Three Aspects of Wage Inequality

by

Marco Leonardi

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Signature of Author ....
Department of Economics
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Certified by ....
Stephen J. Nickell
External member MPC Unit, Bank of England and Professor of Economics, LSE
Thesis Supervisor

Accepted by ....
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Abstract

This work presents three contributions to the study of wage inequality. The first is concerned with between-group wage inequality, the second and third with within-group or residual wage inequality. Chapter 1 reviews the literature on wage inequality. Chapter 2 explores the possibility that a shift in consumer demand might have played a role in the rise of wage inequality. If more skilled workers demand more skill-intensive goods, then an exogenous increase in relative skill supplies will also induce a shift in relative demand. This channel reduces the need to rely on technology and trade to explain the patterns in the data. I illustrate this mechanism with a simple two-sector general equilibrium model. The empirical part demonstrates that in the UK more educated and richer workers demand more skill-intensive goods. Calibration of the model suggests that this induced demand shift can explain 3% of the total relative demand shift in the UK between 1981 and 1997. The baseline model only explains between-industry shifts in skill upgrading and wage inequality, while empirically, most of these changes took place within industries. An extension of the model with different qualities of goods and labor can also explain some of the within-industry changes. Chapter 3 provides some empirical evidence and a theory of the relationship between within-group wage inequality and the increasing dispersion of capital/labor ratios across firms. In the empirical part, I document the increasing variance of capital/labor ratios across firms in the US labor market. I also show that the increase in the capital intensity variance across firms is associated with the increasing wage variance across workers. To explain this empirical fact, I adopt a search model where firms differ in their optimal capital choice. The decline of the relative price of equipment makes the firm distribution of capital/labor ratios more dispersed. In a frictional labor market this force generates wage dispersion among identical workers. Simple calibration of the model indicates that the dispersion of capital/labor ratios can explain up to one third of the total increase in residual wage inequality. Chapter 4 presents a study of earnings instability. I use the PSID to decompose the rise in wage inequality in a permanent and a transitory component. I consider separately job stayers and job changers. I find that the result of increasing earnings instability (increasing variance of the transitory component of earnings) holds in a sample of job changers but does not hold in a sample of job stayers. I interpret the evidence in a search and matching model with on-the-job search. The increasing variance of the transitory component of earnings is modeled as a mean-preserving spread of the distribution of productivity shocks. The mean-preserving spread induces on-the-job search on a wider range of productivity values and reduces the range of values where workers stay on the same job. As a result, the variance in the transitory part of earnings is increased for job changers. The effect on the wage variance of job stayers is ambiguous and depends on the composition of stayers between non-seekers and seekers who did not find a new job.

Thesis Supervisor: Stephen J. Nickell
Title: External member MPC Unit, Bank of England and Professor of Economics, LSE

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Chapter 1

The Literature on Wage Inequality

After a long period of relative quiet, the last decades have seen important changes in the wage structure of many OECD countries. During the 1970s, overall wage dispersion declined in most countries. The same thing happened to education and occupation wage differentials. The decline of wage inequality stopped in almost all countries during the 1980s and 1990s. Since the early 1980s, the US and UK took divergent paths and experienced sharp increases in wage inequality, both in terms of widening educational and occupational wage differentials and in terms of unexplained residual wage inequality. Other OECD countries witnessed a decrease in the employment rates of the less skilled. Both the increase in wage inequality and the decrease in employment among the less skilled occurred in the face of an expanding relative supply of educated workers. This fact indicates a common shift of labor demand against the less skilled while the differences among countries point to the important role of institutions in shaping the wage structure. Both theoretical and empirical research has been directed to understanding those changes in the labor market. The motivation is that a widening wage distribution causes increasing inequalities in income and consumption and is potentially disruptive for society as a whole.

This chapter reviews the existing literature on wage inequality, focusing on both the studies that are primarily concerned with the increase in educational and occupational wage differentials (between-group wage inequality) and on those that investigate residual wage inequality (within-group wage inequality). The literature review aims to place this thesis in the framework of the existing literature and to provide a quick reference to the main models cited in the three papers. There are already many surveys on wage inequality. This first chapter draws extensively from Acemoglu (2002) and Katz and Autor (1999).

1.1 Basic Framework and Stylized Facts

The distribution of wages can be decomposed into the difference in wages across education or occupation groups (between-group wage inequality) and residual wage inequality. The wage and employment changes of different education and occupation groups are due to the market forces of supply and demand and to institutions such as the unions and the minimum wage. Within-group wage inequality can also be attributed to both market forces that raised the returns to unobserved ability and to wage setting institutions.

Katz and Autor (1999) propose a supply, demand and institutions framework to analyze changes in the wage structure. The wage of an individual can be decomposed in the competitive wage given by the interaction of demand and supply and institutional or non-competitive factors that cause the wage to deviate from the competitive level. In the formulation of Katz and Autor (1999):

$$w_k = w_{kc} + r_k$$

w_k is the mean log wage of the demographic group k (education, age, sex). w_k is given by the sum of the competitive log wage and the rents. The competitive wage w_{kc} is determined by supply and demand for group k. The rents r_k can arise form non-competitive or institutional forces. For simplicity's sake let us consider three of them: interindustry wage differentials, union wage effects and the impact of the minimum wage or other non-competitive wage setting rules.

The mean log wage for group k can be written:

$$w_k = w_{kc} + \sum_j (I_{jk}\phi_{jk} + \lambda_k U_k + \delta_k M_k)$$

where $\phi_{jk} = \frac{N_{jk}}{N_k}$ is the share of workers of group k that work in industry j, I_{jk} is the interindustry wage differential of group k. U_k is the share of workers of group k that are unionized, λ_k is the union wage premium. M_k is the share of workers of group k that are affected by the minimum wage, δ_k is the effect of the minimum wage. The wage of each group k can change either because of market forces that affect its competitive wage or because of changes in average rents. Within-group wage dispersion can change because of supply and demand factors that affect the distribution of the competitive wage within the group or because of institutional changes that affect the distribution of rents within the group.

The stylized facts about wage inequality in the US and UK are the following:

- Wage inequality declined in most countries during the 70s.
- Wage inequality increased for both men and women in US and UK during the '80s and the '90s. The 90/10 percentile of weekly earnings rose by over 25% from 1979 to 1995

in the US, and it rose by a similar amount in the UK. In particular, wage returns to education, occupation and experience increased during the '80s and '90s.

- The same period saw a large increase in the supply of educated workers.
- Wage differences within groups of workers with the same observable characteristics increased.
- In the US, higher education workers have had increasing real wages and lower education workers stagnant or falling real wages. In continental Europe and the UK all education groups experienced increasing wages. The employment/population ratio decreased slightly for the higher educated workers and much more for the lower educated ones. Most of the decline is due to early retirement of older workers.
- Year-to-year earnings mobility is stable or slightly decreasing. Increased wage inequality is not matched by an increase in year-to-year mobility. The permanent (returns to observed and unobserved skills) and transitory component of individual earnings have increased by similar amounts.

The evolution of wage inequality in the US raises two important puzzles. The first puzzle concerns wage inequality between education groups. Although the relative supply of college educated workers has increased noticeably in the past 30 years, in the same period the ratio of average wages of college and high school graduates has increased by about 25%. The second puzzle concerns wage inequality within education and age groups. The rise of within-group wage inequality accounts for more than half of the total rise in wage inequality and occurred before the rise of between-group wage inequality. The rise of within-group wage inequality affected the temporary component of income, while between-group inequality mainly affected the permanent component of income.

While the second puzzle has been barely addressed so far, there is already a considerable literature on the rise of between-group wage inequality. The first part of this review discusses the theories and the evidence regarding the increase in between-group wage inequality. Two of the most popular explanations are based on supply and demand factors: skill-biased technical change and increasing trade with developing countries. The third explanation focuses on the effect of the change in institutions, in particular, on the decline of the unions. The second part of this review looks at some of the possible explanations of within-group wage inequality and its relationship with earnings instability.

1.2 The Theories on Between Group Wage Inequality

1.2.1 Skill Biased Technical Change

The predominant view is that technological change increases the relative demand of skilled workers by making them more productive. As long as the relative demand of skilled workers grows faster than the relative supply, technological change will contribute to the increase in wage inequality.

In a basic framework of Acemoglu (1998) there are two types of workers, high education H and low education L workers and they are imperfect substitutes in production. The technologies used by skilled and unskilled workers only improve their productivity, they never replace skilled or unskilled labor. The production function is a CES:

$$Y = [(A_l L)^\rho + (A_h H)^\rho]^{\frac{1}{\rho}}$$

The elasticity of substitution is $\sigma = \frac{1}{(1-\rho)}$. The workers are gross substitutes when $\sigma > 1$ and gross complements when $\sigma < 1$. If markets are competitive, relative labor demand is given by:

$$\omega = \frac{w_h}{w_l} = \left(\frac{A_h}{A_l}\right)^{\rho} \left(\frac{H}{L}\right)^{-(1-\rho)} \tag{1.1}$$

For given relative productivity $\frac{A_h}{A_l}$, the skill premium ω decreases when the relative supply of skilled workers $\frac{H}{L}$ increases. This is the usual substitution effect: when there are more skilled workers in the market they take over the jobs previously done by the unskilled but get paid lower wages. Note that in this model there is no unemployment. Nickell and Layard (1999) propose a version of this model with unemployment.

Skill-biased technical change increases the relative productivity of skilled workers: $\frac{A_h}{A_l}$. The skill premium ω increases as $\frac{A_h}{A_l}$ increases if workers are gross substitutes in production i.e. if $\sigma > 1$. When workers are substitutes, the demand for the more productive workers rises more than demand for the unproductive and relative wages change in favor of the more skilled. The opposite is true if $\sigma < 1$ and skilled and unskilled workers are complements in production. In that case an increase in A_h, the productivity of skilled workers, increases the demand both for skilled and unskilled workers. The most reliable estimates of σ indicate that $\sigma > 1$ and therefore that skilled and unskilled workers are substitutes in production. From now on, I consider only the case $\sigma > 1$.

From stylized facts two and three in the previous section we know that although in the '80s and '90s there was a large increase in the relative supply of educated workers $\frac{H}{L}$, the skill premium $\frac{w_h}{w_l}$ increased. Taking logs of the relative demand for skilled workers in equation 1.1:

$$\log \frac{w_h}{w_l} = \rho \log \frac{A_h}{A_l} - (1-\rho) \log \frac{H}{L}$$

This equation implies that skill-biased technical change, in the form of a rise in $\frac{A_h}{A_l}$, must have taken place to increase the relative demand of skilled workers and counterbalance the negative effect of the increasing supply $\frac{H}{L}$ on the wage premium.

Assuming different values for the elasticity of substitution $\sigma = \frac{1}{(1-\rho)}$, it is possible to get an idea of the rise in $\frac{A_h}{A_l}$ that is necessary to reconcile the pattern of changes of wage and employment of different groups. Autor, Katz and Krueger (1998) assume an elasticity of substitution $\sigma = 1.4$ and estimate that the relative productivity of college graduates with respect to workers with a high school diploma, $\frac{A_h}{A_l}$, must have increased at least threefold between 1980 and 1990 to accommodate for the changes in $\frac{w_h}{w_l}$ and $\frac{H}{L}$ that occurred during this period.

Steady Demand Shifts

Some theories in the literature on skill-biased technical change claim that relative productivity $\frac{A_h}{A_l}$ has been growing at a constant pace over time, some others argue that an acceleration of $\frac{A_h}{A_l}$ in the '80s is necessary to explain the data. The first set of theories attributes rising skill differentials to a decrease in the growth rate of the supply of skills and the increase in unskilled immigration. According to this view, a slowing supply of skills coupled with a steady growth in the demand of skilled workers could account for the observed rise in wage inequality. Katz and Murphy (1992) develop a simple way to explain relative wage and employment changes only on the basis of relative supply and demand shifts. Let the aggregate production function be:

$$y = (\alpha_1 L_1^{\alpha} + \alpha_2 L_2^{\alpha} + ..\alpha_n L_n^{\alpha})^{\frac{1}{\alpha}}$$

Different demographic groups (education, sex, age) are imperfect substitutes in production with elasticity of substitution $\sigma = \frac{1}{1-\alpha}$. With competitive labor markets, relative labor demand is given by:

$$\frac{w_i}{w_j} = \frac{\alpha_i}{\alpha_j}(\frac{L_i}{L_j})^{\alpha-1} \tag{1.2}$$

If we move along a fixed relative demand, factor quantities and wages of the same group must be negatively correlated:

$$\sum_{i=1}^{n} \Delta w_i \Delta L_i < 0 \tag{1.3}$$

With fixed relative demand, an increase in relative supply of each group must lead to a decline in its relative wage. Katz and Murphy (1992) consider 64 demographic groups according to age, sex and education and test whether inequality 1.3 is satisfied. The results indicate that inequality 1.3 is not satisfied during the '80s and demand shifts in favor of college graduates and women are necessary to explain the observed wage and employment patterns of these groups.

Katz and Murphy then test the hypothesis that the relative wage and employment of college graduates are consistent with a stable trend in demand changes in favor of that group. They take logs of equation 1.2:

$$\log \frac{w_h}{w_l} = \log \frac{\alpha_h}{\alpha_l} + (\alpha - 1) \log \frac{L_h}{L_l} \tag{1.4}$$

and substitute a time trend in the relative demand changes:

$$\log \frac{\alpha_h}{\alpha_l} = \gamma_0 + \gamma_1 time \tag{1.5}$$

Such a time trend might represent skill-biased technical changes at a constant pace or steady shifts in employment towards more skill-intensive sectors. The empirical estimates indicate that a stable trend in demand shifts does much better than the hypothesis of fixed demand at fitting the data. They conclude that a slowing supply of college graduates coupled with a steady growth in demand can account for most of the changes in the college premium during the last 40 years.

Shift Share Analysis

The demand shifts towards skilled labor are usually attributed to skill-biased technical change or trade liberalization. Demand shifts can take place within industry or between industry. The within-industry and between-industry decomposition of demand shifts (shift share analysis) has been extensively used to distinguish between the skill-biased technical change and the trade hypothesis (Berman, Bound and Machin 1998 and Machin and van Reenen 1998). Within-industry shifts may be due to skill-biased technological change or changes in the relative prices of non-labor inputs such as capital equipment. Between-industry shifts may be generated by shifts in product demand across industries either because of shifts in domestic tastes or because of shifts in international trade that reduce the share of output of low-skilled industries produced at home.

Over the past 50 years, there has been an important shift of employment from low-skilled manufacturing towards high-skilled services. However, between-industry demand shifts are not enough to explain the pattern of wage and employment of college graduates. If it were so, we would have observed the decline of employment rates of college graduates within industry given their increasing wage differential. We observe, instead, strong substitution of poorly educated workers with highly educated workers within industry.

Katz and Murphy propose a way to decompose the aggregate changes in labor demand in between-industry and within-industry factors. Consider a production function that only uses skilled and unskilled labor: $y_j = (l^\rho + h^\rho)^{\frac{1}{\rho}}$. The demand for skilled labor in sector j is:

$$h_j = C_w(w_l, w_h)y_j$$

where C is the cost function. Taking the total differential:

$$dh_j = y_j C_{ww}(w_l, w_h)dw + C_w(w_l, w_h)dy_j$$

Factor demands are homogeneous of degree zero, therefore $w'C_{ww}(w_l, w_h) = 0$. As a result, the percentage change in output is equal to the value weighted percentage change in inputs:

$$\frac{dy_j}{y_j} = \frac{w'dh_j}{w'h_j}$$

and

$$dh_j = h_j \frac{w'dh_j}{w'h_j} + y_j C_{ww}(w_l, w_h) dw \tag{1.6}$$

The first term in this expression represents the change in demand when relative wages are held fixed. The first term is estimated by using the shift share index:

$$\Delta H = \sum_s \left(\frac{E_{sk}}{E_k}\right)\left(\frac{\Delta E_s}{E_s}\right) \tag{1.7}$$

This index proxies for the percentage change in demand for skilled labor. It is a weighted average of percentage employment growth in each sector s and the weights are given by the employment distribution of skilled labor in each sector. When the sector s is occupation-industry cells, the index measures total change in demand, when s is industry only, the index measures between-industry demand shifts only. Within-industry changes are obtained as the difference between total demand shifts and between-industry shifts.

Shift share analysis has been used extensively in the wage inequality literature but is subject to a criticism. In index 1.7, relative wages are held fixed. Therefore, the index does not measure the effect on labor demand of the changing distribution of employment across sectors, for that part of the change that is due to the change in relative wages. Some growth in low-skilled industries might not reflect the true product demand shifts calculated at fixed factor prices but factor substitution in response to changing factor prices, i.e. the second term in the following equation:

$$dY = dY^* + Y_p dp = dY^* + Y_p C_w dw$$

In this equation dY^* is the true product demand shifts computed at fixed factor prices, p is the vector of output prices and $dp = C_w dw$ comes from the constant returns to scale assumption. Failing to take factor and product prices into account leads to overestimating the growth of low-skilled industries and underestimating the growth of high-skilled industries. The index can be written:

$$dH = C_w' dY = C_w' dY^* + C_w' Y_p C_w dw \tag{1.8}$$

The fact that skilled workers experienced rising relative wages implies a negative second term in equation 1.8. The result is that this index will underestimate the between-industry demand shift in favor of skilled workers.

Acceleration in Skill Biased Technical Change: The Evidence

There is some evidence that skill-biased technical change accelerated during the '80s and '90s. Autor, Katz and Krueger (1998) report employment and wage bill shares of college graduates from 1940 to 1990. According to their data, the supply of educated workers increased faster from 1970 to 1990 than from 1940 to 1970. Returns to college decreased in the '70s while they increased between the '70s and the '90s. A steady increase in the demand for skills is not consistent with these facts.

Acceleration in skill-biased technical change is usually attributed to the spread of computers in the labor market in the last twenty years. Berman, Bound and Griliches (1994), Autor, Katz and Krueger (1998) and Machin and van Reenen (1998) used simple shift-share analysis and showed that most of the increase in employment of educated workers is accounted by within-sector shifts. All industries substituted uneducated workers with college graduates, and the substitution was more rapid in those industries that use more computers. Although this evidence suggests complementarity between the use of computers and skilled workers, the causation is difficult to establish. More computerized industries may demand more skilled workers for many other reasons and not because of computers.

Another piece of evidence on the effect of computers on the labor market comes from Krueger (1993). He documents that workers that use computers have a substantial wage premium. Once again, as pointed out by DiNardo and Pischke (1997), it is difficult to establish the causation link between the use of computers and higher wages. The observed wage premium could be due to rewards for any unobservable skill and not necessarily for the use of computers.

Acceleration in Skill Biased Technical Change: The Theories

The theories based on accelerated technical change have to deal with two main criticisms. First, it is difficult to find direct evidence of faster technical change in the last thirty years. Secondly, this period was characterized by slow productivity growth at least until 1995. The proponents of acceleration of skill-biased technical change respond with two arguments. The first argument claims that measures of productivity growth are deceiving since they do not take into account improvements in the quality of products. The second argument claims that new technologies imply slower growth at the start since workers have to learn how to use them and only later do they improve productivity.

Krusell, Ohanian, Rios Rull and Violante (2000) propose a theory of acceleration in skill-biased technical change that builds on the evidence of complementarity between computers and skilled workers. Although the relative price of equipment capital has been declining for a long time, the rate of decline began to accelerate in the '70s with the advent of computers. In response to the decline in its price, firms have increased the use of equipment capital. Demand for skilled workers increased since skills are complementary to computers. Their theory can be summarized in the production function:

$$Y = K_s^{\alpha}[b_1 L^{\mu} + (1-b_1)(b_2 K_e^{\lambda} + (1-b_2)H^{\lambda})^{\frac{\mu}{\lambda}}]^{\frac{(1-\alpha)}{\mu}}$$

In this production function, equipment capital K_e is more complementary to skilled workers than unskilled workers as long as $\mu > \lambda$. If $\mu > \lambda$ then $\sigma_1 = \frac{1}{1-\mu} > \sigma_2 = \frac{1}{1-\lambda}$: σ_1 is the elasticity of substitution between unskilled labor and the combination of skilled labor and equipment capital. σ_2 is the elasticity of substitution between skilled workers and equipment capital. The relative demand for labor derived from this production function is:

$$\frac{w_h}{w_l} = \frac{(1-b_2)(1-b_1)H^{\lambda-1}(b_2 K_e^{\lambda} + (1-b_2)H^{\lambda})^{\frac{(\mu-\lambda)}{\lambda}}}{b_1 L^{\mu-1}}$$

This equation implies that the skill premium $\frac{w_h}{w_l}$ increases when K_e increases. In this model, the acceleration in the skill bias is due to the faster decline in the price of equipment capital during the past thirty years. The decline of the relative price of equipment capital led to higher investment and a higher skill premium.

The Market Size Effect Another model of accelerated technical change is proposed by Acemoglu (1998). In this model, skill-biased technical change is endogenous. The increase in supply of skilled workers lead to the development of skill-biased technologies, in the framework of equation 1.9 below, a shift from A_l to A_h. This happens since R&D activity is monopolistic in nature and technology producers make more profits the more workers use their new technology. The market size effect is captured in the equation:

$$\log \frac{A_h}{A_l} = \alpha + \beta time + \gamma \log \frac{H}{L}$$

Unlike equation 1.5 in the Katz and Murphy framework where skill-biased technical change $\frac{A_h}{A_l}$ follows a constant time trend, here skill-biased technical change accelerates because of an increase in the relative supply of skills $\frac{H}{L}$.

A simplified version of the model assumes that aggregate production-consumption requires two types of goods, one produced only by unskilled workers, the other only by skilled workers. The aggregate production function is:

$$Y = [(A_l L^{\beta})^{\rho} + \gamma(A_h H^{\beta})^{\rho}]^{\frac{1}{\rho}} \tag{1.9}$$

the relative prices of intermediate goods are given by:

$$\frac{p_h}{p_l} = \gamma \left(\frac{Y_h}{Y_l} \right)^{\rho - 1}$$

and relative wages by :

$$\frac{w_h}{w_l} = \frac{p_h}{p_l} \frac{A_h}{A_l} \left(\frac{H}{L} \right)^{\beta - 1}$$

The novelty of this model is that technology is endogenous and it is modelled as:

$$A_h = \int_0^1 q_h(i)\, x_h(i)^{1-\beta}\, di \qquad \text{and} \qquad A_l = \int_0^1 q_l(i)\, x_l(i)^{1-\beta}\, di$$

Technology in the skilled sector h uses different machines i with i that goes from 0 to 1. $x(i)$ is the quantity of each machine i and $q(i)$ is the top quality of machine i. In this framework, only the top quality of each machine i is used.

A new quality (or new technology) $q(i)$ is developed in monopoly regime. Monopolists set the price χ_i of a new technology taking demand $x(i)$ as given. The marginal cost of producing a new machine of quality $q(i)$ is increasing linearly in $q(i)$. As a result, technology A_h and A_l can be written:

$$A_h = p_h^{(1-\beta)/\beta} \int_0^1 q_h(i)\, di \qquad \text{and} \qquad A_l = p_l^{(1-\beta)/\beta} \int_0^1 q_l(i)\, di$$

Denote $Q_j = \int_0^1 q_j(i)\,di$ the aggregate productivity of machines used in sector $j = h, l$. We now have to establish only how monopolistic R&D sector decides $\frac{Q_h}{Q_l}$ i.e. how much to develop new technologies for the skilled sector rather than for the unskilled one. The value of owning the leading vintage of machine i in sector $j = h, l$ is:

$$rV_j(i) = \pi_j(i) - z_j(i)\,V_j(i)$$

where $\pi_j(i)$ is the flow rate of monopoly profit and $z_j(i)$ is the flow rate of new inventions. The free entry condition of new R&D firms assumes that the cost of producing a new quality $q_j(i)$ is B units of the final good: $V_j(i) = Bq_j(i)$ in both sectors $j = h, l$. Solving the model gives the direction of technical change:

$$\frac{z_h}{z_l} = f(\frac{H}{L}, \frac{p_h}{p_l}) \tag{1.10}$$

The direction of technical change is an increasing function of the relative prices of goods and the relative supply of workers. The price effect implies that technologies producing more expensive goods will be upgraded faster. The market size effect implies that the more workers use the technology, the faster the new technology will be developed. Solving the model in steady state implies that the discounted profits of developing a new quality machine in both sectors $j = h, l$ must be equal, therefore $z_h = z_l$. This, in turn, implies that $\frac{Q_h}{Q_l}$ and $\frac{A_h}{A_l}$ are increasing in $\frac{H}{L}$ and hence that skill bias in technology depends on the supply of skilled workers. The acceleration in skill-biased technologies in this model is due to the increase in the relative supply of skills $\frac{H}{L}$.

The Diffusion of a General Purpose Technology Another possibility is that skilled workers are more flexible and can adapt more easily to new technologies. In this case, periods of rapid technical change or technological revolutions favor the more skilled and increase the skill premium. Models of this type are Aghion and Howitt (1999), Caselli (1999), Galor and Moav (2000). Here I briefly illustrate Aghion and Howitt (1999). Their model focuses on the diffusion of General Purpose Technologies (GPT). A GPT is a technological breakthrough that affects the entire economy just like the Information Technology revolution. The diffusion of a new GPT consists of a wave of secondary innovations, each of which creates a new product or process in a particular sector. The crucial features of this type of model are:

- Experimentation and adoption of a new GPT requires skilled labor.
- The diffusion of a new GPT over time follows a logistic curve: it is slow at the start, then accelerates only to slow down again.

Formally the aggregate production function is:

$$y = \left[\int_0^1 (A_i x_i)^\alpha di \right]^{\frac{1}{\alpha}}$$

$A_i = 1$ in sectors where the old GPT is still used, and $A_i = \gamma > 1$ in sectors where the new GPT is used. x_i is the flow of intermediate good i used in production of the final good. As the production technology in the intermediate sector is assumed to be one-for-one with labor, x_i also denotes labor demand in sector i. Total labor force L is divided into skilled and unskilled. The old sectors with $A_i = 1$ are indifferent between skilled and unskilled labor, while the new sectors with $A_i = \gamma > 1$ require skilled labor only. Let us assume that the supply of skilled workers L_s is growing at a constant rate over time:

$$L_s(t) = L - (1 - s)Le^{-\beta t}$$

where s is the initial fraction of skilled workers and β is a parameter that measures the speed of skill acquisition. Denote n_2 the current fraction of new sectors. Let us assume that new sectors are such when they receive a template of the new GPT. Templates arrive at the Poisson rate:

$$\lambda(n_2) = \begin{pmatrix} \lambda_0 & \text{if} \quad n_2 < \overline{n} \\ \lambda_0 + \Delta & \text{if} \quad n_2 >= \overline{n} \end{pmatrix}$$

The threshold effect is due, for example, to strategic complementarities in cross-sector imitations or social learning. The evolution over time of the number of new sectors is given by a logistic curve, which accelerates at first and then slows down as n_2 approaches 1:

$$\frac{dn_2}{dt} = \lambda\,(n_2)\,(1 - n_2)$$

The transition process from the old to the new GPT has two phases. In the first phase (when t is low) the number of new sectors n_2 is too small to absorb the entire skilled labor force. This implies that some skilled workers have to work in the old sectors at the same wage as the unskilled. In the first phase of transition, the labor market is unsegmented and the wage rate is common to the skilled and the unskilled, $w_s = w_u = w$. w is determined by the market clearing condition:

$$L = (1 - n_2)x_o + n_2 x_n$$

where x_o denotes the demand for labor in old sectors and x_n the demand for labor in new sectors.

In the second phase, the number of new sectors n_2 is sufficiently large to absorb the entire skilled labor force. The labor market becomes segmented: skilled workers are employed only in the new sectors, unskilled workers only in the old sectors. The skilled wage w_s is determined by the market clearing condition:

$$L_s = n_2 x_n$$

and the unskilled wage w_u by the condition:

$$L - L_s = (1 - n_2)x_o$$

This model predicts that the skill premium $\frac{w_s}{w_u}$ first increases with the spread of the new GPT, but then goes down as the entire labor force becomes skilled and everybody ends up earning the same skilled wage.

Both the market size (Acemoglu) and the GPT (Aghion and Howitt) explanation of wage inequality are consistent with the time pattern of the US skill premium in the last thirty years. An increase in the supply of skilled workers is associated with a decrease in the skill premium in the early '70s, followed by a sharp increase in the '80s. This might be explained by a change in the direction of technical progress (Acemoglu) and/or an acceleration in the spread of a new GPT (Aghion and Howitt).

Both explanations of accelerated technical change have to be reconciled with two other pieces of evidence. The first piece of evidence is of historical nature and claims that previous increases in the supply of skilled workers (at the beginning of the century) were not followed by a widening in the wage distribution (Goldin and Katz 1999). The second piece of evidence concerns the productivity slowdown: although over the last thirty years there have been big increases in human capital investment and in R&D, the productivity growth rate has decreased over time.

The response to the first historical issue is that the first industrial revolution was characterized by skill-replacing technical change, while technological change in the last sixty years has been mostly skill-complementary. In the nineteenth century, skilled artisans were replaced by unskilled workers in the factory. Today, workers with computer skills substitute unskilled workers in production. From the market size point of view, it can be argued that it was the differential changes in supply of skilled and unskilled workers which promoted the development of skill-replacing rather than skill-complementary techniques. At the start of the century, the big increase in the unskilled labor force in the English cities increased the monopoly rents of technical innovations targeted at the unskilled and therefore promoted skill-replacing technical change (Acemoglu 2002).

All models of skill-biased technical change are at odds with the evidence of sluggish productivity growth during the last thirty years at least until 1995. It is probably true that increases in productivity due to the spread of computer technology are taking place mainly in the service sector where output and improvements in the quality of output is difficult to measure. However it is also documented that the productivity slowdown is common to all sectors, even those where there are very few doubts about measuring output and its quality. In response to this last critique, the literature invokes decreasing returns to R&D or the slow adjustment of workers and firms to the new technology. However it is certainly true that it is difficult to reconcile theories of accelerated technical change with the evidence of thirty years of slow productivity growth and stagnant average real wages.

1.2.2 The Effect of Trade on Wages

The Theory

skill-biased technical change and trade are the most popular explanations of the shifts in relative labor demand in favor of the skilled. The trade explanation is based on the Heckscher-Ohlin theory. Take two countries A and B with different endowments of skilled and unskilled labor. Developed country A is endowed with a lot of skilled labor H_A while underdeveloped country B is endowed with a lot of unskilled labor L_B. Therefore $\frac{H_A}{L_A} > \frac{H_B}{L_B}$. Assume, furthermore, that both goods are tradable and that both countries have access to the same technology A_h and A_l.

The utility function is a CES in both countries and is defined over two goods, the skill-intensive $y_h = A_h H$ and the low skill-intensive $y_l = A_l L$:

$$U = [(A_l L)^\rho + (A_h H)^\rho]^{\frac{1}{\rho}}$$

In a closed autharchic economy, the relative price of skill-intensive goods in the developed country A, $p^c = \frac{p_h}{p_l}$ is given by:

$$p^c = \frac{p_h}{p_l} = \left(\frac{A_h H_A}{A_l L_A}\right)^{\rho-1} \tag{1.11}$$

and the wage ratio by:

$$\omega^c = \frac{w_h}{w_l} = p^c \frac{A_h}{A_l} = \left(\frac{A_h}{A_l}\right)^\rho \left(\frac{H_A}{L_A}\right)^{\rho-1} \tag{1.12}$$

In an open economy setting, after trade liberalization, the final product markets are joined and there will be a single world relative price:

$$p^w = \left(\frac{A_h(H_A + H_B)}{A_l(L_A + L_B)}\right)^{\rho-1} > p^c \tag{1.13}$$

and therefore a single relative wage:

$$\omega^w > \omega^c \tag{1.14}$$

The Heckscher-Ohlin theory implies that in an open economy, each country will export the good whose factor of production is abundant. The developed country will specialize in skill-intensive products since skilled labor is relatively cheap. Trade will have a negative effect on unskilled labor in the developed country as long as imported goods are produced by employing unskilled workers and exported goods are very skill intensive. The assumption is that imported goods could have been produced at home using domestic unskilled labor.

The Evidence

The trade explanation of wage inequality runs counter to several empirical problems:

- Trade with developing countries is too small to explain such big changes in the wage structure.

- Trade would imply, according to equation 1.13, that the relative price of skill-intensive goods should rise in developed countries. But according to the empirical evidence, this does not seem to be true.

- An implication of trade is that labor in developed countries should be reallocated from low-skill to high-skill industries. However, many empirical studies have established that most of the demand shift from uneducated to educated workers occurred within-industry rather than between-industry. Furthermore, there has also been a rise in relative employment of skilled workers in the non-traded sectors.

- Finally, equation 1.14 implies that wage inequality should increase in developed countries and decrease in underdeveloped ones. This, again, does not seem to be the case.

I shall now briefly review the empirical methods used in the literature to evaluate the trade hypothesis. A common way of estimating the impact of trade as a source of relative demand shifts is factor content analysis. It consists in estimating the content of domestic unskilled labor embedded in imports and exports. The difference between the supplies of unskilled labor used in export and imports gives an estimate of the impact of trade on relative labor demand. Using the same notation of the shift share analysis of equation 1.7, the factor content of trade in year t can be written as the sum over all industries of unskilled labor embedded in net imports of each industry i:

$$L_t^k = \sum_i e_i^k E_{it} \left(\frac{I_{it}}{Y_{it}} \right)$$

where I_{it} is net imports in industry i in year t. Y_{it} is domestic output of industry i in year t. E_{it} is the share of total employment of industry i in year t. e_i^k is the proportion of workers of group k in industry i. To build a measure of relative demand shift simply take:

$$T_t^k = -\frac{L_t^k}{E^k} + \sum_i E_{it}\left(\frac{I_{it}}{Y_{it}}\right)$$

where the factor content of workers of group k in year t, L_t^k, is divided by the average share in employment of workers of group k in the base year, E^k. The second term is added so that the demand shift is expressed in relative terms and $\sum_k T_i^k E^k = 0$.

