)	(0.05)	(0.07)	(0.05)	(0.05)	(0.07)	(0.05)	(0.07)
R^2 (%)	68.65	67.53	77.55	65.35	55.98	9.30	64.39	66.42	61.44	70.30	50.80	5.61

Panel C: Portfolio Characteristics

	Manufacturing					Services				
Size	12.80	12.70	12.48	12.66	12.58	12.69	13.04	12.63	12.56	12.67
# Employees	9756	10091	6947	6866	6775	9741	12996	5745	6125	9365
Book to Market	0.66	0.76	0.86	0.92	0.93	0.80	0.85	0.85	0.82	0.81
Leverage	0.23	0.23	0.24	0.25	0.28	0.26	0.28	0.29	0.23	0.25
Labor Intensity	2.67	3.20	3.56	3.31	3.32	3.18	3.29	3.11	3.54	4.07

Table 1.7: **Manufacturing - Four- and Five-Factor Models**

Panel A reports the Carhart (1997) four-factor model regression results both for equal-weighted (columns 2-8) and value-weighted (columns 10-16) portfolio returns. Panel B tabulates similar regression results for the five-factor model of Fama and French (2015). Monthly α estimates are expressed in percent. $Offshorability$ is lagged by 18 months. Returns are at a monthly frequency. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers returns of manufacturing industries from July 1991 to June 2016.

	Equal-Weighted Returns						Value-Weighted Returns					
	L	2	3	4	H	L-H	L	2	3	4	H	L-H
Panel A: Manufacturing - Carhart (1997) Four-Factor												
Alpha (%)	0.272*	0.163	0.355***	-0.258*	-0.399***	0.671***	0.556***	0.054	0.335**	-0.002	-0.225	0.782***
	(0.15)	(0.14)	(0.14)	(0.15)	(0.15)	(0.22)	(0.19)	(0.16)	(0.16)	(0.18)	(0.17)	(0.29)
MKT Beta	1.071***	1.001***	0.878***	1.011***	0.766***	0.306***	0.940***	0.821***	0.654***	1.019***	0.761***	0.180**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.05)	(0.06)	(0.05)	(0.04)	(0.07)	(0.05)	(0.08)
SMB Beta	0.583***	0.411***	0.250***	0.308***	0.284***	0.299***	0.285***	-0.081*	-0.193***	0.097	-0.034	0.319***
	(0.06)	(0.08)	(0.09)	(0.07)	(0.08)	(0.11)	(0.09)	(0.05)	(0.07)	(0.07)	(0.07)	(0.13)
HML Beta	0.301***	0.390***	0.232***	0.238***	0.182***	0.119	-0.134	0.222***	0.089	-0.179**	-0.214**	0.081
	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.09)	(0.10)	(0.08)	(0.06)	(0.08)	(0.10)	(0.18)
UMD Beta	-0.021	-0.059	-0.140***	-0.216***	-0.157***	0.136*	0.145***	-0.013	-0.005	-0.274***	-0.272***	0.417***
	(0.07)	(0.05)	(0.04)	(0.03)	(0.03)	(0.08)	(0.05)	(0.06)	(0.05)	(0.07)	(0.07)	(0.11)
R^2 (%)	82.26	80.74	75.39	79.64	69.85	17.98	61.02	64.63	51.48	69.70	66.83	16.70
Panel B: Manufacturing - Fama and French (2015) Five-Factor												
Alpha (%)	0.092	-0.196	0.077	-0.617***	-0.594***	0.687***	0.571***	-0.145	0.167	-0.144	-0.257	0.828***
	(0.14)	(0.12)	(0.15)	(0.16)	(0.16)	(0.24)	(0.22)	(0.16)	(0.16)	(0.20)	(0.19)	(0.35)
MKT Beta	1.159***	1.175***	1.005***	1.173***	0.848***	0.311***	0.945***	0.919***	0.739***	1.070***	0.754***	0.191**
	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.07)	(0.07)	(0.06)	(0.05)	(0.06)	(0.05)	(0.09)
SMB Beta	0.679***	0.599***	0.343***	0.331***	0.342***	0.337***	0.372***	0.012	-0.132**	-0.105	-0.195**	0.567***
	(0.06)	(0.05)	(0.07)	(0.08)	(0.07)	(0.10)	(0.09)	(0.06)	(0.06)	(0.08)	(0.09)	(0.16)
HML Beta	0.185***	0.185***	0.180***	0.129	0.236***	-0.051	-0.270***	0.063	-0.074	-0.122	0.034	-0.304*
	(0.08)	(0.06)	(0.07)	(0.10)	(0.09)	0.131	(0.11)	(0.08)	(0.08)	(0.10)	(0.10)	0.170
RMW Beta	0.302***	0.591***	0.324***	0.207**	0.196*	0.106	0.210	0.312***	0.227***	-0.409***	-0.390***	0.600**
	(0.08)	(0.05)	(0.10)	(0.10)	(0.11)	0.168	(0.17)	(0.10)	(0.09)	(0.13)	(0.15)	0.278
CMA Beta	0.097	0.154**	0.039	0.313*	-0.112	0.209	0.055	0.182	0.240***	0.370**	-0.091	0.146
	(0.11)	(0.07)	(0.12)	(0.17)	(0.13)	(0.20)	(0.19)	(0.12)	(0.10)	(0.19)	(0.17)	(0.32)
R^2 (%)	83.39	85.92	75.39	77.33	68.11	15.86	59.98	66.96	53.46	68.19	62.42	8.80

Table 1.8: **Subsample Analysis**

The table reports univariate portfolio sorts for manufacturing industries for different time subsamples. Panel A tabulates results for equal-weighted returns and Panel B for value-weighted returns. L-H is an investment strategy that is long the portfolio of firms with low offshorability (L) and short the portfolio of firms with high offshorability (H). Column *MR* reports the p-values of the "monotonic relationship (MR)" test by Patton and Timmermann (2010). Standard errors are adjusted for heteroscedasticity and autocorrelation (Newey-West). Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample includes manufacturing firms and covers the period July 1991 to June 2016.

Panel A: Equal-weighted Returns

	Offshorability						
	L	2	3	4	H	L-H	MR
1991:07 - 2016:06	1.134***	0.949***	0.945***	0.387	0.103	1.031***	0.005***
	(0.34)	(0.31)	(0.29)	(0.33)	(0.27)	(0.44)	
1991:07 - 1999:12	1.484***	1.123***	0.888**	0.660	0.446	1.038*	0.000***
	(0.50)	(0.47)	(0.44)	(0.44)	(0.41)	(0.62)	
2000:01 - 2009:12	0.813	0.630	0.712	-0.019	-0.086	0.899	0.017**
	(0.65)	(0.57)	(0.51)	(0.65)	(0.50)	(0.65)	
2010:01 - 2016:06	1.171**	1.211**	1.376***	0.653	-0.054	1.225*	0.332
	(0.57)	(0.54)	(0.52)	(0.56)	(0.49)	(0.72)	
2000:01 - 2008:08	0.906*	0.705*	0.834*	-0.134	-0.057	0.963	0.068*
	(0.48)	(0.40)	(0.47)	(0.56)	(0.47)	(0.62)	

Panel B: Value-weighted Returns

	Offshorability						
	L	2	3	4	H	L-H	MR
1991:07 - 2016:06	1.257***	0.614***	0.737***	0.466	0.045	1.212***	0.162
	(0.32)	(0.26)	(0.22)	(0.34)	(0.29)	(0.43)	
1991:07 - 1999:12	1.956***	0.970**	0.917***	0.805**	0.619**	1.336***	0.003***
	(0.65)	(0.46)	(0.36)	(0.39)	(0.30)	(0.71)	
2000:01 - 2009:12	0.733	0.063	0.186	-0.038	-0.582	1.315*	0.016**
	(0.49)	(0.45)	(0.35)	(0.72)	(0.63)	(0.70)	
2010:01 - 2016:06	1.150***	0.996***	1.348***	0.797	0.258	0.892*	0.946
	(0.44)	(0.39)	(0.41)	(0.53)	(0.30)	(0.54)	
2000:01 - 2008:08	0.887*	0.094	0.184	-0.061	-0.681	1.568*	0.067*
	(0.48)	(0.36)	(0.34)	(0.72)	(0.68)	(0.83)	

TABLE 1.9: **Panel OLS Regressions - Annual Regressions**

This table reports panel regression results. Panel A tabulates results for the sample of manufacturing firms and Panel B for services firms. The regression design is as follows:

$$r_{i,t} = a + b_{j,t} + c * OFF_{i,t-1} + d * controls_{i,t-1} + \epsilon_{i,t}$$

where the subscripts i stand for firm i = 1, ..N, and t stands for time t = 1, .., T . The explained variable is $r_{i,t}$, the firm's i future annual excess stock return. Realized annual stock returns are aggregated from July of year t to June of year $t + 1$ and are expressed in percentages. Control variables are the following: a is a constant term; $b_{j,t}$ is an industry×year fixed effect, where industries represent the Fama-French 17 industries; OFF is the offshorability score lagged by 18 months; Size is the firm's lagged market capitalization; BM is the firm's lagged log book-to-market ratio; *R&D* is the firm's lagged R&D investment scaled by assets; *Leverage* is the firm's lagged leverage ratio; HN is the firm's lagged hiring rate; IK is the firm's lagged physical investment rate; *StockReturn* is the lagged stock return; *CashFlow* is the firm's lagged cash flow according to Zhang (2016); *Op.Lev* is the firm's lagged operational leverage, as in Donangelo (2014); $LaborInt$ is the lagged labor intensity following Donangelo (2014); $Profitability$ is a firm's gross profitability, as defined in Novy-Marx (2011). See appendix for definitions of firm characteristics. All variables are standardized. Standard errors are clustered at the firm and year level and reported in parentheses. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers stock returns from July 1991 to June 2016.

Panel A: Manufacturing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OFF_{t-1}	-4.64*	-4.74*	-5.06**	-4.52*	-5.00*	-5.04*	-4.84*	-4.84*	-4.72*	-5.73**
	(2.57)	(2.56)	(2.56)	(2.64)	(2.72)	(2.79)	(2.61)	(2.56)	(2.53)	(2.88)
$Size_{t-1}$		-4.69***								-2.33
		(1.79)								(1.89)
BM_{t-1}			6.16***							4.36***
			(1.30)							(1.28)
$Mkt.Leverage_{t-1}$				3.42**						1.39
				(1.58)						(1.22)
HN_{t-1}					-3.63***					-2.63***
					(0.58)					(1.03)
IK_{t-1}						-2.22*				-1.37
						(1.18)				(1.15)
$StockReturn_{t-1}$							-2.75***			-2.97**
							(1.16)			(1.28)
$Op.Lev_{t-1}$								3.48***		0.28
								(0.88)		(0.83)
$Profitability_{t-1}$									2.55*	5.75***
									(1.54)	(1.62)
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	39,387	39,336	37,552	32,481	34,743	34,899	38,369	36,103	39,387	25,194
R^2 (%)	10.26	10.55	11.01	10.03	10.63	10.23	10.54	9.78	10.34	11.23

Panel B: Services

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OFF_{t-1}	-1.98*	-2.02	-1.50	-1.74	-1.71	-1.46	-1.90	-1.75	-2.11*	-0.96
	(1.21)	(1.29)	(1.34)	(1.41)	(1.24)	(1.29)	(1.33)	(1.23)	(1.22)	(1.31)
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind
Clustered	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	33,824	33,729	31,701	28,090	28,742	28,976	32,837	30,703	33,824	19,912
R^2 (%)	8.69	9.21	9.39	9.41	9.28	8.95	8.92	9.02	8.86	11.51

TABLE 1.10: **Offshorability and Low Wage Countries' Import Penetration**

Panel A reports equal- and value-weighted excess returns conditionally double-sorted on import penetration from low wage countries and offshorability. In any given month, stocks are first sorted into three portfolios based on their industry import penetration from low wage countries and then into five portfolios based on industry offshorability. Import penetration from low wage countries is calculated as in Bernard, Jensen, and Schott (2006a). Due to data availability, import penetration can only be calculated until 2011. See appendix for more details on the calculation of import penetration. The split into low (1), medium (2) and high (3) import penetration industries is based on import penetration terciles calculated each year. Offshorability is lagged 18 months. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). Panel B tabulates conditional panel regression results, as in table 1.9. Low IP (High IP) refers to regressions based on firms that belong to industries with import penetration below (above) the median. For each group, the results for regression specifications 1 and 10 are reported. All variables are standardized. Standard errors are clustered at the firm and year level and reported in parentheses. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample includes manufacturing firms from 1991 to 2011.

Panel A: Return Double Sorts

Equal-weighted Returns

		Offshorability					
		L	2	3	4	H	L-H
Imp Penetration	1	1.015***	1.007***	0.798***	0.275	0.429	0.585
		(0.34)	(0.36)	(0.30)	(0.44)	(0.28)	(0.44)
	2	1.067***	0.709	0.764**	0.356	0.282	0.785
		(0.42)	(0.46)	(0.38)	(0.41)	(0.41)	(0.59)
	3	1.515***	1.172***	1.009	0.085	-0.128	1.643***
		(0.47)	(0.44)	(0.65)	(0.40)	(0.47)	(0.66)

Value-weighted Returns

		Offshorability					
		L	2	3	4	H	L-H
Imp Penetration	1	0.789***	0.716***	0.629***	0.401	0.570**	0.219
		(0.29)	(0.30)	(0.26)	(0.38)	(0.29)	(0.41)
	2	0.858***	0.949**	0.730**	0.198	-0.063	0.921
		(0.36)	(0.48)	(0.32)	(0.38)	(0.46)	(0.58)
	3	1.533***	0.873	1.253*	-0.180	-0.004	1.537***
		(0.42)	(0.56)	(0.66)	(0.39)	(0.46)	(0.62)

Panel B: Conditional Panel Regressions

	Low IP	Low IP	High IP	High IP
OFF_{t-1}	-1.78	-2.85	-4.80*	-5.90*
	(2.60)	(199)	(2.53)	(3.15)
Firm Control	N	Y	N	Y
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	18,676	11,477	16,866	11,100
R^2 (%)	10.66	12.39	11.87	12.71

TABLE 1.11: **Offshorability and Shipping Costs**

Panel A reports equal- and value-weighted excess returns sorted on offshorability and shipping costs. In any given month, stocks are sorted into three portfolios based on their industry shipping costs and five portfolios on industry offshorability. Shipping costs are calculated as in Barrot, Loualiche, and Sauvagnat (2017). The split into low (1), medium (2) and high (3) shipping cost industries is based on shipping cost terciles calculated each year. Offshorability is lagged 18 months. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). Panel B tabulates conditional panel regression results, as in table 1.9. Low SC (High SC) refers to regressions based on firms that belong to industries with shipping costs below (above) the median. For each group, the results for regression specifications 1 and 10 are reported. All variables are standardized. Standard errors are clustered at the firm and year level and reported in parentheses. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample includes manufacturing firms from July 1991 to June 2016.

Panel A: Return Double Sorts

Equal-weighted Returns

		Offshorability					
		L	2	3	4	H	L-H
Shipping Costs	1	1.469***	0.838*	0.554*	0.218	0.129	1.340**
		(0.48)	(0.46)	(0.29)	(0.38)	(0.34)	(0.59)
	2	0.940***	0.923***	0.867***	0.165	0.053	0.887
		(0.36)	(0.34)	(0.32)	(0.34)	(0.45)	(0.58)
	3	0.962**	0.944***	0.670	-0.002	0.406	0.556
		(0.45)	(0.36)	(0.42)	(0.48)	(0.43)	(0.63)

Value-weighted Returns

		Offshorability					
		L	2	3	4	H	L-H
Shipping Costs	1	1.504***	0.797*	0.657***	0.169	0.079	1.425***
		(0.51)	(0.45)	(0.26)	(0.41)	(0.33)	(0.61)
	2	0.675**	0.678***	0.713**	0.543	-0.011	0.686
		(0.31)	(0.29)	(0.31)	(0.35)	(0.44)	(0.54)
	3	0.625*	0.799***	0.683*	0.359	0.490	0.135
		(0.36)	(0.27)	(0.40)	(0.36)	(0.39)	(0.53)

Panel B: Conditional Panel Regressions

	Low SC	Low SC	High SC	High SC
OFF_{t-1}	-4.86*	-5.92*	-2.22	-1.66
	(2.94)	(3.43)	(1.52)	(1.13)
Firm Controls	N	Y	N	Y
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	17,145	10,489	16,129	10,691
R^2 (%)	10.19	12.13	11.11	12.86

Table 1.12: **Offshorability and Multinational Companies**

Panel A reports the post-ranking mean of equal- and value-weighted excess returns of stocks sorted on offshorability for multinational manufacturing firms and domestic manufacturing firms. Excess Returns are calculated as realized monthly returns minus the one-month risk-free rate. *EW* refers to equal-weighted and *VW* to value-weighted portfolio returns. L-H stands for an investment strategy that is long the portfolio of firms with low offshorability (L) and short the portfolio of firms with high offshorability (H). The column *MR* reports the p-values of the "monotonic relationship (MR)" test by Patton and Timmermann (2010). Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). The sample includes manufacturing firms from July 1991 to June 2016. Panel B tabulates conditional panel regression results, as in table 1.9. MNC (Domestic) refer to regressions based on multinational (domestic) manufacturing firms. For each group, the results for regression specifications 1 and 10 are reported. All variables are standardized. Standard errors are clustered at the firm and year level and reported in parentheses. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%.

Panel A: Univariate Return Sorts

	Offshorability						
	L	2	3	4	H	L-H	MR
	Multinational Manufacturing Firms						
EW	1.146***	1.031***	0.872***	0.381	0.076	1.071***	0.001***
	(0.34)	(0.32)	(0.32)	(0.29)	(0.28)	(0.45)	
VW	1.209***	0.837***	0.687***	0.480	0.021	1.188***	0.004***
	(0.30)	(0.28)	(0.23)	(0.32)	(0.31)	(0.43)	
	Domestic Manufacturing Firms						
EW	0.979***	0.694*	0.805*	0.120	-0.016	0.995*	0.127
	(0.41)	(0.41)	(0.46)	(0.46)	(0.32)	(0.52)	
VW	1.044***	0.522	1.064***	-0.082	0.132	0.912***	0.871
	(0.34)	(0.39)	(0.45)	(0.46)	(0.17)	(0.38)	

Panel B: Conditional Panel Regressions

	MNC		Domestic	
OFF_{t-1}	-4.16*	-4.56*	-5.11*	-6.06*
	(2.34)	(2.66)	(2.95)	(3.50)
Firm Controls	N	Y	N	Y
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	21,769	16,195	17,509	10,376
R^2 (%)	12.51	14.15	9.62	11.19

Table 1.13: **Model Parameters**

This table reports the parameters used in the benchmark calibration of the model (see section 1.4.6 for a more detailed description).

Parameter		Value	Source
Industry Parameters:			
Expenditure share differentiated goods	$a_0, a_0^\star$	0.1, 0.9	Barrot, Loualiche, and Sauvagnat (2017)
Elasticity across industries	θ	1.2	Loualiche (2015)
Elasticity of industry demand	σ_s	3.8	Broda and Weinstein (2006)
Pareto tail parameter	κ_s	3.4	Ghironi and Melitz (2005)
Industry taste parameter	δ_s	0.5	
Production:			
Headquarter intensity	α_s	0.55, 0.95	OECD, Blinder (2009)
Wage costs	c, $c^\star$	0.32, 0	labor costs other than wages/salaries for time actually worked
Labor supply	$L, L^\star$	1.02, 5	match ratio of working age population in U.S. and China
Mass of firms	N_s, $N_s^\star$	30, 2.57	match ratio of market capitalization in U.S. and China
Trade:			
Iceberg costs	τ_s, $\tau_s^\star$	1.1	Ghironi and Melitz (2005)
Fixed exporting costs	f_X, $f_X^\star$	3, 0.01	Barrot, Loualiche, and Sauvagnat (2017) & match avg import penetration
Fixed offshoring costs	f_O	$5e^{-3}$	match avg import penetration
Aggregate Productivity			
West	ρ_a	0.98	U.S. GDP, Barrot, Loualiche, and Sauvagnat (2017)
	σ_a	1.6%	U.S. GDP, Barrot, Loualiche, and Sauvagnat (2017)
East	$\rho_a^\star$	0.96	Chinese imports to the U.S., Barrot, Loualiche, and Sauvagnat (2017)
	$\sigma_a^\star$	6%	Chinese imports to the U.S., Barrot, Loualiche, and Sauvagnat (2017)
Stochastic Discount Factor:			
Discount factor	β	0.99	Bansal and Yaron (2004a)
Intertemporal Elasticity of Substitution	ψ	1.50	Bansal and Yaron (2004a)
Risk aversion parameter	γ	80	match U.S. equity premium

Table 1.14: **Model Simulations: Targeted and Model-Implied Moments**

The table reports the main moments of the model-generated data. Panel A tabulates the targeted moments in the model and the data. The share of the market capitalization (MC) in China is calculated as $MC_{China}/(MC_{US} + MC_{China})$ and the share of the working age population (WP) in China as $WP_{China}/(WP_{US}+WP_{China})$. Panel B (C and D) focuses on moments of macroeconomic (industry and financial) quantities. Column titles "Low" and "High" refer to low and high offshorability industries. The model is solved using perturbation methods and is approximated to the 3rd-order around the deterministic steady state. Moments are calculated based on simulations over 10'000 periods (with a burn-in period of 1'000 periods).

Panel A: Targeted Moments

	model	data
Share Market Capitalization China	0.28	0.25
Share Working Age Population China	0.17	0.17
Avg Import Penetration China - Mean	6.26%	6.36%
Avg Import Penetration China - Std	4.08%	2.75%

Panel B: Macro Moments

	Agg. Consumption		Risk-free Rate		Labor Share	
	model	data	model	data	model	data
mean			2.80%	2.63%	60.54%	58.40%
std	9.44%	2.00%	0.27%	2.12%		

Panel C: Industry Quantities

	Import Penetration		Industry Profits	
	Low	High	Low	High
mean	7.39%	5.36%	0.28	0.32
std	5.91%	2.83%	8.14%	3.67%
cov(,A)	-0.60	-0.30	0.24	0.12
cov(,$A^{\star}$)	5.00	2.48	-1.75	-0.79
cov(,C)	-0.51	-0.26	0.76	0.34

Panel D: Asset Prices and Excess Returns

	Valuations		Excess Returns		Export Excess Returns	
	Low	High	Low	High	Low	High
mean	10.31	19.96	6.44%	3.53%	8.04%	3.62%
std	2.14%	1.65%	16.33%	8.42%	19.07%	9.14%
cov(,A)	0.09	0.06	0.07	0.02	0.13	0.03
cov(,$A^{\star}$)	-0.43	-0.34	-0.90	-0.31	-1.28	-0.31
cov(,C)	0.20	0.16	0.09	0.03	0.13	0.03

TABLE 1.15: **Variance Decomposition, Model Predictions and Counterfactuals**

The left (right) part of Panel A shows industry profits and excess returns for the model economy with shocks only to A ($A^{\star}$). Panel B reports panel regression results for profit and sales volatility. Firm-specific profit and sales volatility are calculated as in Minton and Schrand (1999). All regressions include year fixed effects. Firm control variables are size, Tobin's Q, leverage and investment. Standard errors are clustered at the firm and year level and reported in parentheses. The sample covers manufacturing firms from 1991 to 2016. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. Panel C investigates the role of import penetration in the model by counterfactually equating import penetration across the two model industries. In addition, Panel C reports moments of industry valuations and excess returns, assuming that industries have zero offshorability, i.e., $\alpha_s = 1$ for any s. In other words, the firm's production function in both industries relies exclusively on headquarter tasks. Consequently, the two industries are no longer distinguishable and, hence, have identical excess returns and valuations. Throughout the table, column titles "Low" and "High" label low and high offshorability industries. The model is solved using perturbation methods and is approximated to the 3rd-order around the deterministic steady state. Moments are calculated based on simulations over 10'000 periods (with a burn-in period of 1'000 periods).

Panel A: Shock Decomposition

	Only Shocks to A				Only Shocks to A*			
	Profits		Excess Returns		Profits		Excess Returns	
	Low	High	Low	High	Low	High	Low	High
mean	0.29	0.32	1.10%	0.59%	0.28	0.32	5.33%	2.93%
std	3.03%	1.33%	4.34%	2.61%	7.59%	3.33%	14.67%	7.70%
cov(,A)	0.24	0.10	0.07	0.04				
cov(,$A^{\star}$)					-1.74	-0.77	-0.87	-0.32
cov(,C)	0.13	0.06	0.04	0.02	0.63	0.28	0.31	0.11

Panel B: Panel Regressions

	One-Year Lagged Offshorability ($x = 1$)				Five-Year Lagged Offshorability ($x = 5$)			
	Profit Vol		Sales Vol		Profit Vol		Sales Vol	
OFF_{t-x}	-0.03**	-0.03*	-0.01	-0.01	-0.06***	-0.06***	-0.02***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Firm Control	N	Y	N	Y	N	Y	N	Y
Fixed Effects	Yr	Yr	Yr	Yr	Yr	Yr	Yr	Yr
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	21,133	20,819	21,133	20,819	15,056	14,838	15,056	14,838
R^2 (%)	1.52	6.41	1.87	10.12	2.58	9.05	3.05	12.57

Panel C: Counterfactuals

	Role of Import Penetration				No Offshorability ($1 - \alpha_s = 0$)			
	Import Penetration		Excess Returns		Valuations		Excess Returns	
	Low	High	Low	High	Low	High	Low	High
mean	7.31%	7.31%	6.99%	4.37%	10.86	10.86	9.64%	9.64%
std	4.97%	3.53%	13.60%	8.36%	2.62%	2.62%	19.45%	19.45%
cov(,A)	-0.50	-0.38	0.08	0.05	0.11	0.11	0.02	0.02
cov(,$A^{\star}$)	4.15	3.10	-0.79	-0.49	-0.52	-0.52	-0.62	-0.62
cov(,C)	-0.47	-0.36	0.09	0.05	0.25	0.25	0.08	0.08

TABLE 1.16: **Double-Sorts: Offshorability and U.S. Trade Elasticities**

Panel A reports equal- and value-weighted excess returns conditionally double-sorted on U.S. trade elasticities and offshorability. In any given month, stocks are first sorted into three portfolios based on their industry trade elasticities and then further into five portfolios based on industry offshorability. U.S. trade elasticities are estimated by Broda and Weinstein (2006) from 1990 to 2001 at the commodity level and are aggregated at the industry level based on total imports over 1990-2001. The split into low (1), medium (2) and high (3) trade elasticity industries is based on trade elasticity terciles. Offshorability is lagged 18 months. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). Panel B tabulates conditional panel regression results as in table 1.9. Low TE (High TE) refers to regressions based on firms that belong to industries with U.S. trade elasticities below (above) the median. For each group, results for regression specifications 1 and 10 are reported. All variables are standardized. Standard errors are clustered at the firm and year level and reported in parentheses. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample includes manufacturing firms from July 1991 to June 2016.

Panel A: Return Double Sorts

Equal-weighted Returns

Trade Elasticities	Offshorability: L	2	3	4	H	L-H
L	0.918***	0.761**	0.785***	0.403	0.027	0.891
	(0.36)	(0.34)	(0.31)	(0.35)	(0.45)	(0.57)
2	1.406***	0.650*	0.109	0.507	0.109	1.2971**
	(0.35)	(0.34)	(0.46)	(0.42)	(0.43)	(0.56)
H	1.879***	0.996***	0.866**	0.535	-0.335	2.213***
	(0.48)	(0.39)	(0.39)	(0.52)	(0.67)	(0.82)

Value-weighted Returns

Trade Elasticities	Offshorability: L	2	3	4	H	L-H
L	0.941***	0.597**	0.750***	0.434	-0.116	1.057*
	(0.31)	(0.26)	(0.27)	(0.31)	(0.43)	(0.53)
2	1.217***	0.900***	0.380	0.566	0.006	1.211**
	(0.33)	(0.31)	(0.42)	(0.38)	(0.44)	(0.55)
H	1.532***	0.818***	0.424	0.601	-0.193	1.725**
	(0.42)	(0.35)	(0.42)	(0.50)	(0.66)	(0.78)

Panel B: Conditional Panel Regressions

	Low TE	Low TE	High TE	High TE
OFF_{t-1}	-2.74	-2.71	-10.36**	-12.14***
	(2.10)	(2.46)	(4.47)	(5.17)
Firm Controls	N	Y	N	Y
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	19,427	13,672	19,667	11,307
R^2 (%)	8.33	10.33	12.86	13.49

TABLE 1.17: **Model Prediction: Consumption CAPM**

Panel A reports consumption CAPM (CCAPM) regressions on simulated model data both for return horizons of 4 and 8 quarters. The reported coefficients, standard errors and R^2 are averages over the regression results of 200 regressions of identical sample size as observed in the data. α estimates are expressed in percent. L and H stand for low and high offshorability industries in the model. Panel B then reports analogous CCAPM regression results for my sample of manufacturing industries. Results are tabulated both for equal-weighted (columns 2-6) and value-weighted (columns 8-12) portfolio returns. 4-quarter, 6-quarter and 8-quarter α estimates are expressed in percent. The portfolios L and H invest in industries with offshorability in the lowest and highest quintiles. $2-4$ is a portfolio that invests in the remaining industries. $Offshorability$ is lagged by 18 months. Returns on consumption are calculated based on U.S. real per capita non-durable consumption, as in Parker and Julliard (2005). Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers returns from July 1991 to June 2016.

Panel A: Model Regressions

	4 Quarter Returns			8 Quarter Returns		
	L	H	L-H	L	H	L-H
Avg Alpha (%)	8.685***	4.745***	3.940***	17.088***	9.361***	7.727***
	(0.25)	(0.07)	(0.19)	(0.48)	(0.13)	(0.37)
Avg C Beta	3.679***	1.452***	2.227***	3.708***	1.461***	2.247***
	(0.06)	(0.02)	(0.04)	(0.08)	(0.02)	(0.06)
Avg R^2 (%)	97.79	98.73	96.62	96.02	98.00	93.80

Panel B: Empirical Evidence

	Equally Weighted Returns				Value-Weighted Returns			
	L	2 - 4	H	L-H	L	2 - 4	H	L-H
4 Quarter Returns								
Alpha (%)	3.708	1.309	-5.346***	9.054***	5.888***	0.605	-5.714*	11.602***
	(3.23)	(2.62)	(2.02)	(2.23)	(2.46)	(2.22)	(3.00)	(3.08)
C Beta	6.318***	4.334***	3.513***	2.805***	6.346***	3.833***	3.755***	2.591**
	(1.61)	(1.47)	(1.07)	(1.16)	(1.45)	(0.96)	(1.10)	(1.32)
R^2 (%)	19.77	14.10	10.62	5.30	16.24	13.790	8.80	2.35
6 Quarter Returns								
Alpha (%)	5.769	3.061	-7.606***	13.375***	8.227***	1.798	-7.339*	15.566***
	(3.65)	(3.50)	(2.45)	(2.88)	(2.60)	(2.93)	(3.75)	(4.19)
C Beta	6.646***	4.042***	3.451***	3.195***	7.352***	3.615***	3.348***	4.004**
	(1.43)	(1.41)	(1.04)	(1.20)	(1.77)	(0.90)	(0.96)	(1.86)
R^2 (%)	27.18	15.03	12.87	6.90	19.68	13.81	8.12	4.62
8 Quarter Returns								
Alpha (%)	7.508*	4.273	-10.375***	17.882***	9.602***	2.957	-8.869**	18.471***
	(3.96)	(4.05)	(2.72)	(3.49)	(3.04)	(3.53)	(4.15)	(5.05)
C Beta	6.911***	3.956***	3.503***	3.408***	8.331***	3.568***	3.107***	5.225***
	(1.06)	(1.24)	(0.96)	(1.17)	(1.69)	(0.81)	(0.80)	(2.07)
R^2 (%)	33.95	15.94	15.11	7.91	27.21	13.66	7.73	6.86

1.7 Figures

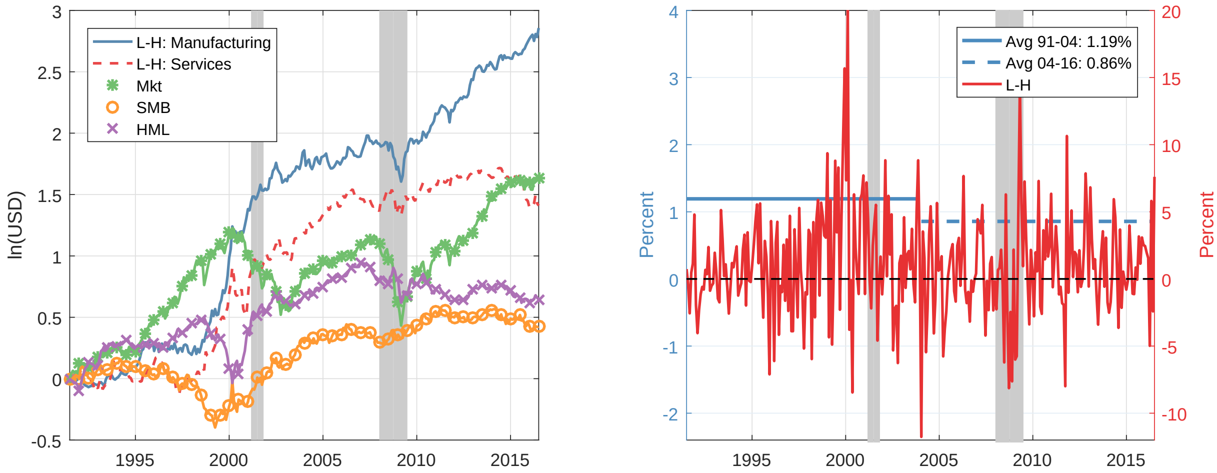


FIGURE 1.1: **Investment Strategy and Excess Returns**

The left figure plots the evolution over time of a one USD investment for the L-H strategy in manufacturing and non-manufacturing industries, the excess return on the market (Mkt), small-minus-big (SMB) and high-minus-low (HML). The results are presented on a logarithmic scale. The right panel plots in red the monthly returns of the L-H portfolio in manufacturing. The blue horizontal lines refer to averages over subsamples. The sample period in both figures runs from July 1991 to June 2016.

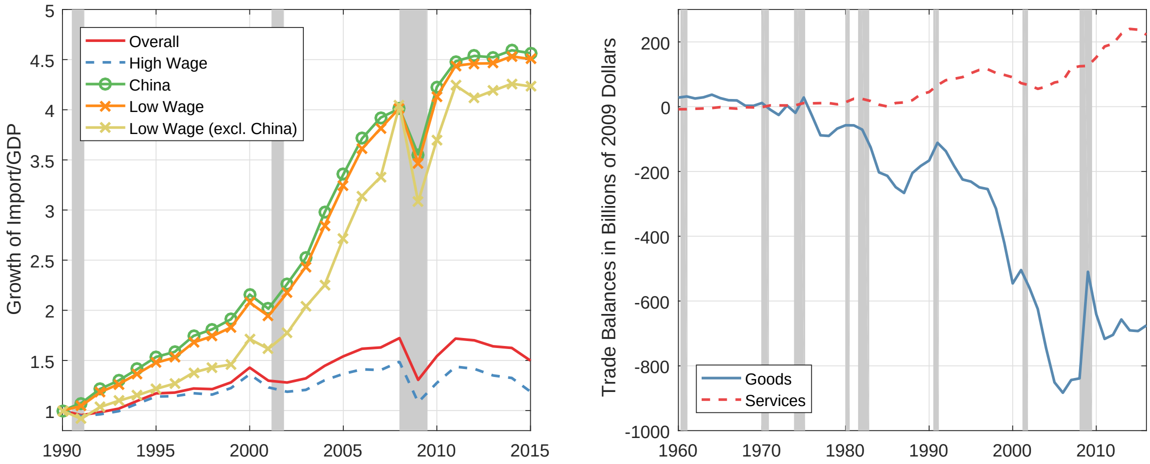


FIGURE 1.2: **U.S. Trade Balances and Growth of Imports/GDP**

The left panel plots the U.S. trade balances (i.e., exports minus imports) in goods and services expressed in 2009 Dollars. Data are obtained from the Bureau of Economic Analysis. The sample period runs from 1960 to 2016. The right panel plots the growth of the ratio of imports to the United States from the world, high-wage countries, China, low-wage countries and low-wage countries excluding China to U.S. Gross Domestic Product (GDP). Details about the calculation of the value of imports from a given country or countries can be found in the online appendix. Low-wage countries are defined as in Bernard, Jensen, and Schott (2006a). The sample consists of all imports of manufacturing firms between 1990 and 2015. Trade data are from Schott (2008).

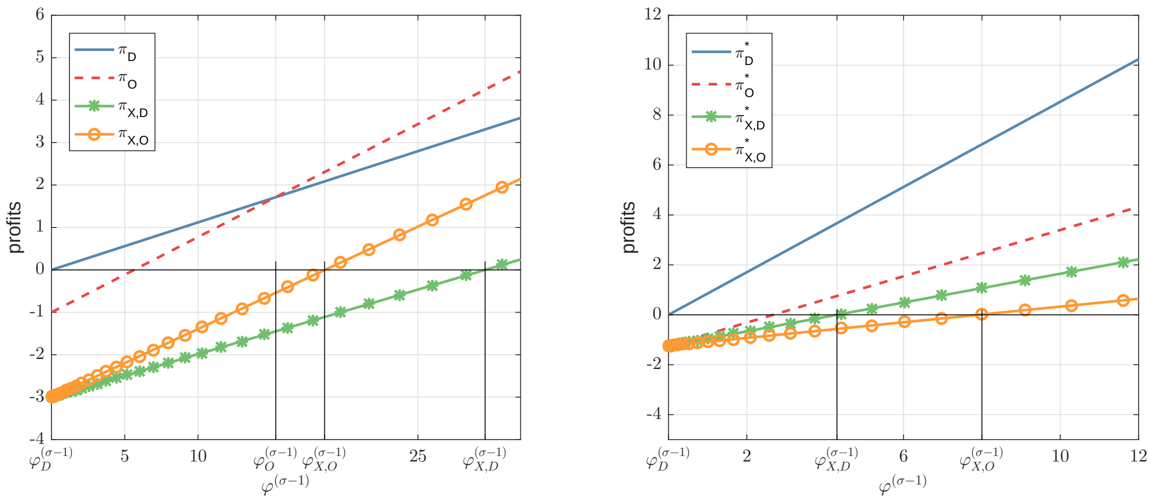


FIGURE 1.3: **Profits for Different Organizational Choices**

This figure plots the profits for different organizational choices against a transformation of idiosyncratic firm productivity, $\varphi^{\sigma-1}$. This is convenient, given that firm profits are linear in $\varphi^{\sigma-1}$. The left panel plots profits for Western firms and the right panel profits for Eastern firms, assuming that the East has a comparative cost advantage in producing offshorable tasks.

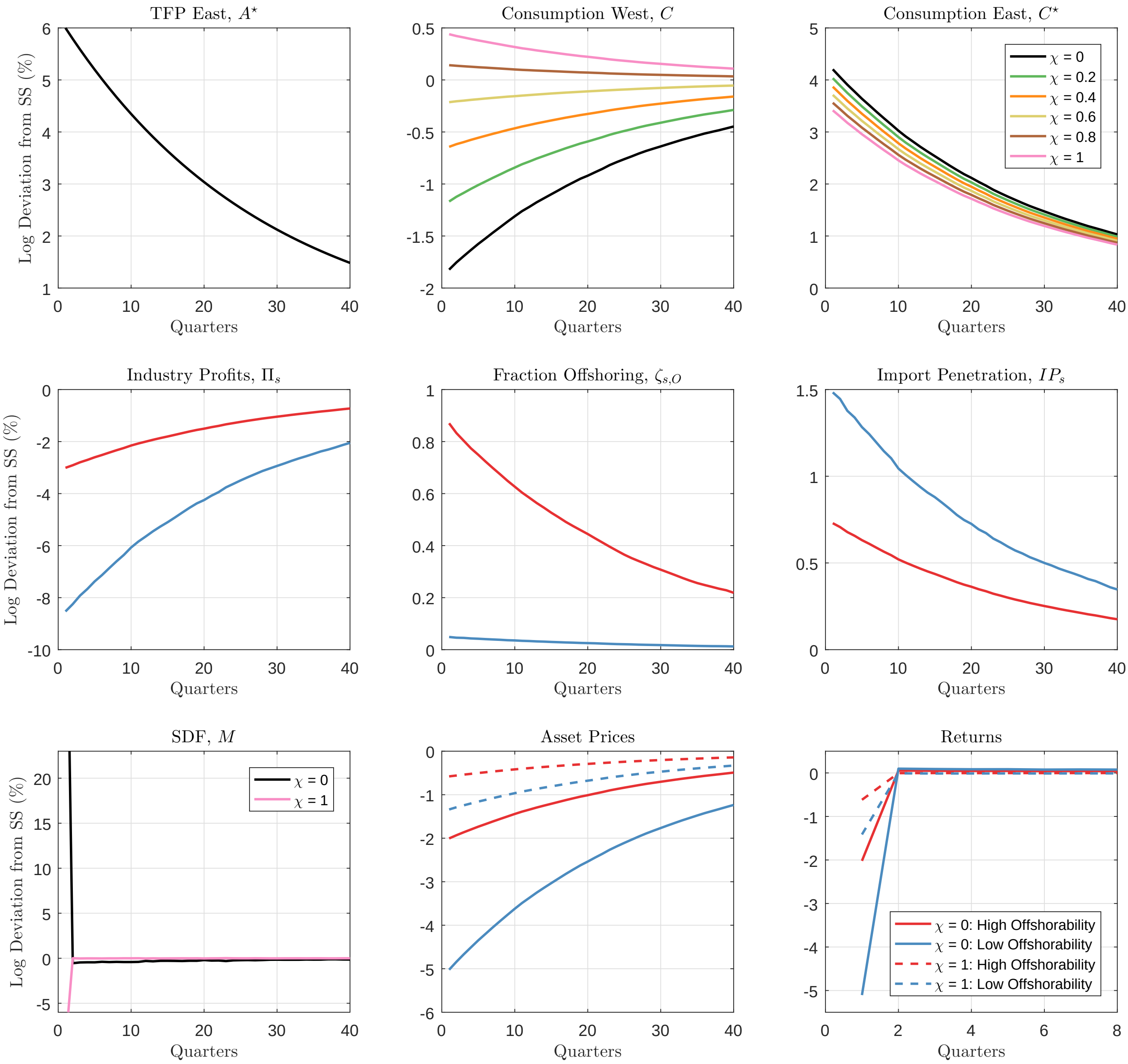


FIGURE 1.4: **Mechanism: Positive Shock to $A^{\star}$**

This figure plots various impulse response functions to a one standard deviation shock to aggregate productivity in the East, $A^{\star}$. The first row shows how the response of aggregate consumption in both countries changes with risk sharing (exogenously determined by χ). The second row contains the responses of industry profits (Π_s), the fraction of firms that offshore ($\zeta_{s,O}$) and import penetration in the West, IP_s with no risk sharing ($\chi = 0$). The three last plots show how the stochastic discount factor (SDF, M), asset prices and excess returns respond under no and full risk sharing.

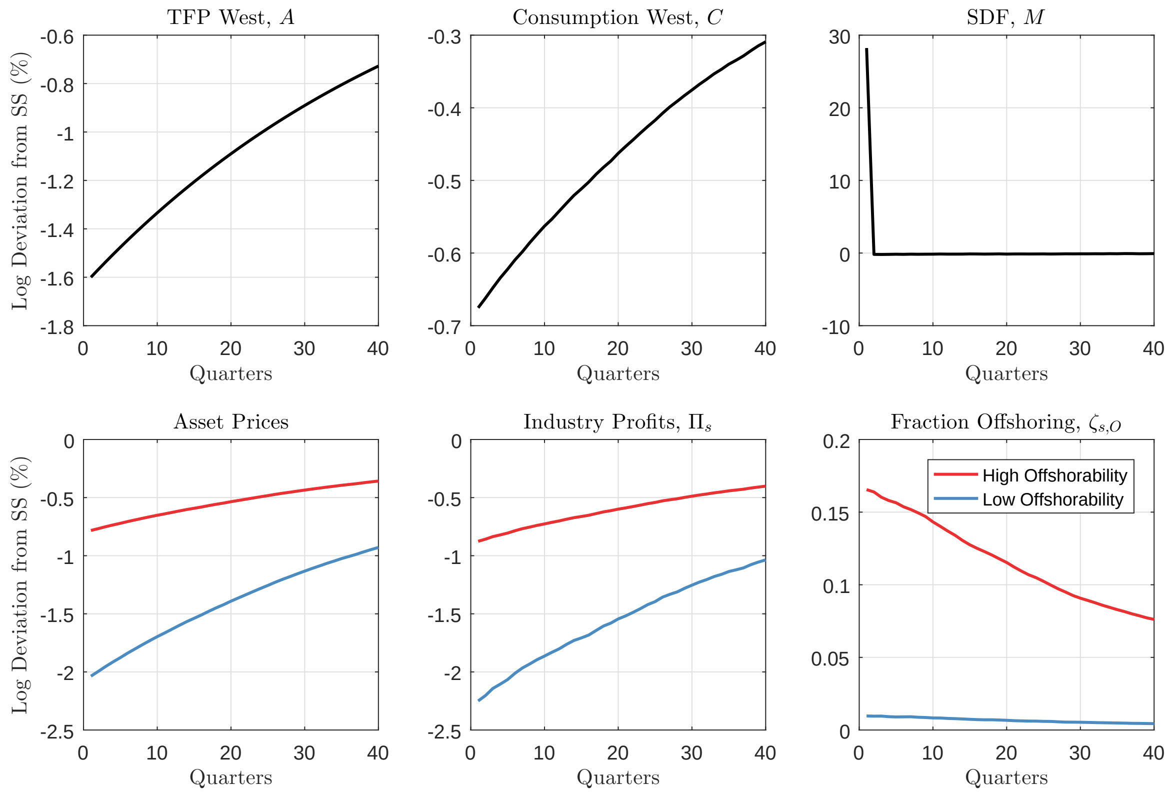


FIGURE 1.5: **Mechanism: Negative Shock to A**

This figure plots the impulse response functions of aggregate productivity in the West (A), consumption (C), the stochastic discount factor (SDF, M), asset prices, industry profits (Π_s) and fraction of firms that offshore ($\zeta_{s,O}$) to a negative one standard deviation shock to aggregate productivity in the West, A.

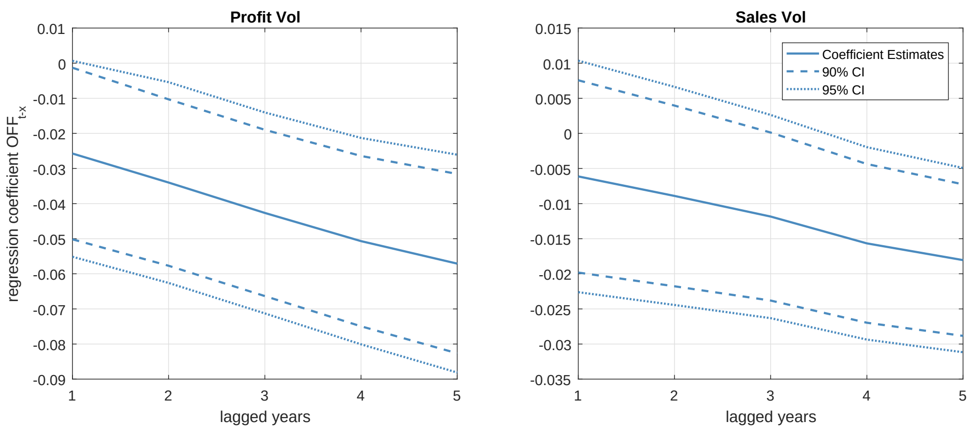


FIGURE 1.6: **Panel Regression Coefficients on OFF_{t-x}**

This figure plots the regression coefficients of OFF_{t-x} for different lags x. The regressions are identical to Panel C of table 1.15. Solid lines indicate the regression coefficient point estimates, dashed lines correspond to the 90% confidence bands and dotted lines correspond to the 95% confidence bands. The regressions control for firm characteristics (size, Tobin's Q, leverage, and investment) and include year fixed effects. The standard errors are clustered at the firm and year level.

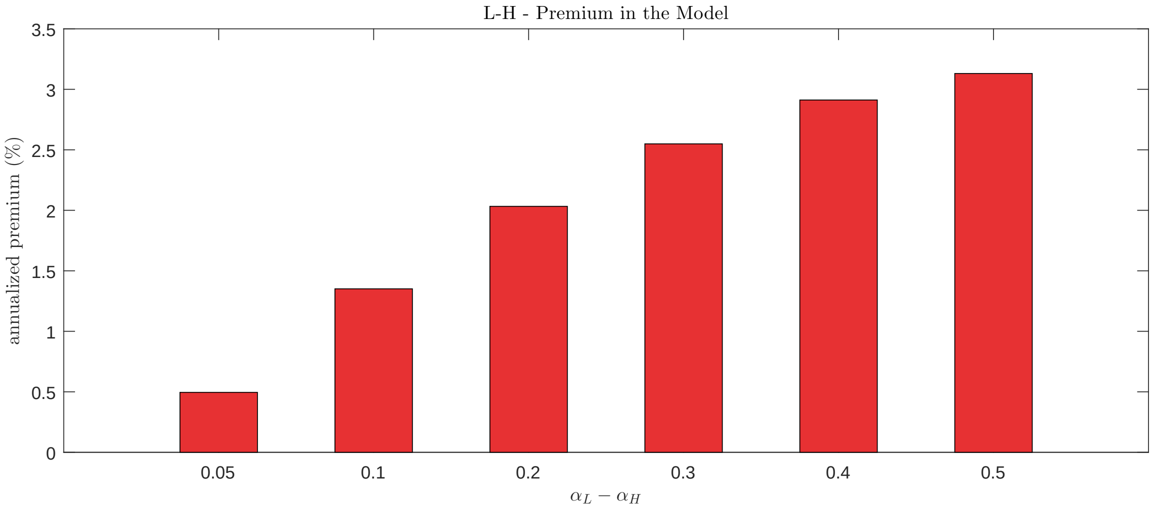


FIGURE 1.7: **L-H Premium in the Model**

This figure plots the model-implied L-H premium as a function of the difference in headquarter intensity across the two model industries. Differences in headquarter intensity across industries directly map into differences in offshoring potential across industries. In other words, $\alpha_L - \alpha_H = (1 - \alpha_H) - (1 - \alpha_L)$.

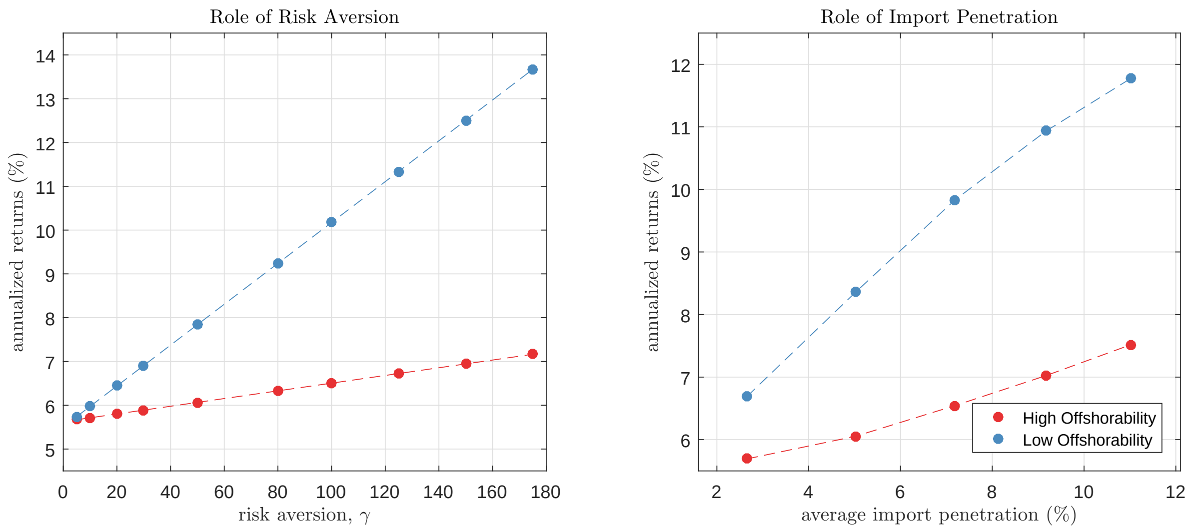


FIGURE 1.8: **Role of Risk Aversion and Import Penetration**

The figures plot averages of simulated model returns for the high and low offshorability industries. The left panel plots mean returns for different coefficients of risk aversion. The right panel plots returns for different levels of average import penetration. Average import penetration is calculated as $IP = \left[\sum_s \eta_s IP_s^{1-\theta}\right]^{\frac{1}{1-\theta}}$, where IP_s is the import penetration of a single industry.

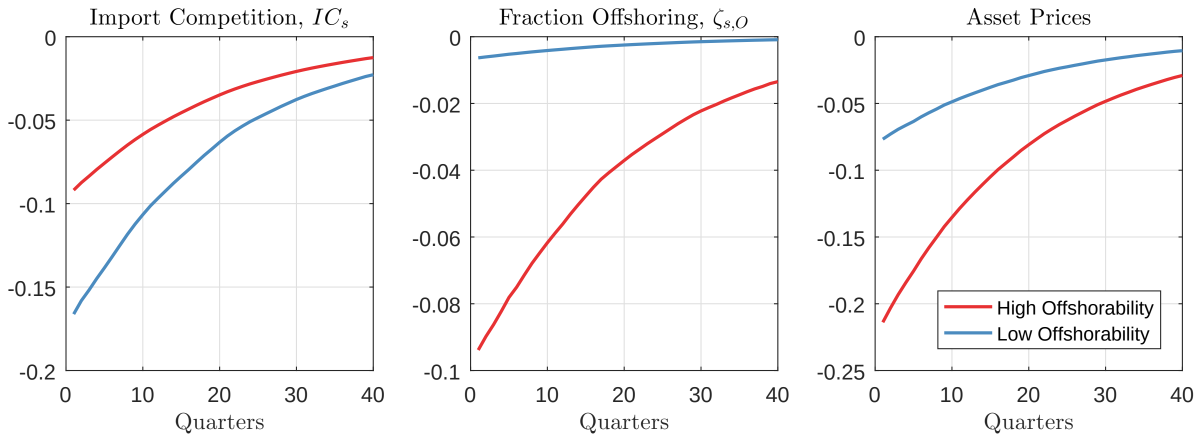


FIGURE 1.9: **Model Counterfactual: Shock to Variable Trade Costs $\tau^{\star}$**

This figure plots the impulse response functions import penetration (IP_s), fraction of firms that offshore ($\zeta_{s,O}$) and asset prices to a positive one percent shock to variable trade costs ($\tau^{\star}$).

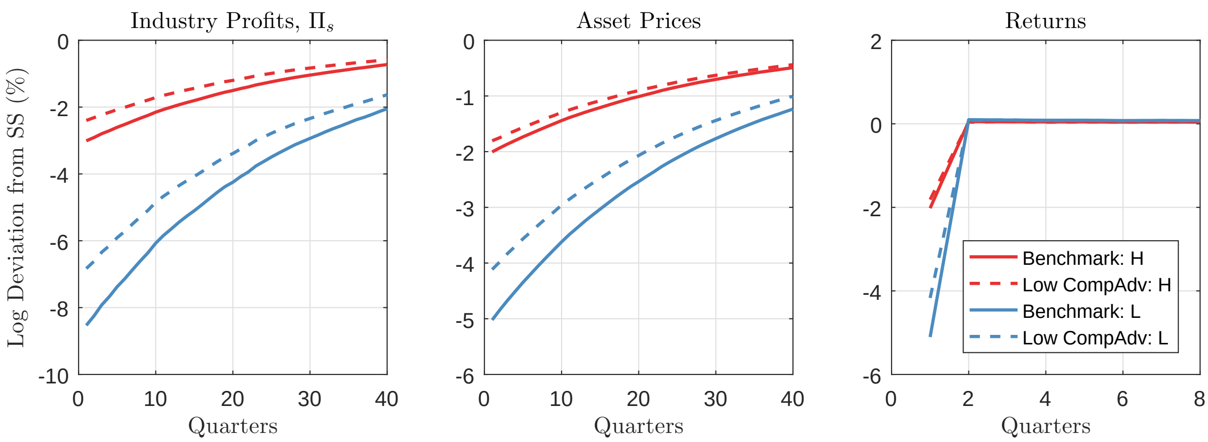


FIGURE 1.10: **Model Counterfactual: Benchmark vs Low Comparative Advantage**

This figure plots the impulse response functions of industry profits (Π_s), asset prices and industry excess returns to a positive one standard deviation shock to aggregate productivity in the East, $A^{\star}$. The solid lines are the impulse responses in the benchmark economy, while the dashed lines correspond to impulse responses in an economy in which the comparative cost advantage in offshorable labor of the East is lower compared to the benchmark calibration.

1.8 Appendix

1.8.1 Sample Construction and Variable Definition

Monthly common stock data is from the Center for Research in Security Prices (CRSP share code SHRCD = 10 or 11). The sample includes stocks listed on NYSE, AMEX, and NASDAQ (exchcd = 1 or 2 or 3). Accounting information is from Standard and Poor's Compustat annual industrial files. I follow the literature and exclude from my sample firms with primary standard industrial classifications between 4900 and 4999 (regulated firms) and between 6000 and 6999 (financial firms). Following Zhang (2016), the firm-level accounting variables and size measures are winsorized at the 1% level to reduce the influence of possible outliers.

