Lecture Notes for Graduate Labor Economics, 14.662

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These notes accompany the lectures I will give for the graduate labor course. They cover 3 related topics:

(1) The theory of human capital.

(2) The determination of the returns to human capital and skills, with special emphasis on the recent changes in the U.S. wage structure.

(3) Determinants of unemployment, with special emphasis on the rise in European unemployment.
Part 1

The Theory of Human Capital Investments
CHAPTER 1

The Basic Theory of Human Capital

1. General Issues

One of the most important ideas in labor economics is to think of the set of marketable skills of workers as a form of capital in which workers make a variety of investments. This perspective is important in understanding both investment incentives, and the structure of wages and earnings.

Loosely speaking, human capital corresponds to any stock of knowledge or characteristics the worker has (either innate or acquired) that contributes to his or her “productivity”. This definition is broad, and this has both advantages and disadvantages. The advantages are clear: it enables us to think of not only the years of schooling, but also of a variety of other characteristics as part of human capital investments. These include school quality, training, attitudes towards work, etc. Using this type of reasoning, we can make some progress towards understanding some of the differences in earnings across workers that are not accounted by schooling differences alone.

The disadvantages are also related. At some level, we can push this notion of human capital too far, and think of every difference in remuneration that we observe in the labor market as due to human capital. For example, if I am paid less than another Ph.D., that must
be because I have lower “skills” in some other dimension that’s not being measured by my years of schooling—this is the famous (or infamous) unobserved heterogeneity issue. The presumption that all pay differences are related to skills (even if these skills are unobserved to the economists in the standard data sets) is not a bad place to start when we want to impose a conceptual structure on empirical wage distributions, but there are many notable exceptions, some of which will be discussed later in the class. Here it is useful to mention three:

1. Compensating differentials: a worker may be paid less in money, because he is receiving part of his compensation in terms of other (hard-to-observe) characteristics of the job, which may include lower effort requirements, more pleasant working conditions, better amenities etc.

2. Labor market imperfections: two workers with the same human capital may be paid different wages because jobs differ in terms of their productivity and pay, and one of them ended up matching with the high productivity job, while the other has matched with the low productivity one.

3. Taste-based discrimination: employers may pay a lower wage to a worker because of the worker’s gender or race due to their prejudices.

In interpreting wage differences, and therefore in thinking of human capital investments and the incentives for investment, it is important to strike the right balance between assigning earning differences to unobserved heterogeneity, compensating wage differentials and labor market imperfections.
2. Uses of Human Capital

The standard approach in labor economics views human capital as a set of skills/characteristics that increase a worker’s productivity. This is a useful starting place, and for most practical purposes quite sufficient. Nevertheless, it may be useful to distinguish between some complementary/alternative ways of thinking of human capital. Here is a possible classification:

(1) The Becker view: human capital is directly useful in the production process. More explicitly, human capital increases a worker’s productivity in all tasks, though possibly differentially in different tasks, organizations, and situations. In this view, although the role of human capital in the production process may be quite complex, there is a sense in which we can think of it as represented (representable) by a unidimensional object, such as the stock of knowledge or skills, $h$, and this stock is directly part of the production function.

(2) The Gardener view: according to this view, we should not think of human capital as unidimensional, since there are many many dimensions or types of skills. A simple version of this approach would emphasize mental vs. physical abilities as different skills. I dub this the Gardener view after the work by the social psychologist Howard Gardener, who contributed to the development of multiple-intelligences theory, in particular emphasizing how many geniuses/famous personalities were very “unskilled” in some other dimensions.
(3) The Schultz/Nelson-Phelps view: human capital is viewed mostly as the capacity to adapt. According to this approach, human capital is especially useful in dealing with “disequilibrium” situations, or more generally, with situations in which there is a changing environment, and workers have to adapt to this.

(4) The Bowles-Gintis view: “human capital” is the capacity to work in organizations, obey orders, in short, adapt to life in a hierarchical/capitalist society. According to this view, the main role of schools is to instill the “correct” ideology and approach towards life to individuals.

(5) The Spence view: observable measures of human capital are more a signal of ability than characteristics independently useful in the production process.

Despite their differences, the first three views are quite similar, in that “human capital” will be valued in the market because it increases firms’ profits. This is straightforward in the Becker and Schultz views, but also similar in the Gardener view. In fact, in many applications, labor economists’ view of human capital would be a mixture of these three approaches. Even the Bowles-Gintis view has very similar implications. Here, firms would pay higher wages to educated workers because these workers will be more useful to the firm as they will obey orders better and will be more reliable members of the firm’s hierarchy. The Spence view is different from the others, however, in that observable measures of human capital may be rewarded because they
are signals about some other characteristics of workers. We will discuss different implications of these views below.

3. Sources of Human Capital Differences

It is useful to think of the possible sources of human capital differences before discussing the incentives to invest in human capital:

(1) Innate ability: workers can have different amounts of skills/human capital because of innate differences. Research in biology/social biology has documented that there is some component of IQ which is genetic in origin (there is a heated debate about the exact importance of this component, and some economists have also taken part in this). The relevance of this observation for labor economics is twofold: (i) there is likely to be heterogeneity in human capital even when individuals have access to the same investment opportunities and the same economic constraints; (ii) in empirical applications, we have to find a way of dealing with this source of differences in human capital, especially when it’s likely to be correlated with other variables of interest.

(2) Schooling: this has been the focus of much research, since it is the most easily observable component of human capital investments. It has to be borne in mind, however, that the $R^2$ of earnings regressions that control for schooling is relatively small, suggesting that schooling differences account for a relatively small fraction of the differences in earnings. Therefore,
there is much more to human capital than schooling. Nevertheless, the analysis of schooling is likely to be very informative if we presume that the same forces that affect schooling investments are also likely to affect non-schooling investments. So we can infer from the patterns of schooling investments what may be happening to non-schooling investments, which are more difficult to observe.

(3) School quality and non-schooling investments: a pair of identical twins who grew up in the same environment until the age of 6, and then completed the same years of schooling may nevertheless have different amounts of human capital. This could be because they attended different schools with varying qualities, but it could also be the case even if they went to the same school. In this latter case, for one reason or another, they may have chosen to make different investments in other components of their human capital (one may have worked harder, or studied especially for some subjects, or because of a variety of choices/circumstances, one may have become more assertive, better at communicating, etc.). Many economists believe that these “unobserved” skills are very important in understanding the structure of wages (and the changes in the structure of wages). The problem is that we do not have good data on these components of human capital. Nevertheless, we will see different ways of inferring what’s happening to these dimensions of human capital below.
3. SOURCES OF HUMAN CAPITAL DIFFERENCES

(4) Training: this is the component of human capital that workers acquire after schooling, often associated with some set of skills useful for a particular industry, or useful with a particular set of technologies. At some level, training is very similar to schooling in that the worker, at least to some degree, controls how much to invest. But it is also much more complex, since it is difficult for a worker to make training investments by himself. The firm also needs to invest in the training of the workers, and often ends up bearing a large fraction of the costs of these training investments. The role of the firm is even greater, once we take into account that training has a more of a “matching” component in the sense that it is most useful for the worker to invest in a set of specific technologies that the firm will be using in the future. So training is often a joint investment by firms and workers, complicating the analysis.

(5) Pre-labor market influences: there is increasing recognition among economists that peer group effects to which individuals are exposed before they join the labor market may also affect their human capital significantly. At some level, the analysis of these pre-labor market influences may be “sociological”. But it also has an element of investment. For example, an altruistic parent deciding where to live is also deciding whether her offspring will be exposed to good or less good pre-labor market influences. Therefore, some of the same issues that arise in thinking about the theory of schooling and training will apply in this context too.
4. A Simple Two-Period Model of Schooling Investments and Some Evidence

I start with the working assumption that human capital, in particular schooling, is directly productive as in the Becker view of human capital (or more generally as in the Gardener or Schultz views), and discuss some of the main theoretical and empirical issues that arise in thinking about human capital investments in this context. I will return later to discuss how high the returns education are in practice, and whether we should think of human capital as directly productive or simply as a signal. Also, for now I will think of wages as reflecting worker productivity, so I will, interchangeably, refer to schooling increasing the human capital, productivity or wages of the worker.

The economy lasts two periods. In period 1 an individual (parent) works, consumes $c$, saves $s$, decides whether to send their offspring to school, $e = 0$ or 1, and then dies at the end of the period. Utility of household $i$ is given as:

\[(4.1) \quad \ln c_i + \ln \hat{c}_i\]

where $\hat{c}$ is the consumption of the offspring. There is heterogeneity among children, so the cost of education, $\theta_i$ varies with $i$. In the second period skilled individuals (those with education) receive a wage $w_s$ and an unskilled worker receives $w_u$.

First, consider the case in which there are no credit market problems, so parents can borrow on behalf of their children, and when they do so, they pay the same interest rate, $r$, as the rate they would obtain
by saving. Then, the decision problem of the parent with income $y_i$ is to maximize (4.1) with respect to $e_i$, $c_i$ and $\hat{c}_i$, subject to the budget constraint:

$$c_i + \frac{\hat{c}_i}{1 + r} \leq \frac{w_u}{1 + r} + e_i \cdot \frac{w_s - w_u}{1 + r} + y_i - e_i \cdot \theta_i$$

The important point to note is that $e_i$ does not appear in the objective function, so the education decision will be made simply to maximize the budget set of the consumer. This is the essence of the *separation theorem*, which says that in the presence of perfect credit markets, pure investment decisions will be independent of preferences. In particular, here parents will choose to educate their offspring if

(4.2) $$\theta_i \leq \frac{w_s - w_u}{1 + r}$$

One important feature of this decision rule is that a greater skill premium as captured by $w_s - w_u$ will encourage schooling, while the higher interest rate, $r$, will discourage schooling, which is a form of investment with upfront costs and delayed benefits.

In practice, this solution may be difficult to achieve for a variety of reasons. First, there is the usual list of informational/contractual problems, creating credit constraints or transaction costs that introduce a wedge between borrowing and lending rates (or even make borrowing impossible for some groups). Second, in many cases, it is the parents who make part of the investment decisions for their children, so the above solution involves parents borrowing to finance both the education expenses and also part of their own current consumption. These loans are then supposed to be paid back by their children. With the above
setup, this arrangement works since parents are altruistic. However, if there are non-altruistic parents, this will create obvious problems.

Therefore, in many situations credit problems might be important. Now imagine the same setup, but also assume that parents cannot have negative savings, which is a simple and severe form of credit market problems. This modifies the constraint set as follows

\[
\begin{align*}
    c_i & \leq y_i - e_i \cdot \theta_i - s_i \\
    s_i & \geq 0 \\
    \hat{c}_i & \leq w_u + e_i \cdot (w_s - w_u) + (1 + r) \cdot s
\end{align*}
\]

First note that for a parent with \( y_i - e_i \cdot \theta_i > 0 \), the constraint of nonnegative savings is not binding, so the same solution as before will apply. Therefore, credit constraints will only affect parents who needed to borrow to finance their children’s education.

To characterize the solution to this problem, look at the utilities from investing and not investing in education of a parent. Also to simplify the discussion let us focus on parents who would not choose positive savings, that is, those parents with \( y_i \leq w_u \). The utilities from investing and not investing in education are given, respectively, by

\[
U(e = 1 \mid y_i, \theta_i) = \ln(y_i - \theta_i) + \ln w_s, \quad \text{and} \quad U(e = 0 \mid y_i, \theta_i) = \ln y_i + \ln w_u.
\]

Comparison of these two expressions implies that parents with

\[
\theta_i \leq y_i \cdot \frac{w_s - w_u}{w_s}
\]

will invest in education. It is then straightforward to verify that:

1. This condition is more restrictive than (4.2) above, since \( y_i \leq w_u < w_s \).
(2) As income increases, there will be more investment in education, which contrasts with the non-credit-constrained case.

One interesting implication of the setup with credit constraints is that the skill premium, \( w_s - w_u \), still has a positive effect on human capital investments. However, in more general models with credit constraints, the conclusions may be more nuanced. For example, if \( w_s - w_u \) increases because the unskilled wage, \( w_u \), falls, this may reduce the income level of many of the households that are marginal for the education decision, thus discourage investment in education.

5. Evidence on Human Capital Investments and Credit Constraints

This finding, that income only matters for education investments in the presence of credit constraints, motivates investigations of whether there are significant differences in the educational attainment of children from different parental backgrounds as a test of the importance of credit constraints on education decisions. Of course, the empirical relationship between family income and education is interesting in its own right.

A typical regression would be along the lines of

\[
\text{schooling} = \text{controls} + \alpha \cdot \log \text{parental income}
\]

which leads to positive estimates of \( \alpha \), consistent with credit constraints. The problem is that there are at least two alternative explanations for why we may be estimating a positive \( \alpha \):
(1) Children’s education may also be a consumption good, so rich parents will “consume” more of this good as well as other goods. If this is the case, the positive relationship between family income and education is not evidence in favor of credit constraints, since the “separation theorem” does not apply when the decision is not a pure investment (enters directly in the utility function). Nevertheless, the implications for labor economics are quite similar: richer parents will invest more in their children’s education.

(2) The second issue is more problematic. The distribution of costs and benefits of education differ across families, and are likely to be correlated with income. That is, the parameter $\theta_i$ in terms of the model above will be correlated with $y_i$, so a regression of schooling on income will capture the direct effect of different costs and benefits of education.

One line of attack to deal with this problem has been to include other characteristics that could proxy for the costs and benefits of education, or attitudes toward education. The interesting finding here is that when parents’ education is also included in the regression, the role of income is substantially reduced.

Does this mean that credit market problems are not important for education? More strongly, does it mean that parents’ income does not have a direct affect on education? Not necessarily. Again, there are two considerations:

(1) First, parents’ income may affect more the quality of education, especially through the choice of the neighborhood in
which the family lives. Therefore, high income parents will “buy” more human capital for their children, not by sending them to school for longer, but by providing them with better schooling.

(2) Parental income is often measured with error, and has a significant transitory component, so parental education may be a much better proxy for permanent income than income observations in these data sets. Therefore, even when income matters for education, all its effect my load on the parental education variable.

Neither problem is easy to deal with, but there are possible avenues. First, we could look at the income of children rather than their schooling as the outcome variable. To the extent that income reflects skills (broadly defined), it will incorporate unobserved dimensions of human capital, including school quality. This takes us to the literature on intergenerational mobility. The typical regression here is

(5.1) \[ \log \text{child income} = \text{controls} + \alpha \cdot \log \text{parental income} \]

Regressions of this sort were first investigated by Becker and Tomes. They found relatively small coefficients, typically in the neighborhood of 0.3 and 0.4. This means that if your parents are twice as rich as my parents, you will typically be about 30 to 40 percent as rich as I. With this degree of intergenerational dependence, differences in initial conditions will soon disappear. In fact, your children will be typically about 10 percent ($\alpha^2$ percent) richer than my children. So this finding implies that we are living in a relatively “egalitarian” society.
To see this more clearly, consider the following simple model:

\[ \ln y_t = \mu + \alpha \ln y_{t-1} + \varepsilon_t \]

where \( y_t \) is the income of \( t \)-th generation, and \( \varepsilon_t \) is a serially independent disturbance term with variance \( \sigma^2_\varepsilon \). Then the long-term variance of log income is:

\[ \sigma^2_y = \frac{\sigma^2_\varepsilon}{1 - \alpha^2} \]  

(5.2)

Using the estimate of 0.3 for \( \alpha \), equation (5.2) implies that the long-term variance of log income will be approximately 10 percent higher than \( \sigma^2_\varepsilon \), so the long-run income distribution will basically reflect transitory shocks to dynasties’ incomes and skills, and not inherited differences.

Returning to the interpretation of \( \alpha \) in equation (5.1), also note that a degree of persistence in the neighborhood of 0.3 and 0.4 is not very different from what we might expect to result simply from the inheritance of IQ between parents and children, or from the children’s adoption of cultural values favoring education from their parents. As a result, these estimates suggest that there is a relatively small affect of parents income on children’s human capital.

This work has been criticized, however, because there are certain simple biases, stacking the cards against finding large estimates of the coefficient \( \alpha \). First, measurement error will bias the coefficient \( \alpha \) towards zero. Second, in typical panel data sets, we observe children at an early stage of their life cycles, where differences in earnings may be less than at later stages, again biasing \( \alpha \) downward. Third, income mobility may be very nonlinear, with a lot of mobility among middle income
families, but very little at the tails. Work by Solon and Zimmerman has dealt with the first two problems. They find that controlling for these issues increases the degree of persistence substantially to about 0.45 or even 0.55. Cooper, Durlauf and Johnson, in turn, find that there is much more persistence at the top and the bottom of income distribution than at the middle.

That the difference between 0.3 and 0.55 is in fact substantial can be seen by looking at the implications of using $\alpha = 0.55$ in (5.2). Now the long-run income distribution will be substantially more disperse than the transitory shocks. More specifically, we will have $\sigma^2_y \approx 1.45 \cdot \sigma^2_\varepsilon$.

To deal with the second empirical issue, one needs a source of exogenous variation in incomes to implement an IV strategy. There aren’t any perfect candidates, but some imperfect ones exist. One possibility, pursued in Acemoglu and Pischke (2000), is to exploit changes in the income distribution that have taken place over the past 30 years to get a source of exogenous variation. The basic idea is that the rank of a family in income distribution is a good proxy for parental human capital, and conditional on that rank, the income gap has widened over the past 20 years. Moreover, this has happened differentially across states. One can exploit this source of variation by estimating regression of the form

\begin{equation}
(5.3) \quad s_{iqjt} = \delta_q + \delta_j + \delta_t + \beta_q \ln y_{iqjt} + \varepsilon_{iqjt},
\end{equation}

where $q$ denotes income quartile, $j$ denotes region, and $t$ denotes time. $s_{iqjt}$ is education of individual $i$ in income quartile $q$ region $j$ time $t$. With no effect of income on education, $\beta_q$’s should be zero. With
credit constraints, we might expect lower quartiles to have positive $\beta$’s. Acemoglu and Pischke report versions of this equation using data aggregated to income quartile, region and time cells. The estimates of $\beta$ are typically positive and significant. However, the evidence does not indicate that the $\beta$’s are higher for lower income quartiles, which suggests that there may be more to the relationship between income and education than simple credit constraints.

6. The Ben-Porath Model

The above model was two-period, consisting of an investment and a consumption period. There are a number of interesting issues that arise when we consider longer time horizons. Some of these are highlighted by the Ben-Porath model, which I discuss briefly here.