Studies of this kind such as those by Katz and Murphy (1992) and Berman, Bound and Griliches (1994) usually conclude that trade-induced changes in relative demand of educated workers are too small with respect to the big increase in the supply of educated workers of the past thirty years. The effect of increased trade is big only for female high-school dropouts who were traditionally employed in import competing industries such as textiles. And in this case, as Borjas, Freeman and Katz (1997) point out, immigration of unskilled workers from abroad also played a significant role in increasing the relative supply of the unskilled.

A second way of estimating the effect of trade on wages looks at the changes in the prices of final products. Trade with developing countries has the effect of depressing prices of the goods produced by unskilled workers and thus increasing wage inequality. The link between product prices and wages is given by the zero profit condition that equates prices to average costs:

$$p = B \times p + A \times w \tag{1.15}$$

where p is a $N \times 1$ vector of output and intermediate inputs prices, B is a $N \times N$ matrix of intermediate inputs requirements whose elements b_{ij} indicate the number of units of intermediate input i necessary to produce one unit of output j. w is a $M \times 1$ vector of factor prices and A is a $N \times M$ matrix of factor requirements. Differentiating this equation we obtain:

$$dp = \vartheta \times dw$$

where ϑ is a $N \times M$ matrix whose elements ϑ_{ij} indicate the share of factor i in the average cost paid to produce one unit of j. This equation relates changes in product prices to changes in factor prices and is called a mandated-wage equation. In regression form, this equation looks like:

$$dp_j = \alpha + \vartheta_{ij}\beta_i + \varepsilon_j$$

where dp_j is the change of product prices over some period of time for industry j. The estimates of β_i are interpreted as the mandated factor price changes i.e. the changes in factor costs that are necessary to keep the zero-profit condition 1.15 valid when product prices dp_j change.

Product price studies include those by Lawrence and Slaughter (1993), Sachs and Shatz (1994) and Krueger (1997). They first estimate whether relative prices of skill-intensive goods increased over time and then calculate the mandated wage change. The results vary according to the study. Most studies find no significant increase in the prices of skill-intensive goods over time. Only Krueger finds that relative prices of skill-intensive goods increased over time and calculates that mandated wage changes are roughly of the same magnitude. He concludes, however, that the increase in product prices is small and not sufficient to explain the large increase in the wage skill premium. A serious problem with the interpretation of product price studies is that the causation from international trade to domestic product prices is difficult to establish. Domestic product prices clearly depend on many different factors and it is difficult to directly relate changes in product prices to either changes in barriers to trade or transportation costs or changes in foreign tastes/technologies or endowments.

Another piece of evidence that runs counter to a trade-based explanation of the increase in wage inequality relies on the shift-share analysis of between- and within-industry shifts. The trade hypothesis implies a shift in relative demand between industries, from low skill intensive goods to high skill-intensive ones. Berman Bound and Griliches (1994), Autor, Katz and Krueger (1998) and Berman, Bound and Machin (1998) document that most of the rise in wage inequality can be accounted for by within-industry shifts of employment from uneducated to educated workers. All industries, even those in non-tradable sectors and those with very low skill intensity increased their demand of educated workers.

Although trade is unlikely to be the cause of the changes in the wage structure, it may have had an important role interacting with technical change. Acemoglu (2003) claims that trade induces skill-biased technical change. Trade liberalization increases the prices of skill-intensive goods as in equation 1.13, according to the usual Hecksher-Ohlin effect. In a model of endogenous technical change, development of skill-biased technologies depends on the relative prices of goods and the relative labor supplies as in equation 1.10. The price effect implies that developing technologies that produce more expensive goods is more profitable. Trade raises the prices of skill-intensive goods and in this way leads to skill-biased technical change.

This theory implies that the effect of trade in shaping the wage distribution may be much bigger than what is captured by factor content analysis. The second implication is that, if the major effect of trade is to promote skill-biased technical change, then within-industry shifts in relative labor demand are consistent with the trade explanation. The third implication concerns the prices of skill-intensive goods. Trade liberalization leads to an initial rise in the relative prices of skill-intensive goods, but, in the long run, prices must go back to their original equilibrium given by equation 1.11. This happens because technology $\frac{A_h}{A_l}$ adjusts according to relative prices $\frac{p_h}{p_l}$ and relative supply of labor $\frac{H}{L}$. The relative supply of labor relevant for the market of new technologies has not changed since technologies are produced only for the internal market and other countries can make free use of them without paying intellectual property rights. The last implication of this theory is therefore that trade-induced skill-biased technical change is consistent with stable prices of skill-intensive goods.

1.2.3 Labor Market Institutions and Wage Inequality

The Evidence

Labor market institutions, such as the degree of centralization in wage setting, minimum wage laws or union density and coverage have an important effect on the distribution of wages. Institutions are more likely to affect the bottom of the wage distribution since unions and the minimum wage tend to compress wages at the bottom. One stream of the literature has linked differences in wage inequality across countries to differences in institutions. Another approach has related changes in wage inequality within countries to changes in institutions.

Blau and Kahn (1996 and 1999) have investigated the effect of labor market institutions on wage inequality across countries decomposing the wage variance in the following way:

$$v_i = a_{ui}v_{ui} + (1 - a_{ui})v_{ni} + a_{ui}(\overline{w}_{ui} - \overline{w_i})^2 + (1 - a_{ui})(\overline{w}_{ni} - \overline{w_i})^2 \qquad (1.16)$$

v_i is the overall variance of wages for country i; a_u is the fraction of unionized workers; v_u and v_n are the variance of union and non-union wages; $\overline{w}_u$ and $\overline{w}_n$ are average union and non-union wages and $\overline{w}_i$ is the country average log wage level.

The last two terms of this expression indicate that the gap between union and non-union wages is important in accounting for the overall variance of wages. The other factors are the wage variance in the unionized and non-unionized sector, v_{ui} and v_{ni}, and union density a_{ui}. Since the wage variance in the unionized sector is typically lower, a higher union density in a country would contribute to a lower overall variance of wages. Collective wage bargaining lowers the wage variance in the unionized sector thus reducing intra-industry and intra-firm wage differentials. Collective bargaining is likely to affect also the wage variance in the non-unionized sector, as long as there are agreements to extend contracts to non-union workers. The US, relative to other countries, has a higher union premium but lower density and coverage and a much higher wage variance in both the unionized and non-unionized sectors.

Using the above framework, Blau and Kahn find that differences in union density account for 12 % of the difference in wage inequality between the US and other countries. The difference in the union premium explains only 2% and the difference in the union and non-union wage variance explains 86% of the difference.

Several studies across countries and within countries have used changes in wage setting agreements to show that the degree of centralization of wage setting is related to a lower wage variance in both the unionized and non-unionized sectors. Many other studies have related institutional change in the labor market to changes in wage inequality within the US. The two major changes in institutions in the recent period are the decline of the unions and the reduced real value of the minimum wage.

Union members have a wage premium that can vary between 10 and 20% relative to non union members. Given that unionization rates are higher for the less skilled, strong unions are likely to reduce educational wage differentials. Unions tend to reduce wage dispersion within the union sector by compressing wages between establishments and jobs. This suggests that the decline of the unions may have had an important effect on the changes in wage inequality. Union membership declined from 30% in 1973 to 18% in 1993. Most of the decline is concentrated among the low educated whose unionization rates declined by 20% points during the same period while unionization rates for college graduates were basically stable.

Adopting the framework of equation 1.16, Freeman (1993) estimates that the decline in union density can explain about 20% of the rise in male wage inequality from 1978 to 1988. He also claims that in the same period deunionization can account for a 1.5 log point increase in the male college premium and almost a 4 log point increase in the college premium among those aged 25 to 34.

DiNardo et al.(1996) use a non-parametric technique to study the effects of union density changes on the wage distribution between 1979 to 1988. They simulate the wage distribution in 1988 as if the unionization rate were the same as in 1979. They then attribute the difference between the real and the simulated distribution in 1988 to the effect of the changes in unionization. Their method is a generalization of equation 1.16: the overall wage distribution is the sum of the wage distribution of union and non-union workers. The wage distribution of union workers is typically more compressed. Reweighting the 1988 wage distribution, using the 1979 union density rate, amounts to giving more importance to the more compressed distribution of union workers. Their results suggest that deunionization can account for up to one third of the total increase in the 90-50 wage differential. The problem with this approach is the assumption that unions have an effect only on the wage distribution of unionized workers while wages of non-union workers are considered independent of the unions. In the plausible case that unions have spillover effects on wages of non-unionized workers, the estimates of the effect of unionization changes will be downward biased. On the other hand, deunionization might be the endogenous response to other market forces like trade and technology. In this latter case, the effect of deunionization may be overestimated.

The other big institutional change that affected the US labor market in the last 20 years is the decline in the real value of the minimum wage. The Federal minimum wage in the US was constant in nominal terms for ten years, from 1981 to 1990. As a result, the real value of the minimum wage declined dramatically. In the early eighties many more workers had a relatively high minimum with respect to the early nineties when the value of the minimum wage declined dramatically relative to average wages. The fact that the minimum wage ceased to be binding for many workers in the early '90s is suggestive that such big changes may have had an effect on the widening of the wage distribution at the bottom.

DiNardo et al. (1996) simulate the wage distribution in 1988 had the real value of the minimum wage stayed the same as in 1979. The approach is the same as before: the total wage distribution is the sum of the distribution below the minimum wage and above the minimum wage. Reweighting the 1988 distribution using the real value of the minimum wage in 1979 means giving more weight to the more compressed distribution below the minimum wage. The difference between the observed and the simulated distribution in 1988 is attributed to the effect of the declining value of the minimum wage. Their results indicate that the decline in the real value of the minimum wage can account for most of the increase in the 50-10 log wage differential. The critical hypothesis here is that the minimum wage affects only the distribution of wages below the minimum wage itself and has no spillover effect on those above the minimum wage. Moreover, the minimum wage is assumed to have no effect on employment levels.

Lee (1999) identifies the effect of the Federal minimum wage on the changes in wage inequality looking at the differences across states in the US. He takes a difference-in-difference approach. The minimum wage is more "biting" in low wage states rather than in high wage states. Low wage states are therefore considered the treatment group and high wage states the control group. The identifying assumption is that the only difference in the trends in the 50-10 wage differential across states is due to the different "bite" of the minimum wage. He finds that most of the widening 50-10 wage differential is accounted for by the decline in the real value of the minimum wage.

The empirical literature on the effects of institutions on wage inequality tends to conclude that deunionization and the decline in the real value of the minimum wage play an important role in explaining the increase in within-group wage inequality and a less relevant role in explaining the increase in the college wage premium. This interpretation is subject to two caveats. The first of an empirical nature, the second of a theoretical nature.

Although both the decline of the minimum wage and deunionization may have played a role in the changing wage distribution, they are unlikely to have played a major role. First, due to their "timing". In the US the decline in the value of the minimum wage began only in the '80s while within-group wage inequality started to increase in the '70s. In the UK, there was never an effective minimum wage before the late '90s. Deunionization in the US started in the '50s, much before the rise in wage inequality. In the UK, union density started declining in the '80s after the rise in wage inequality. Moreover, workers paid the minimum wage are only a small fraction (less than 8%) of the total; it is very unlikely that the minimum wage can explain the changes that affected the entire wage distribution. Wage inequality increased in the public sector when the unions were still very strong and in many occupations where wages were never much affected by the presence of the unions.

The Interaction Between Institutions and Technology

From the theoretical point of view, it seems implausible to consider institutions as completely immune from market forces. The effects that we attribute to changes in institutions may be due to the response of institutions to changes in supply and demand factors like technology and trade. Acemoglu, Aghion and Violante (2001) suggest that technical change may have caused deunionization and the overall changes in wage inequality. In their model, unions compress the wage structure but give a benefit to workers because they either capture rents or increase productivity. The outside option of skilled workers is to work in the non-union sector paid at their full marginal product. Skill-biased technological change increases the productivity difference between the skilled and the unskilled and destroys the coalition between the skilled and the unskilled that supports the union. In formulas, the skill-unskilled wage ratio in the non-union sector is equal to the productivity ratio $\frac{w_h}{w_l} = \frac{A_h}{A_l}$. In the union sector, the wage structure is compressed, $\frac{w_h}{w_l} = \phi\frac{A_h}{A_l}$ with $\phi < 1$, but unions provide a benefit of β to all workers. Therefore, the zero profit condition for a unionized firm is: $(w_h - \beta)H + (w_l - \beta)L = A_hH + A_lL$. The resulting wage for the skilled in the union sector is:

$$w_h = \frac{(A_h + \beta)H + (A_l + \beta)L}{A_hH + \phi^{-1}A_lL}A_h$$

Since $\frac{A_h}{A_l}$ increases because of technical change, w_h will eventually become smaller than A_h

and skilled workers will prefer the non-union sector. On the other hand unskilled workers will experience a decline in their wage since the coalition that supports the union will break down.

1.3 The Theories of Residual Wage Inequality

1.3.1 The Juhn, Murphy and Pierce Decomposition

Changes in wage inequality reflect changes in both price and quantities of workers' observable characteristics and changes in residual wage inequality. To quantify the role played by observables and unobservables in rising wage inequality Juhn, Murphy and Pierce (1993) adopted a simple variance decomposition framework. Let us start from the simple wage regression:

$$w_{it} = X_{it}\beta_t + u_{it} \tag{1.17}$$

where w_{it} is log wage of individual i in period t. X_{it} is a vector of observable characteristics and β_t is the vector of OLS estimated returns. u_{it} is the residual which reflects price and quantities of unobserved skills. The wage variance can be written:

$$var(w_{it}) = var(X_{it}\beta_t) + var(u_{it})$$

the first term is between-group wage inequality and the second one is within-group or residual wage inequality. Juhn, Murphy and Pierce (1993) report that the growth in residual wage inequality accounts for roughly 60% of the total increase in the variance of male and female log wages in the U.S. during the period 1963-1995. The rise in within-group wage inequality started earlier than the rise in between-group inequality. During the '70s, while returns to education were declining, residual wage inequality was already rising. During the '80s and '90s, returns to education and experience increased but the gender pay gap decreased with the result that the contribution of between-group wage inequality to the total rise in wage inequality remained constant.

The decomposition can be improved to analyze other measures of wage dispersion apart from the variance and to separately assess the role played by the rise in the returns to observables β_t and the changes in the distribution of individual characteristics X_{it}. From estimation of equation 1.17, the estimated OLS residuals u_{it} for each individual i in each year t are obtained. u_{it} can be written as $u_{it} = F_t^{-1}(\vartheta_{it})$ where ϑ_{it} is the percentile in the distribution function of the residuals in year t. The decomposition can be rewritten:

$$w_{it} = X_{it}\overline{\beta} + X_{it}(\beta_t - \overline{\beta}) + \overline{F^{-1}}(\vartheta_{it}) + [F^{-1}(\vartheta_{it}) - \overline{F^{-1}}(\vartheta_{it})]$$

where $\overline{\beta}$ is the average return to observables in the period under study, $\overline{F^{-1}}(\cdot)$ is the average inverse cumulative distribution of residuals. In this decomposition, the first term captures the changes in the distribution of observable characteristics X_{it}. The second term measures the contribution of the changing prices of observables and the last term the changes in the distribution of residuals. This decomposition makes it possible to simulate the wage distribution that would prevail if one of the components were to be held fixed at the base year. Keeping observable skill returns β and the residual distribution $F(\vartheta_{it})$ fixed, wages are determined only by the changing composition of workers' observable characteristics:

$$w_{it}^{1} = X_{it}\overline{\beta} + \overline{F^{-1}}(\vartheta_{it})$$

Keeping the residual distribution fixed, wages are determined by the changing prices and quantities in observable characteristics:

$$w_{it}^{2} = X_{it}\beta_{t} + \overline{F^{-1}}(\vartheta_{it})$$

Calculating the distributions w_{it}, w_{it}^{1}, and w_{it}^{2} for each year in the sample, the changes in w_{it}^{1} can be attributed to changes in observable characteristics; the changes in $w_{it}^{2} - w_{it}^{1}$ to changes in the prices of observable characteristics and the changes in $w_{it} - w_{it}^{2}$ to changes in the distribution of residuals.

Applying this method Juhn, Murphy and Pierce (1993) claim that roughly 60% of the increase in the 90-10 log wage differential can be accounted for by changes in the residual distribution. Of the 40% accounted for by changes in observable characteristics and prices, most of it (80%) is due to changes in the returns to education. Any explanation of the increase in wage inequality should therefore account not only for the rising returns to observable characteristics but also for the rise in within-group wage inequality.

1.3.2 The Theories

The Single Index Model

The theories of within-group wage inequality are far less developed than those of between-group inequality reviewed in the previous sections. The simplest model of residual wage inequality is a single index model as in Card and Lemieux (1996). In a single index model there is only one type of skill which is correlated with education. A college graduate has probability ϕ_c of being high skilled while a high school graduate has a lower probability $\phi_n < \phi_c$ of being high skilled. If the skill premium is $\omega = \frac{w_h}{w_l}$, then in this simple model the college premium is:

$$\omega^c = \frac{w_c}{w_n} = \frac{\phi_c w_h + (1-\phi_c)w_l}{\phi_n w_h + (1-\phi_n)w_l} = \frac{\phi_c \omega + (1-\phi_c)}{\phi_n \omega + (1-\phi_n)} \tag{1.18}$$

An explanation of within-group and between-group wage inequality based on this model would claim that either the true returns to skills ω have increased over time or the dispersion of unobserved skills has increased over time, i.e. that ϕ_c has increased relative to ϕ_n. The first possibility is that ω has increased while ϕ_c and ϕ_n are constant. However if ϕ_c and ϕ_n are constant over time, then the single index model of residual wage inequality runs up against the difficulty of explaining the different evolution of between-group and within-group wage inequality in the '70s. Since equation 1.18 clearly shows that the skill premium ω and the college premium ω^c always move together, therefore this model cannot account for the simultaneous rise in residual wage inequality and decline in returns to college during the '70s. The second possibility is that ϕ_c has increased relative to ϕ_n. The idea is that within-group wage inequality may arise from increased dispersion of unobserved skills in the new cohorts of labor market entrants. Increased dispersion of unobserved ability could affect the returns to education as education and unobserved ability are positively correlated. The reason for an increase in the dispersion of unobserved ability in the new cohorts is blamed on increased differences in school quality or in social conditions across neighborhoods within cities. If this were the explanation and the distribution of skills were more dispersed in the younger cohorts, then we would observe a different college premium for different cohorts. Juhn, Murphy and Pierce (1993) compare the changes in wage inequality and residual wage inequality in the 70s for the cohort aged 25-29 in 1970 with changes in the wage inequality in the 80s for the cohort aged 25-29 in 1980. They find that changes in wage inequality within cohorts are very similar to the general pattern of increasing wage inequality. This suggests that the rise in wage inequality is due to changes in the true returns to skills rather than to the different dispersion of unobserved skills within different cohorts.

The Two Index Model

Another possible model is a two-index model of residual wage inequality as proposed by Acemoglu (1998). In this model there are four types of workers that are differentiated by education and unobserved skills. The aggregate production function is:

$$Y = [(A_{lu}L_u)^{\rho} + (A_{ls}L_s)^{\rho} + (A_{hu}H_u)^{\rho} + (A_{hs}H_s)^{\rho}]^{\frac{1}{\rho}}$$

where L_u is the supply of low-skilled, low-education workers. The fraction of high skill workers is higher among the educated workers: $\phi_h = \frac{H_s}{H_u} > \phi_l = \frac{L_s}{L_u}$. In this setup within-group wage inequality is given by:

$$\frac{w_{L_s}}{w_{L_u}} = \left(\frac{A_{ls}}{A_{lu}}\right)^{\rho} \phi_l^{-(1-\rho)} \quad \text{and} \quad \frac{w_{H_s}}{w_{H_u}} = \left(\frac{A_{hs}}{A_{hu}}\right)^{\rho} \phi_h^{-(1-\rho)}$$

and the college premium is given by:

$$\omega = \frac{\phi_h^{\rho} A_{hs}^{\rho} + A_{hu}^{\rho}}{\phi_l^{\rho} A_{ls}^{\rho} + A_{lu}^{\rho}} \left(\frac{1+\phi_l}{1+\phi_h}\right)^{\rho} \left(\frac{H}{L}\right)^{-(1-\rho)}$$

In this model, the direction of technical change is endogenous and depends on the relative supply $\frac{H}{L}$. The market size effect encourages the development of skill-complementary technologies. When $\frac{H}{L}$ rises, the college premium declines as in the '70s while within-group wage inequality is not affected. As new skill-complementary technologies are developed, within-group wage inequality and the college premium both start to rise. This model provides a better explanation of the differential behavior of residual wage inequality and the returns to college during the '70s. In this model, within-group wage inequality rises as a result of directed technical change.

The Vintage Model

The theories of within-group wage inequality are faced with an empirical puzzle: Bludell and Preston (1999) and Gottschalk and Moffitt (1994) have documented the transitory nature of within-group wage inequality. According to the evidence, the rise in within-group wage inequality affected the temporary component of income while between-group wage inequality mainly affected the permanent component of income. The "vintage" model proposed by Aghion, Howitt and Violante (2002) tackles this problem. In each period a new technology embodied in new machines spreads to a new sector. Workers are ex-ante identical and only a random fraction of them has the opportunity to adapt to the new vintage of machines. Furthermore the workers who can adapt to the new technology several periods in a row can more easily transfer to the new machines the skills acquired through learning by doing on their previous job. Within-group wage inequality rises because there is a premium to the workers that can adapt to the new technologies and because those that can adapt more times can also transfer their skills.

Each period t a new vintage of machines A is introduced, the machines last only two periods. At time t there are only two technologies to consider:

$$y_{0t} = A_t x_{0t}^{1-\alpha}$$

where x_{0t} is the labor input working with the new technology, and

$$y_{1t} = A_{t-1}[(1+\eta)x_{1t}]^{1-\alpha}$$

where x_{1t} is the labor input working with the old technology at time t and η is a learning-by-doing parameter. Each new technology is $(1+\gamma)$ more productive than the previous one: $A_t = (1+\gamma)A_{t-1}$. In steady state, the productivity adjusted production in the two sectors can be written:

$$y_0 = x_0^{1-\alpha} \quad \text{and} \quad y_1 = \frac{1}{1+\gamma}[(1+\eta)x_1]^{1-\alpha}$$

Only a random fraction σ of workers can adapt immediately to the new technology. The workers that move from the leading technology to the next leading one can transfer τ part of their η learning-by-doing to the new machines. In formulas, one unit of labor services generate one unit of labor input except for the workers that move from a leading technology to the next leading one. One unit of their labor service generates $(1+\tau)$ units of labor input:

$$\begin{aligned} x_0 &= (1+\tau)n_{00} + n_{10} \\ x_1 &= n_{00} + n_{10} \end{aligned}$$

where n_{ij} is the labor flow from technology $i = 0, 1$ last period to technology $j = 0, 1$ this period. The labor flows must satisfy the following conditions:

$$\begin{aligned} n_{00} + n_{10} + n_{01} + n_{11} &= 1 \\ n_{00} &< = \sigma(n_{00} + n_{10}) \\ n_{10} &< = \sigma(n_{01} + n_{11}) \\ n_{01} &= n_{10} \end{aligned}$$

The first is a market clearing condition. The second and third are the adaptability conditions and the fourth is the stationarity condition.

Now the model can be solved. The labor demand schedule will be equal to the ratio of the marginal products in sector 0 and 1. Firms take the wage as given:

$$\frac{w_0}{w_1} = \frac{1+\gamma}{(1+\eta)^{1-\alpha}} \left(\frac{x_0}{x_1}\right)^{-\alpha}$$

It must also be true that $w_{00} = (1+\tau)w_0$, $w_{10} = w_0$, and $w_{01} = w_{11} = w_1$ where w_{ij} denotes the wage of a worker that moves from sector i to sector j.

The equilibrium wage ratio between sector 0 and 1, $\frac{w_0}{w_1}$, will be determined at the intersection of supply and demand. To determine the labor supply, assume that each worker supplies 1 unit of work inelastically and has logaritmic utility in consumption. The workers' only choice is whether to move into the new technology sector (when given the chance with probability σ) or to stay in the old sector. Denoting with v_{i0} the present discounted value of moving from sector $i = 0, 1$ to sector 0, and with v_1 the present discounted value of staying in sector 1, the relevant Bellman equations are:

$$
\begin{aligned}
v_{i0} &= w_{i0} + \beta\{\sigma \max[v_{00}, v_1] + (1-\sigma)v_1\} \\
v_1 &= w_1 + \beta\{\sigma \max[v_{10}, v_1] + (1-\sigma)v_1\}
\end{aligned}
$$

There are three possible solutions:

- $v_1 = v_{10}$ which is equivalent to $\frac{w_{i0}}{w_1} = \Omega = \frac{1}{1+\beta\sigma\tau}$. In this case, the workers who worked in sector 1 last period are indifferent between the two sectors this period. Workers who worked in sector 0 last period will prefer to move to the new leading edge this period because they have a transferability premium. The first adaptability constraint is binding but n_{10} can take any value between 0 and $\sigma(n_{01}+n_{11})$. Therefore the relative labor supply $\frac{x_0}{x_1}$ is indeterminate.

- $v_{10} > v_1$ or $\frac{w_{i0}}{w_1} > \Omega$. In this case, the adaptability constraints are binding for both types of workers as all those who are given the chance will move to the new technology. This leads to the relative labor supply $\frac{x_0}{x_1} = \frac{\sigma(1+\sigma\tau)}{(1-\sigma)} = \chi$.

- $v_{i1} > v_{i0}$. In this case, workers of type i prefer to stay in the old sector, therefore $n_{i0} = 0$ and $x_0 = 0$.

The equilibrium $\frac{w_0}{w_1}$ is given by the intersection of the relative demand and supply curves. $\frac{w_0}{w_1} = \Phi = \frac{1+\gamma}{(1+\eta)^{1-\alpha}}[\frac{1-\sigma}{\sigma(1+\sigma\tau)}]$ is the point where the relative demand schedule meets the vertical supply curve $\frac{x_0}{x_1} = \chi$. The equilibrium wage rate is therefore given by $\frac{w_0}{w_1} = \max(\Omega, \Phi)$.

Within-group wage inequality can be written in this model as the ratio between the maximum and the minimum wage: R_w. The maximum wage w_{00} is earned by workers that adapt to the new technology for two periods in a row:

$$R_w = \max(\frac{w_{00}}{w_0}, \frac{w_{00}}{w_1} = \frac{w_{00}}{w_0}\frac{w_0}{w_1}) = \max[1+\tau, (1+\tau)\Phi]$$

This measure of within-group wage inequality increases with the rate of technical progress γ and with trasferability of knowledge by adaptable workers τ. In this model, within-group wage inequality corresponds to individual variability of earnings. This model is therefore consistent with the evidence in Blundell and Preston (1999) and in Gottshalk and Moffitt (1994) about the transitory nature of within-group wage inequality.

1.3.3 Organizational Change

I have put organizational change in the section devoted to within-group wage inequality since most of the theories regarding organizational change are concerned with unobservable individual skills.

The Evidence

There is evidence that considerable organizational changes have been taking place at the firm level over the past decades. Cappelli and Wilk (1997) show that there have been big changes in recruitment practices of firms. There is evidence of more selective practices and more accurate screening at recruitment level. Sicherman (1991) finds evidence of better matching between firms and workers. Using PSID data, he shows that more workers have the exact amount of education required for their job. According to the answers to the question "do you think you have more/exact/less education than necessary to do your job", fewer workers are overeducated or undereducated in recent years.

Acemoglu (1999) documents changes in the distribution of jobs. Building industry-occupation cells and ranking them according to their average wage, there is a shift of employment towards the lower and higher ranking cells. This is interpreted as changing composition of jobs towards both higher and lower quality jobs. Constantine and Neumark (1994) show that the distribution of on-the-job training has become more unequal across jobs. As on-the-job training is correlated with high wages and capital investment in the job, this evidence is interpreted as a more unequal distribution of jobs. Similarly, Caselli (1999) reports a sharp increase in the capital/labor ratio difference between the 90th percentile of most capital-intensive industries and the 10th percentile. A more unequal distribution of capital/labor ratios across industries is evidence in favor of a changing composition of jobs.

Finally, Caroli and van Reenen (1999) provide evidence suggesting that changes in organizational form are related to changes in wages in a sample of English and French firms.

The Theories

The idea behind models of organizational change and wage inequality is simple: as the relative productivity of skilled workers increases, it becomes more profitable for them to work by themselves rather than working together with the unskilled. Kremer and Maskin (2000) build a model with two types of workers and two types of production. In the first type of firm, skilled and unskilled workers work together, in the second type skilled workers work alone. In the first type of firm the productivity of low skilled workers affects the productivity of high skilled workers, in the second type of firm it does not. An increase in the variance of skills or skill-biased technical change increases the productivity difference between high and low skilled workers. This may increase wage inequality as high skilled workers separate from low skilled workers. Kremer and Maskin also provide some evidence of the increased segregation of high skilled and low skilled workers in specific plants.

Acemoglu (1999) builds a model where the increase in the relative supply of skills and in the relative productivity changes firms' investment decisions. When there are few skilled workers and the productivity gap between the skilled and unskilled is limited, firms create one type of job (one single level of k) and pool across all types of workers. When the supply of skilled workers or their relative productivity increases, firms tend to differentiate the types of jobs they offer. Some firms invest in more capital and target skilled workers only. Some other firms target low skilled workers only.

The simple static version of this model has ϕ skilled workers with productivity $\eta > 1$ and $1 - \phi$ unskilled workers with productivity normalized to 1. Firms sink their capital before searching for workers. When the match occurs and is not turned down by either the firm or the worker, firms produce $y = k^{1-\alpha}h^{\alpha}$ where $h = \eta$ or 1 and spend ck to install their capital.

Wages are set by Nash bargaining therefore $w = \beta y$. Expected profits of the firm before the match are:

$$E\pi = \phi x^H[(1-\beta)k^{1-\alpha}\eta^\alpha - ck)] + (1-\phi)x^L[(1-\beta)k^{1-\alpha} - ck)]$$

where x^H and x^L are the probabilities that the skilled and unskilled workers accept the job once the match occurs. The first order condition w.r.t. to the capital choice k, given x^H and x^L, gives two types of equilibria. One pooling equilibrium where both skilled and unskilled workers accept the job, i.e. $x^H = 1$ and $x^L = 1$, and one separating equilibrium where only skilled workers accept, i.e. $x^H = 1$ and $x^L = 0$. Substituting in $E\pi$ the values for the pooling equilibrium capital choice k_P and the separating equilibrium choice k_S, we obtain the value of a job in the two cases: V_P and V_S. The pooling equilibrium will be preferred to the separating one if:

$$V_P > V_S \Longleftrightarrow \eta < \left(\frac{1-\phi}{\phi^\alpha - \phi}\right)^{\frac{1}{\alpha}}$$

This means that when the supply of skilled workers ϕ is low or the productivity difference between skilled and unskilled workers η is low, all firms will tend to choose one single level of capital k_P and hire both skilled and unskilled workers in the same job. When either the supply of skilled workers ϕ or the productivity difference η rises, then the separating equilibrium will prevail and some firms will invest k_S and produce using only skilled workers. In the transition from the pooling to the separating equilibrium wage inequality increases.

In the pooling equilibrium, both skilled and unskilled workers work with the same level of physical capital k_P. Therefore, the unskilled end up working with a higher physical/human capital ratio and the wage skill premium is compressed i.e. it is lower than the productivity difference $\frac{w_h}{w_l} = \eta^{\alpha} < \eta$. In the separating equilibrium, firms produce only with the skilled and the unskilled get $w_l = 0$.

1.4 Permanent and Transitory Components of Earnings

The growing literature on the permanent and transitory components of income is closely linked to the literature on wage inequality. The rising variance in the transitory component of income is also known as the growth of earnings instability.

The literature on earnings instability starts from the decomposition of the series of individual wages in a permanent and transitory part. Gottschalk and Moffitt (1994) decompose log earnings in a simple way. They subdivide the PSID data in two 9-year periods. The permanent component of earnings is the mean over 9 years of annual earnings and the transitory part is the deviation of the current annual earnings from the mean. The permanent variance is the variance of the individuals' permanent means. The transitory variance is obtained calculating the variance of the transitory deviations for each individual and then averaging the variances across individuals. An individual is affected by an increase in earnings instability if the variance of his transitory earnings increases over the two nine-year periods.

Baker and Solon (2003), Gottschalk and Moffitt (1995), and Dickens (2000) model earnings in a more formal way. The simplest model looks like:

$$y_{it} = p_t \mu_{it} + \lambda_t v_{it} \tag{1.19}$$

where y_{it} is log annual earnings, $\mu_{it} = \mu_{it-1} + \eta_{it}$ is the permanent random walk component (permanent observed and unobserved skills) and p_t is the time varying price of those skills. v_{it} is the transitory part and λ_t its time varying price. μ_{it} and v_{it} are orthogonal.

The link between the decomposition of individual earnings in their permanent and transitory part and cross-sectional wage inequality is simply expressed by taking the variance of equation 1.19. The variance of cross-sectional earnings is:

$$var(y_{it}) = p_t^2 \sigma_{\mu t}^2 + \lambda_t^2 \sigma_v^2$$

The nice feature of this model is that it provides a clear distinction between inequality in current and permanent earnings. An increase in either p_t or λ_t over the two periods generates increased dispersion of current earnings. The feature of the increase in inequality is, however, very different depending on which one of p_t or λ_t increases. A rise in p_t increases inequality in permanent earnings as well as in current earnings. A rise in λ_t increases cross-section inequality as individuals make larger jumps in the earnings distribution. In other words, a rise in p_t maintains the order of individuals in the earnings distribution but spreads them out further apart and decreases mobility rates. A rise in λ_t increases mobility.