I construct the following variables for every firm:

- $Assets$ is the logarithm of a firm's total book assets (AT).
- $Cash$ is a firm's cash holdings defined as cash and short-term investments (CHE) scaled by total book assets (AT).
- Q is a firm's Tobin's Q defined as total book assets (AT) minus common equity (CEQ) plus the market value of equity scaled by total assets (AT) following Dasgupta, Noe, and Wang (2011).
- $PP\&E$ is net property, plant and investment (PPENT) scaled by total book assets (AT).
- $Size$ and $BooktoMarket$ are calculated following Fama and French (1992).
- $R\&D$ is defined as R&D expenses (XRD) scaled by total book assets (AT).
- $Mkt.Leverage$ is the firm's financial leverage and defined as the proportion of total debt of the market value of the firm defined following Fan, Titman, and Twite (2012). Total debt is the book value of short-term (DLC) and long-term interest bearing debt (DLTT). The market value of the firm is the market value of common equity defined as in Fama and French (1992).
- HN and IK are a firm's hiring and investment rate defined following Belo, Lin, and Bazdresch (2014).
- $CashFlow$ is the cash flow of a firm which is defined following Malmendier and Tate (2005): earnings before extraordinary items (IB) plus depreciation (DP) divided by capital stock (PPENT) at the beginning of the following year.

- *Op.Lev* is a firm's operating leverage defined as in Novy-Marx (2011). It is calculated as cost of goods sold (COGS) plus selling, general, and administrative expenses (SGA) divided by total book assets (AT).

- *LaborInt.* is a firm's labor intensity defined as the logarithm of the ratio of the number of employees divided by gross property, plant and investment (PPEGT) following Donangelo (2014).

- *Profitability* is a firm's gross profitability defined as revenues (REVT) minus cost of goods sold (COGS) scaled by assets (AT) as defined by Novy-Marx (2011).

- I classify every sample firm in either a domestic, exporter or multinational firm as in Fillat and Garetto (2015). To do so I use information on geographical company segments from COMPUSTAT.

- I calculate a firm's profit and sales volatility following the methodology of Minton and Schrand (1999). In particular, I use Compustat quarterly for all manufacturing firms and download quarterly sales, revenues and costs of goods sold. Following Novy-Marx (2011), I define gross profits as revenues minus costs of goods sold.

I construct the following variables at the industry-level:

- *Offshorability* is calculated as discussed in the main body of the paper.

- *Skill* is calculated as in Ochoa (2013):

$$Skill_{i,t} = \sum_j \lambda_j \times \frac{emp_{i,j,t} \times wage_{i,j,t}}{\sum_j emp_{i,j,t} \times wage_{i,j,t}}, \tag{1.7}$$

  where λ_j is the skill-level of occupation j. λ_j is the "job zone" of a given occupation which ranges between one and five.

- *Routine* is calculated as follows:

$$Routine_{i,t} = \sum_j \mathbb{1}_{\{routine_j > routine_{p66}\}} \times routine_j \times \frac{emp_{i,j,t} \times wage_{i,j,t}}{\sum_j emp_{i,j,t} \times wage_{i,j,t}}, \tag{1.8}$$

  where $routine_j$ is the routine task score for occupation j which is calculated using task level content from O*NET as in Acemoglu and Autor (2011).

- *Shipping Costs* are calculated following Barrot, Loualiche, and Sauvagnat (2017).

- *Value Share of Imports* and *Import Penetration* are calculated following Bernard, Jensen, and Schott (2006a). The value share of imports from low wage countries, for example, is calculated as the total imports from low wage countries in an industry divided by the total imports in the same industry. Import penetration by low wage countries of a given industry i at time t is calculated as follows:

$$LWPEN_{i,t} = \Big(\frac{V^L_{i,t}}{V_{i,t} + Q_{i,t} - X_{i,t}}\Big),$$

where $V^L_{i,t}$ and $V_{i,t}$ represent the value of imports from low wage countries and all countries, respectively, $Q_{i,t}$ is domestic production, and $X_{i,t}$ represents US exports.

1.8.2 OES Data and Industry Offshorability across Sectors

While the OES survey methodology is designed to create detailed cross-sectional employment and wage estimates for the U.S., States, metropolitan and nonmetropolitan areas, across industry and by industry, comparisons of two or more points in time might be difficult. The time-series interpretation of OES data might be misleading due to various changes in the construction of the data over time such as changes in the occupational and industrial classification. The nature of these changes are summarized on the webpage of the Bureau of Labor Statistics as follows:

(Excerpts were downloaded on October 10, 2017 from https://www.bls.gov/oes/oes_ques.htm)

Changes in occupational classification: The OES survey used its own occupational classification system through 1998. The 1999 OES survey data provide estimates for most of the nonresidual occupations in the 2000 Standard Occupational Classification (SOC) system. The 2004-2009 OES data provides estimates for all occupations in the 2000 SOC. The May 2010 data provides estimates for most occupations in the 2010 SOC (for more on the 2010 occupations, see below). Because of these changes, it may be difficult to compare some occupations even if they are found in both classification systems. For example, both the old OES system and the 2000 SOC include the occupation "computer programmers." However, estimates for this occupation may not be comparable over time because the 2000 SOC has several computer-related occupations that were not included in the older classification system. Workers in newly classified occupations, such as systems software engineers and applications software engineers, may have been reported as computer programmers in the past. Therefore, even occupations that appear the same in the two systems may show employment shifts due to the addition or deletion of related occupations.

Changes in industrial classification: In 2002, the OES survey switched from the Standard Industrial Classification (SIC) system to the North American Industry Classification System (NAICS). As a result, there were changes in many industry definitions. Even definitions that appear similar between the two industry classifications may have differences because of the way auxiliary establishments are treated. For example, under SIC the industry "grocery stores" included their retail establishments, warehouses, transportation facilities, and administrative headquarters. Under NAICS, the four establishment types would be reported in separate industries. Only the retail establishments would be included in the NAICS industry for "grocery stores." The change in industrial classification also resulted in changes to the occupations listed on the survey form for a given industry. In 2008, the OES survey switched to the 2007 NAICS classification system from the 2002 NAICS. The most significant revisions are in the Information Sector, particularly within the Telecommunications area. Beginning in 2010, Tennessee Valley Authority (TVA) data is included in the Federal Government estimates.

While the main paper shows rankings of industry offshorability for manufacturing and services separately, table 1.19 reports corresponding rankings across all industries. In 1992, the industries with the highest offshoring potential were almost exclusively manufacturing industries whereas the bottom industries feature mining industries. In 2015, the industry ranking looks very different. Industries among the top ten are by no means only related to manufacturing. The bottom industries, however, do not seem to have drastically changed in their nature compared to 1992. Interestingly, the top ten in 2015 are mostly service industries which is consistent with Jensen (2011), Blinder (2009) and Amiti and Wei (2009) who discuss that recent advances in communication technologies increasingly allow for offshoring of service industry jobs. Moreover, this change over time is in line with recent papers which document that offshoring and replacement of offshorable jobs with imports have led to a substantial decrease in manufacturing employment over the recent past.[82] This can be seen from figure 1.11 which plots a strongly negative relationship between U.S. imports as percentage of GDP and the manufacturing employment share. As a result of this, one would expect that the manufacturing sector becomes relatively less offshorable compared with services over time. Given that the rankings within manufacturing and services are very persistent over time, the drastic change in top ten industries in 1992 and 2015 is likely to be due to structural changes across sectors, i.e. services and manufacturing.

Yet another way to look at this sectoral change in offshorability over time is to plot cross-sectional correlations of industry offshorability and industry routine-task labor and skill at different points in time. The results are plotted in figure 1.12. While offshorability

[82]See among others Autor, Dorn, and Hanson (2013), Acemoglu, Autor, Dorn, Hanson, and Price (2016) and Autor, Dorn, and Hanson (2016).

and routine are significantly and positively correlated at the beginning of the sample, the correlation coefficients decrease continuously from 1997 onwards. This pattern is not due to wage-weighting when constructing the offshorability index. The correlations look almost identical for the $OFF^{\star}_{i,t}$ measure that does not rely on wages (right panel in figure 1.12). The sudden drop in correlation in 2001 coincides with the sharp decrease in routine-labor in the U.S. documented by Zhang (2016) and the decrease in manufacturing employment which was fueled by China's admission to the World Trade Organization (WTO) in 2001 as discussed in Autor, Dorn, and Hanson (2016).

Finally, figure 1.13 reports additional evidence on the importance of China for the U.S. trade deficit in goods. The left panel plots the U.S. trade balance in goods when considering all countries (solid blue line) and China only (red solid line). The importance of trades with China for the overall trade balance are striking. In the year 2009, 44.5% of the U.S. trade deficit in goods was due to trades with China. Interestingly, the right panel of figure 1.13 shows the trade balance in goods for the U.S. and China, respectively. Consistent with the interpretation of comparative advantage, the U.S. and Chinese trade balances in goods look like a mirror image. Of course, this is at best suggestive evidence because the countries potentially trade with many other countries, i.e. have various and heterogenous trade partners.

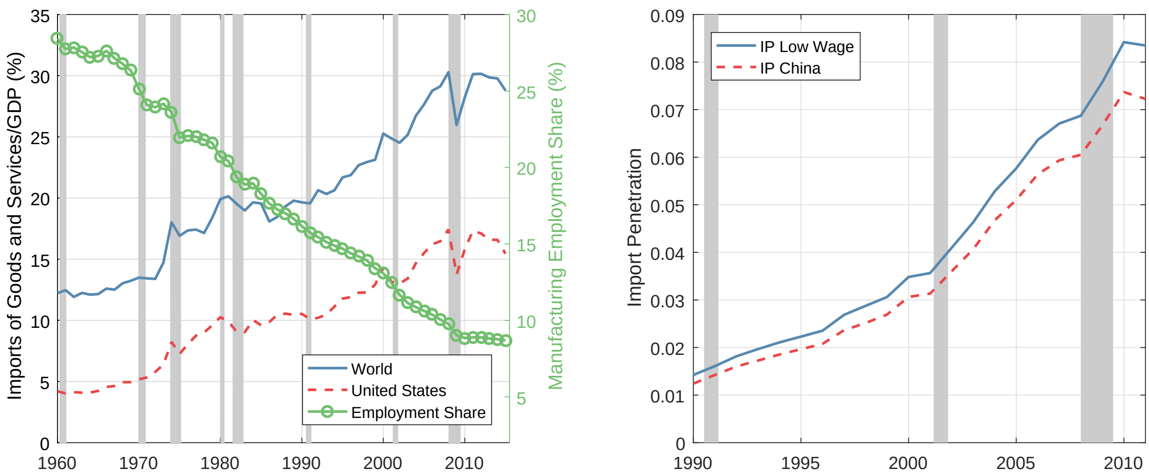


FIGURE 1.11: **Imports of Goods and Services as a Percentage of GDP**

The left figure plots the imports of goods and services as a percentage of GDP (left axis) as well as the manufacturing employment share (right axis). Data are obtained from the World Bank national accounts data and the OECD National Accounts data files. The sample period runs from 1960 to 2015. The right figure shows annual U.S. import penetration from low wage countries and China between 1990 and 2011.

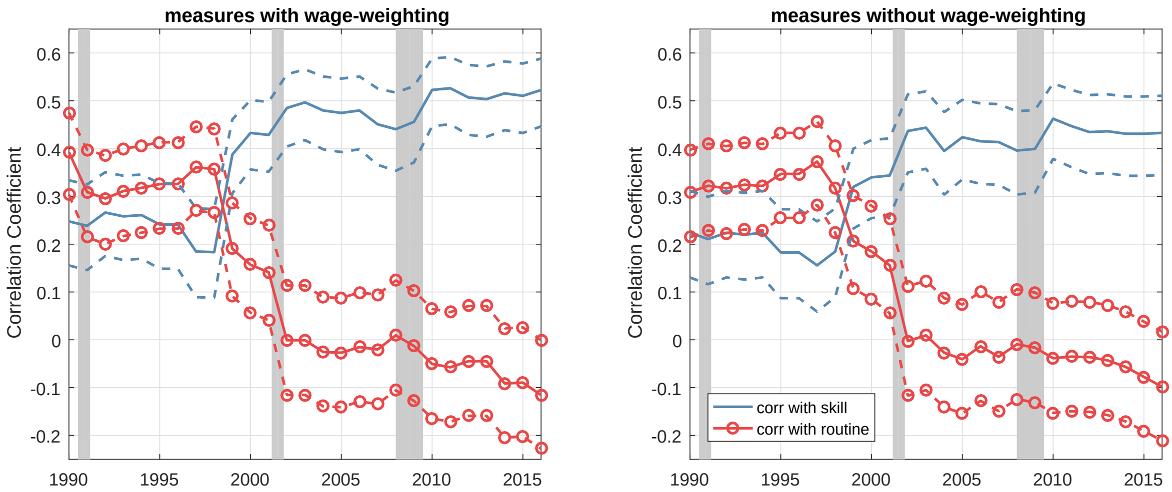


FIGURE 1.12: **Correlation of Offshorability with Skill/Routine over time**

This figures plot the cross-sectional correlation coefficients (solid lines) along with 95% confidence intervals (dotted lines) of offshorability and skill and routine, respectively. The correlation coefficient in a given year is calculated as the Spearman rank correlation between quintiles of offshorability and skill or routine. The left panel plots the results for the wage-weighted industry offshorability measure and the right panel for industry offshorability without wage-weighting. The sample period runs from 1990 to 2016.

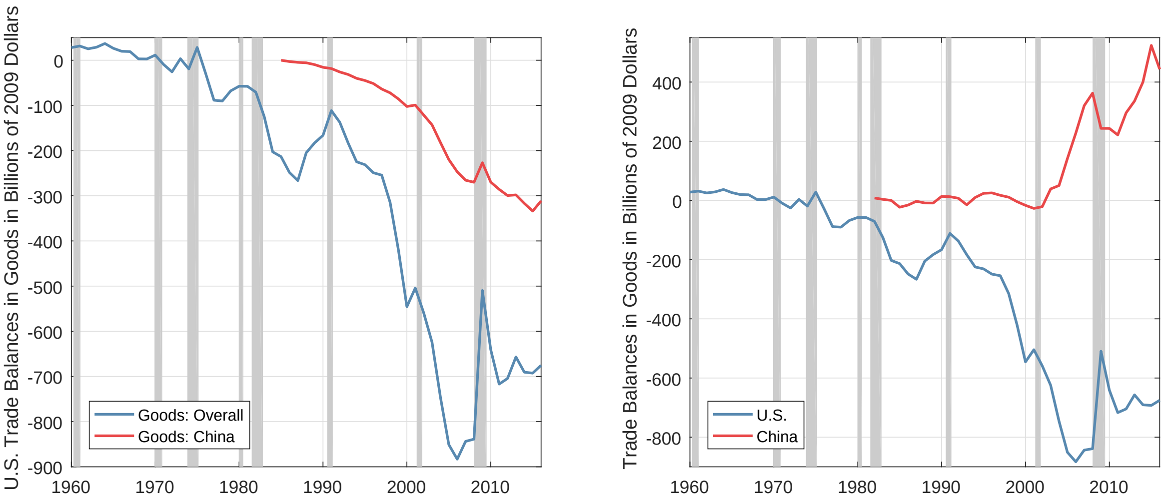


FIGURE 1.13: **Trade Balances in Goods**

The left panel plots the U.S. trade balances (i.e. exports minus imports) in goods in 2009 Dollars. The blue solid line refers to the overall trade balance in goods. In other words, trades between the U.S. and any other country are considered. On the other hand, the red solid line plots the U.S. trade balance in goods with China only. The right panel plots the overall trade balance in goods both for the U.S. and China. Data are obtained from the Bureau of Economic Analysis. The sample period runs from 1960 to 2016.

1.8.3 Robustness: Asset Pricing Results

This section delivers further robustness tests for the asset pricing results in the main paper. Table 1.20 reports regression results across all industries for the unconditional

(Panel A) and conditional CAPM (Panel B) as well as the Fama and French (1993) three factor model (Panel C).

Table 1.21 splits the sample into manufacturing and services industries and reports regression results for the Fama and French (1993) three factor model.

Table 1.22 reports univariate returns both for the full as well as for various subsamples. In this robustness test I keep the ranking of industry offshorability fixed over time. In other words, for the period between 1991 and 2002, I keep the industry offshorability fixed at the values for 1990, and for the period from 2002 to 2016, I fix offshorability at the values from the year 2001. Hence, I simply fix offshorability at the first observation available for the two industry classification regimes in the OES data (as discussed above).

Table 1.23 shows robustness tests for the predictability regressions of the main paper. Panel A and B report regression results for manufacturing and services for different industry definitions. While the baseline specification uses industry×year fixed effects based on 17 industries as defined in Fama and French (1988), I assess the robustness of the results for 49 industries as defined in Fama and French (1997), industries defined by one and two digit SIC codes as well as with only year fixed effects.

Table 1.24 shows monthly excess return double sorts on import penetration from China and offshorability. The results are very similar to the double sorts on import penetration from low-wage countries and offshorability.

Finally, tables 1.25 and 1.26 report factor model regression results which control for the globalization risk premium as defined in Barrot, Loualiche, and Sauvagnat (2017) and factors based on foreign exchange exposure from Lustig, Roussanov, and Verdelhan (2011) and Verdelhan (2017).

Table 1.18: **Occupation Tasks that define Offshorability**

This table tabulates the tasks used to calculate occupation offshorability by Firpo, Fortin, and Lemieux (2013). The acronyms *WA* and *WC* in the third column stand for work activity and work context.

	Firpo, Fortin and Lemieux (2013)	
Face-to-Face Contact		
4.C.1.a.2.l	Face-to-Face Discussions	WC
4.A.4.a.4	Establishing and Maintaining Interpersonal Relationships	WA
4.A.4.a.5	Assisting and Caring for Others	WA
4.A.4.a.8	Performing for or Working Directly with the Public	WA
4.A.4.b.5	Coaching and Developing Others	WA
On-site		
4.A.1.b.2	Inspecting Equipment, Structures, or Material	WA
4.A.3.a.2	Handling and Moving Objects	WA
4.A.3.a.3	Controlling Machines and Processes	WA
4.A.3.a.4	Operating Vehicles, Mechanized Devices, or Equipment	WA
4.A.3.b.4	Repairing and Maintaining Mechanical Equipment (*0.5)	WA
4.A.3.b.5	Repairing and Maintaining Electronic Equipment (*0.5)	WA
Decision-Making		
4.A.2.b.1	Making Decisions and Solving Problems	WA
4.A.2.b.2	Thinking Creatively	WA
4.A.2.b.4	Developing Objectives and Solving Problems	WC
4.C.1.c.2	Responsibility for Outcomes and Results	WC
4.C.3.a.2.b	Frequency of Decision Making	

Table 1.19: **Most Offshorable and Non-Offshorable Industries**

Panels A and B tabulate the top and bottom ten industries in terms of their offshoring potential, $OFF_{i,t}$, for the years 1992 and 2015, respectively. Industries are defined at the three-digit SIC level until 2001 and at the four-digit NAICS level thereafter.

Panel A: 1992 - Top and Bottom Ten Industries by Offshorability

SIC	Industry Title	$OFF_{i,t}$	SIC	Industry Title	$OFF_{i,t}$
8720	Accounting, Auditing, and Bookkeeping Services	2.419	8650	Political Organizations	-2.174
2310	Men's and Boys' Suits, Coats, and Overcoats	2.392	8620	Professional Membership Organizations	-2.213
7250	Shoe Repair Shops and Shoeshine Parlors	2.257	3760	Guided Missiles and Space Vehicles and Parts	-2.254
2320	Men's and Boys' Furnishings, Work Clothing, and Allied Garments	2.141	3660	Communications Equipment	-2.430
2360	Girls', Children's, and Infants' Outerwear	2.120	8730	Research, Development, and Testing Services	-2.438
2330	Women's, Misses', and Juniors' Outerwear	1.921	8630	Labor Unions and Similar Labor Organizations	-2.631
2340	Women's, Misses', Children's, and Infants' Undergarments	1.759	1060	Ferroalloy Ores, Except Vanadium	-2.715
2340	Hats, Caps, and Millinery	1.649	4820	Telegraph Communication	-2.827
3150	Leather Gloves and Mittens	1.543	3810	Aeronautical and Nautical Systems	-3.019
2380	Miscellaneous Apparel and Accessories	1.541	1230	Anthracite Mining	-3.843

Panel B: 2015 - Top and Bottom Ten Industries by Offshorability

NAICS	Industry Title	$OFF_{i,t}$	NAICS	Industry Title	$OFF_{i,t}$
511200	Software Publishers	3.240	237100	Nonscheduled Air Transportation	-1.307
541200	Acccounting, Tax Preparation, Bookkeeping, and Payroll Services	3.150	483200	Utility System Construction	-1.307
519100	Other Information Services	3.057	485500	Inland Water Transportation	-1.336
541500	Compuer Systems Design and Related Services	3.017	481100	Charter Bus Industry	-1.397
523900	Other Financial Activities	2.901	487900	Scenic and Sightseeing Transportation	-1.425
334100	Computer and Peripheral Equipment Manufacturing	2.521	212100	Coal Mining	-1.458
518200	Data Processing, Hosting, and Related Services	2.473	485200	Interurban and Rural Bus Transportation	-1.604
541100	Legal Services	2.470	485100	Urban Transport Sytems	-1.612
524100	Insurance Carriers	2.450	621200	Offices of Dentists	-1.706
511100	Newspaper, Periodical, Book, and Directory Publishers	2.346	621900	Other Ambulatory Health Care Services	-1.948

Table 1.20: **CAPM and Three-Factor Model**

Panel A reports unconditional CAPM regression results both for equal-weighted (columns 2-8) and value-weighted (columns 10-16) portfolio returns. Panel B tabulates results for conditional CAPM regressions and Panel C for the Fama and French (1992) three-factor model. Monthly α estimates are expressed in percent. $Offshorability$ is lagged by 18 months. Returns are at a monthly frequency. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers returns from July 1991 to June 2016.

	Equal-Weighted Returns						Value-Weighted Returns					
	L	2	3	4	H	L-H	L	2	3	4	H	L-H
Panel A: Unconditional CAPM												
Alpha (%)	0.313*	0.160	0.041	-0.335	-0.163	0.476**	0.468***	0.240*	0.049	-0.169	-0.367**	0.835***
	(0.17)	(0.16)	(0.15)	(0.15)	(0.15)	(0.24)	(0.18)	(0.13)	(0.13)	(0.17)	(0.18)	(0.31)
MKT Beta	1.176***	1.151***	1.065***	1.154***	0.955***	0.222***	0.949***	0.920***	0.859***	0.966***	0.993***	-0.044
	(0.07)	(0.07)	(0.05)	(0.05)	(0.05)	(0.09)	(0.07)	(0.06)	(0.04)	(0.07)	(0.07)	(0.13)
R^2 (%)	76.11	76.60	79.93	78.38	71.81	5.95	65.55	75.85	73.98	69.40	69.35	0.45
Panel B: Conditional CAPM												
Avg. Alpha (%)	0.239*	0.107	0.066	-0.233	-0.171	0.411	0.192	0.199	0.100	0.078	-0.215	0.406*
	(0.14)	(0.14)	(0.12)	(0.17)	(0.24)	(0.27)	(0.22)	(0.21)	(0.20)	(0.28)	(0.16)	(0.22)
Avg. MKT Beta	1.297***	1.230***	1.083***	1.215***	0.987***	0.310	1.093***	0.858***	0.774***	0.853*	0.986***	0.107
	(0.38)	(0.31)	(0.32)	(0.34)	(0.31)	(0.28)	(0.44)	(0.30)	(0.28)	(0.50)	(0.39)	(0.28)
Avg. R^2 (%)	76.32	77.91	78.78	73.35	68.93	11.51	71.92	74.24	72.95	71.42	71.27	3.62
Panel C: Fama and French (2015) Three-Factor												
Alpha (%)	0.218*	0.036	-0.042	-0.417***	-0.176	0.394*	0.476***	0.213*	0.029	-0.148	-0.298*	0.775***
	(0.12)	(0.10)	(0.13)	(0.13)	(0.16)	(0.20)	(0.16)	(0.13)	(0.13)	(0.16)	(0.16)	(0.28)
MKT Beta	1.031***	1.043***	1.006***	1.065***	0.906***	0.125	0.877***	0.938***	0.910***	0.952***	1.018***	-0.141
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.08)	(0.08)	(0.06)	(0.04)	(0.07)	(0.07)	(0.13)
SMB Beta	0.617***	0.460***	0.254***	0.380***	0.207*	0.410***	0.301***	-0.072*	-0.212***	0.058	-0.110	0.411***
	(0.04)	(0.09)	(0.08)	(0.10)	(0.11)	(0.10)	(0.07)	(0.04)	(0.06)	(0.06)	(0.10)	(0.15)
HML Beta	0.256***	0.387***	0.270***	0.245***	0.014	0.242**	-0.078	0.113*	0.110**	-0.087	-0.236**	0.158
	(0.06)	(0.06)	(0.06)	(0.08)	(0.08)	(0.11)	(0.10)	(0.06)	(0.05)	(0.11)	(0.10)	(0.19)
R^2	89.08	87.15	84.35	84.34	73.61	20.81	69.13	76.62	77.20	69.63	71.30	5.66

Table 1.21: **Manufacturing vs. Services: Fama & French Three-Factor Model**

Panel A (B) reports Fama and French (1992) three-factor model regression results for the sample of manufacturing (services) industries. Results are tabulated both for equal-weighted (columns 2-8) and value-weighted (columns 10-16) portfolio returns. Monthly α estimates are expressed in percent. $Offshorability$ is lagged by 18 months. Returns are at a monthly frequency. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers returns from July 1991 to June 2016.

	Equal-Weighted Returns						Value-Weighted Returns					
	L	2	3	4	H	L-H	L	2	3	4	H	L-H
Panel A: Manufacturing - Fama and French (2015) Three-Factor												
Alpha (%)	0.255*	0.112	0.234	-0.443***	-0.533***	0.788***	0.681***	0.044	0.331**	-0.237	-0.458***	1.139***
	(0.14)	(0.14)	(0.15)	(0.16)	(0.16)	(0.22)	(0.20)	(0.16)	(0.15)	(0.19)	(0.17)	(0.32)
MKT Beta	1.079***	1.021***	0.927***	1.085***	0.819***	0.259***	0.890***	0.825***	0.656***	1.113***	0.854***	0.036
	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.06)	(0.05)	(0.05)	(0.04)	(0.07)	(0.06)	(0.09)
SMB Beta	0.581***	0.404***	0.233**	0.282***	0.265***	0.315***	0.303***	-0.083*	-0.194***	0.064	-0.066	0.369**
	(0.06)	(0.08)	(0.10)	(0.09)	(0.10)	(0.12)	(0.10)	(0.05)	(0.07)	(0.07)	(0.09)	(0.17)
HML Beta	0.309***	0.412***	0.285***	0.320***	0.241***	0.068	-0.189*	0.226***	0.090	-0.076	-0.111	-0.077
	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.11)	(0.11)	(0.07)	(0.06)	(0.10)	(0.12)	(0.22)
R^2 (%)	82.29	80.52	73.57	76.33	67.27	15.60	59.61	64.73	51.64	65.21	59.80	4.25
Panel B: Services - Fama and French (2015) Three-Factor												
Alpha (%)	0.190	-0.012	-0.363***	-0.087	-0.103	0.293	0.316*	-0.067	-0.173	-0.154	-0.022	0.338
	(0.15)	(0.15)	(0.14)	(0.18)	(0.18)	(0.22)	(0.19)	(0.17)	(0.20)	(0.18)	(0.19)	(0.26)
MKT Beta	1.037***	1.009***	1.103***	0.970***	0.798***	0.239***	1.006***	0.964***	1.006***	1.060***	0.798***	0.208***
	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.07)	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)
SMB Beta	0.637***	0.586***	0.430***	0.442***	0.124	0.512***	0.248***	-0.018	0.082	-0.004	-0.020	0.268***
	(0.06)	(0.07)	(0.07)	(0.12)	(0.10)	(0.09)	(0.06)	(0.07)	(0.11)	(0.12)	(0.09)	(0.11)
HML Beta	0.144**	0.289***	0.177***	0.093	0.094	0.051	-0.054	0.121*	0.203**	-0.299***	0.113	-0.167
	(0.07)	(0.08)	(0.06)	(0.10)	(0.09)	(0.09)	(0.10)	(0.07)	(0.09)	(0.11)	(0.08)	(0.12)
R^2 (%)	80.27	79.54	83.54	71.49	56.65	22.92	66.21	66.77	62.58	72.73	51.05	9.77

Table 1.22: **Subsample Analysis - Fixed Quintiles**

The table reports univariate portfolio sorts for manufacturing industries for different time subsamples. Panel A tabulates results for equal-weighted returns and Panel B for value-weighted returns. L-H is an investment strategy that is long the portfolio of firms with low offshorability (L) and short the portfolio of firms with high offshorability (H). The column *MR* reports the p-values of the "monotonic relationship (MR)" test by Patton and Timmermann (2010). Standard errors are adjusted for heteroscedasticity and autocorrelation (Newey-West). Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample includes manufacturing firms and covers the period from July 1991 to June 2016.

Panel A: Equal-weighted Returns

	Offshorability						
	L	2	3	4	H	L-H	MR
1991:07 - 2016:06	1.029***	0.854***	0.892***	0.287	0.173	0.856*	0.058*
	(0.35)	(0.32)	(0.33)	(0.29)	(0.27)	(0.45)	
1991:07 - 1999:12	1.466***	0.830**	0.906*	0.723*	0.462	1.004	0.085*
	(0.51)	(0.38)	(0.47)	(0.42)	(0.41)	(0.65)	
2000:01 - 2009:12	0.556	0.642	0.641	-0.178	-0.015	0.571	0.181
	(0.68)	(0.62)	(0.65)	(0.56)	(0.49)	(0.84)	
2010:01 - 2016:06	1.184**	1.211**	1.260**	0.431	0.085	1.099	0.055*
	(0.57)	(0.56)	(0.54)	(0.48)	(0.50)	(0.75)	
2000:01 - 2008:08	0.601	0.737	0.591	-0.203	0.025	0.576	0.261
	(0.54)	(0.47)	(0.54)	(0.49)	(0.46)	(0.71)	

Panel B: Value-weighted Returns

	Offshorability						
	L	2	3	4	H	L-H	MR
1991:07 - 2016:06	1.105***	0.817***	0.652***	0.452	0.207	0.898**	0.000***
	(0.38)	(0.25)	(0.23)	(0.29)	(0.23)	(0.44)	
1991:07 - 1999:12	2.173***	1.065***	0.793**	0.809**	0.615**	1.557**	0.021**
	(0.65)	(0.41)	(0.40)	(0.39)	(0.30)	(0.71)	
2000:01 - 2009:12	0.235	0.420	0.092	-0.033	-0.128	0.363	0.037**
	(0.70)	(0.45)	(0.38)	(0.58)	(0.47)	(0.85)	
2010:01 - 2016:06	1.047***	1.101***	1.330***	0.730	0.187	0.859*	0.955
	(0.43)	(0.40)	(0.40)	(0.47)	(0.30)	(0.52)	
2000:01 - 2008:08	0.313	0.502	0.077	-0.055	-0.157	0.470	0.018**
	(0.76)	(0.35)	(0.37)	(0.53)	(0.49)	(0.90)	

TABLE 1.23: **Robustness: Industry Specification**

This table reports robustness checks for the panel regression results in the main body of the paper. In particular, the table reports the two main regression specifications (regression specifications 1 and 14 in the main table) for different industry classifications both for manufacturing (Panel A) and services (Panel B). All variables are standardized. Standard errors are clustered at the firm and year level and reported in parentheses. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers stock returns from July 1991 to June 2016.

Panel A: Manufacturing - Alternative Industry Classifications

	Baseline		FF49		SIC1		SIC2		No Ind.	
OFF_{t-1}	-4.64*	-5.73**	-2.60**	-3.79***	-5.68**	-6.77**	-3.72*	-4.29*	-5.61**	-7.46**
	(2.57)	(2.88)	(1.30)	(1.40)	(2.92)	(3.06)	(2.13)	(2.27)	(2.54)	(3.32)
Firm Controls	N	Y	N	Y	N	Y	N	Y	N	Y
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr	Yr
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	39,387	25,194	39,387	25,194	39,387	25,194	39,387	25,194	39,387	25,194
R^2	10.26	11.23	12.44	14.07	6.79	8.75	10.16	11.80	6.46	8.10

Panel B: Services - Alternative Industry Classifications

	Baseline		FF49		SIC1		SIC2		No Ind.	
OFF_{t-1}	-1.98*	-0.96	-0.90	-0.25	-1.91	-0.49	-1.34	-0.25	-2.64*	-1.74
	(1.21)	(1.31)	(1.04)	(1.14)	(1.25)	(1.26)	(1.33)	(1.46)	(1.46)	(1.44)
Firm Controls	N	Y	N	Y	N	Y	N	Y	N	Y
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind	Yr	Yr
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	33,824	19,912	33,824	19,912	33,824	19,912	33,824	19,912	33,824	19,912
R^2	8.69	11.51	10.41	13.54	8.44	11.16	10.65	13.72	5.28	7.51

Table 1.24: **Double-Sorts: Offshorability and China's Import Penetration**

Panel A reports equal- and value-weighted excess returns conditionally double-sorted on import penetration from China and offshorability. In any given month, stocks are first sorted into three portfolios based on their industry import penetration from China and then into five portfolios based on industry offshorability. Import penetration from China is calculated as in Bernard, Jensen, and Schott (2006a). Due to data availability import penetration can only be calculated until 2011. See appendix for more details on the calculation of import penetration. The split into low (1), medium (2) and high (3) import penetration industries is based on import penetration terciles calculated each year. Offshorability is lagged 18 months. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). The sample includes manufacturing firms from 1991 to 2011. Panel B tabulates conditional panel regression results identical to the ones in table 9 of the main paper. Low IP (High IP) refers to regressions based on firms that belong to industries with import penetration below (above) the median. For each group, results for regression specifications 1 and 10 are reported. All variables are standardized. Standard errors are clustered at the firm and year level and reported in parentheses. R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%.

Panel A: Return Double Sorts

Equal-weighted Returns

		Offshorability					
		L	2	3	4	H	L-H
Imp Penetration	1	1.010***	0.914***	0.752***	0.445	0.408	0.602
		(0.33)	(0.39)	(0.30)	(0.46)	(0.27)	(0.43)
	2	1.134***	0.896**	0.778**	0.436	0.188	0.945
		(0.41)	(0.45)	(0.37)	(0.39)	(0.44)	(0.60)
	3	1.475***	1.184***	0.975	0.036	-0.135	1.610***
		(0.47)	(0.46)	(0.73)	(0.39)	(0.47)	(0.66)

Value-weighted Returns

		Offshorability					
		L	2	3	4	H	L-H
Imp Penetration	1	0.805***	0.662**	0.621***	0.461	0.581**	0.224
		(0.28)	(0.30)	(0.26)	(0.43)	(0.28)	(0.39)
	2	0.925***	1.111**	0.812***	0.264	-0.168	1.093*
		(0.35)	(0.48)	(0.32)	(0.36)	(0.48)	(0.59)
	3	1.481***	0.875	1.319*	-0.175	0.021	1.460**
		(0.42)	(0.56)	(0.74)	(0.39)	(0.46)	(0.62)

Panel B: Conditional Panel Regressions

	Low IP	Low IP	High IP	High IP
OFF_{t-1}	-1.84	-2.95	-4.77*	-5.82*
	(2.58)	(1.96)	(2.57)	(3.18)
Firm Control	N	Y	N	Y
Fixed Effects	Yr x Ind	Yr x Ind	Yr x Ind	Yr x Ind
Clustered by	Yr & ID	Yr & ID	Yr & ID	Yr & ID
N	18,661	11,476	16,881	11,100
R^2 (%)	10.74	12.55	10.75	12.62

Table 1.25: **Manufacturing - Offshorability and SC Betas**

This table replicates the findings of Barrot, Loualiche, and Sauvagnat (2017). Panel A reports mean excess returns and Sharpe ratios for portfolios sorted on shipping costs. The remaining table reports time-series regression results with equal-weighted (Panel B) and value-weighted (Panel C) portfolios returns as dependent variables. The portfolios are sorted on $Offshorability$ which is lagged by 18 months. The long-short shipping costs portfolio (L-H from Panel A), SC, is the only independent variable in all regressions. Returns are at a monthly frequency. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers returns of manufacturing industries from July 1991 to June 2016.

Panel A: Portfolio Sorts

	Shipping Cost Portfolios					
	L	2	3	4	H	L-H
Mean Excess Retrun (%)	1.517***	1.209***	1.144***	1.100**	0.878*	0.639**
Sharpe Ratio	0.62	0.58	0.59	0.59	0.57	0.48

Panel B: Equal-Weighted Returns

	Offshorability					
	L	2	3	4	H	L-H
Alpha (%)	1.009***	0.919***	0.888***	0.327	0.055	0.954***
	(0.35)	(0.32)	(0.29)	(0.34)	(0.28)	(0.23)
SC Beta	0.189***	0.044	0.085	0.091	0.073	0.116
	(0.06)	(0.06)	(0.08)	(0.08)	(0.07)	(0.08)
R^2 (%)	4.22	0.04	0.98	0.79	0.75	3.32

Panel C: Value-Weighted Returns

	Offshorability					
	L	2	3	4	H	L-H
Alpha (%)	1.047***	0.600**	0.681***	0.295	-0.078	1.125***
	(0.29)	(0.26)	(0.21)	(0.34)	(0.29)	(0.32)
SC Beta	0.317***	0.021	0.085	0.258***	0.185*	0.132
	(0.05)	(0.05)	(0.08)	(0.10)	(0.10)	(0.13)
R^2 (%)	13.58	0.24	1.72	7.35	5.94	2.07

Table 1.26: **Manufacturing - Offshorability and FX Betas**

This table reports regression results of two factor models based on the US market excess return and three different currency factors, respectively. I use the currency factor (excess return of high interest rate currencies minus low interest rate currencies) from Lustig, Roussanov, and Verdelhan (2011) in Panel A, the carry factor from Verdelhan (2017) in Panel B and the dollar factor from Verdelhan (2017) in Panel C. Each model is estimated for equal-weighted (columns 2-7) and value-weighted (columns 8-13) portfolio returns. Monthly α estimates are expressed in percent. $Offshorability$ is lagged by 18 months. Returns are at a monthly frequency. Standard errors reported in parentheses are adjusted for heteroscedasticity and autocorrelation (Newey-West). R^2 is adjusted for degrees of freedom. Significance levels are denoted by * = 10%, ** = 5%, and *** = 1%. The sample covers returns of manufacturing industries from July 1991 to June 2016.

	Equal-Weighted Returns						Value-Weighted Returns					
	L	2	3	4	H	L-H	L	2	3	4	H	L-H
Panel A: Currency Factor - Lustig, Roussanov and Verdelhan (2011)												
Alpha (%)	0.406**	0.330*	0.338**	-0.321*	-0.345**	0.751***	0.623***	0.101	0.418***	-0.323*	-0.532***	1.155***
	(0.19)	(0.19)	(0.17)	(0.18)	(0.17)	(0.23)	(0.22)	(0.18)	(0.15)	(0.19)	(0.19)	(0.35)
MKT Beta	1.109***	1.029***	0.907***	1.102***	0.811***	0.298***	0.937***	0.787***	0.612***	1.118***	0.868***	0.070
	(0.07)	(0.07)	(0.05)	(0.06)	(0.04)	(0.07)	(0.06)	(0.05)	(0.05)	(0.08)	(0.08)	(0.12)
FX Beta	0.050	-0.031	0.059	-0.036	-0.031	0.081	0.062	0.000	-0.068	0.088	0.019	0.043
	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.09)	(0.09)	(0.07)	(0.06)	(0.08)	(0.08)	(0.13)
R^2 (%)	70.63	70.00	68.11	71.72	61.87	11.45	54.56	60.95	47.61	65.12	59.48	0.53
Panel B: Carry Factor - Verdelhan (2017)												
Alpha (%)	0.592***	0.401**	0.427	-0.210	-0.251	0.843***	0.785***	0.140	0.184	-0.182	-0.469*	1.255***
	(0.23)	(0.21)	(0.20)	(0.21)	(0.18)	(0.28)	(0.26)	(0.20)	(0.19)	(0.23)	(0.25)	(0.43)
MKT Beta	1.093***	0.988***	0.868***	1.092***	0.799***	0.294***	0.953***	0.761***	0.593***	1.119***	0.888***	0.064
	(0.07)	(0.07)	(0.05)	(0.07)	(0.04)	(0.07)	(0.07)	(0.06)	(0.05)	(0.09)	(0.09)	(0.13)
Carry Beta	-0.014	0.008	-0.119	0.018	-0.033	0.019	0.017	-0.004	0.068	-0.106	-0.072	0.089
	(0.08)	(0.08)	(0.07)	(0.07)	(0.07)	(0.09)	(0.11)	(0.08)	(0.06)	(0.09)	(0.09)	(0.15)
R^2 (%)	68.61	67.67	67.57	71.50	62.02	9.29	51.87	58.07	46.25	63.64	59.09	0.44
Panel C: Dollar Factor - Verdelhan (2017)												
Alpha (%)	0.602***	0.416**	0.386**	-0.200	-0.269	0.871***	0.795***	0.147	0.208	-0.230	-0.501**	1.296***
	(0.22)	(0.21)	(0.20)	(0.21)	(0.18)	(0.27)	(0.26)	(0.21)	(0.18)	(0.23)	(0.24)	(0.42)
MKT Beta	1.059***	0.957***	0.875***	1.082***	0.818***	0.241***	0.941***	0.740***	0.588***	1.152***	0.910***	0.031
	(0.07)	(0.07)	(0.05)	(0.06)	(0.04)	(0.07)	(0.07)	(0.06)	(0.05)	(0.09)	(0.08)	(0.13)
USD Beta	-0.287***	-0.230	-0.129	-0.051	0.098	-0.385***	-0.065	-0.167	0.062	0.099	0.062	-0.127
	(0.11)	(0.15)	(0.09)	(0.12)	(0.11)	(0.13)	(0.16)	(0.10)	(0.10)	(0.12)	(0.11)	(0.21)
R^2 (%)	69.30	68.21	67.40	71.52	62.12	11.85	51.90	58.48	46.14	63.53	59.01	0.41

TABLE 1.27: **Low-wage Countries**

This table lists the low-wage countries. I follow Bernard, Jensen, and Schott (2006a) and define a country as low-wage in year t if its per capita GDP is less than 5% of U.S. per capita GDP.

Afghanistan	China	India	Pakistan
Albania	Comoros	Kenya	Rwanda
Angola	Congo	Lao PDR	Samoa
Armenia	Equitorial Guinea	Lesotho	Sao Tome
Azerbaijan	Eritrea	Madagascar	Sierra Leone
Bangladesh	Ethiopia	Malawi	Somalia
Benin	Gambia	Maldives	Sri Lanka
Bhutan	Georgia	Mali	St. Vincent
Burkina Faso	Ghana	Mauritania	Sudan
Burundi	Guinea	Moldova	Togo
Cambodia	Guinea-Bissau	Mozambique	Uganda
Central African Rep	Guyana	Nepal	Vietnam
Chad	Haiti	Niger	Yemen

1.8.4 Model

1.8.4.1 Demand Side

1st Layer - Sector Demand

In the first layer, households decide how to optimally allocate consumption between homogenous and differentiated goods:

$$\max c_0^{1-a_0} C_T^{a_0}, \text{ s.t. } P_T C_T + p_0 c_0 \leq Y,$$

where C_T is the consumption index aggregated from consumption in the S industries consisting of differentiated goods, P_T is the corresponding price index, c_0 and p_0 are the consumption and price of the homogenous good, and Y is the total income of consumers. First-order conditions imply the following demand functions and the aggregate price index, P:

$$\begin{aligned} c_0 &= (1-a_0)\frac{PC}{p_0} \\ C_T &= a_0\frac{PC}{P_T} \\ P &= \left(\frac{P_T}{a_0}\right)^{a_0}\left(\frac{p_0}{1-a_0}\right)^{1-a_0} \end{aligned}$$

The good 0 is produced under constant returns to scale and a production function that is linear in labor.[83] Moreover, the good is freely traded and used as a numeraire in each country. Its price is set to 1.[84] Consequently, productivity changes across countries can be interpreted as real productivity changes.

2nd Layer - Industry Demand

The aggregation over industry consumption is constant elasticity of substitution with elasticity θ. The optimization problem is as follows:

$$\max \left[\sum_s \delta_s^{\frac{1}{\theta}} C_s^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \text{ s.t. } \sum_s P_s C_s \leq P_T C_T,$$

where P_s are industry price levels and η_s are industry taste parameters such that $\sum_s \eta_s = 1$. First-order conditions imply demand functions and price indices:

$$\begin{aligned} C_s &= \delta_s \left(\frac{P_s}{P_T} \right)^{-\theta} C_T \\ P_T &= \left[\sum_s \delta_s P_s^{1-\theta} \right]^{\frac{1}{1-\theta}} \end{aligned}$$

3rd Layer - Product Demand

Demand for the product variety, ω, produced by firms:

$$c_s(\varphi) = \left(\frac{p_s(\varphi)}{P_s} \right)^{-\sigma_s} C_s$$

Price index in industry s:

$$P_s = \left[\int_{\Omega_s} p_s(\varphi)^{1-\sigma_s} d\varphi \right]^{\frac{1}{1-\sigma_s}}$$

[83] In other words, one unit of labor produces one unit of good 0.

[84] This normalization also leads to wages being equal to 1 in both countries.

1.8.4.2 Aggregation - Western Firms

Domestic Production

The fraction of firms that choose not to offshore is:

$$\zeta_{s,D} = Prob\{\varphi < \varphi_{s,O}\} = G(\varphi_{s,O}) = 1 - \left(\frac{\varphi_{s,O}}{\varphi_{min}}\right)^{-\kappa_s}$$

The average productivity of firms with productivity higher than the minimum productivity $\varphi_{s,min}$ but lower than the cutoff value $\varphi_{s,O}$ is equal to:

$$\bar{\varphi}_{s,D} = \left[\frac{\int_{\varphi_{s,min}}^{\varphi_{s,O}} \varphi^{\sigma_s-1} dG_s(\varphi)}{G(\varphi_{s,O})}\right]^{\frac{1}{\sigma_s-1}} = \nu_s \left[\frac{\varphi_{min}^{\sigma_s-1} - \varphi_{min}^{\kappa_s}\varphi_{s,O}^{(\sigma_s-1)-k_s}}{1-\left(\frac{\varphi_{s,min}}{\varphi_{s,O}}\right)^{k_s}}\right]^{\frac{1}{\sigma_s-1}}$$

where $\nu_s = \left[\frac{\kappa_s}{k_s-(\sigma_s-1)}\right]^{\frac{1}{\sigma_s-1}}$.

Partially Offshored Firms

The fraction of firms that choose to offshore is:

$$\zeta_{s,O} = Prob\{\varphi > \varphi_{s,O}\} = 1 - G(\varphi_{s,O}) = \left(\frac{\varphi_{s,O}}{\varphi_{s,min}}\right)^{-\kappa_s}$$

The average productivity of firms with productivity higher than cutoff value $\varphi_{s,O}$ is equal to:

$$\bar{\varphi}_{s,O} = \left[\frac{\int_{\varphi_{s,O}}^{\infty} \varphi^{\sigma_s-1} dG_s(\varphi)}{1-G(\varphi_{s,O})}\right]^{\frac{1}{\sigma_s-1}} = \nu_s\varphi_{s,O}$$

Export: Partially Offshored Firms

This is the relevant case for firms with headquarter in the West. The average productivity of firms with productivity higher than the cutoff $\varphi_{s,X,O}$ is equal to:

$$\bar{\varphi}_{s,X,O} = \left[\frac{\int_{\varphi_{s,X,O}}^{\infty} \varphi^{\sigma_s-1} dG_s(\varphi)}{1-G(\varphi_{s,X,O})}\right]^{\frac{1}{\sigma_s-1}} = \nu_s\varphi_{s,X,O}$$

The fraction of firms that choose to offshore is:

$$\zeta_{s,X,O} = Prob\{\varphi > \varphi_{s,X,O}\} = 1 - G(\varphi_{s,X,O}) = \left(\frac{\varphi_{s,X,O}}{\varphi_{s,min}}\right)^{-\kappa_s}$$

1.8.4.3 Aggregation - Eastern Firms

Domestic Production

All firms engage in domestic production. Hence, the fraction is equal to 1. The average productivity of firms with productivity higher than the minimum productivity $\varphi_{s,min}$ but lower than the cutoff value $\varphi_{s,O}$ is equal to:

$$\bar{\varphi}^{\star}_{s,D} = \left[\int_{\varphi^{\star}_{s,min}}^{\infty} \varphi^{\sigma_s - 1} dG_s(\varphi) \right]^{\frac{1}{\sigma_s - 1}} = \nu_s \varphi^{\star}_{s,min}$$

Export: Purely Domestic Firms

The fraction of firms that choose to export is:

$$\zeta^{\star}_{s,X,D} = Prob\{\varphi > \varphi^{\star}_{s,X,D}\} = 1 - G(\varphi^{\star}_{s,X,D}) = \left(\frac{\varphi^{\star}_{s,X,D}}{\varphi^{\star}_{s,min}} \right)^{-\kappa_s}$$

The average productivity of firms with productivity higher than the cutoff $\varphi^{\star}_{s,X,D}$ is equal to:

$$\bar{\varphi}^{\star}_{s,X,D} = \left[\frac{\int_{\varphi^{\star}_{s,X,D}}^{\infty} \varphi^{\sigma_s - 1} dG_s(\varphi)}{1 - G(\varphi^{\star}_{s,X,D})} \right]^{\frac{1}{\sigma_s - 1}} = \nu_s \varphi^{\star}_{s,X,D}$$

1.8.4.4 Model Extension: International Bond Trading

In this section, I allow for international sovereign bond trading as in Ghironi and Melitz (2005). Allowing for bond trading is an important model extension because it allows model households to smooth consumption intertemporally. In addition, introducing bonds allows one to study current accounts for the two countries in the model.

Households can trade bonds domestically and internationally. Western (Eastern) bonds are issued by Western (Eastern) households and denominated in Western (Eastern) currency. Hence, bonds issued by each country provide a risk-free real return in units of that country's consumption basket. International asset markets, however, are incomplete, as only risk-free bonds are traded across countries. This would imply indeterminacy of steady-state net foreign assets and non-stationarity. As a remedy, I assume that agents must pay a convex adjustment cost when adjusting their bond holdings, which can be interpreted as a fee paid to financial intermediaries. This is sufficient to uniquely pin down the steady state, and it leads to stationary dynamics of responses to shocks.

Additional Model Equations

Bond trading affects the households' budget constraints, which become

$$\begin{aligned}
P_t Q_{D,t+1} + P_t F_t Q_{X,t+1} + P_t \frac{\xi}{2} Q_{D,t+1}^2 + P_t \frac{\xi}{2} F_t Q_{X,t+1}^2 + P_t C_t \\
\leq (1 + r_{f,t}) P_t Q_{D,t} + (1 + r_{f,t}^\star) F_t P_t Q_{X,t+1} + T_t^f + \Pi_t(\alpha) \\
P_t^\star Q_{D,t+1}^\star + P_t^\star \frac{Q_{X,t+1}^\star}{F_t} + P_t^\star \frac{\xi}{2} \left(Q_{D,t+1}^\star\right)^2 + P_t^\star \frac{\xi}{2} \frac{\left(Q_{X,t+1}^\star\right)^2}{F_t} + P_t^\star C_t^\star \\
\leq (1 + r_{f,t}^\star) P_t^\star Q_{D,t}^\star + (1 + r_{f,t}) P_t^\star \frac{Q_{X,t+1}^\star}{F_t} + T_t^{\star,f} + \Pi_t^\star(\alpha),
\end{aligned}$$

where $F_t = \frac{P_t^\star}{P_t}$ denotes the real exchange rate, $Q_{D,t+1}$ ($Q_{X,t+1}$) denote Western households' bond holdings of the Western (Eastern) bond, $(\xi/2)\, Q_{D,t+1}^2$ is the cost of adjusting holdings of the Western bonds, $(\xi/2)\, F_t Q_{X,t+1}^2$ is the cost of adjusting holdings of the Eastern bonds and T_t^f is the fee rebate, taken as given by the household (note $T_t^f = (\xi/2) \left[F_t Q_{X,t+1}^2 + F_t Q_{X,t+1}^2\right]$ in equilibrium). Symmetry implies analogous equations for Eastern quantities. For simplicity, I assume that the cost parameter ξ is identical for Western and Eastern bonds and set it to a value of 0.0025, as in Ghironi and Melitz (2005).

Western and Eastern households maximize their respective intertemporal utility functions subject to the respective constraints. Taking first-order conditions leads to two Euler equations for the risk-free rate in each country:

$$\begin{aligned}
1 + \xi Q_{D,t+1} &= (1 + r_{f,t+1})\, \mathbb{E}\left[M_{t,t+1}\right] \\
1 + \xi Q_{X,t+1} &= \left(1 + r_{f,t+1}^\star\right) \mathbb{E}\left[M_{t,t+1} \frac{F_{t+1}}{F_t}\right] \\
1 + \xi Q_{D,t+1}^\star &= \left(1 + r_{f,t+1}^\star\right) \mathbb{E}\left[M_{t,t+1}^\star\right] \\
1 + \xi Q_{X,t+1}^\star &= (1 + r_{f,t+1})\, \mathbb{E}\left[M_{t,t+1}^\star \frac{F_t}{F_{t+1}}\right]
\end{aligned}$$

The terms related to the stock of bonds on the left-hand side of the Euler equations are key for determinacy of the steady state and model stationarity. Basically, they ensure that zero holdings of bonds are the unique steady state in which the product of the SDF and the gross interest rate equals one in each country such that the economy returns to this initial position after temporary shocks.

Moreover, equilibrium requires that Western and Eastern bonds be in global zero net supply:

$$
\begin{aligned}
Q_{D,t+1} + Q^{\star}_{X,t+1} &= 0 \\
Q^{\star}_{D,t+1} + Q_{X,t+1} &= 0
\end{aligned}
$$

Lastly, current accounts can be introduced to the model. Current accounts are, by definition, equal to the changes in aggregate bond holdings in the two countries:

$$
\begin{aligned}
CA_t &= Q_{D,t+1} - Q_{D,t} + F_t \left(Q_{X,t+1} - Q_{X,t} \right) \\
CA^{\star}_t &= Q^{\star}_{D,t+1} - Q^{\star}_{D,t} + \frac{Q^{\star}_{X,t+1} - Q^{\star}_{X,t}}{F_t}
\end{aligned}
$$

The global zero net supply conditions for the bond market imply that a country's borrowing must equal the other country's lending, $CA_t + F_t CA^{\star}_t = 0$.

Table 1.28 reports the results for model simulations with international bond trading. Not surprisingly, the standard deviation of consumption decreases compared to the baseline model, as bonds allow households to smooth their consumption intertemporally. This also leads to a lower overall risk premium, which can be seen from the lower mean of industry excess returns. Importantly, however, the L-H spread is unaffected by the introduction of international bond trading. Effectively, trading risk-free bonds allows households to transfer consumption across time in a state- and industry-independent manner, which does not help mitigate industry-specific exposure to aggregate shocks.

Similar to table 1.15, Panels C and D of table 1.28 report the moments related to the two shocks in the model. Also, after introducing bond trading to the model, shocks to $A^{\star}$ make up for roughly 88% of the L-H spread.

Finally, the model with sovereign bonds allows one to examine how productivity shocks affect the balance of current accounts in each country. Figure 1.14 reports impulse response functions of CA_t and $CA^{\star}_t$ to productivity shocks in the West (first row) and East (second row). As in Ghironi and Melitz (2005), positive productivity shocks in the East (West) are associated with increases (decreases) in consumption, which leads to a current account surplus (deficit) in the East and a current account deficit (surplus) in the West.