Consider an individual who lives for $T$ periods, starts with a uni-dimensional measure of human capital, $H_0$, and can borrow and lend at the interest rate $r$. As noted above, the separation theorem implies that this individual will act to maximize the net present discounted value of his income using the discount rate $r$. Denote the stock of human capital at time $t$ by $H_t$. Of this, a fraction $s_t$ (a fraction $s_t$ of the individual’s time) is spent for further human capital accumulation, and the rest is sold in the labor market at the price $w$. So we have

\[
\dot{H}_t = I_t - \delta H_t
\]

where $\delta$ is a depreciation rate of human capital (for example, because of the introduction of new technologies that make part of the existing human capital obsolete), and $I_t$ is new investment in human capital.
Table 4
Fixed effects regressions for the probability of attending college within two years of high school controlling for income quartile region by income quartile cells, 1972-1992

<table>
<thead>
<tr>
<th></th>
<th>Ever attending any college</th>
<th>Ever attending four-year college</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) (2) (3) (4)</td>
<td>(5) (6) (7) (8)</td>
</tr>
<tr>
<td>Independent variable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log mean family income</td>
<td>0.218 (0.101)</td>
<td>0.107 (0.044)</td>
</tr>
<tr>
<td>Return to college</td>
<td>1.336 (0.491)</td>
<td>— (0.616)</td>
</tr>
<tr>
<td>Region effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Income quartile effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year effects</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Income quartile \times Region effects</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Income quartile \times Year effects</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Region \times Year effects</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

*Data are cell level means for 4 Census regions, 4 years, and 4 quartiles for the income of the student’s family. Number of cells is 64. Dependent variable is the fraction of students enrolled in any college or in a four-year college within two years of high school graduation calculated from the NLS-72, HSB Senior and Sophomore cohorts, and the NELS. Students left high school in 1972, 1980, 1982, and 1992. Return to college is the relative wage of those with exactly 4 years of college to those with a high school degree (for workers with 1-5 years of experience) calculated from the Census for 1970, 1980, and 1990.*
Table 5
Fixed effects regressions for the probability of attending college within two years of high school effects by income quartile region by income quartile cells, 1972–1992

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Ever attending any college</th>
<th>Ever attending four-year college</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) (2) (3) (4)</td>
<td>(5) (6) (7) (8)</td>
</tr>
<tr>
<td>Log mean family income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 1</td>
<td>0.018 (0.143)</td>
<td>0.010 (0.085)</td>
</tr>
<tr>
<td></td>
<td>0.154 (0.056)</td>
<td>0.108 (0.052)</td>
</tr>
<tr>
<td></td>
<td>0.139 (0.064)</td>
<td>0.064 (0.053)</td>
</tr>
<tr>
<td></td>
<td>−0.039 (0.187)</td>
<td>−0.016 (0.190)</td>
</tr>
<tr>
<td>Log mean family income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>0.229 (0.258)</td>
<td>0.151 (0.153)</td>
</tr>
<tr>
<td></td>
<td>0.189 (0.113)</td>
<td>0.128 (0.105)</td>
</tr>
<tr>
<td></td>
<td>0.167 (0.117)</td>
<td>0.087 (0.101)</td>
</tr>
<tr>
<td></td>
<td>0.201 (0.334)</td>
<td>−0.205 (0.339)</td>
</tr>
<tr>
<td>Log mean family income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 3</td>
<td>0.617 (0.273)</td>
<td>0.428 (0.162)</td>
</tr>
<tr>
<td></td>
<td>0.161 (0.116)</td>
<td>0.174 (0.107)</td>
</tr>
<tr>
<td></td>
<td>0.148 (0.129)</td>
<td>0.150 (0.112)</td>
</tr>
<tr>
<td></td>
<td>0.328 (0.283)</td>
<td>0.039 (0.287)</td>
</tr>
<tr>
<td>Log mean family income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 4</td>
<td>0.405 (0.152)</td>
<td>0.392 (0.092)</td>
</tr>
<tr>
<td></td>
<td>0.012 (0.071)</td>
<td>0.212 (0.066)</td>
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<td></td>
<td>−0.005 (0.072)</td>
<td>0.183 (0.063)</td>
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<tr>
<td></td>
<td>0.231 (0.132)</td>
<td>0.147 (0.134)</td>
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<td>0.053 (0.623)</td>
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<tr>
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<td>−1.049 (0.759)</td>
<td>−1.577 (0.659)</td>
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<td>0.599 (0.556)</td>
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<td>−1.032 (0.726)</td>
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<tr>
<td>Quartile 3</td>
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<td>0.171 (0.622)</td>
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<tr>
<td></td>
<td>−0.963 (0.722)</td>
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<tr>
<td>Quartile 4</td>
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<td>1.304 (0.564)</td>
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<td></td>
<td>−0.438 (0.723)</td>
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<tr>
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<td>Income quartile × Year</td>
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<tr>
<td>Region × Year effects</td>
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*Data are cell level means for 4 Census regions, 4 years, and 4 quartiles for the income of the student's family. Number of cells is 64. Dependent variable is the fraction of students enrolled in any college or in a four-year college within two years of high school graduation calculated from the NLS-72, HSB Senior and Sophomore cohorts, and the NELS. Students left high school in 1972, 1980, 1982, and 1992. Return to college is the relative wage of those with exactly 4 years of college to those with a high school degree (for workers with 1–5 years of experience) calculated from the Census for 1970, 1980, and 1990.
The production function for new investment is

\[ I_t = B (sH_t)\alpha D^\beta_t \]

where \( D_t \) is purchased inputs used for human capital investments (schooling, vocational courses, books, etc.), and the price of this input is assumed to be constant over time at \( P \).

The net present discounted value of (net) income is therefore

\[
\int_0^T \exp(-rt) (w (1 - s_t) H_t - PD_t) \, dt
\]

subject to (6.1) and (6.2). Notice that, because of the separation theorem, I did not have to specify the utility function of the individual.

The solution to this problem is somewhat messy to characterize, but conceptually quite simple. There will generally be three phases of human capital accumulation:

1. \( s_t = 1 \), full-time schooling and no earnings. Early on it makes sense for individuals to invest all (or most) of their time in schooling since the opportunity costs of doing so (the forgone market earnings) are small. Moreover, there is a relatively long horizon left for the individual to recoup the costs.

2. \( s_t \in (0, 1) \), there is positive earnings (no full-time schooling) but also investment in human capital. So we will see earnings grow over time in this regime. As time progresses in this phase, \( s_t \) declines, since both the opportunity cost of investment increases and the time horizon shortens. This suggests that the rate of earnings growth should slow down as the individual ages.
(3) $s_t = 0$, investment has stopped and earnings are falling due to depreciation. Once there is a short enough horizon left, it makes sense for the individual to stop investing in human capital. This is the same reasoning which suggests that it will be the younger workers that adopt new technologies, since they have a longer time horizon.

This model provides a useful way of thinking of the lifecycle of the individual, which starts with full-time schooling, and then there is a period of “full-time” working, but still accompanied by investment in human capital and thus increasing earnings. The increase in earnings takes place at a slower rate as the individual ages, and then there is also some evidence that earnings may start falling at the very end of workers’ careers.

The available evidence is consistent with these predictions. Nevertheless, this evidence comes from cross-sectional age-experience profiles, so it has to be interpreted with some caution. For example, the decline at the very end could be due to “selection,” as the higher-ability workers retire earlier.

Perhaps more worrisome for this interpretation is the fact that the increase in earnings may reflect not the accumulation of human capital due to investment, but either:

1. simple age effects; individuals become more productive as they get older. Or
2. simple experience effects: individuals become more productive as they get more experienced—this is independent of whether they choose to invest or not.
It is difficult to distinguish between the Ben-Porath model and the second explanation. But there is some evidence that could be useful to distinguish between age effects vs. experience effects (automatic or due to investment).

Josh Angrist’s paper on Vietnam veterans basically shows that workers who served in the Vietnam War lost the experience premium associated with the years they served in the war. Presuming that serving in the war has no productivity effects, this evidence suggests that much of the age-earnings profiles are due to experience not simply due to age. Nevertheless, this evidence is consistent both with direct experience effects on worker productivity, and also a Ben Porath type explanation where workers are purposefully investing in their human capital while working, and experience is proxying for these investments.

7. Selection and Wages—The One-Factor Model

We often mention the possibility of selection bias in discussing, among other things, education, migration, labor supply, and sectoral choice decisions. The basic idea can be seen by considering a situation which each worker has $J > 1$ choices. The unobserved characteristics of those making different choices will differ, and this difference will have an effect on the outcomes of interest, such as wages, over and above the direct effect of the choices themselves.

It is useful to distinguish between selection based on a single factor, which is often referred to as the one-factor model, and multidimensional selection, often referred to as the Roy model.
Suppose that individuals are distinguished by an unobserved type, $z$, which is assumed to be distributed uniformly between 0 and 1. Individuals decide whether to obtain education, which costs $c$. The wage of an individual of type $z$ when he has no education is

$$w_0(z) = z$$

and when he obtains education, it is

(7.1) $$w_1(z) = \alpha_0 + \alpha_1 \cdot z,$$

where $\alpha_0 > 0$ and $\alpha_1 > 1$. $\alpha_0$ is the main effect of education on earnings, which applies irrespective of ability, whereas $\alpha_1$ interacts with ability. The assumption that $\alpha_1 > 1$ implies that education is complementary to ability, and will ensure that high-ability individuals are “positively selected” into education.

Individuals make their schooling choices to maximize income. It is straightforward to see that all individuals of type $z \geq z^*$ will obtain education, where

$$z^* \equiv \frac{c - \alpha_0}{\alpha_1 - 1},$$

which, to make the analysis interesting, I assume lies between 0 and 1. The diagram gives the wage distribution in this economy.

Now let us look at mean wages by education group. By standard arguments, these are

$$\bar{w}_0 = \frac{c - \alpha_0}{2 (\alpha_1 - 1)},$$

$$\bar{w}_1 = \alpha_0 + \alpha_1 \frac{\alpha_1 - 1 + c - \alpha_0}{2 (\alpha_1 - 1)}$$

It is clear that $\bar{w}_1 - \bar{w}_0 > \alpha_0$, so the wage gap between educated and uneducated groups is greater than the main effect of education in
\[ \omega_1(z) = \alpha_0 + \alpha_1 z \]

\[ \omega_0(z) = z \]

\[ z^* = \frac{c - \alpha_0}{\alpha_1 - 1} \]
7. SELECTION AND WAGES—THE ONE-FACTOR MODEL

Equation (7.1)—since \( \alpha_1 - 1 > 0 \). This reflects two components. First, the return to education is not \( \alpha_0 \), but it is \( \alpha_0 + \alpha_1 \cdot z \) for individual \( z \). Therefore, for a group of mean ability \( \bar{z} \), the return to education is

\[
\tilde{w}_1(\bar{z}) - \tilde{w}_0(\bar{z}) = \alpha_0 + (\alpha_1 - 1) \cdot \bar{z},
\]

which we can simply think of as the return to education evaluated at the mean ability of the group.

But there is one more component in \( \bar{w}_1 - \bar{w}_0 \), which results from the fact that the average ability of the two groups is not the same, and the earning differences resulting from this ability gap are being counted as part of the returns to education. In fact, since \( \alpha_1 - 1 > 0 \), high-ability individuals are selected into education increasing the wage differential.

To see this, rewrite the observed wage differential as follows

\[
\bar{w}_1 - \bar{w}_0 = \alpha_0 + (\alpha_1 - 1) \left[ \frac{c - \alpha_0}{2(\alpha_1 - 1)} \right] + \frac{\alpha_1}{2}.
\]

Here, the first two terms give the return to education evaluated at the mean ability of the uneducated group. This would be the answer to the counter-factual question of how much the earnings of the uneducated group would increase if they were to obtain education. The third term is the additional effect that results from the fact that the two groups do not have the same ability level. It is therefore the selection effect.

Alternatively, we could have written

\[
\bar{w}_1 - \bar{w}_0 = \alpha_0 + (\alpha_1 - 1) \left[ \frac{\alpha_1 - 1 + c - \alpha_0}{2(\alpha_1 - 1)} \right] + \frac{1}{2},
\]

where now the first two terms give the return to education evaluated at the mean ability of the educated group, which is greater than the return.
to education evaluated at the mean ability level of the uneducated group. So the selection effect is somewhat smaller, but still positive.

This example illustrates how looking at observed averages, without taking selection into account, may give misleading results, and also provides a simple example of how to think of decisions in the presence of this type of heterogeneity.

It is also interesting to note that if $\alpha_1 < 1$, we would have negative selection into education, and observed returns to education would be less than the true returns. The case of $\alpha_1 < 1$ appears less plausible, but may arise if high ability individuals do not need to obtain education to perform certain tasks.
CHAPTER 2

The Theory of Training Investments

1. General Vs. Specific Training

In the Ben-Porath model, an individual continues to invest in his human capital after he starts employment. We normally think of such investments as “training”, provided either by the firm itself on-the-job, or acquired by the worker (and the firm) through vocational training programs. This approach views training just as schooling, which is perhaps too blackbox for most purposes.

More specifically, two complications that arise in thinking about training are:

(1) Most of the skills that the worker acquires via training will not be as widely applicable as schooling. As an example, consider a worker who learns how to use a printing machine. This will only be useful in the printing industry, and perhaps in some other specialized firms; in this case, the worker will be able to use his skills only if he stays within the same industry. Next, consider the example of a worker who learns how to use a variety of machines, and the current employer is the only firm that uses this exact variety; in this case, if the worker changes employer, some of his skills will become redundant. Or more extreme, consider a worker who learns how to get along with
his/her colleagues or with the customers of its employer. These skills are even more “specific”, and will become practically useless if he changes employer.

(2) A large part of the costs of training consist of forgone production and other costs borne directly by the employer. So at the very least, training investments have to be thought as joint investments by the firm and the worker, and in many instances, they may correspond to the firm’s decisions more than to that of the worker.

The first consideration motivates a particular distinction between two types of human capital in the context of training:

(1) Firm-specific training: this provides a worker with *firm-specific skills*, that is, skills that will increase his or her productivity *only* with the current employer.

(2) General training: this type of training will contribute to the worker’s general human capital, increasing his productivity with a range of employers.

Naturally, in practice actual training programs could (and often do) provide a combination of firm-specific and general skills. The second consideration above motivates models in which firms have an important say in whether there will be training or not. In the extreme case where the costs are borne naturally by the firm (for example, because the process of training reduces production), we can think of the situation in which the firm decides whether there will be training or not.
2. The Becker Model of Training

Let us start with investments in general skills. Consider the following stylized model:

• At time $t = 0$, there is an initial production of $y_0$, and also the firm decides the level of training $\tau$, incurring the cost $c(\tau)$. Let us assume that $c(0) = 0$, $c'(0) = 0$, $c'(\cdot) \geq 0$ and $c''(\cdot) > 0$. The second assumption here ensures that it’s always socially beneficial to have some amount of positive training.

• At time $t = 1/2$, the firm makes a wage offer $w$ to the worker, and other firms also compete for the worker’s labor. The worker decides whether to quit and work for another firm. Let us assume that there are many identical firms who can use the general skills of the worker, and the worker does not incur any cost in the process of changing jobs. This assumption makes the labor market essentially competitive.

• At time $t = 1$, there is the second and final period of production, where output is equal to $y_1 + \alpha(\tau)$, with $\alpha(0) = 0$, $\alpha'(\cdot) > 0$ and $\alpha''(\cdot) < 0$. For simplicity, let us ignore discounting.

Before Becker analyzed this problem, the general conclusion, for example conjectured by Pigou, was that there would be underinvestment in training. The reasoning went along the following lines. Suppose the firm invests some amount $\tau > 0$. For this to be profitable for the firm, at time $t = 1$, it needs to pay the worker at most a wage of $w_1 < y_1 + \alpha(\tau) - c(\tau)$ to recoup its costs. But suppose that the firm
was offering such a wage. Could this be an equilibrium? No, because there are other firms who have access to exactly the same technology, they would be willing to bid a wage of \( w_1 + \varepsilon \) for this worker’s labor services. Since there are no costs of changing employer, for \( \varepsilon \) small enough such that \( w_1 + \varepsilon < y_1 + \alpha (\tau) \), a firm offering \( w_1 + \varepsilon \) would both attract the worker by offering this higher wage and also make positive profits. This reasoning implies that in any competitive labor market, we must have \( w_1 = y_1 + \alpha (\tau) \). But then, the firm cannot recoup any of its costs and would like to choose \( \tau = 0 \). Despite the fact that a social planner would choose a positive level of training \( \tau^* \) such that \( c'(\tau^*) = \alpha'(\tau^*) \), the pre-Becker view was that this economy would fail to invest in training (that \( \tau^* \) is strictly positive immediately follows from the fact that \( c'(0) = 0 \) and \( \alpha'(0) > 0 \)).

The mistake in this reasoning was that it did not take into account the worker’s incentives to invest in his own training. In effect, the firm does not get any of the returns from training because the worker is receiving all of them. In other words, the worker is the full residual claimant of the increase in his own productivity, and in the competitive equilibrium of this economy without any credit market or contractual frictions, he would have the right incentives to invest in his training.

Let us analyze this equilibrium now. As is the case in all games of this sort, we are interested in the subgame perfect equilibria. So we have to solve the game by backward induction. First note that at \( t = 1 \), the worker will be paid \( w_1 = y_1 + \alpha (\tau) \). Next recall that \( \tau^* \) is the efficient level of training given by \( c'(\tau^*) = \alpha'(\tau^*) \). Then in the unique subgame perfect equilibrium, in the first period the firm will offer the
following package: training of $\tau^*$ and a wage of $w_0 = y_0 - c(\tau^*)$. Then, in the second period the worker will receive the wage of $w_1 = y_1 + \alpha(\tau^*)$ either from the current firm or from another firm.

To see why no other allocation could be an equilibrium, suppose that the firm offered $(\tau, w_0)$, such that $\tau \neq \tau^*$. For the firm to break even we need that $w_0 \leq y_0 - c(\tau)$, but by the definition of $\tau^*$, we have

$$y_0 - c(\tau^*) + y_1 + \alpha(\tau^*) > y_0 - c(\tau) + y_1 + \alpha(\tau) \geq w_0 + y_1 + \alpha(\tau)$$

So the deviation of offering $(\tau^*, y_0 - c(\tau^*) - \varepsilon)$ for $\varepsilon$ sufficiently small would attract the worker and make positive profits. Thus, the unique equilibrium is the one in which the firm offers training $\tau^*$.

Therefore, in this economy the efficient level of training will be achieved with firms bearing none of the cost of training, and workers financing training by taking a wage cut in the first period of employment (i.e, a wage $w_0 < y_0$).

There are a range of examples for which this model appears to provide a good description. These include some of the historical apprenticeship programs where young individuals worked for very low wages and then “graduated” to become master craftsmen; pilots who work for the Navy or the Air Force for low wages, and then obtain much higher wages working for private sector airlines; securities brokers, often highly qualified individuals with MBA degrees, working at a pay level close to the minimum wage until they receive their professional certification; or even academics taking an assistant professor job at Harvard despite the higher salaries in other departments.


3. Market Failures Due to Contractual Problems

The above result was achieved because firms could commit to a wage-training contract. In other words, the firm could make a credible commitment to providing training in the amount of $\tau^*$. Such commitments are in general difficult, since outsiders cannot observe the exact nature of the “training activities” taking place inside the firm. For example, the firm could hire workers at a low wage pretending to offer them training, and then employ them as cheap labor.

To capture these issues let us make the timing of events regarding the provision of training somewhat more explicit.

- At time $t = -1/2$, the firm makes a training-wage contract offer $(\tau', w_0)$. Workers accept offers from firms.
- At time $t = 0$, there is an initial production of $y_0$, the firm pays $w_0$, and also unilaterally decides the level of training $\tau$, which could be different from the promised level of training $\tau'$.
- At time $t = 1/2$, wage offers are made, and the worker decides whether to quit and work for another firm.
- At time $t = 1$, there is the second and final period of production, where output is equal to $y_1 + \alpha(\tau)$.

Now the subgame perfect equilibrium can be characterized as follows: at time $t = 1$, a worker of training $\tau$ will receive $w_1 = y_1 + \alpha(\tau)$. Realizing this, at time $t = 0$, the firm would offer training $\tau = 0$, irrespective of its contract promise. Anticipating this wage offer, the worker will only accept a contract offer of the form $(\tau', w_0)$, such that $w_0 \geq y_0$, and $\tau$ does not matter, since the worker knows that the firm is
not committed to this promise. As a result, we are back to the outcome conjectured by Pigou, with no training investment by the firm.

A similar conclusion would also be reached if the firm could write a binding contract about training, but the worker were subject to credit constraints and \( c(\tau^*) > y_0 \), so the worker cannot take enough of a wage cut to finance his training. In the extreme case where \( y_0 = 0 \), we are again back to the Pigou outcome, where there is no training investment, despite the fact that it is socially optimal to invest in skills.

4. Training in Imperfect Labor Markets—The Basic Ideas

4.1. Motivation. The general conclusion of both the Becker model with perfect (credit and labor) markets and the model with incomplete contracts (or severe credit constraints) is that there will be no firm-sponsored investment in general training. This conclusion follows from the common assumption of these two models, that the labor market is competitive, so the firm will never be able to recoup its training expenditures in general skills later during the employment relationship.

Is this a reasonable prediction? The answer appears to be no. There are many instances in which firms bear a significant fraction (sometimes all) of the costs of general training investments.

The first piece of evidence comes from the German apprenticeship system. Apprenticeship training in Germany is largely general. Firms training apprentices have to follow a prescribed curriculum, and apprentices take a rigorous outside exam in their trade at the end of the apprenticeship. The industry or crafts chambers certify whether firms fulfill the requirements to train apprentices adequately, while works
councils in the firms monitor the training and resolve grievances. At least in certain technical and business occupations, the training curricula limit the firms’ choices over the training content fairly severely. Estimates of the net cost of apprenticeship programs to employers in Germany indicate that firms bear a significant financial burden associated with these training investments. The net costs of apprenticeship training may be as high as DM 6,000 per worker.

Another interesting example comes from the recent growth sector of the US, the temporary help industry. The temporary help firms provide workers to various employers on short-term contracts, and receive a fraction of the workers’ wages as commission. Although blue-collar and professional temporary workers are becoming increasingly common, the majority of temporary workers are in clerical and secretarial jobs. These occupations require some basic computer, typing and other clerical skills, which temporary help firms often provide before the worker is assigned to an employer. Workers are under no contractual obligation to the temporary help firm after this training program. Most large temporary help firms offer such training to all willing individuals. As training prepares the workers for a range of assignments, it is almost completely general. Although workers taking part in the training programs do not get paid, all the monetary costs of training are borne by the temporary help firms, giving us a clear example of firm-sponsored general training. This was first noted by Krueger and is discussed in more detail by David Autor.