Many studies in the US and UK have focused on disentangling the permanent and transitory part of earnings and evaluating the relative contribution of these two components to the increase in the total variance. The literature has followed two complementary approaches. Gottschalk and Moffitt (1995) for the US, Baker and Solon (2003) for Canada, and Dickens (2000) for the UK have modelled the persistent and transitory components of earnings. Buchinsky and Hunt (1996) and Gittleman and Joyce (1995) have looked at year-to-year mobility rates across quantiles of the earnings distribution. A rise in the variance of the permanent component of earnings implies declining mobility rates as individuals' earnings will be more autocorrelated over time. A rise in the variance of the transitory component implies increasing mobility of individuals across the distribution.

The results of the literature for the US indicate an equal increase in the variance of the permanent (observed and unobserved skills) and transitory components (Gottschalk and Moffitt 1995; Katz and Autor 1999). Consistent with that, mobility rates are stable or slightly declining over time. Results on the UK indicate a more pronounced increase in the variance of the permanent component and declining mobility rates (Dickens, 2000). In both the US and the UK the rise in earnings instability is still quantitatively important. The estimates of Gottschalk and Moffitt (1995) for the US and Dickens (2000) for the UK indicate an increase of 40% of λ_t over time and therefore an increase in transitory inequality.

The rise in cross-sectional wage inequality reflects a rise in both the permanent and transitory components of earnings. The rise of between-group wage inequality (returns to education, age, occupation) must reflect the increase in the variance of the permanent component of earnings. The sharp increase in within-group wage inequality could be due to either increased returns to unobserved persistent abilities or a rise in the transitory (year-to-year) earnings variance. An increase in the returns to unobserved ability implies a permanent effect on earnings inequality while an increase in year-to-year earnings mobility has only temporary welfare consequences.

Finally, from the theoretical point of view, the rise in the transitory component is not well explained by models of skill-biased technical change. Models of skill-biased technical change focus on the rising returns to observed and unobserved workers' characteristics which are both reflected in the rise of the permanent component of earnings. The rise in the transitory component of earnings is still a bit of a puzzle in terms of the theory. Violante (2002) proposes a model of within-group wage inequality with the intent of reconciling the theory with the empirical evidence of rising earnings instability.

1.5 Conclusions

In the first chapter of this thesis, I reviewed the literature on wage inequality. I presented the most popular theories that try to explain both between and within-group wage inequality. The literature faces two puzzles.

The first puzzle concerns wage inequality between education groups. Over the past 30 years both the relative supply of college educated workers and the college premium have increased noticeably in the US and in the UK. Among the theories that try to account for the relative demand shifts in favor of educated workers, I focused on skill-biased technical change, trade liberalization, organizational change and the changes in institutions. The first chapter also includes the evidence in favor and against each of them. The consensus seems to give a predominant role to skill-biased technical change.

The second puzzle concerns wage inequality within education and age groups. Within-group wage inequality accounts for more than half of the total rise in wage inequality. The rise in within-group wage inequality occurred before the rise in between-group wage inequality and affected the temporary component of income, while between-group inequality affected mainly the permanent component of income. The first chapter contains a review of the theories and the evidence on within-group wage inequality. The theories on within-group wage inequality are far less developed than those on between-group wage inequality.

Chapter 2 explores a new mechanism that could contribute to explaining the rise in between-group wage inequality. Chapter 3 is concerned with within-group wage inequality and chapter 4 presents a study of earnings instability.

Chapter 2

Product Demand Shifts and Wage Inequality

2.1 Introduction

Wage inequality increased substantially in the US and UK during the 1980s. The 90-10 log wage differential for male workers increased from 0.9 to 1.17 from 1979 to 1994 in the UK and from 1.16 to 1.45 in the US (Katz and Autor, 1999). Wage differentials by education also increased sharply. College graduates in the US earned 41 percent more than high-school graduates in 1980; by 1995 they earned 62 percent more (Autor, Katz and Krueger, 1998). In 1978, median wages of UK workers who left full-time education after age 18 were 40 percent higher than those who left full-time education at or before 16. By 1995, this differential had increased to over 60 percent (Machin, 1999). At the same time, the employment share of US college graduates rose from 19.2% in 1980 to 26.7% in 1996. In the UK, it rose from 8% in 1980 to 13% in 1997.

Although the pattern of the increase in wage inequality and the skill premium in the US and UK during the 1980s has been well documented, there is still much disagreement about the causes of the changes. All the theories face the challenge of explaining why the demand for skills accelerated and the college premium increased soon after an unprecedented increase in the supply of skills during the 1970s and 1980s. Several reasons have been proposed to explain the shift in demand against low skilled workers, in particular skill-biased technical change, trade liberalization and deunionization.

In the skill-biased technical change literature, Katz and Murphy (1992) claim that a steady growth in the relative demand for skilled workers combined with a slowing supply is the reason for the rise in wage inequality in the '80s and '90s. Other studies argue that there has been an acceleration in the relative demand for skills in the 1980s. The most popular studies are based on skill-biased technical change associated with changes in production techniques (Acemoglu, 1998), organizational change (Acemoglu, 1999), the reduction of the relative price of computers (Krusell et al., 1999) or the diffusion of "technological revolutions" (Aghion and Howitt, 1998).

The trade literature has instead focused on increased competition from developing countries. Increased trade will have an adverse effect on the demand for less skilled workers as long as import-competing industries are low skill-intensive and exporting industries are high skill-intensive (Wood, 1996). The trade explanation, however, is not supported by the evidence. First, trade with developing countries is only a very small proportion of the GDP of most industrialized countries and therefore is unlikely to have a big effect on wage inequality (Krugman, 1995). Second, although the trade explanation implies a rise in the relative prices of skill-intensive goods in developed countries, empirical studies find little evidence of this (Sachs and Shatz, 1994; Krueger, 1997). Third, the trade explanation is based on the relocation of labor from low skill-intensive to high skill-intensive sectors. However, the empirical evidence indicates that most of the shift away from the low skilled took place as a result of within-industry changes (60% to 80%) rather than between-industry changes (Berman, Bound and Griliches, 1994; Katz and Murphy, 1992).

Other studies argue that the change in wage setting institutions, such as the decline of the unions and of the real value of the minimum wage, can be associated with the increase in wage inequality (DiNardo et al., 1996; Lee, 1999). The main problem with this explanation is that, in the US, deunionization began much before wage inequality started to rise. In the UK, deunionization began later than the rise in wage inequality.

In this paper, I investigate another mechanism that can generate wage inequality. If more skilled workers demand more skill-intensive goods, then an exogenous increase in relative skill supply will also induce a shift in relative demand. With non-homothetic preferences, an increase in the relative supply of skilled workers can shift demand for final products in favor of skill-intensive goods and contribute to explaining the rise in the relative demand for skills. Sectors whose technology requires a large proportion of skilled workers are becoming increasingly important in the economy. Skill-intensive industries such as financial services, health services, education, pharmaceuticals, computers, and legal services have an increasing weight both in terms of wage bill share and share of total employment. If workers who enter those sectors tend to consume more of the goods produced by the same sectors, then an increase in their supply may help create additional demand for their own labor services. Part of the outward shift in the relative demand for skills can be explained by the shift in expenditure from low skill-intensive goods to high skill-intensive goods caused by the increase in the relative supply of skilled workers. This mechanism reduces the need to rely on trade and technology to explain the rise in wage inequality.

This paper is related to recent literature which claims that changes in skill supply may induce changes in skill demand. Acemoglu (1998) gives an explanation in terms of directed technical change. In that model an increase in the supply of college graduates increases the size of the market for skill-complementary technologies. This induces a change in the direction of technical change towards skill-complementary technologies and a shift in the relative demand for skills. In another paper, Acemoglu (1999) gives an interpretation in terms of organizational change. He suggests that when the fraction of skilled workers increases, profit maximizing firms tend to create more jobs for the skilled. When there are few skilled workers and the productivity gap between the skilled and unskilled is limited, firms create one type of job (one single level of capital) and pool across all types of workers. When the supply of skilled workers rises or their relative productivity increases, firms tend to differentiate the types of jobs they offer. Some firms invest in more capital than others and target skilled workers only. As a result, skilled workers work with a higher level of capital and wage inequality increases. In an expanding varieties model, Kiley (1997) shows that an increase in the supply of skills can induce skill-biased technical change and wage inequality. In Kiley's model, as in Acemoglu's (1998), the attractiveness of investing in skill-biased technology depends on the supply of the factor that complements that technology.

My paper differs from this literature in that the link between skill supply and skill demand is due to consumption elasticities. The mechanism at work is the following: an increase in the supply of skilled workers moves the economy down the relative labor demand curve; at the same time, higher education elasticities of skill-intensive goods raise the relative demand for skill-intensive goods and the relative demand of skilled labor. Two questions are addressed in this paper. First, is it true that more educated workers tend to consume more skill-intensive goods? Second, how much can such a mechanism contribute to explaining the outward shift in the relative demand for skilled labor?

The demand for skill-intensive goods may respond to the increase in the supply of education but may also depend from a pure income effect. To isolate the effect of education, I estimate education elasticities controlling for income. I also look at the income effect on product demand estimating income elasticities controlling for education. Income elasticities are allowed to vary according to the level of income, to capture the effects of rising income inequality at different levels of income. Keeping education constant, an increase in income inequality may also shift product demands towards skill-intensive products increasing income inequality further.

In section 2, the theoretical part of this paper, I build a simple two-sector general equilibrium model using non-homothetic preferences and derive the condition that links the exogenous rise in the supply of skilled workers with the rise of wage inequality. In section 3, the empirical part of this paper, I aim to establish whether educated consumers consume more skill-intensive goods. To do so, I adopt a three-step procedure. First, I match micro data on consumption from the UK Family Expenditure Survey (FES) to industry data from the UK Labour Force Survey (LFS). 46 consumption goods, representing 98% of non-durable household expenditure, are matched to 46 manufacturing industries. I then estimate education elasticities for each consumption good using the Almost Ideal System proposed by Deaton and Muellbauer (1980). Finally, to establish whether educated consumers tend to consume more skill-intensive goods, I regress education elasticities on the industry skill intensity. I also show the results of a regression of income elasticities, keeping education constant, on industry skill intensity. The results show that both education and income elasticities are positively related to the industry skill intensity. The demand for products seems to be endogenous to both an increase in education, keeping income constant and to rising income inequality, keeping education constant.

In the course of the empirical exercise, I address the issue of intermediate inputs and import penetration. While the 46 consumption goods represent 98% of non-durable consumption, the 46 industries matched to the consumption goods represent only 25% of the total wage bill and 28% of employment in the economy. I use Input-Output tables to take into account the contribution of the industries that produce intermediate inputs and all those industries that do not have a direct match with any consumption good. Input-Output tables are also used to correct the skill intensity of those goods that are mostly imported, since imports do not contribute to the domestic relative demand of skills. Even after controlling for intermediate inputs and import penetration, the results indicate a positive relationship between education and income elasticities of consumption goods and the skill intensity of the producing industries.

Although the regression results demonstrate that skilled workers tend to consume more skill-intensive goods, they are not informative regarding the quantitative importance of education and income elasticities in increasing relative labor demand. To estimate the quantitative importance of this mechanism, I calibrate the theoretical model using UK data between 1982 and 1998. In section 4, I give an estimate of the relationship between wage inequality and the relative supply of skills implied by the model. The result indicates that an education and income effect that favors skill-intensive goods can explain about 3 % of the total shift in relative labor demand.

The basic model explains labor demand shifts between sectors and considers wage inequality between different education groups. However, the empirical evidence indicates that 50% to 70% of the rise in wage inequality took place within groups with the same education (Juhn, Murphy and Pierce, 1993). Moreover, most of the shifts in relative labor demand occurred within industries rather than between different industries (Berman, Bound and Griliches, 1994; Katz and Murphy, 1992). In section 5, the model is extended to explain the increase in wage inequality within education group and labor demand shifts within industries. The extension considers production of goods of different qualities within industries and workers of different skills within the same education group. Unfortunately, the empirical exercise cannot investigate this extension of the model due to lack of data regarding consumption of goods of different qualities within industries. However, the theory can be tested indirectly by establishing whether income elasticities have risen over time.

The plan of the paper is as follows. Section 2 presents the basic model. Section 3 analyses the empirical evidence. Section 4 calibrates the model and gives an estimate of the contribution of education and income elasticities in explaining the shift in relative labor demand. Section 5 extends the model to explain wage inequality within education groups and labor demand shifts within industries. Section 6 provides a conclusion.

2.2 The Model

In this section, I formalize the basic idea of the paper. If preferences are non-homothetic and skilled workers tend to consume more skill-intensive goods, then an increase in the supply of skilled workers increases the final demand for skill-intensive goods and shifts the relative demand for skilled labor.

The formal model builds on 2×2 production-consumption models used in the early trade and public finance theory. The economy consists of H skilled workers and L unskilled workers. In this model skill coincides with education. Skilled workers are workers with a university degree, unskilled workers are workers without a university degree. Labor supply is assumed to be exogenous and inelastic. There are two types of goods: Y_h, the high skill-intensive commodity and Y_l, the low skill-intensive commodity. Production of high skill-intensive goods employs a high percentage of skilled workers; production of low skill-intensive goods employs mostly unskilled workers. Production functions are assumed to be CES. Labor markets are competitive. Demands for goods have a generic form that allows for non-homotheticity, and are different for skilled and unskilled workers.

The aim of this model is to explain the concurrent increase in the relative supply and relative demand of skilled workers (college graduates). The mechanism that shifts demand in response to an increase in supply acts through education and income elasticities. This model links the relative supply of skills to the skill premium through education and income elasticities of consumption.

The basic structure of the economy is:

Production:

$$Y_h = F_1(L_1, H_1) \tag{2.1}$$

$$Y_l = F_2(L_2, H_2) \tag{2.2}$$

Demand:

$$Y_h = Hy_h^h(\frac{p_h}{p_l}, w_h) + Ly_h^l(\frac{p_h}{p_l}, w_l) \tag{2.3}$$

$$Y_l = Hy_l^h(\frac{p_h}{p_l}, w_h) + Ly_l^l(\frac{p_h}{p_l}, w_l) \tag{2.4}$$

Factor supplies:

$$L = L_1 + L_2 \tag{2.5}$$

$$H = H_1 + H_2 \tag{2.6}$$

Factor returns:

$$w_h = p_h F_{1H}(L_1,H_1) = p_l F_{2H}(L_2,H_2) \quad (2.7)$$

$$w_l = p_h F_{1L}(L_1,H_1) = p_l F_{2L}(L_2,H_2) \quad (2.8)$$

Equation 2.3 is the total demand for the skill-intensive commodity Y_h. The first term of the RHS of equation 2.3 represents demand by the H skilled workers, the second term is demand by the L unskilled workers. Skilled and unskilled workers may have different price and income elasticities for skill-intensive goods. Equation 2.4 has the same interpretation for the low skill-intensive commodity Y_l.

The unskilled wage is normalized to unity, $w_l = 1$. The system is completely described by the following five equations:

$$p_h F_1(H_1, L_1) = L_1 + w_h H_1 \quad (2.9)$$

$$p_l F_2(H - H_1, L - L_1) = L - L_1 + w_h(H - H_1) \quad (2.10)$$

$$d\log(\frac{H_1}{L_1}) = -\sigma_1 d\log w_h \quad (2.11)$$

$$d\log(\frac{H - H_1}{L - L_1}) = -\sigma_2 d\log w_h \quad (2.12)$$

$$H y_h^h(\frac{p_h}{p_l}, w_h) + L y_h^l(\frac{p_h}{p_l}, 1) = F_1(H_1, L_1) \quad (2.13)$$

The first two equations, 2.9 and 2.10, restate the constant returns assumption. Equations 2.11 and 2.12 are definitions of substitution elasticities in a CES technology. The last equation 2.13 is the market equilibrium condition for commodity Y_h. According to Walras' law, equilibrium in the market for factors and for commodity Y_h implies that the market for commodity Y_l clears.

Taking the total differential and logs:

$$\begin{aligned} d\log p_h &= a_1 d\log w_h \\ d\log p_l &= a_2 d\log w_h \\ d\log H_1 - d\log L_1 &= -\sigma_1 d\log w_h \\ (1+\lambda_H)d\log H - \lambda_H d\log H_1 + \frac{H}{L}(1+\lambda_L)d\log H - \lambda_L d\log L_1 &= -\sigma_2 d\log w_h \end{aligned}$$

$$R_1[\varepsilon^h_{hp} d\log(\frac{p_h}{p_l}) + \varepsilon^h_{hm} d\log w_h + d\log H] +$$
$$+ (1-R_1)[d\log L + \varepsilon^l_{hp} d\log(\frac{p_h}{p_l})] = a_1 d\log H_1 - (1-a_1)d\log L_1$$

The parameter $a_1 = \frac{w_h H_1}{p_h y_h}$ denotes the wage bill share of skilled labor in the high skill-intensive sector h, a_2 is the wage bill share of skilled labor in the low skill-intensive sector l. $\lambda_H = \frac{H_1}{H-H_1}$ and $\lambda_L = \frac{L_1}{L-L_1}$ are respectively the ratio of skilled labor used in sector h and l and the ratio of unskilled labor used in sector h and l. $R_1 = \frac{Hy^h_h(.)}{Hy^h_h(.)+Ly^l_h(.)}$ is the share of total expenditure on the skill-intensive commodity h by skilled workers. ε^i_{hp} is the price elasticity of demand for the skill-intensive commodity h. The index $i = h, l$ indicates that the elasticity may be different for skilled and unskilled workers. ε^h_{hm} is the income elasticity of demand for the skill-intensive commodity h.

The system is solved for dw_h as a function of dH. Assume that $dH = -dL$, i.e. the total labor supply is fixed. The result is:

$$\frac{d\log w_h}{d\log H} = \frac{(\lambda_H+\lambda_L)[R_1-(1-R_1)\frac{H}{L}]-(2a_1-1)[1+\lambda_H+\frac{H}{L}(1+\lambda_L)]}{-(\lambda_H+\lambda_L)T-(2a_1-1)(\lambda_L\sigma_1-\sigma_2)} \tag{2.14}$$

where $T = \{R_1[\varepsilon^h_{hp}(a_1-a_2)+\varepsilon^h_{hm}]+(1-R_1)\varepsilon^l_{hp}(a_1-a_2)+(1-a_1)\sigma_1\}$. Equation 2.14 establishes the condition that links wage inequality $\frac{w_h}{w_l}$ to a rise in the skill ratio $\frac{H}{L}$. The sign and the magnitude of the numerator will depend crucially on the value of R_1 and of a_1. $R_1 = \frac{Hy^h_h(.)}{Hy^h_h(.)+Ly^l_h(.)}$ is the share of total expenditure on skill-intensive goods by skilled workers. $a_1 = \frac{w_h H_1}{p_h y_h}$ is the wage bill share of skilled labor in the skill-intensive sector. Given that $a_1 - a_2 > 0$, because sector Y_h is skill-intensive, the sign and the magnitude of the denominator will depend on ε^h_{hm}, the income elasticity of demand for skill-intensive goods by skilled workers.

An increase in the supply of college graduates has two effects. The standard substitution effect moves the economy along a downward sloping relative demand curve and decreases the skill premium. The effect through income elasticities may raise the demand of skill-intensive goods and therefore the relative demand of skilled labor. As average income increases over time, this model implies a rising demand of consumption items with large income elasticities.

This model can offer an explanation of the increase in the relative labor demand for skilled labor in its between-industry component, but it does not explain labor demand shifts within industries nor does it explain the rise of wage inequality within educational groups. In section 5, I extend the model to explain within-group wage inequality and within-industry labor demand shifts and provide a test of the theory.

2.3 The Empirical Evidence

Figure 2-1 documents the concurrent rise of the relative employment and the relative wage of workers who left full-time education at 21 or later in the UK from 1978 to 1998. The data are drawn from the UK Family Expenditure Survey (FES). In the FES there is no information on the educational degree obtained. I consider that those who left full-time education at or after 21 have had some form of college education. All heads of household in the sample who worked at least one hour in the past week and have a positive weekly wage are included. The percentage of heads of household who left full-time education at or after 21 rose from 6% in 1978 to 13% in 1998. During the same period, the ratio of the average weekly wage of heads of household who left full-time education at or after 21 over the average weekly wage of head of households who left full-time education before 21 rose from 1.32 to 1.75.

The model in section 2 shows that an increase in the supply of college-educated workers can generate an increase in the demand for skills if skilled workers prefer consuming skill-intensive goods. The hypothesis that education elasticities for high-skill-intensive goods are higher than for low-skill-intensive goods is crucial in deriving this result. In this section, I relate education elasticities of consumption goods to the skill intensity of the producing industry using UK data. A related question is whether product demand is endogenous to increases in income inequality, keeping education constant. Therefore I also estimate income elasticities allowing the income effect to vary according to the level of income itself. I proceed in two steps. I first match two datasets: the UK Family Expenditure Survey (FES) which contains data on consumption, and the UK Labour Force Survey (LFS) which contains data on industry skill intensity. I then estimate education and income elasticities for each consumption item and regress the estimates on the skill intensity of the manufacturing industry.

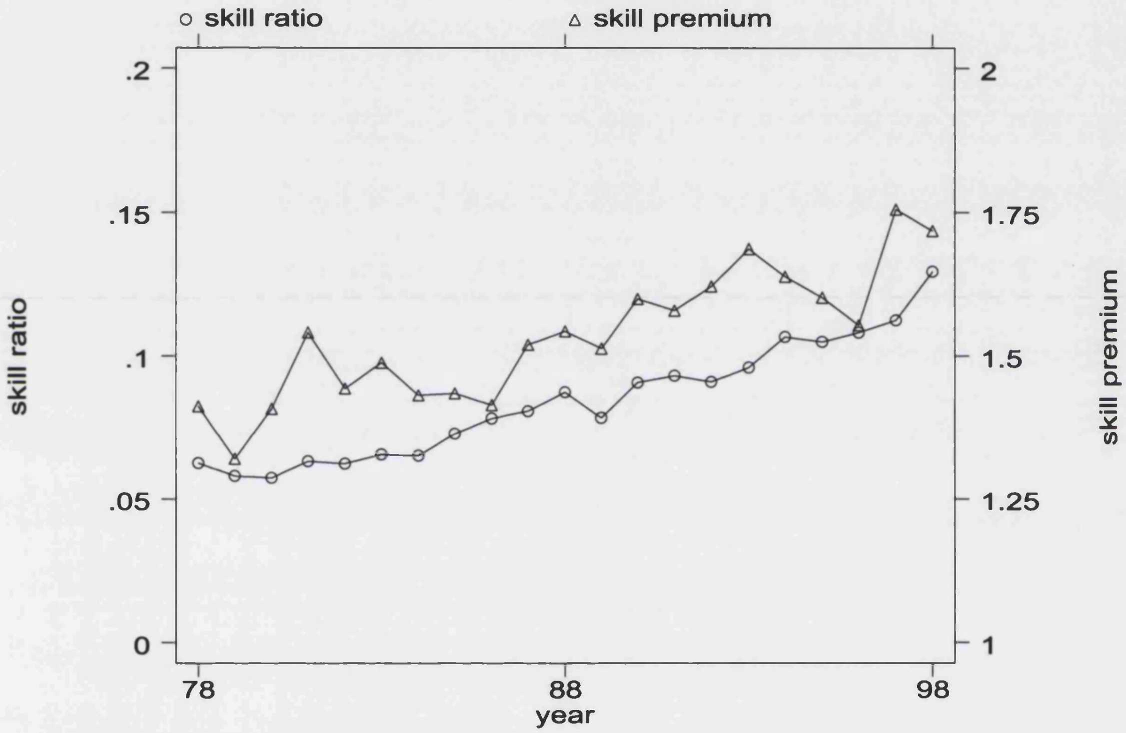

Figure 2-1: Percentage of heads of household who left full-time education at 21 or later. Ratio of average weekly wage of workers who left full-time education at 21 over average weekly wage of workers who left full-time education before 21. Source: FES data.

2.3.1 The Match Industry-Consumption Item

The data on consumption are drawn from the Family Expenditure Survey, 1982 to 1998. The survey contains information on a detailed set of goods recorded in a two-week diary and on household composition. I use data on all the goods whose consumption has been consistently recorded from 1982 to 1998. I exclude expenditure on housing and purchase of motor vehicles. I also exclude expenditure on TV licence and car tax and insurance because they do not have an obvious industry match. I consider consumption of 46 goods as shown in Table 2.4 in the Appendix. They represent 98% of total non-durable household expenditure and 85% of total expenditure including durables. The 46 goods are divided in thirteen main groups: food, food eaten out, alcohol, tobacco, home energy, household goods, household services, clothing, private transport, fares, personal goods and services, leisure goods and leisure and other services. In Table 2.4 in the Appendix, I match all 46 consumption goods to their manufacturing industry using the 1992 Standard Industrial Classification code.

Table 2.5 ranks the industries according to their skill intensity shown in the first column. The data on industry skill intensity are taken form the Labour Force Survey from 1982 to 1997 using information on the highest qualification obtained. The industry skill intensity is calculated as the share of workers who obtained a degree-level qualification. The least skill-intensive industries are hairdressing, footwear manufacturing and soft furnishing manufacturing. Less than 2% of workers in these industries hold a degree-level qualification. The most skill-intensive industries are professional services, pharmaceuticals and education. More than 50% of workers in the education industry hold a degree-level qualification.

2.3.2 The Education and Income Elasticities

Almost Ideal Demand System

The estimation method for education and income elasticities is the Almost Ideal Demand System proposed by Deaton and Muellbauer (1980) and Anderson and Blundell (1983). The expenditure decision is modelled following the two-stage budgeting approach (Blundell et al., 1993). At each period t, each household h makes a decision on how much to consume conditional on various household characteristics and conditional on the consumption level of a second group of other demands. This latter group includes housing and durables such as cars that are not considered in the estimation. The two groups are assumed to be weakly separable in utility and therefore prices of housing and durables do not affect consumption of the goods under consideration. Preferences are also assumed to be weakly separable over time, therefore incomes and prices outside the period have no effect on the current period consumption decision.

Let y_t be expenditure allocated by a household to these goods in period t. Given y_t, the household decides how much to spend on individual goods according to the following share equation (Deaton and Muellbauer, 1980, time subscripts omitted):

$$\omega_i = \alpha + \theta_i X + \gamma_i ed + \beta_{1i} \log(\frac{y}{P}) + \beta_{2i}(\log(\frac{y}{P}))^2 + \sum_{j=1}^{n} \zeta_{ij} \log p_j + \varepsilon_i \qquad (2.15)$$

where $\omega_i = \frac{p_i x_i}{y}$ is the expenditure share of item i. $\log y$ is log total expenditure. $P = \sum_j w_j \log p_j$ is the Stone price index where w_j is the monthly average share of commodity j in the data. $\log p_j$ are the consumption items' price series. X contains a quadratic in age, sex and regional dummies, the total number of components and the number of children in the household. *ed* is an education dummy which is equal to one if the head of household left full-time education at age 21 or later. The education elasticity will be equal to:

$$\widehat{\eta}_i^{ed} = \frac{\widehat{\gamma}_i * \overline{ed}}{\overline{\omega}_i}$$

where $\overline{\omega}_i$ is the average budget share of item i and $\overline{ed}$ is the percentage of head of households who left full-time education at 21 or later. In the estimation sample 1982-1998 $\overline{ed}$= 0.086. The budget elasticity will be equal to:

$$\widehat{\eta}_{ih}^{budget} = \frac{(\widehat{\beta}_{1i} + 2\widehat{\beta}_{2i}\log(\frac{y}{p})_h)}{\overline{\omega}_i} + 1$$

Unlike the education elasticity, the budget elasticity will exhibit substantial variation across households h because it depends on the level of the budget itself. The quadratic specification in income allows to account for the differential effect of income on product demand at low and high levels of income. In the course of the paper I will loosely refer to budget elasticities as to income elasticities.

The system estimation is carried out by using a two-step procedure. In the first stage, each equation is estimated separately by instrumenting total expenditure. The need to consider total expenditure as an endogenous variable comes from the occurrence of zero expenditures in the diary records. Many of the commodity groups considered are purchased infrequently. Since the zero expenditures affect both the dependent variable and the total real expenditure $\log(\frac{y}{p})$, ordinary least square OLS will be biased. Instrumental variable estimation, permitting all terms in $\log(\frac{y}{P})$ to be endogenous, removes this measurement error problem. Total net income is used as an instrument. In the first stage, single equation restrictions, such as zero-degree homogeneity in prices, are also imposed. The system 2.15 exhibits homogeneity if $\sum_{j=1}^{n} \zeta_{ij} = 0$ for all i.

Given the first-step estimates, the symmetry cross-equation restrictions are imposed by means of a minimum distance estimator. The symmetry cross-equation restrictions are $N * (N-1)/2$ symmetry restrictions on the price coefficients: $\zeta_{ij} = \zeta_{ji}$ for $i \neq j$. Denoting ϕ the vector of unrestricted parameters and ϕ^* the restricted parameters, the symmetry restrictions can be expressed as:

$$\phi = R\phi^*$$

To impose the symmetry restrictions the minimum distance estimator chooses ϕ^* to minimize:

$$m = (\widehat{\phi} - R\phi^*)'\Sigma_{\widehat{\phi}}^{-1}(\widehat{\phi} - R\phi^*) \tag{2.16}$$

where $\widehat{\phi}$ are the first-step estimates and $\Sigma_{\widehat{\phi}}^{-1}$ is an estimate of the variance-covariance matrix. The minimized value of the quadratic form in 2.16 is an optimal χ^2 test of the restrictions.

The symmetry-constrained system of 46 share equations cannot be estimated because of multicollinearity in the price series. Although we have price series for each commodity, using 46 price series in the system estimation results in a singular matrix of the regressors. The symmetry-constrained system is estimated only on the main thirteen consumption groups:

food, food eaten out, alcohol, tobacco, home energy, household goods, household services, clothing, private transport, fares, personal goods and services, leisure goods and leisure and other services. The education and budget elasticities for each of the 46 goods are estimated in the following section using an unconstrained system of equations and only the thirteen price series of the main groups.

Table 2.6 in the Appendix shows the means of the variables used in the estimation and the expenditure shares of the thirteen main consumption groups. The second and third columns of Table 2.6 show the means of the data within the households at the top and at the bottom quintile of the net income distribution. These two columns show that rich and poor families have very different expenditure patterns. Poor families tend to spend relatively more on food and home energy, rich families allocate a relatively larger proportion of their total expenditure in food eaten out, clothing, private transport and leisure goods and services.

I now turn to the estimated parameters and the implied elasticities of the individual-household expenditure allocations. Table 2.1 shows the unconstrained and symmetry-constrained estimates of the budget elasticities for each consumption group. Food and home energy are necessities, tobacco is an inferior good, all other items are luxuries. A comparison of the unrestricted and restricted estimates of the budget elasticities in Table 2.1 indicates that the budget elasticities are only marginally affected by the imposition of the restrictions. In fact, the imposition of the symmetry constrains affects mostly the estimates of the price elasticities which are not relevant for the purpose of this paper. The third column of Table 2.1 shows the education elasticities. Keeping income constant, educated workers tend to consume less alcohol, tobacco and clothing and more personal and leisure goods and services.

Table 2.7 in the Appendix reports the symmetry-constrained estimates of the thirteen-equation system. The table documents that household characteristics have an effect on ex-

Table 2.1: Education and Income Elasticities of the Main Consumption Groups

	Unconstrained budget elasticity		Constrained budget elasticity		Education elasticities	
Food	0.54	(0.01)	0.55	(0.01)	0.00	(0.01)
Food eaten out	1.50	(0.00)	1.48	(0.00)	-0.01	(0.00)
Alcohol	1.08	(0.00)	1.08	(0.00)	-0.03	(0.00)
Tobacco	-0.17	(0.00)	-0.16	(0.00)	-0.05	(0.00)
Home energy	0.46	(0.00)	0.46	(0.00)	0.00	(0.00)
Household goods	1.24	(0.00)	1.24	(0.00)	-0.01	(0.00)
Household services	1.31	(0.00)	1.29	(0.00)	0.02	(0.00)
Clothing	1.42	(0.00)	1.46	(0.00)	-0.02	(0.00)
Private transport	1.43	(0.00)	1.44	(0.00)	0.00	(0.00)
Fares	1.23	(0.00)	1.21	(0.00)	-0.00	(0.00)
Personal goods and services	1.21	(0.00)	1.21	(0.00)	0.03	(0.00)
Leisure goods	1.27	(0.00)	1.29	(0.00)	0.01	(0.00)
Leisure and other services	1.48	(0.00)	1.46	(0.00)	0.03	(0.00)

Notes: Standard errors in parenthesis are calculated using the Delta method.

penditure shares. For example the estimated coefficients indicate that the presence of an additional child under 18 in the household will, other things equal, increase the expenditure share on food by 0.033. The head of household who left full-time education at 21 or later will have, ceteris paribus, a lower expenditure share on alcohol and on tobacco, respectively by -0.015 and -0.014. The homogeneity restrictions are tested equation by equation by means of a simple T-ratio test. The tests reported in Table 2.7 indicate that I am unable to reject the homogeneity restrictions implied by the theory in six equations out of thirteen. The χ^2 test reported at the bottom of Table 2.7 is the minimized value of the quadratic form 2.16 and refers to the joint test of zero-degree homogeneity in prices and cross-equation price symmetry. The high value of the test indicates that the constrained estimates are statistically rejected.