1.8.4.5 Elasticities

Elasticities related to total, sector and industry consumption:

$$\begin{aligned}
\eta^{\star}(C) &= -\eta^{\star}(P) + \frac{\Pi}{L+\Pi}\eta^{\star}(\Pi) \\
\eta^{\star}(C_T) &= \eta^{\star}(C) - (1-a_0)\,\eta^{\star}(P_T) = \eta^{\star}(C) - \left(\frac{1}{a_0} - 1\right)\eta^{\star}(P) \\
\eta^{\star}(C_s) &= -\theta\eta^{\star}(P_s) + \theta\eta^{\star}(P_T) + \eta^{\star}(C_T) = -\theta\eta^{\star}(P_s) + \eta^{\star}(C) + [\theta - (1-a_0)]\,\eta^{\star}(P_T)
\end{aligned}$$

Elasticities related to total and sector price indices:

$$\begin{aligned}
\eta^{\star}(P) &= a_0\eta^{\star}(P_T) \\
\eta^{\star}(P_T) &= \sum_S \delta_s \left(\frac{P_T}{P_s}\right)^{\theta-1} \eta^{\star}(P_s)
\end{aligned}$$

Elasticities related to offshoring and exporting cutoffs and fractions:

$$\begin{aligned}
\eta^{\star}(\zeta_{s,O}) &= -\kappa_s\eta^{\star}(\varphi_{s,O}) \\
\eta^{\star}(\bar{\varphi}_{s,O}) &= \eta^{\star}(\varphi_{s,O}) \\
\eta^{\star}(\zeta_{s,X,O}) &= -\kappa_s\eta^{\star}(\varphi_{s,X,O}) \\
\eta^{\star}(\bar{\varphi}_{s,X,O}) &= \eta^{\star}(\varphi_{s,X,O})
\end{aligned}$$

The elasticity of total industry profits is driven by the elasticities of domestic profits and profits from exports:

$$\eta^{\star}(\Pi) = \eta^{\star}\left(\Pi^D\right) + \eta^{\star}\left(\Pi^X\right)$$

Elasticity of total domestic profits:

$$\begin{aligned}
\eta^{\star}\left(\Pi^D\right) = {} & \underbrace{-(\sigma_s - \theta)\left(-\eta^{\star}(P_s)\right)}_{\text{competition effect}} + \underbrace{\eta^{\star}(C_s) + \frac{1-a_0-\theta}{a_0}\left(-\eta^{\star}(P)\right)}_{\text{expenditure effect}} + \\
& \left[\underbrace{\kappa_s \frac{\zeta_{s,O}\left(\pi_{s,O} - \pi_{s,D}\right)}{\Pi^D}}_{\text{relative benefits from offshoring}} - \underbrace{(\sigma_s - 1)\frac{\zeta_{s,D}\pi_{s,D}\Phi + \zeta_{s,O}\pi_{s,O}}{\Pi^D}}_{\text{industry composition effect}}\right]\left(-\eta^{\star}(\varphi_{s,O})\right) + \\
& \underbrace{\frac{\zeta_{s,O}\pi_{s,O}}{\Pi^D}(\sigma_s - 1)(1-\alpha_s)}_{\text{productivity gain from offshoring}}
\end{aligned}$$

where

$$\Phi = \frac{\varphi_{s,min}^{\kappa_s}}{\sigma_s - 1} \left[\frac{\varphi_{s,O}^{\sigma_s - \kappa_s} \left[\kappa_s - (\sigma_s - 1)\right]}{\varphi_{s,min}^{\sigma_s - 1} - \varphi_{s,min}^{\kappa_s} \frac{1}{\varphi_{s,O}^{\kappa_s - (\sigma_s - 1)}}} - \frac{\kappa_s}{\varphi_{s,O}^{\kappa_s} - \varphi_{s,min}^{\kappa_s}} \right]$$

and $\Phi > 0$ and $\frac{\partial \Phi}{\partial \varphi_{s,O}} > 0$. This means that the negative response of domestic profits after a shock to $A^\star$ is more pronounced when fewer firms offshore. This result is intuitive, since firms that offshore directly profit from the increase in productivity, which makes them more resistant against increases in competition.

Elasticity of total profits from exports:

$$\eta^\star\left(\Pi^X\right) = \underbrace{-\sigma_s \left[1 + \frac{\kappa_s - (\sigma_s - 1)}{\sigma_s - 1}\right] \left[-\eta^\star\left(P_s^\star\right)\right]}_{\text{price effect}} + \underbrace{\left[1 + \frac{\kappa_s - (\sigma_s - 1)}{\sigma_s - 1}\right] \eta^\star\left(C_s^\star\right)}_{\text{demand effect}}$$
$$+ \underbrace{\left(1 - \alpha_s\right) \kappa_s}_{\text{productivity gain from offshoring}}$$

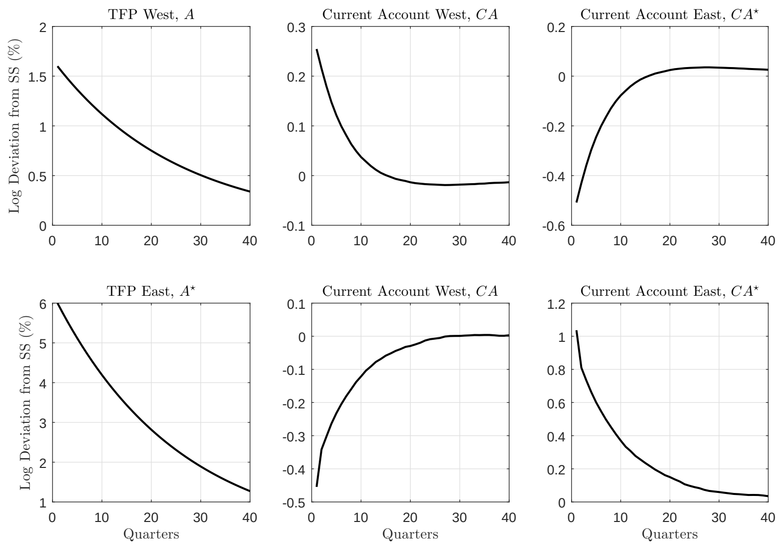


FIGURE 1.14: **Responses of Current Accounts**

This figure plots the impulse response functions of current accounts CA_t and $CA_t^\star$ to productivity shocks in the West (first row) and East (second row).

Table 1.28: **Model Simulation Results with International Bond Trading**

The table reports simulated moments of macro variables and industry quantities for the extended model with international bond trading. Column titles "Low" and "High" label low and high offshorability industries. The model is solved using perturbation methods and is approximated to the 3rd-order around the deterministic steady state. Moments are calculated based on simulations over 10'000 periods (with a burn-in period of 1'000 periods).

	Macro Moments				Industry Quantities			
	Consumption		Risk-free Rate		Industry Profits		Excess Returns	
	model	data	model	data	model	data	model	data
mean			4.59%	2.63%	0.28	0.32	4.59%	1.64%
std	8.43%	2.00%	0.29%	2.12%	8.10%	3.72%	14.98%	7.24%
cov(,A)					0.24	0.12	0.07	0.02
cov(,$A^{\star}$)					-1.74	-0.80	-0.88	-0.30
cov(,C)					0.64	0.28	0.06	0.02

Chapter 2

Level and Volatility Shocks to Fiscal Policy: Term Structure Implications

Lorenzo Bretscher, Alex Hsu, Andrea Tamoni [1]

2.1 Introduction

Fiscal policy shocks and fiscal volatility shocks have first order effects on economic activity. Government spending and taxation can impact corporate investment-borrowing choices, household consumption-saving behavior, and economic aggregates such as inflation. The study of fiscal policy commands a large area of literature in economics.[2] The majority of papers focuses on optimal taxation or government spending and its impact on the output multiplier or consumption. Similarly, uncertainty about government spending and tax rates can alter the decision-making process faced by economic agents and firms. Bloom (2009) finds productivity uncertainty shocks produce large fluctuations in aggregate output and employment. More recently, Fernández-Villaverde,

[1]We thank M. Andreasen, R. Barsky, R. Dittmar, F. Gourio, Haitao Li, H. Kung (discussant), P. Lopez, D. J. Lucas, I. Mitra (discussant), F. Palomino (discussant), G. Segal (discussant), and Min Wei (discussant) for their helpful suggestions. We also thank seminar participants at Carey-JHU, EDHEC London, LSE, at the Annual Symposium of the Society for Nonlinear Dynamics and Econometrics, at the Econometric Society European Meeting - Lisbon, at the EFA - Mannheim, at the NFA - Halifax, at the South Carolina FIFI Conference, at the SFS Cavalcade - Nashville and at the WFA - Whistler. We also thank Mike Chernov and Philippe Mueller for sharing their data on real yields.

[2]Papers in this field is too numerous to list. See Barro (1974), Aschauer (1985), Aiyagari, Christiano, and Eichenbaum (1992), Baxter and King (1993), Ramey and Shapiro (1998), Gali, Valles, and Lopez-Salido (2007), Christiano, Eichenbaum, and Rebelo (2011) for equilibrium examples.

Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) show that unexpected increase in the return on capital tax rate uncertainty has strong negative impact on output.[3]

The link between fiscal policy and policy uncertainty with the term structure of interest rates, on the other hand, is less well established. Dai and Philippon (2005) provide empirical evidence of fiscal deficits driving nominal yield curve dynamics in a no-arbitrage affine macro-finance model, but the model does not accommodate endogenous inflation, which Piazzesi and Schneider (2007) document to be the main risk factor in generating bond risk premia.[4] Furthermore, given that monetary policy was at the zero lower bound (ZLB) until recently and the high political uncertainty in the U.S., the impact of fiscal level and volatility shocks on bond risk premia has never been more relevant. In this paper, we estimate a dynamic stochastic general equilibrium (DSGE) model to investigate the effects of fiscal policy and policy uncertainty on the term structure of interest rates and bond risk premia. We focus on two specific aspects of fiscal policy: government spending and the tax rate on the return of capital.

Through the lens of the estimated model, we document four main findings in this paper. First, level shocks to government spending generate positive inflation risk premium as inflation is high precisely when consumption declines. This term structure level effect is the opposite for level and volatility shocks to the return on capital tax rate: inflation decreases in bad times producing negative inflation risk premium. Second, volatility shocks to government spending are observed to have substantial slope effect on the term structure. Increased volatility to government spending steepens the yield curve, producing positive term premium. Third, fiscal volatility shocks are the primary factors in generating term premia fluctuations. Fourth, when the nominal short rate is at zero, consumption, inflation, and long-term interest rate reactions are more pronounced following level and volatility shocks to fiscal policy, implying considerable bond risk premia.

In reduced form empirical analysis, excess return predictive regressions are performed for nominal bonds across maturities employing estimated fiscal level and volatility shocks as explanatory variables as well as controlling for bond supply. We document government spending level and volatility shocks predict positive future excess returns, while capital tax level and volatility shocks weakly predict negative excess returns. Furthermore, the

[3]Following the literature (see e.g., (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015)) we interpret the unexpected changes in the time-varying volatility of the fiscal instrument (e.g. government expenditure) innovations as a representation of unexpected variations in uncertainty about fiscal policy. We also use the term "uncertainty" as shorthand for what would more precisely be referred to as "risk". See also Bachmann, Bai, Lee, and Zhang (2015) where the authors quantify the welfare costs of fiscal uncertainty in a neo-classical stochastic growth model.

[4]For the purpose of exposition, "bond risk premia" and "nominal term premia" are used interchangeably to denote a combination of "inflation risk premia" (term structure level effect) and "real term premia" (slope effect).

government spending volatility shock dominates the other fiscal shocks in terms of return predictability in the regression specification when all four fiscal shocks are included. Model implied predictive regressions using simulated data are able to replicate these findings, further validating the performance of the estimated model.

The theoretical analysis is conducted in a general equilibrium model with production. Ricardian equivalence in the model is disrupted by introducing distortionary taxation for return on capital. The representative agent has Epstein and Zin (1989) recursive preferences. The production sector is in line with the standard New-Keynesian[5] stochastic growth model. The production function is Cobb-Douglas employing transitory TFP shocks and permanent labor productivity shocks. The monetary authority sets the nominal short-term interest rate using a Taylor rule with contemporaneous feedbacks from inflation and output growth plus a shock which represents any unexpected deviations of the nominal short rate. The fiscal authority chooses the amount of current period lump-sum taxes to collect. Government revenue is a combination of the lump-sum transfer and tax on the return of capital such that the government budget constraint is satisfied. Government spending is exogenous and shocks to government spending exhibits stochastic volatility following an autoregressive process.

There are eight economic shocks driving the dynamics of the theoretical model: transitory and permanent productivity shocks, volatility shocks to transitory productivity, monetary policy shocks, as well as level and volatility shocks to government spending and the tax rate of return on capital. Since the impact of both productivity shocks and monetary policy shocks have been examined in the equilibrium term structure literature, our analysis is centered on the four fiscal shocks.[6]

A positive level shock to government spending drives up demand of output, and it also crowds out consumption of the agents. The negative wealth effect of lower consumption increases labor supply and depresses real wage. The precautionary savings motive also drives investment higher. Increase in return on capital generates a spike in inflation immediately after the positive level shock is realized, producing positive average inflation risk premium. On the other hand, a positive shock to government spending volatility lowers government debt and inflation in our benchmark model. Increase in spending volatility makes capital investment more attractive over debt for consumption smoothing because government spending is expected to be high, implying higher future taxes. The oversupply of capital causes the return on capital to decline, while increase in labor supply puts downward pressure on real wage. This leads to lower inflation as marginal

[5]The intermediate-good firms adjust prices according to the Calvo (1983) process, under which only a fraction of the firms are allowed to maximize present value of their expected profits by choosing the optimal price each period. This mechanism induces monetary policy non-neutrality with respect to the real economy allowing us to make comparisons between fiscal policy and monetary policy impacts.

[6]For example, see Rudebusch and Swanson (2012), Kung (2015), and Hsu, Li, and Palomino (2015).

cost of production decreases, generating negative average inflation risk premium due to government spending volatility shocks.

That said, government spending volatility shocks have differential impact on short-maturity and long-maturity bonds. With higher uncertainty, the decline in real wage and return on capital are transitory, and the increase in investment and saving are short-lived. This makes short-maturity government bonds especially valuable as a consumption hedge relative to long-maturity Treasuries. Short-dated bonds become more expensive compared to the long-dated bonds causing long-term bonds to be risky when marginal utility is high. As a result, the spending volatility shock steepens the yield curve and generates positive term premium. From the impulse response functions of the model, we find the positive term premium dominates the negative inflation risk premium such that the nominal term premium is positive on average following a positive second moment shock to spending.

We solve the model using perturbation methods (see Schmitt-Grohe and Uribe (2004)). We compute a third-order approximate solution[7] of the model around its non-stochastic steady state using the pruning algorithm suggested by Andreasen, Fernández-Villaverde, and Rubio-Ramírez (2017) (AFVRR hereafter). Importantly, AFVRR provide closed-form solutions for first and second moments of the pruned DSGE model. This allows us to estimate our model using means, variances and contemporaneous covariances of macro and financial series through generalized method of moments (GMM). Last but not least, the impulse response functions in an economy approximated to third order depend on the values of the state variables. Motivated by the situation in the United States following the financial crisis, we analyze the propagation of fiscal level and volatility shocks when the model economy is at the zero lower bound (ZLB). We find that, when the nominal short rate is held at zero for prolonged periods of time after the initial fiscal shocks are realized, the impulse responses of output, investment and inflation are greatly amplified relative to normal times. The effects are especially exaggerated for the government spending volatility shock and the return on capital tax rate level shock. Each of which produces a decline in output of about 10% and a drop in inflation of more than 30%.

This paper belongs to a growing literature examining the relation between government policies, economic activity, and asset prices. The joint modeling of the yield curve and macroeconomic variables has received much attention since Ang and Piazzesi (2003), where the authors connect latent term structure factors to inflation and the output gap. More recently, many term structure studies incorporate monetary policy elements in

[7]A first-order approximation of the model and bond price (i.e., a log-linearization) eliminates the term premium entirely and a second-order approximation to the solution of the model and bond price produces a term premium that is nonzero but constant.

their models using the fact that the nominal short rate is the monetary policy instrument. However, these models are generally silent on the effects of fiscal policy on the term structure despite evidence suggesting that it has nontrivial effects on interest rates. The primary contribution of this paper is establishing the link between fiscal policy and risk premia on nominal bonds, namely the term premium and the inflation risk premium. The model shows loose fiscal policy and high government spending cause investors to demand higher returns in exchange for holding Treasury securities.

This paper is most closely related to the literature on term structure and bond risk premia in equilibrium. Campbell (1986) specifies an endowment economy in which utility maximizing agents trade bonds of different maturities. When the exogenous consumption growth process is negatively autocorrelated, term premia on long-term bonds are positive, generating upward sloping yield curves because they are bad hedges against consumption risk compared to short-term bonds. More recently, Piazzesi and Schneider (2007), using Epstein and Zin (1989) preferences, show that inflation is the driver that generates a positive term premium on nominal long-term bonds. Negative covariance between consumption growth and inflation translates into high inflation when consumption growth is low and marginal utility to consume is high. Wachter (2006) generates upward sloping nominal and real yield curves employing habit formation. In her model, bonds are bad hedges for consumption as agents wish to preserve previous level of consumption as current consumption declines. Campbell, Pflueger, and Viceira (2015) study the effect of monetary policy rule and uncertainty on bond risk premium. They find that intensified monetary policy focus on inflation increases bond risks while a shifting policy focus to stabilize output does the opposite.

Rudebusch and Swanson (2008) and Rudebusch and Swanson (2012) examine bond risk premia in general equilibrium where utility-maximizing agents supply labor to profit-maximizing firms to produce consumption goods. The best-fit model in the latter paper is successful in matching the basic empirical properties of the term structure using only transitory productivity shocks. Palomino (2010) studies optimal monetary policy and bond risk premia in general equilibrium. More specifically, he shows that the welfare-maximizing monetary policy affects inflation risk premia depending on the credibility of the monetary authority in the economy as well as the representative agent's preference. Kung (2015) builds a equilibrium model with stochastic endogenous growth to explain the impact of monetary policy shocks on bond risk premium. Hsu, Li, and Palomino (2015) examine risk premia on real bonds in general equilibrium. Calibrated to TIPS data, they find that productivity growth shocks alone generate negative term premium on real bonds, but the presence of wage rigidities makes term premium positive.

This paper is also related to the literature on the interaction between fiscal policy and asset pricing. Croce, Kung, Nguyen, and Schmid (2012) study the effects of fiscal policies in a production-based general equilibrium model in which taxation affects corporate decisions. They find that tax distortions have negative effects on the cost of equity and investment. Our interest is different. We analyze the impact of government spending level and uncertainty shocks on the term structure of interest rates. Our interest in fiscal volatility shocks is motivated by Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015), who uncover evidence of time-varying volatility in tax and government spending processes for the United States. Using both a VAR and a New Keynesian model, they document that the fiscal volatility shocks can have a sizable adverse effect on economic activity. To the best of our knowledge, our paper is the first attempt to evaluate the dynamic consequences on the bond risk premium due to unexpected changes in fiscal volatility.

The rest of the paper is structured as follows. The next section documents the estimation of the fiscal shocks as well as their impact on bond risk premium using reduced form regression analysis. Section 2.3 introduces the model. Section 2.4 discusses the data used for GMM estimation, presents our solution method and estimation approach. Section 2.5 presents detailed analysis of the model and associated term structure. Section 2.6 studies the implications of fiscal shocks at the ZLB on the model. Section 2.7 concludes. Detailed derivations are deferred to the Appendix.

2.2 Empirical Analysis

In this section we estimate fiscal rules with time-varying volatility using data on taxes and government spending. The estimated rules will discipline our quantitative experiments by assuming that past fiscal behavior is a guide to assessing current behavior. We then present our regression results using bond yields and predicted bond returns as dependent variables to explore their dependence on fiscal shocks.

2.2.1 Fiscal Policy Uncertainty

Our two policy instruments, i.e. government spending as a share of output and tax rates on capital income, evolve as follows:

$$x_{t+1} = (1 - \phi_x)\theta_x + \phi_x x_t + e^{\sigma_{x,t+1}} \epsilon_{x,t+1} \tag{2.1}$$

$$\sigma_{x,t+1} = (1 - \phi_{\sigma_x})\theta_{\sigma_x} + \phi_{\sigma_x} \sigma_{x,t} + \sigma_{\sigma_x} \epsilon_{\sigma,t+1} \tag{2.2}$$

for $x \in \{g, \tau^k\}$ where g is government spending as a share of output, and τ^k is the tax rate on capital income. Each policy instrument features stochastic volatility since the log of the standard deviation of the innovation, $\sigma_{x,t}$, is random. The parameter θ_{σ_x} determines the average standard deviation of a fiscal shock to the policy instrument x, $\frac{\sigma_{\sigma_x}}{\sqrt{(1-(\phi_{\sigma_x})^2)}}$ is the unconditional standard deviation of the fiscal volatility shock to instrument x, and ϕ_{σ_x} controls the shock's persistence. Following (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015), we estimate Eqs. (2.1) and (2.2) for each fiscal instrument separately, and we set the means in equation (2.1) to each instrument's average value (see Table 2.3 Panel A). We estimate the rest of the parameters following a Bayesian approach by combining the likelihood function with uninformative priors and sampling from the posterior with a Markov Chain Monte Carlo.[8] Table 2.3 Panel B reports the posterior median for the parameters along with 95 percent probability intervals. Both tax rates and government spending as a share of output are persistent. E.g., the half-life of government spending is around $-\log(2)/\log(0.98) = 34$ quarters. Deviations from average volatility last also for some time. The $\epsilon_{x,t}$s have an average standard deviation of $100 \times \exp(-4.84) = 0.79$ and $100 \times \exp(-6.03) = 0.24$ percentage point for tax and government spending, respectively. These results are in line with (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) (see in particular their Table 1).

Figure 2.1 allows us to build an analytic narrative of fiscal volatility shocks. Panels 2.2(a) and 2.2(b) display the 95 percent posterior probability intervals of the smoothed fiscal volatility shock to government spending, $100\exp(\sigma_{g,t})$, and capital tax rates, $100\exp(\sigma_{\tau^k,t})$, over the sample. Next, we focus on government spending volatility and refer the interest reader to (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) for a similar analysis of the fiscal volatility shock to capital income tax rates. Our smoothed estimate of the government spending volatility was high in 1974-1975. These were indeed times of unusual fiscal policy uncertainty: for example, in a talk given at Stanford University on May 13, 1975, George P. Shultz (Secretary of the Treasury from June 12, 1972 to May 8, 1974) stated that "This is an age of ambiguity ... And the result is that people are experiencing a great sense of unease and uncertainty."[9] Volatility was climbing again in the early 80s. These years were difficult ones for fiscal policy, with numerous proposals being floated to address the large fiscal deficits created during the early years of the Reagan administration. The 1985 Economic Report of the President made deficit reduction one of the President's priorities, with an emphasis on

[8]Specifically, for government spending we adopt a beta distribution for ϕ_{σ_g} and ϕ_g with mean 0.8 and 0.85 respectively, a uniform distribution between -11 and -3 for θ_{σ_g}, and an inverse gamma for σ_{σ_g} with mean 0.1. Correspondingly, for capital tax we use a beta distribution for $\phi_{\sigma_{\tau^k}}$ and ϕ_{τ^k} with mean 0.85 and 0.8 respectively, a uniform distribution between -8 and -3 for $\theta_{\sigma_{\tau^k}}$, and an inverse gamma for $\sigma_{\sigma_{\tau^k}}$ with mean 0.2.

[9]See "Leaders and Followers in an Age of Uncertainty," George P. Shultz, pp. 26-27.

expenditure control. This event is reflected in a "moderation" of our volatility series. Our fiscal volatility then raises in the period from 2001:II to 2002:I. These quarters witnessed the 9/11 terrorist attacks (with their potentially vast fiscal implications) and the 2001–2002 recession.

2.2.2 Bond Yields, Bond Returns and Fiscal Policy: Basic Tests

Tables 2.1 and 2.2 shows regressions of yield spreads and future returns on our fiscal instruments. Throughout we use the *filtered* series of volatilities to remove any look-ahead bias present in the smoothed estimates.[10] Also, we employ a one-sided filter to remove a decadal trend in the level of fiscal series, and we use the business cycle component of government spending and capital tax rates as regressors. Appendix 2.10.2 discusses in details this transformation, and provides additional robustness and interpretations. Finally, observations are quarterly.

The results of the yield regression are in Table 2.1. The first row in Panels A and B provide a benchmark: the government debt supply – as proxied by the maturity-weighted debt to GDP, see (Greenwood and Vayanos 2014) – is an important determinant of the slope. The second specification in Panels A and B shows that the level and uncertainty of government spending improve substantially the fit of the regression with the R^2 increasing from 10% to 39%. The third specification shows that capital tax rates do not appear to play an important role for the slope of the term structure after controlling for government spending.

We next turn to the results on returns. Table 2.2 shows regressions of future returns on our fiscal level and volatility series:

$$rx_{t+k,k}^{(\tau)} = \beta_0 + \beta_1 g_t + \beta_2 \sigma_{g,t} + \beta_3 \tau_t^k + \beta_4 \sigma_{\tau^k,t} + \text{Controls} + u_{t+k}$$

where $rx_{t+k,k}^{(\tau)}$ is the future k-year return of the τ-year bond in excess of the k-year yield, and $\sigma_{x,t}$ is our fiscal volatility series, and $x \in \{g, \tau^k\}$. We perform this regression for one-year returns for all bonds in our sample, and for three- and five-year returns for the long-term bond. We report t-statistics using Newey and West (1987) standard errors and allowing for 6 quarters of lags. Allowing for more lags does not seem to affect the results.[11]

[10] More precisely, we use the median of the filtered volatility series obtained from our Bayesian estimation.

[11] (Cochrane 2008) suggests using a parametric alternative to the non-parametric Newey-West. (Bauer and Hamilton 2017) suggest using a bootstrap procedure to address small-sample distortions in bond returns predictive regressions. Although we use the simple Newey-West approach, our model will shed further light on the plausibility of our empirical results.

We again start with a benchmark in Panel A: government debt supply is a strong predictor for future returns.[12] Panel B shows that the government spending level and uncertainty series more than double the adjusted R^2 for 1-year holding period returns on bond with maturity ranging from 2- to 10-years. We add the capital tax rate level and volatility series in Panel C. We observe that the R^2 are almost identical to those in Panel B. Similarly, the magnitude and significance of government spending volatility, and to a lesser extend government spending level, are hardly affected by the inclusion of capital tax rates. Importantly, both government spending and capital tax seem to convey independent information about future bond excess returns after controlling for government debt supply. Across all panels the bond supply is the main driver for 5-year long-term bond returns consistent with the view that supply captures a lower-frequency component of expected returns. Our fiscal level and uncertainty instruments instead seem to capture a complementary, higher-frequency (mainly business cycle) component of risk premia. The additional robustness checks in Appendix 2.10.2 confirm the picture drawn by these basic regressions: fiscal policy, and in particular government spending, is an important determinant of bond risk premia. The discussion that follows will shed light on the exact mechanism trough the lens of our model.

[Insert Table 2.1 and 2.2 about here.]

2.3 The Benchmark Model

We implement a New-Keynesian[13] model with government spending and distortionary tax on the return of capital for the analysis. The monetary authority implements the Taylor rule and sets the nominal short rate as a function of inflation and output growth. On the production side, firms maximize profits under staggered price setting. The model also features nominal wage rigidities. We leave the description of the optimal investment decision and staggered wage setting for the appendix.

2.3.1 The Household Problem

The representative agent has the ability to save current income in order to smooth future consumption by purchasing government bonds. With Epstein and Zin (1989),

[12]Our results largely replicates those in (Greenwood and Vayanos 2014) despite our use of quarterly data from 1970-Q1 to 2007-Q4 ((Greenwood and Vayanos 2014) uses monthly observations for the longer 1952-2007 sample period). The main difference lies in R^2: This is because (Greenwood and Vayanos 2014) forecast bond returns, whereas we forecast bond *excess* returns.

[13]For a detailed exposition on the New-Keynesian framework, see Clarida, Gali, and Gertler (1999).

the representative agent maximizes lifetime utility by solving the following:

$$\begin{aligned}
\max \quad & V(C_t, N_t) = \left\{(1-\beta)\left(\frac{{C_t}^{1-\psi}}{1-\psi} - \lambda_t \frac{{N_t}^{1+\omega}}{1+\omega}\right) + \beta E_t\left[V_{t+1}^{1-\gamma}\right]^{\frac{1-\psi}{1-\gamma}}\right\}^{\frac{1}{1-\psi}}, \\
\text{s.t.} \quad & P_t C_t + P_t Inv_t + Q_t^{(1)} B_t(t+1) + P_t Tax_t \\
& = P_t W_t N_t + (1-\tau_t^k) P_t R_t^k K_{t-1} + B_{t-1}(t) + P_t \Psi_t.
\end{aligned}$$

where β denotes the time discount factor, ψ is the inverse of the intertemporal elasticity of substitution (IES), the Epstein-Zin parameter γ is related to the coefficient of relative risk aversion, and ω is the inverse of the Frisch elasticity of labor supply. λ_t is the time varying parameter as a function of the permanent technology shock ($A_t^{1-\psi}$) in order to achieve balanced path in the wage demand equation.

C_t and N_t are real consumption and labor, respectively. Inv_t denotes investment in real terms. P_t is the price level in the economy. $B_t(t+1)$ is the amount of nominal bonds outstanding at the end of period t and due in period $t+1$. W_t refers to real labor income, which is the same across households in the economy. Tax_t is real lump-sum tax collected by the fiscal authority to keep the real debt process from exploding, and Ψ_t is dividend income coming from the firms. K_t is capital and R_t^k is the return on capital.

V_t is the value function of the dynamic programming problem for the representative agent, and V_{t+1} is the "continuation utility" of the value function. The budget constraint states that the agent has periodic after-tax income from labor, capital, and dividends as well as bonds maturing at time t. The agent then decides how much to consume after taxes, how much to invest, and how much to pay for newly issued bonds at time t at price $Q_t^{(1)}$.

The nominal pricing kernel written in terms of return on consumption and return on labor income with distortionary taxes is

$$M_{t,t+1}^{\$} = \left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\psi}\right]^{\frac{1-\gamma}{1-\psi}} \left(\frac{P_t}{P_{t+1}}\right) \left[(1-share_t) R_{t+1}^c + share_t R_{t+1}^l\right]^{\frac{\psi-\gamma}{1-\psi}},$$

where

$$R_{t+1}^c = \frac{(1+P_{t+1}^c) C_{t+1}}{P_t^c C_t} \text{ and } R_{t+1}^l = \frac{(1+P_{t+1}^l) LI_{t+1}}{P_t^l LI_t}.$$

P^c and P^l are prices of the consumption and labor claims, and LI is labor income.

2.3.2 The Firm's Problem

There is a dispersion of firms, denoted by j, with identical production technology in the economy. With nominal price stickiness and monopolistic competition, each firm is faced with the following optimization problem:

$$\begin{aligned}
\max_{P_t^*(j)} \quad & E_t\left[\sum_{s=0}^{\infty}\alpha^s M_{t,t+s}^{\$}\left\{P_t^*(j)Y_{t+s}(j) - P_{t+s}\left[W_{t+s}N_{t+s}(j) + R_{t+s}^k K_{t+s}(j)\right]\right\}\right] \\
\text{s.t.} \quad & Y_{t+s}(j) = Z_{t+s}K_{t+s-1}(j)^{\kappa}(A_t N_{t+s}(j))^{1-\kappa} && (2.3) \\
& Y_{t+s}(j) = \left(\frac{P_t^*(j)}{P_{t+s}}\right)^{-\eta} Y_{t+s} && (2.4) \\
& P_t = \left[\int_0^1 P_t(j)^{1-\eta}dj\right]^{\frac{1}{1-\eta}} = \left[(1-\alpha)P_t^{*1-\eta} + \alpha P_{t-1}^{1-\eta}\right]^{\frac{1}{1-\eta}}. && (2.5)
\end{aligned}$$

Using Calvo (1983) pricing, a firm can choose to optimally adjust price to $P_t^*(j)$ with probability $(1-\alpha)$ each period independent of the time elapsed between adjustments. The objective function of the firm is simply profit maximization: revenue minus labor cost and rent on capital. The within-period profits are discounted by the nominal pricing kernel and the probability that the firm has not been allowed to adjust its price optimally up to that period. Each period, with probability α, the firm is stuck with the price from the previous period. The cash-flow stream is discounted by the nominal stochastic discount factor between times t and $t+s$, $M_{t,t+s}^{\$}$. $P_t^*(j)Y_{t+s}(j)$ is total sales for firm j at time $t+s$. $W_{t+s}N_{t+s}(j)$ and $R_{t+s}^k K_{t+s}(j)$ are the real labor cost of and the real rental cost of capital, respectively. Notice real wage and real return on capital are determined in equilibrium with the households and are common across all firms.

There are three constraints faced by the firm in optimizing its profit. Equation (2.3) is the production function of firm j, where Z_t is the transitory productivity shock, the parameter κ is the capital share of input in the Cobb-Douglas production function, and A_t is the permanent productivity shock driving growth in the economy. Equation (2.4) is the demand equation for firm j's output as a function of the optimal price it sets at time t. Lastly, equation (2.5) is the price aggregator as a weighted average of the optimal price at time t and the sticky price from time $t-1$.

$P_t^*(j)$ is the optimal price the firm j charges for one unit of the consumption good set at time t. α is the probability in each period $t+s$ that the firm is not allowed to adjust its price optimal so it has to keep charging $P_t^*(j)$. If a firm is not allowed to adjust its price optimally, then it charges $P_t^*(j)$ at time $t+s$, as the price is not indexed. All variables indexed by j is firm-specific. For example, $Y_{t+s}(j)$ means output of firm j at time $t+s$ given the last time firm j was able to set its optimal price was at time t. Without the index j, the variable is common across all firms, such as the price level P_{t+s} and the productivity shock Z_{t+s}. Finally, η determines the markup charged by the firm when it sets $P_t^*(j)$ due to monopolistic competition.

Z_t is the economy-wide productivity shock on output. Log productivity follows an exogenous AR(1) process such that

$$\begin{aligned} z_{t+1} &= \log(Z_t) = \phi_z z_t + e^{\sigma_{z,t+1}}\epsilon_{z,t+1} \\ \sigma_{z,t+1} &= (1-\phi_{\sigma_z})\theta_{\sigma_z} + \phi_{\sigma_z}\sigma_{z,t} + \sigma_{\sigma_z}\epsilon^z_{\sigma,t+1} \ , \end{aligned}$$

with $\epsilon_{z,t} \sim$ i.i.d. $\mathcal{N}(0,1)$. The log growth rate of the permanent productivity shock evolves according to an AR(1) process with mean growth rate g_a:

$$\Delta a_t = (1-\phi_a)g_a + \phi_a \Delta a_{t-1} + \sigma_a \epsilon_{a,t} \ ,$$

with $\epsilon_{a,t} \sim$ i.i.d. $\mathcal{N}(0,1)$. Note that we allow for stochastic volatility in technology since uncertainty in transitory productivity has been shown to have a sizable impact on bond prices (see, e.g., Andreasen, (2012), and Kung, (2015)), and we want our analysis of fiscal policy implications for term premia to be robust to this alternative channel.[14]

The firm's optimal price setting behavior has to satisfy the following equation in the presence of nominal price rigidities such that it can only adjust its price optimally each period with probability α.

$$\left[\frac{1}{1-\alpha}\left(1-\alpha\left(\frac{1}{\Pi_t}\right)^{(1-\eta)}\right)\right]^{\frac{1}{(1-\eta)}} F_t = \frac{\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)} R_t^{K\kappa} W_t^{(1-\kappa)} J_t}{Z_t A_t^{1-\kappa}}, \tag{2.6}$$

where $\nu = \frac{\eta}{\eta-1}$ is the frictionless markup and Π^* is the inflation target of the central bank. F_t and J_t are recursively defined as

$$F_t = 1 + \alpha \mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{Y_{t+1}}{Y_t}\right)\Pi^{\eta}_{t+1}F_{t+1}\right] \tag{2.7}$$

$$J_t = 1 + \alpha \mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{Z_t}{Z_{t+1}}\right)\left(\frac{A_t}{A_{t+1}}\right)^{1-\kappa}\left(\frac{R^K_{t+1}}{R^K_t}\right)^{\kappa}\left(\frac{W_{t+1}}{W_t}\right)^{(1-\kappa)}\left(\frac{Y_{t+1}}{Y_t}\right)\Pi^{(1+\eta)}_{t+1}J_{t+1}\right] \tag{2.8}$$

2.3.3 The Monetary Authority

Disengaging monetary policy neutrality by augmenting the model with the New-Keynesian framework, we assess the implications of fiscal policy on bond risk premia in the presence of an effective monetary authority. The Taylor rule used by the monetary authority to

[14](Justiniano and Primiceri 2008a) show that time-varying volatility in permanent productivity accounts for about 20 percent of the variance of GDP growth and real wages but they did not explore its implications for asset prices. (Segal 2016) provides evidence for productivity volatility of different sectors as an important determinant of equity prices.

set the nominal short rate, $R_t^{(1)}$, in the model is:

$$\frac{R_t^{(1)}}{R} = \left(\frac{R_{t-1}^{(1)}}{R}\right)^{\rho_r} \left(\frac{\Pi_t}{\Pi^*}\right)^{(1-\rho_r)\rho_\pi} \left(\frac{Y_t/A_t}{Y_{t-1}/A_{t-1}}\right)^{(1-\rho_r)\rho_x} e^{u_t},$$

where R is the steady state nominal rate, $\Pi_t = \left(\frac{P_t}{P_{t-1}}\right)$ is inflation, Π^* is the long-run inflation target, Y is the steady state output, and u_t is the monetary policy shock. The parameter ρ_r is the autoregressive coefficient used for interest rate smoothing. The monetary rule is said to satisfy the Taylor principle when $\rho_\pi > 1$. Finally, the monetary policy shock follows an autoregressive process of order one

$$u_t = \phi_u u_{t-1} + \sigma_u \epsilon_t^u,$$

with $\epsilon_t^u \sim$ iid $\mathcal{N}(0,1)$.

2.3.4 Equilibrium

The competitive equilibrium is characterized by the set of market clearing conditions: composite labor, capital stock, bonds, and final goods. Furthermore, given prices and wages of other households, each optimizing household chooses the optimal allocation to solve his/her utility maximization problem. Finally, given wages and prices of other firms, each firm chooses the optimal production input to solve its profit maximization problem. In equilibrium, $N_t^d = N_t$. In this economy, total output has to equal to total private consumption and private investment plus total government spending:

$$Y_t = C_t + Inv_t + Gov_t. \tag{2.9}$$

In the model, because the market is complete and there is a representative marginal pricer, there exists an unique pricing kernel which allows us to price all assets in the economy, including long- and short-term bonds.

2.3.5 The Government's Budget Constraint

The government's flow budget constraint balances resources with uses:

$$P_t Tax_t + Q_t^{(1)} B_t(t+1) = B_{t-1}(t) + P_t Gov_t,$$

where Gov_t is consumption by the government or government spending. Gov_t is not productive in the model economy. Furthermore,

$$Tax_t = \tau_t + \tau_t^k R_t^k u_t K_{t-1},$$

such that τ_t is the lump-sum tax described below. Government spending as a fraction of output, $g_t = \frac{Gov_t}{Y_t}$, and the capital tax rate, τ_t^k, follow two independent AR(1) with stochastic volatility, c.f. Section 2.2.1, Eqs. (2.1)-(2.2).

The lump-sum tax is meant to be collected to keep the borrowing path of the government from exploding. Following standard procedure in the literature, we specify the lump-sum tax as a function of real debt and government spending.

$$\tau_t = \rho_b D_{t-1}(t) + \rho_g Gov_t,$$

where D denotes real debt such that $D_{t-1}(t) = \frac{B_{t-1}(t)}{P_t}$. The simple fiscal rule is widely used in the literature on the macroeconomic impact of fiscal policy shocks, see Gali, Valles, and Lopez-Salido (2007) and Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) for two recent examples. In the previous working version of the paper, we model long-term bonds directly using a geometrically declining series to proxy for the maturity structure of government debt similar to Cochrane (2001). We find that the modeling of long-term bonds using a geometric series did not alter the term structure implications we focus on here. For simplicity, we abstract away from that setup to obtain a simpler government budget constraint and fiscal rule.[15]

2.4 Inference and the Observable Variables

To estimate the parameters of our model we rely on the generalized method of moments (GMM) using first and second unconditional moments of macroeconomic and financial data. This section provides a detailed description of the estimation method and discusses the data used to evaluate the unconditional moments.

2.4.1 Data and Moments for GMM

The time unit is defined to be one quarter. We estimate the model using the following quarterly time series: (i) log output growth, Δy_t (henceforth, Δ denotes the temporal

[15] The maturity structure of government debt is an interesting question to itself. There is no clear consensus in the literature on how it should be modeled. However, this is a question beyond the scope of our current paper.

difference operator); (ii) log investment growth, Δinv_t; (iii) log consumption growth, Δc_t; (iv) inflation, π_t; (v) the 1-quarter nominal interest rate, r_t; (vi) the 10-year nominal interest rate, $y_t^{(40)}$; (vii) the slope of the term structure, $y_t^{(40)} - r_t$. The sample spans 1970.Q1 to 2014.Q2.[16] Appendix 2.10.1 gives detailed variable definitions and sources.

To estimate model parameters we use the mean, the variance and the contemporaneous covariances in the data as moments.[17] Provided the model's solution is stable, (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017) derive closed-form solutions for first and second unconditional moments of the (non linear) state-space of the DSGE. This is important since it allows us to compute in a reasonable amount of time the unconditional moments for our DSGE model solved up to third-order. Appendix 2.10.4 provides additional details.

2.4.2 Inducing Stationarity and Solution Method

The exogenous productivity process A_t displays a stochastic trend. This random trend is inherited by the endogenous variables of the model. We focus our attention on equilibrium fluctuations around this stochastic trend. To this end, we perform a stationarity-inducing transformation of the endogenous variables by dividing them by their trend component. Appendix 2.10.3.7 describes this transformation and presents the complete set of equilibrium conditions in stationary form.

To analyze the role of fiscal shocks and the implications for time-varying risk premia, we solve the benchmark DSGE model using perturbation methods (see (Schmitt-Grohe and Uribe 2004)).[18]

To fit the term structure to data, we compute the yield curve implied by the model using the fact that bond prices beyond the policy rate, $r_t = \log R_t^{(1)}$, do not affect allocations and prices. Taking advantage of this property, we follow (Andreasen and Zabczyk 2015) and first solve the model without bond prices exceeding one period, and then we recursively compute all remaining bond prices based on

$$Q_t^{(k)} = E_t \left[M_{t,t+1}^{\$} Q_{t+1}^{(k-1)} \right] \ ,$$

[16] The starting date follows (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) and it is dictated by the start of our fiscal series. We have also repeated our estimation exercise with moments computed from a sample period that exclude the financial crisis, from 1970.Q1 to 2007.Q4, and find that the results remain qualitatively the same.

[17] We have also repeated our procedure adding to the first and second moments used in the baseline estimation the first and fifth autocovariances to capture the persistence in the data. Our point estimates do not significantly change and the conclusion from model-implied moments remain qualitatively the same. Results are available upon request.

[18] Our model has a relatively large number of state variables and eight shocks. Because of this high dimensionality, discretization and projection methods are computationally infeasible.

where $M^{\$}_{t,t+1} = M_{t,t+1}\frac{1}{\Pi_{t+1}}$ denotes the nominal stochastic discount factor, and $M_{t,t+1}$ denotes the real stochastic discount factor. We let $k = 2, \ldots, 40$ quarters. The nominal yield curve with continuous compounding is then given by $y_t^{(k)} = -\frac{1}{k}\log Q_t^{(k)}$. We also compute the real term structure based on

$$Q_{t,real}^{(k)} = E_t\left[M_{t,t+1}Q_{t+1,real}^{(k-1)}\right] .$$

Finally, we define the 10-year nominal term premium to be the difference between the 10-year interest rate and the yield-to-maturity on the corresponding bond under risk-neutrality. The latter is computed by discounting payments by r_t instead of the stochastic discount factor.

2.5 Estimation Results

2.5.1 Parameter Estimates

Given the large scope of the model, we fix a small number of parameters to values commonly used in the literature, see Table 2.3 Panel A. In particular the rate of depreciation on capital is 0.02 as employed by (Kaltenbrunner and Lochstoer 2010). This value implies a steady-state investment-output ratio of 21 percent. The capital share of intermediate output, κ, is 0.33. The following parameter values are standard in New-Keynesian models. The price rigidity parameter, α, is 0.66. This means every period, two thirds of the firms in the economy are not able to adjust their prices to the optimal level. The higher the α, the stickier the nominal prices are. We also set the wage rigidity parameter, θ, to 0.66. The price markup parameter resulting from monopolistic competition, η, and the wage markup parameter in union wage setting, η_w, are both equal to 6. Hence, steady-state price and wage markup are both equal to 20%. Consistent with previous studies, our calibrated parameters imply a steady-state capital-output ratio, $\frac{Y}{4K}$, of about 2. We also set the monetary policy rule coefficient on inflation, ρ_π, to the typical value of 1.5 used in the literature. We set the government spending–output ratio, θ_g, to 20.2%, and the mean of the tax rate, θ_{τ^k}, to 40%, according to the data. Finally, we calibrate the parameters for *transitory* productivity to values commonly adopted in the literature, see, e.g., (Andreasen 2012) and (Kung 2015).[19]

[19]The only parameter which deserves attention is σ_{σ_z}. We set the volatility of volatility to 0.03 in line with (Andreasen 2012). We do so for two reasons. First, this value implies an unconditional standard deviation in $\sigma_{z,t}$ of 0.19, which is the same as one would obtain from fitting a GARCH model on log productivity. Second, our chosen value for the vol-of-vol parameter lies on the higher hand of those used in the literature, and makes our results for fiscal policy conservative. Indeed, lower values for σ_{σ_z} would only increase the relative contribution of fiscal volatility shocks relative to uncertainty in productivity.

As discussed in Section 2.2.1 we estimate the processes for capital tax rate and for government spending outside of the model, see Table 2.3 Panel B. This procedure has the benefit of ensuring that the latent fiscal (tax and government spending) volatility factors maintain their intended economic interpretation.[20]

Table 2.3 Panel C reports the estimates of the structural parameters in our model.

[Insert Table 2.3 about here.]

The estimation assigns a relatively high value of 0.995 to β. This value is needed in order to obtain a sufficiently low mean value for the one-period nominal interest rate. The parameter γ is estimated to be 181. Since the representative agent in the model can earn labor income as a mean to smooth consumption, his/her attitude toward risk is different than those who do not supply labor. Following Swanson (2012), we adjust the risk aversion parameter by taking into account the labor margin using the closed-form formula $\frac{\psi}{1+\frac{\psi}{\omega\nu}} + \frac{\gamma-\psi}{1-\frac{1-\psi}{1+\omega}}$ with $\nu = \frac{\eta}{\eta-1}$. The representative saver's true coefficient of relative risk aversion is therefore ≈ 111. This may seem like a high value; however, other term structure studies using Epstein-Zin preferences also typically estimate a high coefficient of relative risk aversion: (Piazzesi and Schneider 2007) estimate a value of 57, (van Binsbergen, Fernández-Villaverde, Koijen, and Rubio-Ramírez 2012) a value of about 66, and (Rudebusch and Swanson 2012) a value near 110.[21]

The estimation procedure picks a low value for the IES, $1/\psi \approx 0.53$. This value is consistent with estimates in the micro literature (e.g., Vissing-Jorgensen, (2002)) and it has also been adopted by (Rudebusch and Swanson 2012) in a general equilibrium context similar to ours. The low value for the IES helps to make consumption less volatile and real interest rates more volatile, both of which improve the fit to the macro moments in the data. The higher interest rate volatility also increases bond price volatility and improves the model's fit with respect to the finance moments. Our estimates of the Frisch elasticity is in line with the literature. The response of the monetary policy authority to output growth, ρ_x, is similar to that used in influential studies such as (Judd and Rudebusch 1998), (Taylor 1999) and (Clarida, Galí, and Gertler 2000). The shock persistence and variance for permanent productivity, ϕ_z and σ_z, are broadly in line with, e.g., the estimates in (Justiniano, Primiceri, and Tambalotti 2011). Finally,

[20] Alternatively we could have used macro and financial variables (bond yields) to estimate the full fledged model with time-varying volatility in fiscal rules. However, bond yields may potentially compromising the interpretation of the volatility in government spending and capital tax rate. Our approach disciplines the stochastic volatility to fit the observed government spending and capital tax rate data only, instead.

[21] (Andreasen and Jorgensen 2016) propose a slightly modified utility kernel for Epstein-Zin preferences to address the puzzlingly high relative risk-aversion in DSGE models. We leave the analysis of such a utility kernel in our setting to future research.

our estimates imply a substantial degree of adjustment costs in investment, in line with previous studies (e.g. (Del Negro, Schorfheide, Smets, and Wouters 2007) and (Smets and Wouters 2007)).

2.5.2 Model's Fit

Given our GMM estimates, how well does the model fit the data? We address this question by comparing a set of statistics implied by the model to those measured in the data. Throughout the section we benchmark the model-implied term premium to the measure provided by (Adrian, Crump, and Moench 2013).

Table 2.4 reports the model-implied as well as the corresponding empirical moments for two sets of variables: (1) the first set comprises the seven variables used in estimation; (2) the second set is composed of additional macro (wages and hours) and financial (3-, 5-, 7-year yields, and the 5- and 10-year term premium) variables whose moments are not directly targeted in the estimation. The table reports the median and the 90 percent probability intervals that account for parameter uncertainty for the standard deviation, autocorrelation, and contemporaneous correlation with output.[22] Although in the estimation we target growth rates of output, consumption, and investment, Panel A displays hp-filtered moments for these macro variables (as well as for wages and hours) to make our analysis comparable to other studies on fiscal policy (see, e.g., Table 5 in Fernandez-Villaverde et al., (2015)).

[Insert Table 2.4 about here.]

Our benchmark model matches the mean and standard deviation of yields over the whole maturity profile, as well as the slope for the nominal term structure (all values fall within the 90% confidence interval). In particular, the model is able to produce a sizable slope of 1.2% and to generate a volatile 10-year rate. With respect to term premium, the model is overall quite successful in reproducing a sizable mean 5-year term premium of about 0.9%, to be compared to 1.3% in the data. The model is also able to account for $0.61/0.86 \approx 71\%$ of the term premium unconditional standard deviation.

Furthermore, the model can simultaneously match key business cycle moments for real variables. In particular, the model matches fairly well the volatility of output, consumption, investment, and inflation. The series of hours, which is not targeted in estimation,

[22] We draw the structural parameters from a Normal distribution with a variance-covariance matrix obtained from our second step GMM estimation procedure. The parameters governing the processes for the fiscal instruments are obtained from the posterior distribution reported in Table 2.3-Panel B. For each parameter draw, we generate an artificial long sample (5000 quarters) of the observable variables after discarding 1000 initial observations. Hence we do not account for small sample uncertainty.

also displays a model-implied volatility quite in line with the data. Finally, although not reported, the model matches the mean of growth rates in output and consumption, and it slightly under-predicts that of investment growth, with a (median) value of 2.8% against 3.5% in the data.

It is worth highlighting the substantial time variation of the nominal short-rate, slope and term premium within the model generated by stochastic volatility of fiscal instruments rather than higher variance in the shocks to fiscal instruments themselves. In untabulated results, we consider the benchmark model without stochastic volatilities in fiscal policies. In particular we set the unconditional variance in shocks to government spending and capital tax rate $\sigma_{x,t+1} = \sigma_x = \theta_{\sigma_x} + \sigma_{\sigma_x}$, with $x \in \{g, \tau^k\}$. Doing so ensures that the unconditional variance in fiscal instruments is comparable to the specification of our benchmark model with stochastic volatility. The experiment showed that a model without fiscal uncertainty is not able to quantitatively match the variability in the short-rate and the slope for the nominal term structure (the model-implied 90% confidence intervals do not include the data values). Also, a model without time-varying uncertainty produces much lower term premium volatility. Overall, time-varying volatility in fiscal shocks seem to be an important driver for variation in the U.S. yield curve and term premia.

Turning to the persistence of quantities and prices, Table 2.4 reports the first-order autocorrelation coefficient while Figure 2.2 displays the entire autocovariance function of the data (black line) and the model (blue line), along with the 90 percent intervals that account for parameter uncertainty.[23] Again, the figure includes all the observable quantities used to estimate the model, as well as additional macro (wages and hours) and financial (3-, 5-, 7-year yields, and term premia) variables whose moments are not directly targeted in the estimation. Overall, the model captures the decaying autocorrelation structure of real and financial variables reasonably well. The success is particularly impressive for the long-term rates (maturities $\geq$ 5 years) and the term premium, for which the data auto-correlations are always within the model-implied confidence bands. The model does a satisfactory job for output, consumption, and investment, but it generates slightly too much persistence in inflation and in the nominal short-term interest rate.

[Insert Figure 2.2 about here.]

We conclude this section by discussing a few more quantitative implications of the model that will support the interpretation of our model-implied term structure.[24] First, our

[23] These moments are not used in the estimation and constitute an out-of-sample test of the model's fit.

[24] We thanks Gill Segal for raising these points to our attention.

model is able to match the empirical correlation of consumption growth and inflation. In our dataset, these two series are negative correlated at -0.14 over the 1970:Q1–2014:Q2 sample period; this negative correlation doubles and is equal to -0.30 over the period 1970:Q1–2007:Q4, which excludes the financial crisis. Consistently with the data, our model implies a negative correlation of -0.29. We will return to this negative correlation in our discussion of government spending level shocks and inflation risk premium, see Section 2.5.3.[25]

[Insert Table 2.5 about here.]

To further discipline the model, we investigate its implications for the real term structure. Table 2.5 displays the means, volatilities, and first autocorrelations of real bond yields of different maturities and the ten-year minus two-year yield spread from the model. We compare these statistics with the real term structure obtained by splicing together yields data from (Chernov and Mueller 2012) and from (Gurkaynak, Sack, and Wright 2010).[26] The volatility of real yields for all maturities is in line with the data, although the average level of the real yield curve in our model is slightly higher than in the data. More importantly, the model-implied average slope and its standard deviation are close to the data, and particularly so for the period that does not comprise the financial crisis. Both in the data and in our model, the average slope of the real yield curve is positive. Similarly, (Campbell, Shiller, and Viceira 2009) report that the real yield on long-term US TIPS has always been positive (see also discussion in Beeler and Campbell, (2012)). An upward-sloping real yield curve implies that long-maturity real bonds have lower payoffs than short-maturity ones when expected consumption growth is low. We will return to this fact in our interpretation of government spending volatility shocks and the term premium.

2.5.3 Impulse Responses

A large literature in financial economics finds that bond risk premia are substantial and vary significantly over time (see (Campbell and Shiller 1991) and (Cochrane and

[25] Although mostly negative, the magnitude of this correlation varies in the literature depending on the sample period. E.g. (Kung 2015) finds in the data an even stronger negative correlation between inflation and consumption growth equal to -0.56. A reconciliation of these facts is provided by (David and Veronesi 2013) who provide a regime switching model with learning where the correlation between earnings and inflation change stochastically over time, in both magnitude and direction.

[26] The data from (Chernov and Mueller 2012) spans 1971:Q3 to 2002:Q4. We merge this data with those from (Gurkaynak, Sack, and Wright 2010). Throughout, we remove data for 2003 due to a high illiquidity premium. For the same liquidity reason, we also consider a shorter sample that excludes the financial crisis. The relative (il)liquidity of TIPS from their inception until 2003, when the Treasury reaffirmed its commitment to the TIPS program, and in the aftermath of the Lehman bankruptcy in late 2008, which resulted in its considerable TIPS inventory being released into the market, have been discussed in (Sack and Elsasser 2004) and (Campbell, Shiller, and Viceira 2009) among others.

Piazzesi 2005)); however, the economic forces that can justify such large and variable term premium are less clear. In this section, we shed some light on this issue by examining the model's impulse responses to shocks.

To understand the role of shocks for the term premium, Figure 2.3 shows the impulse responses of the stochastic discount factor (SDF, henceforth), inflation, long-term bond yield, and term premium to a positive one-standard-deviation shock to government spending level (column 1) and volatility (column 2), and to capital tax rate level (column 3) and volatility (column 4); Figure 2.4 shows the impulse responses to shocks in transitory productivity and its time-varying volatility (columns 1 and 2, respectively), to permanent productivity (column 3) and monetary policy shocks (column 4).

[Insert Figures 2.3 and 2.4 about here.]

Figures 2.3 and 2.4 show that fiscal shocks together with innovations in transitory productivity represent the main drivers of bond risk premia. On the other hand term premium fluctuations induced by permanent productivity and monetary shocks are minimal. Comparing the last row in Figure 2.3 with that in Figure 2.4, we see that fluctuations in term premium due to government spending volatility shocks are larger than those generated by volatility in productivity. Government spending level shocks too stand out as a source of term premium as important as level shocks in transitory productivity. Both government spending level and volatility shocks demand a positive, and quite persistent term premium.

Next, we investigate the behavior of inflation risk premium induced by government spending shocks. To this end, we look at the response of the SDF and inflation. A key and novel result conveyed by Figure 2.3 is that the relationship between consumption and inflation depends critically on the nature of the underlying fiscal shocks: government spending level shocks imply a negative correlation between consumption growth and inflation, while government spending uncertainty shocks imply exactly the opposite relation. Therefore, in our model, an increase in government spending level implies that inflation is high exactly when agents wish to consume more; but high inflation makes payoffs on nominal bonds low in real terms, and the *positive* covariance between marginal utility of consumption and inflation generates positive inflation risk premia. On the other hand, following a positive government spending uncertainty shock, consumption growth and inflation move in the same direction, which in turn delivers an average negative inflation risk premia.

Figure 2.3 further shows that both the level and volatility shocks to government spending have positive impact on the nominal term premium for long-term bonds. This is straightforward to rationalize for level shocks since inflation risk premium is positive. The fact that government spending volatility shocks command a positive nominal term premium in the second column despite the negative inflation risk premium suggests that long-term nominal bonds are riskier relative to short-term nominal bonds. In other words, when the marginal utility is high (spike in the SDF), long-term bond price appreciates less than the price of short-term bonds. The overall implication of the government spending volatility shock on the nominal term structure is that it has a negative level effect but a positive slope effect. The steepening of the nominal yield curve due to a positive spending volatility shock is confirmed in Figure 2.6(b) by observing the large decline in the 1-quarter nominal yield.

Turning to capital tax shocks in the third and fourth columns of Figure 2.3, inflation risk premia are negative on average and nominal term premia fall in response to both level and uncertainty shocks to tax rate. When the marginal utility to consume is high following tax shocks, inflation declines thus making nominal bonds an effective hedge against real consumption risk, resulting in a negative inflation risk premium. The third row of Figure 2.3 shows long-term nominal yields drop significantly exactly when the stochastic discount factor spikes, resulting in further decline in the 5-year nominal term premium. In sum, both level and volatility shocks to the return on capital tax rate have negative level effects on the nominal term structure.

Our discussion here based on the impulse responses of the model can be validated in the regression analysis in Table 2.2 in several dimensions. First, government spending level and volatility shocks command positive term premium, in line with positive coefficient estimates β_1 and β_2 from the predictive regressions (see Panel B and C). Second, return on capital tax rate level and volatility shocks command negative term premium with large error bands, consistent with coefficient estimates β_3 and β_4, which are mostly negative or statistically insignificant (Panel C). Third, government spending volatility shocks dominate level shocks in driving term premium variation. This is similarly reflected in the comparison of statistical significance between β_1 and β_2 in Panel C of Table 2.2.