Other evidence is not as clear-cut, but suggests that firm-sponsored investments in general skills are widespread. A number of studies have
investigated whether workers who take part in general training programs pay for the costs by taking lower wages. The majority of these studies do not find lower wages for workers in training programs, and even when wages are lower, the amounts typically appear too small to compensate firms for the costs. Although this pattern can be explained within the paradigm of Becker’s theory by arguing that workers selected for training were more skilled in unobserved dimensions, it is broadly supportive of widespread firm-sponsored-training.

There are also many examples of firms that send their employees to college, MBA or literacy programs, and problem solving courses, and pay for the expenses while the wages of workers who take up these benefits are not reduced. In addition, many large companies, such as consulting firms, offer training programs to college graduates involving general skills. These employers typically pay substantial salaries and bear the full monetary costs of training, even during periods of full-time classroom training.

How do we make sense of these firm-sponsored investments in general training? I will now illustrate how in frictional labor markets, firms may also be willing to make investments in the general skills of their employees.

4.2. A Basic Framework. Consider the following two-period model. In period 1, the worker and/or the employer choose how much to invest in the worker’s general human capital, $\tau$. There is no production in the first period. In period 2, the worker either stays with the firm and
produces output $y = f(\tau)$, where $f(\tau)$ is a strictly increasing and concave function. The worker is also paid a wage rate, $w(\tau)$ as a function of his skill level (training) $\tau$, or he quits and obtains an outside wage. The cost of acquiring $\tau$ units of skill is again $c(\tau)$, which is strictly increasing and convex, and $c'(0) = 0$. There is no discounting, and all agents are risk-neutral.

Assume that all training is *technologically general* in the sense that $f(\tau)$ is the same in all firms.

If a worker leaves his original firm he will earn $v(\tau)$ in the outside labor market. Suppose $v(\tau) < f(\tau)$. That is, despite that fact that $\tau$ is general human capital, when the worker separates from the firm, he will get a lower wage than his marginal product in the current firm. The fact that $v(\tau) < f(\tau)$ implies that there is a surplus that the firm and the worker can share when they are together.

Let us suppose that this surplus will be divided by Nash bargaining, which gives the wage of the worker as:

\begin{equation}
(4.1) \quad w(\tau) = v(\tau) + \beta [f(\tau) - v(\tau)],
\end{equation}

where $\beta \in [0, 1]$ is the bargaining power of the worker.

An important point to note is that the equilibrium wage rate $w(\tau)$ is independent of $c(\tau)$: the level of training is chosen first, and then the worker and the firm bargain over the wage rate. At this point the training costs are already sunk, do not feature in the bargaining calculations (bygones are bygones).
Assume that \( \tau \) is determined by the investments of the firm and the worker, who independently choose their contribution, \( c_w \) and \( c_f \), and \( \tau \) is given by \( c(\tau) = c_w + c_f \). Assume that $1 investment by the worker costs \( p \) where \( p \geq 1 \). When \( p = 1 \), the worker has access to perfect credit markets and when \( p \to \infty \), the worker is severely constrained and cannot invest at all.

More explicitly, the timing of events are:

- The worker and the firm simultaneously decide their contributions to training expenses, \( c_w \) and \( c_f \). The worker receives an amount of training \( \tau \) such that \( c(\tau) = c_w + c_f \).
- The firm and the worker bargain over the wage for the second period, \( w(\tau) \), where the threat point of the worker is the outside wage, \( v(\tau) \), and the threat point of the firm is not to produce.
- Production takes place.

Given this setup, the contributions to training expenses \( c_w \) and \( c_f \) will be determined noncooperatively. More specifically, the firm chooses \( c_f \) to maximize profits:

\[
\pi(\tau) = f(\tau) - w(\tau) - c_f = (1 - \beta) [f(\tau) - v(\tau)] - c_f.
\]

subject to \( c(\tau) = c_w + c_f \). The worker chooses \( c_w \) to maximize utility:

\[
u(\tau) = w(\tau) - pc_w = \beta f(\tau) + (1 - \beta)v(\tau) - pc_f\]

subject to the same constraint.

The first order conditions are:
(4.2) \[(1 - \beta) [ f'(\tau) - v'(\tau)] - c'(\tau) = 0 \quad \text{if} \quad c_f > 0 \]

(4.3) \[v'(\tau) + \beta [ f'(\tau) - v'(\tau)] - pc'(\tau) = 0 \quad \text{if} \quad c_w > 0 \]

Inspection of these equations implies that generically, one of them will hold as a strict inequality, therefore, one of the parties will bear the full cost of training.

The result of no firm-sponsored investment in general training by the firm obtains when \( f(\tau) = v(\tau) \), which is the case of perfectly competitive labor markets. (4.2) then implies that \( c_f = 0 \), so when workers receive their full marginal product in the outside labor market, the firm will never pay for training. Moreover, as \( p \to \infty \), so that the worker is severely credit constrained, there will be no investment in training.

In contrast, suppose there are labor market imperfections, so that the outside wage is less than the productivity of the worker, that is \( v(\tau) < f(\tau) \). It is enough to ensure firm-sponsored investments in training? The answer is no. To see this, first consider the case with no wage compression, that is the case in which a marginal increase in skills is valued appropriately in the outside market. Mathematically this corresponds to \( v'(\tau) = f'(\tau) \) for all \( \tau \). Substituting for this in the first-order condition of the firm, (4.2), we immediately find that if \( c_f > 0 \), then \( c'(\tau) = 0 \). So in other words, there will be no firm contribution to training expenditures.

Next consider the case in which there is wage compression, i.e., \( v'(\tau) < f'(\tau) \). Now it is clear that the firm may be willing to invest
in the general training of the worker. The simplest way to see this is again to take the case of severe credit constraints on the worker, that is, $p \to \infty$, so that the worker cannot invest in training. Then, $v'(0) < f'(0)$ is sufficient to induce the firm to invest in training.

This shows the importance of *wage compression* for firm-sponsored training. The intuition is simple: wage compression in the outside market translates into wage compression inside the firm, i.e., it implies $w'(\tau) < f'\left(\tau\right)$. As a result, the firm makes greater profits from a more skilled (trained) worker, and has an incentive to increase the skills of the worker.

To clarify this point further, the figure draws the productivity, $f(\tau)$, and wage, $w(\tau)$, of the worker. The gap between these two curves is the profit of the firm. When $f'(\tau) = w'(\tau)$, this profit is independent of the skill level of the worker, and the firm has no interest in increasing the worker’s skill. A competitive labor market, $f(\tau) = v(\tau)$, implies this case. In contrast, if $f'(\tau) > w'(\tau)$, which is implied by $f'(\tau) > v'(\tau)$, then the firm makes more profits from more skilled workers, and is willing to invest in the general skills of its employees.

Let $\tau_w$ be the level of training that satisfies (4.3) as equality, and $\tau_f$ be the solution to (4.2). Then, it is clear that if $\tau_w > \tau_f$, the worker will bear all the cost of training. And if $\tau_f > \tau_w$, then the firm will bear all the cost of training (despite the fact that the worker may have access to perfect capital markets, i.e. $p = 1$).
To derive the implications of changes in the skill premium on training, let \( v(\tau) = a f(\tau) - b \). A decrease in \( a \) is equivalent to a decrease in the price of skill in the outside market, and would also tilt the wage function inside the firm, \( w(\tau) \), decreasing the relative wages of more skilled workers because of bargaining between the firm and the worker, with the outside wage \( v(\tau) \) as the threat point of the worker. Starting from \( a = 1 \) and \( p < \infty \), a point at which the worker makes all investments, a decrease in \( a \) leads to less investment in training from (4.3). This is simply an application of the Becker reasoning; without any wage compression, the worker is the one receiving all the benefits and bearing all the costs, and a decline in the returns to training will reduce his investments.

As \( a \) declines further, we will eventually reach the point where \( \tau_w = \tau_f \). Now the firm starts paying for training, and a further decrease
in a increases investment in general training (from (4.2)). Therefore, there is a U-shaped relation between the skill premium and training, so starting from a compressed wage structure, a further decrease in the skill premium may increase training. Holding \( f(\tau) \) constant a tilting up of the wage schedule, \( w(\tau) \), reduces the profits from more skilled workers, and the firm has less interest in investing in skills.

Changes in labor market institutions, such as minimum wages and unionization, will therefore affect the amount of training in this economy. To see the impact of a minimum wage, consider the next figure, and start with a situation where \( v(\tau) = f(\tau) - \Delta \) and \( p \to \infty \) so that the worker cannot invest in training, and there will be no training. Now impose a minimum wage as drawn in the figure. This distorts the wage structure and encourages the firm to invest in skills up to \( \tau^* \), as long
as $c(\tau^*)$ is not too high. This is because the firm makes higher profits from workers with skills $\tau^*$ than workers with skills $\tau = 0$.

This is an interesting comparative static result, since the standard Becker model with competitive labor markets implies that *minimum wages should always reduce training*. The reason for this is straightforward. Workers take wage cuts to finance their general skills training, and minimum wages will prevent these wage cuts, thus reducing training.

Therefore, an empirical investigation of the relationship between minimum wage changes and worker training is a way of finding out whether the Becker channel or the wage-compression channel is more important. Empirical evidence suggests that higher minimum wages are typically associated with more training for low-skill workers (though this relationship is not always statistically significant).

5. Training in Imperfect Labor Markets—General Equilibrium

The above analysis showed how in imperfect labor market firms will find it profitable to invest in the general skills of their employees as long as the equilibrium wage structure is compressed. The equilibrium wage structure will be compressed, in turn, when the outside wage structure, $v(\tau)$, is compressed—that is, when $v'(\tau) < f'(\tau)$. The analysis was partial equilibrium in that this outside wage structure was taken as given. There are many reasons why in frictional labor markets we may expect this outside wage structure to be compressed. These include adverse selection, bargaining, and efficiency wages, as
Table 9
The Effect of Minimum Wage Increases on Affected Workers

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum wage increased and wage in prior year is below the current minimum wage</td>
<td>0.010</td>
<td>(0.014)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Minimum increased and wage in prior year is below the current minimum and above prior year minimum</td>
<td>--</td>
<td>0.016</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Minimum wage increased and wage in prior year is below 150% of the current minimum wage</td>
<td>--</td>
<td>--</td>
<td>(0.008)</td>
<td>--</td>
</tr>
<tr>
<td>Minimum wage increased and wage in prior year is below 130% of the current minimum wage</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Change in high school graduation status</td>
<td>0.070</td>
<td>0.070</td>
<td>0.070</td>
<td>0.070</td>
</tr>
<tr>
<td>Change in new job status</td>
<td>0.032</td>
<td>0.032</td>
<td>0.032</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Notes: Basic sample with all workers with high school education or less, who do not move between states from one year to the next. Dependent variable is the change in training incidence between two consecutive years. All regressions also include a constant and year dummies. Regressions are weighted by NSLY sampling weights. Standard errors are adjusted for the presence of state*time effects in the error term, and therefore robust to the MA structure of the error. Sample size is 17101.
well as complementarity between general and specific skills. Here I will discuss how adverse selection leads to wage compression.

5.1. The Basic Model of Adverse Selection and Training.
This is a simplified version of the model in Acemoglu and Pischke (1998). Suppose that fraction $p$ of workers are high ability, and have productivity $\alpha(\tau)$ in the second period if they receive training $\tau$ in the first period. The remaining $1 - p$ are low ability and produce nothing (in terms of the above model, I am setting $y = 0$).

No one knows the worker’s ability in the first period, but in the second period, the current employer learns this ability. Firms never observe the ability of the workers they have not employed, so outsiders will have to form beliefs about the worker’s ability.

The exact timing of events is as follows:

- Firms make wage offers to workers. At this point, worker ability is unknown.
- Firms make training decisions, $\tau$.
- Worker ability is revealed to current employer and to the worker.
- Employers make second period wage offers to workers.
- Workers decide whether to quit.
- Outside firms compete for workers in the “secondhand” labor market. At this point, these firms observe neither worker ability nor whether the worker has quit or was laid off.
- Production takes place.

Since outside firms do not know worker ability when they make their bids, this is a (dynamic) game of incomplete information. So
we will look for a Perfect Bayesian Equilibrium of this game, which again involves backward induction, but also makes use of Bayes’ rule to determine beliefs.

First, note that all workers will leave their current employer if outside wages are higher. In addition, a fraction $\lambda$ of workers, irrespective of ability, realize that they form a bad match with the current employer, and leave whatever the wage is. The important assumption is that firms in the outside market observe neither worker ability nor whether a worker has quit or has been laid off. However, worker training is publicly observed.

These assumptions ensure that in the second period each worker obtains expected productivity conditional on his training. That is, his wage will be independent of his own productivity, but will depend on the average productivity of the workers who are in the secondhand labor market.

By Bayes’s rule, the expected productivity of a worker of training $\tau$, is

$$v(\tau) = \frac{\lambda \alpha(\tau)}{\lambda p + (1 - p)}$$

To see why this expression applies, note that all low ability workers will leave their initial employer, who will at most pay a wage of 0 (since this is the productivity of a low ability worker), and as we will see, outside wages are positive, low ability workers will quit (therefore, the offer of a wage of 0 is equivalent to a layoff). Those workers make up a fraction $1 - p$ of the total workforce. In addition, of the high ability workers who make up a fraction $p$ of the total workforce, a fraction $\lambda$ of
them will also leave. Therefore, the total size of the secondhand labor market is \( \lambda p + (1 - p) \), which is the denominator of (5.1). Of those, the low ability ones produce nothing, whereas the \( \lambda p \) high ability ones produce \( \alpha (\tau) \), which explains this expression.

Anticipating this outside wage, the initial employer has to pay each high ability worker \( v (\tau) \) to keep him. This observation, combined with (5.1), immediately implies that there is wage compression in this world, in the sense that

\[
v' (\tau) = \frac{\lambda p \alpha' (\tau)}{\lambda p + (1 - p)} < \alpha' (\tau),
\]

so the adverse selection problem introduces wage compression, and via this channel, will lead to firm-sponsored training.

To analyze this issue more carefully, consider the previous stage of the game. Now firm profits as a function of the training choice can be written as

\[
\pi (\tau) = (1 - \lambda) p [\alpha (\tau) - v (\tau)] - c (\tau).
\]

The first-order condition for the firm is

\[
\pi' (\tau) = (1 - \lambda) p [\alpha' (\tau) - v' (\tau)] - c' (\tau) = 0
\]

\[
= \frac{(1 - \lambda) p (1 - p) \alpha' (\tau)}{\lambda p + (1 - p)} - c' (\tau) = 0
\]

There are a number of noteworthy features:

(1) \( c' (0) = 0 \) is sufficient to ensure that there is firm-sponsored training (that is, the solution to (5.2) is interior).

(2) There is underinvestment in training relative to the first-best which would have involved \( p \alpha' (\tau) = c' (\tau) \) (notice that the first-best already takes into account that only a fraction \( p \) of
the workers will benefit from training). This is because of two reasons: first, a fraction \( \lambda \) of the high ability workers quit, and the firm does not get any profits from them. Second, even for the workers who stay, the firm is forced to pay them a higher wage, because they have an outside option that improves with their training, i.e., \( v'(\tau) > 0 \). This reduces profits from training, since the firm has to pay higher wages to keep the trained workers.

(3) The firm has monopsony power over the workers, enabling it to recover the costs of training. In particular, high ability workers who produce \( \alpha(\tau) \) are paid \( v(\tau) < \alpha(\tau) \).

(4) Monopsony power is not enough by itself. Wage compression is also essential for this result. To see this, suppose that we impose there is no wage compression, i.e., \( v'(\tau) = \alpha'(\tau) \), then inspection of the first line of (5.2) immediately implies that there will be zero training, \( \tau = 0 \).

(5) But wage compression is also not automatic; it is a consequence of some of the assumptions in the model. Let us modify the model so that high ability workers produce \( \eta + \alpha(\tau) \) in the second period, while low ability workers produce \( \alpha(\tau) \). This modification implies that training and ability are no longer complements. Both types of workers get exactly the same marginal increase in productivity (this contrasts with the previous specification where only high ability workers benefited from training, hence training and ability were highly complementary). Then, it is straightforward to check that we will
have
\[ v(\tau) = \frac{\lambda \eta}{\lambda p + (1-p)} + \alpha(\tau), \]
and hence \( v'(\tau) = \alpha'(\tau) \). Thus no wage compression, and firm-sponsored training. Intuitively, the complementarity between ability and training induces wage compression, because the training of high ability workers who are contemplating whether to leave the firm or not is judged by the market as the training of a relatively low ability worker (since low ability workers are overrepresented in the secondhand labor market). Therefore, the marginal increase in a (high ability) worker’s productivity due to training is valued less in the outside market, which views this worker, on average, as low ability. Hence the firm does not have to pay as much for the marginal increase in the productivity of a high ability worker, and makes greater profits from more trained high-ability workers.

(6) What happens if \( \pi(\tau) = (1-\lambda) p [\alpha(\tau) - v(\tau)] - c(\tau) > 0 \), that is, if firms are making positive profits at the level of training that they choose in equilibrium? If there is free entry at time \( t = 0 \), this implies that firms will compete for workers, since hiring a worker now guarantees positive profits in later periods. As a result, firms will have to pay a positive wage at time \( t = 0 \), precisely equal to \( W = \pi(\tau) \) as a result of this competition. This is because once a worker accepts a job with a firm, the firm has enough monopsony power at time \( t = 1 \) to make positive profits. Competition then implies that these profits have to be transferred to the worker at time \( t = 0 \). The
interesting result is that not only do firms pay for training, but they may also pay workers extra in order to attract them.

5.2. Evidence. How can this model be tested? One way is to look for evidence of this type of whether selection among highly trained workers. The fact that employers know more about their current employees may be a particularly good assumption for young workers, so a good area of application would be for apprentices in Germany.

According to the model, workers who quit or are laid off should get lower wages than those who stay in their jobs, which is a prediction that follows simply from adverse selection (and Gibbons and Katz tested in the U.S. labor market for all workers by comparing laid-off workers to those who lost their jobs as a result of plant closings). The more interesting implication here is that if the worker is separated from his firm for an exogenous reason that is clearly observable to the market, he should not be punished by the secondhand labor market. In fact, he’s “freed” from the monopsony power of the firm, and he may get even higher wages than stayers (who are on average higher ability, though subject to the monopsony power of their employer).

To see this, note that a worker who is exogenously separated from his firm will get to wage of $p\alpha(\tau)$ whereas stayers, who are still subject of the monopsony power of their employer, obtain the wage of $v(\tau)$ as given by (5.1), which could be less than $p\alpha(\tau)$. In the German context, workers who leave their apprenticeship firm to serve in the military provide a potential group of such exogenous separators. Interestingly, the evidence suggests that although these military quitters
are on average lower ability than those who stay in the apprenticeship firm, the military quitters receive higher wages.

5.3. Adverse selection and training in the temporary help industry. An alternative place to look for evidence is the temporary help industry in the U.S. Autor (2001) develops an extended version of this model, which also incorporates self-selection by workers, for the temporary help industry. Autor modifies the above model in four respects to apply it to the U.S. temporary help industry. These are:

1. The model now lasts for three periods, and in the last period, all workers receive their full marginal products. This is meant to proxy the fact that at some point temporary-help workers may be hired into permanent jobs where their remuneration may better reflect their productivity.

2. Workers have different beliefs about the probability that they are high ability. Some workers receive a signal which makes them believe that they are high ability with probability \( p \), while others believe that they are high ability with probability \( p' < p \). This assumption will allow self-selection among workers between training and no-training firms.

3. Worker ability is only learned via training. Firms that do not offer training will not have superior information relative to the market.