The Results on the Complete Set of Goods

Table 2.8 in the Appendix shows the education and the budget elasticities for each one of the 46 goods. Each row shows the results of a single share equation 2.15. The unconstrained system of equations is estimated using the thirteen price series of the main consumption groups and the same regressors as above. The terms in total expenditure are instrumented using total net income. The standard errors in parenthesis indicate that both the education and the budget elasticities are always estimated with extreme precision.

The 46 goods in Table 2.8 in the Appendix are ranked according to the skill intensity of their manufacturing industries. The education elasticities indicate that, keeping income constant, more educated workers tend to consume less tobacco and beer but spend more on education and on transport fares such as rail and airplane fares. The table also indicates that high skill-intensive products have in general a higher income elasticity than low skill-intensive products. In particular, expenditure on skill-intensive services such as education and professional services have a budget elasticity much higher than one. However, expenditures on some skill-intensive products like drugs and household consumables have an income elasticity lower than one. Most low skill-intensive products have an income elasticity lower or just over one except for domestic help which is a luxury service.

I run two regressions. First I regress the estimated education elasticities on the corresponding industry's skill intensity, then I regress the estimated income elasticities on the industry's skill intensity. The two regressions indicate whether more educated and richer consumers tend to consume more skill-intensive goods. I estimate:

$$\widehat{\eta}_i = \alpha + \gamma z_i + \varepsilon_i \tag{2.17}$$

where $\widehat{\eta}_i$ is in turn the estimate of education and of budget elasticity for commodity i and z_i is industry's i skill intensity. Skill intensity z_i is reported in Table 2.4 in the Appendix and is defined as the percentage of workers with a degree-level qualification that work in industry i. The regressions are weighted by the inverse of the estimates' variance. The results of the estimation are given in the first column of Table 2.2. The regression of education elasticities on skill intensity gives a coefficient γ =0.149(0.037). This result indicates that, keeping income constant, more educated workers tend to consume more skill-intensive goods. The regression of income elasticities on skill intensity gives a coefficient γ =1.858(0.821). A positive relationship between income elasticities and skill intensities indicates that richer consumers indeed consume more skill-intensive goods.

Input-Output Table

In the previous section I considered the matching between 46 consumption items and their manufacturing industries. However, the industries which have a direct match to the consumption items represent only a minor part in the total economy. I divide the 46 consumption goods in 23 low skill-intensive goods and 23 high skill-intensive goods according to the ranking in Table 2.5. Figure 2-2 shows the wage bill share of the 23 least skill-intensive industries compared to the 23 most skill-intensive. Since the LFS does not contain wage information prior to 1992, the wage bill share in Figure 2-2 is calculated on New Earnings Survey data. The wage bill share of the 23 most skill-intensive industries rose from 20% in 1982 to 23.7% in

1995. The wage bill share of the 23 least skill-intensive declined from 5.5% to 4.6%. In total, the 46 industries which have a direct match to a consumption item represent only about 25% of the total wage bill and 28% of total employment.

When matching consumption items directly to their manufacturing industries, I disregard the retail sector and all other sectors that do not have a direct match to a consumption item. Furthermore, I do not consider either intermediate inputs or the import penetration in the different sectors. Intermediate goods may be important because the industries that produce inputs may have a different skill intensity than those that produce the final output. Import penetration in the different industries is relevant because consumption goods with very high income elasticities may be mainly produced abroad and therefore contribute nothing to the increase in the domestic demand for skilled labor.

To account for the skill intensity of the input-producing industries, I use the UK industry-by-industry Input-Output tables in year 1995. The Input-Output tables provide information on the input contribution of 123 industries. The industries are classified according to the same 1992 Standard Industry Classification code which I used to match the consumption items to their manufacturing industries, except for very few cases.[1] In the second column of Table 2.5 in the Appendix I calculate the skill intensity of each of the 46 original industries as the weighted average of the skill intensity of their inputs. In formulas, the skill intensity of final product j, z_j^A, is calculated as $z_j^A = \sum_i \frac{I_{ij}}{\Sigma_i I_{ij}} z_i$. The weights $\frac{I_{ij}}{\Sigma_i I_{ij}}$ indicate industry's i input contribution to produce one unit of product in industry j and are provided by the Input-

[1] The only discrepancies between the coding used to calculate skill intensity in the first column of Table 2.5 in the Appendix, and the coding of the Input-Output table used to calculate skill intensity in the second and third column of the same Table, are the following: SIC 1992 codes 93.02 hairdressing and 93.05 domestic help are joint in 93 other service activities. SIC codes 15.91+15.92 alcoholic drinks distilling, 15.93 wine production and 15.96+15.97 beer production are joint in 15.91 to 15.97 alcoholic beverages. SIC codes 22.1+22.2 printing and publishing and 22.3 reproduction of recorded media are joint in 22 printing and publishing and reproduction of recorded media.

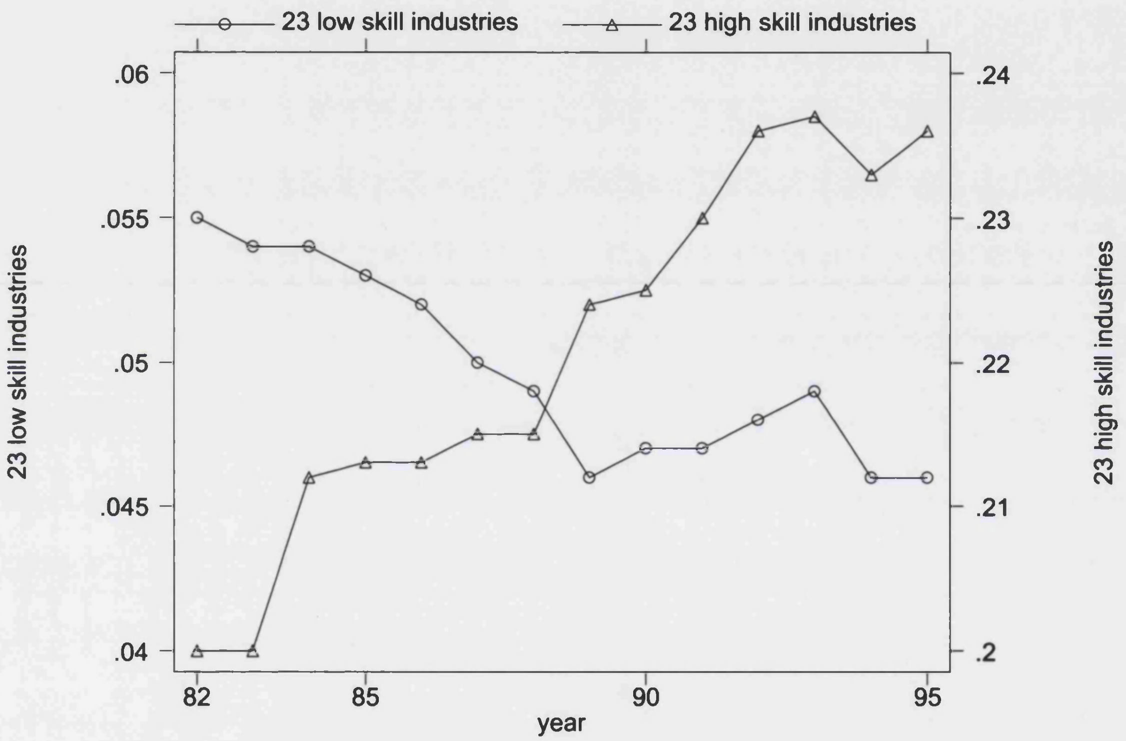

Figure 2-2: Wage bill share of the 23 most skill intensive and 23 least skill intensive industries 1982-1995. Source: NES data

Output table. z_i is the skill intensity of intermediate industry i. An eye-ball comparison of the first and second column of Table 2.5 in the Appendix shows that taking into account intermediate inputs increases the skill intensity of the low skill-intensive goods and reduces the skill intensity of the high skill-intensive goods. Low skill-intensive intermediate inputs, like the retail sector, are expected to reduce the skill intensity of all final products. For the low skill-intensive final goods the effect of the retail sector is offset by the contribution of other intermediate inputs which are relatively more skill-intensive.

To take into account import penetration, I multiply skill intensity z_j^A by the import penetration of the final industry. The import penetration of industry j, NX_j, is calculated as $NX_j = 1 + (E_j - I_j)/Y_j$. In this expression E_j, I_j and Y_j are exports of goods and services, imports of goods and services and total final demand of industry j. E_j, I_j and Y_j are obtained from the Input-Output tables. The resulting measure of skill intensity, $z_j^B = z_j^A * NX_j$, increases the skill intensity of the exporting sectors and reduces the skill intensity of the importing sectors. A comparison of the second and third column of Table 2.5 shows that the UK tends to export most finite goods and services, in particular some of the most skill-intensive ones such as drugs, oil and financial services.

Table 2.2 compares the results of regression 2.17 in three cases. In the first row, skill intensity z_j is the skill intensity of the manufacturing industry; in the second row, skill intensity z_j^A is corrected for the contribution of intermediate inputs; in the third row, skill intensity $z_j^B = z_j^A * NX_j$ takes into account both the contribution of intermediate inputs and import penetration. The results in the second and third row of Table 2.2 answer two different questions. The first question asks whether skilled (or richer) workers consume more skill-intensive goods. In this case we do not need to consider the import penetration of each industry. The relevant results are those of the second row of Table 2.2, where skill intensity is corrected for

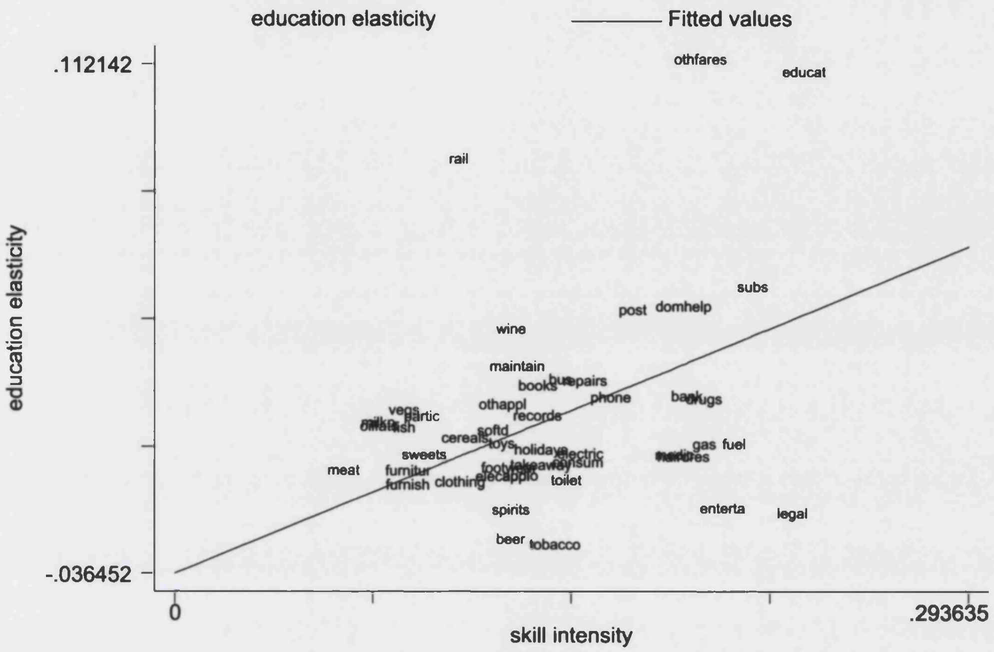

Figure 2-3: OLS regression of education elasticities on industry skill intensity.

the contribution of intermediate inputs. The second row gives a result of γ =0.324 (0.105) for education elasticities and γ =5.968 (2.390) for income elasticities. Figure 2-3 plots the estimated education elasticities in Table 2.8 in the Appendix against the skill intensities in the second column of Table 2.5 in the Appendix. Figure 2-4 does the same with income elasticities. The second question asks how relevant are the education and income elasticities in increasing the domestic demand for skilled labor. In this case we should weigh the skill intensity of the manufacturing industry for imports since imported goods are not going to increase domestic labor demand. The relevant results are shown in the third row of Table 2.2. When the industry skill intensity is weighted by import penetration, the regression in equation 2.17 gives a result of γ =0.188(0.099) for education elasticities and γ =3.773(2.187) for income elasticities.

The coefficient γ, which indicates the association between education and income elasticities

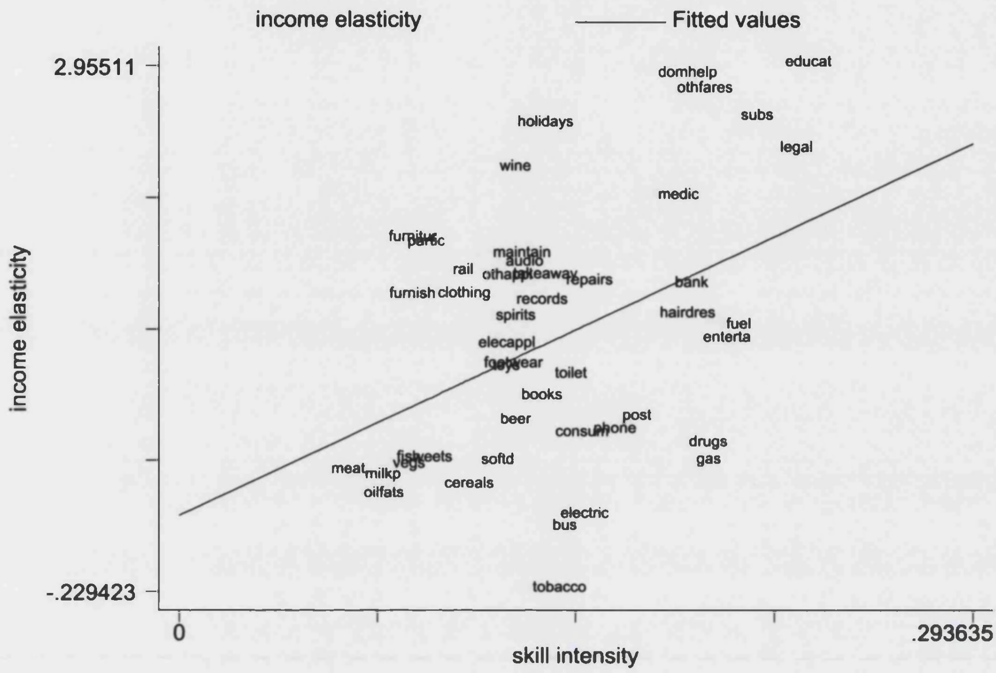

Figure 2-4: OLS regression of income elasticities on industry skill intensity.

and skill intensity, is always positive and significative in Table 2.2. A positive value of γ indicates that more educated and richer consumers tend to consume more skill-intensive goods. However, this coefficient does not tell us the extent to which an increase in education or income raises the demand for skilled labor. To answer this question, in the next section, I calibrate the model using the data of the UK economy.

2.4 Model Calibration

This section describes a calibrated version of the model, choosing parameters in line with the UK economy. I quantify the increase in the relative demand of skilled labor in response to an increase in the relative supply of skills making use of the relationship between the skill premium and the skill ratio implied by the model in section 2. Calibration of equation 2.14,

Table 2.2: OLS Regression of Education and Income Elasticities on Various Measures of Skill Intensity

	Dependent variable					
	education elasticities			income elasticities		
	(1)	(2)	(3)	(1)	(2)	(3)
Skill intensity=z_j	0.149			1.858		
	(0.037)			(0.821)		
Skill intensity=z_j^A		0.324			5.968	
		(0.105)			(2.390)	
Skill intensity=$z_j^A * NX_j$			0.188			3.773
			(0.099)			(2.187)
R square	0.26	0.17	0.07	0.10	0.12	0.06
Sample size	46	46	46	46	46	46

Notes: In the first row, skill intensity of the manufacturing industry. In the second row, skill intensity is corrected for intermediate inputs. In the third row, skill intensity is corrected for intermediate inputs and import penetration. OLS regressions wieghted by the inverse of the dependent variable variance.

obtained from the model in section 2, will quantify the importance of income elasticities in explaining the rise of wage inequality. I repeat equation 2.14:

$$\frac{d\log w_h}{d\log H} = \frac{(\lambda_H + \lambda_L)[R_1 - (1-R_1)\frac{H}{L}] - (2a_1 - 1)[1 + \lambda_H + \frac{H}{L}(1+\lambda_L)]}{-(\lambda_H + \lambda_L)T - (2a_1 - 1)(\lambda_L\sigma_1 - \sigma_2)}$$

where $T = \{R_1[\varepsilon^h_{hp}(a_1 - a_2) + \varepsilon^h_{hm}] + (1-R_1)\varepsilon^l_{hp}(a_1 - a_2) + (1-a_1)\sigma_1\}$.

The calibration of the model is conducted using data on the 46 consumption items and on the 46 corresponding industries listed in Table 2.4 in the Appendix. The 46 commodities and the corresponding industries are divided into 23 low skill-intensive goods and 23 high skill-intensive goods to match the characteristics of the model in section 2. I calibrate λ_H, λ_L, $\frac{H}{L}$, a_1 and a_2 using Labour Force Survey data from 1993 to 1997; R_1, ε^h_{hp}, ε^l_{hp} and ε^h_{hm} using Family Expenditure Survey data from 1982 to 1997. σ_1 and σ_2 are taken from Katz and

Murphy (1992).

The ratio of the number of college-educated workers who work in the 23 most skill-intensive industries over those who work in the 23 least skill-intensive industries is calculated at $\lambda_H = \frac{H_1}{H_2} = 23.1$. The ratio of the number of workers without a college education who work in the 23 most skill-intensive industries over those who work in the 23 least skill-intensive industries is calculated at $\lambda_L = \frac{L_1}{L_2} = 1.98$. The total skill ratio in the economy is $\frac{H}{L} = 0.11$. The value of the wage bill share of college-educated workers in the 23 most skill-intensive industries is $\alpha_1 = \frac{w_h H_1}{p_h y_h} = 0.48$; in the 23 least skill-intensive industries it is $\alpha_2 = \frac{w_h H_2}{p_l y_l} = 0.1$.

An estimate of the income elasticity is obtained from a simple OLS estimate of regression 2.15 with fixed effects for each commodity. The standard errors of this regression are clustered at the household level. In this regression, I consider only the 23 most skill-intensive goods and college-educated workers, i.e. those who left full-time education at 21 or later. The average expenditure share on skilled goods by college-educated workers is calculated at $\overline{\omega} = 0.015$. This implies an income elasticity of ε^h_{hm} =1.28. The price elasticities ε^h_{hp} and ε^l_{hp} are estimated from two separate OLS regressions 2.15 with fixed effects for each of the 23 skill-intensive goods considered. To estimate ε^h_{hp}, I consider only college-educated workers and construct an aggregate price index of the 23 skill-intensive goods using as weights their shares in total expenditure. To estimate ε^l_{hp}, I adopt the same procedure considering only workers without a college education and an aggregate price index of the 23 low skill-intensive goods. ε^h_{hp} and ε^l_{hp} are estimated at ε^h_{hp} =-0.7(0.2) and ε^l_{hp} =-0.6(0.1). The share of expenditure on the 23 most skill-intensive goods by college-educated workers is calculated at $R_1 = \frac{Hy^h_h(.)}{Hy^h_h(\cdot)+Ly^l_h(\cdot)} = 0.12$. The value of the elasticity of substitution between skilled and unskilled workers $\sigma_1 = \sigma_2 = 1.4$ is taken from Katz and Murphy (1992). Plugging the values of all parameters in equation 2.14, the final result is $\frac{d\log w_h}{d\log H} = -0.10$.

The interpretation of this number makes sense with respect to what would have happened without the income effect in favor of skill-intensive goods. The same model, solved with homothetic preferences ($\varepsilon^h_{hm} = 1$) that disregard the income effect in favor of skill-intensive goods, implies an even bigger fall of $\frac{w_h}{w_l}$, $\frac{d \log w_h}{d \log H} = -0.11$. As a matter of fact, according to the FES data plotted in Figure 2-1, $\frac{H}{L}$ increased by 88% between 1982 and 1997 in the UK and $\frac{w_h}{w_l}$ increased by 13%. The model with the income effect in favor of skill-intensive goods implies that $\frac{w_h}{w_l}$ should have fallen by 8.8% as a result of an increase in $\frac{H}{L}$ of 88%. The model with homothetic preferences implies a fall of $\frac{w_h}{w_l}$ by 9.6%. With respect to the model with homothetic preferences, the total shift in relative labor demand is of 22.6% (the actual 13% plus the counterfactual 9.6% along a fixed relative demand curve). These calculations imply that the income effect in favor of skill-intensive goods can explain only around 3% of the total shift in the relative demand of labor. The effect of non-homothetic preferences reduces by 0.8% the fall of the relative wage (8.8% instead of 9.6%). These 0.8% points constitute only 3% of the 22.6% total shift in the relative labor demand.

2.5 Within-Group Wage Inequality

The baseline model can explain only between-industry skill upgrading and wage inequality between workers with college education and without college education. However, the empirical literature has shown that most of the shifts in relative labor demand occurs within detailed industries. Katz and Murphy (1992) show that between-industry shifts in the composition of employment are not enough to account for the total shift in the relative skill demand in the US. Machin and van Reenen (1998) show that within-industry shifts in relative labor demand are predominant across a sample of OECD countries. Furthermore, Juhn, Murphy and Pierce

(1993) attribute from one half to two thirds of the total increase in wage inequality in the US to wage differentials within observable individual characteristics.

In this section, the model in section 2 is extended to account for within-industry labor demand shifts and for wage inequality within workers with the same education. To explain within-educational group wage inequality and within-industry relative labor demand shifts, it is necessary to introduce goods of different qualities within sectors and workers of different skills within educational group. I introduce goods of high and low quality within both the high skill-intensive and the low skill-intensive sectors and high-skilled and low-skilled workers within both the college-educated and the non-college educated workers. I assume that only college graduates work in the skill-intensive sector. Furthermore I assume that within the college graduates only those who are skilled produce high-quality goods, the unskilled produce low-quality goods. The same applies to the low skill-intensive sector where only non-college educated workers work.

In formal terms, the model can be specified as follows. There are four types of workers differentiated by education and unobserved skills. There are four sectors in the economy and each of them produces using only one type of worker. The production functions in the skill-intensive sector are of the type:

$$y_{hj} = H_j \quad \text{where } j = s, u$$

H_s skilled college-educated workers produce high-quality goods y_{hs} in the skill-intensive sector of the economy. H_u unskilled college-educated workers produce low-quality goods y_{hu}. By the same token, the production functions in the low skill-intensive sector are of the type:

$$y_{lj} = L_j \quad \text{where } j = s, u$$

I assume that the fraction of skilled workers in each education group is constant with $\phi_h = \frac{H_s}{H_u} > \phi_l = \frac{L_s}{L_u}$. The proportion of skilled workers among the college-educated is bigger than among the non-college educated. In this model, within-group wage inequality is given by:

$$\frac{w_{hs}}{w_{hu}} = \frac{p_{hs}}{p_{hu}}\phi_h$$

and

$$\frac{w_{ls}}{w_{lu}} = \frac{p_{ls}}{p_{lu}}\phi_l$$

The equilibrium in the model is given by four zero-profit conditions and three market-clearing conditions of the type:

$$\phi_h H_u y_{ij}^{hs}(\frac{p_{ij}}{p}, w_{hs}) + H_u y_{ij}^{hu}(\frac{p_{ij}}{p}, w_{hu}) + \phi_l L_u y_{ij}^{ls}(\frac{p_{ij}}{p}, w_{ls}) + L_u y_{ij}^{lu}(\frac{p_{ij}}{p}, 1) = y_{ij}$$

where $y_{ij}^{ij}(\frac{p_{ij}}{p}, w_{ij})$ for $i = h, l$ and $j = s, u$ is the demand for each of the four types of goods by each of the four types of workers. Total demand is equal to production y_{ij}. The last market-clearing condition is satisfied by Walras' law.

Normalize total labor supply $H + L = 1$. Consider an increase in the supply of college-educated workers H (in this case an increase in H_u and a proportional increase in $H_s = \phi_h H_u$) and the corresponding decrease of the non-college educated L. The condition that ensures an increase in within-group wage inequality in the skill-intensive sector is:

$$\frac{\delta \log w_{hs}}{\delta \log H_u} > \frac{\delta \log w_{hu}}{\delta \log H_u} \Longleftrightarrow \epsilon_{hm}^s > \epsilon_{hm}^u$$

To generate wage inequality within the college-educated in the skill-intensive sector, the model requires the income elasticity of the high-quality goods to be greater than the income elasticity of the low-quality ones. This means that preferences are non-homothetic in favor of skill-intensive goods and non-homothetic in the quality of goods. As consumers become richer, they want to consume more high skill-intensive goods and also want to consume more high-quality goods within the high-skill intensive. The result is that an income effect increases the demand of high-quality goods and the wage of the skilled workers who produce them. Since we can observe workers' education but cannot observe their skills, we can say that this model can account for an increase in residual wage inequality.

The empirical test of this extension of the model is not straightforward because consumption surveys do not contain information on the quality of the goods purchased. The estimated income elasticities will be averages of the income elasticities of high-quality and low-quality goods:

$$\epsilon_{hm} = \frac{y_h^s \epsilon_{hm}^s + y_h^u \epsilon_{hm}^u}{y_h^s + y_h^u}$$

The demands for high-quality and low-quality goods within the high skill-intensive sector, y_h^s and y_h^u , are unobservable. We have only total demand of skill-intensive goods, $y_h^s + y_h^u$, and the corresponding income elasticity ϵ_{hm}. The hypothesis that high-quality goods have a higher income elasticity than low-quality goods can be tested looking at the evolution of income elasticities over time. If the hypothesis $\epsilon_{hm}^s > \epsilon_{hm}^u$ is correct, then over time, we should observe a higher relative demand of high-quality goods y_h^s and a rise in the estimated elasticity ϵ_{hm}. In fact $\frac{\delta\epsilon_{hm}}{\delta y_h^s} > 0$ if $\epsilon_{hm}^s > \epsilon_{hm}^u$. For the low skill-intensive sector we should observe a shift in demand from y_l^u to y_l^s, but also a decline in total demand for low skill-intensive goods, $y_l^s + y_l^u$.

To test this implication of the model I estimate a fixed effect model where I regress income elasticities estimates in each year of the sample on a time trend and a dummy for each commodity i:

$$\widehat{\eta}_{it} = \alpha + \beta t + \xi_i + \varepsilon_{it} \tag{2.18}$$

where $\widehat{\eta}_{it}$ is the estimated income elasticity of commodity i in year t, t is a time trend and ξ_i is a dummy for each commodity. Each observation is weighted by the inverse of its variance. The estimates $\widehat{\eta}_{it}$ are obtained with a simple OLS regression of equation 2.15 in each year from 1982 to 1997. The first two columns of Table 2.3 present the results of equation 2.18 estimated separately on the sample of the 23 most skill-intensive goods and on the sample of the 23 less skill-intensive goods. The results for both the skilled and unskilled sectors show a rising trend in the estimated income elasticities. The last column of Table 2.3 shows the results of equation $\widehat{\eta}_{it} = \alpha + \gamma(t * z_i) + \xi_i + \varepsilon_{it}$. This equation is estimated using the whole

Table 2.3: Fixed Effect Regression of Income Elasticities on Time Trend

	Dependent Variable		
	Income elasticities High skill-intensive goods	Income elasticities Low skill-intensive goods	Income elasticities Full sample
Trend	0.017	0.004	0.006
	(0.001)	(0.000)	(0.001)
Trend*Skill intensity			0.02
			(0.005)
R square	0.96	0.94	0.97
Sample size	276	276	552

Notes: Weighted regression.

sample of 46 goods. $t * z_i$ indicates the interaction between skill intensity and a time trend. The results in the last column of Table 2.3 indicate that there is a steeper upward trend in income elasticities for the more skill-intensive goods.

2.6 Conclusions

In this paper I have claimed that the shift in relative skill demand does not need to be attributed exclusively to skill-biased technical change or trade. The shift in relative skill demand can be at least partially explained by an education effect that increases the demand of skill-intensive products. If more skilled workers spend a higher percentage of their income on skill-intensive goods, then an exogenous increase in the relative skill supply can induce a shift in relative skill demand. A related mechanism predicts that product demand is endogenous to an increase in income inequality. If richer consumers, keeping education constant, tend to consume more skill-intensive goods, then an increase in income inequality will shift product demand towards skill-intensive products and this will increase income inequality further.

I have built a simple general equilibrium model to explore the relationship between wage inequality and the skill ratio when preferences are non-homothetic. In the empirical part of this paper, I have matched data on consumption to data on industry skill intensity. I have shown that college graduates, keeping income constant, tend to spend a larger proportion of their income on skill-intensive goods. But also richer consumers, keeping education constant, tend to consume more skill-intensive goods. Both these results are robust to different measures of skill intensity. I have used Input-Output tables to take into account the contribution of intermediate inputs and import penetration in the skill intensity of final goods. A simple calibration of the model has suggested that the estimated income elasticities can explain around 3% of the total increase in relative skill demand in the UK from 1982 to 1997. Finally, I have extended the model to explain wage inequality within educational groups and labor demand shifts within industries. I have also offered an indirect empirical test of this extension of the model which indicates that income elasticities of the consumption goods have increased over time.

2.7 Appendix: Data and Tables

The data used in this paper come from the Family Expenditure Survey 1982-1997 for consumption data and from the Labour Force Survey 1993-1997 for industry skill intensity data. The main aim is to consider the relationship between income elasticities of consumption goods and the skill intensity of their manufacturing industry. This requires matching the FES data to the LFS data.

The aggregation of FES data into the 46 consumption items considered in this paper follows a rather obvious procedure. For reasons of space, the exact procedure can be provided upon request. The only items not considered in the aggregation are cars and housing and other very minor expenditures such as TV licence and car tax and insurance which did not have any obvious industry match. Total expenditure is calculated as the sum of the 46 items considered, excluding cars and housing. The price series were provided by the Office of National Statistics. The level of aggregation was kept at the most disaggregated level possible. When the consumption items were aggregated at a higher level, the corresponding price series were constructed as a weighted average of their basic components.

The skill intensity of the 46 industries considered is calculated on pooled LFS data 1993-1997. The industry skill intensity is defined as the ratio of workers with a degree-level qualification over the total number of workers. The Input-Output tables used to account for intermediate inputs and import penetration are the industry-by-industry domestic use matrices at basic prices for the UK in 1995. The tables are available at www.statistics.gov.uk.

Table 2.4: The Consumption Item-Industry Match

Consumption Item	SIC 1992 code	Industry name
Food		
Bread and biscuit	15.81+15.82	Bread and biscuit manufacture
Meat	15.1	Meat production
Fish	15.2	Fish processing
Edible oils and fats	15.4	Oils and fats manufacture
Milk products	15.5	Dairy products
Soft drinks	15.98	Soft drinks production
Sugar and sweets	15.83+15.84	Sugar and sweets manufacture
Fruit and vegetables	15.3	Fruit and vegetables
Food eaten out	55	Restaurants and take-away
Alcohol		
Beer	15.96+15.97	Beer production
Wine	15.93	Wine production
Spirits	15.91+15.92	Alcoholic drinks distilling
Tobacco	16	Tobacco products
Home energy		
Electricity bill	40.10	Electricity generation
Gas bill	40.2	Gas production supply
Household goods		
Furniture	36.1	Wood furniture
Home furnishings	36.15	Soft furnishings manufacture
Domestic electrical appliances	29.71	Domestic electrical appliances manufacure
Other domestic appliances	29.72	Domestic non electrical appliances manufacture
Household consumables	24.1+24.2	Pesticides and detergents manufacture
Household services		
Postage	64.1	Post services
Phone bill	64.2	Telecommunications
Domestic help	93.05	Domestic service activities
Repairs	52.7	Repairs to personal and household goods

Table 2.4: continued

Consumption Item	SIC 1992 code	Industry name
Clothing		
Men's and women's clothing	17+18	Textile manufacturing
Footwear	19.3	Footwear
Private transport		
Petrol	23.2	Mineral oil refining
Motor vehicle maintenance	50.2+50.4	Maintenance and repair of motor vehicles
Fares		
Bus fares	60.2	Road passenger transport
Rail fares	60.1	Transport via railways
Other fares	62.1+62.2	Air transport
Personal goods and services		
Personal articles	19.1+19.2, 36.2+36.3	Luggage, jewellery and musical instruments
Soap and toiletries	24.5	Soap and toilet preparations
Drugs	24.4	Pharmaceuticals
Hairdressing	93.02	Hairdressing
Leisure goods		
Records	22.3	Reproduction of recorded media
Books	22.1+22.2	Printing and publishing
Toys	36.5	Toys production
Domestic electronic appliances	32	Electronic equipment manufacture
Leisure and other services		
Holidays in UK	55.1+55.2	Hotels and provision of lodgings
Entertainment	92.1 to 92.7	Recreational activities
Subscriptions to organisations	91.1 to 91.3	Membership organisations
Professional services fees	74.1 to 74.8	Professional services
Bank charges	65.1+65.2	Financial intermediation
Health expenditure	85.1	Human health activities
Education expenditure	80	Education

Table 2.5: Industry Skill Intensity

SIC 1992 code	Industry name	Skill 1	Skill 2	Skill 3
93.02	Hairdressing	0.010	0.188	0.170
19.3	Footwear	0.019	0.123	0.172
36.15	Soft furnishing manufacturing	0.020	0.086	0.081
93.05	Domestic help	0.022	0.188	0.170
50.2+50.4	Maintenance of motor vehicles	0.023	0.126	0.119
15.1	Meat production	0.025	0.062	0.065
15.2	Fish processing	0.029	0.084	0.084
55	Restaurants and take-away	0.031	0.135	0.154
60.2	Road passenger transport	0.032	0.142	0.141
64.1	Post services	0.035	0.169	0.165
36.1	Wood furniture	0.042	0.086	0.081
17+18	Textile manufacturing	0.043	0.105	0.124
15.81+15.82	Bread and biscuits manufacturing	0.044	0.107	0.104
55.1+55.2	Hotels and lodgings	0.047	0.135	0.154
29.71	Domestic electrical appliances manuf	0.050	0.121	0.134
29.72	Domestic non electrical appliances manuf	0.051	0.121	0.134
52.7	Repairs of personal and household goods	0.053	0.151	0.147
15.98	Soft drinks production	0.064	0.117	0.113
16	Tobacco production	0.071	0.140	0.199
15.5	Dairy products	0.072	0.075	0.073
15.3	Fruit and vegetables	0.082	0.084	0.084
15.83+15.84	Sugar and sweets	0.084	0.092	0.097
19.1+19.2, 36.2+36.3	Luggage, jewellery and musical instruments	0.092	0.091	0.164
60.1	Railways	0.092	0.105	0.106
15.4	Oils and fats manufacture	0.100	0.075	0.070
15.96+15.97	Beer production	0.113	0.124	0.173
36.5	Toys production	0.119	0.120	0.175
24.5	Soap and toiletries	0.133	0.144	0.182
22.1+22.2	Printing and publishing	0.139	0.134	0.133
32	Domestic electronic appliances	0.143	0.127	0.180
40.2	Gas supply	0.147	0.196	0.174
64.2	Telecomunications	0.156	0.161	0.159
40.10	Electricity generation	0.159	0.150	0.144
15.93	Wine production	0.166	0.124	0.173

Table 2.5: continued

SIC 1992 code	Industry name	Skill 1	Skill 2	Skill 3
65.1+65.2	Financial intermediation	0.167	0.189	0.197
62.1+62.2	Air transport	0.168	0.194	0.232
85.1	Human health activities	0.175	0.184	0.177
15.91+15.92	Alcoholic drinks distilling	0.189	0.124	0.173
92.1 to 92.7	Entertainment	0.202	0.202	0.206
24.1+24.2	Pesticides and detergents	0.206	0.149	0.150
22.3	Reproduction of recorded media	0.235	0.134	0.133
23.2	Mineral oil refining	0.238	0.207	0.235
91.1 to 91.3	Membership organisations	0.267	0.213	0.190
74.1 to 74.8	Professional services	0.294	0.228	0.230
24.4	Pharmaceuticals	0.301	0.195	0.289
80	Education	0.538	0.232	0.233

Notes: Skill 1 is calculated from LFS data 1982-1997 as the share of workers in the industry with a degree-level qualification. Skill 2 is calculated using the 1995 industry-by-industry Input-Output table. Skill 3 is calculated using the Input-Output tables weighted for import penetration. See the text for more details.