We conclude this section by quantifying the contribution of each shock to the variability of macroeconomic and financial variables.[27]

[Insert Table 2.6 about here.]

[27] The task of measuring the contribution of each of the eight shocks in our model to aggregate fluctuations is complicated because, with a third-order approximation to the policy function and its associated nonlinear terms, we cannot neatly divide total variance among the shocks as we would do in the linear case. We follow (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and set the realizations of seven of the shocks to zero and measure the volatility of the economy with the remaining shock.

Table 2.6 Panel B shows that, consistent with the results in Table 2.1, uncertainty in government spending is the single most important source of variation in the slope of the term structure. Government spending uncertainty is also as important as volatility in productivity to generate movements in term premium. On the other hand, level shocks in transitory productivity generate negligible variability in term premium, a result which contrasts with (Rudebusch and Swanson 2008). All shocks are important drivers of nominal yields movements, except for permanent productivity, whose effects are puny, and monetary shocks, whose effects dissipate quickly along the term structure of interest rates. Turning to the real side of the economy, Table 2.6 Panel A shows that transitory productivity level shocks are a key determinant of consumption and output volatilities. However, spending and capital tax (level and volatility) shocks generate sizable effects on investment, hours and inflation.

To summarize, we find that stochastic volatility in government spending shocks can generate sizable variation in the term premium without distorting the ability of the model to match key macroeconomic moments.

2.5.4 Model Implied Return Predictability

We compare the predictability of bond excess returns in the data to that obtained from simulations of our fiscal model[28] in Table 2.7. Panel A of Table 2.7 shows that, similar to the data, the government debt level is an important predictor of bond excess returns. Panel B shows that the loadings on the level and volatility of government spending are positive and statistically significant in the model regressions. Panel C, shows that adding capital tax rates leaves unaffected the conclusion on the level and volatility of government spending. Moreover the level of capital tax rate enters almost always with a negative coefficient, albeit the point estimate is insignificant. All these implications from our model are in line with the data, see Table 2.2.

Before concluding we remark that Table 2.7 shows population results from a long simulation of the model where parameters are fixed at their point estimates; so our model-implied predictive regressions do not account for parameter uncertainty and small sample uncertainty. Accounting for these two sources of uncertainty would close the gap between the estimated coefficients on government spending level and volatility in the data (Table 2.2) and those implied by the model. In fact, in untabulated results, we show that the 90% confidence interval from finite sample simulation always include the point

[28]In the data, we use the maturity-weighted debt to GDP ratio and the filtered volatility from our Bayesian procedure to proxy for the supply of debt and fiscal uncertainty. In the model-implied regressions we use instead the real maturing debt $D_{t-1}(t)$ and the true volatility process for fiscal instruments. Also, we apply a (one-sided) hp-filter to the level of the fiscal variables within the model as we did in the data.

estimate in the data for the level of government spending, and gets closer to that for uncertainty. Similarly, finite sample simulations deliver a 90% interval for R^2 in Panel C equal to [11%, 24%] for one-year holding period returns (across maturities), which encompasses s the $R^2 \approx 21\%$ measured in the data.

2.5.5 Economic Intuition of Inflation Risk Premium from Government Spending

The decomposition of nominal bond yields consists of real yields, expected inflation, and inflation risk premium. In closed form:

$$i_t^{(n)} = r_t^{(n)} + \frac{1}{n}\left\{E_t\left[\pi_{t,t+n}\right] + cov_t(m_{t,t+n}, \pi_{t,t+n}) - \frac{1}{2}var_t(\pi_{t,t+n})\right\},$$

where the conditional covariance of the marginal rate of consumption substitution between times t and $t+n$ with inflation during the same period gives us the compensation for inflation risk for holding n-period to maturity nominal bonds. To derive some intuition on inflation risk premium in the current model, we study this covariance term by examining the impact of fiscal shocks on $m_{t,t+1}$ and on $\pi_{t,t+1}$.

The real stochastic discount factor can be written in logs such that,[29]

$$m_{t-1,t} = \frac{1-\gamma}{1-\psi}\left[\log(\beta) - \psi\left(c_t^o - c_{t-1}^o\right)\right] + \frac{\psi-\gamma}{1-\psi}log(R_t^{cl}),$$

where R_t^{cl} is the return on the wealth (consumption and labor income) portfolio of the representative saver. Because the representative household is Ricardian with respect to government spending, positive level shocks to government spending increase saving while crowding out consumption. The resulting high marginal utility state generates higher $m_{t-1,t}$ because consumption growth $(c_t - c_{t-1})$ is low.

To decipher the impact of government spending shocks on inflation, we loglinearize the Phillips curve in Equation (2.6) after detrending the growth variables to get,

$$\frac{\alpha}{1-\alpha}\pi_t + f_t = \log(\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}) + \kappa r_t^K + (1-\kappa)\tilde{w}_t + j_t - z_t, \qquad (2.10)$$

where the tilde above a variable indicates stationarity. Therefore, $\tilde{w}_t = log\left(\frac{W_t}{A_t}\right)$. The first term can be obtained by assuming the steady state log inflation, π, is zero. The interpretation of this equation is that inflation is not only functions of the contemporaneous marginal cost to the firm (r_t^K and $\tilde{w}_t$), but also expected inflation and expected

[29] For the ease of exposition, the remainder of this section contains lower case variables denoting the log-version of their upper case counterparts.

marginal cost, according to Equations (2.7) and (2.8), during the period before the optimal price can be set again.

Rearrange Eq. (2.10), we have[30]

$$
\begin{aligned}
& \frac{\alpha}{1-\alpha}\pi_t \\
= \; & \log(\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}) + \kappa r_t^K + (1-\kappa)\tilde{w}_t - z_t + j_t - f_t \\
\approxeq \; & \log(\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}) + \underbrace{\kappa r_t^K + (1-\kappa)\tilde{w}_t}_{\text{contemporaneous marginal cost}} - z_t \\
& +const\left\{\mathbb{E}_t\left[\underbrace{\pi_{t+1}}_{\text{inflation expectation}} - \Delta z_{t+1} + \underbrace{\kappa\Delta r_{t+1}^K + (1-\kappa)\Delta\tilde{w}_{t+1}}_{\text{expected marginal cost}}\right.\right. \\
& + j_{t+1} - f_{t+1}] + \frac{1}{2}\left[var_t(\Delta z_{t+1}) + \kappa^2 var_t(\Delta r_{t+1}^K) + (1-\kappa)^2 var_t(\Delta\tilde{w}_{t+1})\right. \\
& \left.\left.\left. + \underbrace{(1-2\eta)}_{-} var_t(\pi_{t+1}) + var_t(j_{t+1}) + var_t(f_{t+1})\right]\right]\right\}. \qquad (2.11)
\end{aligned}
$$

Recall the last equality is an approximation after dropping the remaining covariance terms. There are a number of takeaways from this derivation. First, higher expected inflation raises current inflation. Second, higher expected marginal cost also raises current inflation. Third, stochastic volatility, which increases conditional variance of the endogenous variables, generally increases current inflation with the except of inflation variance since η is much greater than 1.

Figure 2.5–Panel (a) shows the impulse responses of endogenous variables to spending shocks and it allows us to inspect further the mechanism. Following a positive government spending level shock, output rises according to the market clearing condition, Equation (2.9). Firms intend to produce more in order to meet the demand by increasing labor and capital input. On the supply side, labor supply is high deriving from the negative wealth effect of the households due to lower consumption, but capital supply is low stemming from the desire of the households to invest in Treasury bonds over capital because they are safer. The result is a drop in real wage, but a strong increase in the return on capital, hiking the marginal cost for the firm. The increase in contemporaneous and expected marginal cost drive up inflation according to the loglinearized Phillips curve. Recall the same positive government spending level shock pushes up marginal utility by lowering consumption growth, thus the covariance generated by the

[30] Given the linearized functional forms of f_t and j_t in Appendix 2.10.3.5, we can simplify the loglinear Phillips curve in Eq. (2.10)). First notice $const_f = const_j = const$ since steady state $\Upsilon = \Phi$ by assuming $\pi = 0$. Second, we ignore the covariance terms in the decomposition of the variance terms within f_t and j_t to keep the intuition simple. Furthermore, many of these covariance terms will cancel out in calculating $j_t - f_t$.

government spending level shock between $m_{t,t+1}$ and π_{t+1}, $cov_t(m_{t,t+1}, \pi_{t+1})$, is positive implying positive inflation risk premium.

Similar to the level shock, a positive government spending volatility shock also raises the marginal utility of consumption. Under the lognormal framework, the second moment shock works through the expectation channel in the following way:

$$\mathbb{E}_t[G_{t+1}] \quad = \quad \mathbb{E}_t[e^{g_{t+1}}] = e^{\mathbb{E}_t[g_{t+1}]+\frac{1}{2}var_t(g_{t+1})}.$$

Uncertainty about government spending affects the expectation of future government spending, amplifying household's precautionary savings motive making current consumption fall. Unlike the level shock, however, because the volatility shock increases the expected return on capital causing marginal Q to rise through the investment equation, the savers prefer investment in capital as opposed to Treasury bonds. Firms, on the other hand, also anticipate the increase in expected demand and coordinate by shifting production from today to tomorrow. By decreasing labor and capital inputs today, current marginal cost goes down resulting in a decline in inflation. The fall in inflation is further reinforced by the increase of the conditional variance of inflation in Equation (2.11) stemming from the government spending volatility shock. Because $(1 - 2\eta) < 0$, higher inflation uncertainty translates into lower current inflation according to the loglinear Phillips curve. On average, the second moment shock to government spending generates low inflation in high marginal marginal state of the world making $cov_t(m_{t,t+1}, \pi_{t+1})$ negative.

2.5.6 Term Premium and Government Spending Volatility Shocks

The bottom row of Figure 2.3 shows that fiscal policy shocks have significant impact on the nominal term premium. The variation is especially pronounced for volatility shocks in the second column. After the realization of a positive one standard deviation government spending volatility shock, the 5-year term premium increases by about 25 bps, on average. Recall that term premium stems from the relative riskiness of long-maturity bonds vs. short maturity bonds. Intuitively, the term premium is positive (negative) when the return for long-maturity bonds is lower (higher) than the return for short-maturity bonds in high marginal utility states. Translating into yields, this implies long-term yields increase (decrease) more (less) compared with short-term yields, thus creating a yield curve steepening effect.

Figure 2.5–Panel (b) presents government spending volatility shock impulse responses for the real economy and the nominal short rate. Notice the 1-quarter nominal rate drops significantly relative to the decline in the 5-year nominal rate in the second column of

Figure 2.3, implying short-dated bonds have greater price increase in bad times making long-dated bonds risky. To get some intuition on what is driving the relative change in bond prices, assume a positive government spending volatility shock is realized at the beginning of time t so the SDF is elevated ($M^{\$}_{t-1,t} \uparrow$). We compare the price of a one-period to maturity bond to the price of a n-period to maturity bond under CRRA utility:

$$
\begin{aligned}
P_t^{(1)} \Big\uparrow = e^{-r_t^{(1)}} \Big\downarrow &= \mathbb{E}_t \left[M^{\$}_{t,t+1} \right] = \mathbb{E}_t \left[e^{-\gamma \Delta c_{t+1} - \pi_{t+1}} \right], \\
P_t^{(n)} \uparrow = e^{-r_t^{(n)}} \downarrow &= \mathbb{E}_t \left[M^{\$}_{t,t+1} M^{\$}_{t+1,t+2} \cdots M^{\$}_{t+n-2,t+n-1} P^{(1)}_{t+n-1} \right] = \mathbb{E}_t \left[e^{-\gamma \Delta c_{t+n} - \pi_{t+n}} \right],
\end{aligned}
$$

where the length of the arrows denotes magnitude. For the price of the one-period to maturity bond to increase more in comparison to the n-period to maturity bond, it has to be the case that the one-period expected consumption growth declines more than the n-period expected consumption growth (assuming inflation differential is trivial for now). Figure 2.5 panel (b) shows that the positive government spending volatility shock causes a temporary decrease in real wage and increase in saving (real debt) in the short-run. However, in the long-run, wage rebounds and debt level falls persistently. The implications of these impulse responses are consistent with a large drop in short-term expected consumption growth and a less dramatic decline in long-term expected consumption growth, which steepens the yield curve and raises term premium.

[Insert Figures 2.5 about here.]

2.5.7 Inspecting the Mechanism due to Capital Tax Rate Shocks

The third and fourth columns of Figure 2.3 document that level and volatility shocks to the return on capital tax rate induce substantial negative nominal term premia. To decipher the mechanism, we examine the impulse response functions to the real economy of the these shocks in panels (a) and (b) in Figure 2.6. In panel (a), a positive level shock to the tax rate lowers output and investment as the marginal return on capital decreases. As a result, marginal cost declines causing inflation to be low when consumption is also low. Moreover, debt issuance drops as the tax revenue increases driving up (down) bond prices (yields), especially at the short-end of the maturity curve. The negative level effect generated by the positive capital tax level shock results in negative inflation risk premium. It is interesting to note that the 1-quarter nominal rate in panel (a) of Figure 2.6 experiences a much more significant drop relative to the 5-year rate in the third column of Figure 2.3. The steepening of the yield curve implies a positive term premium, and yet the overall nominal term premium is negative following the tax rate level shock. Therefore, we conclude that the negative term structure level effect dominates the positive slope effect in this case.

[Insert Figures 2.6 about here.]

Opposite to the government spending volatility shock, the term premium driven by tax rate volatility shock is negative. A positive one standard deviation shock to the return on capital tax rate volatility leads to a 30 bps fall in the 5-year term premium in the fourth column of Figure 2.3. This is reflected in panel (b) of Figures 2.6. Following a positive one standard deviation volatility shock to the return on capital tax rate, households cut investment immediately because tax rate is expected to be high tomorrow. At the same time, real wage gets a temporary bump up while savings start to decline. Over the long horizon, investment recovers, and wage falls as aggregate demand stays below its steady state. In contrast to panel (a), the decrease in investment is more attenuated for tax rate volatility shocks compared to level shocks, and marginal cost actually increases slightly due to higher wage. However, in the long-run, as wage declines, expected marginal cost also lessens to produce lower inflation. This is a pure term structure level effect as the positive tax rate volatility shock induces a parallel shift downward of the yield curve. The 1-quarter short rate decreases by roughly the same magnitude in panel (b) of Figure 2.6 as the 5-year nominal rate in the last column of 2.3.

Furthermore, the impulse response functions to a volatility shock of the capital return tax rate are broadly in line with the empirical findings documented by (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015). Notably our model replicates both the decrease in inflation (see Figure 2.3, column 4) and nominal interest rate documented in (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015), a fact that was challenging to obtain in their baseline model economy. Intuitively, faced with higher tax uncertainty, households want to save more. At the same time households invest less because of the increased probability of higher tax rate on capital income. The increased uncertainty surrounding capital tax raises the demand for bonds leading to decline in yields across maturities.

2.5.8 The Importance of Fiscal Shocks for the Term Premium

Ex ante, productivity, fiscal and monetary policy shocks could all be very important drivers of the term premium. Table 2.6 has already highlighted that, in fact, fiscal volatility shocks turn out to be a key driver of variation in term premium within our model. To further substantiate our claim that fiscal shocks represent a key determinant of the term premium, we feed our model with the filtered shocks from the estimated government spending and capital tax rate dynamics, see Eqs. (2.1) and (2.2). Figure 2.8(a) compares the model's prediction for the term premium to the empirical measure of term premium obtained in (Adrian, Crump, and Moench 2013). The left Panel presents the term premium obtained when we feed into our model shocks to government and capital rate *level* only; the right Panel presents the premium when we feed our model with both fiscal *level* and *volatility* shocks.[31]

[Insert Figure 2.7 about here.]

The figure shows how the fiscal level shocks make the model able to track the average term premium whereas the volatility shocks helps in capturing the variability of the term premium. Also, the interaction of shocks to level and volatility captures the trending down in the late 90s. Finally, our model captures the increase in term premium around the financial crisis. To our eyes, (the fiscal shocks in) the model provides a tantalizing account of the cyclical and longer-term fluctuations in the term premium.

We also quantify the relative contribution of real and inflation risk premia to the overall nominal compensation. Figure 2.8(b) shows the result. The Figure superimposes the model-implied nominal and real term premium, as well as their difference, the inflation risk premium. The left panel shows that fiscal level shocks generate both a sizable level effect via real term premium and, more importantly, substantial variability through movements in inflation risk premium. Looking at the right chart, we observe that adding fiscal volatility shocks leads to remarkable fluctuations in real term premia. In all, the compensation investors require for bearing real interest rate risk – the risk that real short rates don't evolve as they expected – represent a force behind movements in nominal term premia as important as inflation risk premium according to our model. This finding bodes well with the reduced form results in (Abrahams, Adrian, Crump, Moench, and Yu 2016).

2.6 Fiscal Shocks at the ZLB

In this section we study the propagation of fiscal shocks when the economy is already at the zero lower bound (ZLB) such that the nominal interest rate is zero. In the aftermath of the 2008 financial crisis, the Federal Reserve Bank aggressively lowered the Fed funds rate to close to zero as a response in order to stimulate economic activity. This led to the longest episode of zero interest in modern U.S. history until interest rate liftoff

[31] We estimate the parameters in Eqs. (2.1) and (2.2) following a Bayesian approach. The particle filter delivers draws for the shocks. We feed each draw into the model; then, we compute the median and 95 percent probability intervals for the model-implied premium.

in late 2015. Over the last decade, the ZLB interest rate economy has been of intense interest to macroeconomists and financial economists alike. The study of fiscal policy at the zero lower bound is especially relevant as the central bank loses its main policy instrument which is the nominal short rate.

The expansionary impact of the fiscal policy response in the absence of monetary policy coordination has been the subject of great debate. In a well cited paper, Christiano, Eichenbaum, and Rebelo (2011) find that the government spending multiplier, or the dollar-to-dollar increase in GDP per dollar spent, is much larger when the nominal interest rate is at the ZLB. In our analysis here, we document that this amplifying effect of the ZLB on the real economy not only holds for government spending level shocks, but the effect is even more pronounced for government spending volatility shocks as well as capital income tax shocks. Implications of the impulse responses due to fiscal shocks at the ZLB lead to intensification of bond risk premia when the nominal short rate is at zero for a prolonged period.

To implement the ZLB analysis in our model, we follow (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) and Sims (2017) by treating the lower bound as an interest rate peg at zero. More precisely, employing news shocks in the Taylor rule of a standard DSGE model, Sims (2017) demonstrates how to solve for the news shocks that allow the interest rate to be held at a constant over various horizons. This technique lets the model produce conditional IRFs at the ZLB. Appendix 2.10.5 provides additional details regarding the implementation. In our analysis of the impact of fiscal level and volatility shocks at the ZLB, we perform two experiments. Assuming the interest rate is already at zero, we perturb the economy with fiscal shocks while forcing the interest to stay at the ZLB for 4 and 8 quarters. In this setting, there is no uncertainty about when departure from the zero interest rate is going to take place, which greatly reduces the complexity of the ZLB analysis. The 4-quarter peg is motivated by the evidence in (Swanson and Williams 2014) that until the Fed put an explicit date for the ZLB into its communications (through fall 2011), professional forecasters expected the ZLB to bind for four quarters. The second scenario of 8 quarters instead strikes a compromise between the ex ante views of professional forecasters and the actual realization of events (which turned out to be roughly 28 quarters).

Figure 2.8 presents the impulse responses following a one standard deviation positive government spending level shock, panel (a), and a one standard deviation positive spending volatility shock, panel (b), conditional on the nominal short rate stays at zero for 4 quarters (long dashed line, ZLB 4Q) and 8 quarters (short-long dashes, ZLB 8Q) after the initial shock. The subplots also overlay the unconditional responses from the benchmark economy (solid line) for comparison purposes. Figure 2.8 panel (a) shows that following a positive level shock to government spending, output increases by more than 2% under ZLB 8Q relative to the benchmark rise of 1%, consistent with Christiano, Eichenbaum, and Rebelo (2011). The increases in investment and inflation are even more pronounced: 4% and 3% respectively under ZLB 8Q compared with less than 1% for both under the benchmark. The drastic increase in output under ZLB 8Q leads to an immediate rise in real wage whereas the benchmark response shows a decline in wage. Higher wage combined with higher return on capital cause marginal cost to increase by more than 1%. On the other hand, the significant rise in investment when the lower bound is binding makes saving less attractive for consumption smoothing, thus the increase in debt is less relative to the benchmark case. Moreover, the ZLB has term structure implications for the spending level shock. The spike in the SDF following a positive spending level shock are similar across the three scenarios so we do not illustrate the impulses here.[32] The fact that the spending shock generates much higher inflation when the lower bound is binding implies the covariance between the SDF and inflation is also higher at the ZLB resulting in greater inflation risk premium. Panel (a) further shows that with the nominal short rate held at zero for multiple periods after the initial shock, the long-term yield rises but not as much as the benchmark case. Whereas the level spending shock has a flattening effect on the yield curve in the benchmark case, the same shock steepens the yield curve slightly at the ZLB.

[Insert Figure 2.8 about here.]

Figure 2.8 panel (b) displays the impulse responses following a positive government spending volatility shock. The first striking result is that the impact of the volatility shock is greatly exacerbated when the ZLB is binding. The declines in output, investment, wages, inflation and marginal cost are orders of magnitude larger for ZLB 8Q than the benchmark. For example, with the short rate held at zero for 8 quarters following the initial shock, output drops by nearly 10% during that window, consistent with the finding of Nakata (2017). Following an uncertainty shock at the zero lower bound, government debt is in high demand as investment falls and precautionary savings motive kicks into high gear. The 30% decline in inflation under ZLB 8Q implies a lower average inflation risk premium stemming from the spending volatility shock. Finally, the IRFs for short rate and the 5-year rate demonstrate the steepening effect of the uncertainty shock on the yield curve for ZLB 8Q, resulting in higher nominal term premium.

Next, we examine the consequences of capital return tax rate shocks at the ZLB. Figure 2.9 presents the IRFs for capital tax level and volatility shocks, in panels (a) and (b),

[32] This is the case for all four fiscal shocks we examine at the ZLB. Therefore, the SDF IRFs are omitted in Figures 2.8 and 2.9.

respectively. Two takeaways are worth pointing out. First, the ZLB amplifies the impact of return to capital tax rate shocks on output, investment, wages, inflation and marginal cost by comparing ZLB 8Q and the benchmark in both panels. Second, unlike the government spending shocks in Figure 2.8, the positive level shock to the capital income tax rate is much more significant than the positive volatility shock in depressing the economy. When the nominal short rate is held at zero for prolonged period of time, a positive one standard deviation shock to the tax rate level causes output to decline by more than 10%, investment by more than 30% and inflation by almost 40% in panel (a). The corresponding declines in panel (b) are 2%, 8% and 4%. On the term structure, Figure 2.9 exhibits low inflation when the SDF is high for both level and volatility shocks to the capital income tax rate, suggesting inflation risk premium is more negative at the ZLB due to these shocks. Furthermore, with the nominal short rate held at zero after the shocks are realized, the 5-year yields dip in both panels (a) and (b). The flattening of the nominal yield curve following capital tax rate level and volatility shocks generates negative term premium when the ZLB is binding.

[Insert Figure 2.9 about here.]

Together, Figures 2.8 and 2.9 establish the amplified impact of fiscal policy shocks on the real economy at the ZLB. Consistent with the findings of Christiano, Eichenbaum, and Rebelo (2011), a positive government spending level shock creates a substantial economic boom shifting savings from government debt to investment, which drives up inflation and inflation risk premium. On the other hand, a positive government spending volatility shock generates a severe economic downturn, pushing the demand curve for debt significantly outward when the zero interest rate is binding, in line with Nakata (2017). Since ZLB only binds temporarily and the shock is transitory, this causes long-term yields to rise as the short rate is fixed. The steepening yield curve in turn produces positive nominal term premium. Lastly, positive shocks to the level and volatility of capital income tax rate also result in economic depressions at the ZLB, but the nominal yield curves tend to flatten following those shocks, making nominal term premia negative.

2.7 Conclusion

We document that our DSGE model featuring fiscal policy and policy uncertainty is successful in matching both macroeconomic and financial moments in the data. Importantly for our purpose, the model is quite successful in reproducing the average 5-year term premium, as well as its dynamic properties as captured by the autocorrelation function. Stochastic volatility in government spending allows to capture up to 70% of the overall term premium variability, whereas a model with no stochastic volatility would account for at most 13% of the term premium volatility.

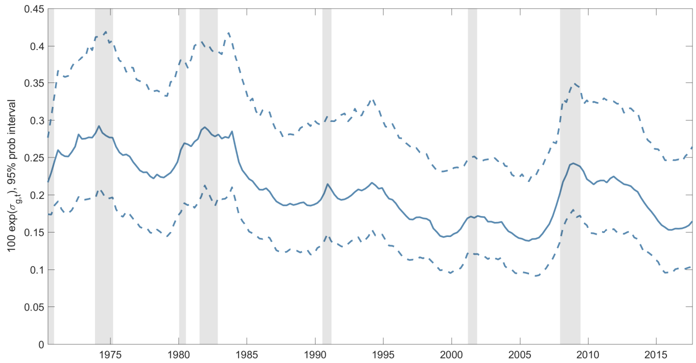
We also show that the relationship between consumption and inflation depends critically on the nature of the underlying fiscal shocks: government spending level shocks imply a negative correlation between consumption and inflation, while government spending uncertainty shocks imply exactly the opposite relationship. Since the empirical relation between consumption and inflation was large and negative in the 1970s and early 1980s, but much smaller in the 1990s and 2000s (see (Piazzesi and Schneider 2007) and (Benigno 2007)), our finding suggests that the relative importance of transitory technology and government level shocks may have been larger in the 1970s and early 1980s than over the rest of the sample where monetary and government spending uncertainty shocks may have become dominant.

Finally, our analysis at the zero lower bound (ZLB) of the nominal interest rate reveals the following three points. First, effects of fiscal shocks on macroeconomic variables are amplified when the ZLB is binding. Second, this amplification is particularly sharp for government spending volatility shocks and capital income tax rate level shocks. Third, bond risk premia implications due to fiscal shocks remain substantial at the ZLB.

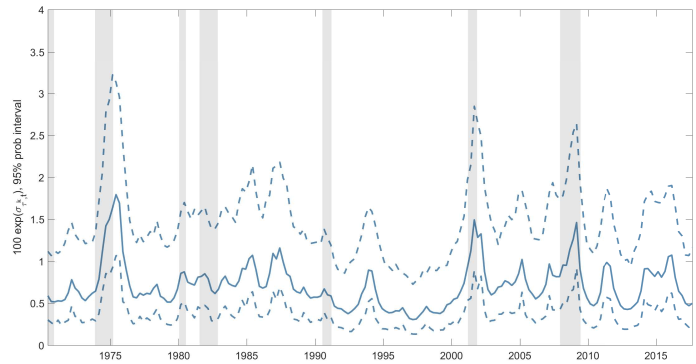
In all, we view our estimated DSGE model as an important step forward to understand what state variables drive variation over time in bond risk premia. Our finding speak to the key role played by shocks to the level and the uncertainty about fiscal policy.

2.8 Figures

FIGURE 2.1: **Smoothed Fiscal Uncertainty**



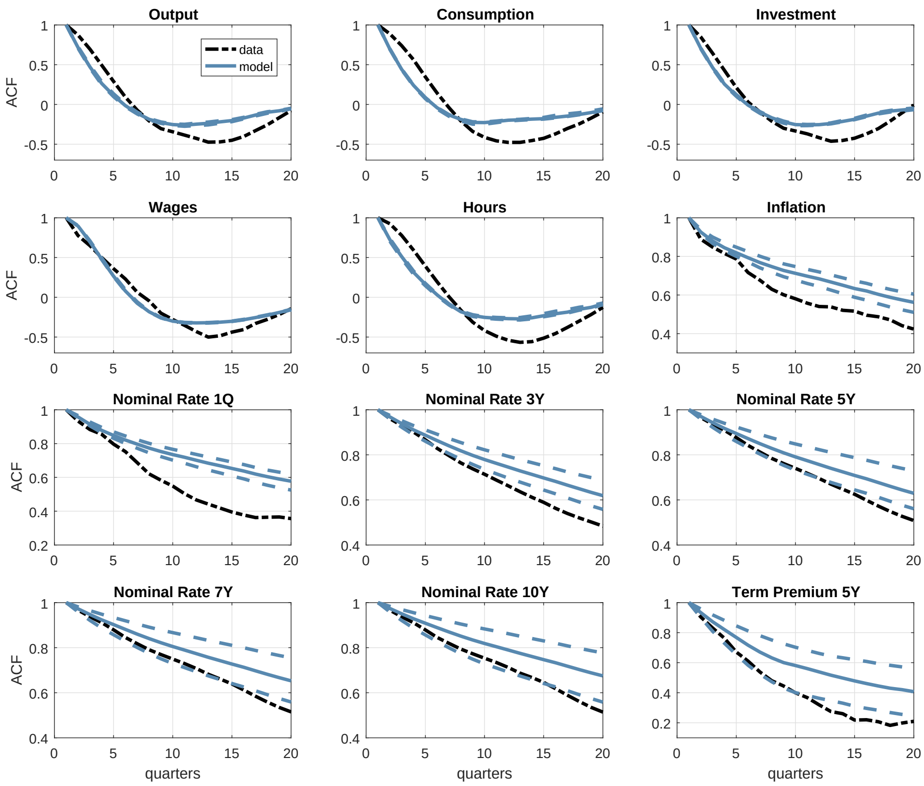
(a) Government Spending Volatility.



(b) Capital Tax Rates Volatility.

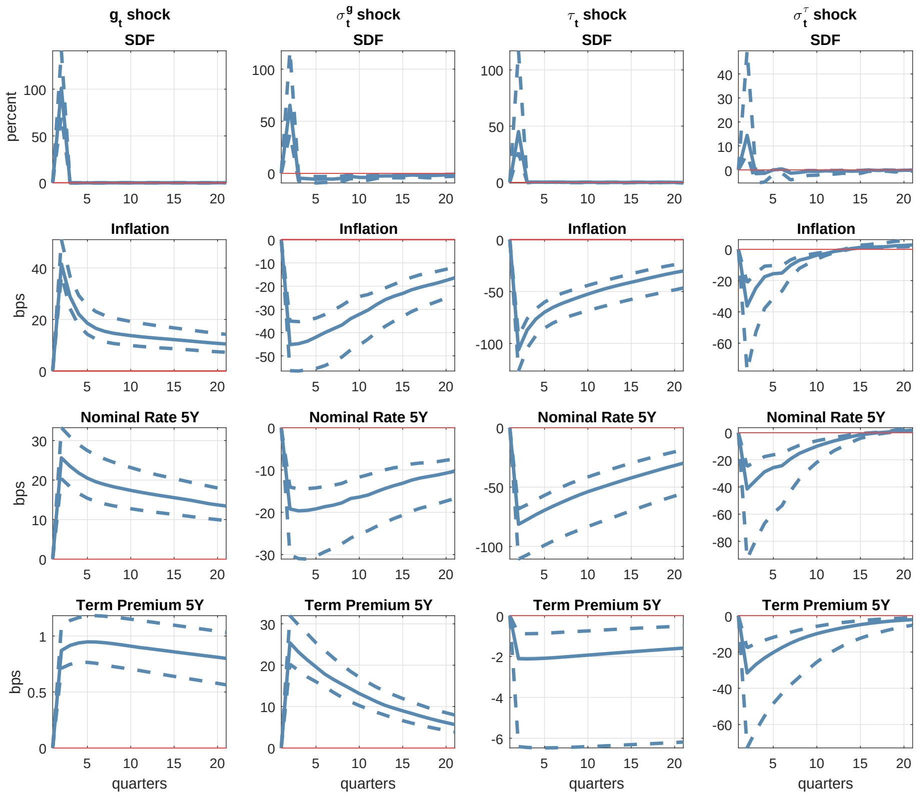
The figure displays the 95 percent posterior probability intervals of the smoothed fiscal volatility shock to policy instruments, $100\exp(\sigma_{x,t})$, over the sample. The panel shows by how many percentage points a one-standard-deviation innovation to the fiscal shock would have moved the government spending (Panel A) and the capital income tax rate (Panel B) at different moments.

FIGURE 2.2: **Autocorrelation Functions**



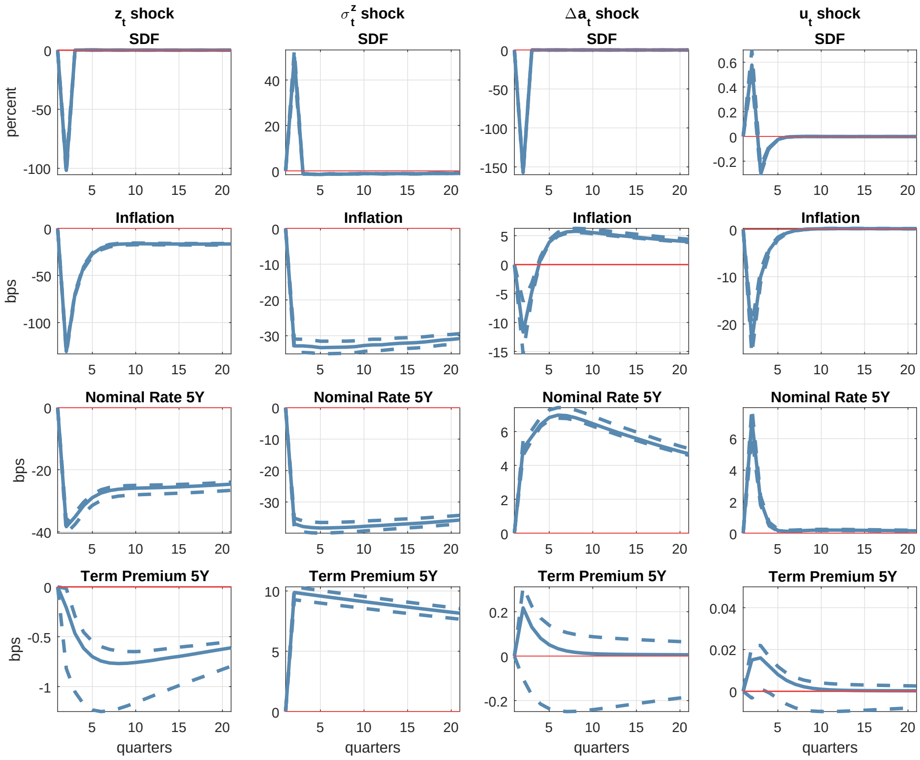
Autocorrelation function of the observable variables in the baseline model and the data. The black line is the data. The blue line is the model's median and the dashed lines are the model's 5th and 95th percentiles. The sample period for the data runs from 1970.Q1 to 2014.Q2.

FIGURE 2.3: **Impulse Responses to Structural Shocks**



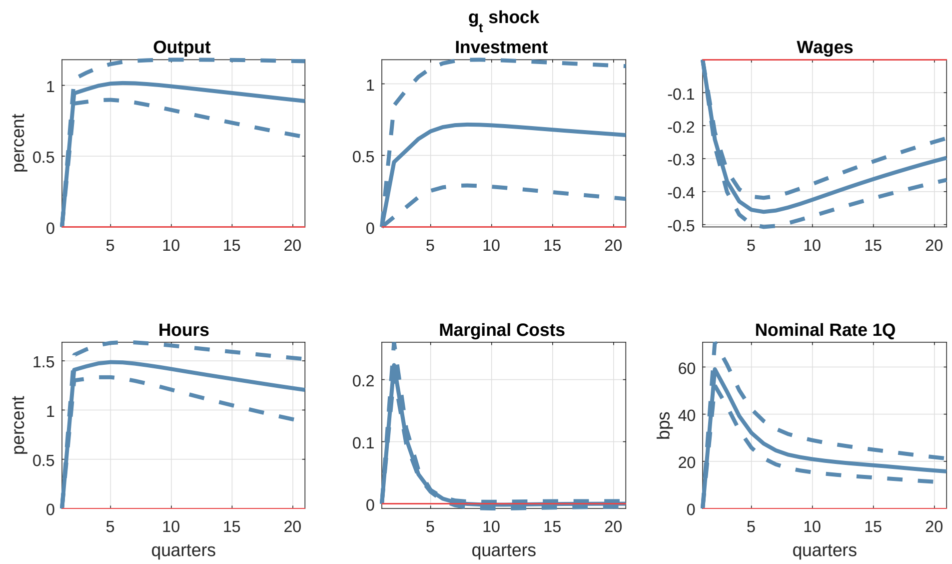
This figure plots the impulse responses of the stochastic discount factor, inflation, long-term bond yields and the term premium to positive one standard deviation shocks to government spending level (g_t), government spending volatility ($\sigma_{g,t}$), capital income tax level (τ^k) and capital income tax volatility ($\sigma_{\tau^k,t}$).

FIGURE 2.4: **Impulse Responses to Structural Shocks**

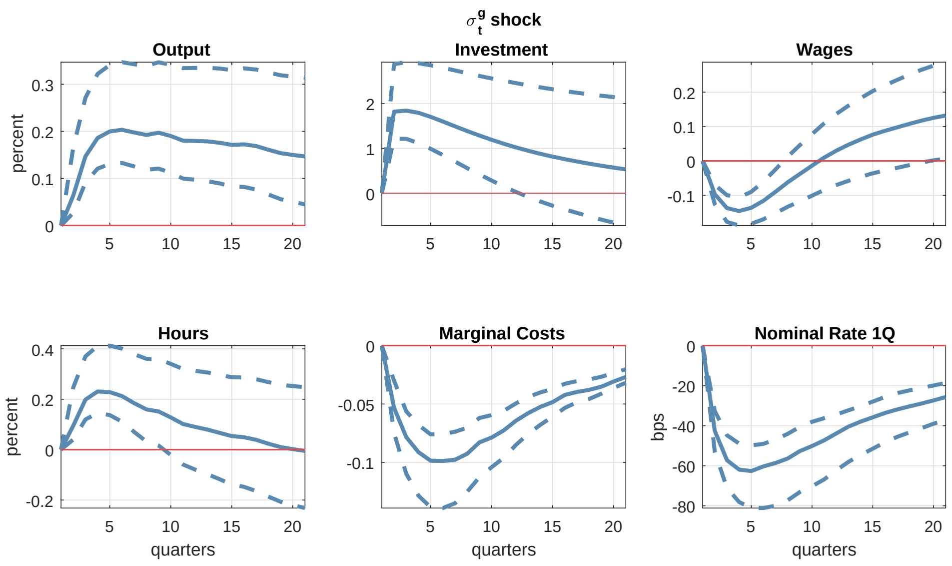


This figure plots the impulse responses of stochastic discount factor, inflation, long-term bond yields and the term premium to positive one standard deviation shocks to transitory productivity level (z_t) and volatility (σ_t^z), to permanent productivity (Δa_t) and to monetary policy (u_t)

FIGURE 2.5: **IRFs to Government Spending Shock**



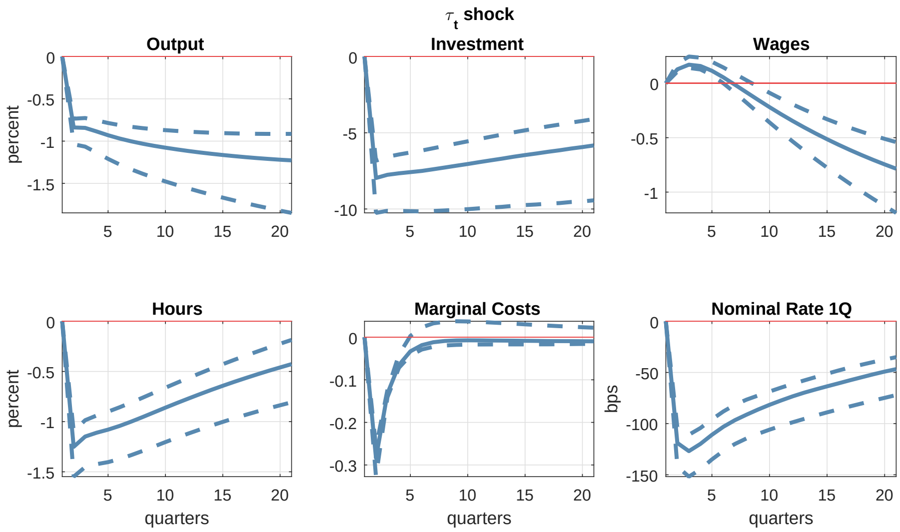
(a) Government spending level (g_t).



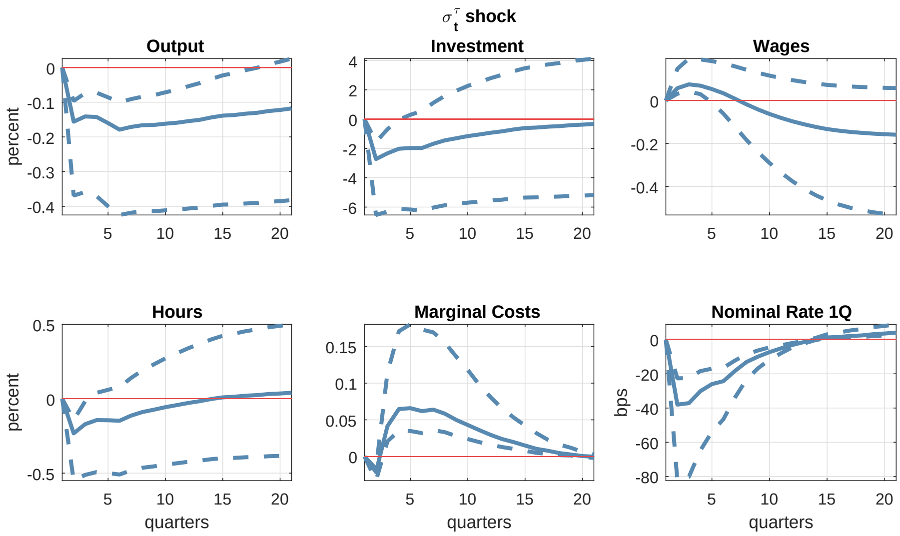
(b) Government spending volatility ($\sigma_{g,t}$).

This figure plots the impulse responses to a one standard deviation shock to government spending level (g_t) and volatiltiy ($\sigma_{g,t}$).

FIGURE 2.6: **IRFs to Capital Income Tax Shock**



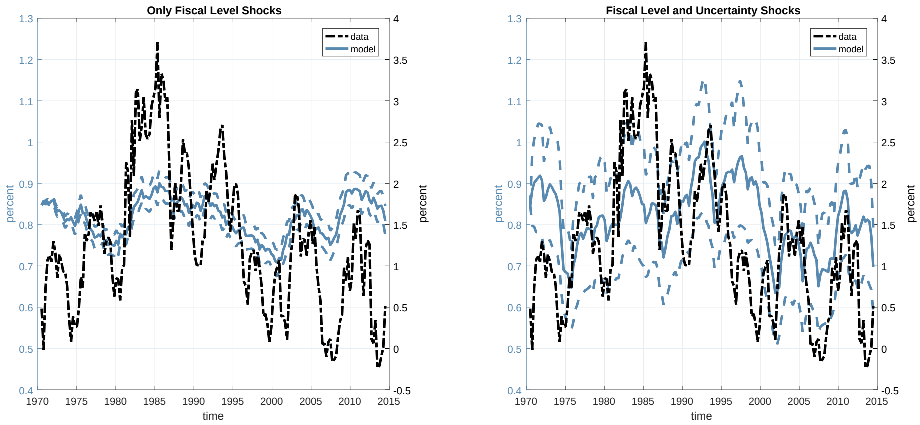
(a) Capital income tax level (τ_t^k).



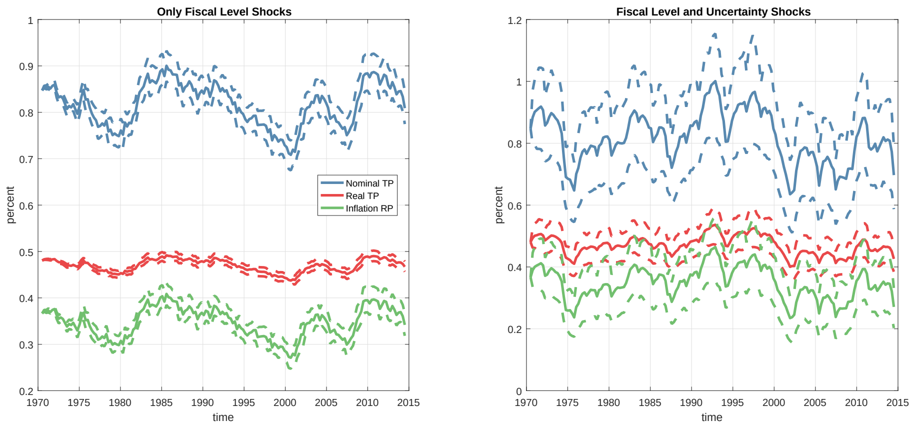
(b) Capital income tax volatility ($\sigma_{\tau^k,t}$).

This figure plots the impulse responses to a one standard deviation shock to capital income tax level (τ^k) and volatility ($\sigma_{\tau^k,t}$).

FIGURE 2.7: **Counterfactual Analysis**



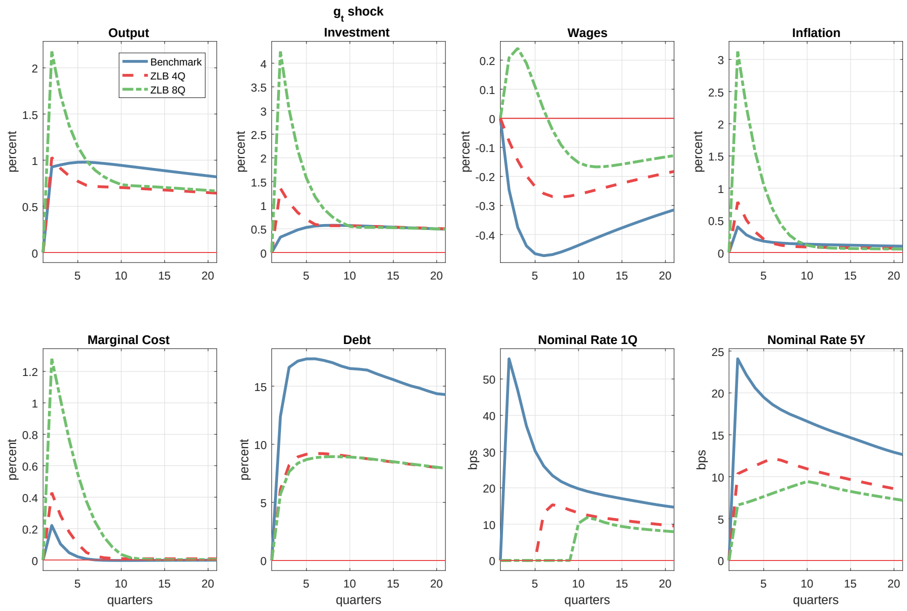
(a) Term Premium - Counterfactual Analysis.



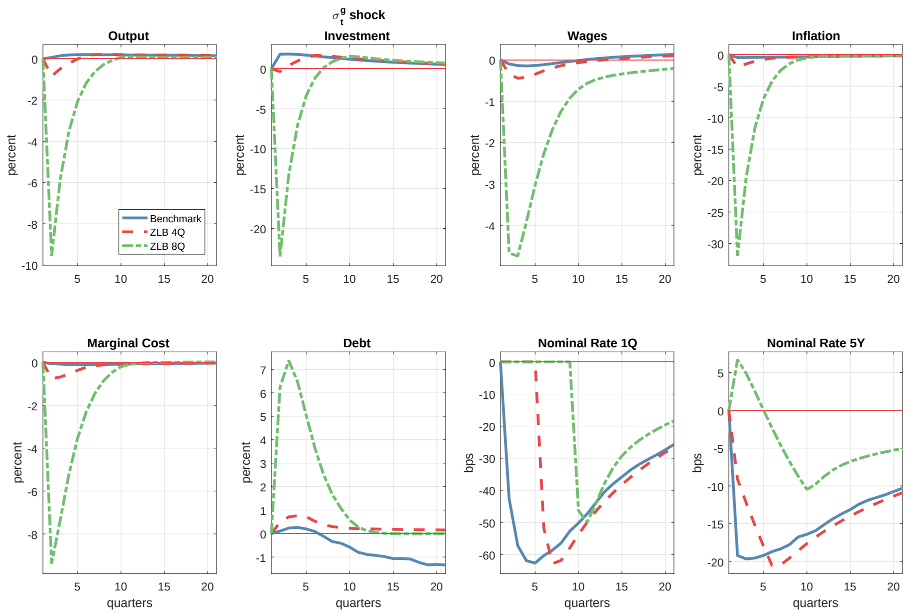
(b) Nominal vs Real Term Premium.

Panel A plots the model-implied term premium against the actual term premium for the period from 1970.Q1 to 2014.Q4. The solid blue line is the median, while the dashed lines are the 5th and 95th percentiles. The correlation between the data and the model-implied term premium is 0.50 in the left panel and 0.54 in the right panel. Panel B plots the model-implied nominal and real term premium as well as the inflation risk premium. The green line is the difference between the median nominal and median real term premium.

FIGURE 2.8: **IRFs to Government Spending Shock at ZLB**



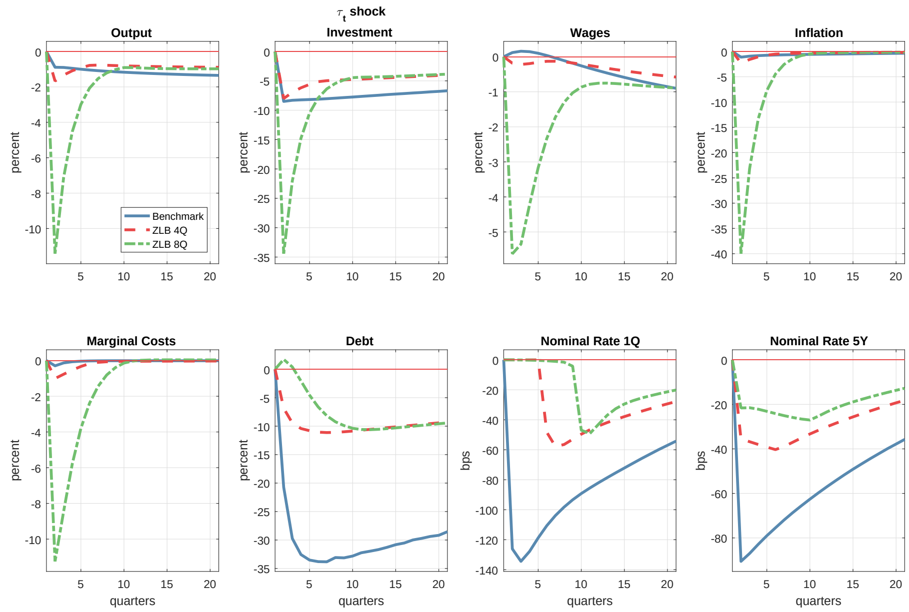
(a) Government spending level (g_t).



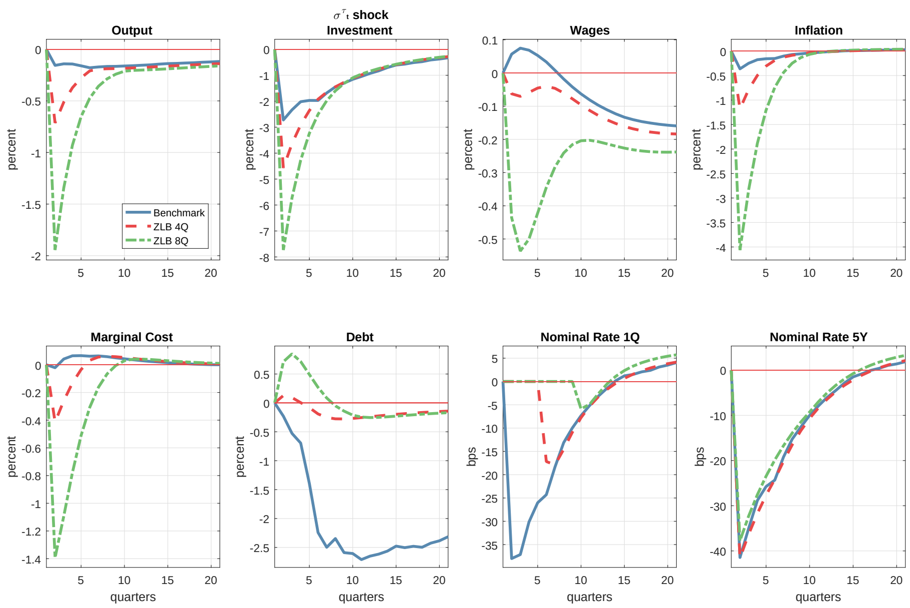
(b) Government spending volatility ($\sigma_{g,t}$).

This figure plots the impulse responses to a one standard deviation shock to government spending level (g_t) and volatiltiy ($\sigma_{g,t}$). The solid lines show the responses under the benchmark case (zero lower bound not binding), the dashed lines under a four period peg, and the dashed-dotted lines under an eight period peg.

FIGURE 2.9: **IRFs to Capital Income Tax Shock at ZLB**



(a) Capital income tax level (τ_t^k).



(b) Capital income tax volatility ($\sigma_{\tau^k,t}$).

This figure plots the impulse responses to a one standard deviation shock to capital income tax level (τ^k) and volatility ($\sigma_{\tau^k,t}$). The solid lines show the responses under the benchmark case (zero lower bound not binding), the dashed lines under a four period peg, and the dashed-dotted lines under an eight period peg.

2.9 Tables

TABLE 2.1: **Bond yields and Fiscal Policy**:

Quarterly time-series regressions. The dependent variable is the slope of the yield curve as measured by the difference between the 5-year and the 1-year rates, $y_t^{(20)} - y_t^{(4)}$ (Panel A), or the 10-year and the 1-year rates, $y_t^{(40)} - y_t^{(4)}$ (Panel B). The independent variable are the maturity-weighted-debt-to-GDP ratio (MWD/GDP, see Greenwood-Vayanos, 2014), the level of government spending (g_t) and capital tax rate (τ^k), and the filtered volatilities of government spending ($\sigma_{g,t}$) and capital income tax ($\sigma_{\tau^k,t}$) series. The t -statistics, reported in parentheses, is based on Newey-West standard errors, with 12 lags. The coefficient on MWD/GDP is multiplied by 100.

Panel A: $y_t^{(20)} - y_t^{(4)} = \beta_0 + \beta_1 g_t + \beta_2 \sigma_{g,t} + \beta_3 \tau_t^k + \beta_4 \sigma_{\tau^k,t} + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

β_1	β_2	β_3	β_4	c	R^2
				0.24	0.10
				(2.04)	
0.48	0.18			0.34	0.39
(3.62)	(3.84)			(2.99)	
0.38	0.13	-0.10	0.00	0.39	0.43
(3.24)	(2.49)	(-1.76)	(1.37)	(3.45)	

Panel B: $y_t^{(40)} - y_t^{(4)} = \beta_0 + \beta_1 g_t + \beta_2 \sigma_{g,t} + \beta_3 \tau_t^k + \beta_4 \sigma_{\tau^k,t} + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

β_1	β_2	β_3	β_4	c	R^2
				0.37	0.12
				(2.24)	
0.71	0.19			0.46	0.39
(3.49)	(2.71)			(3.01)	
0.60	0.12	-0.13	0.00	0.52	0.42
(3.76)	(1.96)	(-1.33)	(0.57)	(3.37)	

TABLE 2.2: **Bond returns and Fiscal Policy**:

Quarterly time-series regression. The dependent variable is the one-year, three-year, or five-year excess return of the τ-year bond. The independent variable are the maturity-weighted-debt-to-GDP ratio (MWD/GDP, see Greenwood-Vayanos, 2014), the level of government spending (g_t) and capital tax rate (τ^k), and the filtered volatilities of government spending ($\sigma_{g,t}$) and capital income tax ($\sigma_{\tau^k,t}$) series. The t-statistics, reported in parentheses, is based on Newey-West standard errors with 6 lags. The coefficient on MWD/GDP is multiplied by 100.

Panel A: $rx^{(\tau)}_{t+k,k} = \beta_0 + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	0.41	0.75	1.08	1.38	2.69	2.04	1.41
	(1.81)	(1.92)	(2.05)	(2.17)	(2.47)	(3.50)	(4.15)
$\bar{R}^2$	0.05	0.06	0.06	0.06	0.07	0.25	0.37

Panel B: $rx^{(\tau)}_{t+k,k} = \beta_0 + \beta_1 \; g_t + \beta_2 \; \sigma_{g,t} + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	0.60	1.06	1.47	1.85	3.59	2.47	1.48
	(3.30)	(3.24)	(3.29)	(3.37)	(3.73)	(4.94)	(4.65)
Govnt Sp Lev.	0.68	1.22	1.65	2.02	3.49	2.15	0.83
	(2.81)	(2.76)	(2.75)	(2.74)	(2.61)	(3.18)	(2.51)
Govnt Sp Vol.	0.38	0.62	0.80	0.97	1.82	0.93	0.22
	(3.27)	(3.12)	(3.05)	(3.03)	(3.03)	(2.34)	(1.39)
$\bar{R}^2$	0.22	0.20	0.19	0.18	0.17	0.47	0.43

Panel C: $rx^{(\tau)}_{t+k,k} = \beta_0 + \beta_1 \; g_t + \beta_2 \; \sigma_{g,t} + \beta_3 \; \tau^k_t + \beta_4 \; \sigma_{\tau^k,t} + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	0.71	1.30	1.82	2.31	4.48	2.74	1.77
	(3.49)	(3.46)	(3.49)	(3.55)	(3.81)	(5.81)	(6.27)
Govnt Sp Lev.	0.45	0.75	0.96	1.13	1.77	1.68	0.40
	(1.56)	(1.44)	(1.37)	(1.32)	(1.13)	(1.98)	(1.18)
Govnt Sp Vol.	0.30	0.45	0.56	0.65	1.16	0.77	0.01
	(2.90)	(2.53)	(2.33)	(2.21)	(2.07)	(1.95)	(1.18)
Capital Tax Lev.	-0.13	-0.28	-0.43	-0.57	-1.22	-0.45	-0.60
	(-1.06)	(-1.24)	(-1.33)	(-1.40)	(-1.56)	(-1.64)	(-3.18)
Capital Tax Vol.	0.01	0.02	0.03	0.04	0.06	-0.00	-0.01
	(1.46)	(1.50)	(1.54)	(1.55)	(1.50)	(-0.13)	(-1.10)
$\bar{R}^2$	0.23	0.21	0.21	0.21	0.20	0.49	0.53

TABLE 2.3: **Calibrated and Estimated Parameters**:

This table reports the parameter values for the baseline model.