4. The degree of competitiveness in the market is modeled by assuming that firms need to make certain level of profits \( \pi \), and a higher \( \pi \) corresponds to a less competitive market. In
<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Qualification and career survey</th>
<th>1984 SOEP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Attended 10th grade</td>
<td>0.160</td>
<td>0.162</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Experience</td>
<td>0.123</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Experience(^4/100)</td>
<td>-0.694</td>
<td>-0.532</td>
</tr>
<tr>
<td></td>
<td>(0.182)</td>
<td>(0.126)</td>
</tr>
<tr>
<td>Experience(^3/10,000)</td>
<td>1.840</td>
<td>1.229</td>
</tr>
<tr>
<td></td>
<td>(0.558)</td>
<td>(0.379)</td>
</tr>
<tr>
<td>Experience(^4/1,000,000)</td>
<td>-1.806</td>
<td>-1.063</td>
</tr>
<tr>
<td></td>
<td>(0.597)</td>
<td>(0.399)</td>
</tr>
<tr>
<td>Apprenticeship in manufacturing</td>
<td>0.024</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>Apprenticeship in trade</td>
<td>0.036</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.022)</td>
<td></td>
</tr>
<tr>
<td>Apprenticeship in other sector</td>
<td>0.041</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td></td>
</tr>
<tr>
<td>Apprenticeship firm had 100–499 employees</td>
<td>0.045</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>Apprenticeship firm had 500–999 employees</td>
<td>0.072</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td></td>
</tr>
<tr>
<td>Apprenticeship firm had 1000+ employees</td>
<td>0.095</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td></td>
</tr>
<tr>
<td>Stayer</td>
<td>0.012</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>Military quitter</td>
<td>0.045</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Ever did military service</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.024)</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.384</td>
<td>0.337</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.126</td>
</tr>
</tbody>
</table>

White standard errors are in parentheses. Samples in the first two columns are pooled from the 1979, 1980/86, and 1981/82 German Qualification and Career Surveys and consist of German males, age 23–59, with nine or ten years of schooling, who left secondary school in 1948 or later, completed private sector apprenticeship training without returning to school after the apprenticeship, were employed in the private sector outside construction, and were working full-time. Column (1) includes workers who did an apprenticeship in a firm with 50 employees or more; column (2) uses apprentices from firms of all sizes. Number of observations is 5,355 in column (1) and 13,051 in column (2). "Stayers" are those workers who continued in their apprenticeship firm after training; "military quitters" are those who left their training firm for military service. Sample in the last column is from the Socioeconomic Panel and consists of German males, age 23–59, with nine or ten years of schooling, who left secondary school in 1948 or later, were employed in the private sector outside construction, and were working full-time. Number of observations is 513. All regressions also include a constant, and the regressions in columns (1) and (2) include two additional dummies for the survey year.
contrast to the baseline version of the above model, it is also assumed that firms can offer different training levels and commit to them, so firms can use training levels as a method of attracting workers.

Autor looks for a “separating”/self-selection equilibrium in which \( p' \) workers select into no-training firms, whereas \( p \) workers go to training firms. In this context, self-selection equilibrium is one in which workers with different abilities (different beliefs) choose to accept jobs in different firms, because ability is rewarded differentially in different firms. This makes sense since training and ability are complements as before. Since firms that do not train their employees do not learn about employability, there is no adverse selection for workers who quit from no-training firms. Therefore, the second-period wage of workers who quit from no-training firms will be simply

\[
v(0) = p'\alpha(0)
\]

In contrast, the secondhand labor market wage of workers from training firms will be given by \( v(\tau) \) from (5.1) above.

In the third period, all workers will receive their full marginal product, hence in expectation this is \( p'\alpha(0) \) for workers who got the non-training firms, and \( p\alpha(\tau) \) for workers who go to training firms.

In the second-period, all workers receive their outside option in the secondhand market, so \( v(0) \) for workers in no-training firms, and \( v(\tau) \) for workers in training firms.

The condition for a self-selection equilibrium is

\[
p(\alpha(\tau) - \alpha(0)) > v(0) - v(\tau) > p'(\alpha(\tau) - \alpha(0)),
\]
that is, expected gain of third-period wages for high-belief workers should outweigh the loss (if any) in terms of second period wages (since there are no costs in the first-period by the assumption that there are no wages in the first-period). Otherwise, there could not be a separating equilibrium.

This immediately implies that if \( v(0) - v(\tau) < 0 \), that is, if workers with training receive higher wages in the second period, then there cannot be a self-selection equilibrium—all workers, irrespective of their beliefs, would like to take a job with training firms. Therefore, the adverse selection problem needs to be strong enough to ensure that \( v(0) - v(\tau) > 0 \). This is the first implication that Autor investigates empirically using data about the wages of temporary help workers in firms that offer free training compared to the wages of workers in firms that do not offer training. He finds that this is generally the case.

The second implication concerns the impact of greater competition on training. To see this more formally, simply return to the basic model, and look at the profits of a typical training firm. These are

\[
\pi(\tau) = \frac{(1 - \lambda)p(1 - p)\alpha(\tau)}{\lambda p + (1 - p)} - c(\tau)
\]

so if \( \pi(\tau) = \pi \) and \( \pi \) increases exogenously, and note that in equilibrium we could never have \( \pi'(\tau) > 0 \), since then the firm can increase both its profits and attract more workers by simply increasing training. But if \( \pi'(\tau) \leq 0 \), then a decline in \( \pi \), that is, increasing competitiveness, will lead to higher training.
### TABLE II
Comparison of Log Hourly Wages of THS Workers at Training and Nontraining Establishments by Major Occupation

<table>
<thead>
<tr>
<th></th>
<th>Log hourly wages</th>
<th>Training</th>
<th>Nontraining</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free training</td>
<td>No training</td>
<td>Difference</td>
</tr>
<tr>
<td>White-collar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>2.66</td>
<td>2.79</td>
<td>-0.13</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(0.05)</td>
<td>(0.06)</td>
<td></td>
</tr>
<tr>
<td>Professional specialty</td>
<td>3.05</td>
<td>3.17</td>
<td>-0.13</td>
</tr>
<tr>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.04)</td>
<td></td>
</tr>
<tr>
<td>Technical</td>
<td>2.41</td>
<td>2.45</td>
<td>-0.05</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(0.05)</td>
<td>(0.06)</td>
<td></td>
</tr>
<tr>
<td>Accountants and auditors</td>
<td>2.72</td>
<td>2.77</td>
<td>-0.06</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(0.06)</td>
<td>(0.07)</td>
<td></td>
</tr>
<tr>
<td>Clerical/sales</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>2.01</td>
<td>2.09</td>
<td>-0.09</td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td></td>
</tr>
<tr>
<td>Clerical and</td>
<td>2.02</td>
<td>2.10</td>
<td>-0.08</td>
</tr>
<tr>
<td>administrative</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>support</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marketing and sales</td>
<td>1.84</td>
<td>1.97</td>
<td>-0.13</td>
</tr>
<tr>
<td>(0.03)</td>
<td>(0.08)</td>
<td>(0.09)</td>
<td></td>
</tr>
<tr>
<td>Blue-collar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>1.76</td>
<td>1.78</td>
<td>-0.02</td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td></td>
</tr>
<tr>
<td>Precision production,</td>
<td>1.89</td>
<td>1.97</td>
<td>-0.08</td>
</tr>
<tr>
<td>craft, and repair</td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Operators, assemblers,</td>
<td>1.79</td>
<td>1.82</td>
<td>-0.03</td>
</tr>
<tr>
<td>and inspectors</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Transport, material</td>
<td>1.89</td>
<td>1.92</td>
<td>-0.03</td>
</tr>
<tr>
<td>movement</td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Handlers, equipment</td>
<td>1.72</td>
<td>1.71</td>
<td>0.01</td>
</tr>
<tr>
<td>cleaners, and laborers</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.02)</td>
</tr>
</tbody>
</table>

All estimates are weighted by BLS national probability sampling weights. Standard errors in parentheses are corrected for clustering of observations at the establishment level. Sample includes 1002 establishments, which may employ workers in multiple occupations.
## TABLE III
OLS Estimates of the Relationship between Establishment Training Policies and Worker Wages, Pooled and Fixed Effects Models
Dependent Variable is the Log Hourly Wage of THS Workers

<table>
<thead>
<tr>
<th></th>
<th>A. Pooled estimates</th>
<th>B. Fixed effect estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Any training provided</td>
<td>-0.020</td>
<td>-0.019</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Up-front training provided</td>
<td></td>
<td>-0.025</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td></td>
</tr>
<tr>
<td>Firm selects trainees</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>Client requests/pays for training</td>
<td></td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td></td>
</tr>
<tr>
<td>Log of establishment size</td>
<td>-0.026</td>
<td>-0.025</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Log of THS employment in MSA-collar</td>
<td></td>
<td>0.051</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Firm fixed effects</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>n</td>
<td>333,888</td>
<td>333,888</td>
</tr>
</tbody>
</table>

All models are weighted by OCS national establishment probability weights and include 103 metropolitan statistical area (MSA) dummies and 8 major occupation dummies. Huber-White standard errors in parentheses are corrected for clustering at the establishment level (1002 establishments). Fixed effect models are limited to workers employed at multiregion firms (50 firms and 395 establishments). Training policies are not mutually exclusive.
<table>
<thead>
<tr>
<th></th>
<th>A. Pooled estimates</th>
<th></th>
<th>B. Fixed effect estimates</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Word processing</td>
<td>Data entry</td>
<td>Computer programming</td>
<td>Any computer training</td>
</tr>
<tr>
<td>Herfindahl in MSA-collard</td>
<td>(1) 0.379</td>
<td>(2) 0.525</td>
<td>(3) 0.111</td>
<td>(4) 0.254</td>
</tr>
<tr>
<td></td>
<td>(0.122)</td>
<td>(0.120)</td>
<td>(0.115)</td>
<td>(0.123)</td>
</tr>
<tr>
<td>Log estab size</td>
<td>0.082</td>
<td>0.082</td>
<td>0.027</td>
<td>0.080</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.007)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Log MSA-collard THS employment</td>
<td>0.019</td>
<td>(1) 0.005</td>
<td>0.008</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.015)</td>
<td>(0.013)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.065</td>
<td>0.260</td>
<td>-0.080</td>
<td>0.096</td>
</tr>
<tr>
<td></td>
<td>(0.133)</td>
<td>(0.160)</td>
<td>(0.131)</td>
<td>(0.145)</td>
</tr>
<tr>
<td>Firm fixed effects</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>R²</td>
<td>0.34</td>
<td>0.32</td>
<td>0.13</td>
<td>0.32</td>
</tr>
<tr>
<td>n</td>
<td>2,244</td>
<td>2,244</td>
<td>2,244</td>
<td>2,244</td>
</tr>
</tbody>
</table>

Huber-White standard errors in parentheses account for correlation of errors within region-collar cells. Models are weighted by BLS area probability sampling weights. All models include 102 MSA indicators, collar main effects, and establishment occupational share measures within collars: 2 in white-collar, 1 in clerical/sales, and 3 in blue-collar. Each establishment may supply (and train) workers in 1, 2, or 3 collars. Pooled estimates include 1002 establishments, 630 supplying white-collar, 859 supplying clerical/sales, and 755 supplying blue-collar workers. Fixed effects estimates are limited to 50 multiregion firms comprising 395 establishments, 285 supplying white-collar, 379 supplying clerical/sales, and 356 supplying blue-collar workers.
Autor investigates this empirically using differences in temporary help firms concentration across MSAs, and finds that in areas where there is greater concentration, training is lower.

5.4. Mobility, training and wages. The interaction between training and adverse selection in the labor market also provides a different perspective in thinking about mobility patterns. To see this, change the above model so that $\lambda = 0$, but workers now quit if

$$w(\tau) - v(\tau) < \theta$$

where $\theta$ is a worker-specific draw from a uniform distribution over $[0, 1]$. $\theta$, which can be interpreted as the disutility of work in the current job, is the worker’s private information. This implies that the fraction of high ability workers who quit their initial employer will be

$$1 - w(\tau) + v(\tau),$$

so the outside wage is now

$$v(\tau) = \frac{p[1 - w(\tau) + v(\tau)] \alpha(\tau)}{p[1 - w(\tau) + v(\tau)] + (1 - p)}$$

(5.3)

Note that if $v(\tau)$ is high, many workers leave their employer because outside wages in the secondhand market are high. But also the right hand side of (5.3) is increasing in the fraction of quitters, $[1 - w(\tau) + v(\tau)]$, so $v(\tau)$ will increase further. This reflects the fact that with a higher quit rate, the secondhand market is not as adversely selected (it has a better composition).

This implies that there can be multiple equilibria in this economy. One equilibrium with a high quit rate, high wages for workers changing jobs, i.e. high $v(\tau)$, but low training. Another equilibrium with low
mobility, low wages for job changers, and high training. This seems to give a stylistic description of the differences between the U.S. and German labor markets. In Germany, the turnover rate is much lower than in the U.S., and also there is much more training. Also, in Germany workers who change jobs are much more severely penalized (on average, in Germany such workers experience a substantial wage loss, while they experience a wage gain in the U.S.).

Which equilibrium is better? There is no unambiguous answer to this question. While the low-turnover equilibrium achieves higher training, it does worse in terms of matching workers to jobs, in that workers often get stuck in jobs that they do not like. In terms of the above model, we can see this by looking at the average disutility of work that workers receive (i.e., the average $\theta$'s).
CHAPTER 3

Tenure, Firm-Specific Skills and Incentives in Organizations

The analysis so far has focused on general skills, acquired in school or by investments in general training. Most labor economists also believe that there are important firm-specific skills, acquired either thanks to firm-specific experience, or by investment in firm-specific skills, or via “matching”. If such firm-specific skills are important we should observe worker productivity and wages to increase with tenure—that is, a worker who has stayed longer in a given job should earn more than a comparable worker (with the same schooling and experience) who has less tenure.

1. The Evidence On Firm-Specific Rents and Interpretation

1.1. Some Evidence. There are two conceptual issues that arise in thinking about the relationship between wages and tenure, as well as a host of econometric issues. The conceptual issues are as follows:

(1) We can imagine a world in which firm-specific skills are important, but there may be no relationship between tenure and wages. This is because, as we will see in more detail below, productivity increases due to firm-specific skills do not necessarily translate into wage increases. The usual reasoning for why high worker productivity translates into higher
wages is that otherwise, competitors would bid for the worker and steal him. This argument does not apply when skills are firm-specific since such skills do not contribute to the worker’s productivity in other firms. More generally, the relationship between productivity and wages is more complex when firm-specific skills are a significant component of productivity. For example, we might have two different jobs, one with faster accumulation of firm-specific skills, but wages may grow faster in the other jobs because the outside option of the worker is improving faster.

(2) An empirical relationship between tenure and wages does not establish that there are imported from-specific effects. It might simply be that there are some jobs with high “rents,” and workers who get these jobs never quit, creating a positive relationship between tenure and wages. Alternatively, a positive relationship between tenure and wages may reflect the fact that high ability workers stay in their jobs longer (selection).

The existing evidence may therefore either overstate or understate the importance of tenure, and there are no straightforward ways of dealing with these problems. In addition, there are important econometric problems, for example, the fact that in most data sets most tenure spells are uncompleted (most workers are in the middle of their job tenure), complicating the analysis. A number of researchers have used the usual strategies, as well as some creative strategies, to deal with the selection and omitted variable biases, pointed out in the second problem. But is still requires us to ignore the first problem (i.e.,
be cautious in inferring the tenure-productivity relationship from the observed tenure-wage relationship).

In any case, the empirical relationship between tenure and wages is of interest in its own right, even if we cannot immediately deduce from this the relationship between tenure and firm-specific productivity.

With all of these complications, the evidence nevertheless suggests that there is a positive relationship between tenure and wages, consistent with the importance of firm-specific skills. Here I will discuss two different types of evidence.

The first type of evidence is from regression analyses of the relationship between wages and tenure exploiting within job wage growth. Here the idea is that by looking at how wages grow within a job (as long as the worker does not change jobs), and comparing this to the experience premium, we will get an estimate of the tenure premium.

In other words, we can think of wages as given by the following model

$$\ln w_{it} = \beta_1 X_{it} + \beta_2 T_{it} + \varepsilon_{it}$$

where $X_{it}$ this total labor market experience of individual $i$, and $T_{it}$ is his tenure in the current job. Then, we have that his wage growth on this job is:

$$\Delta \ln w_{it} = \beta_1 + \beta_2 + \Delta \varepsilon_{it}$$

If we knew the experience premium, $\beta_2$, we could then immediately compute the tenure premium $\beta_1$. The problem is that we do not know the experience premium. Topel suggests that we can get an upper bound for the experience premium by looking at the relationship between entry-level wages and labor market experience (that is, wages in
jobs with tenure equal to zero). This is an upper bound to the extent that workers do not randomly change jobs, but only accept new jobs if these offer a relatively high wage. Therefore, whenever $T_{it} = 0$, the disturbance term $\varepsilon_{it}$ in (1.1) is likely to be positively selected. According to this reasoning, we can obtain a lower bound estimate of $\beta_2$, using a two-step procedure—first estimate the rate of within-job wage growth, and then subtract from this the estimate of the experience premium obtained from entry-level jobs.

Using this procedure Topel estimates relatively high rates of return to tenure. For example, his main estimates imply that ten years of tenure increase wages by about 25 percent, over and above the experience premium.

It is possible, however, that this procedure might generate tenure premium estimates that are upward biased. For example, this would be the case if the return to tenure or experience is higher among high-ability workers, and those are underrepresented among the job-changers. On the other hand, the advantage of this evidence is that it is unlikely to reflect simply the presence of some jobs that offer high-rents to workers, unless these jobs that provide high rents also have (for some reason) higher wage growth (one possibility might be that, union jobs pay higher wages, and have higher wage growth, and of course, workers do not leave union jobs, but this seems unlikely).

The second type of evidence comes from the wage changes of workers resulting from job displacement. A number of papers, most notably Jacobson, LaLonde and Sullivan, find that displaced workers experience substantial drop in earnings. Part of this is due to non-employment
1. THE EVIDENCE ON FIRM-SPECIFIC RENTS AND INTERPRETATION

Following displacement, but even after three years a typical displaced worker is earning about $1500 (1987 dollars). Econometrically, this evidence is simpler to interpret than the tenure-premium estimates. Economically, the interpretation is somewhat more difficult than the tenure estimates, since it may simply reflect the loss of high-rent (e.g. union) jobs.

In any case, these two pieces of evidence together are consistent with the view that there are important firm-specific skills/expertises that are accumulated on the job.

1.2. What Are Firm-Specific Skills? If we are going to interpret the above evidence as reflecting the importance of firm-specific skills, then we have to be more specific about what constitutes firm-specific skills. Here are four different views:

(1) Firm-specific skills can be thought to result mostly from firm-specific training investments made by workers and firms. Here it is important to distinguish between firms’ and workers’ investments, since they will have different incentives.

(2) Firm-specific skills simply reflect what the worker learns on-the-job without making any investments. In other words, they are simply unintentional byproducts of working on the job. The reason why I distinguish this particular view from the firm-specific investments view is that according to this view, we do not need to worry about the incentives to acquire firm-specific skills. However, most likely, even for simple skills that
workers can acquire on-the-job, they need to exert some effort, so this view may have relatively little applicability.

(3) Firm-specific skills may reflect “matching” as in Jovanovic’s approach. Here, there is no firm-specific skill, but some workers are better matches to some firms. Ex ante, neither the firm nor the worker knows this, and the information is revealed only slowly. Only workers who are revealed to be good matches to a particular job will stay on that job, and as a result, they will be more productive in this job than a randomly chosen worker. We can think of this process of learning about the quality of the match as the “accumulation of firm-specific skills”.