Table 2.6: Sample Means. FES 1982-1998.

	Full Sample		20th percentile of net income distrib.		80th percentile of net income distrib.	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Number of families	107856		21577		21577	
Age of head	50.2		61.9		44.7	
Years of education of head	9.8		8.4		11.4	
Number of persons	2.5		1.4		3.2	
Number of children under 18	0.6		0.2		0.8	
Number of retired	0.4		0.7		0.1	
Income after tax	197.6	(166.2)	61.7	(15.8)	414.2	(243.6)
Average expenditure	145.5	(139.6)	53.3	(41.9)	244.7	(201.3)
Expenditure shares						
Food	0.23	(0.12)	0.31	(0.13)	0.16	(0.08)
Food eaten out	0.05	(0.05)	0.03	(0.05)	0.07	(0.05)
Alcohol	0.05	(0.07)	0.03	(0.07)	0.06	(0.06)
Tobacco	0.03	(0.06)	0.04	(0.07)	0.02	(0.03)
Home energy	0.09	(0.07)	0.16	(0.10)	0.05	(0.04)
Household goods	0.08	(0.10)	0.07	(0.09)	0.09	(0.11)
Household services	0.05	(0.06)	0.07	(0.06)	0.06	(0.06)
Clothing	0.07	(0.08)	0.05	(0.08)	0.09	(0.09)
Private transport	0.12	(0.14)	0.03	(0.08)	0.11	(0.09)
Fares	0.02	(0.05)	0.02	(0.05)	0.03	(0.06)
Personal goods and services	0.04	(0.05)	0.04	(0.05)	0.05	(0.06)
Leisure goods	0.05	(0.06)	0.04	(0.05)	0.06	(0.07)
Leisure and other services	0.05	(0.06)	0.05	(0.06)	0.06	(0.08)

Notes: Income after tax and average expenditure are expressed in weekly equivalents in 1987 pounds.

Table 2.7: The Almost Ideal Demand System

	Share Equations						
	(1) Food	(2) Food out	(3) Alcohol	(4) Tobacco	(5) Energy	(6) Household goods	(7) Household services
Constant	0.611	0.031	0.198	0.248	0.323	-0.049	-0.123
	(0.047)	(0.016)	(0.010)	(0.017)	(0.025)	(0.017)	(0.014)
Sex of head	-0.006	-0.009	-0.040	-0.014	0.014	0.015	0.017
	(0.009)	(0.003)	(0.001)	(0.003)	(0.005)	(0.003)	(0.002)
Age of head	0.001	-0.001	-0.001	-0.001	0.001	-0.000	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Education dummy	0.001	-0.005	-0.015	-0.014	0.002	-0.007	0.017
	(0.011)	(0.003)	(0.001)	(0.004)	(0.006)	(0.003)	(0.003)
N of adults	0.033	-0.008	0.003	0.015	0.002	-0.009	-0.019
	(0.008)	(0.002)	(0.001)	(0.003)	(0.004)	(0.002)	(0.002)
N of children under 18	0.033	-0.009	-0.016	0.000	0.007	-0.002	-0.002
	(0.004)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Total expenditure	-0.107	0.029	0.005	-0.038	-0.058	0.022	0.022
	(0.011)	(0.003)	(0.002)	(0.004)	(0.006)	(0.003)	(0.003)
Own price	-0.086	-0.075	-0.002	0.013	0.115	0.037	0.059
	(0.143)	(0.064)	(0.043)	(0.022)	(0.043)	(0.074)	(0.043)
Homogeneity t value	0.592	7.327	10.551	0.454	0.154	4.591	5.976

Table 2.7: continued

	Share equations					
	(8) Clothing	(9) Personal goods and services	(10) Private transport	(11) Fares	(12) Leisure goods	(13) Leisure services
Constant	-0.066	-0.097	0.047	0.042	-0.014	-0.153
	(0.016)	(0.015)	(0.012)	(0.011)	(0.014)	(0.018)
Sex of head	0.024	0.020	-0.030	0.008	-0.005	0.006
	(0.003)	(0.002)	(0.002)	(0.001)	(0.002)	(0.003)
Age of head	-0.000	0.000	-0.000	-0.000	0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Education dummy	-0.014	0.000	0.000	0.008	0.005	0.021
	(0.003)	(0.003)	(0.007)	(0.001)	(0.002)	(0.003)
N of adults	0.002	-0.006	0.011	0.000	-0.007	-0.016
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
N of children under 18	0.002	-0.003	-0.006	-0.006	-0.003	0.004
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Total expenditure	0.033	0.025	0.013	0.006	0.018	0.031
	(0.004)	(0.003)	(0.002)	(0.001)	(0.002)	(0.004)
Own price	0.121	0.009	0.123	0.170	0.015	0.036
	(0.034)	(0.078)	(0.039)	(0.063)	(0.073)	(0.067)
Homogeneity t value	6.637	0.162	11.315	0.279	11.720	1.286

Symmetry: $\zeta_{ij} = \zeta_{ji}$, $\chi^2_{[78]} = 634.92$

Notes: Standard errors in parenthesis. Cross-equation price symmetry constrained the estimates. Total expenditure is treated as endogenous and is instrumented using total net income. The other variables included in the estimation are age, age square, sex and years of education of the head of household, the total number of children under 18 years of age, the total number of adults, the price series of all thirdteen commodity groups and regional dummies. The coefficients on the price series (except for the own price) and the regional dummies are not reported for reasons of space. The homogeneity t value is a t ratio test of zero-degree price homogeneity equation-by-equation. The symmetry test is a joint χ^2 test of cross-equation price symmetry and price homogeneity. Estimation Sample: January 1987-December 1997, number of observations 107856.

Table 2.8: Instrumental Variable Estimates of Education and Income Elasticities

Consumption Item	Education elasticity	S. E.	Income elasticity	S.E.	Expenditure share
Hairdressing	-0.003	(0.000)	1.433	(0.000)	0.012
Footwear	-0.007	(0.000)	1.136	(0.000)	0.017
House furnishing	-0.012	(0.000)	1.557	(0.000)	0.012
Domestic help	0.040	(0.000)	2.891	(0.000)	0.011
Maintenance	0.022	(0.000)	1.792	(0.000)	0.020
Meat	-0.007	(0.000)	0.480	(0.000)	0.076
Fish	0.004	(0.000)	0.551	(0.000)	0.011
Food eaten out	-0.006	(0.000)	1.672	(0.000)	0.059
Bus fares	0.018	(0.000)	0.146	(0.000)	0.013
Postage	0.039	(0.000)	0.813	(0.000)	0.004
Furniture	-0.007	(0.000)	1.894	(0.000)	0.011
Men's and women's clothing	-0.011	(0.001)	1.550	(0.000)	0.064
Bread and biscuits	0.001	(0.000)	0.394	(0.000)	0.041
Holidays	-0.001	(0.001)	2.593	(0.000)	0.023
Domestic electrical appliances	-0.009	(0.000)	1.254	(0.000)	0.012
Domestic non electrical appliances	0.011	(0.000)	1.661	(0.000)	0.013
Repairs	0.018	(0.000)	1.633	(0.000)	0.005
Soft drinks	0.004	(0.000)	0.542	(0.000)	0.021
Tobacco	-0.029	(0.001)	-0.222	(0.000)	0.045
Milk products	0.006	(0.001)	0.452	(0.000)	0.037
Fruit and vegetables	0.010	(0.000)	0.529	(0.000)	0.047
Sugar and sweets	-0.003	(0.000)	0.551	(0.000)	0.014
Personal articles	0.008	(0.000)	1.870	(0.000)	0.009
Rail fares	0.083	(0.000)	1.690	(0.000)	0.005
Edible oils and fats	0.005	(0.000)	0.343	(0.000)	0.008
Beer	-0.027	(0.000)	0.792	(0.000)	0.039
Toys	0.000	(0.000)	1.116	(0.000)	0.006
Soap and toiletries	-0.010	(0.000)	1.061	(0.000)	0.016
Books	0.017	(0.000)	0.931	(0.000)	0.038
Domestic electronic appliances	-0.009	(0.000)	1.742	(0.000)	0.007
Gas bill	0.000	(0.000)	0.541	(0.000)	0.042
Phone bill	0.013	(0.001)	0.730	(0.000)	0.034
Electricity bill	-0.002	(0.000)	0.218	(0.000)	0.055
Wine	0.033	(0.000)	2.329	(0.000)	0.010

Table 2.8: continued

Consumption Item	Education elasticity	S. E.	Income elasticity	S.E.	Expenditure share
Bank charges	0.013	(0.000)	1.621	(0.000)	0.001
Other fares	0.112	(0.000)	2.792	(0.000)	0.001
Health expenditure	-0.003	(0.000)	2.151	(0.000)	0.005
Spirits	-0.019	(0.000)	1.428	(0.000)	0.010
Entertainment	-0.018	(0.000)	1.281	(0.000)	0.025
Household consumables	-0.005	(0.000)	0.710	(0.000)	0.018
Records	0.008	(0.000)	1.512	(0.000)	0.006
Petrol	0.000	(0.000)	1.376	(0.000)	0.054
Subscriptions to organisations	0.045	(0.000)	2.638	(0.000)	0.003
Professional sevices fees	-0.020	(0.000)	2.430	(0.000)	0.001
Drugs	0.013	(0.000)	0.655	(0.000)	0.008
Education	0.108	(0.001)	2.953	(0.000)	0.007

Notes: Unconstrained estimates of system 2.15 in the text. Terms in total expenditure instrumented by total net income.

Chapter 3

Firm Heterogeneity in Capital/Labor Ratios and Wage Inequality

3.1 Introduction

Changes in wage inequality reflect changes in both price and quantities of workers' observable characteristics and changes in residual wage inequality. Juhn, Murphy and Pierce (1993) claim that roughly 60% of the increase in the 90-10 log wage differential can be accounted for by changes in the residuals' distribution, i.e. in unobserved attributes of workers belonging to the same demographic or educational group.

While there are already many studies on increasing wage dispersion, much less research has been devoted to the increasing dispersion of capital intensity across firms. This paper is divided into three parts. The first part is an analysis of dispersion of equipment/labor ratios across firms. The second part provides some empirical evidence of the link between the dispersion of wages across workers and the dispersion of capital intensity across firms. In the third part of the paper, I propose a theory of residual wage inequality based on the increased dispersion of capital intensities across firms.

In the first part of this paper I use panel data on individual firms (Compustat) from 1970 to 1992 to document the increase in the variance of equipment/labor ratios over time. I focus on equipment capital since equipment is complementary to skills and differential stocks of equipment capital across firms may be correlated with the demand for skills. The results show that the log standard deviation across firms of equipment/labor ratios increased by about 12% from 1970 to 1992. The rise in dispersion of equipment/capital occurred both between and within industry and is concentrated in the mid-late eighties.

In the second part of the paper, I study the correlation between the increasing dispersion of wages across workers and the increasing dispersion of capital intensities across firms. The data on wages are from March CPS and five waves of the Displaced Workers Survey (DWS). The reason to study displaced workers is twofold. First, in the DWS there is a panel dimension that allows one to control for unobserved heterogeneity, secondly displaced workers are less likely to select themselves in the best paying industries or firms. This implies that the capital intensity premium is more likely to reflect "true" firms' effects rather than sorting. I match Compustat data on firms' capital intensity to CPS and DWS data on wages at the industry-year level. The results indicate that a 1% increase in the average industry capital intensity is associated with a 0.11% increase in the average weekly wage in the CPS and with a 0.13% increase in the DWS. Consistently with the literature on inter-industry wage differentials, there is no increase in the cross-industry effect of capital intensity on wages over time. More importantly for the purpose of this paper, within-industry dispersion of equipment/labor ratios appears to be related to within-industry dispersion of wages both in the CPS and in the DWS. Both the variance of equipment/labor ratios across firms and the variance of wages across workers have increased over time. The association between the dispersion of equipment/labor ratios across firms and the dispersion of wages across workers holds within industry even after controlling for time dummies.

In the theoretical part I build a model that explains the rise in the variance of wages in view of the evidence on the increasing variance across firms of the equipment/labor ratios. The intuitive idea is simple. The two main ingredients of the model are non-competitive labor market and random matching of identical workers to two types of firms. In a non-competitive labor market, workers' wages are linked to their individual output and therefore to the capital they are matched with. Identical workers are matched randomly to two types of firms that co-exist in equilibrium. "Good" firms have high job creation costs and are more productive, "bad" firms have low job creation costs but are less productive. "Good" firms invest more in equipment capital, "bad" invest less. As the relative price of equipment capital falls, "good" firms with high equipment invest more and increase their productivity relative to "bad" firms. Wages for identical workers are more dispersed as a consequence of a higher dispersion of capital intensities. This feature of the model that explains the increase in wage inequality with increasing dispersion of capital intensities across firms is consistent with recent evidence that indicates that the bulk of the increase in wage inequality took place between plants rather than within plants (Dunne et al., 2002).

3.1.1 A Brief Overview of the Related Literature

Work on dispersion of capital/labor ratios is fairly rare in the literature. Caselli (1999) uses industry-level data to document the increase in the 90-10 log differential of capital intensities across four-digit manufacturing industries. In this paper, I use data on individual firms to study the increasing dispersion of equipment/labor ratios across firms.

The empirical part of this paper is connected to the literature that uses establishment-level data to study the dispersion of wages and productivity across plants. Davis and Haltiwanger (1991) and Dunne et al. (2002) show that the increase in wage dispersion is mainly a between-plant phenomenon. Using both individual wage data and establishment-level data they decompose the total variance of wages in three components: between-industry, between-plant and within-plant. The results show that most of the increase in wage dispersion is due to between-plant dispersion within the same industries. Related work by Doms et al. (1997) finds that an important factor in explaining wage dispersion across plants is the differential adoption of technologies. Dunne et al. (2002) find that between-plant measures of wage and productivity dispersion have increased over time and are strongly positively correlated. They also find that a significant fraction of the rising dispersion of wages and productivity is associated with changes in the distribution of computer investment across plants.

Unlike the case of wages and computers, however, there has been little analysis of the changes in the distribution of capital intensity over time and of the association between wages and capital intensity.[1] All previously cited papers use establishment-level data limited to manufacturing. In this paper, I use Compustat data to study the evolution of the distribution of capital intensity over time across firms in all industries.

In the theoretical part, I propose a model of residual wage inequality based on the increased dispersion of capital intensities across firms. There are many theories of within-group wage inequality built on the complementarity between unobservable skills and new technologies.

[1] Although in the published version, Dunne at al. (2002) focus on the relationship between wage and computer investment across plants, in the Working Paper version, they also study the relationship between capital intensity and wages.

Most models, however, interpret unobservable skills as ex-ante differences in ability across individuals. The model of residual wage inequality presented here is not based on ex-ante differences in unobservable ability. In this model, identical workers are matched to different firms.

The mainstream view in the literature is that within-group wage inequality is the result of the increase in the price of unobserved ability. Acemoglu (1999) builds a model where identical firms search for workers with different abilities. Skill-biased technical change induces firms to switch from a pooling equilibrium where one job fits everyone, to a separating equilibrium where different jobs for different abilities are created. Caselli (1999) suggests that a technological revolution occurs when a new type of machine is introduced. Operating the new machine requires a new type of skill. Workers have different costs of learning the new skill and those with lower learning costs can get a higher wage premium. Galor and Maov (2000) claim that ability helps workers to adapt to the new work organization, therefore big organizational changes raise the return to ability. Kremer and Maskin (2000) build a model where production requires many complementary tasks. Wage inequality increases as workers with different skills are increasingly segregated across plants. Segregation occurs because of the complementarity of tasks and the exogenous force that sets the mechanism in motion is the increasingly dispersed distribution of skills across workers.

Although these models provide explanations through which technology might affect inequality, they are all based on ex-ante differences in ability. Models based on fixed ex-ante differences in ability come under severe criticism. Unobserved ability is a permanent characteristic of the individual, therefore, all models based on differences in innate ability imply that the rise in residual wage inequality should be accounted for by the rise in the variance of the persistent component of individual earnings. Gottschalk and Moffitt (1994) and the subsequent literature show that this is not the case and earnings instability (the variance of the transitory component) explains much of the total increase.

On the basis of this criticism, Violante (2002) and Hornstein, Krusell and Violante (2002) propose a model based on ex-ante identical workers where wage inequality is due to an acceleration of technical change. In each period, a new vintage technology embodied in new machines spreads in the economy. Workers are ex-ante identical and have vintage specific skills. The degree of transferability of these skills between different vintages is proportional to the productivity difference between the machines. An acceleration in technical change increases the productivity differences across successive vintages and decreases the degree of transferability of skills. As a result, wage inequality across identical workers matched to different vintages of machines increases.

The models of Acemoglu (1999), Caselli (1999), Violante (2002) and Hornstein, Krusell and Violante (2002) are all consistent with an increasingly dispersed distribution of capital intensity. My model is built around an increasingly dispersed distribution of capital intensity. Like Violante (2002), my model does not rely on ex-ante differences in abilities. Unlike Violante (2002), my model is not based on a technological acceleration and the reduction in the transferability of skills. In my model, a decline in the relative price of equipment capital increases the dispersion of capital intensities across firms, thus raising wage inequality.

The model presented in this paper is related to the literature that explains wage dispersion among equivalent workers within a search framework. Some of these models such as Montgomery (1991), Acemoglu (2001) and Pissarides (1994) consider firms with different job-creation costs and derive wage dispersion as a consequence of cost dispersion. My model is closest to Acemoglu (2001). He also considers a search model with different job-creation costs across firms but he focuses on the effect of more generous unemployment insurance and minimum wage on the composition of jobs.

Finally, an increasingly dispersed distribution of equipment/labor ratios can have an effect on wage differentials across identical workers as long as the market is not competitive and firm effects are important in determining the wage. This paper is therefore related to the literature on inter-industry wage differentials. There is a controversy on the importance of unobserved person or firm effects in explaining inter-industry wage differentials. Krueger and Summers (1988) and Gibbons and Katz (1992) claim that the differentials cannot be explained by person effects. Murphy and Topel (1990) claim that person effects are the primary explanation. Using employer-employee matched data, Abowd, Kramarz and Creecy (2003) estimate that person and firm effects can each account for approximately 50% of the inter-industry wage differentials in the US.

The structure of the paper is as follows. In the next section I document the increase in the variance of capital/labor ratios between and within industry over time. In section 3, I relate the variance of wages to the variance of capital/labor ratios. In section 4, I present the model that interprets the evidence. Section 5 presents the conclusions.

3.2 Firm Equipment/Labor Ratios

In this section I examine changes over time in the cross-firm distribution of capital/labor ratios. I use Compustat data from 1970 to 1992. Compustat is a dataset of US companies listed on the stock market. They represent less than 1% of the total number of companies in the US but more than 50% of total employment. Figure 3-1 plots the employment-weighted standard deviation of log equipment/labor across firms in each year. To build the equipment/labor ratio, I use information on equipment (COMPUSTAT 156) and on the number of employees

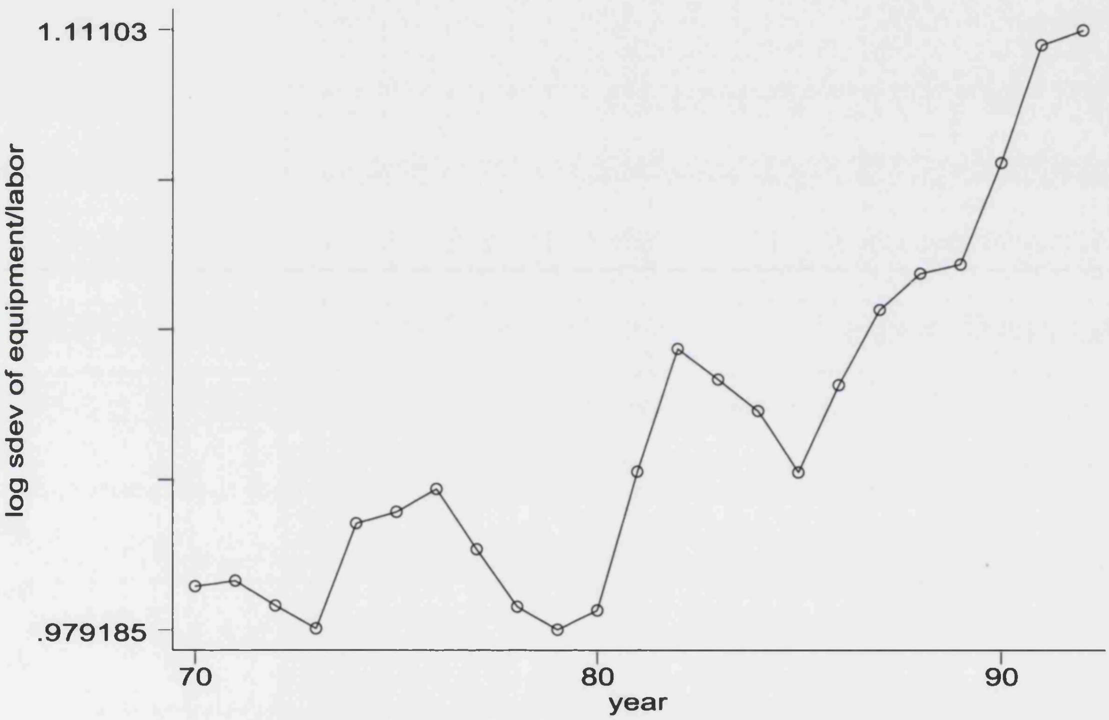

Figure 3-1: Employment weighted log standard deviation of equipment/labor ratios. Source: Compustat Industrial Data.

(COMPUSTAT 129). Equipment represents the capitalized cost of machinery and equipment used to generate revenue minus accumulated depreciation. Equipment is deflated using the 1-digit industry specific deflators form the Bureau of Economic Analysis and is expressed at the real value in 1992.

Figure 3-1 shows an increase in the employment-weighted standard deviation of log equipment/labor ratios across firms of 12.3% between 1970 and 1992.[2] The increase in dispersion of equipment/labor ratios starts in 1980 and continues through the '80s. This paper is concerned with the increasing dispersion of equipment/labor ratios facing workers, hence the log standard deviation of equipment/labor ratios is employment-weighted.

Figure 3-2 shows that the divergence in equipment/labor ratios is pervasive and not limited to part of the distribution. Figure 3-2 plots the change in log equipment/labor ratios from 1970-73 to 1989-92. The changes are calculated for each fifth percentile of the cross-sectional distribution of firms in 1989-92 and in 1970-73. Each point in Figure 3-2 is calculated as $[p_{89-92}(\log \frac{e}{l}) - p_{70-73}(\log \frac{e}{l})]$ where p is each fifth percentile of the employment-weighted cross-sectional distribution in years 1989-92 and years 1970-73. The change in real equipment/labor ratios at the bottom 10th percentile of the distribution is 55%, at the top 90th percentile of the distribution is 103%. The picture exhibits a concave shape with inequality rising more at the bottom 50% of the distribution.

The four charts in Figure 3-3 decompose the rise in equipment/labor dispersion in four periods. I look at changes between each five-year period. The first chart compares log equipment/labor ratios by percentile between the periods 1970-74 and 1975-79. The changes at each percentile are normalized by comparing the change at each percentile with the change in mean

[2]The results do not change if I exclude from the sample the new firms that are included in the sample after 1974.

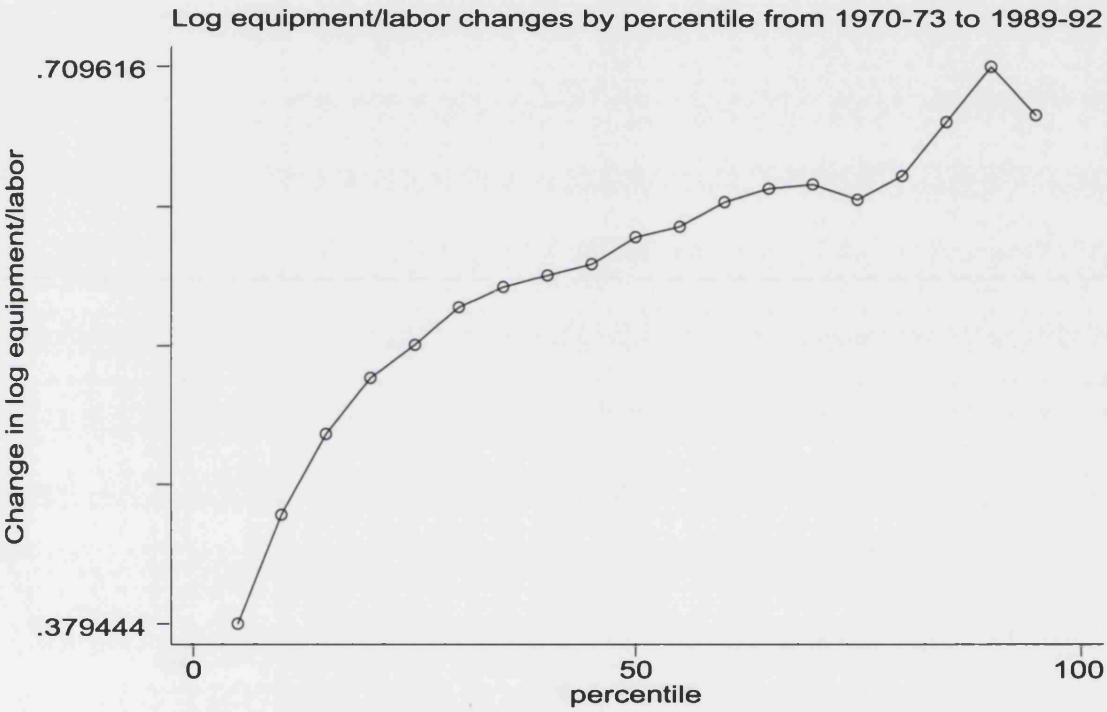

Figure 3-2: Log equipment/labor ratio changes by percentile between 1970-1973 and 1989-1992.

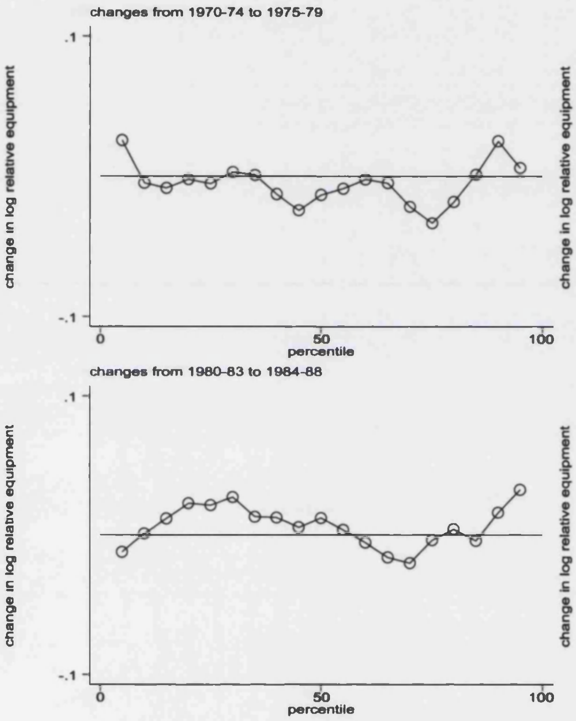

Figure 3-3: Changes in the log equipment/labor ratio by percentile. Changes relative to the period mean. Four periods.

log equipment/labor ratios. Each point in Figure 3-3 is calculated as $[p_t(\log \frac{e}{l}) - p_{t-1}(\log \frac{e}{l})]$ $-[E_t(\log \frac{e}{l}) - E_{t-1}(\log \frac{e}{l})]$ where p is each fifth percentile of the employment-weighted log distribution in period t. E is the employment-weighted average. The four charts show that from 1970-74 to 1975-79 and from 1980-83 to 1984-88 equipment/labor ratios at each percentile moved more or less in line with the mean. The top right and bottom right charts in Figure 3-3 show that the increase in dispersion of equipment/labor ratios across firms took place in the early and late eighties. The increase in dispersion is concentrated at the bottom of the distribution in the early eighties (top right chart) with the bottom percentiles left much behind relative to the mean. The increase in dispersion slowed down somewhat in the mid-eighties (bottom left chart) but continued from the mid-eighties to the nineties (bottom right chart). In the late eighties (bottom right chart) the bottom percentiles grew about 10% less than the overall mean, the top percentiles grew about 10% more than the mean.

3.2.1 Between and Within Industry Dispersion

In this subsection I look at the increase in the dispersion of equipment/labor ratios between and within industry and size groups.

Table 3.1 and 3.2 report log equipment/labor differentials across industry and across size class. Table 3.1 and 3.2 report the mean capital intensity (column one), the within-group standard deviation (column two) and the frequency in the sample (column three). The mean log equipment/labor differentials by industry and size group (first column Table 3.1 and 3.2) are defined as the difference between the average log equipment/labor ratio within the group and the overall average log equipment/labor ratio. Table 3.1 reports time series averages and Table 3.2 reports time series changes between 1970-73 and 1989-92. I consider four-year groups at the beginning and at the end of the sample to minimize measurement error.

Agriculture and construction are dropped due to their small sample size. The sectors with the highest average equipment/labor ratios (Table 3.1, column one) are mining and transportation and utilities. These two sectors have much higher equipment/labor ratios than the overall mean. The lowest capital-intensive industries are wholesale and retail trade. The heterogeneity of log equipment/labor ratios across firms of the same industry (Table 3.1, column two) is higher within mining, transportation and utilities, and finance. Equipment/labor ratios are higher in small companies with less than 100 workers and in very large companies with more than 4000 workers. The differences across size groups are less impressive than the differences across industry groups. Differences are larger between small and medium-sized firms. Small firms have more heterogeneous equipment/labor ratios than large firms. The heterogeneity of equipment/labor ratios within size classes decreases with size.

Looking at the time series changes in Table 3.2, the average equipment/labor ratio (Table 3.2, column one) in mining, transportation, retail and business and professional services increased less than the overall average between 1970 and 1992. Wholesale and finance gained ground relative to the mean. Between-firm equipment/labor dispersion (Table 3.2, column two) rose in all sectors except for mining, transportation and personal and business services. The highest increases occurred in manufacturing, wholesale trade and finance. The differentials in equipment/labor ratios across size classes increased dramatically over time. The difference between firms with less than 100 workers and firms with more than 4000 workers increased by 50 log points between 1970 and 1992. Between-firm dispersion in equipment/labor ratios increased within all size classes except for companies with less than 100 workers which became relatively less capital intensive over time and much more homogenous.

Finally, the last column of Table 3.2 indicates a sizeable shift from manufacturing to business and professional services and a shift from large firms of more than 1000 workers to

	Mean log equipment/labor differential	Between-firm standard deviation	Frequency
Industry			
Mining	1.07	1.26	1.45
Durable manufacturing	0.00	0.87	40.07
Non durable manufacturing	0.30	0.97	21.82
Transportation/utilities	1.16	1.32	5.12
Wholesale	-0.49	0.97	4.89
Retail	-0.84	0.66	10.79
Finance	-0.26	1.33	3.15
Other Services	-0.13	1.28	12.69
Size Class			
1-100 employees	0.11	1.30	14.31
100-500	-0.03	1.12	23.32
500-1000	-0.01	1.09	13.12
1000-4000	-0.07	1.07	24.93
4000+	0.04	1.03	24.32

Notes: Time series averages. Mean log equipment/labor differentials and between firm dispersion by industry and size groups.