Panel A: Calibrated Parameters			**Panel B: Separately Estimated Parameters**			**Panel C: Estimated Parameters**			
	Coefficient Description	Value		Coefficient Description	Value		Coefficient Description	1. Step GMM	2. Step GMM
δ	capital depreciation	0.02	ϕ_g	autocorrelation of government spending level	0.98	β	time discount parameter	0.995	0.994
					[0.95;0.99]			(0.022)	(0.000)
κ	capital share of production	0.33	ϕ_{σ_g}	autocorrelation of government spending volatility	0.92	ψ	inverse of the elasticity of intertemporal substitution	1.901	1.876
					[0.80;0.96]			(3.048)	(0.062)
α	share of firms with rigid prices	0.65	θ_{σ_g}	steady-state of government spending volatility	-6.03	γ	risk aversion	181.421	185.024
					[-6.31; -5.83]			(46.843)	(2.755)
θ	share of firms with rigid wages	0.65	σ_{σ_g}	volatility of government spending volatility	0.31	ω	inverse of Frisch labor elasticity	0.452	0.450
					[0.08;0.42]			(3.861)	(0.085)
η	markup parameter	6.00				ζ	capital adjustment cost	2.001	2.068
								(1.976)	(0.087)
ρ_r	interest-rate smoothing coefficient	0.35							
ρ_π	Taylor rule coefficient on inflation	1.5				ρ_x	Taylor rule coefficient on output gap	0.098	0.072
								(1.490)	(0.013)
η_w	markup parameter	6.00	ϕ_τ	autocorrelation of capital tax level	0.98				
					[0.92;0.99]				
θ_g	steady-state government spending level	0.20	ϕ_{σ_τ}	autocorrelation of capital tax volatility	0.78	ρ_b	fiscal response to debt	0.650	0.662
					[0.58;0.89]			(2.207)	(0.839)
θ_τ	steady-state capital tax level	0.37	θ_{σ_τ}	steady-state of capital tax volatility	-4.84	ρ_g	fiscal response to government spending	0.125	0.124
					[-5.21; -4.70]			(2.592)	(0.417)
ϕ_z	autocorrelation of transitory productivity level	0.98	σ_{σ_τ}	volatility of capital tax volatility	0.54	ϕ_a	autocorrelation of permanent productivity shock	0.180	0.150
					[0.32;0.70]			(0.755)	(0.081)
ϕ_{σ_z}	autocorrelation of transitory productivity volatility	0.99				g_a	steady-state of permanent productivity shock	0.007	0.007
								(0.049)	(0.000)
θ_{σ_z}	steady-state of transitory productivity volatility	-4.82				σ_a	volatility of permanent productivity shock	0.004	0.004
								(0.003)	(0.000)
σ_{σ_z}	volatility of transitory productivity volatility	0.03				σ_u	volatility of monetary policy shock	0.003	0.002
								(0.038)	(0.000)

TABLE 2.4: **Empirical and Model-Based Unconditional Moments**:

This table reports the mean, standard deviations and correlations for observable variables in the baseline model. The sample period for the data is 1970.Q1 to 2014.Q2. All data, except nominal interest rates, term premium and inflation, are in logs, HP-filtered, and multiplied by 100 to express them in percentage deviation from trend. In Panel B, interest rates and the term premia are expressed at an annual rate. The slope is proxied by the spread between the ten-year and one-quarter rates.

Panel A: Macro Moments

	Model			Data		
	SD	AR(1)	Cor(.,yt)	SD	AR(1)	Cor(.,yt)
Output	1.49	0.71	1.00	1.54	0.87	1.00
	[1.44; 1.58]	[0.71; 0.72]				
Consumption	1.23	0.70	0.26	1.27	0.89	0.88
	[1.16; 1.39]	[0.70; 0.70]	[0.13; 0.36]			
Investment	7.01	0.71	0.61	7.07	0.85	0.92
	[5.69; 9.21]	[0.70;0.71]	[0.58; 0.63]			
Wages	1.16	0.90	0.39	1.13	0.78	-0.29
	[1.14; 1.21]	[0.90;0.90]	[0.30; 0.46]			
Hours	1.49	0.73	0.61	1.94	0.93	0.87
	[1.37; 1.67]	[0.72;0.73]	[0.57; 0.65]			
Inflation	0.69	0.93	0.05	0.61	0.89	0.11
	[0.61; 0.80]	[0.92;0.93]	[0.01; 0.09]			

Panel B: Finance Moments

	Model				Data			
	Mean	SD	AR(1)	Cor(.,yt)	Mean	SD	AR(1)	Cor(.,yt)
Nominal Rate 1Q	5.62	4.09	0.99	0.06	5.62	3.88	0.94	0.22
	[5.00; 6.59]	[3.60; 4.80]	[0.98; 0.99]	[0.02; 0.10]				
Nominal Rate 3Y	6.39	3.22	0.97	0.10	6.04	3.26	0.97	0.04
	[5.98; 7.04]	[2.80; 3.88]	[0.97; 0.97]	[0.07; 0.14]				
Nominal Rate 5Y	6.53	2.85	0.97	0.10	6.34	3.06	0.97	0.00
	[6.14; 7.09]	[2.44; 3.52]	[0.97; 0.98]	[0.06; 0.14]				
Nominal Rate 7Y	6.65	2.54	0.97	0.10	6.58	2.90	0.97	-0.02
	[6.31; 7.06]	[2.20; 3.16]	[0.97; 0.98]	[0.06; 0.14]				
Nominal Rate 10Y	6.84	2.18	0.97	0.09	6.84	2.71	0.97	-0.05
	[6.35; 7.12]	[1.88; 2.80]	[0.97; 0.98]	[0.04; 0.13]				
Slope	1.23	2.17	0.92	-0.02	1.23	2.09	0.77	-0.47
	[0.37; 1.63]	[2.00; 2.36]	[0.92; 0.93]	[-0.05; 0.14]				
Term Premium 5Y	0.86	0.61	0.93	0.04	1.29	0.86	0.91	-0.34
	[0.38; 1.10]	[0.32; 1.01]	[0.91; 0.95]	[0.02; 0.09]				
Term Premium 10Y	1.16	0.72	0.95	0.04	1.95	1.07	0.92	-0.32
	[0.30; 1.56]	[0.40; 1.28]	[0.94; 0.97]	[0.02; 0.09]				

Table 2.5: **Real term structure of interest rates**:

This table presents the mean, standard deviation, and first autocorrelation of the two-year (RY8), three-year (RY12), five-year (RY20), seven-year (RY28), and ten-year (RY40) real yields, and the 10-year and two-year spread from the model and the data. Interest rates are expressed at an annual rate.

Model						
	Slope	**RY8**	**RY12**	**RY20**	**RY28**	**RY40**
mean:	0.48	3.42	3.69	3.78	3.83	3.90
std:	0.75	1.48	1.22	1.07	0.95	0.81
AC1:	0.91	0.95	0.97	0.97	0.97	0.97
Data:1971:3 - 2007:4						
	Slope	**RY8**	**RY12**	**RY20**	**RY28**	**RY40**
mean:	0.47	2.33	2.41	2.56	2.67	2.80
std:	0.75	1.51	1.36	1.17	1.05	0.92
AC1:	0.76	0.89	0.91	0.93	0.93	0.94
Data:1971:3 - 2014:2						
	Slope	**RY8**	**RY12**	**RY20**	**RY28**	**RY40**
mean:	0.62	1.87	1.96	2.19	2.33	2.49
std:	0.84	1.80	1.67	1.43	1.29	1.13
AC1:	0.76	0.89	0.91	0.93	0.94	0.94

TABLE 2.6: **Variance Decomposition - The Effect of Structural Shocks**:

This table reports the variance decomposition for the different structural shocks in the baseline model. A and Z stand for permanent and transitory productivity, respectively. G stands for government spending. In Panel B, the one-quarter, three-year, five-year, seven-year, ten-year nominal yields, the slope (ten-year and one-quarter spread), and the term premia are expressed at an annual rate.

Panel A: Macro Moments

	Output	**Consumption**	**Investment**	**Wages**	**Hours**	**Inflation**
All Shocks	1.49	1.23	7.01	1.16	1.49	0.69
Only A	0.51	0.48	0.69	0.31	0.24	0.04
Only Monetary	0.15	0.10	0.38	0.04	0.22	0.03
Only Z Level	0.96	0.80	1.75	1.01	0.28	0.22
Only Z Uncertainty	0.10	0.04	0.50	0.03	0.15	0.29
Only G Level	0.45	0.30	0.34	0.19	0.68	0.07
Only G Uncertainty	0.12	0.15	1.41	0.13	0.16	0.21
Only Tax Level	0.44	0.20	3.60	0.17	0.65	0.21
Only Tax Uncertainty	0.12	0.23	2.01	0.11	0.17	0.08

Panel B: Finance Moments

	Nominal Yields					**Slope**	**Term Premia**	
	1Q	**3Y**	**5Y**	**7Y**	**10Y**	**10Y-1Q**	**5Y**	**10Y**
All Shocks	4.09	3.22	2.85	2.54	2.18	2.17	0.61	0.72
Only A	0.20	0.18	0.16	0.15	0.13	0.14	0.00	0.00
Only Monetary	0.53	0.06	0.04	0.03	0.02	0.51	0.00	0.00
Only Z Level	1.12	0.88	0.84	0.80	0.75	0.51	0.02	0.02
Only Z Uncertainty	1.75	1.49	1.37	1.26	1.10	0.65	0.29	0.44
Only G Level	0.42	0.32	0.30	0.28	0.26	0.20	0.03	0.05
Only G Uncertainty	1.22	0.69	0.47	0.33	0.21	1.05	0.34	0.37
Only Tax Level	1.23	0.97	0.84	0.73	0.60	0.66	0.07	0.10
Only Tax Uncertainty	0.45	0.48	0.46	0.42	0.36	0.11	0.37	0.33

TABLE 2.7: **Bond returns and Fiscal Policy**:

Model-implied regression. The dependent variable is the one-year, three-year, or five-year excess return of the τ-year bond. The independent variable are the maturing debt level $D_{t-1}(t)$, the level of government spending and capital tax rate, and the filtered volatilities of government spending and capital tax rate series. The t-statistics, reported in parentheses, is based on Newey-West standard errors with 6 lags.

Panel A: $rx^{(\tau)}_{t+k,k} = \beta_0 + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	1.97	3.56	4.87	5.97	9.06	9.23	5.40
	(6.95)	(7.00)	(6.98)	(6.94)	(6.68)	(5.33)	(2.97)
$\bar{R}^2$	0.05	0.05	0.05	0.05	0.04	0.03	0.01

Panel B: $rx^{(\tau)}_{t+k,k} = \beta_0 + \beta_1 \; g_t + \beta_2 \; \sigma_{g,t} + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	1.96	3.56	4.88	5.97	9.02	9.31	5.65
	(7.01)	(7.07)	(7.05)	(7.01)	(6.73)	(5.68)	(3.32)
Govnt Sp Lev.	0.33	0.50	0.65	0.80	1.63	2.33	1.23
	(2.55)	(2.16)	(2.06)	(2.07)	(2.62)	(2.53)	(1.35)
Govnt Sp Vol.	0.13	0.22	0.29	0.36	0.63	1.30	1.25
	(6.05)	(5.88)	(5.84)	(5.84)	(5.94)	(5.75)	(5.76)
$\bar{R}^2$	0.07	0.07	0.07	0.07	0.07	0.08	0.06

Panel C: $rx^{(\tau)}_{t+k,k} = \beta_0 + \beta_1 \; g_t + \beta_2 \; \sigma_{g,t} + \beta_3 \; \tau^k_t + \beta_4 \; \sigma_{\tau^k,t} + c \text{ MWD/GDP}_t + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	1.92	3.47	4.75	5.81	8.81	8.84	5.04
	(7.18)	(7.22)	(7.20)	(7.17)	(6.94)	(5.75)	(3.06)
Govnt Sp Lev.	0.34	0.51	0.67	0.83	1.68	2.41	1.32
	(2.67)	(2.28)	(2.18)	(2.20)	(2.75)	(2.74)	(1.50)
Govnt Sp Vol.	0.13	0.22	0.29	0.36	0.63	1.30	1.25
	(6.10)	(5.92)	(5.87)	(5.86)	(5.97)	(5.78)	(5.82)
Capital Tax Lev.	-0.01	-0.04	-0.06	-0.06	0.02	-0.36	-0.96
	(-0.11)	(-0.26)	(-0.27)	(-0.24)	(0.05)	(-0.54)	(-1.34)
Capital Tax Vol.	-0.02	-0.03	-0.04	-0.05	-0.08	-0.12	-0.10
	(-2.58)	(-2.57)	(-2.58)	(-2.59)	(-2.65)	(-3.36)	(-3.59)
$\bar{R}^2$	0.09	0.10	0.10	0.10	0.10	0.11	0.09

2.10 Appendix

2.10.1 Data

We follow (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) and construct the macroeconomic observable variables used in the estimation as:

1. Output is real GDP (GDPC1).
2. Consumption is real personal consumption expenditures (PCECC96).
3. Investment is real gross private domestic investment (GPDIC96).
4. Civilian Noninstitutional Population (CNP16OV, quarterly averages).
5. Real Per Capita GDP = (1) / (4).
6. Real Per Capita Consumption = (2) / (4).
7. Real Per Capita Investment = (3) / (4).
8. Inflation is GDP deflator (GDPDEF).
9. Hourly real wage is compensation per hour in the business sector (HCOMPBS) divided by the GDP deflator (GDPDEF).
10. Hours per capita are measured by hours of all persons in the business sector (HOABS).

Data for the period 1970:Q1–2014:Q2 are taken from the St. Louis Fed's FRED database (mnemonics are in parentheses).

Government spending and capital tax rates data are from (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015). In particular, the tax data are constructed from national income and product accounts (NIPA) as in (Leeper, Plante, and Traum 2010) (see also Appendix B in (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) for details). Government spending is government consumption and gross investment, both from NIPA.

With regard to the financial variables, the Treasury yield data are from (Gurkaynak, Sack, and Wright 2007) (data are available for download on the website http://www.federalreserve.gov/Pubs/feds/2006/200628/feds200628.xls) and the series for the 10-year Term premia is from (Adrian, Crump, and Moench 2013) (data available at https://www.newyorkfed.org/research/data_indicators/term_premia.html). We thank the authors for making these data available for download.

2.10.2 Predictive regressions: Robustness

We perform a number of robustness tests. Table 2.8 shows that our results for the (level and volatility of) government spending and capital tax rate series remain significant after controlling for the one-year yield ((Gertler and Karadi 2015) suggest to take the one-year government bond rate as the relevant monetary policy indicator, rather than the federal funds rate), and for trend inflation (see (Kozicki and Tinsley 2001) show that highly persistent expected inflation dynamics determines the level of interest rates in the long run and across maturities; see also (Cieslak and Povala 2015)).

TABLE 2.8: **Quarterly time-series regression for bond returns**

The dependent variable is the one-year, three-year, or five-year return of the τ-year bond. The independent variable is the filtered government spending volatility series. The regressions control for the MWD/GDP (see Greenwood-Vayanos, 2014), the maturity-weighted-debt-to-GDP ratio and for the one-year yield (Panel A) and an inflation trend (Panel B). The t-statistics, reported in parentheses, is based on Newey-West standard errors with 6 lags. The coefficient on MWD/GDP is multiplied by 100.

Panel A: $r^{(\tau)}_{t+k,k} = \beta_0 + \beta_1\ g^{BC}_t + \beta_2\ \sigma_{g,t} + \beta_3\ \tau^k_t + \beta_4\ \sigma_{\tau^k,t} + c\ \text{MWD/GDP}_t + d\ y^4_t + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	0.73	1.32	1.85	2.34	4.51	2.80	1.90
	(1.89)	(1.33)	(1.00)	(0.78)	(0.39)	(3.43)	(3.05)
Govnt Sp Lev.	0.67	1.04	1.27	1.43	2.04	2.23	0.57
	(2.36)	(1.96)	(1.73)	(1.56)	(1.21)	(2.52)	(1.54)
Govnt Sp Vol.	0.32	0.48	0.59	0.68	1.19	0.82	0.08
	(2.77)	(2.39)	(2.21)	(2.12)	(2.06)	(2.08)	(0.49)
Capital Tax Lev.	-0.07	-0.20	-0.34	-0.49	-1.15	-0.31	-0.43
	(-0.61)	(-0.90)	(-1.08)	(-1.22)	(-1.57)	(-1.22)	(3.32)
Capital Tax Vol.	0.01	0.02	0.03	0.03	0.06	-0.01	-0.01
	(1.01)	(1.14)	(1.24)	(1.30)	(1.38)	(-0.55)	(-1.05)
1-yr yield	0.16	0.22	0.23	0.22	0.20	0.42	0.36
	(3.87)	(3.70)	(3.67)	(3.69)	(3.86)	(6.88)	(6.44)
$\bar{R}^2$	0.28	0.24	0.23	0.22	0.20	0.54	0.65

Panel B:

$r^{(\tau)}_{t+k,k} = \beta_0 + \beta_1\ g^{BC}_t + \beta_2\ \sigma_{g,t} + \beta_3\ \text{Capital Tax Lev.}_t + \beta_4\ \text{Capital Tax Vol.}_t + c\ \text{MWD/GDP}_t + d\tau^{\text{CPI}} + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	0.72	1.29	1.80	2.27	4.39	2.74	1.81
	(3.46)	(3.39)	(3.41)	(3.47)	(3.75)	(5.68)	(6.26)
Govnt Sp Lev.	0.46	0.69	0.83	0.90	1.15	1.68	0.40
	(1.60)	(1.30)	(1.13)	(1.01)	(0.72)	(2.01)	(1.12)
Govnt Sp Vol.	0.30	0.45	0.54	0.62	1.09	0.77	0.02
	(2.81)	(2.49)	(2.35)	(2.27)	(2.20)	(1.94)	(0.14)
Capital Tax Lev.	-0.13	-0.32	-0.51	-0.71	-1.60	-0.45	-0.55
	(-0.97)	(-1.28)	(-1.48)	(-1.65)	(-2.09)	(-1.76)	(-3.54)
Capital Tax Vol.	0.01	0.02	0.03	0.04	0.08	-0.00	-0.01
	(1.47)	(1.66)	(1.80)	(1.90)	(2.02)	(-0.13)	(-1.18)
Infl. Trend	0.01	-0.11	-0.27	-0.44	-1.19	0.01	0.16
	(0.08)	(-0.32)	(-0.57)	(-0.76)	(-1.16)	(0.02)	(0.54)
$\bar{R}^2$	0.23	0.22	0.22	0.22	0.22	0.48	0.54

Tables 2.1, 2.2, and 2.9 use the business cycle component of government spending and capital tax rates. The components are obtained using the one-sided filter of (Ortu, Tamoni, and Tebaldi 2013). The filter amounts to remove from the g_t series an 8-year (equally weighted) moving average based on past observation. Table 2.9 shows an alternative interpretation of this result. We focus on government spending for ease of exposition. Panel A in Table 2.9 shows regressions of bond returns on the business cycle component of government spending and its volatility, after controlling for the maturity-weighted debt to GDP, and a time trend. Panel B shows the results when we replace the business cycle component of government spending with the raw series. Despite the the time trend being strongly statistically significant in Panel B, the two panels depicts the same picture, with R^2 that are almost identical for maturities 3- to 10-years.

TABLE 2.9: **Quarterly time-series regression for bond returns**

The dependent variable is the one-year, three-year, or five-year return of the τ-year bond. The independent variable are the government spending level and the filtered government spending volatility series. The regressions control for the MWD/GDP (see Greenwood-Vayanos, 2014), the maturity-weighted-debt-to-GDP ratio and for a time trend. The t-statistics, reported in parentheses, is based on Newey-West standard errors with 6 lags. The coefficients on MWD/GDP and the time trend are multiplied by 100.

Panel A: $r^{(\tau)}_{t+k,k} = \beta_0 + \beta_1\ g^{BC}_t + \beta_2\ \sigma_{g,t} + c\ \text{MWD/GDP}_t + d\ \text{Time trend} + \epsilon_{t+k}$

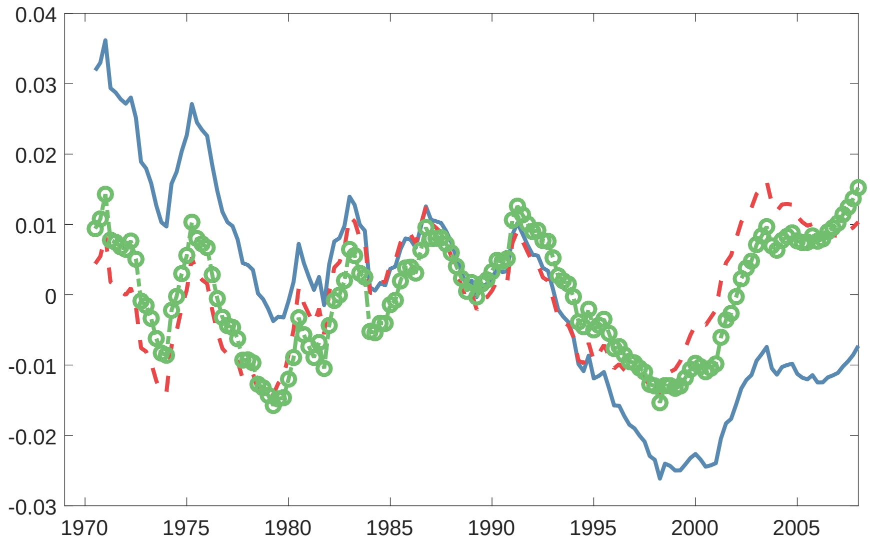
	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	0.65	1.11	1.49	1.84	3.37	2.07	1.10
	(2.68)	(2.53)	(2.54)	(2.60)	(2.90)	(3.04)	(3.12)
Govnt Sp Lev.	0.72	1.25	1.67	2.01	3.32	2.00	0.88
	(3.06)	(2.82)	(2.66)	(2.53)	(2.12)	(2.82)	(2.83)
Govnt Sp Vol.	0.36	0.60	0.80	0.97	1.88	0.99	0.26
	(3.30)	(3.20)	(3.18)	(3.20)	(3.24)	(2.54)	(1.60)
Time Trend	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00
	(-.41)	(-.21)	(-0.08)	(0.04)	(0.39)	(1.03)	(2.05)
$\bar{R}^2$	0.22	0.19	0.18	0.18	0.17	0.48	0.45

Panel B: $r^{(\tau)}_{t+k,k} = \beta_0 + \beta_1\ g_t + \beta_2\ \sigma_{g,t} + c\ \text{MWD/GDP}_t + d\ \text{Time trend} + \epsilon_{t+k}$

	1-yr, 2-yr bond	1-yr, 3-yr bond	1-yr, 4-yr bond	1-yr, 5-yr bond	1-yr, 10-yr bond	3-yr, 10-yr bond	5-yr, 10-yr bond
MWD/GDP	0.55	0.94	1.27	1.58	2.93	1.77	1.23
	(2.12)	(2.01)	(2.03)	(2.09)	(2.45)	(2.65)	(3.26)
Govnt Sp Lev.	0.45	0.81	1.12	1.37	2.35	1.10	0.02
	(1.71)	(1.79)	(1.85)	(1.87)	(1.80)	(1.45)	(1.05)
Govnt Sp Vol.	0.35	0.58	0.77	0.94	1.82	0.97	0.27
	(2.77)	(2.68)	(2.68)	(2.71)	(2.85)	(2.13)	(1.30)
Time. Trend	0.02	0.03	0.04	0.06	0.11	0.07	0.01
	(1.52)	(1.66)	(1.80)	(1.91)	(2.27)	(2.12)	(0.78)
$\bar{R}^2$	0.16	0.15	0.14	0.14	0.14	0.40	0.39

The understand this result it is useful to think of the time trend in Panel B as a filtering device on its own, trying to remove the decadal trend in the raw government spending series. This is easily seen in Figure 2.10 where we show the government spending series, its business cycle component, and the series $g_t + 0.03 \times$ Time Trend. The correlation between the two filtered series is about 85%. Indeed, conclusions would be unchanged had we included a time trend as a regressor in Tables 2.1, 2.2, and 2.9, and used the raw series of government spending.

FIGURE 2.10: **Government Spending and the Business Cycle**



The figure displays the government spending series (solid, blue line), the business cycle component obtained using the decomposition of Ortu et al. (2013) (red, dashed line), and the detrended government spending series implied by the regressions in Panel B, Table 8 (green line with circles).

2.10.3 Solving the Benchmark Model

2.10.3.1 Households with Epstein-Zin Preference

The savers' optimization problem is:

$$\begin{aligned} \max \quad & V(C_t, N_t) = \left\{(1-\beta)U(C_t, N_t)^{1-\psi} + \beta E_t \left[V_{t+1}^{1-\gamma}\right]^{\frac{1-\psi}{1-\gamma}}\right\}^{\frac{1}{1-\psi}} \\ \text{s.t.} \quad & E_t \left[\sum_{s=0}^{\infty} M_{t,t+s}^{\$} P_{t+s} C_{t+s}\right] \leq E_t \left[\sum_{s=0}^{\infty} M_{t,t+s}^{\$} (W_{t+s} P_{t+s} N_{t+s} - P_{t+s} T_{t+s} + P_{t+s} \Psi_{t+s})\right], \end{aligned}$$

where

$$C_t = \left[\int_0^1 C_t(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}$$

and

$$U(C_t, N_t) = \left[\frac{C_t^{1-\psi}}{1-\psi} - A_t^{1-\psi}\frac{N_t^{1+\omega}}{1+\omega}\right]^{\frac{1}{1-\psi}}.$$

The first order conditions are:

$$\frac{\partial V_t}{\partial C_t} : \frac{1}{1-\psi}\left[V_t^{1-\psi}\right]^{\frac{1}{1-\psi}-1}(1-\beta)C_t^{-\psi} - \lambda M_{t,t}^{\$}P_t = 0 \tag{2.12}$$

$$\frac{\partial V_t}{\partial N_t} : \frac{1}{1-\psi}\left[V_t^{1-\psi}\right]^{\frac{1}{1-\psi}-1}(1-\beta)(-A_t^{1-\psi}N_t^{\omega}) + \lambda M_{t,t}^{\$}W_tP_t = 0 \tag{2.13}$$

$$\frac{\partial V_t}{\partial C_{t+1}} : \frac{1}{1-\psi}\left[V_t^{1-\psi}\right]^{\frac{1}{1-\psi}-1}\beta\left(\frac{1-\psi}{1-\gamma}\right)E_t\left[V_{t+1}^{1-\gamma}\right]^{\frac{1-\psi}{1-\gamma}-1}(1-\gamma)V_{t+1}^{-\gamma}\frac{\partial V_{t+1}}{\partial C_{t+1}} - \lambda M_{t,t+1}^{\$}P_{t+1} = 0 \tag{2.14}$$

Furthermore,

$$\frac{\partial V_{t+1}}{\partial C_{t+1}} = \frac{1}{1-\psi}\left[V_{t+1}^{1-\psi}\right]^{\frac{1}{1-\psi}-1}(1-\beta)C_{t+1}^{-\psi}. \tag{2.15}$$

Combining (2.12) and (2.13), I have the household's intratemporal consumption and labor supply optimality condition:

$$\frac{\lambda(1-\psi)}{V_t^{\psi}(1-\beta)} = \frac{C_t^{-\psi}}{P_t} = \frac{A_t^{1-\psi}N_t^{\omega}}{W_tP_t} \Rightarrow W_t = A_t^{1-\psi}C_t^{\psi}N_t^{\omega}.$$

Finally, combining (2.12) ,(2.14) and (2.15), I obtain the intertemporal consumption optimality condition:

$$\frac{\lambda(1-\psi)}{V_t^{\psi}(1-\beta)} = \frac{C_t^{-\psi}}{P_t} = \beta\left(\frac{C_{t+1}^{-\psi}}{P_{t+1}}\right)\left(\frac{V_{t+1}^{\psi-\gamma}}{M_{t,t+1}^{\$}}\right)E_t\left[V_{t+1}^{\frac{1}{1-\gamma}}\right]^{\frac{\gamma-\psi}{1-\gamma}}.$$

To get the nominal pricing kernel, I solve for $M_{t,t+1}^{\$}$,

$$M_{t,t+1}^{\$} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\psi}\left(\frac{P_{t+1}}{P_t}\right)^{-1}\left[\frac{V_{t+1}}{E_t[V_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right]^{\psi-\gamma}. \tag{2.16}$$

2.10.3.2 Wage Rigidities and Optimal Wage Setting

Optimal price setting in the presence of wage stickiness is done through the following optimization problem. There is a continuum of optimizing households in the economy, indexed by k. Each period, only a fraction, $1-\theta$, of the optimizing households has the ability to adjust wage demand optimally. The objective function is:

$$\begin{aligned}
\max_{W_t^{\$,*}(k)} \quad & E_t\left[\sum_{s=0}^{\infty}\theta^s M_{t,t+s}^{\$}\left\{I_{t,t+s}^{w}W_t^{\$,*}(k)N_{t+s}(k) - P_{t+s}MRS_{t+s}(k)N_{t+s}(k)\right\}\right] \\
\text{s.t.} \quad & N_{t+s}(k) = \left(\frac{W_t^{\$,*}(k)}{W_{t+s}^{\$}}\right)^{-\eta_w} N_{t+s}^{d} \\
& W_t^{\$} = \left[\int_0^1 W_t(k)^{1-\eta_w}dk\right]^{\frac{1}{1-\eta_w}} \\
& = \left[(1-\theta){W_t^{\$,*}}^{1-\eta_w} + \theta(I_{t-1,t}^{w}W_{t-1}^{\$})^{1-\eta_w}\right]^{\frac{1}{1-\eta_w}},
\end{aligned}$$

where $W_t^{\$,*}(\cdot)$ is the optimal *nominal* wage chosen at time t and I_{t+s}^{w} is the wage index in the case when $W_t^{\$,*}$ is not adjusted optimally in following periods. η_w is the wage markup parameter. $MRS_{t+s}(k)$ is the marginal rate of substitution between consumption and labor dis-utility. $W_t^{\$}$ is the prevailing nominal market-clearing wage at time t, and N_{t+s}^{d} is the aggregate labor demand. The Calvo (1983) style staggered wage setting is standard in the macroeconomic literature.

The optimal wage demand equation is:

$$\left[\frac{1}{1-\theta}\left\{W_t^{1-\eta_w} - \theta\left(I_{t-1,t}^{w}\frac{W_{t-1}}{\Pi_t}\right)^{1-\eta_w}\right\}\right]^{\frac{1}{1-\eta_w}} H_t = \nu_w A_t^{1-\psi}{C_t}^{\psi}{N_t}^{\omega}G_t,$$

where

$$\begin{aligned}
H_t &= 1+\theta\mathbb{E}_t\left[M_{t,t+1}^{nom}{I_{t,t+1}^{w}}^{-\eta_w}\left(\frac{N_{t+1}^{d}}{N_t^{d}}\right)\left(\Pi_{t+1}\frac{W_{t+1}}{W_t}\right)^{\eta_w}H_{t+1}\right] \\
G_t &= 1+\theta\mathbb{E}_t\left[M_{t,t+1}^{nom}{I_{t,t+1}^{w}}^{-\eta_w}\left(\frac{A_{t+1}}{A_t}\right)^{1-\psi}\left(\frac{C_{t+1}}{C_t}\right)^{\psi}\left(\frac{N_{t+1}}{N_t}\right)^{\omega}\left(\frac{N_{t+1}^{d}}{N_t^{d}}\right)\right. \\
&\quad \left.\times\Pi_{t+1}^{1+\eta_w}\left(\frac{W_{t+1}}{W_t}\right)^{\eta_w}G_{t+1}\right].
\end{aligned}$$

In the above formulation, W_t is real wage, Π_t is inflation, and $\nu_w = \frac{\eta_w}{\eta_w-1}$ is the wage markup. The equilibrium condition states that the optimal real wage is equal to the marginal cost of providing an extra unit of labor $(A_t^{1-\psi}{C_t}^{\psi}{N_t}^{\omega})$ multiplied by a time-varying markup $\left(\nu_w\frac{G_t}{H_t}\right)$ stemming from the monopolistic behavior of the agents in the labor market.

2.10.3.3 The Investment Decision

The households rent out capital to the firms in exchange for earning the return on capital, R_t^k. The capital accumulation equation is standard with convex quadratic adjustment cost, Φ:

$$K_t = (1-\delta)K_{t-1} + \Phi\left(\frac{Inv_t}{K_{t-1}}\right)K_{t-1},$$

where δ is the rate of capital depreciation.

The representative agent's optimal investment strategy has to satisfy the following equation :

$$\begin{aligned} Q_t^{inv} \;&=\; \mathbb{E}_t\left[M_{t,t+1}\left[(1-\tau_t^k)R_{t+1}^k + Q_{t+1}^{inv}\left\{(1-\delta)+\Phi\left(\frac{Inv_{t+1}}{K_t}\right)\right.\right.\right. \\ &\left.\left.\left. -\Phi'\left(\frac{Inv_{t+1}}{K_t}\right)\frac{Inv_{t+1}}{K_t}\right\}\right]\right], \end{aligned}$$

where Q_t^{inv} is the shadow price of investment, and Φ' is the first derivative of the quadratic adjustment cost function.

Similar to the standard investment first order condition from Q-theory, we derive here the intertemporal relationship of investment's Q as a function of the return on capital, the rate of depreciation, and the marginal rate of investment adjustment cost.

2.10.3.4 Monopolistic Producers and Price Rigidities

There is a dispersion of firms, denoted by j, with identical production technology in the economy. With nominal price stickiness and monopolistic competition, each firm is faced with the following optimization problem:

$$\max_{P_t^*} \quad E_t\left[\sum_{s=0}^{\infty}\alpha^s M_{t,t+s}^{\$}\left(P_t^*(\Pi^*)^s Y_{t+s|t}(j) - W_{t+s|t}(j)P_{t+s}N_{t+s|t}(j)\right)\right] \tag{2.17}$$

$$\text{s.t.} \quad Y_{t+s|t}(j) = Z_{t+s}N_{t+s|t}(j) \tag{2.18}$$

$$Y_{t+s|t}(j) = \left(\frac{P_t^*(\Pi^*)^s}{P_{t+s}}\right)^{-\theta} Y_{t+s} \tag{2.19}$$

$$P_t = \left[\int_0^1 P_t(j)^{1-\theta}dj\right]^{\frac{1}{1-\theta}} = \left[(1-\alpha)P_t^{*1-\theta} + \alpha(P_{t-1}\Pi^*)^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{2.20}$$

Using Calvo (1983) pricing, a firm can choose to optimally adjust price to P_t^* with probability $(1-\alpha)$ each period independent of the time elapsed between adjustments. Furthermore, $t+s|t$ denotes the value in period $t+s$ given that the firm last adjusted price in period t. Π^* is the natural level of inflation that firms use to adjust their prices to from period to period if they cannot optimally set the price, and Z_t is the productivity shock on output. Log productivity is an exogenous AR(1) process such that

$$z_{t+1} = ln(Z_{t+1}) = \phi_z z_t + \sigma_z\epsilon_{z,t+1}.$$

The first order condition for firm j is:

$$E_t\left[\sum_{s=0}^{\infty}\alpha^s M^{\$}_{t,t+s}Y_{t+s|t}(j)\left(P^*_t(\Pi^*)^s-\nu P_{t+s}\frac{W_{t+s|t}(j)}{Z_{t+s}}\right)\right]=0, \tag{2.21}$$

where $\nu=\frac{\theta}{\theta-1}$ is the frictionless markup in the absence of price adjustment constraint. Utilizing (2.19) and the fact that $W_{t+s|t}(j)=W_{t+s}$, (2.21) can be rewritten as:

$$\left(\frac{P^*_t}{P_t}\right)F_t=\nu\frac{W_t}{Z_t}J_t$$

or after manipulating (2.20):

$$\left[\frac{1}{1-\alpha}\left(1-\alpha\left(\frac{\Pi^*}{\Pi_t}\right)^{1-\theta}\right)\right]^{\frac{1}{1-\theta}}F_t=\nu\frac{W_t}{Z_t}J_t. \tag{2.22}$$

F_t can be recursively expressed as:

$$F_t=1+E_t\left[\sum_{s=1}^{\infty}(\alpha\Pi^*)^s M^{\$}_{t,t+1}M^{\$}_{t+1,t+s}\left(\frac{Y_{t+s}}{Y_{t+1}}\right)\left(\frac{Y_{t+1}}{Y_t}\right)\left(\frac{P_t\Pi^*}{P_{t+1}}\right)^{-\theta}\left(\frac{P_{t+1}(\Pi^*)^{s-1}}{P_{t+s}}\right)^{-\theta}\right]=1+$$

$$\alpha\Pi^*E_t\left[M^{\$}_{t,t+1}\left(\frac{Y_{t+1}}{Y_t}\right)\left(\frac{P_t\Pi^*}{P_{t+1}}\right)^{-\theta}E_{t+1}\left[\sum_{s=1}^{\infty}(\alpha\Pi^*)^{s-1}M^{\$}_{t+1,t+s}\left(\frac{Y_{t+s}}{Y_{t+1}}\right)\left(\frac{P_{t+1}(\Pi^*)^{s-1}}{P_{t+s}}\right)^{-\theta}\right]\right]$$

$$=1+\alpha\Pi^*E_t\left[M^{\$}_{t,t+1}\left(\frac{Y_{t+1}}{Y_t}\right)\left(\frac{\Pi^*}{\Pi_{t+1}}\right)^{-\theta}F_{t+1}\right],$$

Similarly, J_t has the following recursive formulation:

$$J_t=1+\alpha\Pi^*E_t\left[M^{\$}_{t,t+1}\left(\frac{Z_t}{Z_{t+1}}\right)\left(\frac{W_{t+1}}{W_t}\right)\left(\frac{Y_{t+1}}{Y_t}\right)\left(\frac{\Pi^*}{\Pi_{t+1}}\right)^{-1-\theta}J_{t+1}\right].$$

2.10.3.5 Loglinearized Phillips Curve

To linearize F_t and J_t, we apply Taylor series expansion to the expectation terms in the following steps for Equation (2.7). First, define $\Upsilon_t=\log\mathbb{E}_t\left[e^{m_{t,t+1}+\Delta\tilde{y}_{t+1}+\Delta a_{t+1}+(\eta-1)\pi_{t+1}+f_{t+1}}\right]$. Then,

$$\begin{aligned}
F_t &= 1+\alpha\mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{Y_{t+1}}{Y_t}\right)\Pi^{\eta}_{t+1}F_{t+1}\right]\\
Fe^{f_t} &= 1+\alpha\Upsilon e^{log\mathbb{E}_t\left[e^{m_{t,t+1}+\Delta\tilde{y}_{t+1}+\Delta a_{t+1}+(\eta-1)\pi_{t+1}+f_{t+1}}\right]}\\
f+f_t &= \log(1+\alpha\Upsilon e^{\Upsilon_t})\\
&= \log(1+\alpha\Upsilon e^{\Upsilon})+\underbrace{\frac{\alpha\Upsilon e^{\Upsilon}}{1+\alpha\Upsilon e^{\Upsilon}}}_{const_f}(\Upsilon_t-\Upsilon).
\end{aligned}$$

Notice a variable without a time subscript implies the non-stochastic steady state of the variable. In steady state, $f = log(1 + \alpha\Upsilon e^{\Upsilon})$, so

$$\begin{aligned} f_t &= const_f \Upsilon_t - const_f \Upsilon \\ &= const_f log \mathbb{E}_t \left[e^{m_{t,t+1} + \Delta\tilde{y}_{t+1} + \Delta a_{t+1} + (\eta-1)\pi_{t+1} + f_{t+1}} \right] - const_f \Upsilon \\ &= const_f \left\{ \mathbb{E}_t \left[m_{t,t+1} + \Delta\tilde{y}_{t+1} + \Delta a_{t+1} + (\eta - 1)\pi_{t+1} + f_{t+1} \right] \right. \\ &\quad \left. + \frac{1}{2} var_t \left(m_{t,t+1} + \Delta\tilde{y}_{t+1} + \Delta a_{t+1} + (\eta - 1)\pi_{t+1} + f_{t+1} \right) \right\} - const_f \Upsilon, \end{aligned}$$

in which the last equality relies on the lognormality assumption.

For J_t, define $\Phi_t = \log \mathbb{E}_t \left[e^{m_{t,t+1} - \Delta z_{t+1} + \kappa \Delta r^K_{t+1} + (1-\kappa)\Delta\tilde{w}_{t+1} + \Delta\tilde{y}_{t+1} + \Delta a_{t+1} + \eta\pi_{t+1} + j_{t+1}} \right]$, then the same procedure as above gives us the loglinearized Equation (2.8):

$$\begin{aligned} & j_t \\ = \;& const_j \Phi_t - const_j \Phi \\ = \;& const_j log \mathbb{E}_t \left[e^{m_{t,t+1} - \Delta z_{t+1} + \kappa \Delta r^K_{t+1} + (1-\kappa)\Delta\tilde{w}_{t+1} + \Delta\tilde{y}_{t+1} + \Delta a_{t+1} + \eta\pi_{t+1} + j_{t+1}} \right] - const_j \Phi \\ = \;& const_j \left\{ \mathbb{E}_t \left[m_{t,t+1} - \Delta z_{t+1} + \kappa \Delta r^K_{t+1} + (1 - \kappa)\Delta\tilde{w}_{t+1} + \Delta\tilde{y}_{t+1} + \Delta a_{t+1} + \eta\pi_{t+1} + j_{t+1} \right] \right. \\ & \left. + \frac{1}{2} var_t \left(m_{t,t+1} - \Delta z_{t+1} + \kappa \Delta r^K_{t+1} + (1 - \kappa)\Delta\tilde{w}_{t+1} + \Delta\tilde{y}_{t+1} + \Delta a_{t+1} + \eta\pi_{t+1} + j_{t+1} \right) \right\} \\ & - const_j \Phi, \end{aligned}$$

where $const_j = \frac{\alpha\Phi e^{\Phi}}{1+\alpha\Phi e^{\Phi}}$.

2.10.3.6 The System of Equations for the Model with Growth

The full model presented in this section has thirty-one endogenous variables: $\{M, R^{cl}, R^c, R^l, share, P^c, P^l, C, LI, N, W, Tax, \tau, H, G, I^w, D, K, Inv, Y, \Phi, \Phi', R^I, R^K, Q, P^{real}, \Pi, F, J, M^{nom}, R^{(1)}\}$. I have a system of thirty-three equations resulting from equilibrium conditions, first order conditions and policy rules:

Pricing kernel,

$$M_{t-1,t} = \left[\beta\left(\frac{C_t}{C_{t-1}}\right)^{-\psi}\right]^{\frac{1-\gamma}{1-\psi}}\left[R_t^{cl}\right]^{\frac{\psi-\gamma}{1-\psi}} \tag{2.23}$$

$$R_t^{cl} = (1-share_{t-1})R_t^c + share_{t-1}R_t^l \tag{2.24}$$

$$share_t = \frac{1}{\left(1-\frac{(1+\omega)P_t^c C_t}{(1-\psi)P_t^l LI_t}\right)} \tag{2.25}$$

$$R_t^c = \frac{(1+P_t^c)C_t}{P_{t-1}^c C_{t-1}} \tag{2.26}$$

$$1 = \mathbb{E}_t[M_{t,t+1}R_{t+1}^c] \tag{2.27}$$

$$R_t^l = \frac{(1+P_t^l)LI_t}{P_{t-1}^l LI_{t-1}} \tag{2.28}$$

$$1 = \mathbb{E}_t[M_{t,t+1}R_{t+1}^l] \tag{2.29}$$

Labor income,

$$LI_t = W_t N_t \tag{2.30}$$

Fiscal rule,

$$Tax_t = \tau_t + \tau_t^k R_t^k K_{t-1} \tag{2.31}$$

$$\tau_t = \rho_b D_{t-1}(t) + \rho_g Gov_t \tag{2.32}$$

Wage setting of the saver,

$$\left[\frac{1}{1-\theta}\left\{W_t^{1-\eta_w} - \theta\left(I_{t-1,t}^w\frac{W_{t-1}}{\Pi_t}\right)^{1-\eta_w}\right\}\right]^{\frac{1}{1-\eta_w}} H_t = \nu_w A_t^{1-\psi} {C_t}^{\psi} {N_t}^{\omega} G_t$$

$$H_t = 1 + \theta\mathbb{E}_t\left[M_{t,t+1}^{nom} {I_{t,t+1}^w}^{-\eta_w}\left(\frac{N_{t+1}^d}{N_t^d}\right)\left(\Pi_{t+1}\frac{W_{t+1}}{W_t}\right)^{\eta_w} H_{t+1}\right]$$

$$G_t = 1 + \theta\mathbb{E}_t\left[M_{t,t+1}^{nom} {I_{t,t+1}^w}^{-\eta_w}\left(\frac{A_{t+1}}{A_t}\right)^{1-\psi}\left(\frac{C_{t+1}}{C_t}\right)^{\psi}\left(\frac{N_{t+1}}{N_t}\right)^{\omega}\left(\frac{N_{t+1}^d}{N_t^d}\right)\Pi_{t+1}^{1+\eta_w}\left(\frac{W_{t+1}}{W_t}\right)^{\eta_w} G_{t+1}\right]$$

Wage indexing,

$$I_{t-1,t}^w = e^{g_a} \tag{2.33}$$

Production function,

$$Y_t = Z_t K_{t-1}^{\kappa}(A_t N_t)^{1-\kappa} \tag{2.34}$$

Capital accumulation,

$$K_t = ((1-\delta)+\Phi_t)K_{t-1} \tag{2.35}$$

Capital adjustment cost,

$$\Phi_t = b1 + \frac{b2}{(1-1/\zeta)}\left(\frac{Inv_t}{K_{t-1}}\right)^{1-1/\zeta} \tag{2.36}$$

$$\Phi'_t = b2\left(\frac{Inv_t}{K_{t-1}}\right)^{-1/\zeta} \tag{2.37}$$

Return on investment,

$$1 = \mathbb{E}_t[M_{t,t+1}R^I_{t+1}] \tag{2.38}$$

$$R^I_t Q_{t-1} = (1-\tau^k_t)R^K_t + Q_t\left(1-\delta+\Phi_t-\Phi'_t\frac{Inv_t}{K_{t-1}}\right) \tag{2.39}$$

$$1 = Q_t\Phi'_t \tag{2.40}$$

Market clearing condition,

$$Y_t = C_t + Inv_t + Gov_t \tag{2.41}$$

Government budget constraint,

$$D_{t-1}(t) = Tax_t - Gov_t + P^{real}_t D_t(t+1) \tag{2.42}$$

Capital labor ratio,

$$W_t = \frac{(1-\kappa)}{\kappa}R^K_t\frac{K_{t-1}}{N_t} \tag{2.43}$$

Optimal price setting,

$$\left[\frac{1}{1-\alpha}\left(1-\alpha\left(\frac{1}{\Pi_t}\right)^{(1-\eta)}\right)\right]^{\frac{1}{(1-\eta)}} F_t = \frac{\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}R^{K\,\kappa}_t W^{(1-\kappa)}_t J_t}{Z_t A^{1-\kappa}_t}$$

$$F_t = 1+\alpha\mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{Y_{t+1}}{Y_t}\right)\Pi^\eta_{t+1}F_{t+1}\right]$$

$$J_t = 1+\alpha\mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{Z_t}{Z_{t+1}}\right)\left(\frac{A_t}{A_{t+1}}\right)^{1-\kappa}\left(\frac{R^K_{t+1}}{R^K_t}\right)^\kappa\left(\frac{W_{t+1}}{W_t}\right)^{(1-\kappa)}\left(\frac{Y_{t+1}}{Y_t}\right)\Pi^{(1+\eta)}_{t+1}J_{t+1}\right]$$

Nominal pricing kernel,

$$M^{nom}_{t-1,t} = \frac{M_{t-1,t}}{\Pi_t} \tag{2.44}$$

Euler equation,

$$\frac{1}{R^{(1)}_t} = \mathbb{E}_t[M^{nom}_{t,t+1}] \tag{2.45}$$

Real bond price,

$$P_t^{real} = \mathbb{E}_t[M_{t,t+1}] \tag{2.46}$$

Taylor rule,

$$\frac{R_t^{(1)}}{R} = \left(\frac{R_{t-1}^{(1)}}{R}\right)^{\rho_r} \left(\frac{\Pi_t}{\Pi^*}\right)^{(1-\rho_r)\rho_\pi} \left(\frac{Y_t/A_t}{Y_{t-1}/A_{t-1}}\right)^{(1-\rho_r)\rho_x} e^{u_t}, \tag{2.47}$$

where g_t, u_t and z_t are exogenous shocks to government spending, monetary policy and productivity, respectively:

$$\begin{aligned}
g_{t+1} &= (1-\phi_g)\theta_g + \phi_g g_t + e^{\sigma_{g,t+1}}\epsilon_{g,t+1} \\
\sigma_{g,t+1} &= (1-\phi_\sigma^g)\theta_\sigma^g + \phi_\sigma^g \sigma_{g,t} + \sigma_\sigma^g \epsilon_{\sigma,t+1}^g \\
{\tau^k}_{t+1} &= (1-\phi_{\tau^k})\theta_{\tau^k} + \phi_{\tau^k}{\tau^k}_t + e^{\sigma_{\tau^k,t+1}}\epsilon_{\tau^k,t+1} \\
\sigma_{\tau^k,t+1} &= (1-\phi_\sigma^{\tau^k})\theta_\sigma^{\tau^k} + \phi_\sigma^{\tau^k}\sigma_{\tau^k,t} + \sigma_\sigma^{\tau^k}\epsilon_{\sigma,t+1}^{\tau^k} \\
z_{t+1} &= \phi_z z_t + e^{\sigma_{z,t+1}}\epsilon_{z,t+1} \\
\sigma_{z,t+1} &= (1-\phi_\sigma^z)\theta_\sigma^z + \phi_\sigma^z \sigma_{z,t} + \sigma_\sigma^z \epsilon_{\sigma,t+1}^z \\
\Delta a_{t+1} &= (1-\phi_a)g_a + \phi_a \Delta a_t + \sigma_a \epsilon_{a,t+1} \\
u_{t+1} &= \phi_u u_t + \sigma_u \epsilon_{u,t+1}.
\end{aligned}$$

2.10.3.7 The Stationary Model

To make the model stationary, output, consumption, investment, capital stock, real wage, real debt, government revenue, and government spending need to be detrended by the permanent component of productivity, A_t.