(4) There may be no technologically firm-specific skills. Instead, you may think of all skills as technologically general, in the sense that if the worker is more productive in a given firm, another firm that adopts exactly the same technologies and organizational structure, and hires the same set of co-workers will also be able to benefit from this hire productivity. These technologically general skills are transformed into de facto firm-specific skills because of market imperfections. For example, if worker mobility is costly, or if it is difficult or unprofitable for firms to copy some other firms’ technology choices, these skills will be de facto specific to the firm that has first made the technology/organizational choices. The reason why it is important to distinguish this view from the second one above
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean [s.d.]</th>
<th>OLS (1)</th>
<th>IV (2)</th>
<th>OLS (3)</th>
<th>OLS (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of Experience (Years of Experience)$^2$</td>
<td>18.14 [10.08]</td>
<td>.0349 (.0027)</td>
<td>.0392 (.0058)</td>
<td>.0288 (.0027)</td>
<td>.0263 (.0031)</td>
</tr>
<tr>
<td>(Yrs of Experience)$^2$</td>
<td>430.77 [407.84]</td>
<td>-.00062 (.00006)</td>
<td>-.00077 (.00014)</td>
<td>-.00048 (.00007)</td>
<td>-.00043 (.00007)</td>
</tr>
<tr>
<td>Years of Current Seniority</td>
<td>8.88 [8.34]</td>
<td>.0106 (.0011)</td>
<td>.00585 (.00128)</td>
<td>.00548 (.00178)</td>
<td>.00520 (.00256)</td>
</tr>
<tr>
<td>E(Completed Job Duration)</td>
<td>20.83 [12.18]</td>
<td>-.0198</td>
<td>-</td>
<td>-</td>
<td>.0265</td>
</tr>
<tr>
<td>(Job Duration)$^2$</td>
<td>631.55 [505.56]</td>
<td>.0024 (.00006)</td>
<td>-</td>
<td>- .00035</td>
<td>- .00059</td>
</tr>
<tr>
<td>$E(\text{Job Duration})^2$</td>
<td>6.02 [10.46]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.00094</td>
</tr>
<tr>
<td>$X[=1 \text{ if } 3 &lt; \text{Seniority} \leq 10]$</td>
<td>165.4 [325.3]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.0009</td>
</tr>
<tr>
<td>$X[=1 \text{ if } 3 &lt; \text{Seniority} \leq 10]$</td>
<td>11.09 [15.78]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.00798</td>
</tr>
<tr>
<td>$E(\text{Job Duration})^2$</td>
<td>380.1 [572.9]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.00455</td>
</tr>
<tr>
<td>$X[=1 \text{ if } \text{Seniority} &gt; 10]$</td>
<td>3696</td>
<td>.3696</td>
<td>.3575</td>
<td>.3871</td>
<td>.3883</td>
</tr>
</tbody>
</table>

$^a$All models also include controls for education, race, marital status, disability, occupation, industry, region, and year. $E(\text{Completed Job Duration})$ is computed using the estimates in col. 1 of Table 2. The numbers shown in parentheses are standard errors. Sample size = 3493.
<table>
<thead>
<tr>
<th></th>
<th>Mean [s.d.]</th>
<th>OLS (1)</th>
<th>IV (2)</th>
<th>OLS (3)</th>
<th>OLS (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of Experience</td>
<td>17.34</td>
<td>.0205</td>
<td>.0173</td>
<td>.0117</td>
<td>.0120</td>
</tr>
<tr>
<td>(Years of Experience)^2</td>
<td>[424.70]</td>
<td>(-.00045)</td>
<td>(-.00042)</td>
<td>(-.00026)</td>
<td>(-.00028)</td>
</tr>
<tr>
<td>Years of Current Seniority</td>
<td>6.31</td>
<td>.0142</td>
<td>.00290</td>
<td>.00241</td>
<td>-.00054</td>
</tr>
<tr>
<td>E(Completed Job Duration)</td>
<td>[7.46]</td>
<td>(.0011)</td>
<td>(.00172)</td>
<td>(.00213)</td>
<td>(.00302)</td>
</tr>
<tr>
<td>(E(Completed Job Duration))^2</td>
<td>[444.45]</td>
<td>(-.00006)</td>
<td>(-.00006)</td>
<td>(-.00024)</td>
<td>(-.00024)</td>
</tr>
<tr>
<td>E(Job Duration) \times [1 if 3 &lt; Seniority \leq 10]</td>
<td>4.57</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.00592</td>
</tr>
<tr>
<td>(E(Job Duration))^2 \times [1 if 3 &lt; Seniority \leq 10]</td>
<td>[8.27]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(.00538)</td>
</tr>
<tr>
<td>E(Job Duration) \times [1 if Seniority &gt; 10]</td>
<td>6.45</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.0241</td>
</tr>
<tr>
<td>(E(Job Duration))^2 \times [1 if Seniority &gt; 10]</td>
<td>[12.90]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(.0055)</td>
</tr>
<tr>
<td>R^2</td>
<td>-</td>
<td>.3878</td>
<td>.3513</td>
<td>.4041</td>
<td>.4098</td>
</tr>
</tbody>
</table>

---

Table 4b—Selected Coefficients from In (average hourly earnings) Models
Blue-Collar Nonunion Sample

---

^aAll models also include the controls listed in Table 4a, fn. a. E (Completed Job Duration) is computed using col. 2, Table 2. Standard errors are shown in parentheses. Sample size = 3554.
Table 5. Within-Job Earnings Growth Equations
(n = 23,692; t statistics in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.045</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a1 + b1)</td>
<td>(15.67)</td>
<td>(6.65)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a2)</td>
<td>(0.43)</td>
<td>(0.19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a3)</td>
<td>(0.17)</td>
<td>(0.08)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b2)</td>
<td>(0.22)</td>
<td>(0.11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔExperience</td>
<td>-0.00026</td>
<td>-0.0029</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a2)</td>
<td>(5.52)</td>
<td>(4.51)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔTenure</td>
<td>-0.0032</td>
<td>-0.0003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b2)</td>
<td>(1.11)</td>
<td>(0.44)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm Size:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-99</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-499</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>500-999</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000-2499</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td></td>
<td></td>
<td>0.0038</td>
</tr>
</tbody>
</table>

"Dependent variable is the change in the natural logarithm of real (1967) quarterly earnings for individuals who did not change jobs between t and t + 1. Experience and Tenure measured in quarters."
TABLE 2
MODELS OF ANNUAL WITHIN-JOB WAGE GROWTH, PSID WHITE MALES, 1968–83
(Independent Variable Is Change in Log Real Wage; Mean = .026)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ Tenure</td>
<td>.1242</td>
<td>.1265</td>
<td>.1258</td>
</tr>
<tr>
<td></td>
<td>(.0161)</td>
<td>(.0162)</td>
<td>(.0162)</td>
</tr>
<tr>
<td>Δ Tenure² (× 10²)</td>
<td>...</td>
<td>-.0518</td>
<td>-.4592</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0178)</td>
<td>(.1080)</td>
</tr>
<tr>
<td>Δ Tenure³ (× 10³)</td>
<td>...</td>
<td>...</td>
<td>.1846</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.0526)</td>
</tr>
<tr>
<td>Δ Tenure⁴ (× 10⁴)</td>
<td>...</td>
<td>...</td>
<td>-.0245</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.0079)</td>
</tr>
<tr>
<td>Δ Experience² (× 10²)</td>
<td>-.6051</td>
<td>-.6144</td>
<td>-.4067</td>
</tr>
<tr>
<td></td>
<td>(.1430)</td>
<td>(.1430)</td>
<td>(.1546)</td>
</tr>
<tr>
<td>Δ Experience³ (× 10³)</td>
<td>.1460</td>
<td>.1620</td>
<td>.0989</td>
</tr>
<tr>
<td></td>
<td>(.0482)</td>
<td>(.0485)</td>
<td>(.0517)</td>
</tr>
<tr>
<td>Δ Experience⁴ (× 10⁴)</td>
<td>.0131</td>
<td>.0151</td>
<td>.0089</td>
</tr>
<tr>
<td></td>
<td>(.0054)</td>
<td>(.0055)</td>
<td>(.0058)</td>
</tr>
<tr>
<td>R²</td>
<td>.022</td>
<td>.023</td>
<td>.025</td>
</tr>
<tr>
<td>Standard error</td>
<td>.218</td>
<td>.218</td>
<td>.218</td>
</tr>
</tbody>
</table>

PREDICTED WITHIN-JOB WAGE GROWTH BY YEARS OF JOB TENURE
(Workers with 10 Years of Labor Market Experience)

<table>
<thead>
<tr>
<th>TENURE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted wage growth (%)</td>
<td>.068</td>
<td>.060</td>
<td>.052</td>
<td>.046</td>
<td>.041</td>
<td>.037</td>
<td>.033</td>
<td>.030</td>
<td>.028</td>
<td>.026</td>
</tr>
</tbody>
</table>

Note.—Estimates are based on within-job first differences of log average hourly earnings. Standard errors are in parentheses. Number of observations is 8,683.
### TABLE 3

**SECOND-STEP ESTIMATED MAIN EFFECTS OF EXPERIENCE ($\beta_1$) AND TENURE ($\beta_2$) ON LOG REAL WAGES, AND LEAST-SQUARES BIAS IN WAGE GROWTH ($b_1 + b_2$)**

<table>
<thead>
<tr>
<th></th>
<th>Experience Effect, $\beta_1$ (1)</th>
<th>Within-Job Wage Growth, $\beta_1 + \beta_2$ (2)</th>
<th>Tenure Effect, $\beta_2$ (3)</th>
<th>Wage Growth Bias, $b_1 + b_2$ (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main effect</strong></td>
<td>.0713</td>
<td>.1258</td>
<td>.0545</td>
<td>.0020</td>
</tr>
<tr>
<td></td>
<td>(.0181)</td>
<td>(.0161)</td>
<td>(.0079)</td>
<td>(.0004)</td>
</tr>
</tbody>
</table>

### ESTIMATED CUMULATIVE RETURN TO JOB TENURE

<table>
<thead>
<tr>
<th></th>
<th>5 Years</th>
<th>10 Years</th>
<th>15 Years</th>
<th>20 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Two-step model</strong></td>
<td>.1793</td>
<td>.2459</td>
<td>.2832</td>
<td>.3375</td>
</tr>
<tr>
<td></td>
<td>(.0235)</td>
<td>(.0341)</td>
<td>(.0411)</td>
<td>(.0438)</td>
</tr>
<tr>
<td><strong>OLS</strong></td>
<td>.2313</td>
<td>.3002</td>
<td>.3203</td>
<td>.3563</td>
</tr>
<tr>
<td></td>
<td>(.0098)</td>
<td>(.0105)</td>
<td>(.0110)</td>
<td>(.0116)</td>
</tr>
</tbody>
</table>

*Note.—Estimated within-job wage growth ($\beta_1 + \beta_2$) from table 2, col. 3. Dependent variable for other estimates is log real hourly earnings less the effects of variables that are consistently estimated from the within-job wage growth model. Other regressors in the second-step model (10) include years of completed schooling, marital status, residence in an SMSA, current disability, union membership, and eight indicators for census region of residence. Estimated cumulative returns are based on the main effect of job tenure ($\beta_2 = .0545$) plus the effects of higher-order terms in tenure shown in col. 3 of table 2. Standard errors (in parentheses) are corrected to reflect sampling error in the first-step estimates. Methods developed in Murphy and Topel (1985) are used for this. Number of observations is 10,685.*
Figure 1. Quarterly Earnings (1987 Dollars) of High-Attachment Workers Separating in Quarter 1982:1 and Workers Staying Through Quarter 1986:4
### Table 4a—Selected Coefficients from In (average hourly earnings) Models
Managerial and Professional Nonunion Sample

<table>
<thead>
<tr>
<th></th>
<th>Mean [s.d.]</th>
<th>OLS (1)</th>
<th>IV (2)</th>
<th>OLS (3)</th>
<th>OLS (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of Experience</td>
<td>18.14 [10.08]</td>
<td>.0349 (.0027)</td>
<td>.0392 (.0058)</td>
<td>.0288 (.0027)</td>
<td>.0263 (.0031)</td>
</tr>
<tr>
<td>(Years of Experience)²</td>
<td>430.77 [407.84]</td>
<td>-.00062 (.00006)</td>
<td>-.00077 (.00014)</td>
<td>-.00048 (.00007)</td>
<td>-.00043 (.00007)</td>
</tr>
<tr>
<td>Years of Current Seniority</td>
<td>8.88 [8.34]</td>
<td>.0106 (.0011)</td>
<td>.00585 (.00128)</td>
<td>.00548 (.00178)</td>
<td>.00520 (.00256)</td>
</tr>
<tr>
<td>E(Completed Job Duration)</td>
<td>20.83 [12.18]</td>
<td>−</td>
<td>−</td>
<td>.0198</td>
<td>.0265</td>
</tr>
<tr>
<td>(E(Completed Job Duration)²</td>
<td>631.55 [505.56]</td>
<td>−</td>
<td>−</td>
<td>−.00035</td>
<td>−.00059</td>
</tr>
<tr>
<td>E(Job Duration) ×[1 if 3 &lt; Seniority ≤ 10]</td>
<td>6.02 [10.46]</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−.00094</td>
</tr>
<tr>
<td>(E(Job Duration)²</td>
<td>165.4 [325.3]</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>.00432</td>
</tr>
<tr>
<td>E(Job Duration) ×[1 if Seniority &gt; 10]</td>
<td>11.09 [15.78]</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−.00798</td>
</tr>
<tr>
<td>(E(Job Duration)²</td>
<td>380.1 [572.9]</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>.00455</td>
</tr>
<tr>
<td>R²</td>
<td>−</td>
<td>.3696</td>
<td>.3575</td>
<td>.3871</td>
<td>.3883</td>
</tr>
</tbody>
</table>

*All models also include controls for education, race, marital status, disability, occupation, industry, region, and year. E (Completed Job Duration) is computed using the estimates in col. 1 of Table 2. The numbers shown in parentheses are standard errors. Sample size = 3493.*
is that it emphasizes how changes in technology/market organization will affect what skills are specific, and how specific certain skills are.

2. Investment in Firm-Specific Skills

2.1. The basic problem. The problem with general training investments was that part of the costs had to be borne by the firm, but, at least in competitive labor markets, the worker was the residual claimants. The worker, in turn, was the residual claimant because the skills were general, and other firms could compete for this worker’s labor services. In contrast, with specific skills, the current employer is the only (or at least the main) “consumer,” so there is no competition from other firms to push up the worker’s wages. As a result, firm-specific skills will make the firm the ex post monopsonist. This creates the converse problem. Now the worker also bears some (perhaps most) of the costs of investment, may not have the right incentives to invest, since the firm will get most of the benefits.

To capture these problems, consider the following very simple model:

- At time $t = 0$, the worker decides how much to invest in firm-specific skills, denoted by $s$, at the cost $\gamma(s)$. $\gamma(s)$ is strictly increasing and convex, with $\gamma'(0) = 0$.
- At time $t = 1$, the firm makes a wage offer to the worker.
- The worker decides whether to accept this wage offer and work for this firm, or take another job.
- Production takes place and wages are paid.
Let the productivity of the worker be $y_1 + f(s)$ where $y_1$ is also what he would produce with another firm. Since $s$ is specific skills, it does not affect the worker’s productivity in other firms.

Let us solve this game by backward induction again, starting in the last period. The worker will accept any wage offer $w_1 \geq y_1$, since this is what he can get in an outside firm. Knowing this, the firm simply offers $w_1 = y_1$. In the previous period, realizing that his wage is independent of his specific skills, the worker makes no investment in specific skills, even though the socially optimal amount of specific investment is strictly positive, given by $\gamma'(s^*) = f'(s^*)$. (Again the fact that $s^*$ is strictly positive follows from the assumption that $\gamma'(0) = 0$).

What is the problem here? By investing in his firm-specific skills, the worker is increasing the firm’s profits. Therefore, the firm would like to encourage the worker to invest. However, given the timing of the game, wages are determined by a take-it-leave-it offer by the firm after the investment. Therefore, it will always be in the interest of the firm to offer a low wage to the worker after the investment, in other words, the firm will hold the worker up. The worker anticipates this holdup problem and does not invest in his firm-specific skills.

Why isn’t there a contractual solution to this underinvestment problem? For example, the firm could write a contract ex ante promising a certain payment to the worker. Leaving aside the problems of enforcing such contracts (the firm could always try to fire the worker, or threaten to fire him), if this contract does not make the wage of the worker conditional on his firm-specific skills, it will not encourage
2. INVESTMENT IN FIRM-SPECIFIC SKILLS

investment. So the only contracts that could help with the underinvestment problem are those that make the worker’s wages contingent on his firm-specific skills. However, such skills are very difficult to observe or verify by outside parties. This motivates the assumption in this literature, as well as in the incomplete contracts literature, that such contingent contracts cannot be written (they cannot be enforced, and hence are useless). Therefore, contractual solutions to the underinvestment problem are difficult to devise.

As a result, there is a severe underinvestment problem here, driven by exactly the converse of the underinvestment problem in general training. The worker will not undertake the required investments, because he’s afraid of being held up by the firm.

2.2. Worker power and investment. How can we improve the worker’s investment incentives?

At a very general level, the answer is simple. The worker’s earnings have to be conditioned on his specific skills. There are a number of ways of achieving this. Perhaps the simplest is to give the worker some “power” in the employment relationship. This power may come simply because the worker can bargain with his employer effectively (either individually or via unions—though the latter raises the issue of whether union bargaining would link wages to productivity). The worker may be able to bargain with the firm, in turn, for a variety of reasons. Here are some:

(1) Because of regulations, such as employment protection legislation, or precisely because of his specific skills, the firm needs
the worker, hence we are in the bilateral monopoly situation, and the rents will be shared (rather than the firm making a take-it-leave-it offer).

(2) The firm may purposefully give access to some important assets of the firm to the worker, so that the worker may feel secure that he will not be held up. This is basically the insight that follows from the incomplete contracting approach to property rights. The literature pioneered by Williamson, and then by Grossman-Hart-Moore basically views the allocation of property rights, which determine who can use assets, as a way of manipulating ex post bargaining, and via this channel ex ante investment incentives.

(3) The firm may change its organizational form in order to make a credible commitment not to hold up the worker.

Here I will give a simple example of investment incentives with bargaining power, and show why firms may preferred to give more bargaining power to their employees in order to ensure high levels of firm-specific investments. In the next section, I discuss alternative "organizational" solutions to this problem.

Modify the above game simply by assuming that in the final period, rather than the firm making a take-it-leave-it offer, the worker and the firm bargain over the firm-specific surplus, so the worker’s wage is

\[ w_1(s) = y_1 + \beta f(s) \]

Now at time \( t = 0 \), the worker maximizes

\[ y_1 + \beta f(s) - \gamma(s) \],
which gives his investment as

\begin{equation}
\beta f'(\hat{s}) = \gamma'(\hat{s})
\end{equation}

Here \( \hat{s} \) is strictly positive, so giving the worker bargaining power has improved investment incentives. However, \( \hat{s} \) is strictly less than the first-best investment level \( s^* \).

To investigate the relationship between firm-specific skills, firm profits and the allocation of power within firms, now consider an extended game, where at time \( t = -1 \), the firm chooses whether to give the worker access to a key asset. If it does, ex post the worker has bargaining power \( \beta \), and if it doesn’t, the worker has no bargaining power and wages are determined by a take-it-leave-it offer of the firm. Essentially, the firm is choosing between the game in this section and the previous one. Let us look at the profits of the firm from choosing the two actions. When it gives no access, the worker chooses zero investment, and since \( w_1 = y_1 \), the firm profits are \( \pi_0 = 0 \). In contrast, with the change in organizational form giving access to the worker, the worker undertakes investment \( \hat{s} \), and profits are \( \pi_\beta = (1 - \beta) f(\hat{s}) \). Therefore, the firm prefers to give the worker some bargaining power in order to encourage investment in specific skills.

Notice the contrast in the role of worker bargaining power between the standard framework and the one here. In the standard framework, worker bargaining power always reduces profits and always causes inefficiency. Here, it may do the opposite. This suggests that in some situations reducing worker bargaining power may actually be counterproductive for efficiency.
Note another interesting implication of the framework here. If the firm could choose the bargaining power of the worker without any constraints, it would set $\bar{\beta}$ such that

$$\frac{\partial \pi_\beta}{\partial \beta} = 0 = -f(\hat{s}(\bar{\beta})) + (1 - \bar{\beta}) f'(\hat{s}(\bar{\beta})) \frac{d\hat{s}(\bar{\beta})}{d\beta},$$

where $\hat{s}(\beta)$ and $\frac{d\hat{s}}{d\beta}$ are given by the first-order condition of the worker, (2.1).

One observation is immediate. The firm would certainly choose $\bar{\beta} < 1$, since with $\bar{\beta} = 1$, we could never have $\frac{\partial \pi_\beta}{\partial \beta} = 0$ (or more straightforwardly, profits would be zero). In contrast, a social planner who did not care about the distribution of income between profits and wages would necessarily choose $\beta = 1$. The reason why the firm would not choose the structure organization that achieves the best investment outcomes is that it cares about its own profits.

If there were an ex ante market in which the worker and the firm could “transact”, the worker could make side payments to the firm to encourage it to choose $\beta = 1$, then the efficient outcome would be achieved. This is basically the solution that follows from the analysis of Grossman-Hart-Moore, but they are thinking of issues of vertical integration, or trying to answer the question of who among many entrepreneurs/managers should own the firm or its assets. In the context of worker-firm relationships, such a solution is not possible, given credit constraints facing workers. Perhaps more important, such an arrangement would effectively amount to the worker buying the firm, which is not possible for two important reasons:
• the entrepreneur/owner of the firm most likely has some essential knowledge for the production process, or
• in practice there are many workers, so it is impossible to improves their investment incentives by making each worker the residual claimant of the firm’s profits.

2.3. Promotions. An alternative arrangement to encourage workers to invest in firm-specific skills is to design a promotion scheme. Consider the following setup. Suppose that there are two investment levels, $s = 0$, and $s = 1$ which costs $c$.

Suppose also that time $t = 1$, there are two tasks in the firm difficult and easy, D and E. Assume outputs in these two tasks as a function of the skill level are

$$y_D(0) < y_E(0) < y_E(1) < y_D(1)$$

Therefore, skills are more useful in the difficult task, and without skills the difficult task is not very productive.

Moreover, suppose that

$$y_D(1) - y_E(1) > c$$

meaning that the productivity gain of assigning a skilled worker to the difficult task is greater than the cost of the worker obtaining skills.

In this situation, the firm can induce firm-specific investments in skills if it can commit to a wage structure attached to promotions. In particular, suppose that the firm commits to a wage of $w_D$ for the difficult task and $w_E$ for the easy task. Notice that the wages do not depend on whether the worker has undertaken the investment, so we
are assuming some degree of commitment on the side of the firm, but not modifying the crucial incompleteness of contracts assumption.

Now imagine the firm chooses the wage structures such that

\[(2.2) \quad y_D (1) - y_E (1) > w_D - w_E > c,\]

and then ex post decides whether the worker will be promoted.