Table 3.1: Time series averages. Log equipment/labor ratios

smaller firms.

To characterize the contribution of observable and unobservable characteristics to the changes in the equipment/labor distribution over time, I use the distribution accounting methodology of Juhn, Murphy and Pierce (JMP).[3] The observable characteristics considered are industry and size. The JMP decomposition can be used to quantify the effects of changes in the observables and unobservables in all parts of the distribution. Table 3.3 reports the

[3]The JMP decomposition decomposes the regression $\log k_{it} = X_{it}\beta_t + u_{it}$, where $\log k_{it}$ is log equipment/labor ratio in firm i in period t and u_{it} can be written as $u_{it} = F_t^{-1}(\vartheta_{it})$, into $\log k_{it}^1 = X_{it}\overline{\beta} + \overline{F^{-1}}(\vartheta_{it})$ and $\log k_{it}^2 = X_{it}\beta_t + \overline{F^{-1}}(\vartheta_{it})$. We can attribute the changes in $\log k_{it}^1$ to changes in industry and size composition, the changes in $\log k_{it}^2 - \log k_{it}^1$ to changes in inter-industry and size specific equipment/labor differentials and the changes in $\log k_{it} - \log k_{it}^2$ to changes in the distribution of residuals.

	Mean log equipment/labor differential	Between-firm standard deviation	Frequency
Industry			
Mining	-0.28	-0.13	-0.14
Durable manufacturing	0.02	0.08	-6.05
Non durable manufacturing	0.00	0.07	-4.95
Transportation/utilities	-0.27	-0.07	3.45
Wholesale	0.48	0.21	-2.20
Retail	-0.32	0.01	1.30
Finance	0.30	0.40	0.90
Other Services	-0.07	-0.11	9.70
Size Class			
1-100 employees	-0.49	-0.22	15.40
100-500	-0.08	0.09	5.36
500-1000	0.04	0.22	-5.56
1000-4000	0.05	0.29	-10.11
4000+	0.01	0.25	-5.09

Notes: Time series changes between 1970-73 and 1989-92. Changes in log equipment/labor relative to the mean log change and changes in between- firm dispersion by industry and size groups.

Table 3.2: Time series changes. Log equipment/labor ratio

Inequality measure	Total change	Observable quantities	Observable betas	Unobservable
Standard deviation	0.12	0.08	0.00	0.04
90-10 differential	0.32	0.09	0.02	0.21
90-50 differential	0.13	0.08	0.01	0.04
50-10 differential	0.19	0.09	0.00	0.10

Notes: The regression specification underlying the decomposition contains 2-digit industry effects and a quartic in size.

Table 3.3: Juhn, Murphy and Pierce decomposition.

results of the decomposition for various inequality measures.

The 90-10 log differential rose from 2.46 in 1970 to 2.78 in 1992 (or 13%). Changes in industrial and size composition over twenty years (holding fixed the equipment/labor differential associated with industry and size) contributed to 28% (0.09/0.32) of the total increase in the 90-10 log differential. Changes in the industry and size differentials alone (holding fixed the industry and size composition) contributed to 6% (0.02/0.32) of the total increase of the 90-10 log differential. Changes in composition and differentials together account for 34% of the total increase of the 90-10 differential. The remaining 66% of the total increase of the 90-10 differential is explained by unobservables, i.e. by the rise in within industry-size groups dispersion. The JMP results indicate that most of equipment/labor ratio dispersion is not due to composition changes.

Table 3.3 also reports the decomposition of time series changes in the 90-50 and 50-10 log equipment/labor differentials. Two important results stand out from the table. First, most of the increase in equipment/labor dispersion occurred in the bottom half of the distribution. Secondly, the contribution of observables to the increase in equipment/labor ratios across firms varies according to the inequality measure reported. The increase in between-size and between-industry inequality (changes in observable quantities and betas) accounts for approximately two thirds of the total increase in the standard deviation of equipment/labor ratios. The increase in between-group inequality accounts for less than half of the increase in the 50-10 ratio and explains more than two thirds of the increase in the 90-50 ratio. Apparently, the capital intensity gap between the 90th percentile of the distribution and the 50th percentile is much more understandable in terms of changes in industrial and size composition and their OLS coefficients than the gap between the 90th and the 50th percentile.

3.3 The Variance of Capital/Labor Ratios and Wage Inequality

In this section, I document the cross-industry correlation between firms equipment/labor ratios and wages from 1970 to 1992. First, I study the correlation between wages and average industry capital intensity, second, I look at the correlation between within-industry dispersion of wages and within-industry dispersion of capital/labor ratios.

The tendency of capital-intensive industries to pay higher wages has been documented by Katz and Summers (1989) in the context of inter-industry wage differentials. The correlation between within-industry dispersion of wages and within-industry dispersion of capital intensities is a novel point.[4] Unlike previous work, I study the relationship between individual wages and industry capital intensity over time. I match individual wages drawn from March CPS to average capital intensity at the industry-year level drawn from Compustat. I also extend the analysis to displaced workers. Displaced workers have been extensively used in the literature on inter-industry wage differentials.[5] The idea is that an exogenous displacement reduces the

[4] The working paper version of Dunne et al.(2002) contains some analysis of the correlation between wages and capital intensities over time in a panel of manufacturing firms.

[5] Krueger and Summers (1988), Gibbons and Katz (1992) and Neal (1995) have used the Displaced Workers Survey to study inter-industry wage differentials.

problem of sorting better workers into better paying industries and gives a better measure of the pure industry effect. Following the same reasoning, I investigate whether an increasing dispersion of wages for displaced workers is associated with an increasing dispersion of capital intensity across firms.

Figure 3-4 shows the log standard deviation of weekly wages and the employment-weighted log standard deviation of equipment/labor ratios. Log equipment/labor ratios are drawn from Compustat, log weekly wages are from March CPS. Wage and capital intensity dispersion have three characteristics in common. First the timing of the increase (Figure 3-1). Second the pervasiveness of the increase in dispersion (Figure 3-2). Third the fact that most of the increase is not due to composition changes but to within-group changes (Figure ??). In the following section, I formally investigate the relationship between wage and capital intensity dispersion.

3.3.1 The "Capital Intensity" Premium

I regress log weekly wages from March CPS on industry employment-weighted average log equipment/labor ratios from Compustat. The two datasets are matched at the one-digit industry-year level.

I restrict the March CPS sample to full-year, full-time workers (those working 35 or more hours per week and at least 40 weeks in the previous year) between the age of 20 and 60 at the time of the survey. I use March CPS data from 1971 to 1993 therefore covering earnings from 1970 to 1992. The sample is restricted to workers without allocated earnings, who earned at least $67 per week in 1982 dollars.[6]

[6] This selection of the March CPS is used in Katz and Autor (1999).

Figure 3-4: Log standard deviation of real weekly wages from March CPS. Employment-weighted log standard deviation of equipment/labor ratios from Compustat.

The regression is of the form:

$$\log w_{ijt} = \alpha + X_{it}\beta + \gamma \log(\frac{k}{l})_{jt} + \varepsilon_{ijt} \tag{3.1}$$

where $\log w_{ijt}$ is the wage of individual i at time t in industry j. X_{it} includes year and industry effects, a quadratic in age, years of education, sex, race and marital status dummies. $\log(\frac{k}{l})_{jt}$ is the employment-weighted average equipment/labor ratio in industry j at time t. Standard errors are clustered at the industry-year level. I consider the following industries: mining, durable manufacturing, non-durable manufacturing, transport and utilities, wholesale trade, retail trade, finance, other services. Agriculture and construction are dropped because of the low sample size of the year cells in Compustat. Workers in public administration are dropped as Compustat data on capital intensity cover only the private sector. Wages are deflated by the CPI, equipment is deflated using 1digit industry-specific deflators from the Bureau of Economic Analysis.

Table 3.4 shows the results of OLS estimation of equation 3.1 separately for the CPS and the DWS. The results show a positive relationship between industry capital intensity and weekly wages. The first row of Table 3.4 shows that a 1% increase in the industry capital intensity is associated with a 0.11% increase in the average weekly wage. The relationship between wages and capital intensity, controlling for year effects, is always positive and significant. This is the well-known result that more capital-intensive industries tend to pay higher wages. Equipment capital intensity and average wages are slightly negatively correlated within industry (Table 3.4, first and second row and third column), and their correlation is insignificant when I control for both industry and time effects (Table 3.4, fourth column). This result is consistent with the view that inter-industry wage differentials have not increased over time. The same results are obtained in the second row of Table 3.4 considering the years 1984-1992 of the CPS. This cut of the sample is used to compare the results with the Displaced Workers Survey.

3.3.2 The Displaced Workers Survey

In this section, I estimate equation 3.1 by using the Displaced Workers Surveys in years 1984, 1986, 1988, 1990 and 1992. The Displaced Workers Survey is a supplement to the January CPS in years 1984, 1986, 1988, 1990, 1992. The DWS asks whether the workers were displaced in the five years prior to the survey. It contains information about the previous and current wage, industry and occupation and information about a respondent's employment history in the previous 5 years.

There are two advantages to using the DWS: First, the DWS has a panel dimension that allows one to control for unobserved heterogeneity; secondly, displaced workers are less likely to select themselves in the most capital-intensive industries and within industry in the most capital-intensive firms. As a result, the coefficient on industry capital intensity is more likely to reflect the true firm effect rather than sorting. The thought experiment that motivates this analysis is the following: imagine a group of workers is exogenously displaced and then randomly assigned to a new firm, either within the same industry or in a different industry. Given the big increase in the dispersion of capital/labor ratios across firms, we expect to see a positive relationship between the variance of the wages and the variance of capital intensity within and between industry.

I restrict the sample to workers who are employed full time in both the pre-displacement and the current job. This restriction is necessary as the wage information is in terms of weekly wages. The sample is further restricted to workers aged 20-60 at the time of the survey. There can be various reasons for displacement and in the following tables I present the results on the whole sample of displaced workers. The results obtained on the subsample of the displaced because of establishment closings are qualitatively similar.

The results of estimation of equation 3.1 on DWS data are shown in Table 3.4 row three. The results are similar to those obtained on CPS data. In the pooled sample (row three, first column), a 1% increase in equipment capital intensity implies a 0.13% increase in the average post-displacement wage. Wages and capital intensity are positively associated across industries (row three, second column), but are not associated within industry (row three, third column). Controlling for both industry and year effects, (row three, fourth column), capital intensity and wages are not significantly associated.

The same pattern holds when the regressions are run using fixed effect estimates. In this case, both the information on pre- and post-displacement wages is used and the average industry capital intensity in the pre-displacement job is matched according to the relevant year and industry. Table 3.4, fourth row, reports the results of the fixed effect estimation. A 1% increase in the change in capital intensity is associated with a 0.06% increase in the weekly wage change (the difference between the post-displacement and the pre-displacement wage). The correlation between capital intensity changes and wage changes disappears when we control for both industry and time effects. All the regressions run with fixed effects include dummies to control for years since displacement (25 dummies: years since displacement go from one to five in each survey wave). The regressions also control for pre- and post-displacement industry change (64 dummies: eight pre-displacement industries combined with eight post-displacement industries).

Sample	Coefficient on average industry equipment/labor ratio				N obs.
CPS 1970-1992	0.112*	0.154*	-0.052*	0.021	603483
	(0.007)	(0.005)	(0.011)	(0.022)	
CPS 1984-1992	0.168*	0.168*	-0.019	-0.037	226497
	(0.008)	(0.007)	(0.050)	(0.040)	
DWS 1984-1992	0.131*	0.130*	0.090	-0.070	8629
	(0.012)	(0.011)	(0.074)	(0.067)	
DWS 1984-1992 FE	0.060*	0.092*	-0.322*	0.041	8029
	(0.013)	(0.013)	(0.059)	(0.082)	
Time effects	No	Yes	No	Yes	
Industry effects	No	No	Yes	Yes	

Notes: Standard errors clustered. Additional controls include a quartic in age, marital status, non-white and sex dummies, years of education. Industries considered are mining, durable, non-durable manufacturing, transport and utilities, wholesale trade, retail trade, finance, other services.

Table 3.4: OLS regression of log earnings on average industry equipment/labor ratio

3.3.3 Within-Industry Dispersion of Wages and Capital Intensities

Regression 3.1 looks at the effect of average industry capital intensity on average wages but does not take into account within-industry dispersion in capital/labor ratios. To look at the effect of dispersion of within-industry capital intensity on within-industry wage dispersion I run the following regression:

$$std(\log w)_{jt} = \alpha + \gamma std(\log \frac{k}{l})_{jt} + \varepsilon_{jt} \tag{3.2}$$

$std(\log \frac{k}{l})_{jt}$ is the employment-weighted log standard deviation of equipment/labor. This regression is weighted with weights proportional to the number of observations that are used to calculate $std(\log \frac{k}{l})_{jt}$ in each industry-year cell.

Table 3.5 shows the results of estimation of equation 3.2 using the March CPS and the DWS. The results that refer to the CPS, Table 3.5 row one and two, show that there is a positive association between capital intensity dispersion and wage dispersion within industries (column three). Wage and capital intensity dispersion are negatively associated across industry (column two). This indicates that the industries with the higher wage dispersion are not the same as those with the higher capital intensity dispersion. Column four, however, shows that within industry, the increase in capital intensity dispersion is associated with the increase in wage dispersion.

The same pattern is present in DWS data. The results appear to be stronger but less precise than those obtained on CPS data. Table 3.5 row three shows the results of estimation of equation 3.2 on the five DWS waves. The correlation between within-industry capital

Sample	Coefficient on within-industry standard deviation of equipment/labor ratios				No. obs.
CPS 1970-1992	-0.029*	-0.043*	0.113*	0.064*	184
	(0.016)	(0.014)	(0.041)	(0.019)	
CPS 1984-1992	-0.042*	-0.046*	0.098*	0.048*	72
	(0.025)	(0.026)	(0.028)	(0.025)	
DWS 1984-1992	0.196*	0.077*	0.479*	0.209	40
	(0.052)	(0.049)	(0.142)	(0.164)	
Time effects	No	Yes	No	Yes	
Industry effects	No	No	Yes	Yes	

Notes: Weighted regression. Industries considered are mining, durable manufacturing, non-durable manufacturing, transport and utilities, wholesale trade, retail trade, finance, other services.

Table 3.5: OLS regression of the standard deviation of wages on the standard deviation of equipment/labor ratios

intensity dispersion and within-industry post-displacement wage dispersion is positive both across industries (column two) and within industries (column three). However, the trend of within-industry wage dispersion is mostly explained by time dummies and is only insignificantly positively associated with the concurrent increase in capital intensity dispersion.

3.4 A Theoretical Interpretation

This section gives an interpretation of the evidence presented earlier. According to the evidence, the increase in capital intensity dispersion across firms is related to wage dispersion across workers.

In this section, I present a model of residual wage inequality based on the increasing variance of firms' capital intensities. Contrary to most previous models of residual wage inequality, this model is not based on the rising rewards of unobservable abilities. I suggest that the variance in the distribution of the demand for skills has increased over time. By the variance of the demand for skills I mean the variance of equipment capital investment across firms. In the next section, I will review some of the existing evidence that supports this hypothesis.

I build a search and matching model with identical workers and two types of jobs. Firms are ex-ante identical but ex post they differ in their optimal equipment capital investment. Firms sink their capital before searching for workers and the matching is random. As the relative price of equipment decreases over time, the dispersion of capital/labor ratios across firms increases. This force generates wage dispersion across identical workers as job changers and new entrants are matched to an increasing dispersed distribution of jobs.

The model is related to the literature on inter-industry wage differentials and in particular to the more recent theoretical developments that explain wage dispersion among equivalent workers in a search framework. In many of these models, firms are assumed to have differences in job-creation costs and wage dispersion is a consequence of cost dispersion. In both Pissarides (1994) and Acemoglu (2001), firms have different job-creation costs. The focus in Pissarides (1994) is on modelling on-the-job search. My model is close to Acemoglu (2001). His model focuses on the effect of unemployment insurance and minimum wages on the composition of jobs. Like in that model, I assume that firms are ex-ante identical but they set up different types of jobs ex post. Unlike Acemoglu (2001), I focus on the effect of a decreasing price of equipment capital on firms' capital choices and on wage inequality.

This paper is also linked to the recent literature that looks directly at the changes in the variance of the distribution of demand of skills. Acemoglu (1999) builds a model where the increase in the relative supply of skills changes firms' investment decisions. When there are few skilled workers and the productivity gap between the skilled and unskilled is limited, firms create one type of job (one single level of k) and pool across all types of workers. When the supply of skilled workers rises or their relative productivity increases, firms tend to differentiate the types of jobs they offer. Some firms invest in more capital than others and target only skilled workers. That model, like mine, implies an increasing variance in equipment/labor ratios across firms. In that model the increasing dispersion of capital is due to the increase in the relative supply or the relative productivity of skills. In my model, the increasing dispersion of capital is due to the decline in the relative price of equipment.

3.4.1 Changes in the Distribution of Demand and Supply of Skills

The increase over time in the average demand for skills has been put forth in numerous papers. The most popular reasons are skill-biased technical change and trade with developing countries. However, skill-biased technical change or organizational changes at the firm level may have also increased the variance of the demand for skills. The clearest exposition of this thesis is in Acemoglu (1999). In the same paper Acemoglu provides a summary of some of the evidence on the increased variance in the composition of jobs. Such evidence comes from different sources.

Murnane and Levy (1996) and Cappelli and Wilk (1997) study the changes in firm recruitment practices. Evidence of more selective practices and more accurate screening at recruitment level are interpreted as signs of a changing composition of jobs. Sicherman (1991) provides evidence of better matching of firms and workers. Evidence from the PSID shows that more workers have the exact amount of education required for their job. The higher efficiency of the match could be due to a wider variety of jobs offered. Constructing industry-occupation cells and ranking them according to their average wage, Acemoglu (1999) shows that there is a shift of employment towards the lower and the higher ranking cells. Constantine and Neumark (1994) show that the distribution of on-the-job training has become more unequal. Since on-the-job training is correlated with high wages and capital investment, this evidence can be interpreted as a more unequal distribution of capital investment. Finally, Caselli (1999) shows some direct evidence of more unequal distribution of capital/labor ratios across industries. He reports a sharp increase in the capital/labor ratio difference between the 90th and 10th most capital-intensive industries.

3.4.2 The Model

In this model, there are identical workers matched to two different types of jobs. Firms are ex-ante identical but ex post they create two different types of jobs. Jobs differ in their job-creation costs (structure capital) and their equipment capital investment. Firms rent a site (structure capital) and immediately after renting a site, before meeting workers, they decide how much equipment capital to install. Equipment capital is irreversible, i.e. when the relationship ends, it becomes obsolete. Equipment capital is optimized but structure capital is fixed. Both types of capital are sunk when the vacancy is opened, expenditure on structure is incurred immediately, expenditure on equipment only when the match takes place. This avoids the "hold up" problem. The driving force behind the increasing dispersion of equipment/labor ratios across firms is the decline in the relative price of equipment capital. As the cost of equipment capital decreases, "good" firms which use a lot of equipment capital increase their optimal capital choice more than "bad" firms. Since labor markets are not competitive and rents are split by Nash bargaining, the increasing dispersion of capital intensities implies an increasing dispersion of wages across identical workers.

The economy is constituted of a mass 1 of risk neutral workers and a larger mass of risk neutral firms. The production technology is:

$$Y = (Y_b^\rho + \gamma Y_g^\rho)^{\frac{1}{\rho}}$$

where Y_b and Y_g are the intermediate inputs. Since the intermediate inputs are sold in competitive markets their prices are:

$$p_b = Y_b^{\rho-1} Y^{1-\rho} \text{ and } p_g = \gamma Y_g^{\rho-1} Y^{1-\rho}$$

Firms can be inactive, vacant or filled. Ex-ante identical firms can choose either one of the two types of intermediate goods (or jobs), the good job g or the bad job b. There is free entry of firms: at every point in time, some inactive firms open a vacancy renting a site at price c_g if it is a "good" firm and c_b if it is a "bad" firm. After opening a vacancy and before meeting the workers, firms have to make their irreversible capital choices k_g and k_b. The cost of installing equipment capital is incurred only at matching. Production takes place in the form of a match one firm-one worker. A worker matched with a firm with capital k_j with $j = g, b$ produces:

$$y_j(k, l) = k_j^{1-\alpha} \tag{3.3}$$

Matching is random. Workers have the probability ϕ of matching with a "good" firm and $(1-\phi)$ of matching with a bad firm. $\phi = \frac{v_g}{v}$ is the proportion of vacant "good" firms among all vacancies. As in the basic search and matching models, vacant firms meet unemployed workers at the rate $q(\theta)$, unemployed workers meet vacant firms at the rate $\theta q(\theta)$ where $\theta = \frac{v}{u}$ is market tightness. Both firms and workers discount the future at rate r. Quits into unemployment to look for another job take place at rate λ. The rate of quits into unemployment is exogenous.

In a competitive labor market, "good" jobs and "bad" jobs cannot coexist as workers are identical. In a search model, "good" and "bad" jobs can co-exist. Since capital costs are sunk before workers are met, capital remains idle until a match is formed. In equilibrium, "good" jobs will have to recover the bigger costs incurred at the beginning with higher flow profits. I solve the model in steady state only and I present the relevant Bellman equations. The discounted value of being unemployed is :

$$rU = \theta q(\theta)[\phi E(k_g) + (1-\phi)E(k_b) - U] \tag{3.4}$$

An unemployed worker meets a good firm with probability $\theta q(\theta)\phi$ where $\theta q(\theta)$ is the flow probability of meeting a vacant firm and ϕ is the proportion of good firms among the vacancies. When the match takes place and both the worker and the firm accept the job, the worker gains $E(k_g)$ or $E(k_b)$ and he loses U. For simplicity's sake, I assume there are no unemployment benefits. The value of being employed in a good firm $E(k_g)$ is:

$$rE(k_g) = w(k_g) - \lambda(E(k_g) - U) \tag{3.5}$$

The value of being employed in a bad firm is:

$$rE(k_b) = w(k_b) - \lambda(E(k_b) - U) \tag{3.6}$$

where $w(k_j)$ is the wage rate for a worker in firm $j = g, b$ and λ is the exogenous rate of quits. The value of a vacant firm $V(k_j)$ for $j = g, b$ is:

$$rV(k_j) = q(\theta)[J(k_j) - Ck_j - V(k_j)] \tag{3.7}$$

where $q(\theta)$ is the flow probability of meeting an unemployed worker. When the match occurs and both the firm and the worker do not turn it down, the firm gains the value of a filled firm $J(k_j)$, incurs in the cost of equipment capital Ck_j and loses $V(k_j)$. The value of a firm $j = g, b$ matched with a worker is:

$$rJ(k_j) = p_j k_j^{1-\alpha} - w(k_j) - \lambda[J(k_j) - V(k_j)] \tag{3.8}$$

When jobs are destroyed at the exogenous rate λ, firms exit the market. The zero profit condition for a firm $j = g, b$ is:

$$V(k_j) = c_j \tag{3.9}$$

as the cost of renting a site is c_j. Notice that "good" and "bad" firms face exogenously different rental costs c_j. The crucial ingredient of this model, as described above, is that firms are different in their capital mix. The driving force of this model is the declining relative cost of equipment capital. The declining cost of equipment capital C favors "good" firms which have a high ratio equipment/structure and makes them increase their capital choice k_g. As long as there are search frictions, there will be rents in the labor market. Rents will be split with Nash bargaining. Wages in good firms $w(k_g)$ will be set such that:

$$(1-\beta)(E(k_g)-U)=\beta(J(k_g)-V(k_g)) \tag{3.10}$$

in bad firms:

$$(1-\beta)(E(k_b)-U)=\beta(J(k_b)-V(k_b)) \tag{3.11}$$

Equipment capital does not appear in the sharing equation as it is sunk at the moment of bargaining and if the workers leave the relationship, equipment capital has to be scrapped. Unemployment in steady state will be given by:

$$u=\frac{\lambda}{\lambda+\theta q(\theta)} \tag{3.12}$$

3.4.3 The Steady State Equilibrium

The equilibrium is given by capital choices k_g and k_b, prices p_g and p_b, unemployment rate u, proportion of good firms ϕ in the vacancy pool, market tightness ϑ and wages $w(k_g)$ and $w(k_b)$ such that:

1) for all k_j : $k_j = \arg\max_{k_j'} V(k_j')$ for $j = g, b$.

2) for all k_j, k_j satisfies $V(k_j) = c_j$ for $j = g, b$.

3) all value functions $J(k_j), V(k_j), U, E(k_j)$ are satisfied for $j = g, b$.

4) u satisfies steady state equation 3.12.

5) wages are given by 3.10 and 3.11.

In equilibrium, both "good" and "bad" jobs meet workers at the same rate and workers accept both types of vacancies. Therefore $Y_b = (1-u)\phi k_b^{1-\alpha}$ and $Y_g = (1-u)(1-\phi)k_g^{1-\alpha}$. Prices are given by:

$$p_g = ((1-\phi)^{\rho} k_b^{(1-\alpha)\rho} + \gamma\phi^{\rho} k_g^{(1-\alpha)\rho})^{\frac{1-\rho}{\rho}} \gamma\phi^{\rho-1} k_g^{(1-\alpha)(\rho-1)} \tag{3.13}$$

$$p_b = ((1-\phi)^{\rho} k_b^{(1-\alpha)\rho} + \gamma\phi^{\rho} k_g^{(1-\alpha)\rho})^{\frac{1-\rho}{\rho}} (1-\phi)^{\rho-1} k_b^{(1-\alpha)(\rho-1)} \tag{3.14}$$

Wages are set from 3.10, substituting 3.5, 3.8:

$$w(k_j) = \beta(p_j k_j^{1-\alpha} - rc_j) + (1-\beta)\, rU \tag{3.15}$$

and from 3.10, 3.8 and 3.9:

$$rU = \theta q(\theta)[\frac{\phi\beta}{(1-\beta)}(\frac{rc_g}{q(\theta)} + Ck_g) + \frac{(1-\phi)\beta}{(1-\beta)}(\frac{rc_b}{q(\theta)} + Ck_b)] \quad (3.16)$$

The optimal capacity k_j in equilibrium comes from $V'(k_j) = 0$ where $V(k_j)$ is obtained using 3.7, 3.8 and 3.15. The two equations that determine capital choice when firms take both prices and wages for given are therefore:

$$V'(k_g) = \frac{q(\theta)}{(r+\lambda)(r+q(\theta))}[p_g(1-\alpha)k_g^{-\alpha} - C] = 0 \quad (3.17)$$

and

$$V'(k_b) = \frac{q(\theta)}{(r+\lambda)(r+q(\theta))}[p_b(1-\alpha)k_b^{-\alpha} - C] = 0 \quad (3.18)$$

In these two equations, the first term indicates the marginal benefit of one more unit of capital while the second term indicates the marginal cost. The crucial result of the model comes from the two equations above. When the relative price of equipment capital C falls, equipment investment of good firms k_g grows more than k_b. Firms with higher creation costs c_j command higher output prices p_j. Since in equilibrium $p_g > p_b$, from equations 3.18 and 3.17 we obtain that $k_g > k_b$, and $\frac{\delta(k_g - k_b)}{\delta C} > 0$.

The equilibrium in the "good" job market and in the "bad" job market is given at the crossing of the "job creation curve" JC_j (which is obtained combining equation 3.7, 3.8 and 3.9) and the wage equation 3.15 in each market. We have two equilibrium loci, one where the "job creation curve" JC_g meets the wage setting curve $w(k_g)$ (equation 3.15) and the other where JC_b meets $w(k_b)$. The two equilibrium loci that together with 3.17 and 3.18 (with 3.13 and 3.16 substituted in) define the equilibrium θ and ϕ are:

$$(1-\beta)(p_j k_j^{1-\alpha} - rU) = [\frac{r(r+q(\theta)+\lambda)}{q(\theta)} - \beta r]c_j + (r+\lambda)Ck_j \tag{3.19}$$

for $j = b, g$.

This model is particularly appealing as it gives a formula for within-group wage inequality that can be tested with the data used in the empirical part. Within-group wage inequality (using 3.15 and 3.19 for $j = b, g$) in this model is given by:

$$w(k_g) - w(k_b) = \frac{(r+\lambda)r(c_g - c_b)}{q(\theta)} + (r+\lambda)C(k_g - k_b) \tag{3.20}$$

In this equation, the optimal capacity k_j comes from equations 3.17 and 3.18 and $\beta = \frac{1}{2}$. Wage differences across identical workers are related to the differences in structure costs $c_g - c_b$, and capital investment $k_g - k_b$. They are also related to the job changing rate λ and to the average duration of a vacancy $q(\theta)$.

3.4.4 Back of the Envelope Calculation

To have an idea of the importance of capital/labor ratios in explaining increasing wage differentials, I calibrate equation 3.20. I assume some values for the parameters of equation 3.20 over the period 1970-1992 : interest rate $r = 0.06$, the job changing rate $\lambda = 0.2$. As an estimate of the matching function $q(\vartheta)$ for the US, I take the values suggested in Blanchard and

Diamond (1989): $q(\vartheta) = (\frac{u}{v})^{\alpha}$ with $\alpha = 0.4$. The unemployment to vacancy ratio $\frac{u}{v}$ is strongly anti-cyclical but on average, during the period 1970-1992, $\frac{u}{v} = 2.5$. For $C(k_g - k_b)$ I take the 90-10 log differential of equipment/labor ratios across firms calculated on Compustat data; this value increased by 0.32 log points over the period. For $(c_g - c_b)$ I take the 90-10 log differential of structure/labor ratios across firms. This value increased by 0.10 log points over the period. Calibration of equation 3.20 implies that within-group wage inequality, $w(k_g) - w(k_b)$ (90-10 log differential of the residual distribution), has increased by roughly 0.08 log points over the period 1970-1992 due to the increasing dispersion of capital/labor ratios across firms. Calculations from the March CPS show that the actual 90-10 log differential of within-group wage inequality increased by 0.26 log points from 1970 to 1992 in the US. This means that the mechanism that acts through the increasing dispersion of firm capital/labor ratios can account for a little less than one third of the total increase in within-group wage inequality.

A caveat regarding this rough calibration is the fact that the results are very sensitive to the assumptions about capital. If capital is assumed to be a creation cost as in Acemoglu (2001), within-group wage inequality is given by:

$$w(k_g) - w(k_b) = \frac{(r + \lambda) r (k_g - k_b)}{q(\theta)} \tag{3.21}$$

where now k_j is total capital i.e. equipment plus structure. Calculation on Compustat shows that the 90-10 log differential of total capital/labor ratios increased by 0.28 log points from 1970 to 1992. Calibration of equation 3.21 shows that the increase in dispersion of capital/labor ratios can explain only about 1/30 of the total increase in wage inequality.

3.5 Conclusions

In this paper I document the increasing cross-firm dispersion of equipment capital/labor ratios in the US labor market using Compustat data. The increase takes place both between and within industries. I match Compustat data on equipment capital intensity to CPS and DWS data on individual wages at the industry-year level. A 1% percent increase in industry capital intensity is associated with a 0.11% increase in the average weekly wage in the CPS and to a 0.13% increase in the Displaced Workers Survey. More importantly for the purpose of this paper, the increase in the capital intensity variance across firms appears to be positively associated with the increasing wage variance across workers. The correlation holds within industries even after controlling for time effects.

To explain these empirical regularities, I adopt a search and matching model where identical workers are matched to two types of firms. Firms differ in their optimal composition of capital between equipment and structure. In response to the decline in the relative price of equipment capital, the distribution of capital/labor ratios becomes more dispersed across firms. Residual wage inequality increases as identical workers are randomly matched to an increasingly dispersed distribution of capital/labor ratios. Simple calibration of the model indicates that the dispersion of capital/labor ratios can account for up to one third of the total increase in within-group wage inequality.

Chapter 4

Earnings Instability of Job Stayers and Job Changers

4.1 Introduction

Many studies have written about the rising wage inequality in the US and the UK. Since the work of Gottschalk and Moffitt (1994) many other papers have focussed on another aspect of the widening wage distribution: the growth of earnings instability or the increasing variance of the transitory component of earnings. Gottschalk and Moffitt (1994) have documented the large growth of earnings instability in the US since the end of the '70s and have claimed that the increase in the variance of the transitory component of earnings has been an important contributor to the recent rise in overall earnings inequality.

Earnings instability is related to within-group wage inequality. The rising returns to education and experience (between-group inequality) must reflect an increase in the variance of the permanent component of earnings, as education and experience are permanent individual characteristics. The increase in within-group (or residual) wage inequality, however, could be due to either increased returns to unobserved persistent abilities or a rise in the transitory year-to-year earnings variance. An increase in the returns to unobserved ability implies a permanent effect on earnings inequality, as innate ability is considered a permanent individual characteristic. An increase in year-to-year earnings variance has only temporary welfare consequences.

The distinction between permanent earnings inequality and transitory earnings instability is important because it will inform on the causes of the increase in wage inequality. If the cross-sectional increase in inequality is associated with an increase in the permanent component of individual earnings, then the causes of inequality must be something that permanently increase the relative earnings of the highly paid. If the association is mainly with earnings instability, then the causes of inequality are something that increase individual earnings volatility but nobody earns systematically more. The implications for individual long-term welfare of an increase in transitory instability are much less serious than an increase in the variance of the permanent component of earnings.

This paper documents the different effect on job stayers and job changers of the increasing variance of transitory wage shocks. In the empirical part, I decompose individual wages in their permanent and transitory component and study the different pattern of earnings instability for job stayers and job changers. In the theoretical part, I explain the different experience of job stayers and job changers in the framework of a standard search and matching model with on-the-job search.