Pricing kernel,

$$M_{t-1,t} = \left[\beta\left(\frac{\frac{C_t}{A_t}A_t}{\frac{C_{t-1}}{A_{t-1}}A_{t-1}}\right)^{-\psi}\right]^{\frac{1-\gamma}{1-\psi}}\left[R_t^{cl}\right]^{\frac{\psi-\gamma}{1-\psi}} \quad (2.48)$$

$$\Longrightarrow M_{t-1,t} = \left[\beta\left(\frac{\widetilde{C_t}}{\widetilde{C_{t-1}}}e^{\Delta a_t}\right)^{-\psi}\right]^{\frac{1-\gamma}{1-\psi}}\left[R_t^{cl}\right]^{\frac{\psi-\gamma}{1-\psi}} \quad (2.49)$$

$$R_t^{cl} = (1-share_{t-1})R_t^c + share_{t-1}R_t^l \quad (2.50)$$

$$share_t = \frac{1}{\left(1-\frac{(1+\omega)P_t^c\frac{C_t}{A_t}}{(1-\psi)P_t^l\frac{LI_t}{A_t}}\right)} \Longrightarrow share_t = \frac{1}{\left(1-\frac{(1+\omega)P_t^c\widetilde{C_t}}{(1-\psi)P_t^l\widetilde{LI_t}}\right)} \quad (2.51)$$

$$R_t^c = \frac{(1+P_t^c)\frac{C_t}{A_t}}{P_{t-1}^c\frac{C_{t-1}}{A_{t-1}}}\frac{A_t}{A_{t-1}} \Longrightarrow R_t^c = \frac{(1+P_t^c)\widetilde{C_t}}{P_{t-1}^c\widetilde{C_{t-1}}}e^{\Delta a_t} \quad (2.52)$$

$$1 = \mathbb{E}_t[M_{t,t+1}R_{t+1}^c] \quad (2.53)$$

$$R_t^l = \frac{(1+P_t^l)\frac{LI_t}{A_t}}{P_{t-1}^l\frac{LI_{t-1}}{A_{t-1}}}\frac{A_t}{A_{t-1}} \Longrightarrow R_t^l = \frac{(1+P_t^l)\widetilde{LI_t}}{P_{t-1}^l\widetilde{LI_{t-1}}}e^{\Delta a_t} \quad (2.54)$$

$$1 = \mathbb{E}_t[M_{t,t+1}R_{t+1}^l] \quad (2.55)$$

Labor income,

$$\frac{LI_t}{A_t} = \frac{W_t}{A_t}N_t \Longrightarrow \widetilde{LI_t} = \widetilde{W}_t N_t \quad (2.56)$$

Fiscal rule,

$$\frac{Tax_t}{A_t} = \frac{\tau_t}{A_t} + \tau_t^k R_t^k \frac{K_{t-1}}{A_{t-1}}\frac{A_{t-1}}{A_t} \Longrightarrow \widetilde{Tax_t} = \widetilde{\tau}_t + \tau_t^k R_t^k \widetilde{K_{t-1}}e^{-\Delta a_t} \quad (2.57)$$

$$\frac{\tau_t}{A_t} = \rho_b\frac{D_{t-1}(t)}{A_{t-1}}\frac{A_{t-1}}{A_t} + \rho_g\frac{Gov_t}{A_t} \Longrightarrow \widetilde{\tau}_t = \rho_b\widetilde{D_{t-1}}(t)e^{-\Delta a_t} + \rho_g\widetilde{Gov_t} \quad (2.58)$$

Wage setting of the saver,

$$\left[\frac{1}{1-\theta}\left\{W_t^{1-\eta_w} - \theta\left(I^w_{t-1,t}\frac{W_{t-1}}{\Pi_t}\right)^{1-\eta_w}\right\}\right]^{\frac{1}{1-\eta_w}} H_t = \nu_w A_t^{1-\psi} {C_t}^{\psi} {N_t}^{\omega} G_t$$

$$\Longrightarrow \left[\frac{1}{1-\theta}\left\{\widetilde{W_t}^{1-\eta_w} - \theta\left(I^w_{t-1,t}\frac{\widetilde{W_{t-1}}}{\Pi_t}\frac{A_{t-1}}{A_t}\right)^{1-\eta_w}\right\}\right]^{\frac{1}{1-\eta_w}} H_t = \nu_w \widetilde{C_t}^{\psi} {N_t}^{\omega} G_t$$

$$H_t = 1 + \theta \mathbb{E}_t\left[M^{nom}_{t,t+1} {I^w_{t,t+1}}^{-\eta_w}\left(\frac{N^d_{t+1}}{N^d_t}\right)\left(\Pi_{t+1}\frac{\frac{W_{t+1}}{A_{t+1}}}{\frac{W_t}{A_t}}\frac{A_{t+1}}{A_t}\right)^{\eta_w} H_{t+1}\right]$$

$$\Longrightarrow \quad H_t = 1 + \theta \mathbb{E}_t\left[M^{nom}_{t,t+1} {I^w_{t,t+1}}^{-\eta_w}\left(\frac{N^d_{t+1}}{N^d_t}\right)\left(\Pi_{t+1}\frac{\widetilde{W_{t+1}}}{\widetilde{W_t}}e^{\Delta a_{t+1}}\right)^{\eta_w} H_{t+1}\right]$$

$$G_t = 1 + \theta \mathbb{E}_t\left[M^{nom}_{t,t+1} {I^w_{t,t+1}}^{-\eta_w}\left(\frac{\frac{C_{t+1}}{A_{t+1}}}{\frac{C_t}{A_t}}\frac{A_{t+1}}{A_t}\right)^{\psi}\left(\frac{N_{t+1}}{N_t}\right)^{\omega}\left(\frac{N^d_{t+1}}{N^d_t}\right)\Pi_{t+1}^{1+\eta_w}\left(\frac{A_{t+1}}{A_t}\right)^{1-\psi}\left(\frac{\frac{W_{t+1}}{A_{t+1}}}{\frac{W_t}{A_t}}\frac{A_{t+1}}{A_t}\right)^{\eta_w} G_{t+1}\right]$$

$$\Longrightarrow \quad G_t = 1 + \theta \mathbb{E}_t\left[M^{nom}_{t,t+1} {I^w_{t,t+1}}^{-\eta_w}\left(\frac{\widetilde{C_{t+1}}}{\widetilde{C_t}}\right)^{\psi}\left(\frac{N_{t+1}}{N_t}\right)^{\omega}\left(\frac{N^d_{t+1}}{N^d_t}\right)\Pi_{t+1}^{1+\eta_w}\left(\frac{A_{t+1}}{A_t}\right)^{1+\eta_w}\left(\frac{\widetilde{W_{t+1}}}{\widetilde{W_t}}\right)^{\eta_w} G_{t+1}\right]$$

Wage indexing,

$$I^w_{t-1,t} = e^{g_a} \tag{2.59}$$

Production function,

$$\frac{Y_t}{A_t} = Z_t\left(\frac{K_{t-1}}{A_{t-1}}\right)^{\kappa} N_t^{1-\kappa}\left(\frac{A_{t-1}}{A_t}\right)^{\kappa} \Longrightarrow \widetilde{Y}_t = Z_t\left(\widetilde{K_{t-1}}e^{-\Delta a_t}\right)^{\kappa} N_t^{1-\kappa} \tag{2.60}$$

Capital accumulation,

$$\frac{K_t}{A_t} = ((1-\delta)+\Phi_t)\frac{K_{t-1}}{A_{t-1}}\left(\frac{A_{t-1}}{A_t}\right) \Longrightarrow \widetilde{K_t} = ((1-\delta)+\Phi_t)\widetilde{K_{t-1}}e^{-\Delta a_t} \tag{2.61}$$

Capital adjustment cost,

$$\Phi_t = b1 + \frac{b2}{(1-1/\zeta)}\left(\frac{\frac{Inv_t}{A_t}}{\frac{K_{t-1}}{A_{t-1}}}\frac{A_t}{A_{t-1}}\right)^{1-1/\zeta} \Longrightarrow \Phi_t = b1 + \frac{b2}{(1-1/\zeta)}\left(\frac{\widetilde{Inv_t}}{\widetilde{K_{t-1}}}e^{\Delta a_t}\right)^{1-1/\zeta} \tag{2.62}$$

$$\Phi'_t = b2\left(\frac{\frac{Inv_t}{A_t}}{\frac{K_{t-1}}{A_{t-1}}}\frac{A_t}{A_{t-1}}\right)^{-1/\zeta} \Longrightarrow \Phi'_t = b2\left(\frac{\widetilde{Inv_t}}{\widetilde{K_{t-1}}}e^{\Delta a_t}\right)^{-1/\zeta} \tag{2.63}$$

Return on investment,

$$
\begin{aligned}
1 &= \mathbb{E}_t[M_{t,t+1}R^I_{t+1}] && (2.64)\\
R^I_t Q_{t-1} &= (1-\tau^k_t)R^K_t + Q_t\left(1-\delta+\Phi_t-\Phi'_t\frac{\frac{Inv_t}{A_t}}{\frac{K_{t-1}}{A_{t-1}}}\frac{A_t}{A_{t-1}}\right) && (2.65)\\
\Longrightarrow R^I_t Q_{t-1} &= (1-\tau^k_t)R^K_t + Q_t\left(1-\delta+\Phi_t-\Phi'_t\frac{\widetilde{Inv_t}}{\widetilde{K_{t-1}}}e^{\Delta a_t}\right) && (2.66)\\
1 &= Q_t\Phi'_t && (2.67)
\end{aligned}
$$

Market clearing condition,

$$
\frac{Y_t}{A_t} = \frac{C_t}{A_t}+\frac{Inv_t}{A_t}+\frac{Gov_t}{A_t} \Longrightarrow \widetilde{Y}_t = \widetilde{C_t}+\widetilde{Inv_t}+\widetilde{Gov_t} \qquad (2.68)
$$

Government budget constraint,

$$
\frac{D_{t-1}(t)}{A_{t-1}}\frac{A_{t-1}}{A_t} = \frac{Tax_t}{A_t}-\frac{Gov_t}{A_t}+P^{real}_t\frac{D_t(t+1)}{A_t} \Longrightarrow \widetilde{D_{t-1}(t)}e^{-\Delta a_t} = \widetilde{Tax_t}-\widetilde{Gov_t}+P^{real}_t\widetilde{D_t(t+1)}
$$

Capital labor ratio,

$$
\frac{W_t}{A_t}\frac{A_t}{A_{t-1}} = \frac{(1-\kappa)}{\kappa}R^K_t\frac{K_{t-1}}{A_{t-1}N_t} \Longrightarrow \widetilde{W}_t e^{\Delta a_t} = \frac{(1-\kappa)}{\kappa}R^K_t\frac{\widetilde{K_{t-1}}}{N_t} \qquad (2.69)
$$

Optimal price setting,

$$
\begin{aligned}
&\left[\frac{1}{1-\alpha}\left(1-\alpha\left(\frac{1}{\Pi_t}\right)^{(1-\eta)}\right)\right]^{\frac{1}{(1-\eta)}}F_t = \frac{\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}R^{K\,\kappa}_t\left(\frac{W_t}{A_t}\right)^{(1-\kappa)}J_t}{Z_t}\\
\Longrightarrow\ &\left[\frac{1}{1-\alpha}\left(1-\alpha\left(\frac{1}{\Pi_t}\right)^{(1-\eta)}\right)\right]^{\frac{1}{(1-\eta)}}F_t = \frac{\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}R^{K\,\kappa}_t\left(\widetilde{W}_t\right)^{(1-\kappa)}J_t}{Z_t}\\
&F_t = 1+\alpha\mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{\frac{Y_{t+1}}{A_{t+1}}}{\frac{Y_t}{A_t}}\frac{A_{t+1}}{A_t}\right)\Pi^{\eta}_{t+1}F_{t+1}\right]\\
\Longrightarrow\ &F_t = 1+\alpha\mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{\widetilde{Y_{t+1}}}{\widetilde{Y}_t}e^{\Delta a_{t+1}}\right)\Pi^{\eta}_{t+1}F_{t+1}\right]\\
&J_t = 1+\alpha\mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{Z_t}{Z_{t+1}}\right)\left(\frac{A_t}{A_{t+1}}\right)^{1-\kappa}\left(\frac{R^K_{t+1}}{R^K_t}\right)^{\kappa}\left(\frac{\frac{W_{t+1}}{A_{t+1}}}{\frac{W_t}{A_t}}\frac{A_{t+1}}{A_t}\right)^{(1-\kappa)}\left(\frac{\frac{Y_{t+1}}{A_{t+1}}}{\frac{Y_t}{A_t}}\frac{A_{t+1}}{A_t}\right)\Pi^{(1+\eta)}_{t+1}J_{t+1}\right]\\
\Longrightarrow\ &J_t = 1+\alpha\mathbb{E}_t\left[M^{nom}_{t,t+1}\left(\frac{Z_t}{Z_{t+1}}\right)\left(\frac{R^K_{t+1}}{R^K_t}\right)^{\kappa}\left(\frac{\widetilde{W_{t+1}}}{\widetilde{W}_t}\right)^{(1-\kappa)}\left(\frac{\widetilde{Y_{t+1}}}{\widetilde{Y}_t}e^{\Delta a_{t+1}}\right)\Pi^{(1+\eta)}_{t+1}J_{t+1}\right]
\end{aligned}
$$

Nominal pricing kernel,

$$
M^{nom}_{t-1,t} = \frac{M_{t-1,t}}{\Pi_t} \qquad (2.70)
$$

Euler equation,

$$\frac{1}{R_t^{(1)}} = \mathbb{E}_t[M_{t,t+1}^{nom}] \tag{2.71}$$

Real bond price,

$$P_t^{real} = \mathbb{E}_t[M_{t,t+1}] \tag{2.72}$$

Taylor rule,

$$\frac{R_t^{(1)}}{R} = \left(\frac{R_{t-1}^{(1)}}{R}\right)^{\rho_r} \left(\frac{\Pi_t}{\Pi^*}\right)^{(1-\rho_r)\rho_\pi} \left(\frac{\widetilde{Y}_t}{\widetilde{Y_{t-1}}}\right)^{(1-\rho_r)\rho_x} e^{u_t}, \tag{2.73}$$

where g_t, u_t and z_t are exogenous shocks to government spending, monetary policy and productivity, respectively:

$$\begin{aligned}
g_{t+1} &= (1-\phi_g)\theta_g + \phi_g g_t + e^{\sigma_{g,t+1}}\epsilon_{g,t+1} \\
\sigma_{g,t+1} &= (1-\phi_\sigma^g)\theta_\sigma^g + \phi_\sigma^g \sigma_{g,t} + \sigma_\sigma^g \epsilon_{\sigma,t+1}^g \\
{\tau^k}_{t+1} &= (1-\phi_{\tau^k})\theta_{\tau^k} + \phi_{\tau^k}{\tau^k}_t + e^{\sigma_{\tau^k,t+1}}\epsilon_{\tau^k,t+1} \\
\sigma_{\tau^k,t+1} &= (1-\phi_\sigma^{\tau^k})\theta_\sigma^{\tau^k} + \phi_\sigma^{\tau^k}\sigma_{\tau^k,t} + \sigma_\sigma^{\tau^k}\epsilon_{\sigma,t+1}^{\tau^k} \\
z_{t+1} &= \phi_z z_t + e^{\sigma_{z,t+1}}\epsilon_{z,t+1} \\
\sigma_{z,t+1} &= (1-\phi_\sigma^z)\theta_\sigma^z + \phi_\sigma^z \sigma_{z,t} + \sigma_\sigma^z \epsilon_{\sigma,t+1}^z \\
\Delta a_{t+1} &= (1-\phi_a)g_a + \phi_a \Delta a_t + \sigma_a \epsilon_{a,t+1} \\
u_{t+1} &= \phi_u u_t + \sigma_u \epsilon_{u,t+1}.
\end{aligned}$$

2.10.3.8 The Steady State System of the Model with Growth

The steady state of the pricing kernel block, with the exception of *share*, can be determined right away by noting $M = \beta e^{-\psi g_a}$: Pricing kernel,

$$M = \beta e^{-\psi g_a}, \tag{2.74}$$

$$R^{cl} = \frac{1}{\beta e^{-\psi g_a}}, \tag{2.75}$$

$$R^c = \frac{1}{\beta e^{-\psi g_a}}, \tag{2.76}$$

$$P^c = \frac{\beta e^{(1-\psi)g_a}}{1-\beta e^{(1-\psi)g_a}}, \tag{2.77}$$

$$R^l = \frac{1}{\beta e^{-\psi g_a}}, \tag{2.78}$$

$$P^l = \frac{\beta e^{(1-\psi)g_a}}{1-\beta e^{(1-\psi)g_a}}. \tag{2.79}$$

In steady state, capital cancel out in the capital accumulation equation such that

$$\Phi = e^{g_a} + \delta - 1. \tag{2.80}$$

Given $\Phi = \delta$, the investment-capital ratio and Φ' can be found using the adjustment cost functions

$$\widetilde{Inv} = \left[(e^{g_a} + \delta - 1 - b1)\frac{(1-1/\zeta)}{b2}\right]^{\zeta/(\zeta-1)} e^{-g_a}\widetilde{K} \tag{2.81}$$

$$\Phi' = b2\left[(e^{g_a} + \delta - 1 - b1)\frac{(1-1/\zeta)}{b2}\right]^{-1/(\zeta-1)}. \tag{2.82}$$

Return on investment is also $\frac{1}{\beta e^{-\psi g_a}}$ which allows us to find the rental cost of capital,

$$R^I = \frac{1}{\beta e^{-\psi g_a}} \tag{2.83}$$

$$Q = \frac{1}{b2}\left[(e^{g_a} + \delta - 1 - b1)\frac{(1-1/\zeta)}{b2}\right]^{1/(\zeta-1)} \tag{2.84}$$

$$R^K = \frac{1}{1-\tau^k}\left[\frac{1}{\beta e^{-\psi g_a}} - e^{g_a} + [(e^{g_a} + \delta - 1 - b1)(1-1/\zeta)]\right]Q. \tag{2.85}$$

To solve for the steady state inflation, we notice the following:

$$M^{nom} = \frac{\beta e^{-\psi g_a}}{\Pi} \tag{2.86}$$

$$R^{(1)} = \frac{\Pi}{\beta e^{-\psi g_a}} \tag{2.87}$$

$$P^{real} = \beta e^{-\psi g_a}. \tag{2.88}$$

From the Taylor rule,

$$\Pi = \left(R\frac{\beta e^{-\psi g_a}}{\Pi^{*\rho_\pi}}\right)^{\frac{1}{1-\rho_\pi}}. \tag{2.89}$$

With steady state inflation given, equilibrium wage offer is:

$$F = \frac{1}{1-\alpha\beta e^{(1-\psi)g_a}\Pi^{\eta-1}} \tag{2.90}$$

$$J = \frac{1}{1-\alpha\beta e^{(1-\psi)g_a}\Pi^{\eta}} \tag{2.91}$$

$$\widetilde{W} = \left\{\left[\frac{1}{1-\alpha}\left(1-\alpha\left(\frac{1}{\Pi}\right)^{(1-\eta)}\right)\right]^{\frac{1}{(1-\eta)}}\frac{\kappa^\kappa(1-\kappa)^{(1-\kappa)}F}{\nu J}R^{K^{-\kappa}}\right\}^{\frac{1}{(1-\kappa)}}. \tag{2.92}$$

With steady state inflation given, equilibrium wage demand is:

$$H = \frac{1}{1-\theta\beta e^{-\psi g_a}\Pi^{\eta_w - 1}} \tag{2.93}$$

$$G = \frac{1}{1-\theta\beta e^{(1-\psi)g_a}\Pi^{\eta_w}} \tag{2.94}$$

$$\widetilde{W} = \widetilde{C}^{\psi} N^{\omega} \underbrace{\nu_w \frac{G}{H}\left[\frac{1}{1-\theta}\left\{1-\theta\left(\frac{1}{\Pi}\right)^{1-\eta_w}\right\}\right]^{\frac{-1}{1-\eta_w}}}_{\Psi}. \tag{2.95}$$

Capital labor ratio delivers capital in terms of labor input,

$$\widetilde{K} = \frac{\kappa}{1-\kappa}\frac{\widetilde{W}e^{g_a}}{R^K}N. \tag{2.96}$$

Combining the production function and the market clearing condition, we can solve for steadying state labor by writing consumption, investment, and capital in terms of labor:

$$\begin{aligned}
(\widetilde{K}e^{-g_a})^{\kappa}N^{1-\kappa} &= \frac{\widetilde{C}+\widetilde{Inv}}{1-\theta_g} \\
\left[\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right]^{\kappa} N &= \frac{1}{1-\theta_g}\left\{\left(\frac{\widetilde{W}}{N^{\omega}\Psi}\right)^{1/\psi} + \left[(e^{g_a}+\delta-1-b1)\frac{(1-1/\zeta)}{b2}\right]^{\zeta/(\zeta-1)}\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}N\right\} \\
\left(\frac{\widetilde{W}}{N^{\omega}\Psi}\right)^{1/\psi} &= \left\{(1-\theta_g)\left[\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right]^{\kappa} - \left[(e^{g_a}+\delta-1-b1)\frac{(1-1/\zeta)}{b2}\right]^{\zeta/(\zeta-1)}\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right\}N \\
\frac{\widetilde{W}}{N^{\omega}\Psi} &= \left\{(1-\theta_g)\left[\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right]^{\kappa} - \left[(e^{g_a}+\delta-1-b1)\frac{(1-1/\zeta)}{b2}\right]^{\zeta/(\zeta-1)}\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right\}^{\psi}N^{\psi} \\
N^{\psi+\omega} &= \frac{\widetilde{W}}{\Psi}\left\{(1-\theta_g)\left[\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right]^{\kappa} - \left[(e^{g_a}+\delta-1-b1)\frac{(1-1/\zeta)}{b2}\right]^{\zeta/(\zeta-1)}\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right\}^{-\psi} \\
N &= \left[\frac{\widetilde{W}}{\Psi}\left\{(1-\theta_g)\left[\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right]^{\kappa} - \left[(e^{g_a}+\delta-1-b1)\frac{(1-1/\zeta)}{b2}\right]^{\zeta/(\zeta-1)}\frac{\kappa}{1-\kappa}\frac{\widetilde{W}}{R^K}\right\}^{-\psi}\right]^{\frac{1}{\psi+\omega}},
\end{aligned}$$

where the second equality uses the fact that $\widetilde{W} = \widetilde{C}^{\psi}N^{\omega}\Psi$. Labor is now written in terms of parameters and known variables. Steady state captial can be calcualted using the capital labor ratio. Steady state investment can be found using the adjustment cost function relating investment to capital.

Production function delivers the steady state output,

$$\widetilde{Y} = (\widetilde{K}e^{-g_a})^{\kappa}N^{1-\kappa}. \tag{2.97}$$

Market clearing condition pins down the steady state aggregate consumption,

$$\widetilde{C} = (1-\theta_g)\widetilde{Y} - \widetilde{Inv}. \tag{2.98}$$

Steady state real debt can be calculated from the fiscal rule and the government budget constraint:

$$\begin{aligned}
\widetilde{D}e^{-g_a} &= \widetilde{Tax} - \theta_g\widetilde{Y} + \beta e^{-\psi g_a}\widetilde{D} \\
\widetilde{D}e^{-g_a} &= \rho_b\widetilde{D}e^{-g_a} + \rho_g\theta_g\widetilde{Y} + (1-\mu)\tau^k R^k\widetilde{K}e^{-g_a} - \theta_g\widetilde{Y} + \beta e^{-\psi g_a}\widetilde{D} \\
(e^{-g_a} - \rho_b e^{-g_a} - \beta e^{-\psi g_a})\widetilde{D} &= (\rho_g - 1)\theta_g\widetilde{Y} + \theta_{\tau^k} R^k\widetilde{K}e^{-g_a} \\
\widetilde{D} &= \frac{(1-\rho_g)\theta_g\widetilde{Y} - \theta_{\tau^k} R^k\widetilde{K}e^{-g_a}}{(\beta e^{-\psi g_a} + \rho_b e^{-g_a} - e^{-g_a})}.
\end{aligned}$$

Steady state lump-sum transfer is:

$$\widetilde{\tau} = \left[\rho_b\frac{(1-\rho_g)\theta_g\widetilde{Y} - \theta_{\tau^k} R^k\widetilde{K}e^{-g_a}}{(\beta e^{(1-\psi)g_a} + \rho_b - 1)} + \rho_g\theta_g\widetilde{Y}\right]. \tag{2.99}$$

Tax revenues are:

$$\widetilde{Tax} = \widetilde{\tau} + \theta_{\tau^k} R^k\widetilde{K}e^{-g_a} \tag{2.100}$$

(2.101)

Finally, the following steady states are trivial:

$$\widetilde{LI} = \widetilde{W}N \tag{2.102}$$

$$share = \frac{1}{1 - \frac{1+\omega}{1-\psi}\frac{P_c\widetilde{C}}{P_l\widetilde{LI}}}. \tag{2.103}$$

2.10.4 Solution and Estimation

To estimate model parameters we use the mean, the variance and the contemporaneous covariances in the data as moments. Hence, we let

$$q_t = \begin{bmatrix} \mathbf{data}_t \\ diag\left(\mathbf{data}_t\mathbf{data}_t'\right) \\ vech\left(\mathbf{data}_t\mathbf{data}_t'\right) \end{bmatrix}.$$

Letting θ contain the structural parameters, our GMM estimator is given by

$$\theta_{GMM} = \text{argmin}_{\theta\in\Theta}\left(\frac{1}{T}\sum_{t=1}^{T} q_t - E\left[q_t(\theta)\right]\right)' W \left(\frac{1}{T}\sum_{t=1}^{T} q_t - E\left[q_t(\theta)\right]\right)$$

Here, W is a positive definite weighting matrix and $E[q_t(\theta)]$ contains the model-implied moments computed as described in the following subsection. We use the conventional two-step implementation of GMM by letting $W_T = \text{diag}\left(\hat{S}^{-1}\right)$ in a preliminary first step to obtain $\widehat{\theta^{\text{step 1}}}$ where $\hat{S}$ denotes the long-run variance of $\frac{1}{T}\sum_{t=1}^{T} q_t$ when re-centered around its sample mean. Our final estimates $\widehat{\theta^{\text{step 2}}}$ are obtained using the optimal weighting matrix $W_T = \text{diag}\left(\hat{S}^{-1}_{\hat{\theta}^{\text{step 1}}}\right)$, where $\hat{S}_{\hat{\theta}^{\text{step 1}}}$ denotes the long-run variance of our moments re-centered around $E\left[q_t\left(\widehat{\theta^{\text{step 1}}}\right)\right]$. The long-run variances in both steps are estimated by the Newey-West estimator using 10 lags, but our results are robust to using more lags.

Given our interest in analyzing time-varying risk premia, we employ a third-order Taylor approximation of the policy functions that characterize the equilibrium dynamics of the model. However, higher-order terms may generate explosive sample paths thus precluding any estimation method that, like GMM, relies on finite moments from stationary and ergodic probability distribution (see e.g. (Sims, Kim, Kim, and Schaumburg 2008) for a discussion of this issue within the context of second-order approximations). To ensure stable sample paths (and existence of finite unconditional moments) we adopt the pruned state-space system for non-linear DSGE models suggested by (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). Intuitively, pruning means we are going to omit terms of higher-order effects than the considered approximation order (third-order, in our case) when the system is iterated forward in time.[33] Provided the linearized solution is stable, (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017) derive closed-form solutions for first and second unconditional moments of the pruned state-space of the DSGE. This is important since it allows us to compute in a reasonable amount of time the unconditional moments for our DSGE model solved up to third-order.[34]

[33]For details on the pruning method, see (Sims, Kim, Kim, and Schaumburg 2008) for second-order and (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017) for higher-order approximations to the solutions of DSGE models.

[34]Although we solve the model by a third-order perturbation, we verified that our model moments are similar when we use a higher-order approximation and no pruning. In particular we checked that our results do not change when we use a fifth order solution to our DSGE model. To obtain a fifth order solution we use the tensor approach proposed by (Levintal 2017). The corresponding results are available upon request.

2.10.5 Conditional IRF at the Zero Lower Bound

To implement an interest rate peg in the model we follow Sims (2017). In particular we augment the Taylor rule with "news" shocks as follows:[35]

$$i_t = i^* + \phi_\pi (\pi_t - \pi^*) + e_t^{(0)} + \sum_{j=1}^{H-1} e_{t-j}^{(1)}$$

where $e_{t-j}^{(j)}$, for $j > 0$ are news shocks, i.e. shocks known to agents in advance of them actually impacting the policy rule.

We can impose an interest rate peg as follows. First, solve the model as described in Section 2.4.2 but where we replaced the Taylor rule with one augmented with news shocks.[36] Second, we simulate a long path of $T-1$ observation so that all state variables are at their ergodic mean in absence of shocks (EMAS). Starting at the EMAS, we compute the IRFs of the economy to, e.g., a government spending shock (at this stage we still have $e_{t-j}^{(j)} = 0$). We then solve for the value of the news shocks $e_{t-j}^{(j)}$, for $j = 0, \ldots, H-1$, which keeps the nominal rate pegged for a desired length of time, i.e. $i_{T+s} = i_{T-1} \equiv i_{\text{EMAS}}$ for $s = 0, \ldots, H-1$. Effectively, we can think about the effects of a shock under an interest rate peg as being something like the sum of the direct effect of the shock, plus the effects of current and anticipated monetary policy shocks so as to keep the nominal the interest rate unresponsive to a shock for the current and subsequent $H-1$ periods, for a total of H periods. We refer to H as the peg period. In Section 2.6 we discuss two policy scenarios: a $H = 4$ period interest rate peg, and a $H = 8$ period interest rate peg.

Few final remarks are in order. First, an important advantage of this approach is that one can still solve the model with perturbations above first order. Second, it is important to write the innovations in the policy rule as anticipated shocks since this guarantees that, at the time of another shock, agents will anticipate that the interest rate will be unresponsive for H total periods. Third, the algorithm so far described is similar to the one used in (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015). Whereas (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) use a combination of innovations to preference and productivity shocks to force the economy to the ZLB, we instead solve for the news shocks which keep the interest rate unresponsive.

[35]For expository purposes, we consider a simplified Taylor rule with no interest rate smoothing and no reaction to output growth.

[36]To augment the Taylor rule with news shocks is reasonably straightforward in Dynare. To do so, one simply needs to create some auxiliary state variables. E.g. suppose one wants a four period peg, $H = 4$. Then one would introduce four new state variables.

Chapter 3

Risk Aversion and the Response of the Macroeconomy to Uncertainty Shocks

Lorenzo Bretscher, Alex Hsu, Andrea Tamoni [1]

3.1 Introduction

Risk matters. A growing strand of literature in economics is focused on documenting the effects of volatility shocks (uncertainty) on macroeconomic dynamics in equilibrium settings. For example, (Bloom 2009) provides evidence of time-varying second moment to productivity growth causing significant distortions in output and employment. (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) estimate an open-economy model to demonstrate the impact of real interest rate volatility shocks on a number of macro variables. These papers find that time-varying risk (or uncertainty) can substantially alter the response of the macroeconomy to exogenous variations. If risk matters, then it is straight forward to conclude that the economic agent's attitude towards risk (or risk aversion) should also matter.[2] We document empirically that increased risk aversion exacerbated the fall in output and investment during the financial

[1] We thank Nick Bloom, Brent Bundick, Sulkhan Chavleishvili (Discussant), Anthony Diercks (Discussant), and Jesus Fernández-Villaverde for valuable comments. We also thank seminar participants at the SITE Conference – Stanford, at the 25th Finance Forum Conference – Universitat Pompeu Fabra, at the 49th Money, Macro, and Finance Conference – King's College London, and at 2018 MFA Annual Meeting.

[2] This might appear to be a trivial point, but (Tallarini 2000), in a model with (Epstein and Zin 1989) – (Weil 1990) recursive preferences and where the elasticity of intertemporal substitution is unity, numerically demonstrates the insignificance of the degree of risk aversion in generating macroeconomic fluctuations in an equilibrium model.

crisis of 2008. Consistently, in standard DSGE models, not only risk matters to equilibrium outcomes, but perhaps more importantly, the degree of risk aversion determines the magnitude of these outcomes. To the extent that a given uncertainty shock induces a nontrivial response in the economy, higher risk aversion can amplify the effect of the uncertainty shock to be on par with that of the level, or first moment, shock. Our finding has significant ramification for general equilibrium modeling in monetary economics (to understand the Great Moderation, for example) and in asset pricing (to extend the (Bansal and Yaron 2004b) long-run risk mechanism from endowment to production economies), both of which rely on the presence of stochastic volatility to generate endogenous economic implications.

The notion of time-varying risk aversion has gained traction in the macroeconomics and finance literature in recent decades. Grounded in theoretical models with habit ((Abel 1990), (Constantinides 1990), and (Campbell and Cochrane 1999)) or heterogeneous agents ((Dumas 1989)), aggregate risk aversion in the economy can exhibit countercyclical variation as evidenced by the countercyclical risk premium in stock returns.[3] Employing the Smoothed Local Projection (SLP) method of (Barnichon and Brownlees 2016), we show that conditional on the fact that risk aversion was elevated during the 2008 crisis, the fall in output and investment driven by uncertainty was deepened by 21%[4] and 16%,[5] respectively. Our empirical proxies for risk aversion used in the forecasting regressions are intermediary leverage and dividend-price ratios taken from the literature. These two variables further demonstrate the causal channel through which financial market conditions led to the deterioration of the macroeconomy during the crisis.

Theoretically, we demonstrate the interaction between risk aversion and uncertainty using two leading models from the recent literature on uncertainty: the demand shock model of (Basu and Bundick 2017) (BB (2017) henceforth) and the small open economy model of (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) (FGRU (2011) henceforth). We establish the following three main findings. First, risk aversion amplifies the magnitude of the response of macroeconomic quantities to uncertainty shocks. Precisely speaking, suppose there are two regime in the economy: low and high risk aversion. Our results suggest that uncertainty shocks are in general much more impactful when risk aversion is high. Second, the risk aversion implication on the economic effects stemming from level shocks is model-dependent: higher risk

[3] See (Chan and Kogan 2002).

[4] Depending on the risk aversion proxy and the forecasting horizon, the amplifying effect on output can be as high as 50% and as low as 20%.

[5] Depending on the RA proxy and the forecasting horizon, the amplifying effect on investment can be as high as 23% and as low as 7%.

aversion can amplify or dampen macroeconomic responses through changing consumption growth expectations. Third, the source of uncertainty is crucial in generating the dynamic response of the model such that risk matters.

The first model of interest is BB (2017). The authors employ a standard New-Keynesian model augmented by Epstein-Zin-Weil utilities with level and volatility shocks to the time discount factor to generate observed comovements in components of aggregate output following uncertainty shocks. The second model under study is the small open-economy proposed by FGRU (2011) where the real interest rate process displays time-varying volatility. We replace the CRRA utility function with Epstein-Zin-Weil recursive utility to separate the effect of risk aversion from that of the elasticity of intertemporal substitution (EIS). Furthermore, we modify BB (2017) to accommodate conditional volatility shocks to productivity.[6]

We conclude that, in both models, the endogenous macroeconomic response stemming from volatility shocks is amplified when agents display higher level of risk aversion. In FGRU (2011), however, the combination of level and volatility shocks to the real interest rate actually has a weaker impact on macroeconomic dynamics when risk aversion is high. This is because the level shock to the real interest rate increases consumption growth expectation by lowering the price of the internationally traded bond. When risk aversion is high, this downward pressure on bond price is less reflected in expected consumption growth, thus generating a dampened current macroeconomic reaction. Moreover, variance decomposition of endogenous variables in these models show that the interaction of uncertainty shocks and risk aversion are much more pronounced due to demand and interest rate shocks relative to technology shocks. This suggests the source of uncertainty is important in the class of DSGE models we consider, and uncertainty shocks to preferences are more effective in driving the dynamic response of macroeconomic quantities.

In a closely related paper, (Gourio 2012)[7] examines the joint implication of risk aversion and time-varying risk on macroeconomic dynamics, but we differ in the source of risk in our models. Rather than focusing on the time-varying probability of disaster risk as in (Gourio 2012), we explore the interaction between stochastic volatility and risk aversion. (Gourio 2012) derives the isomorphic relationship between time-varying disaster probability and level shocks to the time discount factor with constant volatility. Conversely,

[6] With conditional volatility shocks in productivity instead of demand, BB(2017) effectively becomes a standard New-Keynesian DSGE model with production uncertainty.

[7] (Gourio 2013) extends the application to credit spreads.

the models discussed in this paper contain stochastic volatility to preference shocks that directly affect the stochastic discount factor.[8]

Our finding potentially has important applications in multiple areas of research. In monetary economics, for example, (Fernández-Villaverde, Guerrón-Quintana, and Rubio-Ramírez 2010) estimate a DSGE model with stochastic volatility and drifting parameters in the Taylor rule to examine the origins of the easing in business cycle fluctuations in the U.S. data between 1984 to 2007 (the Great Moderation). They find that modifications in monetary policy implementation contributed to the observed decline in macroeconomic volatility. However, the literature is inconclusive in the source of the Great Moderation as (Cogley and Sargent 2005) and (Sims and Zha 2006) have argued otherwise and show that fundamental changes in the volatility process is driving the decline. (Fernández-Villaverde, Guerrón-Quintana, and Rubio-Ramírez 2010) employ log utility with simple habit in the estimation of conditional volatility processes. Given our documented joint determination of risk aversion and uncertainty shocks, the preference specification is non-trivial, and recursive utility with regime dependent risk aversion can be an essential ingredient in the structural model for the purpose of volatility estimation.

High-order perturbation techniques have become one of the standard method for solving DSGE models.[9] It is also well know that risk premiums are unaffected by first-order terms and completely determined by those second- and higher-order terms. A widespread macro-finance *separation* paradigm, first proposed by (Tallarini 2000), suggests that the moments of macroeconomic quantities are not very sensitive to the addition of second-order and higher-order terms. This result is important since it implies that by varying the risk aversion parameter while holding the other parameters of the model constant, one is able to fit the asset pricing facts without compromising the model's ability to fit the macroeconomic data.[10] Our paper suggests that risk aversion not only determines the level of asset returns, but it also matters in calibrating the model to match the standard deviations of macroeconomic variables to those in the data. The simultaneity of risk aversion and uncertainty in driving macroeconomic dynamics poses an additional challenge in our understanding of time-varying expected returns as risk cannot be filtered solely by observing macroeconomic volatilities. The macro-finance separation does not hold in DSGE models featuring stochastic volatility when the solution technique takes into account the non-linearity of the model.

[8]The demand shock in BB (2017) effectively produces a stochastic discount factor with time-varying time discount factor. The shock to the real international risk-free rate in FGRU (2011) is a stochastic shock to the expectation of the stochastic discount factor.

[9]See (Aruoba, Fernández-Villaverde, and Rubio-Ramírez 2006) for a discussion about perturbation and alternative solution methods.

[10]Risk aversion only appears in the perturbation solution in higher than first-order terms, see (Koijen, van Binsbergen, Rubio-Ramírez, and Fernández-Villaverde 2008).

Our paper is linked with different streams of literature in economics. The use of time-varying uncertainty has a long history in the financial economics literature. E.g. (Kandel and Stambaugh 1991) study the implications for asset returns of time-varying first and second moments of consumption growth in a model with a representative Epstein-Zin investor. In a similar spirit, (Bansal and Yaron 2004b) incorporate time-varying first and second moments of consumption growth and recursive preferences in an endowment asset pricing model, and show that stochastic volatility not only generated time-variation in risk premiums but also significantly increased the mean equity risk premium. As already discussed, our result adds another dimension of complication in extending these types of macro-finance models that employ stochastic volatility from endowment economies to full general equilibrium as macroeconomic and asset pricing moments need to be calibrated simultaneously.

An increasing body of research has studied how uncertainty fluctuations influence business cycle dynamics. Within the framework of irreversible investment (see (Bernanke 1983), (Dixit and Pindyck 1994), (Abel and Eberly 1996), (Hassler 1996)), (Bloom 2009) studies the propagation of *firm-level* uncertainty shocks. Following an increase in uncertainty about future profitability, firms will slow down activities that cannot be easily reversed, i.e. they "wait and see". After the heightened uncertainty is resolved, pent-up demand for capital goods leads to an investment boom. Another growing literature stresses the interaction of risk and economic activity propagated through financial, rather than physical frictions. Using a model with financial frictions, (Gilchrist, Sim, and Zakrajsek 2014) argue that increases in firm risk lead to an increase in bond premia and the cost of capital which, in turn, triggers a decline in investment activity and measured aggregate productivity. (Arellano, Bai, and Kehoe 2016) show that firms downsize investment projects to avoid default when faced with higher risk. Finally, (Christiano, Motto, and Rostagno 2014) analyze the macroeconomic implications of volatility shocks in the context of a financial accelerator model adapted from (Bernanke, Gertler, and Gilchrist 1999). Our analysis shows that when risk aversion is elevated, uncertainty shocks have larger and more prolonged impact. Although we take the increase in risk aversion to be exogenous, our analysis supports the literature that points to financial market frictions as an additional channel through which volatility fluctuations can affect macroeconomic outcomes: if risk aversion rises with tightening financial constraints, uncertainty may affect the economy via an increase in the risk premium.

More recently, the literature has also started investigating the impact of shocks to *aggregate* uncertainty. (Justiniano and Primiceri 2008b) and (Fernández-Villaverde and Rubio-Ramírez 2007) estimate dynamic equilibrium models with heteroskedastic shocks and show that time-varying volatility helps to explain the Great Moderation between 1984 and 2007. (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and

Uribe 2011) and (Born and Pfeifer 2014) find that risk shocks are an important factor in explaining business cycles in emerging market economies. (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez 2015) document the important role of fiscal volatility for output fluctuations. (Basu and Bundick 2017) study the interaction of aggregate risk shocks with precautionary saving in an environment with nominal rigidities. Building on this literature, our paper investigates the interaction of aggregate uncertainty with risk aversion and emphasizes the importance of the source of uncertainty (productivity vs. demand shocks).

A number of papers have also investigated the possibility that spikes in uncertainty may be the result of adverse economic conditions rather than being a driving force of economic downturns, see e.g. (Van Nieuwerburgh and Veldkamp 2006, Fostel and Geanakoplos 2012, Bachmann, Elstner, and Sims 2013). In this paper we study the amplification role of risk aversion for exogenous impulses to uncertainty, and we leave the analysis of the interaction between risk aversion with endogenous response of uncertainty as an interesting avenue for future research.

Finally, our paper is closely related to (Gorodnichenko and Ng 2017) who use the insight from higher-order perturbation of policy functions to empirically separate the level from the volatility factors. (Gorodnichenko and Ng 2017) conclude that "[T]he interaction between the first- and second-order dynamics is worthy of more theorizing in light of the evidence for non-trivial second-moment variations." Our analysis of level and volatility shocks and their interaction with risk aversion is a first step in this direction.

3.2 Risk Aversion and Uncertainty: Empirical Evidence

In this section we estimate the dynamic responses of macroeconomic quantities to an uncertainty shock, conditional on risk aversion being low or high. The estimation of state-dependent impulse response functions have recently been the subject of expressed interest in macroeconomics, see e.g. (Auerbach and Gorodnichenko 2012b), (Auerbach and Gorodnichenko 2012a), and (Ramey and Zubairy 2018) for investigations of the size of fiscal multipliers when the economy is in recession, or more broadly, during periods of economic slack. (Tenreyro and Thwaites 2016) examine the response of the U.S. economy to monetary policy shocks predicated on the state of the business cycle. To the best of our knowledge, the role of risk aversion as a state variable concerning the macroeconomic response to uncertainty shocks is unexplored so far.

To estimate the state-dependent IRFs, we rely on the smoothed version of local projections proposed by (Jorda 2005). More precisely, we apply the technique developed by (Barnichon and Brownlees 2016).[11] The Smooth Local Projections (SLP) strikes a balance between the efficiency of Vector Autoregressions (VAR) and the robustness (to model misspecification) of the Local Projections (LP) approach. In practice, SLP consists in estimating LP under the assumption that the impulse response is a smooth function of the forecast horizon. Specifically, we estimate an h-step ahead predictive regressions,

$$y_{t+h} = \alpha_h + (\beta_{0,h} + \beta_{1,h}\mathrm{RA}_t)\,\mathrm{UNC}_t + \sum_{i=0}^{p} \gamma_{i,h} w_{t-i} + u_{t+h} \tag{3.1}$$

where h ranges from 0 to H and i is the number of lags used for the control variables, w_t. y_{t+h} is the h period ahead realization of the macroeconomic variable of interest. RA_t is the state variable. UNC_t is our measure of uncertainty. To capture state dependence, the response of y_{t+h} to uncertainty at time t is a linear function, $\beta_{0,h} + \beta_{1,h}\mathrm{RA}_t$, of risk aversion. In what follows, the $\beta_{1,h}$ coefficient capturing the amplification/contraction effect due to risk aversion is called the *state multiplier*. We are interested in knowing whether uncertainty shock has a larger effect on, e.g., output during high risk aversion states. We estimate the state-dependent dynamic multiplier, $\beta_{0,h} + \beta_{1,h}\mathrm{RA}$, of y_{t+h} with respect to a change in UNC_t, keeping all other variables constant.

For our empirical application, we follow (Basu and Bundick 2017) and include gross domestic product (GDP), consumption, investment, hours worked, the GDP deflator, the M2 money stock, and a measure of the stance of monetary policy as control variables. We employ VXO as the uncertainty proxy because it is a well known and readily-observable measure of aggregate uncertainty. Since the VXO data start in 1986, we estimate our baseline empirical model using quarterly data over the 1986−2014 sample period. We choose $p = 2$, and let all other variables enter in log levels with the exception of the monetary policy measure. Finally, we use a recursive identification scheme with the VXO ordered first.[12]

To estimate the state dependent IRFs, we follow (Barnichon and Brownlees 2016) and include the set of controls w_t and their interaction with the state variable, RA_t. We report the estimation for two different proxies of risk aversion. Relying on the intuition of the habit models (**?**, see)]Campbell:Cochrane:1999,Santos:Veronesi, we use either the leverage variable proposed by (He, Kelly, and Manela 2017) (see Figure 3.1), or the dividend-price ratio (see Figure 3.2).[13] We discretize the log dividend-price ratio and

[11] We thank C. Brownless for clarifying various aspects about the SLP technique.

[12] Appendix 3.10.3 shows that the linear SLP methodology delivers responses that are almost identical to those obtained by BB (2014) using a VAR of order four.

[13] (Campbell and Cochrane 1999) note that the price-dividend ratio is nearly linear in the surplus consumption ratio (see their Figure 3), the key state variable in the habit model. Our measure of leverage is based on market prices (market leverage) and, in the model of (Santos and Veronesi 2016),

the leverage ratio, and let RA_t take value equal to 1 when the risk aversion proxies are above the 75% percentile, RA_t is equal to -1 when they are below the 25% percentile, and RA_t is set to zero otherwise. We then standardize both variables. Very similar, yet slightly noisier, results are obtained when we use the continuous version of these proxies.

[Insert Figures 3.1 and 3.2 about here.]

The left column in Figures 3.1 and 3.2 plot the responses of GDP, consumption, and investment to an uncertainty shock that is realized (i) in a high risk aversion state ($RA_t = 1$), (ii) in an average state ($RA_t = 0$), and (iii) in a low risk aversion state ($RA_t = -1$). The right column in Figures 3.1 and 3.2 plot the state multipliers obtained from SLP. Recall that the state multiplier, $\beta_{1,h}$, captures the extent to which the state variable, namely risk aversion, affects the IRF at each horizon. A negative value of the state multiplier implies that the IRF response to a positive uncertainty shock is more negative when the risk aversion is high in the economy ($RA_t = 1$).

Figures 3.1 and 3.2 deliver a clear message about the state-dependent nature of uncertainty shocks: the response of the macroeconomic aggregate to a VXO shock is substantially larger when risk aversion is heightened. The peak decline in output, consumption, and investment when $RA_t = 1$ is roughly twice as large as the decline obtained in a low risk aversion environment when $RA_t = -1$. In general, the impulse responses obtained in a low risk aversion state return to zero after about two years, whereas those in a high risks aversion state tend to stay low for longer.

To quantify the amplifying effect of increased risk aversion on the economic impact of uncertainty shocks, we use the estimates from Eq. (3.1) to generate the fitted values of output and investment with and without elevated risk aversion. In other words, we construct fitted values with the state multiplier, $\beta_{1,h}$, set to either the estimated value (high RA) or to zero (average RA). Specifically, we examine output and investment declines during the financial crisis using the post 2007Q4 sample and choose the forecast horizon, h, to be four quarters.[14]

Figure 3.3 presents the time series plots of realized and fitted values of output, while Figure 3.4 presents the same plots for investment. In both figures, subplot (a) is derived from the SLP where leverage is the risk aversion proxy, and subplot (b) is derived from the SLP where dividend-price ratio is the proxy. Focusing on output in Figure 3.3, we see

the debt-to-wealth ratio is monotonically decreasing in the surplus consumption ratio (see their Corollary 13).

[14]Our results here are robust to using various other forecast horizons. Four quarters is chosen since it corresponds to the maximal impact on output, consumption, and investment in the uncertainty shock IRFs in figures 3.1 and 3.2. Furthermore, given the short sample period, long horizon forecasts are less appropriate.

the one-year ahead forecast of output (dashed line) from the SLP matches the realized path of output (solid line) in both subplots well. In particular, the forecasted maximal drop in output appears within two quarters of the actual minimal output during the financial crisis. Next, we set the state multiplier to zero and repeat the forecast while keeping all other coefficient estimates from the SLP. The resulting fitted output path (square-dashed line) is plotted along the original forecast for counter-factual analysis. Figure 3.3 subplot (a) shows that relative to the level of output at the onset of the crisis, the maximal decline in output due to uncertainty is exacerbated by roughly 50% conditional on high risk aversion (dashed vs. square-dashed lines), as proxied by leverage. In subplot (b), the amplifying effect is roughly 21% conditional on high risk aversion, as approximated by dividend-price ratio.

Quantitatively, heightened risk aversion during the financial crisis generates significantly larger decline in investment due to uncertainty. Figure 3.4 presents the realized (solid line), the actual one-year ahead forecast (dashed line), and the counter-factual forecast (square-dashed line) of investment. Similar to Figure 3.3, the SLP forecast of investment matches reasonably well with the realized path, especially in subplot (a) when leverage is used as the risk aversion proxy. Relative to the level of investment at the end of 2007, Figure 3.4 shows the maximal forecasted decline in investment is 23% and 16% greater, in subplots (a) and (b) respectively, when we allow for risk-aversion-dependence of uncertainty in the SLP.

Overall, the economic significance of risk aversion on macroeconomic dynamics cannot be overlooked. Our results from applying the SLP methodology to examine the financial crisis can perhaps be viewed in one of two ways. First, in the absence of state-dependence, the econometrician cannot decipher the true impact of uncertainty shocks on economic aggregates. Second, conversely, intensified risk aversion aggravated the depth of the recession by causing uncertainty shocks to be more effective through some general equilibrium mechanism. In the next section, we explore the interaction between risk aversion and uncertainty in relation to the macroeconomy in a structural setting employing DSGE models.

3.3 Quantitative Effects of Risk Aversion and Uncertainty in Structural Models

This section quantifies the effects of risk aversion on the dynamics of real quantities in DSGE models with time-varying volatility. To study how uncertainty shocks and risk aversion jointly determine business cycle moments we consider impulse response functions (IRFs) and variance decomposition analysis. Appendix 3.8 discusses the technical details behind the computation of IRFs and variance decompositions in general equilibrium models featuring stochastic volatility.

We consider two models: (1) the (Basu and Bundick 2017) model, BB (2017), that features a stochastic volatility shock to the representative household's intertemporal preferences; (2) the (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) model, FGRU (2011), that allows for time-varying volatilities affecting the real interest rate. In addition, we investigate the interplay of risk and risk aversion in a model that introduces stochastic volatility in the stationary technology shock by modifying BB (2017).

3.3.1 The Basu-Bundick (2017) Model

(Basu and Bundick 2017) build a small-scale dynamic stochastic general equilibrium model with monopolistic competition and sticky prices and show that demand uncertainty can generate a substantial fall in output, consumption, and investment. BB (2017) adopt a recursive structure for intertemporal utility, where a representative household chooses sequences of consumption, C_t, and labor, N_t, to maximize

$$U_t = \left[a_t \left(C_t^{\eta}(1-N_t)^{1-\eta}\right)^{\frac{1-\gamma}{\theta}} + \beta\left(E_t U_{t+1}^{1-\gamma}\right)^{\frac{1}{\theta}}\right]^{\frac{\theta}{1-\gamma}}$$

where $\theta \equiv (1-\gamma)/(1-\psi)$, γ determines the coefficient of relative risk aversion, ψ is the inverse of intertemporal elasticity of substitution, β is the subjective discount factor, and η determines the Frisch elasticity of labor supply. The model is calibrated to quarterly frequency by matching impulse responses to a one standard deviation increase in the VXO from a vector autoregression (see Figure D.1 in Appendix D.3). We use the values listed in Basu and Bundick (2017) – Table I (these are also reported in Table 3.7 for the reader's convenience).Next we describe how (Basu and Bundick 2017) model the demand uncertainty channel.

3.3.1.1 Stochastic Volatility in Household's Intertemporal Preferences

The coefficient on current utility, a_t, is a preference shock that follows

$$a_t = (1-\rho_a)\,a + \rho_a a_{t-1} + e^{\sigma_{a,t}}\varepsilon_{a,t} \tag{3.2}$$

$$\sigma_{a,t} = (1-\rho_\sigma)\,\sigma_a + \rho_\sigma \sigma_{a,t-1} + \sigma_\sigma \varepsilon_{\sigma_a,t} \tag{3.3}$$

where $\varepsilon_{a,t}$ and $\varepsilon_{\sigma_a,t}$ are uncorrelated. Importantly, the standard deviation of the preference shock, $\sigma_{a,t}$ introduces time-varying demand uncertainty into the model.

3.3.1.2 Volatility Shocks, Risk Aversion and Macro Dynamics

Figures 3.5(a) and 3.5(b) show the IRFs to a level and volatility shock to the representative household's intertemporal preferences, respectively.

[Insert Figure 3.5 about here.]

Figure 3.5(a) shows that IRFs to level shocks are hardly affected by the level of risk aversion, whereas Figure 3.5(b) shows that in response to a volatility shock the decline in output, consumption, and investment is stronger the greater the risk aversion. Thus, the effects of *volatility shocks* on the real economy are intertwined with the magnitude of the risk aversion coefficient.

To gauge the contribution of the volatility shocks to aggregate fluctuations for different levels of risk aversion, it is instructive to consider a variance decomposition. Table 3.1 shows the variance decomposition of output, consumption, investment, and hours among different shocks. Each column corresponds to a specific simulation: (1) the benchmark case with all three shocks (productivity, level and volatility shocks to the representative household's intertemporal preferences); (2) when we have a shock only to productivity; (3) when we have shocks to the level and the volatility of the household's intertemporal preferences; (4) when we have shocks only to the level of the household's intertemporal preferences; and (5) when we have shocks only to the volatility (pure demand uncertainty channel).

[Insert Table 3.1 about here.]

The last column shows that volatility alone makes a relatively important contribution to the fluctuations of real variables; more importantly doubling the risk aversion almost doubles these contributions. Looking at the second to last column we observe that risk aversion amplifies not only the simulation with volatility shocks (column 5) but also the simulation where both level and volatility shocks are simultaneously active (column 4). For example, doubling risk aversion raises investment volatility by about 13% (5.29/4.68) in a simulation with level and volatility shocks. To sum up, we have documented that within the BB (2017) economy: (1) volatility shocks are amplified when risk aversion is high; (2) the amplification effect of risk aversion is also present, although attenuated, in a simulation where both level and volatility shocks are active.

3.3.1.3 Intuition on the Interaction of Risk Aversion and Uncertainty

Utilizing the setup of the illustrative model of Section **??** in the Online Appendix, we shed light on the mechanism through which elevated risk aversion exaggerates the macroeconomic response to uncertainty shocks, specifically capital accumulation through investment. We start by augmenting the q equation under rational expectation in Equation **??** with a stochastic discount factor including the demand shock term:

$$\mathbb{E}_t \left[\beta \left(\frac{a_{t+1}}{a_t} \right) C_{t+1}^{-\psi} V_{t+1}^{\psi-\gamma} \left\{ \alpha e^{z_{t+1}} K_{t+1}^{\alpha-1} - (1-\delta) \right\} - C_t^{-\psi} \mathbb{E}_t \left[V_{t+1}^{1-\gamma} \right]^{\frac{\psi-\gamma}{1-\gamma}} \right] = 0,$$

where γ is risk aversion and ψ is the inverse of the elasticity of intertemporal substitution. Recall this is a model with no capital adjustment cost, and V_t is the value function of Epstein-Zin-Weil utility. Furthermore, the within period utility is additive in consumption and labor dis-utility.

After rearranging the terms, we get the familiar looking investment equation:

$$\mathbb{E}_t \left[\beta \underbrace{\left(\frac{a_{t+1}}{a_t} \right)}_{\text{Effective Demand}} \underbrace{\left(\frac{C_{t+1}}{C_t} \right)^{-\psi} \left[\frac{V_{t+1}}{\mathbb{E}_t \left[V_{t+1}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}} \right]^{\psi-\gamma}}_{\text{Epstein-Zin-Weil SDF}} \left\{ \underbrace{\alpha e^{z_{t+1}} K_{t+1}^{\alpha-1}}_{\text{Return on Capital}} - (1-\delta) \right\} \right] = 1.$$

Notice the risk aversion parameter, γ, governs the curvature of the continuation utility. As γ increases, given V_{t+1} is concave and differentiable everywhere, the difference between V_{t+1} and $\mathbb{E}_t \left[V_{t+1}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}$ also widens causing marginal utility to rise.

A positive shock to demand uncertainty raises the expected effective demand, $\mathbb{E}_t \left[a_{t+1} \right]$. Holding risk aversion constant and shutting down the transitory productivity shock ($z_{t+1} = 0$), higher expected demand implies higher marginal utility tomorrow, which lowers the return on capital, $\alpha K_{t+1}^{\alpha-1}$. As a result, the household reduces investment at time t to bring down the stock of capital at time $t+1$ after demand uncertainty is realized.

As we elevate the risk aversion, the Epstein-Zin-Weil stochastic discount factor increases causing the return on capital to decline since capital is a hedge against consumption risk. This implies that as the return on capital is depressed by higher risk aversion, the drop in investment is even more severe following the uncertainty shock to effective demand at time t which pushes marginal utility even higher at time $t+1$. The result is the exacerbated response of macroeconomic dynamics under the high risk aversion scenario in Figure 3.5 Panel (b). Lastly, notice risk aversion, γ, distorts the time t expectation of the continuation utility term from its actual value at time $t+1$. On the other hand, level shocks to effective demand have contemporaneous impact on consumption but are less consequential to the continuation utility. Therefore, broadly speaking, a level shock to effective demand at time t does not result in differential response under high and low risk aversion calibrations as reflected in Figure 3.5 Panel (a).

3.3.2 The FGRU (2011) Model

The FGRU (2011) model is a standard small open economy business cycle model calibrated to match data from four emerging economies: Argentina, Brazil, Ecuador, and Venezuela. The small open economy is populated by a representative household.[15] Differently from FGRU (2011), the preferences of the household are described by a recursive utility function (see (Epstein and Zin 1989) and (Weil 1990)). We do so because we want to separate the effect of the risk aversion from that of the intertemporal substitution. Trivially, when the risk aversion equals the inverse of the elasticity of substitution we obtain exactly the same results of FGRU (2011) (see Table 3.8 in Appendix 3.10.1). The household can invest in two types of assets: the stock of physical capital, K_t, and an internationally traded bond, D_t. The stock of capital evolves according to the law of motion with adjustment costs:

$$K_{t+1} = (1-\delta) + \left(1 - \frac{\phi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) I_t \ .$$

Firms rent capital and labor from households to produce output in a competitive environment according to the technology $Y_t = K_t^\alpha \left(e^{X_t} H_t\right)^{1-\alpha}$, where X_t corresponds to a labor-augmenting productivity shock that follows an AR(1) process

$$X_t = \rho_x X_{t-1} + \sigma_x u_{x,t} \ , \tag{3.4}$$

where $u_{x,t}$ is a normally distributed shock with zero mean and variance equal to one.

Firms maximize profits by equating wages and the rental rate of capital to marginal productivities. Thus,

$$Y_t - C_t - I_t = D_t - \frac{D_{t+1}}{1+r_t} + \frac{\Phi_D}{2}\left(D_{t+1} - D_t\right)^2$$

where $\Phi_D > 0$ is a parameter that controls the costs of holding a net foreign asset position.

[15] For the interested reader, a detailed derivation of the model equations, and steady states is available in (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011), and hence not repeated here.

The model is calibrated to monthly frequency. Following the original approach, we construct quarterly simulated data, and we report results on a quarterly basis. We refer the interested reader to the online Appendix 3.10.2 for details on the model aggregation. Finally FGRU (2011) takes the real interest rate, r_t, as an exogenously defined process. We now turn to describe these dynamics.

3.3.2.1 Stochastic Volatility in Real Interest Rate

The real interest rate, r_t, a country faces on loans denominated in US dollars is decomposed as the international risk-free real rate plus a country–specific spread:

$$r_t = r + \varepsilon_{tb,t} + \varepsilon_{r,t}$$

where r is the mean of the international risk-free real rate plus the mean of the country spread; the term $\varepsilon_{tb,t}$, equals the international risk-free real rate subtracted from its mean, and $\varepsilon_{r,t}$ equals the country spread subtracted from its mean. Both $\varepsilon_{tb,t}$ and $\varepsilon_{r,t}$ follow AR(1) processes described by

$$\begin{aligned} \varepsilon_{tb,t} &= \rho_{tb}\varepsilon_{tb,t-1} + e^{\sigma_{tb,t}} u_{tb,t} \\ \varepsilon_{r,t} &= \rho_r \varepsilon_{r,t-1} + e^{\sigma_{r,t}} u_{r,t} \ , \end{aligned}$$

where both $u_{r,t}$ and $u_{tb,t}$ are normally distributed random variables with mean zero and unit variance. Importantly, the process for interest rates displays stochastic volatility. In particular, the standard deviations $\sigma_{tb,t}$ and $\sigma_{r,t}$ follow an AR(1) process:[16]

$$\sigma_{tb,t} = (1 - \rho_{\sigma_{tb}})\,\sigma_{tb} + \rho_{\sigma_{tb}}\sigma_{tb,t-1} + \eta_{tb} u_{\sigma_{tb},t} \tag{3.5}$$

$$\sigma_{r,t} = (1 - \rho_{\sigma_r})\,\sigma_r + \rho_{\sigma_r}\sigma_{r,t-1} + \eta_r u_{\sigma_r,t}, \tag{3.6}$$

where both $u_{\sigma_{tb},t}$ and $u_{\sigma_r,t}$ are normally distributed random variables with mean zero and unit variance.[17]

Each of the components of the real interest rate is affected by two innovations. For instance, $\varepsilon_{tb,t}$ is hit by $u_{tb,t}$ and $u_{\sigma_{tb},t}$. The first innovation, $u_{tb,t}$, changes the rate, while the second innovation, $u_{\sigma_{tb},t}$, affects the standard deviation of $u_{tb,t}$. The innovations $u_{r,t}$ and $u_{\sigma_r,t}$ have a similar reading. Section 3.10.4 highlights why it is key to have two separate innovations, one to the level of the interest rate and one to the volatility of the level.

[16] This specification has been adopted by (Justiniano and Primiceri 2008b) among others.

[17] (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) re-estimate the process relaxing the assumption that innovations to the country spread and its volatility are uncorrelated. We defer the discussion of correlated shocks to Section 3.3.2.4.