Again by backward induction, we have to look at the decisions in the final period of the game. When it comes to the promotion decision, and the worker is unskilled, the firm will naturally choose to allocate him to the easy task (his productivity is higher in the easy task and his wage is lower). If the worker is skilled, and the firm allocates him to the easy task, his profits are \(y_E (1) - w_E\). If it allocates him to the difficult task, his profits are \(y_D (1) - w_D\). The wage structure in (2.2) ensures that profits from allocating him to the difficult task are higher. Therefore, with this wage structure the firm has made a credible commitment to pay the worker a higher wage if he becomes skilled, because it will find it profitable to promote the worker.

Next, going to the investment stage, the worker realizes that when he does not invest he will receive \(w_E\), and when he invests, he will get the higher wage \(w_D\). Since, again by (2.2), \(w_D - w_E > c\), the worker will find it profitable to undertake the investment.

2.4. Investments and layoffs—The Hashimoto model. Consider the following model which is useful in a variety of circumstances. The worker can invest in \(s = 1\) at time \(t = 0\) again at the cost \(c\). The investment increases the worker’s productivity by an amount \(m + \eta\) where \(\eta\) is a mean-zero random variable officer of only by the firm at
$t = 1$. The total productivity of the worker is $x + m + \eta$ (if he does not invest, his productivity is simply $x$). The firm unilaterally decides whether to fire the worker, so the worker will be fired if

$$\eta < \eta^* \equiv w - x - m,$$

where $w$ is his wage. This wage is assumed to be fixed, and cannot be renegotiated as a function of $\eta$, since the worker does not observe $\eta$. (There can be other more complicated ways of revealing information about $\eta$, using stochastic contracts, but we ignore them here).

If the worker is fired or quits, he receives an outside wage $v$. If he stays, he receives the wage paid by the firm, $w$, and also disutility, $\theta$, only observed by him. The worker unilaterally decides whether to quit or not, so he will quit if

$$\theta > \theta^* \equiv w - v$$

Denoting the distribution function of $\theta$ by $Q$ and that of $\eta$ by $F$, the expected profit of the firm is

$$Q(\theta^*) \left[ 1 - F(\eta^*) \right] [x + m - w + E(\eta \mid \eta \geq \eta^*)]$$

The expected utility of the worker is

$$v + Q(\theta^*) \left[ 1 - F(\eta^*) \right] [w - v - E(\theta \mid \theta \leq \theta^*)]$$

In contrast, if the worker does not invest in skills, he will obtain

$$v \text{ if } w > x$$

$$v + Q(\theta^*) [w - v - E(\theta \mid \theta \leq \theta^*)] \text{ if } w \leq x$$

So we can see that a high wage promise by the firm may have either a beneficial or an adverse effect on investment incentives. If $w = x + \varepsilon >$
v, the worker realizes that he can only keep his job by investing. But on
the other hand, a high wage makes it more likely that $\eta < \eta^*$, so it may
increase the probability that given the realization of the productivity
shock, profits will be negative, and the worker will be fired. This will
reduce the worker’s investment incentives. In addition, a lower wage
would make it more likely that the worker will quit, and through this
channel increase inefficiency and discourage investment.

According to Hashimoto, the wage structure has to be determined
to balance these effects, and moreover, the ex post wage structure cho-
sen to minimize inefficient separations may dictate a particular division
of the costs of firm-specific investments.

An interesting twist on this comes from Carmichael, who suggests
that commitment to a promotion latter might improve incentives to
invest without encouraging further layoffs by the firm. Suppose the firm
commits to promote $N_h$ workers at time $t = 1$ (how such a commitment
is made is an interesting and difficult question). Promotion comes with
an additional wage of $B$. So the expected wage of the worker, if he keeps
his job, is now

$$w + \frac{N_h}{N}B,$$

where $N$ is employment at time $t = 1$, and this expression assumes that
a random selection of the workers will be promoted. A greater $N_h$ or
$B$, holding the layoff rate of the firm constant, increases the incentive
of the worker to stay around, and encourages investment.
Next think about layoff rate of the firm. The total wage bill of the firm at time $t = 1$ is then

$$W = Nw + N_hB.$$ 

The significance of this expression is that if the firm fires a worker, this will only save the firm $w$, since it is still committed to promote $N_h$ workers. Therefore, this commitment to (an absolute number of) promotions, reduces the firm’s incentive to fire, while simultaneously increasing the reward to staying in the firm for the worker.

This is an interesting idea, but we can push the reasoning further, perhaps suggesting that it’s not as compelling as it first appears. If the firm can commit to promote $N_h$ workers, why can’t it commit to employing $N'$ workers, and by manipulating this number effectively make a commitment not to fire workers? So if this type of commitment to employment level is allowed, promotions are not necessary, and if such a commitment is not allowed, it is not plausible that the firm can commit to promoting $N_h$ workers.
1. The Signaling Approach to Human Capital

1.1. The basic story. The models we’ve discussed so far are broadly in the tradition of Becker’s approach to human capital. Human capital is viewed as an input in the production process. The leading alternative is to view education purely as a signal. Consider the following simple model to illustrate the issues.

There are two types of workers, high ability and low ability. The fraction of high ability workers in the population is $\lambda$. Workers know their own ability, but employers do not observe this directly. High ability workers always produce $y_h$, while low ability workers produce $y_l$. In addition, workers can obtain education. The cost of obtaining education is $c_h$ for high ability workers and $c_l$ for low ability workers. The crucial assumptions is that $c_l > c_h$, that is, education is more costly for low ability workers. This is often referred to as the “single-crossing” assumption, since it makes sure that in the space of education and wages, the indifference curves of high and low types intersect only once. For future reference, I denote the decision to obtain education by $e = 1$. 

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For simplicity, I assume that education does not increase the productivity of either type of worker. Once workers obtain their education, there is competition among a large number of risk-neutral firms, so workers will be paid their expected productivity. This is again a dynamic game of incomplete information, so we will look for the Perfect Bayesian Equilibria of this game. However, differently from the previous incomplete information game that we analyzed, here the party that has private information moves first. This implies that the concept of Perfect Bayesian Equilibrium is not strong enough to rule out some types of equilibria, and we may want to strengthen this notion of equilibrium (see below).

In general, there can be two types of equilibria in this game.

1. Separating, where high and low ability workers choose different levels of schooling, and as a result, in equilibrium, employers can infer worker ability from education.
2. Pooling, where high and low ability workers choose the same level of education.

In addition, there can be semi-separating equilibria, where some education levels are chosen by more than one type.

Let me start by characterizing a possible separating equilibrium, which illustrates how education can be valued, even though it has no directly productive role.

Suppose that we have

\begin{equation}
(1.1) \quad y_h - c_h > y_l > y_h - c_l
\end{equation}
This is clearly possible since $c_h < c_l$. Then the following is an equilibrium: all high ability workers obtain education, and all low ability workers choose no education. Wages (conditional education) are:

$$w(e = 1) = y_h \text{ and } w(e = 0) = y_l$$

Notice that these wages are conditioned on education, and not directly on ability, since ability is not observed by employers. Let us now check that all parties are playing best responses. First consider firms. Given the strategies of workers (obtain education for high ability and do not obtain education for low ability), a worker with education has productivity $y_h$ while a worker with no education has productivity $y_l$. So no firm can change its behavior and increase its profits.

What about workers? If a high ability worker deviates to no education, he will obtain $w(e = 0) = y_l$, whereas he’s currently getting $w(e = 1) - c_h = y_h - c_h > y_l$. If a low ability worker deviates to obtaining education, the market will perceive him as a high ability worker, and pay him the higher wage $w(e = 1) = y_h$. But from (1.1), we have that $y_h - c_l < y_l$, so this deviation is not profitable for a low ability worker, proving that the separating allocation is indeed an equilibrium.

In this equilibrium, education is valued simply because it is a signal about ability. Education can be a signal about ability because of the single-crossing property. This can be easily verified by considering the case in which $c_l \leq c_h$. Then we could never have condition (1.1) hold, so it would not be possible to convince high ability workers to obtain education, while deterring low ability workers from doing so.
Notice also that if the game was one of perfect information, that is, the worker type were publicly observed, there could never be education investments here. This is of course an extreme result, due to the assumption that education has no productivity benefits. But it illustrates the forces at work.

1.2. Pooling equilibria in signaling games. However, the separating equilibrium is not the only one. Consider the following allocation: both low and high ability workers do not of education, and the wage structure is

\[ w(e = 1) = (1 - \lambda) y_l + \lambda y_h \text{ and } w(e = 0) = (1 - \lambda) y_l + \lambda y_h \]

What is happening here is that the market does not view education as a good signal, so a worker who “deviates” and obtains education is viewed as an average-ability worker, not as a high-ability worker.

To simplify the discussion, let us strengthen the condition (1.1) to (1.2)

\[ y_h - c_h > (1 - \lambda) y_l + \lambda y_h \text{ and } y_l > y_h - c_l \]

It is straightforward to check that no worker has any incentive to obtain education (given that education is costly, and there are no rewards to obtaining it). Since all workers choose no education, the expected productivity of a worker with no education is \((1 - \lambda) y_l + \lambda y_h\), so firms are playing best responses. (what they do in response to a deviation by a worker who obtains education is not important, since this does not happen along the equilibrium path).

What I have just described is a Perfect Bayesian Equilibrium. But is it reasonable? The answer is no. This equilibrium is being supported by the belief that the worker who gets education is no better than
a worker who doesn’t. But education is much more costly for low ability workers, so they should be less likely to deviate to obtaining education. There are many refinements in game theory which basically try to restrict beliefs in information sets that are not reached along the equilibrium path, ensuring that “unreasonable” beliefs, such as those that think a deviation to obtaining education is more likely from a low ability worker, are ruled out.

Perhaps the simplest is The Intuitive Criterion by Cho and Kreps. The underlying idea is as follows. If there exists a type who will never benefit from taking a particular deviation, then the uninformed parties (here the firms) should deduce that this deviation is very unlikely to come from this type. This falls within the category of “forward induction” where rather than solving the game simply backwards, we think about what type of inferences will others derive from a deviation.

In any case, take the pooling equilibrium above. Consider a deviation to $e = 1$. There is no circumstance under which the low type would benefit from this deviation, since by assumption (1.1) we have $y_l > y_h - c_l$, and the most a worker could ever get is $y_h$, and the low ability worker is now getting $(1 - \lambda) y_l + \lambda y_h$. Therefore, firms can deduce that the deviation to $e = 1$ is coming from the high type, and offer him a wage of $y_h$. Then (1.1) ensures that this deviation is profitable for the high types, breaking the pooling equilibrium.

The reason why this refinement is called The Intuitive Criterion is that it can be supported by a relatively intuitive “speech” by the deviator along the following lines: “you have to deduce that I must be the high type deviating to $e = 1$, since low types would never ever
consider such a deviation, whereas I would find it profitable if I could convince you that I am indeed the high type). Of course, this is only very loose, since such speeches are not part of the game, but it gives the basic idea.

The overall conclusion is that as long as the separating condition is satisfied, we expect the equilibrium of this economy can involve a separating allocation, where education is valued as a signal.

1.3. Generalizations. It is straightforward to generalize this equilibrium concept to a situation in which education has a productive role as well as a signaling role. Then the story would be one where education is valued for more than its productive effect, because it is also associated with higher ability.

Let me give the basic idea here. Imagine that education is continuous \( e \in [0, \infty) \). And the cost functions for the high and low types are \( c_h(e) \) and \( c_l(e) \), which are both strictly increasing and convex, with \( c_h(0) = c_l(0) = 0 \). The single crossing property is that \( c'_h(e) < c'_l(e) \) for all \( e \), that is, the marginal cost of investing in a given unit of education is always higher for the low type.

Moreover, suppose that the output of the two types as a function of their educations are \( y_h(e) \) and \( y_l(e) \), with \( y_h(e) > y_l(e) \) for all \( e \). Again there are many equilibria, some separating, some pooling and some semi-separating. But applying a stronger form of the Intuitive Criterion reasoning, we will take the Riley equilibrium of this game, which is a particular separating equilibrium. It is characterized as follows. We first find the most preferred education level for the low
type in the perfect information case, which will be given by

\[ y'_l (e_l) = c'_l (e_l), \]

then we write the incentive compatibility constraint for the low type, such that when the market expects low types to obtain education \( e_l \), the low type does not try to mimic the high type and choose the education level the market expects the high type to obtain, \( e \). This incentive compatibility constraint is

(1.3) \[ y_l (e_l) - c_l (e_l) \geq y_h (e) - c_l (e) \]

Let \( e_h \) be such that this constraint holds as an equality: \( y_l (e_l) - c_l (e_l) = y_h (e_h) - c_l (e_h) \). Then the Riley equilibrium is such that low types choose \( e_l \) and obtain the wage \( w(e_l) = y_l (e_l) \), and high types choose \( e_h \) and obtain the wage \( w(e_h) = y_h (e_h) \). That high types are happy to do this follows immediately from the single-crossing property, since

\[ y_h (e_h) - c_h (e_h) > y_h (e_h) - c_l (e_h) = y_h (e_h) - c_l (e_h) \]

Notice that in this equilibrium, high ability workers are typically investing more than they would have done in the perfect information case, in the sense that \( e_h \) characterized here is greater than the education level that high ability individuals chosen with perfect information, given by \( y'_h (e^*_h) = c'_h (e^*_h) \).

1.4. Evidence on labor market signaling. Is the signaling role of education important? There are a number of different ways of approaching this question. Unfortunately, direct evidence is difficult to
find. Here I will discuss a number of different attempts that investigate the importance of labor market signaling. In the next section, I will discuss empirical work that may give a sense of how important signaling considerations are in the aggregate.

Before this discussion, note the parallel between the selection stories discussed above and the signaling story. In both cases, the observed earnings differences between high and low education workers will include a component due to the fact that the abilities of the high and low education groups differ. There is one important difference, however, in that in the selection stories, the market observed ability, it was only us the economists who were unable to do so. In the signaling story, the market is also unable to observed ability, and is inferring it from education. For this reason, proper evidence in favor of the signaling story should go beyond documenting the importance of some type of “selection”

There are 4 different approaches to determining whether signaling is important. The first line of work looks at whether degrees matter, in particular, whether a high school degree or the fourth year of college that gets an individual a university degree matter more than other years of schooling (e.g., Kane and Rouse). This approach suffers from two serious problems. First, the final year of college (or high school) may in fact be more useful than the third-year, especially because it shows that the individual is being able to learn all the required information that makes up a college degree. Second, and more serious, there is no way of distinguishing selection and signaling as possible explanations for these patterns. It may be that those who drop out of
high school are observationally different to employers, and hence receive different wages, but these differences are not observed by us in the standard data sets. This is a common problem that will come back again: the implications of unobserved heterogeneity and signaling are often similar, and many misleading claims exist in the literature.

Second, a creative paper by Lang and Kropp tests for signaling by looking at whether compulsory schooling laws affect schooling above the regulated age. The reasoning is that if the 11th year of schooling is a signal, and the government legislates that everybody has to have 11 years of schooling, now high ability individuals have to get 12 years of schooling to distinguish themselves. They find evidence for this, which they interpret as supportive of the signaling model. The problem is that there are other reasons for why compulsory schooling laws may have such effects. For example, an individual who does not drop out of 11th grade may then decide to complete high school. Alternatively, there can be peer group effects in that as fewer people drop out of school, it may become less socially acceptable the drop out even at later grades.

The third approach is the best. It is pursued in a very creative paper by Tyler, Murnane and Willett. They observe that passing grades in the Graduate Equivalent Degree (GED) differ by state. So an individual with the same grade in the GED exam will get a GED in one state, but not in another. If the score in the exam is an unbiased measure of human capital, and there is no signaling, these two individuals should get the same wages. In contrast, if the GED is a signal, and
employers do not know where the individual took the GED exam, these two individuals should get different wages.

Using this methodology, the authors estimate that there is a 10-19 percent return to a GED signal. The attached table shows the results.

An interesting result that Tyler, Murnane and Willett find is that there are no GED returns to minorities. This is also consistent with the signaling view, since it turns out that many minorities prepare for and take the GED exam in prison. Therefore, GED would be not only a positive signal, but also likely a signal that the individual was at some point incarcerated. Hence not a good signal at all.

The fourth approach is discussed in the next section.

2. Human Capital Externalities

Many economists believe that human capital not only creates private returns, increasing the earnings of the individual will acquires it, but it also creates externalities, i.e., it increases the productivity of other agents in the economy (e.g., Jacobs, Lucas). If so, existing research on the private returns to education is only part of the picture—the social return, i.e., the private return plus the external return, may far exceed the private return. Conversely, if signaling is important, the private return overestimates the social return to schooling. Estimating the external and the social returns to schooling is a first-order question.

2.1. Theory. To show how and why external returns to education may arise, I will briefly discussed two models. The first is a theory of non-pecuniary external returns, meaning that external returns arise
from technological linkages across agents or firms. The second is pecuniary model of external returns, thus externalities will arise from market interactions and changes in market prices resulting from the average education level of the workers.

Suppose that the output (or marginal product) of a worker, \( i \), is

\[
y_i = A \cdot h_i^\nu,
\]

where \( h_i \) is the human capital (schooling) of the worker, and \( A \) is aggregate productivity. Assume that labor markets are competitive. So individual earnings are \( W_i = Ah_i^\nu \).

The key idea of externalities is that the exchange of ideas among workers raises productivity. This can be model by allowing \( A \) to depend on aggregate human capital. In particular, suppose that

\[
(2.1) \quad A = BH^\delta \equiv E[h_i]^\delta,
\]

where \( H \) is a measure of aggregate human capital, \( E \) is the expectation operator, \( B \) is a constant.

Individual earnings can then be written as \( W_i = Ah_i^\nu = BH^\delta h_i^\nu \).

Therefore, taking logs, we have:

\[
(2.2) \quad \ln W_i = \ln B + \delta \ln H + \nu \ln h_i.
\]

If external effects are stronger within a geographical area, as seems likely in a world where human interaction and the exchange of ideas are the main forces behind the externalities, then equation (2.2) should be estimated using measures of \( H \) at the local level. This is a theory of non-pecuniary externalities, since the external returns arise from the technological nature of equation (2.1).
The alternative is pecuniary externalities, as first conjectured by Marshall (1961) who argued that increasing the geographic concentration of specialized inputs increases productivity since the matching between factor inputs and industries is improved. A similar story is developed in Acemoglu (1997), where firms find it profitable to invest in new technologies only when there is a sufficient supply of trained workers to replace employees who quit. I refer to this sort of effect as a pecuniary externality since greater human capital encourages more investment by firms and raises other workers’ wages via this channel.

Here, I will briefly explain a simplified version of the model in Acemoglu (1996).

Consider an economy lasting two periods, with production only in the second period, and a continuum of workers normalized to 1. Take human capital, \( h_i \), as given. There is also a continuum of risk-neutral firms. In period 1, firms make an irreversible investment decision, \( k \), at cost \( Rk \). Workers and firms come together in the second period. The labor market is not competitive; instead, firms and workers are matched randomly, and each firm meets a worker. The only decision workers and firms make after matching is whether to produce together or not to produce at all (since there are no further periods). If firm \( f \) and worker \( i \) produce together, their output is

\[
(2.3) \quad k_f^\alpha \cdot h_i^\nu,
\]

where \( \alpha < 1, \nu \leq 1 - \alpha \). Since it is costly for the worker-firm pair to separate and find new partners in this economy, employment relationships generate quasi-rents. Wages will therefore be determined
by rent-sharing. Here, simply assume that the worker receives a share $\beta$ of this output as a result of bargaining, while the firm receives the remaining $1 - \beta$ share.

An equilibrium in this economy is a set of schooling choices for workers and a set of physical capital investments for firms. Firm $f$ maximizes the following expected profit function:

\[(2.4) \quad (1 - \beta) \cdot k_f^\alpha \cdot E[h_i^\nu] - R \cdot k_f,\]

with respect to $k_f$. Since firms do not know which worker they will be matched with, their expected profit is an average of profits from different skill levels. The function (2.4) is strictly concave, so all firms choose the same level of capital investment, $k_f = k$, given by

\[(2.5) \quad k = \left(\frac{(1 - \beta) \cdot \alpha \cdot H}{R}\right)^{1/(1-\alpha)},\]

where

\[H \equiv E[h_i^\nu]\]

is the measure of aggregate human capital. Substituting (2.5) into (2.3), and using the fact that wages are equal to a fraction $\beta$ of output, the wage income of individual $i$ is given by

\[W_i = \beta \left(\frac{(1 - \beta) \cdot \alpha \cdot H}{R}\right)^{\alpha/(1-\alpha)} (h_i)^\nu.\]

Taking logs, this is:

\[(2.6) \quad \ln W_i = c + \frac{\alpha}{1-\alpha} \ln H + \nu \ln h_i,\]

where $c$ is a constant and $\frac{\alpha}{1-\alpha}$ and $\nu$ are positive coefficients.