After the initial attempt of Gottschalk and Moffitt (1994), nobody else in the earnings instability literature has looked at the differences between job stayers and job changers. In the empirical part of this paper, I decompose the rise in wage inequality into a permanent and a transitory part. I first use the full PSID sample and confirm the common result in the literature about the rise in earnings instability. I then consider separately a balanced sample of job stayers and a balanced sample of job changers. I find that job stayers are hardly affected by any significant rise in earnings instability. The rise in the transitory variance of earnings is mostly due to job changers. To check the robustness of the results, I provide some comparisons using different definitions of job stayer and job changer and different models of transitory/permanent decomposition.

The empirical part of this paper is related to the many studies that, after Gottschalk and Moffitt (1994), have focussed on evaluating the relative contribution of the permanent and transitory part of earnings to the increase in the total variance of earnings. The literature has followed two complementary approaches. Gottschalk and Moffitt (1995 and 2002), Haider (2001), Baker and Solon (2003) and Dickens (2000) have modelled the persistent and transitory components of earnings in different countries. Buchinsky and Hunt (1996) and Gittleman and Joyce (1996) have looked at year-to-year mobility rates across quantiles of the earnings distribution. The results of the literature on the US indicate an equal increase in the variance of the permanent (observed and unobserved skills) and transitory components (Gottschalk and Moffitt 1994; Katz and Autor 1999; Haider 2001). Consistent with that, mobility rates are stable or slightly declining over time.[1] Results on the UK indicate a more pronounced increase in the variance of the permanent component and declining mobility rates (Dickens 2000). In the course of the empirical exercise I will provide some comparisons of my results with the previous US literature.

[1]Buchinsky and Hunt find declining mobility rates but they use the NLSY and therefore only one cohort of young workers. The results are not entirely comparable with those obtained on the PSID (Gottschalk and Moffitt 1994) or the March-March matched CPS files (Gittleman and Joyce 1996).

4.1.1 Motivation

Differences in earnings instability across stayers and changers may inform on the sources of the increase in the transitory component of earnings. The distinction between changers and stayers is important because they have different earnings dynamics. Different events are associated with the permanent and transitory component of earnings. Promotions within the job typically lead to permanent gains. Displacement has a permanent and a transitory component. After the initial wage loss, displaced workers gradually catch up over time until they reach a permanently lower wage level (Jacobson, LaLonde and Sullivan 1993). Temporary layoffs, overtime and performance pay typically lead to transitory variations. If the increased wage volatility affects only job changers, this means that the sources of volatility are to be found in between-job changes. If job stayers do not experience an increased wage volatility, this may suggest that the increase in inequality among job stayers is of a permanent nature and stayers are insulated from the increasing variance of transitory wage shocks.

A recent paper looks at transitory shocks to the wages of job stayers from the point of view of the provision of insurance within the firm. Using an Italian employer-employee matched dataset, Guiso, Pistaferri and Schivardi (2002) find that job stayers are well insulated from transitory shocks to the firm profits. They allow workers' wages to respond to both permanent and transitory shocks to the firm and find that firms provide full insurance to transitory shocks and partial insurance to permanent shocks. Their results are obviously valid only for stayers. My results on PSID data seem to be consistent with theirs.

The distinction between different patterns of instability for changers and stayers is also relevant in the context of different theories of wage inequality and unemployment. One of the recent theories of unemployment refer explicitly to the evidence on rising earnings instability.

This theory has clear implications about earnings instability of job stayers and job changers that have not been verified with the empirical evidence. The increase in "turbulence" in the labor market is at the basis of the Ljungqvist and Sargent (1998) theory of the different evolution of unemployment in the US and EU. The only evidence of increased "turbulence" in the labor market is the evidence of rising earnings instability reported in Gottschalk and Moffitt (1994). Ljungqvist and Sargent (1998) model instability in the labor market as the probability of skill depreciation for workers who separate from an employment relationship. In their view, an increase in turbulence is equivalent to an increase in the average skill depreciation after job loss. They claim that the increase in European unemployment is a consequence of the interaction of more turbulence and generous unemployment benefits. The rise in turbulence increases the fraction of unemployed workers entitled to high unemployment benefits, this raises the reservation wage and causes unemployment. The results in Ljungqvist and Sargent (1998) depend on the assumption that the increase in earnings instability is only limited to involuntary layoffs. Den Haan, Haefke and Ramey (2002) show that the same mechanism of Ljungqvist and Sargent, applied to a matching model, does not work if voluntary quits are subject to the same probability of skill loss.

In the wage inequality literature, the causes of the increase in earnings instability are not yet well understood. The evidence on the rising variance of the temporary component of earnings is at odds with models of within-group wage inequality that rely exclusively on ex-ante differences in unobserved permanent ability. If within-group wage inequality were due only to the rising returns to unobserved ability, this would be reflected only in the rise of the permanent variance of individual earnings with no effect on the transitory variance. Violante (2002) builds a model of residual wage inequality with the purpose of reconciling the theory with the evidence that increasing residual wage inequality reflects increased earnings instability. Unlike previous models of residual wage inequality, his model is not based on ex-ante differences in ability. In his model the increase in residual wage inequality (and earnings instability) is due to an acceleration in technical change that reduces workers' capacity to transfer skills from old to new machines. In this model the increase in earnings instability is common across stayers and changers. The evidence presented in this paper regarding earnings instability of job stayers and job changers sheds further light on the possible sources of the increase in instability.

4.1.2 Overview of the Theory

In the theoretical part of this paper I illustrate the mechanism that may insulate job stayers from the increase in earnings instability. I use a search and matching model with on-the-job search by Pissarides (2000). Although the original model was intended to study unemployment, I use it to describe differences in transitory wage inequality across stayers and changers in the face of an increase in the overall variance of transitory shocks. The model has two appealing properties: the first is that individuals are ex-ante identical and wages are affected only by transitory shocks and not by permanent differences across individuals, the second is that wages of job stayers and job changers are different. These two characteristics make the model appropriate to study the distribution of the transitory component of wages separately across stayers and changers when the overall distribution of the transitory shocks is subject to a mean-preserving spread. This model has nothing to say about the variance of the permanent component of earnings.

In the model, identical individuals are matched to jobs with different transitory productivities. In every instant each job is hit at the Poisson rate λ by a transitory productivity shock $x \rightsquigarrow G(x)$. This shock is transitory since it arrives at the Poisson rate λ and every

x' is independent from the previous x. Wages are affected by the transitory shock because they are renegotiated after the realization of the shock. In a search and matching model with on-the-job search, both the unemployed and part of the employed search for new jobs. Wages of on-the-job seekers and non-seekers are different since there is perfect information and on-the-job seekers must compensate the firm in anticipation of the likely event of job change. On-the-job seekers are job changers with a probability given by the matching function. All non-seekers and those seekers who do not find a new match are job stayers.

A mean-preserving spread of the distribution $G(x)$ formalizes an increase in the variance of the transitory component of wages, i.e. the increase in overall earnings instability. The mean-preserving spread has the effect of increasing the range of productivities over which workers seek on the job, and reducing the range of productivities over which workers decide not to seek and stay in the same job. As a result, the variance of wages across job changers is increased after the mean-preserving spread. However, the effect on the variance across job stayers is ambiguous. The ambiguity for job stayers comes from the fact that although the total proportion of employed job stayers is reduced, their composition between non-seekers and seekers who did not find a job may change. While non-seekers have a lower wage variance after the mean-preserving spread, job seekers have a higher variance.

The model illustrates the evidence shown in the empirical part of the paper that indicates that the increase in earnings instability affects changers rather than stayers. This model is based on the increase in the number of job seekers following a mean-preserving spread of the distribution of transitory productivity shocks. This is of course only one of the possible explanations of the difference between stayers and changers in terms of wage instability, the other being internal labor markets that protect the wages of "insiders" from transitory shocks.

The rest of the paper proceeds as follows. In section 2 I describe the data and the sample of job stayers and job changers. Section 3 illustrates the statistical model and the estimation technique. In section 4 I discuss the results. Section 5 presents a simple model to interpret the evidence and section 6 provides the conclusion.

4.2 Wage Data of Job Stayers and Job Changers

The objective of the empirical exercise is to quantify the relative importance of permanent and transitory shocks to earnings of job stayers and job changers. In particular the aim is to verify whether the increase in earnings instability affects stayers and changers in the same fashion. To do so I proceed in three steps. First, I split the full sample of individuals into job stayers and job changers. Second, I fit a statistical model of the permanent and transitory component of earnings to the full sample of individuals, disregarding the difference between job stayers and job changers. Third, I fit the same model separately on a sample of job stayers and on a sample of job changers. I compare the results obtained on job stayers and on job changers to the results obtained on the full sample.

4.2.1 Sample Selection

The data source is the PSID, a longitudinal survey which follows a sample of US households. Approximately 5,000 households were interviewed in the initial year of the survey, including a core sample of about 3,000 households and a supplementary low-income (SEO) sample of around 2,000 households. At the interview date each year, the head of household is asked about annual labor earnings and hours worked in the previous year. I use data from 1970 to 1992. The earnings information therefore applies to years 1969 to 1991. I restrict the sample to male heads of household between the age of 20 and 59 who are not students or self employed at the time of the survey. To control for outliers, I exclude those who worked less than 520 hours and those who worked more than 5096 hours. I also exclude those whose earnings are top coded and those whose nominal wage is less than half the national minimum wage. The SEO sample is excluded. This selection process gives a final sample of 37,699 individual/year observations. In the course of this paper, I use log real hourly wages. The hourly wage is defined as the ratio of annual labor earnings to hours of work deflated by the CPI. The real wage is expressed in terms of 1991 dollars.

4.2.2 Definition of Stayers and Changers

Identifying a job separation in the PSID is a difficult task since the survey does not contain employers' codes. Typically, in addition to the question on the "current employment status", two questions are used: one asking the number of "months with the current employer", the other asking the "reason for separation from previous employer". I identify a separation on the basis of the information on tenure with the current employer. In the section where I check the robustness of my results, I also use a definition of job change on the basis of the "reason for separation" question.

The question regarding tenure in the PSID underwent numerous changes in the course of twenty years.[2] From 1970 to 1975 the question regarding tenure with the current employer is expressed in years brackets. In 1976-77 and between 1981 and 1992 tenure with the current employer is expressed in months. In 1978 the question was asked only to those under age 45. In 1979 and 1980 the information regarding tenure is missing. Furthermore, in 1984 there was a change in the tenure question. Until 1983 workers were asked how long they had been working for the present employer. After 1983 the question asked the total time they had been working for the current employer, implying that workers with more than one spell of employment with

[2] See the Appendix in Polsky (1999) for the exact wording of the question over time.

the same employer would respond differently before and after 1983. According to Gottschalk and Moffitt (1999), this change in the question does not affect their results on job separations.

A job changer is everybody with less than one year of tenure before 1976. The change in the measurement of tenure in 1976 requires a change in the definition of job changers. After 1976 a job changer is defined if "months with current employer" at the time of the interview is less than twelve. All individuals who are unemployed in the current year are classified as job changers.

A job stayer is the residual definition. Anybody with recorded job tenure of more than one year before 1976 is a job stayer. After 1976 a job changer is defined if "months with current employer" at the time of the interview is more than twelve. A job stayer is required to be employed in the current year.

It must be made clear that identifying the effects of job change on earnings in the PSID is complicated by the fact that earnings are measured on an annual basis. The change in earnings for job changers cannot be exactly measured since the earnings during the year of the job change are a mixture of the earnings from the old and the new job. Although this issue is obviously very important in a cross-sectional study of the effects of job change on earnings, it should be less relevant in a time series study that compares the effects over time.

In Figure 4-1 in the Appendix, I plot the job changers and the job stayers as a proportion of the total sample. The information regarding tenure is missing in 1978, 1979 and 1980, therefore job changers and job stayers are not defined in those years. The proportion of job changers (unemployed and those with less than 12 month of tenure) is rather stable around 18% of the sample during the course of the panel.

4.2.3 The Samples of Job Stayers and Job Changers

To identify the effect of shocks on job stayers I build two balanced samples of stayers at the beginning and at the end of the period. I divide the PSID in two periods: 1970-1980 and 1981-1992. Job stayers are defined over the periods 1970-1977 and 1981-1992 since there is no information on tenure from 1978 to 1980. A stayer is anybody who satisfies the definition of stayer for all years in the period 1970-1977 or 1981-1992. There are 412 stayers in the years 1970-1977 and 359 stayers in the years 1981-1992.

The choice of a balanced sample is due to the fact that the identification of the permanent and transitory component of income requires the use of longitudinal data. To identify the effects of a permanent or a transitory wage shock on job stayers we must consider stayers throughout 1970-1977 and throughout 1981-1992. The choice of two separate balanced samples is due to sample size considerations and to the fact that the information on job tenure is interrupted between 1978 and 1980.

The same reasoning applies to job changers. I construct two balanced samples of job changers between 1970-1977 and between 1981-1992. A changer in each of the two balanced samples is anybody who has positive hourly wages in each year and has been classified as a job changer at least once during that period. There are 269 job changers in the period 1970-1977 and 321 job changers in the period 1981-1992.

4.2.4 Descriptive Statistics

Table 4.1 in the Appendix shows the descriptive statistics for the full sample of individuals, the changers in each year t, the stayers in each year t and the two balanced samples of stayers and changers in 1970-1977 and 1981-1992. The cross-sectional log wage variance of the full sample increases by around 10 points between 1970 and 1992. The increase is concentrated in the 1980s and the log variance reaches its peak in 1992, the last year of the sample. These numbers and the timing of the increase are broadly consistent with the results reported in Katz and Autor (1999) on the CPS.

The different pattern of the log variance of wages of job stayers and job changers are shown in Figure 4-2 in the Appendix. In Figure 4-2, I plot the variance of log real hourly wages for the whole sample, the stayers and the changers. The log wage variance across stayers goes from 0.18 in 1970 to 0.26 in 1992. The log wage variance across changers goes from 0.22 in 1970 to 0.34 in 1992. The timing of the increase is common across stayers and changers, the extent of the increase is different: job stayers see an increase in the log variance of wages of around 8 points from 1970 to 1992, job changers an increase of 12 points.

Changers and stayers also differ across observable characteristics such as age and education (not reported in Table 4.1). Stayers are on average older and more educated than changers. The mean age across stayers is 37.7 years and the percentage of stayers with some college is 24.4%. The mean age across changers is 32.8 years, the percentage of changers with some college is 19.9%. These differences probably reflect the fact that the definition of changers also includes the unemployed.

Finally the last four columns of Table 4.1 in the Appendix show the descriptive statistics of the two balanced panels of job changers and of job stayers. In the following two paragraphs, I compare the wage statistics of the balanced samples of job stayers (changers) to the sample of all job stayers (changers). I claim that the balanced samples of stayers (changers) are sufficiently similar to the full samples of job stayers (changers).

The two balanced panels of stayers are a restricted sample of individuals who have tenure of more than 12 months in all years from 1970 to 1977 and from 1981 to 1992. There are 412 stayers in the years 1970-1977 and 359 stayers in the years 1981-1992. The log wage variance across the 412 stayers of the balanced panel goes from 0.134 in 1970 to 0.149 in 1977. The log wage variance in the sample of all stayers in t goes form 0.187 in 1970 to 0.202 in 1977. The log variance of wages in the balanced sample of stayers is unsurprisingly lower than in the sample of all stayers, the extent of the increase is similar. The same comparison can be made between the 359 job stayers of the balanced panel 1981-1992 and the full sample of stayers in the same period. The log wage variance across the full sample of stayers goes form 0.198 in 1981 to 0.260 in 1992. The log wage variance across the 359 stayers of the balanced panel 1981-1992 goes from 0.144 in 1981 to 0.155 in 1992. The lowest and the highest wage variance in the balanced sample of stayers is 0.136 in 1982 and 0.165 in 1990. The variance of log wages across the 359 stayers in the balanced sample is lower than in the full sample. Although the extent of the increase in the log variance of wages is also lower than in the full sample of stayers, it is still a sizeable 3 log points (or about 21%) from the value of 0.136 in 1982 to 0.165 in 1990.

The two balanced samples of job changers include those individuals who have been classified as job changers at least once in the period 1970-1977 or 1981-1992. There are 269 job changers in the years 1970-1977 and 321 job changers in the years 1981-1992. The log wage variance across the 269 job changers in the balanced sample goes from 0.187 in 1970 to 0.188 in 1977. The log wage variance across the full sample of changers goes form 0.226 in 1970 to 0.220 in 1977. Like in the case of job stayers, the wage variance in the balanced sample is lower than in the full sample of changers. However, the pattern of the log wage variance is similarly stable during the period 1970-1977 in both samples. In the period 1981-1992, the log wage variance across the 321 job changers of the balanced sample increases from 0.177 in 1981 to 0.236 in 1992 or 33%. Similarly the log wage variance in the full sample of changers increases by 28%, from 0.270 in 1970 to 0.346 in 1992.

I will base my conclusions on earnings instability of stayers on the results obtained on the 412 stayers in the balanced panel 1970-1977 and on the 359 stayers in the balanced panel 1981-1992. The same reasoning applies to job changers. The results on earnings instability of job changers are based on the balanced samples of 269 job changers in 1970-1977 and of 312 job changers in 1981-1992. The balanced panels of stayers (changers) are two very selected samples of individuals. However I argue that they still maintain a sufficient similarity with the broader sample of stayers (changers) and that this selection is necessary to assess the effect of permanent and transitory shocks to wages of job stayers and job changers.

4.3 Statistical Model

I start by running the following first-stage regression:

$$w_{it} = \alpha_t + X_{it}\beta_t + y_{it} \tag{4.1}$$

w_{it} denotes the log hourly wage for individual i at time t. α_t is a set of year dummies to control for fluctuations in aggregate wages. X_{it} contains a quadratic in experience. The parameter vector β_t is allowed to change by year since the returns to experience have increased during the sample period. y_{it} is the residual from which I identify the permanent and transitory component.

I estimate one of the most popular models of permanent/transitory variance decomposition. This model has been estimated by Gottshalk and Moffitt (1995 and 2002) on PSID data and by Dickens (2000) on UK data. The model allows for an individual effect μ_{it} and for a transitory shock v_{it}. The two components are orthogonal to each other and are allowed to vary by time with the respective loading factors ϕ_t and π_t:

$$y_{it} = \phi_t \mu_{it} + \pi_t v_{it} \tag{4.2}$$

μ_{it} is a Random Walk $\mu_{it} = \mu_{it-1} + \eta_{it}$ with initial variance σ_μ^2 and $\eta_{it} \rightsquigarrow iid(0, \sigma_\eta^2)$.[3] The individual effect is modelled as a Random Walk to allow for non-stationarity of wages. The individual effect will also capture individual permanent characteristics such as "ability" and education. The time-varying loading factor ϕ_t will reflect the changing market returns to education and unobserved skills. v_{it} is an AR(1) process: $v_{it} = \rho v_{it-1} + \epsilon_{it}$ where $\epsilon_{it} \rightsquigarrow iid(0, \sigma_\epsilon^2)$ is white noise. The AR(1) process is the most appropriate model of the autocovariance structure of wages which shows a large drop at the first lag and then a decline at a geometric rate.[4] v_{it} will also incorporate measurement error in wages, but this fact should not be of immediate concern unless the importance of measurement error were changing over time.

The entries of the theoretical covariance matrix are:

$$\begin{aligned} var(y_{it}) &= \phi_t^2(\sigma_\mu^2 + t\sigma_\eta^2) + \pi_t^2 \frac{\sigma_\epsilon^2}{1-\rho^2} \\ cov(y_{it}, y_{it-s}) &= \phi_t \phi_{t-s}[\sigma_\mu^2 + (t-s)\sigma_\eta^2] + \pi_t \pi_{t-s} \rho^s \frac{\sigma_\epsilon^2}{1-\rho^2} \end{aligned}$$

Since I am mostly interested in the long run changes in earnings instability, I smooth the time dummies ϕ_t, π_t to third order polynomials in time:

[3] μ_{it} could be made vary by age to reflect life-cycle effects in the wage variance. For simplicity purposes I prefer this specification.

[4] The sample covariance structure of wages in the PSID has been studied by many in the literature. The covariance structure of wages in this sample is similar to the one obtained by Gottshalk and Moffitt (1995) and Haider (2001) and is available upon request.

$$\phi_t = 1 + \sum_{j=1}^{3} \phi_j (t-1)^j \qquad \text{and} \qquad \pi_t = 1 + \sum_{j=1}^{3} \pi_j (t-1)^j$$

I estimate this model both on the full unbalanced panel of individuals and separately on the two balanced panels of job stayers and job changers.

4.3.1 Estimation

I fit the sample covariance structure of log (residual) hourly wages to the covariance structure implied by model 4.2 using a minimum distance estimator. The basic unit of data for each individual is the vector of estimated mean-zero residuals from regression 4.1:

$$y_i = \begin{pmatrix} \widehat{y}_{i1} \\ . \\ \widehat{y}_{iT} \end{pmatrix} \tag{4.3}$$

where T is the total length of the panel. For the full sample panel of individuals $T = 23$. The full sample of individuals constitutes an unbalanced panel therefore some entries of the vector 4.3 are missing for some individuals in some years.

The empirical covariance matrix of log residual wages is given by: $C = \frac{\sum_{i=1}^{n} \widehat{y}_i \widehat{y}_i'}{I}$ where n is the number of individuals. Since the panel is unbalanced, not all individuals contribute to each entry of C. To keep this into account, I define for each individual i a vector d_i of dimension $(T \times 1)$ of indicator variables. Each indicator variable is equal 1 if $\widehat{y}_{it}$ is non missing and 0 otherwise. $I = \sum_{i=1}^{n} d_i d_i'$ is the denominator of C.

In the paper I estimate a model of C. Let m be the vector of the distinct elements of C which contains $T(T+1)/2$ elements. To estimate the model in equation 4.2 I minimize:

$$\min_b [m - f(b)]' A [m - f(b)]$$

where A is the identity matrix and $f(b)$ is the theoretical covariance matrix implied by model 4.2. Under some general conditions the estimator $\widehat{b}$ has asymptotic distribution $\sqrt{N(\widehat{b} - b)} \sim N(0, \Omega)$. The variance matrix $\Omega = (G'G)^{-1}G'VG(G'G)^{-1}$ can be estimated with the empirical counterpart of the gradient matrix $G = \frac{\delta f(b)}{\delta b}$ and of $V = [m - f(b)][m - f(b)]'$.

I estimate the model 4.2 on the full sample and then separately on the two balanced panels of stayers and changers. Stayers and changers are defined in the periods 1970-1977 and 1981-1992. Therefore T=8 for the period between 1970 and 1977 and T=12 for the period between 1981 and 1992. The two panels of stayers and changers are balanced therefore in this case the covariance matrix is simply $C = \frac{\sum_{i=1}^{n} \widehat{v}_i \widehat{v}_i'}{n}$.

4.4 Results

Table 4.2 shows the results of estimating model 4.2 on the full unbalanced sample of individuals from 1970 to 1992. Figure 4-3 shows the log variance of the residuals of the first-stage equation 4.1 and the fit of the model. The results of the variance decomposition are plotted in Figure 4-4. The largest component is the permanent component but the relative contribution of the two components changes over time. The permanent component seems to decline in the 1970s in correspondence with the declining education premium. Consistent with the previous literature on the PSID, the rise in the permanent component accounts for most of the rising wage inequality in the 1980s. The transitory component increases first in the 1970s and again in the 1990s. The results on the transitory component of earnings are also in line with most of the literature on PSID data. Haider (2001) uses PSID data from 1967-1991 and finds an increasing transitory component in the 1970s and flat transitory component in the 1980s. Gottschalk and Moffitt (2002) use PSID data from 1970-1995 and find that the transitory component rises in the late 1980s. Heathcote et al. (2003) use PSID data from 1967-1995 and find a rising transitory component in the 1970s and in the 1990s, a flat transitory component in the 1980s.

In Table 4.3, I show the results of model 4.2 estimated on the two balanced panels of stayers. In Figure 4-5 I group together the pictures of the model fit and of the variance decomposition for both sample of stayers. On the top part of Figure 4-5 I put the two pictures of the log variance of the residual wages for stayers. On the bottom part of the same figure I put the variance decomposition results. The log variance of residual wages across stayers is lower than in the full sample, as was clear already from the raw statistics of Table 4.1, yet it increases over time. The two bottom pictures of Figure 4-5 show the crucial empirical finding of the paper. The variance decomposition results for the stayers show that most of the total variance is accounted for by the permanent component and that the transitory component contributes virtually nothing to the increase in wage inequality across this group.

Table 4.4 in the Appendix shows the results of model 4.2 estimated on the two balanced panels of changers. The two bottom panels of Figure 4-6 show the variance decomposition results for changers. The vertical axis are scaled in the same way in Figure 4-6 and 4-5 to facilitate the comparison between stayers and changers. The results show that both the variance of the permanent and of the transitory part of earnings increased across job changers. The difference in the results of Figure 4-6 and 4-5 show that the increasing earnings instability found in the full sample (Figure 4-4) is mostly due to job changers.

4.4.1 Robustness Check: Stayers

In Table 4.5 in the Appendix, I verify the robustness of the results on earnings instability of job stayers along three dimensions. I compare two different definitions of stayers, two different models of earnings instability and four different wage measures. I now proceed to explain the terminology used in Table 4.5.

"Stayer Definition 1" in Table 4.5 is the definition used in this paper based on the "months with current employer" question and described above. "Stayer Definition 2" is the definition of job stayer based on the "reason for separation from previous employer" question. According to this definition, anybody who is currently employed and did not give any reason for separation from the previous employer is recorded as a job stayer. "Stayer Definition 2" does not require a valid value of tenure with the current employer. The question "reason for separation from previous employer" is available every year of the sample therefore the two balanced samples of stayers cover the years 1970-1980 and 1981-1992. When defined according to definition 2, the balanced samples of stayers contain 342 individuals in the period 1970-1980 and 586 individuals in the period 1981-1992.

"Unit Root Model" in Table 4.5 corresponds to the model 4.2 explained above. "Stationary Model" in Table 4.5 substitutes the random walk term in model 4.2 with a time-invariant individual fixed effect. "Stationary Model" indicates a model of the following form:

$$y_{it} = \phi_t \mu_i + \pi_t v_{it} + \tau_t \eta_{it} \tag{4.4}$$

μ_i is an individual time-invariant effect with variance σ^2_μ and with time-varying loading factor ϕ_t. Like in model 4.2, the individual fixed effect will capture individual permanent characteristics such as "ability" and education, but it will not allow for non-mean-reverting shocks. The time-varying loading factor ϕ_t will reflect the changing market return to education and unobserved skills. Like in model 4.2, v_{it} is an AR(1) process: $v_{it} = \rho v_{it-1} + \epsilon_{it}$ where $\epsilon_{it} \rightsquigarrow iid(0, \sigma_\epsilon^2)$ is white noise. $\eta_{it} \rightsquigarrow iid(0, \sigma_\eta^2)$ is a purely transitory term with the associated loading factor τ_t. In this model measurement error in wages will be captured by η_{it}.

The robustness check considers different wage measures and different samples. "Hourly Wage Residuals" in Table 4.5 corresponds to the benchmark measure used in tables 4.2 and 4.3. Log hourly wages are purged of year and experience effects with the first-stage regression 4.1. "Hourly Wage Residuals (2)" considers the residuals of a regression of wages on a quadratic in experience, year dummies and 1 digit industry*year dummies. This purges the transitory variance from fluctuations in industry-specific wages. In this case, the first-stage regression 4.1 becomes: $w_{ijt} = X_{it}\beta + \alpha_t + \psi_{jt} + y_{it}$ where the subscript j indicates the industry, α_t indicates year dummies and ψ_{jt} indicates a set of interactions 1 digit industry*year. "Hourly Wage Residuals (3)" includes the low-income SEO sample. Finally "Annual Earnings Residuals" are included with the intent of avoiding the problem of measurement error in hours. "Hourly Wage Residuals (3)" and "Annual Earnings Residuals" are both residuals from the first-stage equation 4.1.

Table 4.5 reports the transitory variance calculated on the two balanced panels of stayers for every combination "model-stayer definition-wage measure". For simplicity only the transitory variance is reported. The reported values correspond to a simple average of the estimated transitory variance during the period. For example the values for the benchmark combination "Unit Root Model-Stayer Definition 1-Hourly Wage Residuals" correspond to the average of the transitory variance plotted in the two bottom charts of Figure 4-5. For "Unit Root Model" the reported values are the average of $\pi_t^2 \frac{\sigma_\epsilon^2}{1-\rho^2}$ over the period of interest, for "Stationary Model" the reported values are the average of $\tau_t^2\sigma_\eta^2$.

Eight out of sixteen of the possible cases in Table 4.5 report a decreasing or a stable value in the average transitory variance for stayers between the periods 1970-77 and 1980-92. The remaining eight cases in Table 4.5 report an increase in the average transitory variance for stayers. Four out of the eight cases of rising transitory variance indicate a very mild increase of less or equal to 0.002 points. Four out of the eight cases of rising transitory variance are concentrated in the "Stationary Model-Stayer Definition 2" bottom right corner of Table 4.5. The "Stationary Model" tends to estimate a higher transitory variance rather than the "Unit Root Model" and a bigger increase over time. The stayers defined according to definition 2 tend to have a larger estimated increase in the transitory variance. Finally when the transitory variance for stayers is calculated using annual earnings rather than hourly wages, it appears to increase in four cases out of four. Apart from the case of annual earnings where the evidence seem to indicate an increase in earnings instability for stayers too, I view the results in Table 4.5 as evidence of stable or very mild increase in earnings instability for stayers.

4.4.2 Robustness Check: Changers

In Table 4.6 in the Appendix, I verify the robustness of the results on earnings instability of job changers. I use the same method as for job stayers.

"Changer Definition 1" is the definition based on the "months with current employer" question and described above. "Changer Definition 2" is the definition based on the "reason for separation from previous employer" question. According to definition 2, anybody who is currently unemployed or has given any reason for separation form the previous employer is considered as a job changer. As in the case of stayers, "Unit Root Model" refers to equation 4.2 in the text, "Stationary Model" refers to equation 4.4. The wage measures used are the same as for job stayers.

The results in Table 4.6 indicate an increase of the transitory variance of wages for job changers in all cases except for three.

4.5 The Model

I interpret the evidence shown in the previous section in a search and matching model with on-the-job search by Pissarides (2000). I argue that Pissarides' model can be fruitfully used to understand the different effects of an increase in the transitory variance of earnings on job stayers and job changers. This model provides different wage equations for stayers and changers and implies that wages are affected by transitory shocks. These characteristics make it a useful model to look at the different effects that an increase in the overall variance of transitory shocks may have on wages of job stayers and job changers.

The novelty introduced in this paper is the application of Pissarides' model to the study of earnings instability. I will look at the effects of a mean-preserving spread of the distribution of transitory shocks on the cross-sectional variance of wages of job stayers and job changers. The recent literature provides some models of the increase in earnings instability. Violante (2002) explains the increase in earnings instability on the basis of an acceleration of technical change and reduced transferability of skills. Aghion, Howitt and Violante (2002) underline the role of the interaction of faster technological change and "random" adaptability to the new technologies. In this paper, I assume the increase in the overall variance of the transitory part of wages and focus on the differences across stayers and changers.

In the empirical part of this paper, I underlined the differences in earnings instability across job stayers and job changers. I claim that the increase in the cross-sectional variance of wages for changers is due to increases in both the variance of the permanent and the transitory part. For job stayers, most of the increase is explained by the increase in the variance of the permanent part of individual wages and very little by the increase in the variance of the transitory part. The following model considers ex-ante identical individuals and therefore disregards differences in permanent characteristics while focussing on wage differences due to transitory shocks. The model provides a rationale for the different evolution of the transitory variance of wages across job stayers and job changers.

I shall now briefly explain the main lines of Pissarides' on-the-job search model. The model is in continuous time. Workers are ex-ante identical with productivity p. Job seekers and jobs are matched via a matching function. Jobs have productivity px where p is the constant productivity and x is the idiosyncratic one. Jobs are created at maximum productivity px with $x = 1$. The match is hit by an idiosyncratic productivity shock $x \rightsquigarrow G(x)$ with $x \in [0, 1]$ at Poisson rate λ. This shock is transitory: the shock x' is independent of the previous x. At every point in time jobs are therefore distinguished by their transitory productivity x.

In a matching model with on-the-job search, both unemployed and part of the employed search for jobs. Since there is perfect information, when the worker is searching on the job, the firm is aware of it and the Nash bargaining that determines the wage takes that into account. This implies that wages for on-the-job seekers and non-seekers are different. Wages are affected by the transitory shock x because, after realization of the shock x, the wage is renegotiated and the surplus is split by Nash bargaining. The rate at which unemployed and employed job seekers move into new jobs is derived from a matching function $m = m(v, u + e)$ where u is the unemployed, e the employed job seekers, and v the number of vacancies. Jobs arrive to each searching worker, employed and unemployed, at the rate $\theta q(\theta)$, where $q(\theta) = m(1, \frac{u+e}{v})$ and $\theta = \frac{v}{u+e}$ is the ratio of vacancies to job seekers.