In comparison with the country spread, the international risk-free real rate has both lower average standard deviation of its innovation (σ_{tb} is smaller than σ_r for all four countries) and less stochastic volatility ($\eta_{tb,t}$ is smaller than $\eta_{r,t}$ for all four countries). These relative sizes justify why in our analysis we concentrate only on the innovation to the volatility of the country spread, $u_{\sigma_{tb},t}$, and forget about shocks to the international risk-free real rate. For simplicity, we refer to the innovation $u_{\sigma_{tb},t}$ as the stochastic volatility shock.

3.3.2.2 Volatility Shocks, Risk Aversion and Macro Dynamics

In this section, we analyze the quantitative implications of the interaction between risk aversion and volatility within the FGRU (2011) model.

We first look at the impulse response functions (IRFs) of the model to shocks in the productivity, country spreads, and its volatility. To save space we report the results only for the model calibrated to Argentina. We consider both the original calibration of (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and the re-calibrated model of (Born and Pfeifer 2014).[18] The IRFs for a one standard deviation shock are reported in Figure 3.6. We plot the IRFs of output (first row of panels), consumption (second row), investment (third row) to the three shocks (columns).

[Insert Figure 3.6 about here.]

The third column plots the IRFs to a one-standard-deviation shock to the volatility of the Argentinean country spread, $u_{\sigma_{tb},t}$. This column shows that there is a large effect of risk aversion on macro dynamics. Importantly, risk aversion plays an important role only for the the impulse responses from a volatility shock in country spread; indeed the second column shows that IRFs to shocks in the level are hardly affected. Zooming in on the third column, we observe that in response to a volatility shock, output, consumption, and investment fall more in the case of high risk aversion, than in the case of low risk aversion. For example, after a shock to volatility, consumption drops 0.41 percent upon impact for a risk aversion equal to 5; the contraction is larger (0.90 percent at impact) for a risk aversion equal to = 15. Similarly, we observe a slow fall in output (after 10 quarters, it falls 0.16 percent) when risk aversion is low. However, for high risk aversion the fall is deeper and more persistent (after 11 quarters years, it falls 0.32 percent). Finally, whereas we observe only a slow decrease of investment (after five quarters it falls 2.18 percent) for low risk aversion, the decrease is substantially larger

[18] We use the same parameters as in (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Born and Pfeifer 2014); these are reported in Table 3.9 for the reader's convenience.

at 3.98 percent for large risk aversion. Columns $2-4$ in Table 3.2 displays the drops in macroeconomic variables, and the length of the recovery phase, for alternative values of risk aversion.

[Insert Table 3.2 about here.]

These IRFs show that the effects of *volatility shocks* on the real economy are intertwined with the magnitude of the risk aversion coefficient. The impact of risk aversion on real quantities is less amplified when one considers instead *level shocks* to productivity or to the real interest rate. These results suggest that increasing the risk aversion parameter to achieve a better fit of model risk premia may have the unintended consequence of affecting the ability of the model to match key macroeconomic moments such as output or investment volatility.[19]

To gauge the contribution of the volatility shocks to aggregate fluctuations for different levels of risk aversion, it is instructive to consider a variance decomposition.[20] Table 3.3 shows the variance decomposition of output, investment, and consumption. Each column corresponds to a specific simulation: (1) the benchmark case with all three shocks (productivity, the country spreads and its volatility); (2) when we have a shock only to productivity; (3) when we have a shock to productivity and to the interest rate (with volatility fixed at its unconditional value); (4) when we have shocks to interest rate and to volatility; (5) when we have a shock only to the interest rate level; and (6) when we have shocks only to interest rate volatility.

[Insert Table 3.3 about here.]

The last column shows that volatility alone makes a relatively important contribution to the fluctuations of consumption (the standard deviation is 0.75) and investment (standard deviation of 3.08). Increasing the risk aversion almost doubles these contributions.

We next move to consider an alternative calibration of the FGRU (2011) model. In particular, (Born and Pfeifer 2014) noted an error in the time aggregation of flow variables, and they show that the model of (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) must be recalibrated. Figure 3.7 compares the IRFs

[19]Two features of the model could potentially affect the results. The FGRU (2011) model assumes that the household faces a cost of holding a net foreign asset position. Importantly, the working paper version Fernandez-Villaverde et al. (2009) quantitatively compared this specification with other ways to close the open economy aspect of the model, and found that the results were if anything, often bigger. Similarly, working capital makes the findings of (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) even stronger. We thus conjecture that our documented interplay between volatility, risk aversion, and real variables is robust to these changes in model specification as well.

[20]Appendix 3.10.2 provides additional details on how to obtain the variance decomposition for the FGRU (2011) economy.

for the recalibrated corrected model with the IRFs in (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) (these are the same as those shown in Figure 3.6, and reproduced here for reader's convenience). As noted in (Born and Pfeifer 2014), the figure clearly shows that a one standard deviation volatility shock now leads to a larger drop in macro quantities than originally reported in (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011). The difference between the two calibrations is further magnified the higher the risk aversion value. Columns $5-7$ in Table 3.2 displays the drops in macroeconomic variables, and the length of the recovery phase, for alternative values of risk aversion.

[Insert Figure 3.7 about here.]

We now turn to quantify the effect of the interaction of volatility shocks with risk aversion, as well as the interaction between level and volatility shocks with risk aversion, for business cycle moments in the recalibrated corrected model of (Born and Pfeifer 2014). Table 3.4 shows the variance decomposition for the alternative calibration proposed by (Born and Pfeifer 2014). First, consistent with (Born and Pfeifer 2014), we find that in the re-calibrated model that corrects for the time-aggregation, the contribution of volatility shocks to business cycle volatility increase, and more so the higher the risk aversion.[21] Second and more important, by comparing Table 3.4 with Table 3.3 an important insight emerges: risk aversion amplifies not only the simulation with volatility shocks only (column 6) but also the simulation where both level and volatility shocks are active (column 5). For example, in the (Born and Pfeifer 2014) re-calibrated economy, investment raises by about 28% (18.11/14.19) when risk aversion raises from 5 to 15. On the other hand, the original (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) calibration does not show any sensitivity of investment to risk aversion in a simulation buffeted by level and volatility shocks. This makes us conclude that: (1) volatility shocks are amplified by the magnitude of risk aversion; (2) the amplification effect of risk aversion in a simulation where both level and volatility shocks are active depends on the specific calibration of the model. The next section digs deeper into this issue and highlights the key role played by the cost of debt parameter Φ_D (which is higher in FGRU (2011) and lower in (Born and Pfeifer 2014), see Table 3.9) in determining the interaction between risk aversion and the level shock to interest rates.

[Insert Table 3.4 about here.]

[21] When compared with the benchmark case with all three shocks (column 1), volatility shocks alone (column 6) account for 6 percent of output volatility and 35 percent of investment volatility. By increasing risk aversion, the contribution of volatility shocks to output and investment raises is a remarkable 35% and 67%, respectively.

3.3.2.3 Level Shock to the Country Spread

Examining the variance decomposition in Table 3.3, it is striking that as risk aversion increases from Panel A to Panel B, the unconditional volatilities of macroeconomic aggregates actually drop in columns (1), (3), (4) and (5). This is driven by the level shock to country spread in column (5), as columns (2) and (6) show that the level shock to TFP and the volatility shock to country spread generate higher economic volatilities with increasing risk aversion. This implies that risk aversion can dampen the macroeconomic response to some shocks while strengthening the response to others.

To understand the mechanism causing elevated risk aversion to attenuate output, consumption and investment volatilities following level shocks to country spread, we focus on the Euler equation specific to the open economy model of FGRU (2011):

$$\frac{1}{1+r_t} = \Phi_D(D_{t+1} - D) + \beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\nu} \right].$$

Here, like the original model, we assume CRRA utilities for the ease of exposition. To start with, assume the debt adjustment parameter, Φ_D, is zero. A positive level shock to r_t increases the country spread and lowers the price ($\frac{1}{1+r_t}$) of the internationally traded bond. Under the low risk aversion calibration, $\nu = 5$ for example, lower bond price today translates into higher expected consumption growth between today and tomorrow in the Euler equation. As a result, the representative agent optimally decides to borrow more today and invest less in capital. As risk aversion increases, to $\nu = 15$ for example, a level shock of the same magnitude to country spread does not raise consumption growth expectation as significantly. To see this, rewrite the Euler equation in logs while keeping $\Phi_D = 0$:

$$e^{-r_t} = \beta \mathbb{E}_t \left[e^{-\nu(c_{t+1} - c_t)} \right].$$

Holding the increase in r_t constant, larger ν means smaller $(c_{t+1} - c_t)$. As consumption growth expectation is tempered due to high risk aversion, the representative agent does not adjust borrowing and investment after the level shock is realized as dramatically relative to the case when risk aversion is low. Taken together, high risk aversion attenuates the dynamic response of macroeconomic variables with respect to level shocks through the consumption growth expectations.

In the benchmark case, however, Φ_D is not zero, and the debt adjustment cost term enters the Euler equation. Under this scenario, a positive level shock to country spread lowers the price of the internationally traded bond and causes debt level to decline (since $\Phi_D > 0$). Furthermore, because the debt adjustment term partially absorbs the price drop, consumption growth expectation does not alter between high and low risk aversion calibrations as much compared to the scenario when Φ_D is zero. Therefore, the representative agent assuages the disinvestment to similar degrees regardless of high or low risk aversion. In other words, debt adjustment cost renders the impact of risk aversion on the debt and investment responses to level shocks to country spread ineffective.

Figure 3.8 demonstrates the FGRU (2011) model implied impulse response functions for output, consumption, investment, hours, q and debt following a positive level shock to country spread under low and high risk aversion calibrations. Panel A presents the IRFs when the debt adjustment cost parameter is set to close to zero ($\Phi_D = 0.0001$), while Panel B contains the IRFs when the same parameter is set to 0.1. When the adjustment term is small in Panel A, higher r_t causes output, investment, hours and q to decline. At the same time, consumption and borrowing increase due to a rise in consumption growth expectation, consistent with the mechanism described above. Furthermore, as risk aversion is elevated from 5 to 15 in Panel A, the drops in output and investment and the increase in borrowing are less exaggerated.

[Insert Figure 3.8 about here.]

In Panel B of Figure 3.8, we set the debt adjustment term to be large. Three takeaways are immediate. First, in comparison to Panel A, the positive level shock to country spread leads to moderate declines in consumption and borrowing as the adjustment cost absorbs most of the "good news" generated by lower price of debt. Second, as consumption growth expectation is mitigated by the cost of changing the debt level, investment only dips mildly in contrast to when $\Phi_D = 0$. Finally, the differential impact of the country spread shock under low and high risk aversion is completely nullified in Panel B in the presence of debt adjustment cost. These implications are in line with our priors formed by examining the Euler equation of the FGRU (2011) model and provide us with insights on the interaction between risk aversion and first moment shocks to the real interest rate.

3.3.2.4 Correlated Level and Volatility Shocks

(Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) argue that in the data, movements in the volatility of real interest rates are highly correlated with variations in levels. Accordingly, in this section, we investigate the scenario under which the innovations to the level and volatility shocks to the country spread are not independent from each other. By allowing for feedback between the first- and second-moment dynamics, our analysis sheds light on the interaction between the level and volatility dynamics, and it complements the work by (Gorodnichenko and Ng 2017).

[Insert Table 3.5 about here.]

Table 3.5 presents the results of the variance decomposition of the FGRU (2011) model under the correlated innovation structure outlined in the original paper, where the columns are consistent with those described in Table 3.3. Comparing Panel A with Panel B in Table 3.5, our previous finding under the baseline calibration of FGRU is preserved: increase in risk aversion amplifies the effect of volatility shocks to country spread on investment volatility in column (6) but dampens the effect of level shocks to country spread on investment volatility in column (5). In column (4) of Table 3.5, however, we see that the correlated shock structure between level and volatility shocks to the country spread allows risk aversion to amplify the effect on investment volatility when both shocks are activated. This is in line with the results from the BB (2017) model in Table 3.1 and the (Born and Pfeifer 2014) calibration in Table 3.4. The correlated innovations to level and volatility shocks to country spread accentuates the positive influence of risk aversion has on the response of investment to the second moment shock.

3.3.3 Stochastic Volatility in Productivity

We next investigate the interplay of risk aversion and stochastic volatility in a model that introduces stochastic volatility in stationary technology shocks. To this end we modify the BB (2017) model economy as described in Appendix D.2 of (Basu and Bundick 2017).[22,23] In particular, we first shut down stochastic volatility the household's intertemporal preferences, i.e. $\sigma_{a,t} = \sigma_a$ in Eq. (3.2) is not time varying. Next, consider intermediate goods-producing firms i with the same constant returns to scale Cobb-Douglas production function, subject to a fixed cost of production Φ and their level of productivity Z_t: $Y_t(i) = (K_t(i)U_t(i))^{\alpha} (Z_t N_t(i))^{1-\alpha} - \Phi$, where $U_t(i)$ is the rate of utilization of their installed physical capital, $N_t(i)$ is labor, $Y_t(i)$ is the intermediate good. The technological process $z_t = \log(Z_t)$ evolves according to a stochastic volatility process

$$z_{t+1} = (1-\rho_z)\, z_{ss} + \rho_z z_t + e^{\sigma_{z,t+1}} \varepsilon_{z,t+1} \tag{3.7}$$

$$\sigma_{z,t+1} = (1-\rho_\sigma)\, \sigma_z + \rho_\sigma \sigma_{z,t} + \varepsilon_{\sigma,t+1} \tag{3.8}$$

with $\varepsilon_{z,t} \sim$ i.i.d.$N(0,1)$, $z_{ss} = \log Z_{ss}$ where Z_{ss} is the steady state level of Z_t, and $\varepsilon_{\sigma,t} \sim$ i.i.d.$N(0,\sigma_\sigma)$. The innovations $\varepsilon_{z,t+1}$ and $\varepsilon_{\sigma,t+1}$ are assumed to be mutually

[22] We use the same parameters as in (Basu and Bundick 2017); these are reported in Table 3.7 for the reader's convenience.

[23] In a previous version of this paper, we considered the (Andreasen 2012) model which also introduces stochastic volatility in stationary technology shocks. Using the (Andreasen 2012) model and the corresponding calibration does not alter any of the conclusions described in this section.

independent at all leads and lags. In words, two independent innovations affect the the level of productivity. The first innovation, $\varepsilon_{z,t+1}$, changes the level of productivity itself, while the second innovation, $\varepsilon_{\sigma,t+1}$, determines the spread of values for the productivity level.

3.3.3.1 Volatility Shocks, Risk Aversion and Macro Dynamics

Figures 3.9(a) and 3.9(b) show the IRFs to a level and volatility shock to technology, respectively. The amplification effect of risk aversion is present only for impulse responses to a volatility shock in technology; responses to level shocks, see Figure 3.9(a), do not display any sensitivity to the risk aversion parameter. Zooming in on the uncertainty channel, Figure 3.9(b) shows that that a higher level of risk aversion generates a more pronounced decline in output, consumption, and hours in response to a volatility shock.

[Insert Figure 3.9 about here.]

We compare the variance decomposition obtained from an economy featuring SV in productivity (see Table 3.6) with the (Basu and Bundick 2017) demand shock model and the variance decompositions of the FGRU (2011) open economy model (see Tables 3.1 and 3.3). The latter two economies are characterized by a much stronger effect of volatility shocks in terms of driving economic dynamics compared with the standard New-Keynesian model with uncertainty in productivity. For example, when rising risk aversion in the economy with productivity uncertainty, the variability of output and consumption due to volatility shocks in productivity increases by 90%. Although these increases are still substantial, they are below those observed for the FGRU (2011) and the (Basu and Bundick 2017) economies.[24]

[Insert Table 3.6 about here.]

To conclude, a careful inspection of the variance decomposition of endogenous variables shows that the interaction of uncertainty shocks and risk aversion is much more pronounced when stochastic volatility materializes in shocks to demand or the real interest rate rather than productivity. The explanation is that capital acts as a hedging instrument to productivity uncertainty. Higher productivity uncertainty today raises expected output tomorrow, which in turn drives the expected return on capital higher since $R_t^k = \frac{\partial Y_t}{\partial K_t}$. Therefore, although the representative agent optimally chooses to disinvest today due to uncertainty, the degree to which the disinvestment occurs is tempered by

[24]In FGRU (2011) the variability of consumption raises by $97\% = 1.48/0.75 - 1$, whereas in Basu-Bundick (2017) it raises by $105\% = 0.43/0.21 - 1$.

the fact that return on capital investment might be large tomorrow when productivity is high. As a result, investment declines following the uncertainty shock to productivity but the effect is much more mild relative to the decline following second moment shocks to interest rate and preferences. This suggests the source of uncertainty is important in the class of DSGE models we consider.

3.4 Conclusion

Our study shows that, within the class of DSGE models widely used for policy analysis, the response of macroeconomic quantities to volatility shocks is stronger for higher level of risk aversion. IRFs to level shocks are less sensitive to the value of risk aversion. The effect we document are quantitatively important: after a shock to volatility, the higher the risk aversion, the larger and more prolonged the decline in economic activity. On the other hand, these models are much more robust to varying degrees of risk aversion with respect to level shocks in the economy.

By examining the interactions of risk aversion and volatility shocks in two well known DSGE models in the literature, we also document that the impact of volatility shocks is significantly more pronounced in models where uncertainty is directly related to preferences rather than production. Variance decompositions of the (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) open economy model and the (Basu and Bundick 2017) demand shock model underscore a much stronger effect of volatility shocks in terms of driving economic dynamics compared to a standard New-Keynesian model with uncertainty in productivity.

Our results could be relevant for policymakers to consider stochastic volatility, and its interplay with financial quantities via risk-aversion, when implementing fiscal and monetary policy.

3.5 Tables

Table 3.1: **Variance Decomposition Basu and Bundick (2017) - The Effect of Structural Shocks when the Discount rate shocks have a time-varying second moment**

This table reports the variance decomposition for the different structural shocks in the model of Basu and Bundick (2017). First column displays moments obtained from data. Second column: 200 simulations of the model; third column: TFP shocks only; fourth column: without TFP shocks fifth column: only level shocks to household discount factor; fifth column: only shocks to the volatility of household discount factor. Panel A (B) reports the simulation results for a risk aversion parameter equal to 80 (160).

	(1)	(2)	(3)	(4)	(5)	(6)
					Preference Shocks	
	Data	All Shocks	TFP only	w/o TFP	Level only	Volatility only
Panel A: $\gamma = 80$, Pruning, 200 Replications						
σ_Y	1.1	1.12	0.72	0.84	0.44	0.40
σ_C	0.7	0.81	0.42	0.68	0.39	0.21
σ_I	3.8	5.00	1.70	4.68	2.74	1.00
σ_H	1.4	0.83	0.17	0.81	0.46	0.25
Panel B: $\gamma = 160$, Pruning, 200 Replications						
σ_Y	1.1	1.36	0.74	1.12	0.48	0.82
σ_C	0.7	0.89	0.41	0.78	0.40	0.43
σ_I	3.8	5.64	1.87	5.29	3.00	2.10
σ_H	1.4	0.97	0.19	0.95	0.49	0.51

Table 3.2: **IRF Analysis - The Effect of a Volatility Shocks in FGRU (2011)**

This table reports displays the drops in macroeconomic variables, and the length of the recovery phase, for alternative values of risk aversion. Results are shown for both the model by (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and the recalibrated corrected model by (Born and Pfeifer 2014). "Recovery time" is defined as time (closest quarter) it takes for a variable to revert back to its unconditional mean. An example: With a risk aversion of 15, it takes 4 quarters for consumption to revert back to its mean level after a one standard deviation shock in volatility. See also Figure 3.7.

	FGRU (2011)			BP (2014)		
(1) Risk Aversion	(2) Largest Drop	(3) Time	(4) Recovery Time	(5) Largest Drop	(6) Time	(7) Recovery Time
Panel A: Consumption						
5	-0.410	1	4	-1.125	1	8
15	-0.896	1	4	-2.757	1	7
20	-1.381	1	5	-4.390	1	7
25	-1.866	1	5	-6.022	1	7
Panel B: Investment						
5	-2.183	5	14	-4.230	5	15
15	-3.979	5	15	-9.778	5	14
20	-5.774	5	15	-15.353	4	14
25	-7.570	5	16	-20.957	4	14
Panel C: Output						
5	-0.165	10	22	-0.287	10	26
15	-0.321	11	25	-0.753	11	26
20	-0.481	11	26	-1.2209	11	26
25	-0.642	12	27	-1.6886	11	26

Table 3.3: **Variance Decomposition FGRU (2011) - The Effect of Structural Shocks**

This table reports the variance decomposition for the different structural shocks in the model of FGRU (2011) with stochastic volatility. First column: 200 simulations of the model; second column: TFP shocks only; third column: without volatility shocks to spread and T-bill rate; fourth column: without TFP shocks; fifth column: only level shocks to the spread and the T-bill rate; sixth column: only shocks to the volatility of spread and the T-bill rate.

	(1)	(2)	(3)	(4)	(5)	(6)
					Interest Rate	
	All Shocks	TFP only	w/o volatility	w/o TFP	Level only	Volatility only
			Panel A: $\gamma = 5$, Pruning, 200 Replications			
σ_Y	5.25	5.02	5.09	1.10	0.64	0.16
σ_C	7.60	2.63	4.70	7.11	4.00	0.75
σ_I	20.63	5.00	12.71	19.90	11.63	3.08
			Panel B: $\gamma = 15$, Pruning, 200 Replications			
σ_Y	5.23	5.01	5.07	1.07	0.57	0.31
σ_C	7.42	2.73	4.38	6.86	3.53	1.48
σ_I	20.42	5.42	11.86	19.57	10.54	5.89

Table 3.4: **Variance Decomposition BP (2014) - The Effect of Structural Shocks**

This table reports the variance decomposition for the different structural shocks in the recalibrated model of BP (2014) with stochastic volatility. First column: 200 simulations of the model; second column: TFP shocks only; third column: without volatility shocks to spread and T-bill rate; fourth column: without TFP shocks; fifth column: only level shocks to the spread and the T-bill rate; sixth column: only shocks to the volatility of spread and the T-bill rate.

	(1)	(2)	(3)	(4)	(5)	(6)
					Interest Rate	
	All Shocks	TFP only	w/o volatility	w/o TFP	Level only	Volatility only
			Panel A: $\gamma = 5$, Pruning, 200 Replications			
σ_Y	4.59	4.46	4.49	0.75	0.40	0.27
σ_C	4.39	2.10	2.72	3.81	1.76	1.40
σ_I	15.51	5.84	9.78	14.19	7.80	5.46
			Panel B: $\gamma = 15$, Pruning, 200 Replications			
σ_Y	4.61	4.44	4.47	0.93	0.38	0.66
σ_C	5.24	2.40	2.65	4.63	1.20	3.38
σ_I	19.54	6.68	9.85	18.11	7.11	13.10

Table 3.5: **Variance Decomposition FGRU (2011) when innovations to the country spread and its volatility are correlated**

This table reports the variance decomposition for the different structural shocks in the model of FGRU (2011) with stochastic volatility. First column: 200 simulations of the model; second column: TFP shocks only; third column: without volatility shocks to spread and T-bill rate; fourth column: without TFP shocks; fifth column: only level shocks to the spread and the T-bill rate; sixth column: only shocks to the volatility of spread and the T-bill rate.

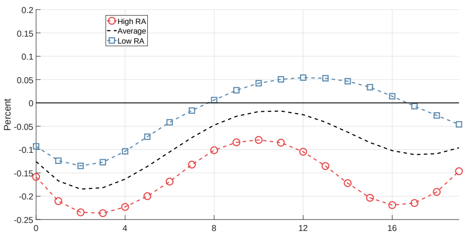
	(1)	(2)	(3)	(4)	(5)	(6)
					Interest Rate	
	All Shocks	TFP only	w/o volatility	w/o TFP	Level only	Volatility only
Panel A: $\gamma = 5$, No Pruning, 200 Replications, Corr(u_r,u_{σ_r})=0.3						
σ_Y	5.28	5.02	5.07	1.30	0.55	0.99
σ_C	7.14	2.53	3.00	6.71	1.91	4.48
σ_I	24.25	6.38	9.98	23.69	8.61	17.93
Panel B: $\gamma = 15$, No Pruning, 200 Replications, Corr(u_r,u_{σ_r})=0.3						
σ_Y	5.28	5.01	5.05	1.36	0.51	1.10
σ_C	7.49	2.60	3.10	7.06	1.95	5.01
σ_I	25.55	6.74	9.46	24.91	7.76	20.13

Table 3.6: **Variance Decomposition Basu and Bundick (2017) - The Effect of Structural Shocks when the Technology shocks have a time-varying second moment**

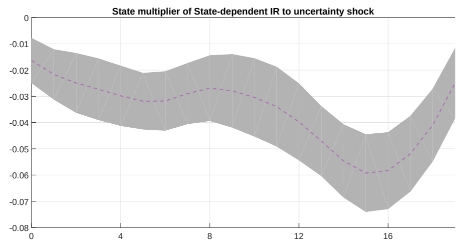
This table reports the variance decomposition for the different structural shocks in the model of Basu and Bundick (2017). First column displays moments obtained from data. Second column: 200 simulations of the model; third column: shocks to the volatility of household discount factor only; fourth column: without shocks to household discount factor; fifth column: only level shocks to household discount factor; fifth column: only shocks to the volatility of household discount factor.

	(1)	(2)	(3)	(4)	(5)	(6)
					Technology Shocks	
	Data	All Shocks	Preference only	w/o Preference	Level only	Volatility only
Panel A: $\gamma = 80$, Pruning, 200 Replications						
σ_Y	1.1	4.48	0.08	4.48	2.65	0.21
σ_C	0.7	3.87	0.26	3.86	2.27	0.22
σ_I	3.8	6.45	0.91	6.38	3.83	0.19
σ_H	1.4	0.46	0.18	0.42	0.24	0.10
Panel B: $\gamma = 160$, Pruning, 200 Replications						
σ_Y	1.1	4.47	0.09	4.46	2.66	0.40
σ_C	0.7	3.85	0.27	3.84	2.24	0.42
σ_I	3.8	6.47	0.96	6.39	3.93	0.38
σ_H	1.4	0.50	0.19	0.46	0.24	0.21

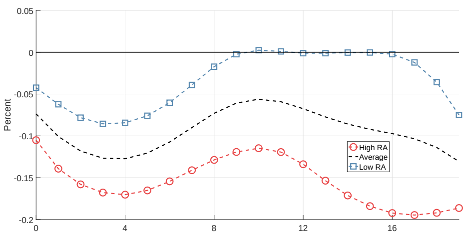
3.6 Figures



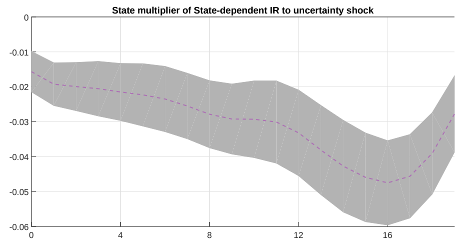
(a) Output.



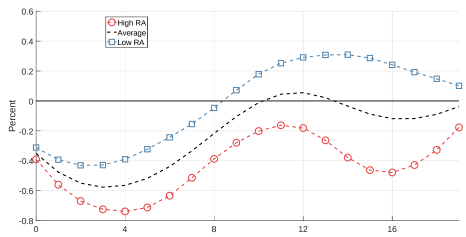
(b) State Multiplier – Output.



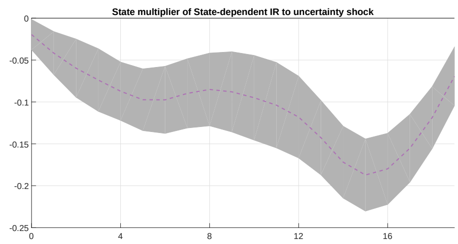
(c) Consumption.



(d) State Multiplier – Consumption.

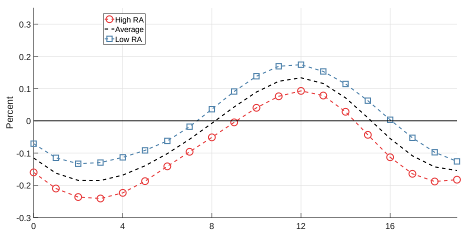


(e) Investment.

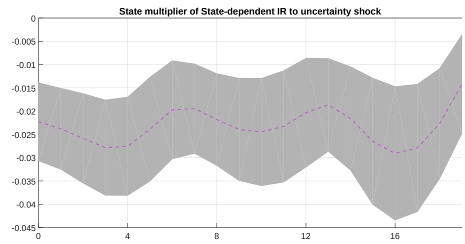


(f) State Multiplier – Investment.

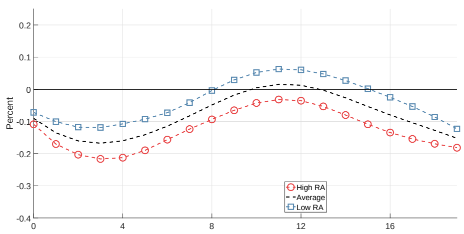
FIGURE 3.1: **State-dependent (leverage) IR to an uncertainty shock**:
This figure plots the empirical impulse responses to an uncertainty shock for different levels of risk aversion. We measure uncertainty using the VXO. Our proxy for risk aversion is intermediary leverage (He, Kelly, Manela, 2016). The state variable s_t takes values -1 (low risk aversion; blue line with squares), 0 (black line), and +1 (high risk aversion; red line with circles) units of $\sigma(s_t)$. The left column shows the state-dependent IR of GDP (top), consumption (mid), and investment (bottom) to a volatility shock are estimated using SLP. The right column reports the state multiplier of the state-dependent IR of GDP (top), consumption (mid),and investment (bottom) to a volatility shock estimated using SLP. The shaded areas denote 68% confidence intervals.



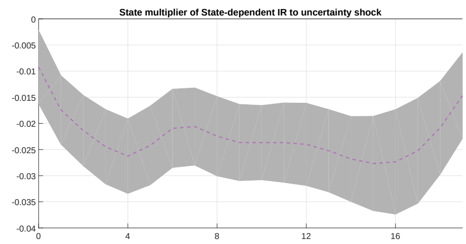
(a) Output.



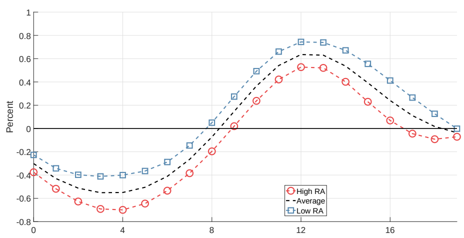
(b) State Multiplier – Output.



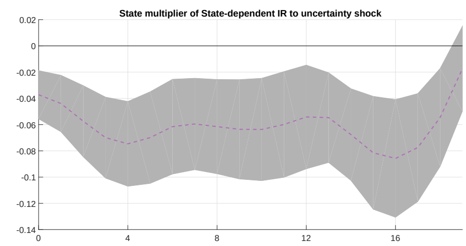
(c) Consumption.



(d) State Multiplier – Consumption.

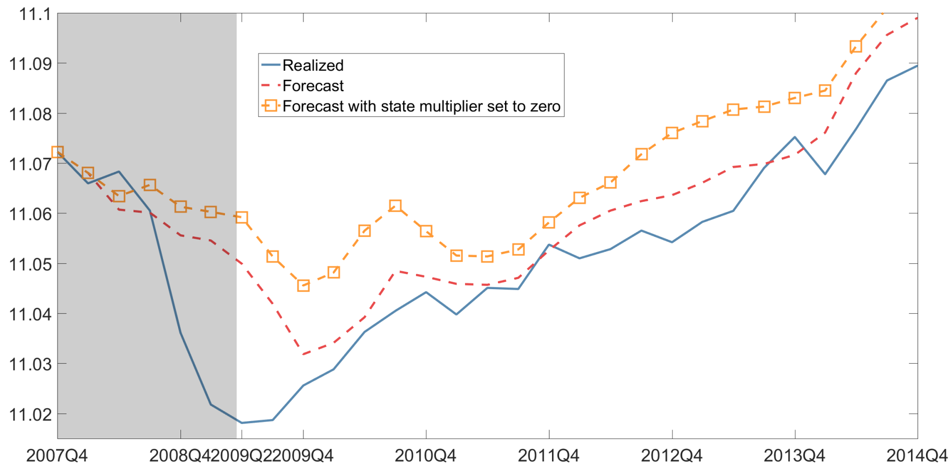


(e) Investment.

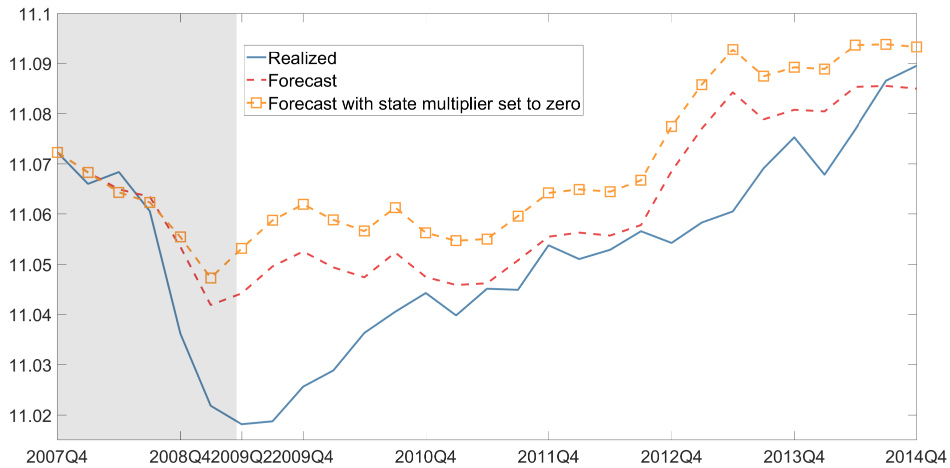


(f) State Multiplier – Investment.

FIGURE 3.2: **State-dependent (dividend-price) IR to an uncertainty shock**: This figure plots the empirical impulse responses to an uncertainty shock for different levels of risk aversion. We measure uncertainty using the VXO. Our proxy for risk aversion is the log dividend-price ratio. The state variable s_t takes values -1 (low risk aversion; blue line with squares), 0 (black line), and +1 (high risk aversion; red line with circles) units of $\sigma(s_t)$. The left column shows the state-dependent IR of GDP (top), consumption (mid), and investment (bottom) to a volatility shock are estimated using SLP. The right column displays the state multiplier of the state-dependent IR of GDP (top), consumption (mid),and investment (bottom) to a volatility shock estimated using SLP. The shaded areas denote 68% confidence intervals.

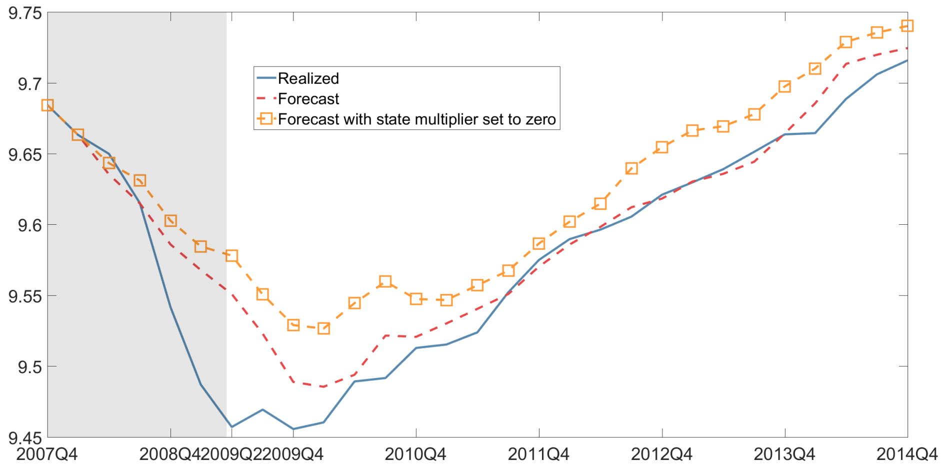


(a) Output and Leverage.

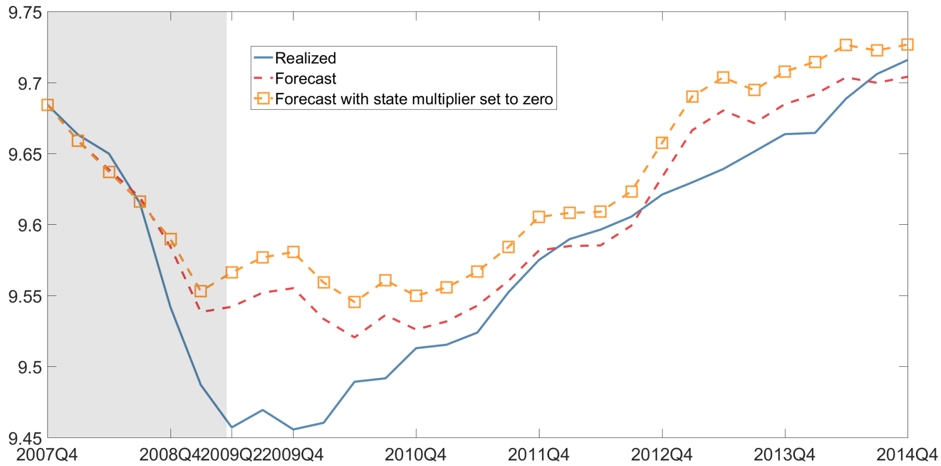


(b) Output and Dividend-price ratio.

FIGURE 3.3: **The Role of the interaction between Uncertainty and Risk aversion in Output**:
The solid line displays (log) per capita, real GDP for our sample. The dashed line is the four periods ahead forecasts from direct regressions that allow for an interaction between risk aversion and uncertainty. The line with squares is the four periods ahead forecasts from direct regression with no interaction between risk aversion and uncertainty. Shaded areas indicate NBER recession dates. We measure uncertainty using the VXO, a well-known and readily-observable measure of aggregate uncertainty. To proxy for risk aversion we use either the intermediary (equity-based) leverage measure by He et al. (2017) (see Panel A), or the dividend-price ratio (Panel B).



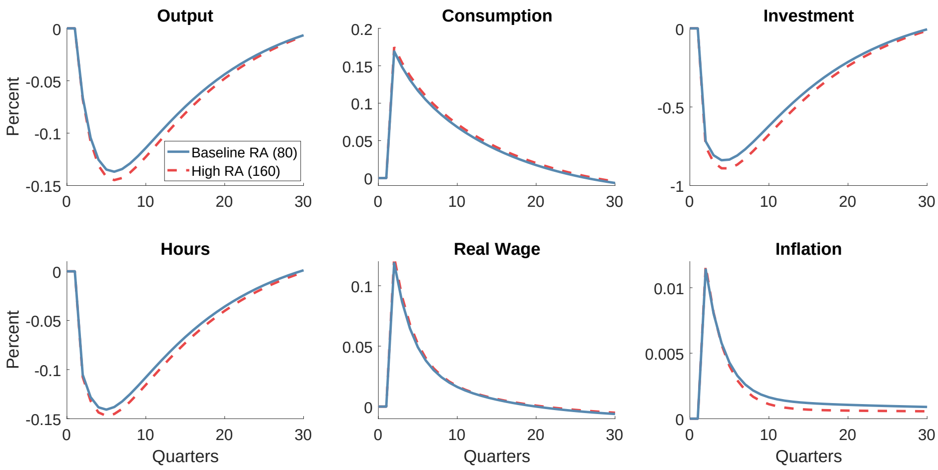
(a) Investment and Leverage.



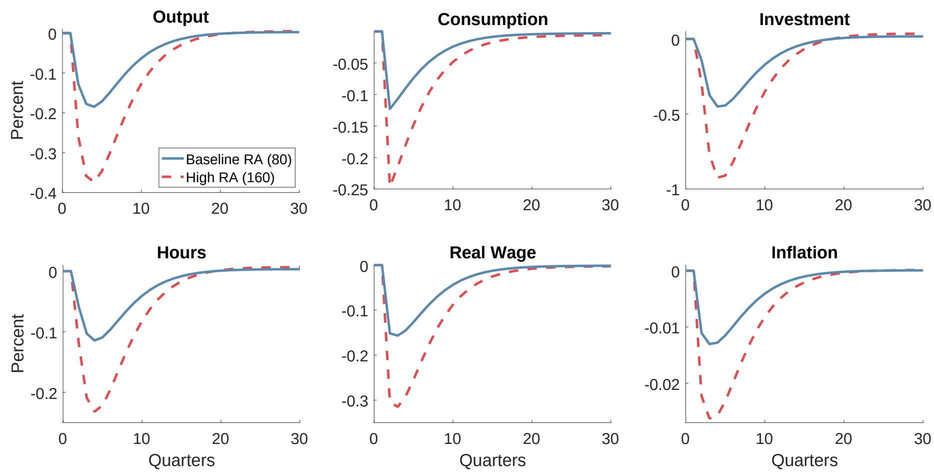
(b) Investment and Dividend-price ratio.

FIGURE 3.4: **The Role of the interaction between Uncertainty and Risk aversion in Investment**:

The solid line displays (log) per capita, real investment for our sample. The dashed line is the four periods ahead forecasts from direct regressions that allow for an interaction between risk aversion and uncertainty. The line with squares is the four periods ahead forecasts from direct regressions with no interaction between risk aversion and uncertainty. Shaded areas indicate NBER recession dates. We measure uncertainty using the VXO, a well-known and readily-observable measure of aggregate uncertainty. To proxy for risk aversion we use either the intermediary (equity-based) leverage measure by He et al. (2017) (see Panel A), or the dividend-price ratio (Panel B).

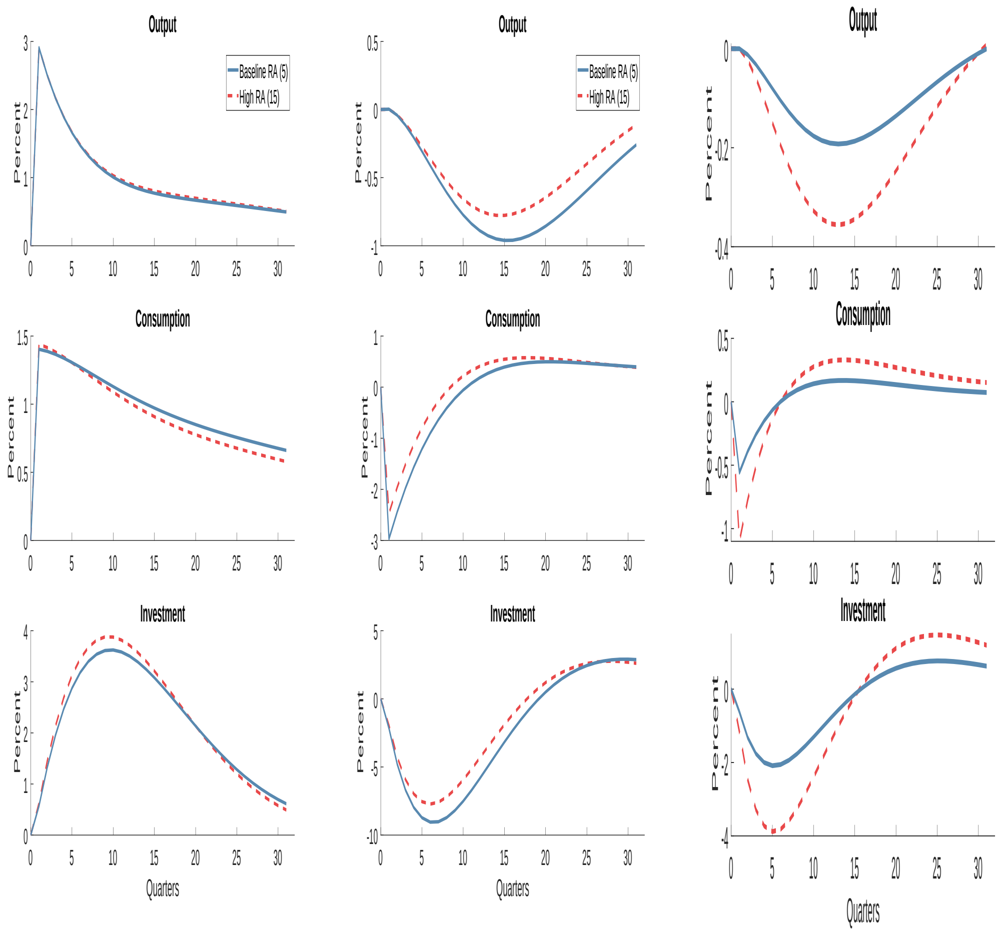


(a) Response to level shock.



(b) Response to volatility shock.

FIGURE 3.5: **Impulse Response Function to Preference Shock– Basu and Bundick (2017)**:
This figure plots the impulse responses for a one standard deviation shock to the (i) level, and (ii) volatility of the exogenous process for household discount factors. Impulse responses are for a one standard deviation shock when the model is approximated up to third order. To construct these responses, we set the exogenous shocks in the model to zero and iterate our third-order solution forward. After a sufficient number of periods, the endogenous variables of the model converge to a fixed point, which we denote the stochastic steady state. We then hit the economy with a one standard deviation uncertainty shock but assume the economy is hit by no further shocks. We compute the impulse response as the percent deviation between the equilibrium responses and the pre-shock stochastic steady state.



(a) Technology level shock. (b) Country spread level shock. (c) Country spread vol shock.

FIGURE 3.6: **Impulse Response Functions – FGRU (2011)**
: This figure plots the impulse responses for a one standard deviation shock to the (i) technology level (ii) interest rate (iii) conditional volatility in interest rate. Impulse responses are for a one standard deviation shock when the model is approximated up to third order. The cost of debt is set to $\Phi_D = 0.001$. To construct these responses, we set the exogenous shocks in the model to zero and iterate our third-order solution forward. After a sufficient number of periods, the endogenous variables of the model converge to a fixed point, which we denote the stochastic steady state. We then hit the economy with a one standard deviation to e.g. country spread shock but assume the economy is hit by no further shocks. The IRFs must be interpreted as the percentage deviations from the ergodic mean in absence of shocks, EMAS. See Appendix 3.10.1 for a comparison between steady state, ergodic mean, and EMAS in the (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) model, and Appendix 3.8 for additional details.

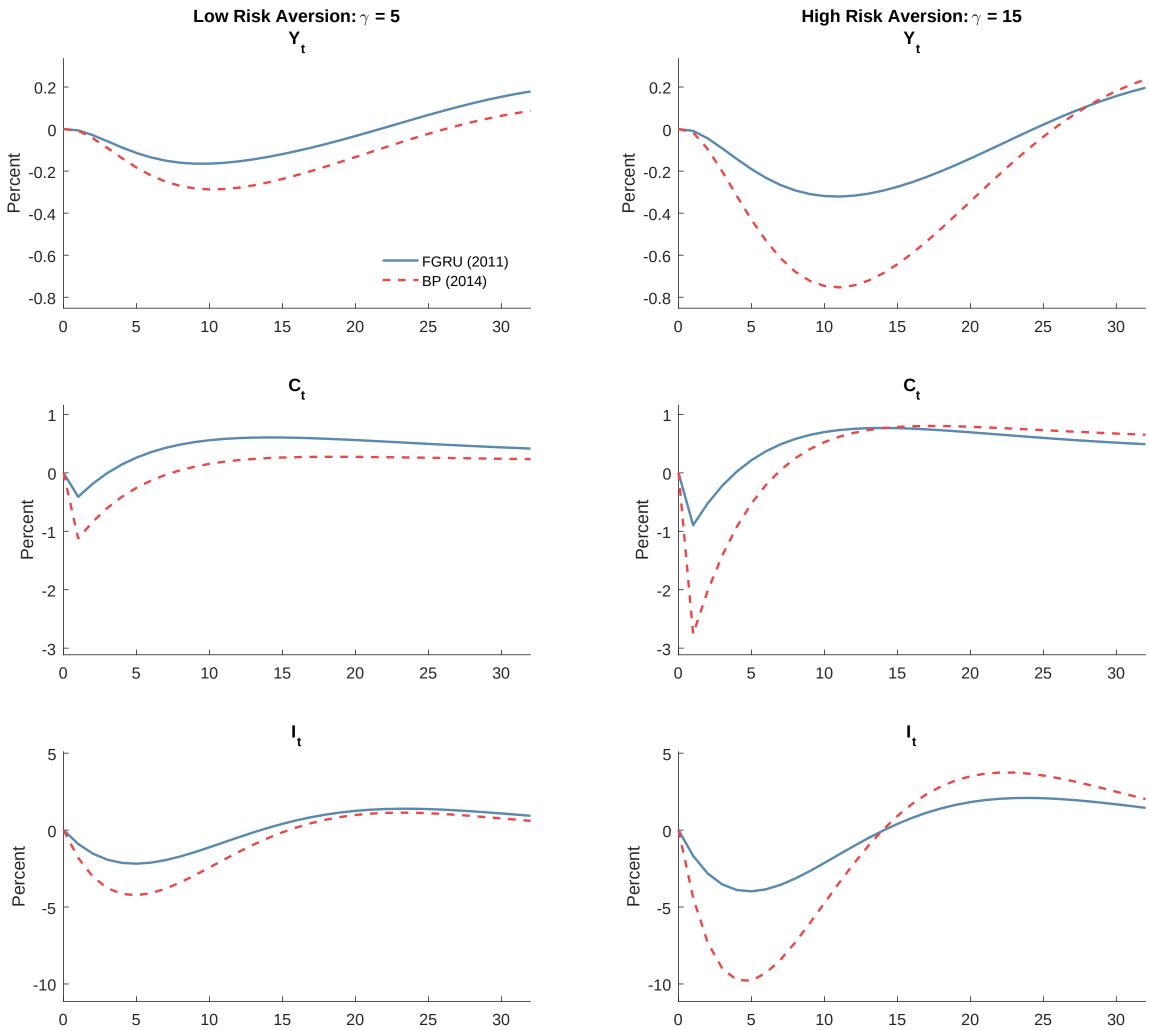
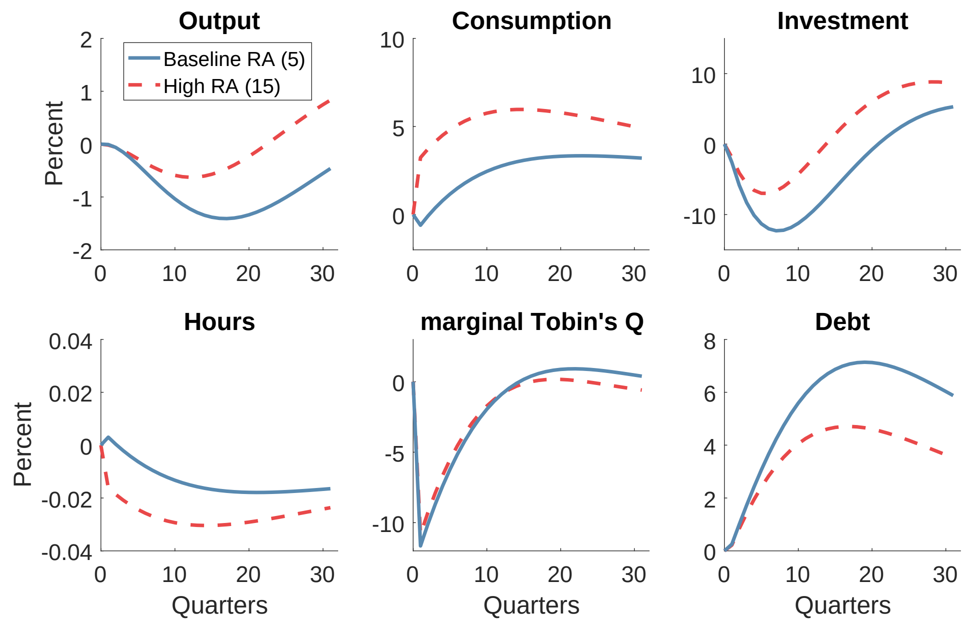
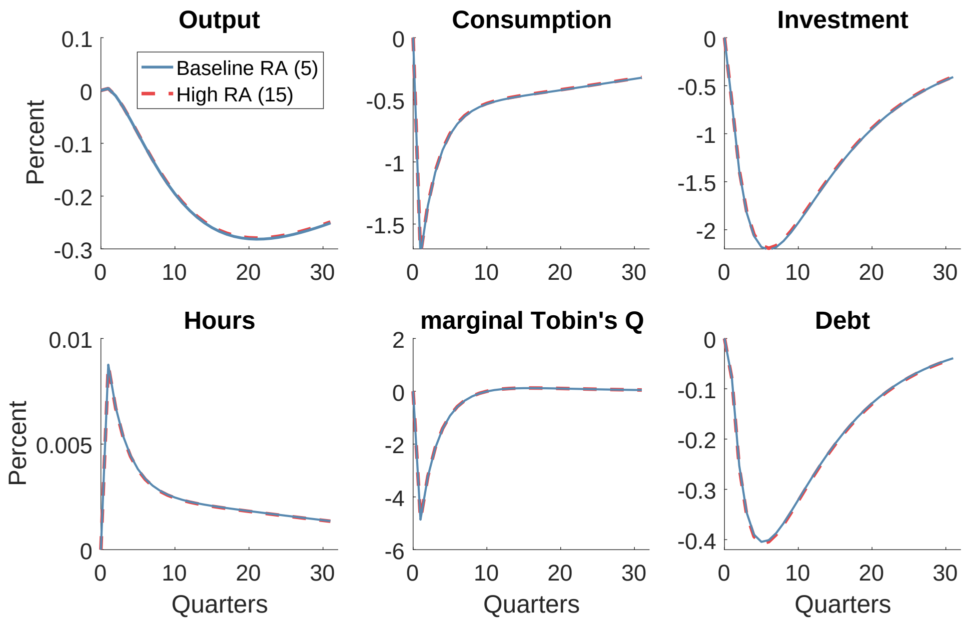


FIGURE 3.7: **Impulse Response Function to a Volatility Shock Interest Rates – FGRU (2011) vs BP (2014)**

Impulse responses are for a one standard deviation shock to the conditional volatility in interest rate when the model is approximated up to third order. The IRFs must be interpreted as percentage deviations from the theoretical mean based on the third-order pruned state space of (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017).



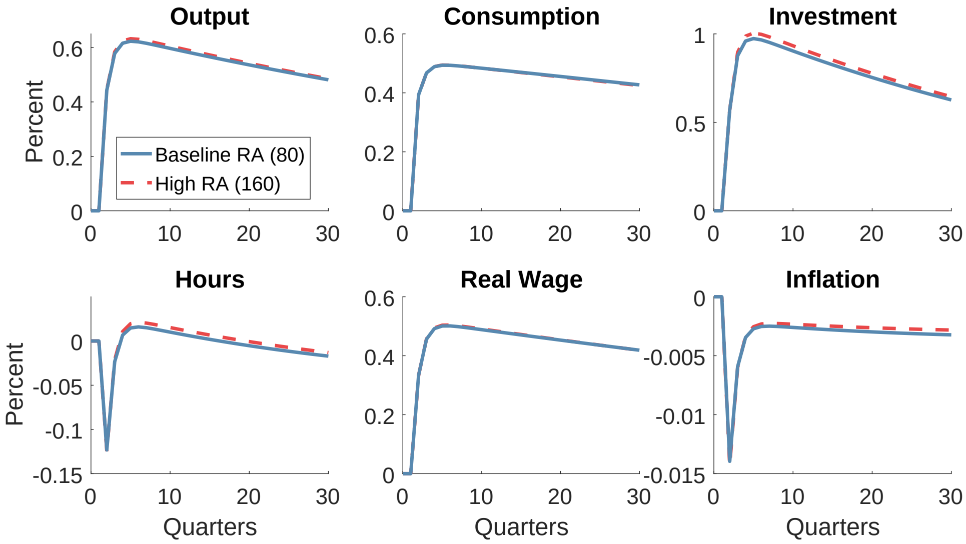
(a) Response to country spread level shock when cost of debt is low.



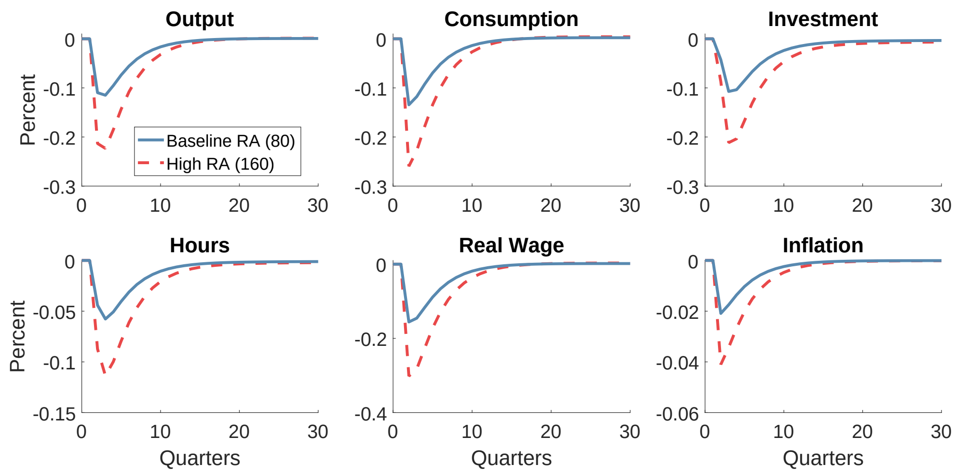
(b) Response to country spread level shock when cost of debt is high.