Human capital externalities arise here because firms choose their physical capital in anticipation of the average human capital of the workers they will employ in the future. Since physical and human
capital are complements in this setup, a more educated labor force encourages greater investment in physical capital and to higher wages. In the absence of the need for search and matching, firms would immediately hire workers with skills appropriate to their investments, and there would be no human capital externalities.

Nonpecuniary and pecuniary theories of human capital externalities lead to similar empirical relationships since equation (2.6) is identical to equation (2.2), with $c = \ln B$ and $\delta = \frac{\gamma}{1-\alpha}$. Again presuming that these interactions exist in local labor markets, we can estimate a version of (2.2) using differences in schooling across labor markets (cities, states, or even countries).

2.2. **Signaling and externalities.** The above models focused on positive externalities to education. However, in a world where education plays a signaling role, we might also expect significant *negative externalities*. To see this, consider the most extreme world in which education is only a signal—it does not have any productive role.

Contrast two situations: in the first, all individuals have 12 years of schooling and in the second all individuals have 16 years of schooling. Since education has no productive role, and all individuals have the same level of schooling, in both allocations they will earn exactly the same wage (equal to average productivity). Therefore, here the increase in aggregate schooling does not translate into aggregate increases in wages. But in the same world, if one individual obtains more education than the rest, there will be a private return to him, because he would signal that he’s of higher ability. Therefore, in a world where signaling
is important, we might also want to estimate an equation of the form (2.2), but we would expect $\delta$ to be negative.

2.3. Evidence. OLS estimation of equations like (2.2) yield very significant and positive estimates of $\delta$, indicating very large positive human capital externalities. The leading example is the paper by Jim Rauch.

There are at least two problems with this type OLS estimates. First, it may be precisely high-wage states that either attract a large number of high education workers or give strong support to education. Rauch’s estimates were using a cross-section of cities. Including city or state fixed affects ameliorates this problem, but does not solve it, since states’ attitudes towards education and the demand for labor may co-move. The ideal approach would be to find a source of quasi-exogenous variation in average schooling across labor markets (variation unlikely to be correlated with other sources of variation in the demand for labor in the state).

Acemoglu and Angrist try to accomplish this using differences in compulsory schooling laws. The advantage is that these laws not only affect individual schooling but average schooling in a given area.

There is an additional econometric problem in estimating externalities, which remains even if we have an instrument for average schooling in the aggregate. This is that if individual schooling is measured with error (or for some other reason OLS returns to individual schooling are not the causal effect), some of this discrepancy between the OLS returns and the causal return may load on average schooling, even when
Table 2
OLS Estimates of Private and Social Returns to Schooling

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<td>0.074</td>
<td>0.078</td>
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<td>(0.000)</td>
<td>(0.000)</td>
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<td>YES</td>
<td>NO</td>
<td>NO</td>
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A. Private Returns

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<tr>
<td>Private Return</td>
<td>0.072</td>
<td>0.073</td>
<td>0.078</td>
<td>0.055</td>
<td>0.068</td>
<td>0.075</td>
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<td>0.094</td>
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<td>Schooling</td>
<td>(0.000)</td>
<td>(0.000)</td>
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<td>(0.026)</td>
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B. Private and Social Returns

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<td>708398</td>
<td>16133</td>
<td>72344</td>
<td>161029</td>
<td>376479</td>
<td>98545</td>
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Notes: Standard errors corrected for state-year clustering are shown in parentheses. The data are from the Census IPUMS for 1950 through 1990, with the sample restricted to white males aged 40-49 in the Census year. All regressions contain Census year, year of birth, and state of birth main effects.
average schooling is instrumented. This suggests that we may need to instrument for individual schooling as well (so as to get to the correct return to individual schooling).

More explicitly, let \( Y_{ijt} \) be the log weekly wage, then the estimating equation is

\[
Y_{ijt} = X_i^\prime \mu + \delta_j + \delta_t + \gamma_1 S_{jt} + \gamma_2 i s_i + u_{jt} + \varepsilon_i,
\]

To illustrate the main issues, ignore time dependence, and consider the population regression of \( Y_i \) on \( s_i \):

\[
Y_{ij} = \mu_0 + \rho_0 s_i + \varepsilon_{0i}; \quad \text{where } E[\varepsilon_{0i} s_i] \equiv 0.
\]

Next consider the IV population regression using a full set of state dummies. This is equivalent to

\[
Y_{ij} = \mu_1 + \rho_1 S_j + \varepsilon_{1i}; \quad \text{where } E[\varepsilon_{1i} S_j] \equiv 0,
\]

since the projection of individual schooling on a set of state dummies is simply average schooling in each state.

Now consider the estimation of the empirical analogue of equation (2.2):

\[
Y_{ij} = \mu^* + \pi_0 s_i + \pi_1 S_j + \xi_i; \quad \text{where } E[\xi_i s_i] = E[\xi_i S_j] \equiv 0.
\]

Then, we have

\[
\begin{align*}
\pi_0 &= \rho_1 + \phi(\rho_0 - \rho_1) \\
\pi_1 &= \phi(\rho_1 - \rho_0)
\end{align*}
\]

where \( \phi = \frac{1}{1-R^2} > 1 \), and \( R^2 \) is the first-stage R-squared for the 2SLS estimates in (2.9). Therefore, we may find positive external returns
2. HUMAN CAPITAL EXTERNALITIES

even when there are none, if it happens to be the case that \( \rho_1 > \rho_0 \), for example because there is measurement error in individual schooling.

If we could instrument for both individual and average schooling, we would solve this problem. But what type of instrument?

Consider the relationship of interest:

\[
Y_{ij} = \mu + \gamma_1 S_j + \gamma_2 s_i + u_j + \varepsilon_i,
\]

which could be estimated by OLS or instrumental variables, to obtain an estimate of \( \gamma_1 \) as well as an average estimate of \( \gamma_2 \), say \( \gamma_2^* \).

An alternative way of expressing this relationship is to adjust for the effect of individual schooling by directly rewriting (2.12):

\[
Y_{ij} - \gamma_2^* s_i \equiv \tilde{Y}_{ij}
\]

\[
= \mu + \gamma_1 S_j + [u_j + \varepsilon_i + (\gamma_2 - \gamma_2^*) s_i].
\]

In this case, instrumental variables estimate of external returns is equivalent to the Wald formula

\[
\gamma_1^V = \frac{E[\tilde{Y}_{ij} | z_i = 1] - E[\tilde{Y}_{ij} | z_i = 0]}{E[S_j | z_i = 1] - E[S_j | z_i = 0]}
\]

\[
= \gamma_1 + \left[ \frac{E[\gamma_2 s_i | z_i = 1] - E[\gamma_2 s_i | z_i = 0]}{E[s_i | z_i = 1] - E[s_i | z_i = 0]} - \gamma_2^* \right] \cdot \frac{E[s_i | z_i = 1] - E[s_i | z_i = 0]}{E[S_j | z_i = 1] - E[S_j | z_i = 0]}
\]

This shows that we should set

\[
\gamma^* = \frac{E[\gamma_2 s_i | z_i = 1] - E[\gamma_2 s_i | z_i = 0]}{E[s_i | z_i = 1] - E[s_i | z_i = 0]}
\]

\[
= \frac{E[(Y_{ij} - \gamma_1 S_j) | z_i = 1] - E[(Y_{ij} - \gamma_1 S_j) | z_i = 0]}{E[s_i | z_i = 1] - E[s_i | z_i = 0]}
\]

This is typically not the OLS estimator of the private return, and we should be using some instrument. The ideal instrument would be affecting exactly in the same people as the compulsory schooling laws.
Quarter of birth instruments might come close to this. Since quarter of birth instruments are likely to affect the same people as compulsory schooling laws, adjusting with the quarter of birth estimate, or using quarter of birth dummies as instrument for individual schooling, is the right strategy.

So the strategy is to estimate an equation similar to (2.2) or (2.10) using compulsory schooling laws for average schooling and quarter of birth dummies for individual schooling.

The results suggest that there are no significant external returns. The estimates are typically around 1 or 2 percent, and statistically not different from zero. They also suggest that in the aggregate signaling considerations are unlikely to be very important (at the very least, they do not dominate positive externalities).

3. Peer Group Effects

The above discussion focused on external returns to education. Another important type of externality that arises in the context of education is peer group effects, or generally social effects in the process of education. The fact that children growing up in different areas may choose different role models will lead to this type of externalities/peer group effects. More simply, to the extent that schooling and learning are group activities, there could be this type of peer group effects.

There are a number of theoretical issues that need to be clarified, as well as important work that needs to be done in understanding where peer group effects are coming from. Moreover, empirical investigation of peer group effects is at its infancy, and there are very difficult issues
Table 4a
The Effect of Compulsory Attendance Laws and Child Labor Laws on Individual Schooling

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*With State of Residence Controls*

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Figure 2. CDF difference by severity of child labor laws. The figure shows the difference in the probability of schooling at or exceeding the grade level on the X-axis. The reference group is 6 or fewer years required schooling.
Figure 1. CDF difference by severity of compulsory attendance laws. The figure shows the difference in the probability of schooling at or exceeding the grade level on the X-axis. The reference group is 8 or fewer years required schooling.
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<th>Individual Schooling Exogenous</th>
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First Stage for State-Year Average Schooling

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<td>CA 11</td>
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</table>
involved in estimation and interpretation. Since there is little research in understanding the nature of peer group effects, here I will simply take peer group effects as given, and briefly discuss some of its efficiency implications, especially for community structure and school quality, and then very briefly mention some work on estimating peer group affects.

3.1. Implications of peer group effects for mixing and segregation. An important question is whether the presence of peer group effects has any particular implications for the organizational schools, and in particular, whether children who provide positive externalities on other children should be put together in a separate school or classroom.

The basic issue here is equivalent to an assignment problem. The general principle in assignment problems, such as Becker’s famous model of marriage, is that if inputs from the two parties are complementary, there should be assortative matching, that is the highest quality individuals should be matched together. In the context of schooling, this implies that children with better characteristics, who are likely to create more positive externalities and be better role models, should be segregated in their own schools, and children with worse characteristics, who will tend to create negative externalities will, should go to separate schools. This practically means segregation along income lines, since often children with “better characteristics” are those from better parental backgrounds, while children with worse characteristics are often from lower socioeconomic backgrounds.
So much is well-known and well understood. The problem is that there is an important confusion in the literature, which involves deducing complementarity from the fact that in equilibrium we do observe segregation (e.g., rich parents sending their children to private schools with other children from rich parents, or living in suburbs and sending their children to suburban schools, while poor parents live in ghettos and children from disadvantage backgrounds go to school with other disadvantaged children in inner cities). This reasoning is often used in discussions of Tiebout competition, together with the argument that allowing parents with different characteristics/tastes to sort into different neighborhoods will often be efficient.

The underlying idea can be given by the following simple model. Suppose that schools consist of two kids, and denote the parental background (e.g., home education or parental expenditure on non-school inputs) of kids by $e$, and the resulting human capitals by $h$. Suppose that we have

$$h_1 = e_1^\alpha e_2^{1-\alpha}$$
$$h_2 = e_1^{1-\alpha} e_2^\alpha$$

where $\alpha > 1/2$. This implies that parental backgrounds are complementary, and each kid’s human capital will depend mostly on his own parent’s background, but also on that of the other kid in the school. For example, it may be easier to learn or be motivated when other children in the class are also motivated. This explains why we have $\frac{\partial h_1}{\partial e_2}, \frac{\partial h_2}{\partial e_1} > 0$. But another important feature of (3.1) is that $\frac{\partial^2 h_1}{\partial e_2 \partial e_1}, \frac{\partial^2 h_2}{\partial e_1 \partial e_2} > 0$, that is, the backgrounds of the two kids are complementary. This implies
that a classmate with a good background is especially useful to another kid with a good background. We can think of this as the “bad apple” theory of classroom: one bad kids in the classroom brings down everybody.

As a digression, notice an important feature of the way I wrote (3.1) linking the outcome variables, $h_1$ and $h_2$, two predetermined characteristics of children $e_1$ and $e_2$, which creates a direct analogy with the human capital externalities discussed above. However, this may simply be the reduced form of that somewhat different model, for example,

$$(3.2)\quad h_1 = H_1(e_1, h_2)$$
$$h_2 = H_2(e_2, h_1)$$

whereby each individual’s human capital depends on his own background and the human capital choice of the other individual. Although in reduced form (3.1) and (3.2) are very similar, they provide different interpretations of peer group effects, and econometrically they pose different challenges.

The complementarity has two implications:

(1) It is socially efficient, in the sense of maximizing the sum of human capitals, to have parents with good backgrounds to send their children to school with other parents with good backgrounds. This follow simply from the definition of complementarity, positive cross-partial derivative, which is clearly verified by the production functions in (3.1).

(2) It will also be an equilibrium outcome that parents will do so.

To see this, suppose that we have a situation in which there are
two sets of parents with background $e_l$ and $e_h > e_l$. Suppose that there is mixing. Now the marginal willingness to pay of a parent with the high background to be in the same school with the other parent is

$$e_h^\alpha e_h^{-\alpha} = 1,$$

while the marginal willingness to pay of a low background parent to stay in the school with the high background parents is

$$e_h^\alpha e_l^{-\alpha} < 1 \text{ since } e_h > e_l.$$

Therefore, the high-background parent can always outbid the low-background parent for the privilege of sending his children to school with other high-background parents. Thus with profit maximizing schools, segregation will arise as the outcome.

Next consider a production function with substitutability (negative cross-partial derivative). For example,

$$\begin{align*}
h_1 &= \phi e_1 + e_2 - \lambda e_1^{1/2} e_2^{1/2} \\
h_2 &= e_1 + \phi e_2 - \lambda e_1^{1/2} e_2^{1/2}
\end{align*}$$

where $\phi > 1$ and $\lambda$ is small, so that human capital is increasing in parental background. With this production function, we again have $\frac{\partial h_1}{\partial e_2}, \frac{\partial h_2}{\partial e_1} > 0$, but now in contrast to (3.1), we also have $\frac{\partial^2 h_1}{\partial e_2 \partial e_1}, \frac{\partial^2 h_2}{\partial e_1 \partial e_2} > 0$. This can be thought to correspond to the “good apple” theory of the classroom, where the kids with the best characteristics and attitudes bring the rest of the class up.
Now because the cross-partial derivative is negative, the marginal willingness to pay of low-background parents to paid to put their kid together with high-background parents is higher than that of high-background parents. With perfect markets, we will observe mixing, and in equilibrium schools will consist of a mixture of children from high- and low-background parents.

Now combining the outcomes of these two models, many people jump to the conclusion that since we do observe segregation of schooling in practice, parental backgrounds must be complementary, so segregation is in fact efficient. Again the conclusion is that allowing Tiebout competition and parental sorting will most likely achieve efficient outcomes.

However, this conclusion is not correct, since even if the correct production function was (3.3), segregation would arise in the presence of credit market problems. In particular, the way that mixing is supposed to occur with (3.3) is that low-background parents make a payment to high-background parents so that the latter send their children to a mixed school. To see why such payments are necessary, recall that even with (3.3) we have that the first derivatives are positive, that is

\[ \frac{\partial h_1}{\partial e_2}, \frac{\partial h_2}{\partial e_1} > 0. \]

This means that everything else being equal all children benefit from being in the same class with other children with good backgrounds. With (3.3), however, children from better backgrounds benefit less than children from good backgrounds. That’s why there has to be payments from parents of less good backgrounds to high-background parents.
Such payments are both difficult to implement in practice, and practically impossible taking into account the credit market problems facing parents from poor socioeconomic status.

Therefore, if the true production function is (3.3) but there are credit market problems, we will observe segregation in equilibrium, and the segregation will be inefficient. Therefore we cannot simply appeal to Tiebout competition, or deduce efficiency from the equilibrium patterns of sorting.

3.2. The Benabou model. A similar point is developed by Benabou even in the absence of credit market problems, but relying on other missing markets. His model has competitive labor markets, and local externalities (externalities in schooling in the local area). All agents are assumed to be ex ante homogeneous, and will ultimately end up either low skill or high skill.

Utility of agent $i$ is assumed to be

$$U^i = w^i - c^i - r^i$$

where $w$ is the wage, $c$ is the cost of education, which is necessary to become both low skill or high skill, and $r$ is rent.

The cost of education is assumed to depend on the fraction of the agents in the neighborhood, denoted by $x$, who become high skill. In particular, we have $c_H (x)$ and $c_L (x)$ as the costs of becoming high skill and low skill. Both costs are decreasing in $x$, meaning that when there are more individuals acquiring high skill, becoming high skill is cheaper (positive peer group effects). In addition, we have

$$c_H (x) > c_L (x)$$
$C_H(x)$  \rightarrow  \text{cost of obtaining high skills}

$C_L(x) \rightarrow \text{cost of low skills}

\pi \rightarrow \text{proportion who obtain high skills}$
so that becoming high skill is always more expensive, and

\[ c'_H (x) > c'_L (x) , \]

so that the effect of increase in the fraction of high skill individuals in the neighborhood is bigger on the cost of becoming high skill.

Since all agents are ex ante identical, in equilibrium we must have

\[ U (L) = U (H) \]

that is, the utility of becoming high skill and low skill must be the same.

Assume that the labor market in the economy is global, and takes the constant returns to scale form \( F (H, L) \). The important implication here is that irrespective of where the worker obtains his education, he will receive the same wage as a function of his skill level.

Also assume that there are two neighborhoods of fixed size, and individuals will compete in the housing market to locate in one neighborhood or the other.

There can be two types of equilibria:

1. Integrated city equilibrium, where in both neighborhoods there is a fraction \( \hat{x} \) of individual obtaining high education.
2. Segregated city equilibrium, where one of the neighborhoods is homogeneous. For example, we could have a situation where one neighborhood has \( x = 1 \) and the other has \( \tilde{x} < 1 \), or one neighborhood has \( x = 0 \) and the other has \( \bar{x} > 0 \).

The important observation here is that only segregated city equilibria are “stable”. To see this consider an integrated city equilibrium, and imagine relocating a fraction \( \varepsilon \) of the high-skill individuals (that is
(1) First possibility: Integrated City Equilibrium

This equilibrium is unstable: if the prop. of H agents in neigh 2 increase to \( \hat{x} + \varepsilon \), then all agents planning to get high skills want to move to 1.

\[
\begin{array}{c|c}
\text{neigh. 1} & \text{neigh. 2} \\
\hline
L_1 = 1 - \hat{x} & L_2 = 1 - \hat{x} \\
H_1 = \hat{x} & H_2 = \hat{x} \\
\end{array}
\]

\( \hat{x} = \frac{1}{2} \)

(2) Segregated City Equilibrium

\[
\begin{array}{c|c}
\text{neigh. 1} & \text{neigh. 2} \\
\hline
L_1 = 1 & L_2 = 1 - \hat{x} \\
H_1 = \hat{x} & H_2 = \hat{x} \\
\end{array}
\]

\( \hat{x} = \frac{1}{2} \)

\( c_1 - c_2 = c_H(\hat{x}) - c_H(1) \)

or

\[
\begin{array}{c|c}
\text{neigh. 1} & \text{neigh. 2} \\
\hline
L_1 = 1 - \hat{x} & \\
H_1 = \hat{x} & H_2 = 1 \\
\end{array}
\]

\( \hat{x} = \frac{1}{2} \)

\( c_1 - c_2 = c_L(0) - c_L(\hat{x}) \)

both types of equilibria stable
individuals getting high skills) from neighborhood 1 to neighborhood 2. This will reduce the cost of education in neighborhood 2, both for high and low skill individuals. But by assumption, it reduces it more for high skill individuals, so all high skill individuals now will pay higher rents to be in that city, and they will outbid low-skill individuals, taking the economy toward the segregated city equilibrium.

In contrast, the segregated city equilibrium is always stable. So we again have a situation in which segregation arises as the equilibrium outcomes, and again because of a reasoning relying on the notion of “complementarity”. As in the previous section, high-skill individuals can outbid the low-skill individuals because they benefit more from the peer group effects of high skill individuals.

But again there are some missing markets, in particular, rather than paying high skill individuals for the positive externalities that they create, as would be the case in complete markets, agents transact simply through the housing market. In the housing market, there is only one rent level, which both high and low skill individuals pay. In contrast, with complete markets, we can think of the pricing scheme for housing to be such that high skill individuals pay a lower rent.

Therefore, there are missing markets, and efficiency is not guaranteed. Is the allocation with segregation efficient?