The optimal policy can be characterized by two reservation rules. There is a reservation productivity R such that jobs $x < R$ are destroyed. There is a second reservation productivity S such that workers in jobs $R < x < S$ seek a new job. Workers in jobs $S < x < 1$ do not search. The expected returns of the employed worker when he searches on the job (s) and when he does not (ns)are respectively:

$$rW^s(x) = w^s(x) - \sigma + \lambda \int_R^1 \max(W^{ns}(s), W^s(s))dG(s) + \lambda G(R)U -$$
$$- \lambda W^s(x) + \theta q(\theta)[W^{ns}(1) - W^s(x)]$$

$$rW^{ns}(x) = w^{ns}(x) + \lambda \int_R^1 \max(W^{ns}(s), W^s(s))dG(s) + \lambda G(R)U - \lambda W^{ns}(x)$$

Job seekers and non-seekers have different wages $w^s(x)$ and $w^{ns}(x)$. When $x < R$ jobs are destroyed and workers get the value of unemployment U. The difference between $W^s(x)$ and $W^{ns}(x)$ is the cost of search σ and the capital gain the job seeker enjoys when he changes job: $\theta q(\theta)[W^{ns}(1) - W^s(x)]$ where $\theta q(\theta)$ is the rate at which job seekers find a new match, and $W^{ns}(1)$ is the value of the new job as jobs are always created at maximum productivity $x = 1$. The flow value of unemployment is:

$$rU = z + \theta q(\theta)[W^{ns}(1) - U]$$

where z is the unemployment benefit.

The value of a filled job is also different if the worker is searching or not:

$$rJ^s(x) = px - w^s(x) + \lambda \int_R^1 \max(J^{ns}(s), J^s(s))dG(s) - [\lambda + \theta q(\theta)]J^s(x) \tag{4.5}$$

$$rJ^{ns}(x) = px - w^{ns}(x) + \lambda \int_R^1 \max(J^{ns}(s), J^s(s))dG(s) - \lambda J^{ns}(x) \tag{4.6}$$

When the worker is searching, $J^s(x)$ contains an additional probability that the job is destroyed given by the probability that the job seeker finds a new match: $\theta q(\theta)$. The flow value of a vacancy is:

$$rV = -pc + q(\theta)[J^{ns}(1) - V]$$

and the zero-profit or free entry condition is $V = 0$.

Wages are set by Nash rule to share the surplus of a match. Therefore for job seekers and non-seekers $i = s, ns$:

$$W^i(x) - U = \frac{\beta}{1-\beta} J^i(x)$$

Knowing the value for workers and firms of vacant and filled jobs, substituting in the Nash rule, we find the wage equation for seekers and non-seekers:

$$w^{s}(x) = (1-\beta)(z+\sigma) + \beta p x \tag{4.7}$$

and

$$w^{ns}(x) = (1-\beta)z + \beta p(x + c\theta) \tag{4.8}$$

When the worker quits to take another job, the return of the firm drops from $J(x)$ to zero. The return from the new job to the worker is $W^{ns}(1)$ since new jobs are created at the maximum productivity $x = 1$. The Nash rule implies that the worker has to compensate the firm for this asymmetry in the returns. Therefore the wage for non-seekers is always higher than for job seekers, at given productivity x, $w^{ns}(x) > w^{s}(x)$. This can be proven rewriting $w^{ns}(x) - w^{s}(x) = (1-\beta)(\frac{\beta}{1-\beta}pc\theta - \sigma)$ and noticing that $\frac{\beta}{1-\beta}pc\theta$ is in equilibrium the expected return from search.

The evolution of the number of employed job seekers e is:

$$\frac{de}{dt} = \lambda(1-u)[G(S) - G(R)] - \lambda e - \theta q(\theta) e \tag{4.9}$$

where the first term on the RHS is the sum of new entry and re-entry in the range $[R, S]$, following the arrival of a productivity shock. The job-to-job number of quits is given by $\theta q(\theta)e$. The evolution of unemployment is given by:

$$\frac{du}{dt} = \lambda(1-u)G(R) - \theta q(\theta)u \qquad (4.10)$$

I now look at the effect of increasing the variance of transitory shocks on the wages of job changers and stayers. The increase in the transitory component of wages is modelled as a mean-preserving spread of $G(x)$. I take a parametric change in the productivity distribution and solve the model with $x(h) = x + h(x - \overline{x})$. I consider the effect of a marginal dh at $h = 0$.

An equilibrium in this model is a value of S, R, market tightness θ, a wage $w(x)$ and unemployment u. To find the reservation rule S, write the value to a worker of a job x, when he is searching on the job and when he is not, $W^s(x)$ and $W^{ns}(x)$. S is such that $W^{ns}(S)$ $= W^s(S)$. The job creation condition is given by $J^{ns}(1)$ and the zero profit condition $V = 0$. The job reservation productivity is R such that $J^s(R) = 0$, this determines the job destruction condition. The equation that determines S, the job creation condition, and the job destruction condition take respectively the following form:

$$\frac{(1+h)(S-R)}{r+\lambda+\theta q(\theta)} = \frac{\beta}{1-\beta}\frac{c}{q(\theta)} - \frac{\sigma}{p\theta q(\theta)} \qquad (4.11)$$

$$\frac{(1+h)(1-R)(1-\beta)}{r+\lambda} = \frac{c}{q(\theta)} + \frac{p\beta c\theta - (1-\beta)\sigma}{p(r+\lambda)} \qquad (4.12)$$

$$(1+h)R - h\overline{x} + \Lambda(R,\theta,\sigma,h) = \frac{z+\sigma}{p} \tag{4.13}$$

where $\Lambda(R,\theta,\sigma,h) = \lambda\int_R^1 \max(J^{ns}(s), J^{s}(s))dG(s)$ is the option value of the job with $\frac{d\Lambda}{d\theta} < 0$, $\frac{d\Lambda}{dR} < 0$ and $\frac{d\Lambda}{dh} > 0$. Equation 4.11 is obtained combining combining 4.5 and 4.6 with 4.7 and 4.8 and substituting $x = x + h(x - \overline{x})$. Equation 4.12 is obtained from 4.6 calculated in $x = 1$ and $V = 0$ and equation 4.11. Equation 4.13 is obtained from $J^{s}(R) = 0$.

The job creation condition 4.12 is negatively sloped in the space R, θ. The last term on the RHS of equation 4.12 is the gain from search going to the firm. The expected productivity gain from job creation (LHS of equation 4.12) minus the gain from search must be equal to the average creation cost. The mean-preserving spread h shifts the job creation curve out. The intuition is that the mean-preserving spread makes productivities above the mean better and productivities below the mean worse. Workers and firms do not consider productivities below R, therefore the benefits from productivities above the mean outweight the costs from productivities below the mean.

The job destruction curve 4.13 implies that the reservation productivity net of the option value of the job is equal to total workers' costs. The job destruction curve 4.13 is upward sloping in the space R, θ. A higher θ reduces the option value of the job because higher θ implies higher job destruction since a searching worker is more likely to find a job and quit. A higher θ also increases the expected returns from search and therefore more search is undertaken and a job is more likely to be destroyed. This also reduces the option value of a job. The total differential of equation 4.13 can be written:

$$(1 + \frac{d\Lambda}{dR})\frac{dR}{dh} = \overline{x} - R - \frac{d\Lambda}{dh} - \frac{d\Lambda}{d\theta}\frac{d\theta}{dh} \tag{4.14}$$

The mean-preserving spread has three effects on R: it increases R directly if $\overline{x} > R$, it increases R through market tightness θ, it decreases R by increasing the option value of a job. The reason $\frac{d\Lambda}{dh} > 0$ is the same as before, the truncation of the productivity distribution at R. Substituting the total differential of equation 4.12 into 4.14, we obtain that $\frac{d\theta}{dh} > 0$ and $\frac{dR}{dh} > 0$.

The total differential of equation 4.11 with respect to h at $h = 0$ gives:

$$\frac{dS}{dh} - \frac{dR}{dh} = -(S - R) + [\frac{\beta}{1-\beta}c(1 + \eta\frac{r+\lambda}{\theta q(\theta)}) + \frac{(1-\eta)(r+\lambda)\sigma}{p\theta^2 q(\theta)}]\frac{d\theta}{dh}$$

Knowing that $\frac{d\theta}{dh} > 0$ and $\frac{dR}{dh} > 0$ and assuming $S - R$ small, the result of a mean-preserving spread is $\frac{dS}{dh} - \frac{dR}{dh} > 0$ and $\frac{dS}{dh} > 0$. This means that the range of productivities over which workers search on the job is larger and the range of productivities over which they do not search is smaller. A mean-preserving spread makes the gap between S and R larger because it increases θ and therefore increases the expected rewards from search. The intuition is again that the mean-preserving spread makes productivities above the mean better and productivities below the mean worse, but workers and firms do not consider productivities below R.

The effects of the mean-preserving spread ($\frac{d\theta}{dh} > 0$ and $\frac{dR}{dh} > 0$) on the level of unemployment $u = \frac{\lambda G(R)}{\lambda G(R)+\theta q(\theta)}$ are ambiguous. At given unemployment both the job destruction rate, $\lambda G(R)$, and the job creation rate, $\theta q(\theta)\frac{u}{1-u}$, are higher. The effect on u in steady state depends on the parameters.

We now look at the implications for the variance of wages of changers and stayers. On-the-job seekers (s) are changers with probability $\theta q(\theta)$. Job stayers are all the non-seekers (ns) plus those seekers (s) who did not change job. From equation 4.9, the number of employed job seekers in steady state is given by:

$$e = \frac{\lambda[G(S) - G(R)]}{\lambda + \theta q(\theta)}(1 - u)$$

Note that e is the steady state number of job seekers already net of the changers. The changers go from a job with productivity in $[R, S]$ to a job with productivity $x = 1$ because all vacancies enjoy maximum productivity. We look at wages of stayers and changers before the change. The proportion of employed job changers in steady state is therefore given by $\frac{e\theta q(\theta)}{1-u}$. The proportion of employed job stayers is given by: $1 - \frac{e\theta q(\theta)}{1-u} = (1 - \frac{e\theta q(\theta)}{1-u} - \frac{e}{1-u}) + \frac{e}{1-u}$. This is the sum of non-seekers net of the changers plus the seekers who did not find a job.

The effect of the mean-preserving spread ($\frac{d\theta}{dh} > 0$ and $\frac{dS}{dh} - \frac{dR}{dh} > 0$) on the number of job seekers, e, on the number of quits, $e\theta q(\theta)$, and on the fraction of employed job seekers $\frac{e}{1-u}$ is ambiguous. The ambiguity of the effect on $\frac{e}{1-u}$ comes from the fact that job seekers search on a wider range $[R, S]$, but more workers find a match and leave the job seekers' pool to become non-seekers. The effect on the job-to-job quit rate $\frac{e\theta q(\theta)}{(1-u)}$ is positive.

The wages of employed seekers and non-seekers are given by:

$$w^s(x) = (1 - \beta)(z + \sigma) + \beta px \qquad \text{for } x \in (R, S)$$

$$w^{ns}(x) = (1-\beta)z + \beta p(x + c\theta) \qquad \text{for } x \in (S, 1)$$

Taking now the variance of the wages for stayers and changers:

$$var(w^{changers}(x)) = \left(\frac{e\theta q(\theta)}{1-u}\right)^2 \beta^2 p^2 var(x \mid R < x < S) \tag{4.15}$$

$$var(w^{stayers}(x)) = \left(1 - \frac{e\theta q(\theta)}{1-u} - \frac{e}{1-u}\right)^2 \beta^2 p^2 var(x \mid x > S) + \tag{4.16}$$
$$+\left(\frac{e}{1-u}\right)^2 \beta^2 p^2 var(x \mid R < x < S)$$

The conditional variance of a random variable increases as the support over which the variance is taken becomes larger. It is therefore clear that the variance of wages across job changers increases after the mean-preserving spread, as both the job-to-job quit rate, $\frac{e\theta q(\theta)}{1-u}$, and the conditional variance, $var(x \mid R < x < S)$, increase. The results for job stayers are ambiguous since the effect of the mean-preserving spread on both the proportion of employed non-seekers, $1 - \frac{e\theta q(\theta)}{1-u} - \frac{e}{1-u}$, and the proportion of employed seekers who did not find a job, $\frac{e}{1-u}$, is in principle ambiguous. The conditional variance $var(x \mid x > S)$ decreases. The ambiguity for job stayers comes from the fact that although the total proportion of employed job stayers is reduced, their composition between non-seekers and seekers who did not find a job may change. While non-seekers have a lower wage variance after the mean-preserving spread, seekers have a higher variance.

4.5.1 The Link between the Theory and the Evidence

A few comments are in order on the relationship between the theory and the empirical evidence. First of all, this theory has nothing to say about the permanent component of wages since individuals are identical and wages differ only because of the different realizations of the transitory shock x. Equations 4.16 and 4.15 in the model indicate the cross-sectional variance of wages across stayers and changers. They are the theoretical counterpart of the transitory variance of wages shown in the bottom lines of the two lower charts of Figure 4-5 for job stayers and of Figure 4-6 for job changers.

Secondly, the assumption of the model is that the productivity shock x is drawn form the general distribution $G(x)$ at the Poisson rate $\lambda < \infty$, i.e. there are periods without shocks. Wages need a certain degree of persistence, in fact, if wages were continuously reset, nobody would search. However, the shock x in the model is really transitory because eventually everybody draws a shock x from the same distribution $G(x)$, and every shock x' is independent from the previous shock x. Equations 4.16 and 4.15 indicate the cross-sectional variance of *i.i.d.* wages. In the empirical part, the benchmark equation 4.2 models the transitory part of wages as an AR(1) process. In equation 4.4, I model the transitory part of wages as an *i.i.d.* process. Therefore it can be argued that the correspondence between the cross-sectional variance of the transitory part of wages in the theory and in the empirical part is not perfect. However, I am interested in the comparative statics of the transitory variance of wages with respect to a mean-preserving spread whatever the process that drives the transitory shock.

Finally, the correspondence between the definition of changers (stayers) used in the empirical part and the one implied by the theory is also not perfect. In the empirical part, I define as job changers those who have less than 12 months of tenure with the current employer or are unemployed and I take their wage in the same year. However, wages in the PSID refer to the previous year and are likely to be a mix of the old and new job's wages. In the theory part, I exclude the unemployed from the definition of changers and I consider the cross-sectional wage variance of changers before the change because after the change all wages are identical with $x = 1$. Furthermore, equations 4.16 and 4.15 in the theory part indicate the cross-sectional variance across all stayers and changers. In the empirical part, Figure 4-5 and 4-6 show the transitory wage variance across a balanced sample of stayers and changers. However, I argued in the empirical section that the balanced sample of stayers (changers) has similar characteristics to the sample of all stayers (changers).

4.6 Conclusions

In this paper, I use the PSID to decompose the rise in wage inequality into permanent and transitory shocks. I show that the increase in the variance of transitory shocks, also known as earnings instability, is mostly restricted to job changers. Job stayers hardly suffer any increase in earnings instability over time. I verify the robustness of the results using two different models of earnings dynamics, two different definitions of job stayers and four different wage measures.

A simple search and matching model with on-the-job search provides an interpretation of the evidence. An increase in the variance of transitory shocks to earnings increases the range of productivities over which workers search on the job. The wage variance across job changers increases as worker search over a wider range of productivities. The direction of the change in the wage variance across job stayers is ambiguous and depends on their composition between non-seekers and seekers who did not find a job.

4.7 Appendix: Tables

Year	Full Sample Variance log(w)	Full Sample Obs.	Changers Variance log(w)	Changers Obs.	Stayers Variance log(w)	Stayers Obs.	Balanced Sample Changers Variance log(w)	Balanced Sample Changers Obs.	Balanced Sample Stayers Variance log(w)	Balanced Sample Stayers Obs.
1970	0.197	1257	0.226	182	0.187	1075	0.187	269	0.134	412
1971	0.221	1310	0.257	222	0.205	1088	0.154	269	0.137	412
1972	0.217	1371	0.222	228	0.202	1143	0.158	269	0.143	412
1973	0.213	1434	0.225	261	0.194	1173	0.174	269	0.142	412
1974	0.212	1500	0.226	283	0.192	1217	0.166	269	0.142	412
1975	0.201	1555	0.223	359	0.177	1196	0.180	269	0.130	412
1976	0.204	1566	0.243	275	0.181	1291	0.169	269	0.138	412
1977	0.219	1601	0.220	299	0.202	1302	0.188	269	0.149	412
1978	0.196	1643	.	.	.	.	.	.	.	.
1979	0.209	1689	.	.	.	.	.	.	.	.
1980	0.223	1737	.	.	.	.	.	.	.	.
1981	0.230	1745	0.270	336	0.198	1409	0.177	321	0.144	359
1982	0.240	1734	0.275	352	0.207	1382	0.199	321	0.136	359
1983	0.256	1716	0.342	344	0.209	1372	0.197	321	0.152	359
1984	0.269	1728	0.273	354	0.236	1374	0.202	321	0.150	359
1985	0.260	1714	0.321	285	0.228	1429	0.194	321	0.143	359
1986	0.274	1754	0.331	308	0.234	1446	0.206	321	0.144	359
1987	0.289	1752	0.367	314	0.248	1438	0.213	321	0.161	359
1988	0.280	1767	0.329	352	0.241	1415	0.215	321	0.165	359
1989	0.291	1773	0.303	328	0.260	1445	0.238	321	0.162	359
1990	0.276	1776	0.266	345	0.248	1431	0.236	321	0.165	359
1991	0.291	1793	0.331	304	0.257	1489	0.234	321	0.161	359
1992	0.293	1784	0.346	315	0.260	1469	0.236	321	0.155	359

Notes: The total number of individual/year observations is 37699. Wages are hourly wages computed as annual earnings divided by annual hours. Wages are expressed in 1991 dollars.

Table 4.1: PSID Sample Descriptive Statistics

Permanent Component			Transitory Component		
	Estimate	S.E.		Estimate	S.E.
ϕ_1	-0.077	(0.001)	π_1	0.038	(0.001)
ϕ_2	0.006	(0.000)	π_2	-0.003	(0.000)
ϕ_3	-0.000	(0.000)	π_3	0.000	(0.000)
σ_μ	0.143	(0.000)	ρ	0.279	(0.000)
σ_η	0.012	(0.000)	σ_ε	0.042	(0.000)

Notes: Parameter estimates and standard errors for the benchmark model on the full sample.

Table 4.2: Parameter Estimates

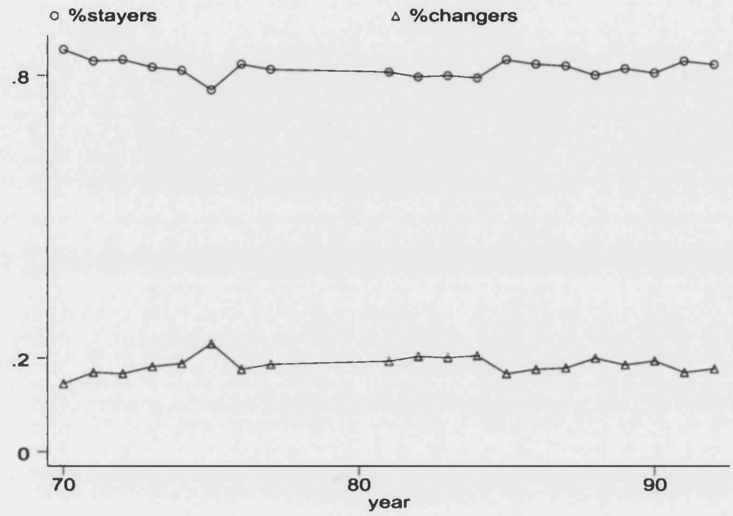

Figure 4-1: Proportion of job stayers and job changers.

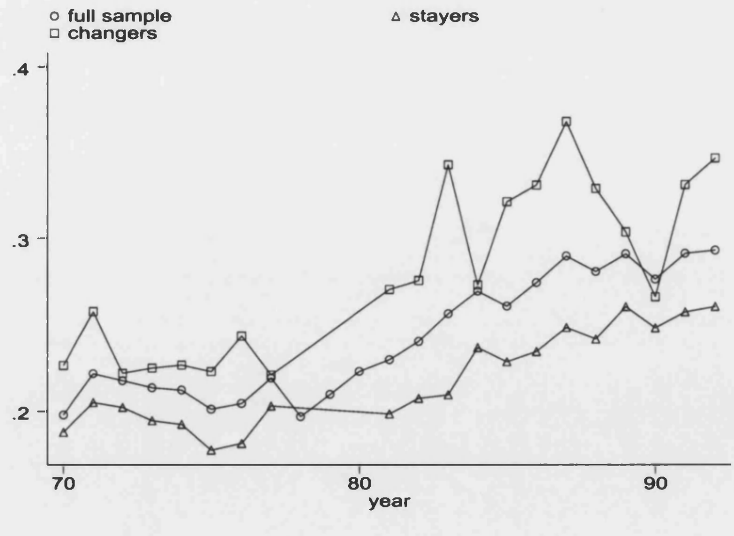

Figure 4-2: Variance of log hourly wages. Job stayers and job changers.

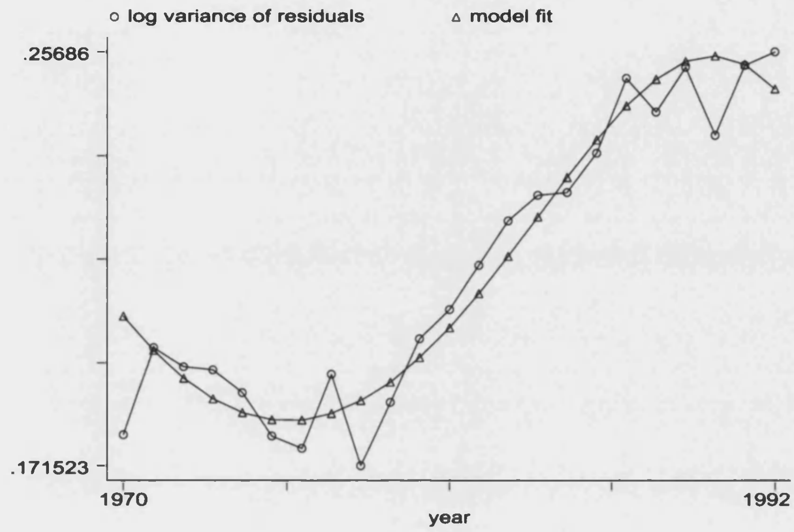

Figure 4-3: Model Fit

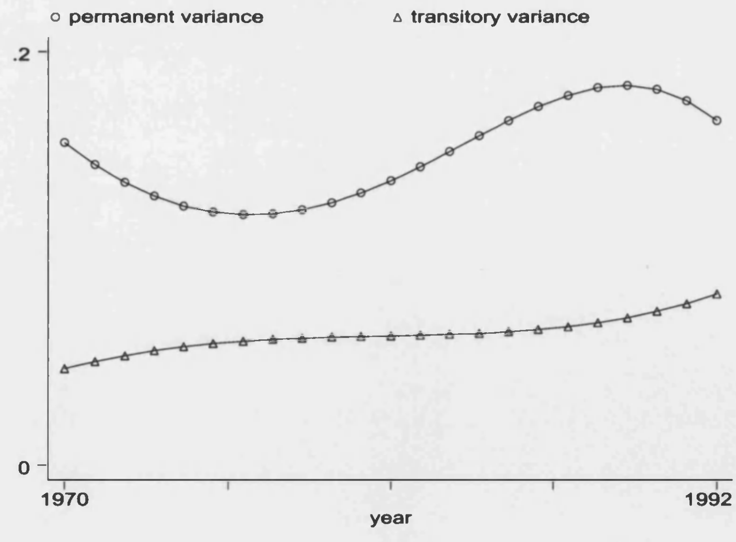

Figure 4-4: Variance Decomposition.

Permanent Component			Transitory Component		
		Stayers 1970-1977			
	Estimate	S.E.		Estimate	S.E.
ϕ_1	0.011	(0.000)	π_1	0.278	(0.057)
ϕ_2	-0.014	(0.000)	π_2	0.184	(0.003)
ϕ_3	0.001	(0.000)	π_3	-0.041	(0.001)
σ_μ	0.113	(0.001)	ρ	0.069	(0.000)
σ_η	0.020	(0.000)	σ_ε	0.003	(0.000)
		Stayers 1981-1992			
	Estimate	S.E.		Estimate	S.E.
ϕ_1	-0.021	(0.000)	π_1	-0.078	(0.005)
ϕ_2	0.001	(0.000)	π_2	-0.184	(0.012)
ϕ_3	-0.000	(0.000)	π_3	0.018	(0.001)
σ_μ	0124	(0.000)	ρ	0.501	(0.025)
σ_η	0.009	(0.000)	σ_ε	0.002	(0.000)

Notes: Parameter estimates and standard errors for the benchmark model on the two balanced panels of stayers.

Table 4.3: Parameter Estimates: Stayers

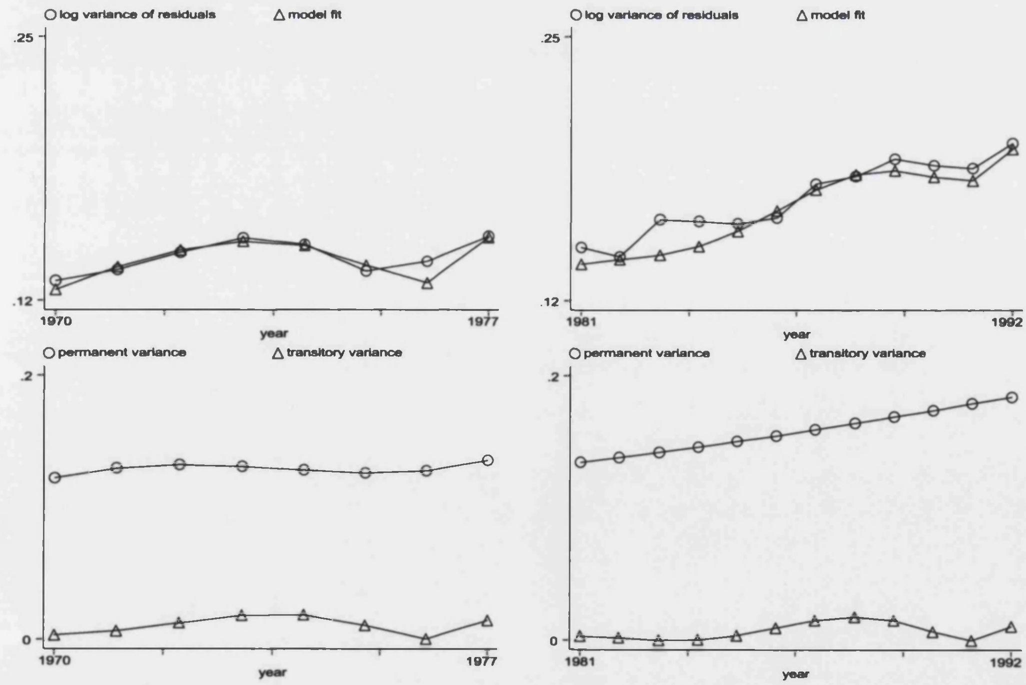

Figure 4-5: Model fit and Variance decomposition: Stayers.

Permanent Component			Transitory Component		
		Changers 1970-1977			
	Estimate	S.E.		Estimate	S.E.
ϕ_1	-0.202	(0.002)	π_1	1.240	(0.151)
ϕ_2	0.042	(0.000)	π_2	-0.348	(0.041)
ϕ_3	-0.003	(0.000)	π_3	0.029	(0.003)
σ_μ	0.106	(0.000)	ρ	0.037	(0.003)
σ_η	0.036	(0.000)	σ_ε	0.005	(0.000)
		Changers 1981-1992			
	Estimate	S.E.		Estimate	S.E.
ϕ_1	-0.100	(0.002)	π_1	1.034	(0.241)
ϕ_2	0.011	(0.000)	π_2	-0.202	(0.044)
ϕ_3	-0.000	(0.000)	π_3	0.010	(0.002)
σ_μ	0117	(0.000)	ρ	-0.092	(0.007)
σ_η	0.036	(0.000)	σ_ε	0.004	(0.001)

Notes: Parameter estimates and standard errors for the benchmark model on the two balanced panels of changers.

Table 4.4: Parameter Estimates: Changers

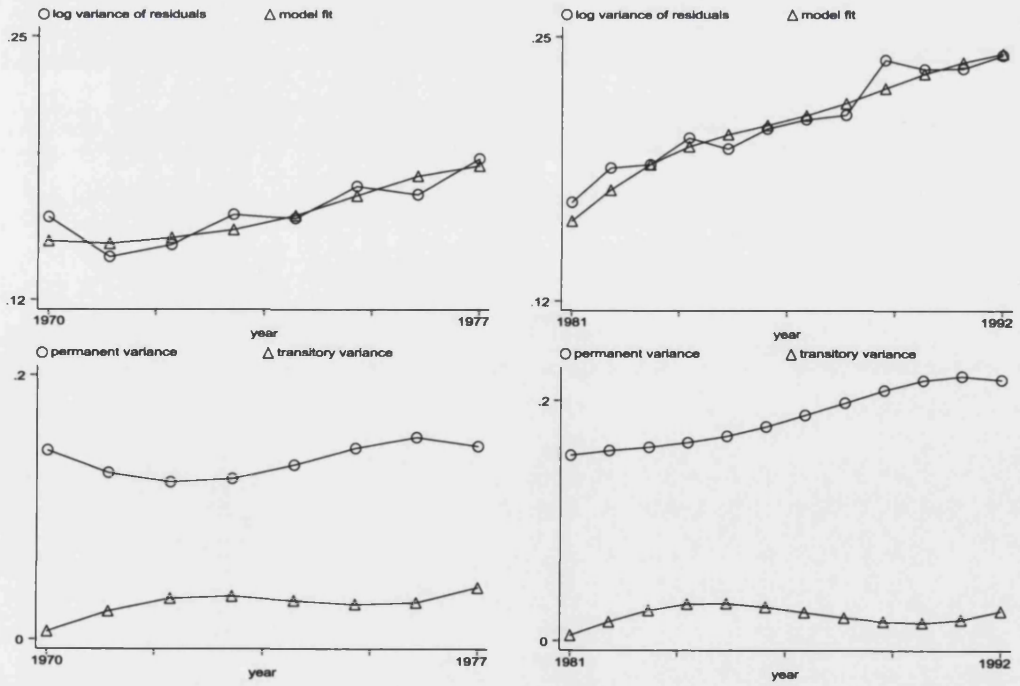

Figure 4-6: Model fit and Variance decomposition: Changers

	Stayer Definition 1		Stayer Definition 2	
	Transitory Variance		Transitory Variance	
Unit Root Model	1970-1977	1981-1992	1970-1980	1981-1992
Hourly Wage Residuals	0.010	0.007	0.009	0.007
	(0.000)	(0.000)	(0.000)	(0.000)
Hourly Wage Residuals (2)	0.012	0.010	0.013	0.010
	(0.000)	(0.000)	(0.000)	(0.001)
Hourly Wage Residuals (3)	0.012	0.009	0.018	0.008
	(0.000)	(0.000)	(0.000)	(0.000)
Annual Earnings Residuals	0.006	0.008	0.006	0.014
	(0.000)	(0.000)	(0.000)	(0.000)
	Transitory Variance		Transitory Variance	
Stationary Model	1970-1977	1981-1992	1970-1980	1981-1992
Hourly Wage Residuals	0.014	0.014	0.013	0.016
	(0.000)	(0.000)	(0.000)	(0.000)
Hourly Wage Residuals (2)	0.014	0.015	0.015	0.019
	(0.000)	(0.000)	(0.000)	(0.001)
Hourly Wage Residuals (3)	0.018	0.017	0.017	0.019
	(0.000)	(0.000)	(0.002)	(0.001)
Annual Earnings Residuals	0.008	0.010	0.005	0.013
	(0.000)	(0.001)	(0.000)	(0.000)

Notes: "Stayer Definition 1" uses the question "Months with current employer". "Stayer Definition 2" uses the question "Reason for separation from previous employer". "Unit Root Model" is equation 4.2 in the text. "Stationary Model" is equation 4.4 in the text. "Hourly Wage Residuals (2)" considers the residuals from an augmented first stage regression $w_{ijt} = X_{it}\beta + \alpha_t + \psi_{jt} + y_{it}$ where ψ_{jt} indicates a set of interactions 1 digit industry-year. "Hourly Wage Residuals (3)" includes the low-income SEO sample.

Table 4.5: Robustness Analysis: Stayers

	Changer Definition 1		Changer Definition 2	
	Transitory Variance		Transitory Variance	
Unit Root Model	1970-1977	1981-1992	1970-1980	1981-1992
Hourly Wage Residuals	0.020	0.021	0.028	0.043
	(0.001)	(0.001)	(0.001)	(0.002)
Hourly Wage Residuals (2)	0.056	0.052	0.033	0.058
	(0.002)	(0.002)	(0.002)	(0.004)
Hourly Wage Residuals (3)	0.038	0.073	0.024	0.049
	(0.001)	(0.003)	(0.001)	(0.002)
Annual Earnings Residuals	0.023	0.036	0.024	0.070
	(0.001)	(0.002)	(0.003)	(0.004)
	Transitory Variance		Transitory Variance	
Stationary Model	1970-1977	1981-1992	1970-1980	1981-1992
Hourly Wage Residuals	0.025	0.030	0.027	0.050
	(0.001)	(0.001)	(0.001)	(0.002)
Hourly Wage Residuals (2)	0.022	0.025	0.031	0.039
	(0.001)	(0.002)	(0.001)	(0.001)
Hourly Wage Residuals (3)	0.036	0.036	0.036	0.057
	(0.002)	(0.003)	(0.002)	(0.004)
Annual Earnings Residuals	0.027	0.039	0.028	0.052
	(0.001)	(0.002)	(0.001)	(0.004)

Notes: "Changer Definition 1" uses the question "Months with current employer". "Changer Definition 2" uses the question "Reason for separation from previous employer". "Unit Root Model" is equation 4.2 in the text. "Stationary Model" is equation 4.4 in the text. "Hourly Wage Residuals (2)" considers the residuals from an augmented first stage regression $w_{ijt} = X_{it}\beta + \alpha_t + \psi_{jt} + y_{it}$ where ψ_{jt} indicates a set of interactions 1 digit industry-year. "Hourly Wage Residuals (3)" includes the low-income SEO sample.

Table 4.6: Robustness Analysis: Changers

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