FIGURE 3.8: **Impulse Response Function to Country Spread Level Shock for different values of the holding cost of debt – FGRU (2011)**

: This figure plots the impulse responses for a one standard deviation shock to the country spread level shock when the (i) cost of debt $\Phi_D = 0.0001$, and (ii) cost of debt $\Phi_D = 0.1$. Impulse responses are for a one standard deviation shock when the model is approximated up to third order. To construct these responses, we set the exogenous shocks in the model to zero and iterate our third-order solution forward. After a sufficient number of periods, the endogenous variables of the model converge to a fixed point, which we denote the stochastic steady state. We then hit the economy with a one standard deviation country spread shock but assume the economy is hit by no further shocks.



(a) Response to level shock.



(b) Response to volatility shock.

FIGURE 3.9: **Impulse Response Function to Technology Shock – Basu and Bundick (2017)**

: This figure plots the impulse responses for a one standard deviation shock to the (i) level, and (ii) volatility of technology. Impulse responses are for a one standard deviation shock when the model is approximated up to third order. To construct these responses, we set the exogenous shocks in the model to zero and iterate our third-order solution forward. After a sufficient number of periods, the endogenous variables of the model converge to a fixed point, which we denote the stochastic steady state. We then hit the economy with a one standard deviation uncertainty shock but assume the economy is hit by no further shocks. We compute the impulse response as the percent deviation between the equilibrium responses and the pre-shock stochastic steady state.

3.7 Appendix

3.8 Perturbation Methods and Generalized Impulse Response Function

This appendix includes a more detailed discussion of the solution of the model and the explanation of how we compute the IRFs and the variance decomposition of the model. We refer the interest reader to the (Born and Pfeifer 2014) Appendix for an exhaustive discussion of the use of perturbation and pruning techniques, and their implications for simulation and IRFs.

To judge the importance of volatility shocks for business cycle moments, and their interaction with risk aversion, our analysis relies on perturbation methods. Perturbation methods were first extensively applied to dynamic stochastic models by (Judd 1998).

Our investigation faces a number of computational challenges. First, we are interested in the implications of a volatility increase while keeping the level of the variable constant. We thus have to consider a third-order Taylor expansion of the solution of the model, see e.g. (Schmitt-Grohe and Uribe 2004), (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Fernández-Villaverde, Guerrón-Quintana, and Rubio-Ramírez 2015). Indeed, in a first-order approximation, stochastic volatility would not even play a role, since the policy rules of the representative agent follow a certainty equivalence principle. In the second-order approximation, only the product of the two innovations appears in the policy function. Only in the third-order approximation do the innovations to volatility play a role by themselves.[25]

Second, higher order perturbation solutions tend to explode due to the accumulation of terms of increasing order. For example, in a second order approximated solution, the quadratic term at time t will be raised to the power of two in the quadratic term at $t + 1$, thus resulting in a quartic term, which will become a term of order 8 at $t + 2$ and so on. As a solution, we adopt the pruning scheme described in (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). This pruning scheme augments the state space to keep track of first to third order terms and uses the Kronecker product of the first and second order terms to compute the third order term. In contrast, (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Born and Pfeifer 2014) use a IRF-pruning scheme were all higher order terms are based on the first-order terms. Also,

[25] Recently, (de Groot 2016) shows that to risk-correct the constant term for the standard deviation of stochastic volatility innovations (a.k.a. vol of vol) a fourth (or sixth, depending on the functional form of the volatility process) order expansion is further needed. (de Groot 2016) shows that this risk-correction has important consequences for the bond and equity risk premia as well as for understanding the welfare cost of business cycle fluctuations.

whereas in (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Born and Pfeifer 2014) the IRF-pruning scheme differs from the scheme used for simulations, we use the same pruning for both IRFs and simulations.

Third, computing IRFs in a nonlinear environment is somewhat involved, since the IRFs are not invariant to rescaling and to the previous history of shocks. To circumvent this problem, we consider the generalized impulse response function (GIRF) proposed by (Koop, Pesaran, and Potter 1996). In particular, we follow (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011), (Born and Pfeifer 2014) and (Basu and Bundick 2017), and we start the IRFs at the ergodic mean in the absence of shocks (EMAS).

Fourth, to judge the importance of risk shocks for business cycle moments, it is instructive to consider a variance decomposition. However, computing a variance decomposition is complicated because, with a third-order approximation to the policy function and its associated nonlinear terms, we cannot neatly divide total variance among the shocks as we would do in the linear case. Thus, to gauge the relative importance of shocks we follow (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Born and Pfeifer 2014), and we simulate the model with only a subset of the shocks. In particular, we set the realizations of one or two of the shocks to zero and measure the volatility of the economy with the remaining shocks. The agents in the model still think that the shocks are distributed by the law of motion that we specified: it just happens that their realizations are zero in the simulation.

3.9 The BB (2017) Model: Additional Details

TABLE 3.7: **Parameters for BB (2017) and BB SV Productivity model economy**

This table reports the parameters used for the (Basu and Bundick 2017) model. These are the same values as in their original papers, and reported here for readers convenience. The high risk aversion scenario refers to a change in γ from 80 to 160, while leaving all other parameters unchanged.

	BB (2017)	BB SV Productivity (2017)
β	0.994	0.994
σ	80.000	80.000
ψ	0.950	0.950
η	0.350	0.350
α	0.333	0.333
δ	0.025	0.025
δ_1	0.030	0.030
δ_2	0.0003	0.0003
ϕ_K	2.090	10.000
ϕ_P	100.000	100.000
θ_u	6.000	6.000
ν	0.900	0.900
Π	1.005	1.005
ρ_π	1.500	1.500
ρ_y	0.200	0.200
ρ_a	0.936	0.936
σ_a	0.003	0.003
ρ_{σ^a}	0.742	
σ_{σ^a}	0.003	
ρ_z	0.988	0.988
σ_z	0.001	0.006
ρ_{σ^z}		0.742
σ_{σ^z}		0.006

3.10 The FGRU (2011) Model: Additional Details

3.10.1 Steady State, EMAS, and Ergodic Mean

This appendix compares the deterministic steady state, the ergodic mean in the absence of shocks (EMAS), and the ergodic mean for the (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) model. It is in fact well know that time-varying volatility moves the ergodic distribution of the endogenous variables of the model away from their deterministic steady state. The theoretical mean are based on the third-order pruned state space of (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). We use the term EMAS for (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011)'s concept of "[s]tarting from the ergodic mean and in the absence of shocks" (p. 10 in their technical appendix). The EMAS is the fixed point of the third order approximated policy functions in the absence of shocks. Sometimes, it is referred to as the "stochastic steady state" (**?**, e.g.)]Juillard:Kamenik:2005, because it is the point of the state space where, in absence of shocks in that period, agents would choose to remain although they are taking future volatility into account.

Table 3.8 compares steady state, ergodic mean, and EMAS in the original model of (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011). Results for the (Born and Pfeifer 2014) re-calibrated model after correcting for time aggregation are available upon request.

Table 3.8: **Ergodic Mean FGRU (2011)**

This table reports the steady-state values, the analytical ergodic means, and the simulated ergodic means in the absence of shocks for the FGRU (2011) model. We consider also the model with Epstein-Zin preferences when risk aversion equals the inverse of the elasticity of substitution.

		Analytical Ergodic Mean		Simulated EMAS	
	Steady State	FGRU	FGRU with EZ	FGRU	FGRU with EZ
D_t	4.00	2.09	2.09	2.55	2.55
K_t	3.29	3.31	3.31	3.29	3.29
C_t	0.88	0.91	0.91	0.89	0.89
H_t	0.00	0.00	0.00	0.00	0.00
Y_t	1.05	1.06	1.06	1.05	1.05
I_t	-0.98	-0.97	-0.97	-0.98	-0.98
NX_t^Y	0.03	0.01	0.01	0.02	0.02
CA_t	0.00	0.00	0.00	0.00	0.00

Table 3.9: **Parameters for FGRU (2011) model economy**

This table reports the parameters used for the (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Born and Pfeifer 2014) models. These are the same values as in their original papers, and reported here for readers convenience. The high risk aversion scenario refers to a change in γ from 5 to 15, while leaving all other parameters unchanged.

	FGRU (2011)	BP (2014)
ψ	5.0000	5.0000
η	1000.0000	1000.0000
γ	5.0000	5.0000
β	0.9804	0.9804
δ	0.0140	1.0560
ϕ	0.0006	0.0010
α	0.3200	0.3200
Φ_D	0.001	0.0006
$\bar{D}$	18.8016	4.0000
φ	47.8376	95.0000
r	0.02	0.02
ρ_x	0.9500	0.9500
σ_x	-3.2168	-4.1997
ρ_r	0.9700	0.9700
σ_r	-5.7100	-5.7100
ρ_{σ_r}	0.9400	0.9400
η_r	0.4600	0.4600
ρ_{tb}	0.9500	0.9500
$\rho_{\sigma_{tb}}$	-8.0600	-8.0600
σ_{tb}	0.9400	0.9400
η_{tb}	0.1300	0.1300

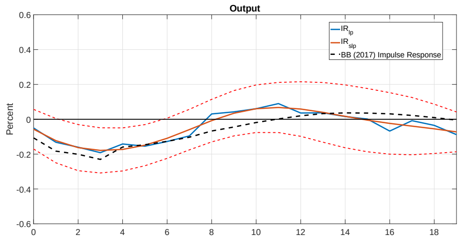
3.10.2 Time Aggregation: Moments, IRFs and Variance Decomposition

(Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) set up their model in monthly terms, but report results at quarterly frequency.We follow their approach, and we aggregate monthly output, consumption, investment to quarterly frequency by summing up monthly percentage deviations. The only exceptions are Figure 3.7 and Table 3.4 where we follow (Born and Pfeifer 2014) and we aggregate by averaging percentage deviations of monthly flow variables.

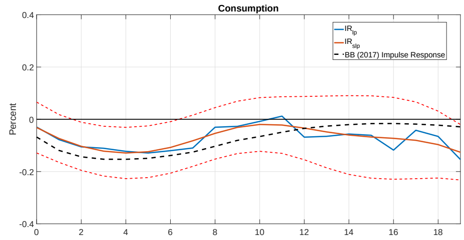
For the moment computations, the percentage deviations are from the deterministic steady state. Following (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Born and Pfeifer 2014), the quarterly variables are HP-filtered before using them to compute the moments.

The variance decomposition in Tables 3.3, 3.4 and 3.5 are obtained as follows. We simulate the model, starting from the ergodic mean, for 96 periods. We hit the equilibrium system with a subset of the shocks. As we mentioned in the main text as well as in the next section, since the data come in quarterly frequency, we build quarters of data from the model-simulated variables, and we H-P filter them. The simulations are always restarted at this point after 96 periods and there is no burn-in. We repeat this exercise 200 times to obtain the mean of the moments over the 200 simulations. Table 3.10 check the stability of our simulations.

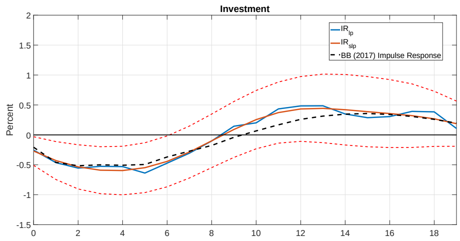
For the impulse response functions in Figure 3.11 the percentage deviations are from the theoretical mean based on the third-order pruned state space of (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). In particular, we compute GIRFs at the true ergodic mean using the methods proposed in (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). However, the analytical expression for the ergodic mean is available only for the third-order (or lower) pruned state space described in (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). Thus in the second and third columns in Figure 3.11 we compute the IRFs at the EMAS. In particular, we first simulate the model, starting from the ergodic mean (obtained analytically using a third-order pruned state space), for 2,096 periods. We disregard the first 2,000 periods as a burn-in and use the last 96 periods to compute the IRFs. In period 2,001 we set the realization of one of the shocks (productivity, the country spreads and its volatility) to one. We repeat this exercise 200 times to obtain the mean of the IRFs over the 200 simulations. As already mentioned, since the data come in quarterly frequency, we build quarters of data from the model-simulated monthly IRFs.



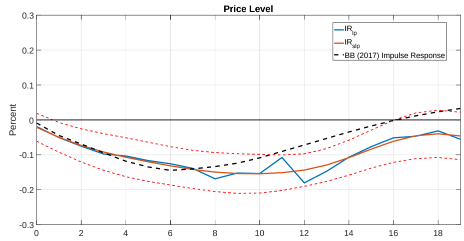
(a) Output.



(b) Consumption.



(c) Investment.



(d) Inflation.

FIGURE 3.10: **IR to a uncertainty shock**:
This figure plots the empirical impulse responses to uncertainty shock. We measure uncertainty using the VXO. The IR of GDP (top), consumption, investment, and inflation (bottom) to a volatility shock are estimated using LP (blue line) and SLP (red line). The black dashed line is the original response in Basu−Bundick (2017). The dashed lines denote the 68% confidence interval.

3.10.3 Local Projection in Basu - Bundick (2017)

In this section we check whether the linear (i.e. $\beta_{1,h} = 0$, in Eq. (1) in the text) LP (and SLP) methodology delivers similar results to the original specification in BB (2017), which is instead based on a VAR. To this end, Figure 3.10 displays the original VAR-based response of BB (2017) overlaid with the responses from our LP and SLP estimation. The figure shows that our methodology replicates in a nonparametric setting the findings of BB (2017) such that higher uncertainty causes declines in output, consumption, investment, and inflation.

3.10.4 Robustness

In the interest of space we run a battery of robustness tests for the FGRU (2011) economy. Analogous results for the BB (2017) economy are available upon request.

Simulation Table 3.10 checks the stability of our simulations. In particular it shows that our results are robust to an increase in the number of replications, and to removing pruning from the simulations.

TABLE 3.10: **Variance Decomposition FGRU (2011) - Robustness Tests**

This table reports the variance decomposition for the different structural shocks in the model of FGRU (2011) with stochastic volatility. First column: 200 simulations of the model; second column: TFP shocks only; third column: without volatility shocks to spread and T-bill rate; fourth column: without TFP shocks; fifth column: only level shocks to the spread and the T-bill rate; sixth column: only shocks to the volatility of spread and the T-bill rate.

	(1)	(2)	(3)	(4)	(5)	(6)
					Interest Rate	
	All Shocks	TFP only	w/o volatility	w/o TFP	Level only	Volatility only
	Panel A: $\gamma = 15$, Pruning, 1000 Replications					
σ_Y	5.29	5.14	5.18	1.07	0.58	0.31
σ_C	7.60	2.81	4.57	7.00	3.63	1.52
σ_I	20.81	5.55	12.13	20.01	10.89	6.01
	Panel B: $\gamma = 15$, No Pruning, 200 Replications					
σ_Y	5.22	5.01	5.07	1.01	0.58	0.29
σ_C	7.18	2.75	4.46	6.57	3.60	1.46
σ_I	19.01	5.43	11.97	18.11	10.63	5.74

Stochastic Volatility and Perturbation Solution To compute impulse response functions we have so far relied on a pruned state-space system for non-linear DSGE models when the model is approximated up to third order, see (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). Moreover, we have followed (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) and (Born and Pfeifer 2014) so that the IRFs we reported so far must be interpreted as deviations from the ergodic mean in absence of shocks, EMAS.

In Figure 3.11 we investigate the effects of pruning and the order of approximation on our results.

The first column shows the IRFs obtained when we use the analytical expressions for the generalized impulse response function (GIRF) derived in (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017) for a model that is pruned and approximated up to third order. These IRFs must be interpreted as the percentage deviations from the theoretical mean based on the third-order pruned state space of (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). The second column in Figure 3.11 shows GIRF

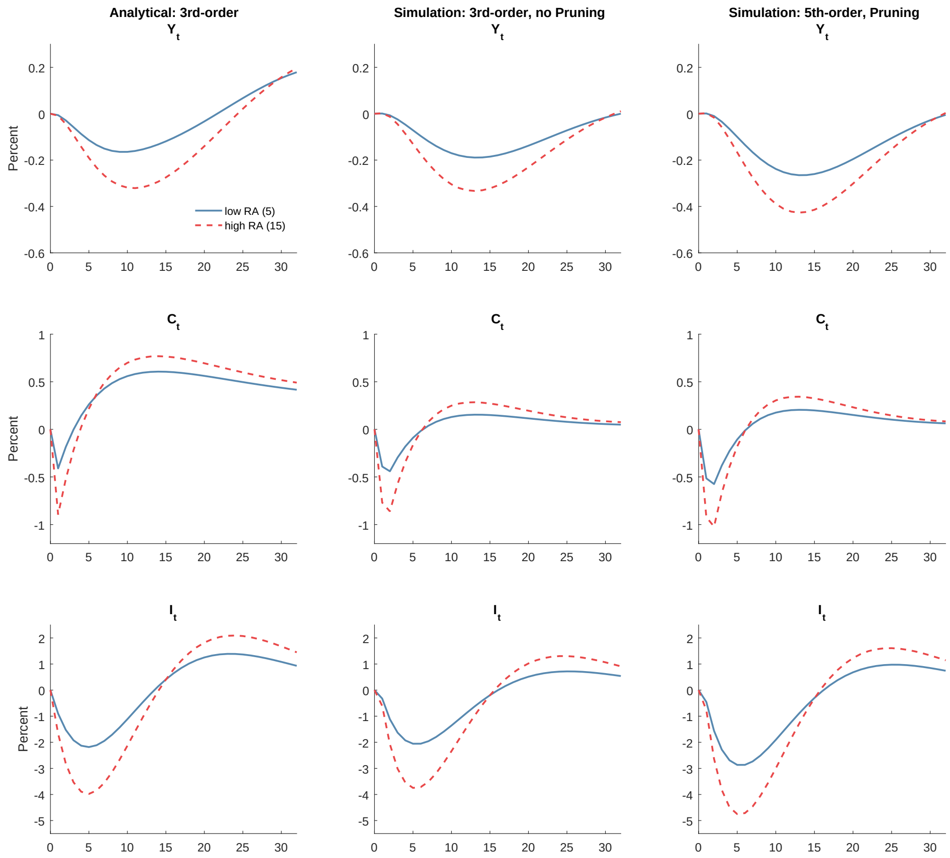


FIGURE 3.11: **Impulse Responses to a Volatility Shock in Interest Rates – FGRU (2011)**:
Impulse responses are for a one standard deviation shock when the model is approximated up to third order (first and second columns) and to the fifth order (last column). The IRFs in the first column must be interpreted as percentage deviations from the theoretical mean based on the third-order pruned state space of (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). The IRFs in the second to third column must be interpreted as percentage deviations from the ergodic mean in the absence of shocks (EMAS).

when the system has not been pruned. Comparing these impulse responses with those in Figure 3.6, it is clear that our results are not affected by pruning, nor by choosing EMAS or ergodic mean as the initial condition.

The third column in Figure 3.11 investigates how our results are affected by adopting a fifth-order (rather than a third-order) solution for the decision rules. We rely on the approach developed by (Fernandez-Villaverde and Levintal 2016) to overcome the computational challenges associated with higher than third-order approximation. The figure shows that fourth- and fifth-order terms are not important for the (Fernández-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Uribe 2011) calibration. Clearly, there might exist parameter values for which these orders are relevant.

Stochastic Volatility: Alternative Functional Forms Figure 3.12 shows how our results change depending on the functional form used for the stochastic volatility process. This analysis is important because the finance and macro literature have largely specified stochastic volatility processes differently. One can re-write Eq. (3.5) as follows:

$$\varepsilon_{r,t} = \rho_r \varepsilon_{r,t-1} + m(x_t) u_{r,t} \tag{3.9}$$

$$x_{t+1} = (1 - \rho_x)\, x + \rho_x x_t + \varepsilon_{x,t+1} \tag{3.10}$$

where now the innovations are scaled by $m\,(x_t)$, but we leave unspecified the functional form of $m\,(\cdot)$. The previous analysis focused on the functional form $m\,(\cdot) \equiv \exp\,(\cdot)$ and $x_t = \sigma_{r,t}$. This specification is commonly used in macroeconomics. In contrast, finance papers like to use $m\,(\cdot) \equiv \sqrt{(\cdot)}$ and $x_t = \sigma^2_{r,t}$.[26] Figure 3.12 shows that our results are not affected by either functional choice.

The ARCH model (Engle, 1982), and its various generalizations, provides another candidate to model time-varying volatility. In a GARCH model, the conditional volatility is a function of lagged volatility and lagged squared residuals of the level process. Thus, a GARCH process is not driven by separate innovations relative to the level process. On the contrary, the specifications we have analyzed so far admitted two innovations, one to the the country-spread and one to the volatility of the country spread, respectively. In unreported results, we analyze the IRFs to a real rate shock when stochastic volatility is modeled with GARCH, and we show that the risk aversion does not affect macro dynamics when the time-varying volatility has no separate innovations relative to the level process.

[26]The benefit of the $m\,(\cdot) \equiv \sqrt{(\cdot)}$ specification is that the stochastic process is still conditionally normal and can be exploited to generate a conditionally log-normal linear approximation that accounts for risk as in Campbell and Shiller (1988). The drawback of this functional form is that it is possible to get a negative standard deviation. The functional form $m\,(\cdot) \equiv \exp\,(\cdot)$ ensures the standard deviation remains strictly positive but, as pointed out by (Andreasen 2010), has the drawback that the level of the process does not have any moments.

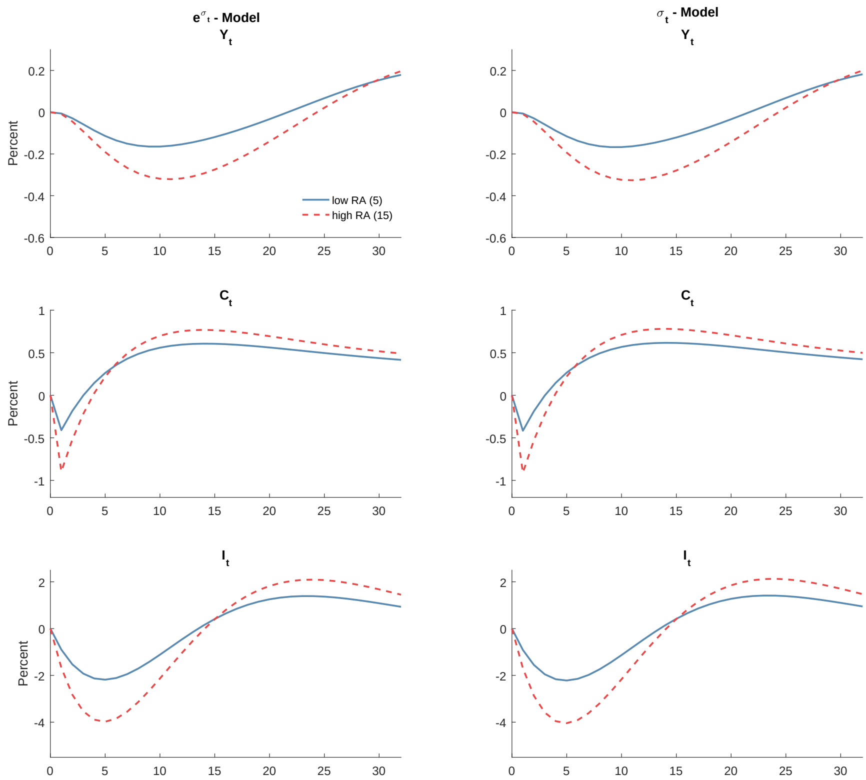


FIGURE 3.12: **Impulse Responses to a Volatility Shock Interest Rates – FGRU (2011)**:

IRFs are for a one standard deviation shock to the conditional volatility in interest rate when the model is approximated up to third order. The IRFs must be interpreted as percentage deviations from the theoretical mean based on the third-order pruned state space of (Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2017). The first column focuses on the specification that is commonly used in macroeconomics: the functional form is $m(x_t) \equiv \exp(x_t)$ with $x_t = \sigma_{r,t}$. The second column focuses the typical specification used in finance papers: the functional form is $m(x_t) \equiv \sqrt{(x_t)}$ and $x_t = \sigma^2_{r,t}$. In all cases, x_t follows an exogenous AR(1) process.

Bibliography

Abel, A. B. (1990): "Asset Pricing under Habit Formation and Catching up with the Joneses," *American Economic Review*, 80(2), 38–42.

Abel, A. B., and J. C. Eberly (1996): "Optimal Investment with Costly Reversibility," *Review of Economic Studies*, 63(4), 581–593.

Abrahams, M., T. Adrian, R. K. Crump, E. Moench, and R. Yu (2016): "Decomposing real and nominal yield curves," *Journal of Monetary Economics*, 84(C), 182–200.

Acemoglu, D., and D. H. Autor (2011): "Skills, tasks and technologies: Implications for employment and earnings," *Handbook of Labor Economics*, 4, 1043–1171.

Acemoglu, D., D. H. Autor, D. Dorn, G. H. Hanson, and B. Price (2016): "Import Competition and the Great U.S. Employment Sag of the 2000s," *jole*, 34, S141–S198.

Adrian, T., R. K. Crump, and E. Moench (2013): "Pricing the term structure with linear regressions," *Journal of Financial Economics*, 110(1), 110–138.

Ahearne, A. G., W. L. Griever, and F. E. Warnock (2004): "Information costs and home bias: an analysis of U.S. holdings of foreign equities," *Journal of Interantional Economics*, 62, 313–336.

Aiyagari, S. R., L. J. Christiano, and M. Eichenbaum (1992): "The Output, Employment, and Interest Rate Effects of Government Consumption.," *Journal of Monetary Economics*, 30(1), 73–86.

Amiti, M., M. Dai, R. C. Feenstra, and J. Romalis (2016): "How Did China's WTO Entry Benefit US Consumers," Working Paper.

Amiti, M., and S.-J. Wei (2009): "Service Offshoring and Productivity: Evidence from the US," *The World Economy*, 32, 203–220.

ANDREASEN, M. (2012): "On the Effects of Rare Disasters and Uncertainty Shocks for Risk Premia in Non-Linear DSGE Models," *Review of Economic Dynamics*, 15(3), 295–316.

ANDREASEN, M. M. (2010): "Stochastic volatility and {DSGE} models," *Economics Letters*, 108(1), 7 – 9.

ANDREASEN, M. M., J. FERNÁNDEZ-VILLAVERDE, AND J. F. RUBIO-RAMÍREZ (2017): "The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications," *The Review of Economics Studies*, 28(4), 755–775.

ANDREASEN, M. M., AND K. JORGENSEN (2016): "The Importance of Timing Attitudes in Consumption-Based Asset Pricing Models," Creates working papers, CREATES.

ANDREASEN, M. M., AND P. ZABCZYK (2015): "Efficient bond price approximations in non-linear equilibrium-based term structure models," *Studies in Nonlinear Dynamics & Econometrics*, 19(1), 1–33.

ANG, A., AND M. PIAZZESI (2003): "A No-arbitrage Vector Autoregression of Term Structure Dynamics with Macroeconomic and Latent Variables.," *Journal of Monetary Economics*, 50, 745–787.

ANTRAS, P. (2015): *Global Production: Firms, Contracts, and Trade Structure*. Princeton University Press, 5 edn.

ANTRAS, P., T. C. FORT, AND F. TINTELNOT (2016): "The Margins of Global Sourcing: Theory and Evidence from U.S. Firms," Working Paper.

ANTRAS, P., AND E. HELPMAN (2004): "Global Sourcing," *Journal of Political Economy*, 112, 552–580.

ARELLANO, C., Y. BAI, AND P. J. KEHOE (2016): "Financial Frictions and Fluctuations in Volatility," NBER Working Papers 22990, National Bureau of Economic Research, Inc.

ARUOBA, B., J. FERNÁNDEZ-VILLAVERDE, AND J. RUBIO-RAMÍREZ (2006): "Comparing Solution Methods for Dynamic Equilibrium Economies.," *Journal of Economic Dynamic and Control*, 30, 2477–2508.

ASCHAUER, D. A. (1985): "Fiscal Policy and Aggregate Demand.," *American Economic Review*, 75(1), 117–127.

ATALAY, E., A. HORTAÇSU, AND C. SYVERSON (2013): "Vertical Integration and Input Flows," *American Economic Review*, 104, 1120–1148.

Auerbach, A., and Y. Gorodnichenko (2012a): "Fiscal Multipliers in Recession and Expansion," in *Fiscal Policy after the Financial Crisis*, pp. 63–98. National Bureau of Economic Research, Inc.

Auerbach, A. J., and Y. Gorodnichenko (2012b): "Measuring the Output Responses to Fiscal Policy," *American Economic Journal: Economic Policy*, 4(2), 1–27.

Autor, D. H., D. Dorn, and G. H. Hanson (2013): "The Cina Syndrome: Local Labor Market Effects of Import Competition in the United States," *American Economic Review*, 103, 2121–2168.

——— (2016): "The China Shock: Learning from Labor Market Adjustment to Large Changes in Trade," *Annual Review of Economics*, forthcoming.

Bachmann, R., J. H. Bai, M. Lee, and F. Zhang (2015): "The Welfare and Distributional Effects of Fiscal Uncertainty: a Quantitative Evaluation," *Working Paper*.

Bachmann, R., S. Elstner, and E. R. Sims (2013): "Uncertainty and Economic Activity: Evidence from Business Survey Data," *American Economic Journal: Macroeconomics*, 5(2), 217–49.

Bandi, F. M., and A. Tamoni (2017): "The horizon of systematic risk: a new beta representation," Working Paper.

Bansal, R., and A. Yaron (2004a): "Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles," *Journal of Finance*, 59, 1481–1509.

Bansal, R., and A. Yaron (2004b): "Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles.," *Journal of Finance*, 59(4), 1481–1509.

Barnichon, R., and C. Brownlees (2016): "Impulse Response Estimation By Smooth Local Projections," CEPR Discussion Papers 11726, C.E.P.R. Discussion Papers.

Barro, R. J. (1974): "Are Government Bonds Net Wealth?," *Journal of Political Economy*, 82(6), 1095–1117.

Barrot, J.-N., E. Loualiche, and J. Sauvagnat (2017): "The Globalization Risk Premium," Working Paper.

Basu, S., and B. Bundick (2017): "Uncertainty Shocks in a Model of Effective Demand.," *Econometrica*, 85(3), 937–958.

Bauer, M. D., and J. D. Hamilton (2017): "Robust Bond Risk Premia," *The Review of Financial Studies*, pp. –.

Baxter, M., and R. G. King (1993): "Fiscal Policy in General Equilibrium.," *American Economic Review*, 83(3), 315–334.

Beeler, J., and J. Y. Campbell (2012): "The Long-Run Risks Model and Aggregate Asset Prices: An Empirical Assessment," *Critical Finance Review*, 1(1), 141–182.

Belo, F., X. Lin, and S. Bazdresch (2014): "Labor hiring, investment and stock return predictability in the cross section," *Journal of Political Economy*, 122, 129–177.

Belo, F., X. Lin, J. Li, and X. Zhao (2015): "Labor-Force Heterogeneity and Asset Prices: the Importance of Skilled Labor," Working Paper.

Benigno, P. (2007): "Discussion of "Equilibrium Yields" by Monika Piazzesi and Martin Schneider," *NBER Macroeconomics Annual*, 21, 443–457.

Bernanke, B. S. (1983): "Irreversibility, Uncertainty, and Cyclical Investment*," *The Quarterly Journal of Economics*, 98(1), 85–106.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999): "The financial accelerator in a quantitative business cycle framework," in *Handbook of Macroeconomics*, ed. by J. B. Taylor, and M. Woodford, vol. 1 of *Handbook of Macroeconomics*, chap. 21, pp. 1341–1393. Elsevier.

Bernard, A. B., J. B. Jensen, J. Eaton, and S. Kortum (2003): "Plants and Productivity in International Trade," *American Economic Review*, 21, 105–130.

Bernard, A. B., J. B. Jensen, S. J. Redding, and P. K. Schott (2016): "Global Firms," NBER Working Paper No. 22727.

Bernard, A. B., J. B. Jensen, and P. K. Schott (2006a): "Survival of the Best Fit: Low Wage Competition and the (Uneven) Growth of Manufacturing Plants," *Journal of Interantional Economics*, 68, 219–237.

——— (2006b): "Trade Costs, Firms and Productivity," *Journal of Monetary Economics*, 53, 917–937.

Blinder, A. S. (2009): "How Many U.S. Jobs Might Be Offshorable," *World Economics*, 10, 41–78.

Bloom, N. (2009): "The Impact of Uncertainty Shocks," *Econometrica*, 77(3), 623–685.

Bloom, N., M. Draca, and J. Van Reenen (2015): "Trade Induced Technical Change: The Impact of Chinese Imports on Innovation, Diffusion and Productivity," *Review of Economic Studies*, pp. 1–33.

Born, B., and J. Pfeifer (2014): "Risk Matters: The Real Effects of Volatility Shocks: Comment," *American Economic Review*, 104(12), 4231–39.

Brainard, W. C., W. R. Nelson, and M. D. Shapiro (1991): "The Consumption Beta Explains Expected Returns at Long Horizons," Manuscript, Economics Department, Yale University.

Breeden, D. T., M. R. Gibbons, and R. H. Litzenberger (1989): "Empirical Tests of the Consumption-Oriented CAPM," *Journal of Finance*, 44, 231–62.

Bretscher, L., C. Julliard, and C. Rosa (2016): "Human Capital and International Portfolio Diversification: A Reappraisal," *Journal of Interantional Economics*, 99, 78–99.

Broda, C., and D. E. Weinstein (2006): "Globalization and the Gains From Variety," *Quarterly Journal of Economics*, 121, 541–585.

Bustamante, M. C., and A. Donangelo (2016): "Product market competition and industry returns," *Review of Financial Studies*, forthcoming.

Calvo, G. (1983): "Staggered Prices in a Utility Maximizing Framework.," *Journal of Monetary Economics*, 12, 383–398.

Campbell, J. Y. (1986): "Bond and Stock Returns in a Simple Exchange Model.," *Quarterly Journal of Economics*, 101, 785–840.

Campbell, J. Y. (1996): "Understanding Risk and Return," *Journal of Political Economy*, 104, 298–345.

Campbell, J. Y., and J. Cochrane (1999): "Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior," *Journal of Political Economy*, 107(2), 205–251.

Campbell, J. Y., C. Pflueger, and L. M. Viceira (2015): "Monetary Policy Drivers of Bond and Equity Risks," *Working Paper*.

Campbell, J. Y., and R. J. Shiller (1991): "Yield Spreads and Interest Rate Movements: A Bird's Eye View.," *The Review of Economic Studies*, 58(3), 495–514.

Campbell, J. Y., R. J. Shiller, and L. M. Viceira (2009): "Understanding Inflation-Indexed Bond Markets," *Brookings Papers on Economic Activity*, 40(1 (Spring), 79–138.

Carhart, M. M. (1997): "On persistence in mutual fund performance," *Journal of Finance*, 52, 57–82.

Chan, Y. L., and L. Kogan (2002): "Catching Up with the Jones: Heterogeneous Preferences and the Dynamics of Asset Prices," *Journal of Political Economy*, 110(6), 1255–1285.

Chaney, T. (2008): "Distorted Gravity: The Intensive and Extensive Margins of International Trade," *American Economic Review*, 98, 1707–1721.

Chen, C., and C. Steinwender (2016): "Import Competition, Heterogenous Preferences of Managers and Productivity," Working Paper.

Chernov, M., and P. Mueller (2012): "The term structure of inflation expectations," *Journal of Financial Economics*, 106(2), 367–394.

Christiano, L. J., M. Eichenbaum, and S. Rebelo (2011): "When is the Government Spending Multiplier Large?," *Journal of Political Economy*, 119(1), 78–121.

Christiano, L. J., R. Motto, and M. Rostagno (2014): "Risk Shocks," *American Economic Review*, 104(1), 27–65.

Cieslak, A., and P. Povala (2015): "Expected Returns in Treasury Bonds," *Review of Financial Studies*, 28(10), 2859–2901.

Clarida, R., J. Gali, and M. Gertler (1999): "The Science of Monetary Policy: A New Keynesian Perspective.," *Journal of Economic Literature*, 37, 1661–1707.

Clarida, R., J. Galí, and M. Gertler (2000): "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *The Quarterly Journal of Economics*, 115(1), 147–180.

Cochrane, J. (2008): "Comments on Bond supply and excess bond returns by Robin Greenwood and Dimitri Vayanos," Unpublished notes, University of Chicago.

Cochrane, J. H. (1996): "A Cross-Sectional Test of an Investment-Based Asset Pricing Model," *Journal of Political Economy*, 104, 572–621.

Cochrane, J. H. (2001): "Long-Term Debt and Optimal Policy in the Fiscal Thoery of the Price Level," *Econometrica*, 69(1), 69–116.

Cochrane, J. H., and M. Piazzesi (2005): "Bond Risk Premia.," *American Economic Review*, 95(1), 138–160.

Coeurdacier, N., and H. Rey (2012): "Home Bias in Open Economy Financial Macroecnomics," *Journal of Economic Literature*, 51, 63–115.

Cogley, T., and T. J. Sargent (2005): "Drifts and Volatilities: Monetary Policies and Outcomes in the Post WWII US," *Review of Economic Dynamics*, 8(2), 262–302.

CONSTANTINIDES, G. M. (1990): "Habit Formation: A Resolution of the Equity Premium Puzzle," *Journal of Political Economy*, 98(3), 519–543.

CORHAY, A., H. KUNG, AND L. SCHMID (2017): "Competition, markups, and predictable returns," Working Paper.

COVAL, J. D., AND T. J. MOSKOWITZ (1999): "Home Bias at Home: Local Equity Preference in Domsetic Portfolios," *Journal of Finance*, 54, 2045–2073.

CROCE, M. M., H. KUNG, T. T. NGUYEN, AND L. SCHMID (2012): "Fiscal Policies and Asset Prices," *Review of Financial Studies*, 25(9), 2635–2672.

DAI, Q., AND T. PHILIPPON (2005): "Fiscal Policy and the Term Structure of Interest Rates.," *Working Paper.*

DANTHINE, J.-P., AND J. B. DONALDSON (2002): "Labour Relations and Asset Returns," *Review of Economic Studies*, 69, 41–64.

DASGUPTA, S., T. H. NOE, AND Z. WANG (2011): "Where Did All the Dollars Go? The Effect of Cash Flows on Capital and Asset Structure," *Journal of Quantitative Analysis*, 46, 1259–1294.

DAVID, A., AND P. VERONESI (2013): "What Ties Return Volatilities to Price Valuations and Fundamentals?," *Journal of Political Economy*, 121(4), 682–746.

DE GROOT, O. (2016): "What order? Perturbation methods for stochastic volatility asset pricing and business cycle models," Discussion Paper Series, Department of Economics 201611, Department of Economics, University of St. Andrews.

DEL NEGRO, M., F. SCHORFHEIDE, F. SMETS, AND R. WOUTERS (2007): "On the Fit and Forecasting Performance of New Keynesian Models," *Journal of Business and Economic Statistics,*, 25(2), 586–606.

DIXIT, A., AND R. PINDYCK (1994): *Investment under Uncertainty.* Princeton University Press, 1 edn.

DIXIT, A. K., AND J. E. STIGLITZ (1977): "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67, 297–308.

DONANGELO, A. (2014): "Labor Mobility: Implications for Asset Pricing," *Journal of Finance*, 68, 1321–1346.

DONANGELO, A., F. GOURIO, M. KEHRIG, AND M. PALACIOS (2016): "The Cross-Section of Labor Leverage and Equity Returns," Working Paper.

Dumas, B. (1989): "Two-Person Dynamic Equilibrium in the Capital Market," *Review of Financial Studies*, 2(2), 157–188.

Ebenstein, A., A. Harrison, M. McMillan, and S. Phillips (2014): "Why are American Workers Getting Poorer? Estimating the Impact of Trade and Offshoring Using the Current Population Surveys," *Review of Economics and Statistics*, 96, 581–595.

Eisfeldt, A. L., and D. Papanikolaou (2013): "Organization capital and the cross-section of expected returns," *Journal of Finance*, 68, 1365–1406.

Epstein, L., and S. E. Zin (1989): "Substitution, Risk Aversion and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework.," *Econometrica*, 57, 937–969.

Fama, E. F., and K. R. French (1988): "Permanent and Temporary Components of Stock Prices," *Journal of Political Economy*, 96, 246–273.

——— (1992): "The cross-section of expected stock returns," *Journal of Finance*, 47, 427–465.

——— (1993): "Common risk factors in the returns on stocks and bonds," *Journal of Financial Economics*, 33, 3–56.

——— (1997): "Industry costs of equity," *Journal of Financial Economics*, 43, 153–193.

——— (2015): "A five-factor asset pricing model," *Journal of Financial Economics*, 116, 1–22.

Fan, J. P., S. Titman, and G. Twite (2012): "An international comparison of capital structure and debt maturity choices," *Journal of Quantitative Analysis*, 47, 23–56.

Favilukis, J., and X. Lin (2016): "Wage Rigidity: A Quantitative Solution to Several Asset Pricing Puzzles," *Review of Financial Studies*, 29, 148–192.

Fernández-Villaverde, J., P. Guerrón-Quintana, K. Kuester, and J. Rubio-Ramírez (2015): "Fiscal Volatility Shocks and Economic Activity," *American Economic Review*, 105(11), 3352–84.

Fernández-Villaverde, J., P. Guerrón-Quintana, and J. F. Rubio-Ramírez (2010): "Fortune or Virtue: Time-Variant Volatilities Versus Parameter Drifting in U.S. Data," NBER Working Papers 15928, National Bureau of Economic Research, Inc.

Fernández-Villaverde, J., P. Guerrón-Quintana, and J. F. Rubio-Ramírez (2015): "Estimating dynamic equilibrium models with stochastic volatility," *Journal of Econometrics*, 185(1), 216–229.

Fernández-Villaverde, J., P. Guerron-Quintana, J. F. Rubio-Ramirez, and M. Uribe (2011): "Risk Matters: The Real Effects of Volatility Shocks," *American Economic Review*, 101(6), 2530–61.

Fernandez-Villaverde, J., and O. Levintal (2016): "Solution Methods for Models with Rare Disasters," NBER Working Papers 21997, National Bureau of Economic Research, Inc.

Fernández-Villaverde, J., and J. Rubio-Ramírez (2007): "Estimating Macroeconomic Models: A Likelihood Approach," *Review of Economic Studies*, 74, 1059–1087.

Fillat, J. L., and S. Garetto (2015): "Risk, Returns, and Multinational Production," *Quarterly Journal of Economics*, 130, 2027–2073.

Firpo, S., N. Fortin, and T. Lemieux (2013): "Occupational Tasks and Changes in the Wage Structure," Working Paper.

Fostel, A., and J. Geanakoplos (2012): "Why does bad news increase volatility and decrease leverage?," *Journal of Economic Theory*, 147(2), 501–525.

French, K. R., and J. M. Poterba (1991): "Investor Diversification and International Equitiy Markets," *American Economic Review*, 81, 222–226.

Frésard, L. (2010): "Financial Strength and Product Market Behavior: The Real Effects of Corporate Cash Holdings," *Journal of Finance*, 65, 61097–1122.

Frésard, L., and P. Valta (2016): "How Does Corporate Investment Respond to Increased Entry Threat?," *Review of Corporate Finance Studies*, 5, 1–35.

Gabaix, X., and D. Laibson (2002): "The 6D Bias and the Equity Premium Puzzle," in *N.B.E.R. Macroeconomics Annual 2001*, ed. by B. Bernanke, and K. Rogoff, pp. 257–312. Cambridge: MIT Press.

Gali, J., J. Valles, and J. D. Lopez-Salido (2007): "Understanding the Effects of Government Spending on Consumption.," *Journal of the European Economic Association*, 5(1), 227–270.

Gertler, M., and P. Karadi (2015): "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7(1), 44–76.

Ghironi, F., and M. Melitz (2005): "International Trade and Macroeconomic Dynamics with Heterogenous Firms," *Quarterly Journal of Economics*, 120, 865–915.

Gilchrist, S., J. W. Sim, and E. Zakrajsek (2014): "Uncertainty, Financial Frictions, and Investment Dynamics," NBER Working Papers 20038, National Bureau of Economic Research, Inc.

Glassman, D. A., and L. A. Riddick (2001): "What causes home asset bias and how should it be measured," *Journal of Empirical Finance*, 8, 35–54.

Gomes, J., U. Jermann, and L. Schmid (2017): "Sticky Leverage," *American Economic Review*, forhcoming.

Goos, M., and A. Manning (2007): "Lousy and Lovely Jobs: The Rising Polarization of Work in Britain," *Review of Economic Studies*, 89, 118–133.

Goos, M., A. Manning, and A. Salomons (2010): "Recent Changes in European Employment Structure: The Roles of Technological Change, Globalization and Institutions," Working Paper.

Gorodnichenko, Y., and S. Ng (2017): "Level and volatility factors in macroeconomic data," *Journal of Monetary Economics*, 91, 52 – 68.

Gourio, F. (2007): "Labor leverage, firms' heterogeneous sensitivities to the business cycle, and the cross-section of expected returns," Working Paper.

Gourio, F. (2012): "Disaster Risk and the Business Cycle.," *American Economic Review*, 102(6), 2734–2766.

——— (2013): "Credit Risk and Disaster Risk.," *American Economic Journal: Macroeconomics*, 5(3), 1–34.

Greenwood, R., and D. Vayanos (2014): "Bond Supply and Excess Bond Returns," *Review of Financial Studies*, 27(3), 663–713.

Gurkaynak, R. S., B. Sack, and J. H. Wright (2007): "The U.S. Treasury yield curve: 1961 to the present," *Journal of Monetary Economics*, 54(8), 2291–2304.

——— (2010): "The TIPS Yield Curve and Inflation Compensation," *American Economic Journal: Macroeconomics*, 2(1), 70–92.

Hansen, P. (2005): "A test for superior predictive ability," *Journal of Business and Economic Statistics*, 23, 365–380.

Harrison, A., and M. McMillan (2011): "Offshoring Jobs? Multinational and U.S. Manufacturing Employment," *Review of Economic Studies*, 93, 857–875.

Hassler, J. (1996): "Variations in risk and fluctuations in demand: A theoretical model," *Journal of Economic Dynamics and Control*, 20(6-7), 1115–1143.

HE, Z., B. KELLY, AND A. MANELA (2017): "Intermediary asset pricing: New evidence from many asset classes," *Journal of Financial Economics*, 126(1), 1–35.

HECKSCHER, E. (1919): "The Effect of Foreign Trade on the Distribution of Income," *Ekonomisk Tidskrift*, pp. 497–512.

HOMBERT, J., AND A. MATRAY (2017): "Can Innovation Help U.S. Manufacturing Firms Escape Import Competition from China?," Working Paper.

HSU, A., E. X. LI, AND F. PALOMINO (2015): "Real and Nominal Equilibrium Yield Curves: Wage Rigidities and Permanent Shocks.," *Working Paper*.

HUMMELS, D. (2007): "Transportation Costs and International Trade in the Second Era of Globalization," *Journal of Economic Perspectives*, 21, 131–154.

HUMMELS, D., R. JØRGENSEN, J. R. MUNCH, AND C. XIANG (2016): "The Wage Effects of Offshoring: Evidence from Danish Matched Worker-Firm Data," *American Economic Review*, 104, 1597–1629.

JENSEN, B. J. (2011): *Global Trade in Services: Fear, Facts, and Offshoring*. Peterson Institute For International Economics, 1 edn.

JENSEN, B. J., AND L. G. KLETZER (2010): "Measuring Tradeable Services and the Task Content of Offshorable Services Jobs," in *Labor in the New Economy*, ed. by K. Abraham, M. Harper, and J. Spletzer, pp. 309–335. University of Chicago Press.

JORDA, O. (2005): "Estimation and Inference of Impulse Responses by Local Projections," *American Economic Review*, 95(1), 161–182.

JUDD, J. P., AND G. RUDEBUSCH (1998): "Taylor's rule and the Fed, 1970-1997," *Economic Review*, pp. 3–16.

JUDD, K. L. (1998): "Numerical Methods in Economics.," *The MIT Press*, p. 1st Edition.

JUSTINIANO, A., G. PRIMICERI, AND A. TAMBALOTTI (2011): "Investment Shocks and the Relative Price of Investment," *Review of Economic Dynamics*, 14(1), 101–121.

JUSTINIANO, A., AND G. E. PRIMICERI (2008a): "The Time-Varying Volatility of Macroeconomic Fluctuations," *American Economic Review*, 98(3), 604–641.

——— (2008b): "The Time-Varying Volatility of Macroeconomic Fluctuations," *American Economic Review*, 98(3), 604–41.

KALTENBRUNNER, G., AND L. A. LOCHSTOER (2010): "Long-Run Risk Through Consumption Smoothing.," *Review of Financial Studies*, 23(8), 3190–3224.

Kandel, S., and R. F. Stambaugh (1991): "Asset returns and intertemporal preferences," *Journal of Monetary Economics*, 27(1), 39–71.

King, M., S. Ruggles, J. T. Alexander, S. Flood, K. Genadek, M. B. Schroeder, B. Trampe, and R. Vick (2010): "Integrated Public Use Microdata Series, Current Population Survey: Version 3.0," Minnesota Population Center, Minneapolis.

Koijen, R. S., J. H. van Binsbergen, J. F. Rubio-Ramírez, and J. Fernández-Villaverde (2008): "Likelihood Estimation of DSGE Models with Epstein-Zin Preferences," 2008 Meeting Papers 1099, National Bureau of Economic Research, Inc.

Koop, G., M. H. Pesaran, and S. M. Potter (1996): "Impulse response analysis in nonlinear multivariate models," *Journal of Econometrics*, 74(1), 119–147.

Kozicki, S., and P. A. Tinsley (2001): "Shifting endpoints in the term structure of interest rates," *Journal of Monetary Economics*, 47(3), 613–652.

Kuehn, L.-A., M. Simutin, and J. J. Wang (2017): "A labor capital asset pricing model," *Journal of Finance*.

Kung, H. (2015): "Macroeconomic Linkages between Monetary Policy and the Term Structure of Interest Rates," *Journal of Financial Economics*, 115(1), 42–57.

Leeper, E. M., M. Plante, and N. Traum (2010): "Dynamics of fiscal financing in the United States," *Journal of Econometrics*, 156(2), 304–321.

Lettau, M., and S. Ludvigson (2001): "Resurrecting the (C)CAPM: A Cross-Sectional Test When Risk Premia Are Time-Varying," *Journal of Political Economy*, 109, 1238–1287.

Levintal, O. (2017): "Fifth-Order Perturbation Solution to DSGE Models," *Journal of Economic Dynamics and Control*, pp. –.

Loualiche, E. (2015): "Asset Pricing with Entry and Imperfect Competition," Working Paper.

Lustig, H., N. Roussanov, and A. Verdelhan (2011): "Common Risk Factors in Currency Markets," *Review of Financial Studies*, 24, 3731–3777.

Lynch, A. (1996): "Decision Frequency and Synchronization across Agents: Implications for Aggregate Consumption and Equity Returns," *Journal of Finance*, 51, 1479–1497.

Magyari, I. (2017): "Firm Reorganization, Chinese Imports, and US Manufacturing Employment," Working Paper.

Malmendier, U., and G. Tate (2005): "CEO overconfidence and corporate investment," *Journal of Finance*, 65, 2661–2700.

Mankiw, G. N., and M. D. Shapiro (1986): "Risk and Return: Consumption Beta versus Market Beta," *Review of Economics and Statistics*, 68, 452–459.

Marshall, D., and N. Parekh (1999): "Can Costs of Consumption Adjustment Explain Asset Pricing Puzzles?," *Journal of Finance*, 54, 623–654.

Melitz, M. (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71, 1695–1725.

Minton, B. A., and C. Schrand (1999): "The impact of cash flow volatility on discretionary investment and the cost of debt and equity financing," *Journal of Financial Economics*, 54, 423–460.

Nakata, T. (2017): "Uncertainty at the Zero Lower Bound," *American Economic Journal: Macroeconomics*, 9(3), 186–221.

Nieuwerburgh, S. V., and L. Veldkamp (2009): "Information Immobility and the Home Bias Puzzle," *Journal of Finance*, 64, 1187–1215, 2009.

Novy-Marx, R. (2011): "Operating leverage," *Review of Finance*, 15, 103–134.

Ochoa, M. J. (2013): "Volatility, Labor Heterogeneity and Asset Prices," Working Paper.

Ohlin, B. (1933): *Interregional and International Trade*. Camebridge, MA: Harvard University Press.

Ortu, F., A. Tamoni, and C. Tebaldi (2013): "Long-Run Risk and the Persistence of Consumption Shocks," *Review of Financial Studies*, 26(11), 2876–2915.

Palomino, F. (2010): "Bond Risk Premia and Optimal Monetary Policy.," *Journal of Economic Dynamics*, Forthcoming.

Parker, J., and C. Julliard (2005): "Consumption Risk and the Cross-Section of Expected Returns," *Journal of Political Economy*, 113, 185–222.

Patton, A. J., and A. Timmermann (2010): "Monotonicity in asset returns: New tests with applications to the term structure, the CAPM, and portfolio sorts," *Journal of Financial Economics*, 98, 605–625.

Piazzesi, M., and M. Schneider (2007): "Equilibrium Yield Curves.," *NBER Macroeconomics Annual*, 21, 389–442.

Pierce, J., and P. Schott (2016): "The Surprisingly Swift Decline of U.S. Manufacturing Employment," *American Economic Review*, 106, 1632–1662.

Ramey, V. A., and M. D. Shapiro (1998): "Costly Capital Reallocation and the Effects of Government Spending.," *Carnegie-Rochester Conference Series on Public Policy*, 48, 145–194.

Ramey, V. A., and S. Zubairy (2018): "Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data," *Journal of Political Economy*, 0(0), 000–000.

Ramondo, N., V. Rappoport, and K. Ruhl (2016): "Intrafirm Trade and Vertical Fragmentation in U.S. Multinational Corporations," *Journal of Interantional Economics*, 98, 51–59.

Ricardo, D. (1821): *On the Principles of Political Economy and Taxation*. London: John Murray, 3rd edition edn.

Romano, J., and M. Wolf (2005): "Stepwise multiple testing as formalized data snooping," *Econometrica*, 73, 1237–1282.

Rudebusch, G. D., and E. T. Swanson (2008): "Examining the Bond Premium Puzzle with a DSGE Model.," *Journal of Monetary Economics*, 55, 111–126.

Rudebusch, G. D., and E. T. Swanson (2012): "The Bond Premium in a DSGE Model with Long-Run Real and Nominal Risks," *American Economic Journal: Macroeconomics*, 4(1), 105–43.

Sack, B. P., and R. Elsasser (2004): "Treasury inflation-indexed debt: a review of the U.S. experience," *Economic Policy Review*, (May), 47–63.

Santos, T., and P. Veronesi (2016): "Habits and Leverage," NBER Working Papers 22905, National Bureau of Economic Research, Inc.

Schmitt-Grohe, S., and M. Uribe (2004): "Solving dynamic general equilibrium models using a second-order approximation to the policy function," *Journal of Economic Dynamics and Control*, 28(4), 755–775.

Schott, P. (2008): "The Relative Sophistication of Chinese Exports," *Economic Policy*, 53, 5–49.

Segal, G. (2016): "A Tale of Two Volatilities: Sectoral Uncertainty, Growth, and Asset-Prices," Unc working papers, UNC.

Sims, C. A., J. Kim, S. Kim, and E. Schaumburg (2008): "Calculating and Using Second Order Accurate Solution of Discrete Time Dynamic Equilibrium Models," *Journal of Economic Dynamics and Control*, 32(3), 3397?–3414.

Sims, C. A., and T. Zha (2006): "Were There Regime Switches in U.S. Monetary Policy?," *American Economic Review*, 96(1), 54–81.

Sims, E. (2017): "The Zero Lower Bound," *Memorandum.*

Smets, F., and R. Wouters (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97(3), 586–606.

Swanson, E. T. (2012): "Risk Aversion and the Labor Margin in Dynamic Equilibrium Models.," *American Economic Review*, 102(4), 1663–1691.

Swanson, E. T., and J. C. Williams (2014): "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates," *American Economic Review*, 104(10), 3154–85.

Tallarini, T. D. (2000): "Risk-sensitive real business cycles," *Journal of Monetary Economics*, 45(3), 507–532.

Taylor, J. B. (1999): "A Historical Analysis of Monetary Policy Rules," in *Monetary Policy Rules*, NBER Chapters, pp. 319–348. National Bureau of Economic Research, Inc.

Tenreyro, S., and G. Thwaites (2016): "Pushing on a String: US Monetary Policy Is Less Powerful in Recessions," *American Economic Journal: Macroeconomics*, 8(4), 43–74.

Tuzel, S., and M. B. Zhang (2017): "Local risk, local factors, and asset prices," *Journal of Finance*, 72, 325–370.

Valta, P. (2012): "Competition and the Cost of Debt," *Journal of Financial Economics*, 105, 661–682.

van Binsbergen, J. H., J. Fernández-Villaverde, R. S. Koijen, and J. Rubio-Ramírez (2012): "The term structure of interest rates in a DSGE model with recursive preferences," *Journal of Monetary Economics*, 59(7), 634–648.

Van Nieuwerburgh, S., and L. Veldkamp (2006): "Learning asymmetries in real business cycles," *Journal of Monetary Economics*, 53(4), 753–772.

Verdelhan, A. (2017): "The Share of Sytematic Variation in Bilateral Exchange Rates," *Journal of Finance*, forhcoming.

VISSING-JORGENSEN, A. (2002): "Limited Asset Market Participation and the Elasticity of Intertemporal Substitution.," *Journal of Political Economy*, 110(4), 825–853.

WACHTER, J. (2006): "A Consumption-Based Model of the Term Structure of Interest Rates.," *Journal of Financial Economics*, 79, 365–399.

WEIL, P. (1990): "Nonexpected Utility in Macroeconomics.," *Quarterly Journal of Economics*, 105(1), 29–42.

XU, J. (2012): "Understanding China's growth: Past, present, and future," *Journal of Economic Perspectives*, 106, 427–446.

ZHANG, M. B. (2016): "Labor-Technology Substitution: Implications for Asset Pricing," Working Paper.