It turns out that it may or may not. To see this considered a problem of a social planner. She will maximize

\[ F (H, L) - H_1 c_H (x_1) - H_2 c_H (x_2) - L_1 c_L (x_1) - L_2 c_L (x_2) \]
where

\[ x_1 = \frac{H_1}{L_1 + H_1} \quad \text{and} \quad x_2 = \frac{H_2}{L_2 + H_2} \]

This problem can be broken into two parts: first to choose the aggregate amount of skilled individuals, and then to choose how to actually allocate them between the two neighborhoods. The second part is simply one of cost minimization, and the solution depends on whether

\[ \Phi (x) = x c_H (x) + (1 - x) c_L (x) \]

is concave or convex. This function is simply the cost of giving high skills to a fraction \( x \) of the population. When it is convex, it means that it’s best to choose the same level of \( x \) in both neighborhoods, and when it’s concave, the social planner minimizes costs by choosing two extreme values of \( x \) in the two neighborhoods.

It turns out that this function can be convex, i.e. \( \Phi'' (x) > 0 \). More specifically, we have:

\[ \Phi'' (x) = 2 \left( c_H' (x) - c_L' (x) \right) + x \left( c_H'' (x) - c_L'' (x) \right) + c_L'' (x) \]

We can have \( \Phi'' (x) > 0 \) when the second and third terms are large. Intuitively, this can happen because although a high skill individual benefits more from being together with other high skill individuals, he is also creating a positive externality on low skill individuals when he mixes with them. This externality is not internalized, potentially leading to inefficiency.

This model gives another example of why equilibrium segregation does not imply efficient segregation.
3.3. Empirical issues and evidence. Peer group effects are generally very difficult to identify. In addition, we can think of two alternative formulations where one is practically impossible to identify satisfactorily. To discuss these issues, let us go back to the previous discussion, and recall that the two “structural” formulations, (3.1) and (3.2), have very similar reduced forms, but the peer group effects work quite differently, and have different interpretations. In (3.1), it is the (predetermined) characteristics of my peers that determine my outcomes, whereas in (3.2), it is the outcomes of my peers that matter. Above we saw how to identify externalities in human capital, which is in essence similar to the structural form in (3.1). More explicitly, the equation of interest is

\[(3.4) \quad y_{ij} = \theta x_{ij} + \alpha \bar{X}_j + \varepsilon_{ij}\]

where $\bar{X}$ is average characteristic (e.g., average schooling) and $y_{ij}$ is the outcome of the $i$th individual in group $j$. Here, for identification all we need is exogenous variation in $\bar{X}$.

The alternative is

\[(3.5) \quad y_{ij} = \theta x_{ij} + \alpha \bar{Y}_j + \varepsilon_{ij}\]

where $\bar{Y}$ is the average of the outcomes. Some reflection will reveal why the parameter $\alpha$ is now practically impossible to identify. Since $\bar{Y}_j$ does not vary by individual, this regression amounts to one of $\bar{Y}_j$ on itself at the group level. This is a serious econometric problem. One imperfect way to solve this problem is to replace $\bar{Y}_j$ on the right hand side by $\bar{Y}_j^{-i}$ which is the average excluding individual $i$. Another approach is
to impose some timing structure. For example:

\[ y_{ijt} = \theta x_{ijt} + \alpha \bar{Y}_{j,t-1} + \varepsilon_{ijt} \]

There are still some serious problems irrespective of the approach taken. First, the timing structure is arbitrary, and second, there is no way of distinguishing peer group effects from “common shocks”.

As an example consider the paper by Sacerdote, which uses random assignment of roommates in Dartmouth. He finds that the GPAs of randomly assigned roommates are correlated, and interprets this as evidence for peer group effects. Despite the very nice nature of the experiment, the conclusion is problematic, because he’s trying to identify (3.5) rather than (3.4). For example, to the extent that there are common shocks to both roommates (e.g., they are in a noisier dorm), this may not reflect peer group effects. Instead, the problem would not have arisen if the right-hand side regressor was some predetermined characteristic of the roommate (i.e., then we would be estimating something similar to (3.4) rather than (3.5)).
TABLE II
OWN PRETREATMENT CHARACTERISTICS REGRESSED ON ROOMMATE PRETREATMENT CHARACTERISTICS
EVIDENCE OF THE RANDOM ASSIGNMENT OF ROOMMATES

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<tr>
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<td>Verbal</td>
<td>Academic</td>
<td>Rank</td>
<td>Academic index</td>
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<tr>
<td>(self)</td>
<td>(self)</td>
<td>class index</td>
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</tbody>
</table>

roommates’ math -0.025 -0.005 (0.028) (0.008)
SAT scores

roommates’ verbal -0.009 -0.005 (0.029) (0.007)
SAT scores

roommates’ HS academic scores
0.010 0.055 (0.028) (0.056)

roommates’ HS class ranks
-0.032 0.031 (0.028) (0.042)

roommates’ HS class rank missing
-0.512 (0.838)

Dummies for housing questions
yes yes yes yes yes

F-test: All roommate background coeff = 0
F(5, 1543) = 0.50
P > F = .78

R²
.09 .03 .04 .03 .04
N
1589 1589 1589 993 1589

Standard errors are in parentheses. In cases with more than one roommate, roommate variables are averaged.

Columns (1)–(5) are OLS. All regressions include 41 dummies representing nonempty blocks based upon responses to the housing questions.

The lack of statistical significance on the coefficients is intended to demonstrate that the assignment process resembles a randomized experiment. In earlier nonrandomly assigned classes (such as the classes of 1995–1996), own and roommate background are highly correlated.
Part 2

Changes in the Wage Structure
In this part I discuss the changes that have taken place in the U.S. wage structure, and also briefly discuss cross-country trends. As is well known, wage and income inequality have increased considerably in the U.S. over the past 25 years. This makes an analysis of changes in the wage structure interesting in its own right. Moreover, changes in the wage structure also imply changing labor market prices of different types of skills. Therefore, studying changes in the wage structure will be informative about the changes in the demand for different types of skills and technological developments. Finally, changes in the wage structure will also lead to different incentives for human capital investments, which we might want to understand.
CHAPTER 5

The Basic Trends and Interpretation

1. Changes in the U.S. Wage Structure

1.1. Some basic facts. Briefly, the following are some of the major changes in the U.S. wage structure.

(1) Returns to education fell during the 1970s, when there was a very sharp increase in the supply of educated workers. Returns to education then began a steep rise during the 1980s. This conclusion is independent of how returns to education are measured. For example, the simple linear return to schooling in a typical Mincer increased sharply. It was approximately 7.5 percent in 1980, and in 1990 it stood closer to 10 percent. But in fact, the increase is more significant between high school graduates in college graduates. Between 1979 and 1987, the average weekly wages of college graduates with one to five years of experience increased by 30 percent relative to the average weekly earnings of comparable high school graduates. The increase in inequality is even more pronounced between high school graduates and those with more than college.

(2) Overall wage inequality, for example as measured by the ratio of the different percentiles of the overall wage distribution (e.g. 90-10), rose sharply beginning in the 1970s.
(3) The single biggest contributor to the increase in overall wage inequality is the increase in within group (residual) inequality—i.e., increases in inequality among observationally equivalent workers. The standard way to compute residual wage inequality is either to look at inequality within very narrowly defined cells (workers with the same education level, the same experience level and of the same sex and race), or to run a standard Mincer wage regression of the form

\[
\ln w_{it} = X_{it}' \beta_t + v_{it},
\]

where \(w_{it}\) is weekly earnings for individual \(i\) observed in year \(t\), and \(X_{it}\) is a set of controls. The fact that \(\beta_t\) is indexed by \(t\) indicates that returns to these observed characteristics are allowed to vary from year-to-year. Measures of residual inequality are calculated as the difference between the 90th and the 10th (or 50th and 10th, etc.) percentile values of the residual distribution from this regression, \(v_{it}\).

(4) Average and median wages have stagnated and wages of low-skill workers have fallen in real terms since 1970. For example, white men aged 30-49 earned $409 a week in 1999 dollars in 1949, and $793 in 1969, which corresponds approximately to a 3.4 percent a year increase in real wages between 1949 and 1969. In contrast, the same age group earned $909 in 1989, or experienced only a 0.6 percent a year increase between 1969 and 1989. In the meantime, the real wages of high school
graduates with 1 to 5 years of experience fell by 20 percent from 1979 to 1987.

(5) These changes have been more pronounced for relatively less experienced workers, and the experience premium—the earning difference between high and low experienced workers—has also changed. In particular, among college graduates, young college graduates now earn relatively more as compared to older college graduates than before. In contrast, among high school graduates, the earnings gap between more and less experienced workers has widened substantially.

(6) The wage differential between men and women has narrowed substantially.

(7) The wage differential between black and white workers, which had been narrowing until the mid-70s, started to expand.

(8) Inequality of compensation, taking into account non-wage and fringe benefits, has expanded more than earnings inequality (Pierce, 2000).

(9) Income inequality has also increased substantially over this time period, mostly reflecting the increase in wage inequality, but also the explosion in CEO pay and the high rates of return on capital and other assets which are held very unequally in the population.

(10) There has been very large increase in the incomes of those at the very top of the earnings distribution (the top 1 percent or even 0.1 percent of income distribution), in part because
of stock options and the very strong performance of the stock market.

Indexed Wages For White Males 1963-1997

Changes in the indexed value of the 90th, 50th and 10th percentiles of the wage distribution for white males (1963 values normalized to 100).
Figure 5
College Premium: All and New Entrants

Source: Coefficient on college education in log earnings regression, estimated separately in each year from the March CPS.
Most of these facts are not controversial. But there is some debate about two of those facts.

(1) There is disagreement regarding when the increase in overall and residual inequality started. The March CPS and census data unambiguously indicate that it started in the 1970s. But May CPS data gives more ambiguous results. DiNardo, Fortin and Lemieux find that wage inequality appears to increase starting in the 1980s in the May CPS data, but the reanalysis of these data by Katz and Autor (2000) shows consistent increases in wage inequality during the 1970s from March and
Figure 1. Output per Hour and Real Hourly Compensation, 1979–90

1973 = 100

FIGURE II
Black-White Weekly Earnings Gap for Men with Less Than Ten Years Experience—1963-1989 (controlling for education)
May CPS data, and from census data. So I take the starting date of the increase in overall and residual inequality to be the early 1970s.

(2) Some economists claim that average and median wages haven’t really fallen, but this reflects mismeasurement of the CPI, which is understating wage growth. This argument is not very convincing, however. Even in the presence of such measurement problems, unless there is an “acceleration” in this bias exactly around the 1970s, there is a large gap between the rate of increase of real wages before and after the 1970s. It has to be noted, however, that part of this gap is due to the increase importance of nonwage income and benefits. In fact, thanks to the increase in benefits, the share of labor in national income has not fallen over this period. So whether average wages have stagnated or continued to increase in line with output growth depends on how benefits are valued relative to earnings.

Finally, there is another major fact which will play an important role in the interpretation of the changes in wage inequality. There has been a remarkable increase in the supply of skills in the U.S. economy over the past sixty years, and this increase in the supply of skills accelerated starting in the early ’70s. In 1939, just over 6 percent of American workers were college graduates. By 1996 this number had increased to over 28 percent. In 1939, almost 68 percent of all workers did not have a high school degree. In 1996, this number had fallen to less than 10 percent. Equally important, the rate of growth of the relative supply of skills significant the accelerated starting in the late 1960s,
because of the Vietnam War draft laws, increase government support for education, and the high college enrollment rates of the baby boom cohorts.

The behavior of the (log) college premium and relative supply of college skills (weeks worked by college equivalents divided by weeks worked of noncollege equivalents) between 1939 and 1996. Data from March CPSs and 1940, 1950 and 1960 censuses.

1.2. **Permanent versus transitory inequality.** An important question for certain purposes is whether the increase in inequality is permanent or transitory (temporary). For example, if it is transitory and individuals can insure against it (for example by saving and borrowing), the increase in income and earnings inequality may not correspond to an increase in “utility” inequality.
The facts suggest that there is also an increase in the transitory component of earnings inequality, meaning that earnings fluctuations of workers around their permanent earnings levels are now greater. This fact was first noted by Gottschalk and Moffit. They document this fact by fitting an age-earnings profile for each individual, and then studying fluctuations of their incomes around this trend. The same pattern seems to arise both in the PSID and the CPS, and also can be seen in the UK.

A word of interpretation is necessary here, because the increase in the temporary component of inequality is often misinterpreted. Such an increase in temporary earnings inequality may result from two distinct causes:

1. a given worker may move up and down more frequently (greater “churning” in the labor market);
2. a worker may move up and down the same amount, but the movements may be bigger.

Mathematically, imagine the worker’s “permanent” earnings level is $w_0$, but every period, with probability $p$ he may get lower earnings, $w_l$, and with probability $q$, higher earnings, $w_h$. The two distinct causes correspond to changes in the probabilities $p$ and $q$, and to changes in earnings levels $w_l$ and $w_h$.

A closer look at the data indicates that all of the increase in the temporary earnings inequality is due to the second cause. For example, there is no greater movement of workers between different deciles of the wage distribution.
This in fact makes a lot of sense. The leading interpretation of the fluctuations of a given worker’s wages is that his skills are fluctuating over time (or the perception of the market regarding his skills are changing, for example as in Jovanovic’s model). So we have \( w_0 = ws_0 \) where \( w \) is the market price of skills and \( s_0 \) is his regular skill level. We also have \( w_h = ws_h \) and \( w_l = ws_l \). If there is an increase in wage inequality corresponding to a greater skill premium, \( w \), this will translate into a greater wage gap between different skill levels and therefore into a greater temporary component in earnings inequality. This can all happen without a change in any of the parameters \( p, q, s_0 \) or \( s_1 \) that correspond to the likelihood and magnitude of skill level fluctuations of workers.

This is important since many applied papers interpret the increase in earnings instability as reflecting greater churning. But there is basically no evidence for greater churning in the labor market. First, measures of job reallocation constructed by Davis and Haltiwanger indicate no increase in job reallocation during the past 20 or so years. Second, despite the popular perception to the contrary, there has not been a large increase in employment instability. The tenure distribution of workers today looks quite similar to what it was 20 years ago. The major exception to this seems to be middle-aged managers, who may be more likely to lose their jobs today than 20-25 years ago.

1.3. Cross-country trends. We know somewhat less about changes in wage inequality in most other countries than in the U.S. But the following are now relatively well-established:
Figure 2.4
Net and Gross Job Flow Rates in Manufacturing:
Annual, 1973 to 1988

Percent of employment

Job reallocation
Job destruction
Job creation
Net growth

(1) Wage inequality, both returns to schooling and residual inequality, increased significantly in the UK.

(2) Wage inequality also increased somewhat in other Anglo-Saxon economies, perhaps quite markedly in New Zealand.

(3) In much of continental Europe, there has been little increase in either returns to schooling or overall inequality.

We return to a discussion of the possible explanations for these patterns below.

2. Interpretation

I will now focus on the two major facts related to the increase in earnings inequality: the increase in the returns to schooling and increased overall and residual inequality. In this section, I will argue two things:

(1) Both of these facts may be reflecting an increase in skill premia—an increase in the market price of skills.

(2) They are unlikely to reflect composition effects, cohort effects or anything related to signaling/selection.

2.1. Increase in inequality and unobserved skills. The idea that the increase in residual inequality may reflect increased skill premia is related to the idea that a large component of earnings dispersion not explained by schooling is nonetheless related to skill differences. If I am less skilled than another worker with the same education, for example, or because he can perform certain tasks that I cannot, the earnings inequality between us will widen when the tasks that he can
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<th>90-50 Percentile Differential</th>
<th>90-10 Percentile Differential</th>
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Table 1.7 Alternative Measures of Wage Inequality for Four Countries, 1979–90

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Note: 90-10 refers to the log wage differential between the ninetieth and the tenth percentile workers. The 90-50 and 50-10 differentials are defined analogously. The wage inequality measures refer to log hourly wages for the United States, Great Britain, and France and to log monthly scheduled wages for Japan.
perform become more valuable. In the data this will show up as increased residual inequality. This argument is put forth forcefully by Juhn, Murphy and Pierce (1993).

More formally, suppose that two otherwise identical individuals differ in terms of their unobserved skills (for example, in terms of interpersonal skills, motivation, specific skills for their job, or IQ). Denote the unobserved skill of individual 1 by $a_1$ and that of individual 2 by $a_2 > a_1$, and assume that wages are given by

$$\ln w_{it} = 2\theta_t a_i + \gamma_t h_i,$$

where $\gamma_t$ is the price of $h$ skills at time $t$, while $\theta_t$ is the price of $a$ skills. Since these individuals are identical in all respects other than their unobserved skills, $a$, the variance of log wages (or of residual wages) among these two individuals is

$$Var(\ln w) = \theta_t^2 (a_2 - a_1)^2.$$

Now if at a later date, $t'$, this variance increases to $Var(\ln w)'$, and we know that these two individuals are still identical in all other respects and that $a_2 - a_1$ has not changed, we can interpret the increase in $Var(\ln w)$ as reflecting an increase in the price of unobserved skills, $\theta_t$.

In other words, if we ignore composition effects, which here correspondent to changes in $a_2 - a_1$, this increase must be due to a rise in the price of (and demand for) unobserved skills.

2.2. Composition effects. Could composition effects explain a significant component of the increase in residual and overall inequality, and also the bulk of the changes in the returns to education?
First, to see the reasoning note that the increase in the returns to education may be simply the result of an increase in the average ability of workers with high education to that of workers with low education over time. This will immediately lead to an increase in the return to education. This change in relative abilities of the two groups may result from selection (for example, today different types of workers than before may be obtaining college degrees). There is no presumption that any signaling is going on here. The employers may well be observing these skill dimensions that we, as the economists, do not observe. Alternatively, these changes in relative abilities of the two groups may result from changes in signaling behavior. College education may have become a much more important signal today, because employers may expect only the very low ability workers not to obtain a college degree. Both of these explanations could potentially account for the increase in the returns to education and residual and overall inequality.

However, the evidence suggests that the increase in the returns to education and residual inequality are not simply due to composition effects. Before discussing this evidence, note first that composition effects cannot by themselves explain the recent changes in inequality: composition effects suggest that inequality among educated and uneducated workers should move in opposite directions (see below). This suggests that changes in the true returns to skills have played at least some role in the changes in inequality.

More generally, to get a sense of how important composition effects may be, consider a variant of equation (2.1) above with two education
levels, high $h = 1$ and low $h = 0$, and suppose wages are given by

\begin{equation}
\ln w_{it} = a_i + \gamma_t h_i + \varepsilon_{it}
\end{equation}

where $h_i$ is a dummy for high education, $a_i$ is unobserved ability, and $\varepsilon_{it}$ is a mean zero disturbance term. Define the (log) education premium—the difference between the average wages of high and low education workers—as:

\[
\ln \omega_t \equiv E (\ln w_{it} \mid h_i = 1) - E (\ln w_{it} \mid h_i = 0) = \gamma_t + A_{1t} - A_{0t}
\]

where $A_{1t} \equiv E (a_i \mid h_i = 1)$ and $A_{0t} \equiv E (a_i \mid h_i = 0)$. The increase in the education premium can be caused by an increase in $\gamma_t$ (a true increase in the returns to skills) or an increase in $A_{1t} - A_{0t}$. There are basically two reasons for an increase in $A_{1t} - A_{0t}$: (1) changes in cohort quality, or (2) changes in the pattern of selection into education.

Consider changes in cohort quality first. If, as many claim, the U.S. high school system has become worse, we might expect a decline in $A_{0t}$ without a corresponding decline in $A_{1t}$. As a result, $A_{1t} - A_{0t}$ may increase.

Alternatively, as a larger fraction of the U.S. population obtains higher education, it is natural that selection into education (i.e., the relative abilities of those obtaining education) will change. It is in fact possible that those who are left without education could have very low unobserved ability, which would translate into a low level of $A_{0t}$, and therefore into an increase in $A_{1t} - A_{0t}$.

Although these scenarios are plausible, theoretically the opposite can happen as well. For example, many academics who have been involved in the U.S. education system for a long time complain about...
the decline in the quality of universities, while the view that American high schools have become much worse is not shared universally.

The selection argument is also more complicated than it first appears. It is true that, as long as those with high unobserved abilities are more likely to obtain higher education, an increase in education will depress $A_0$. But it will also depress $A_1$. To see why assume that there is perfect sorting—i.e., if an individual with ability $a$ obtains education, all individuals with ability $a' > a$ will do so as well. In this case, there will exist a threshold level of ability, $\bar{\alpha}$, such that only those with $a > \bar{\alpha}$ obtain education. Next consider a uniform distribution of $a_i$ between $b_0$ and $b_0 + b_1$. Then,

$$A_0 = \frac{1}{\bar{\alpha} - b_0} \int_{b_0}^{\bar{\alpha}} ada = \frac{\bar{\alpha} + b_0}{2}$$

and

$$A_1 = \frac{1}{b_1 - b_0 - \bar{\alpha}} \int_{\bar{\alpha}}^{b_0 + b_1} ada = \frac{b_0 + b_1 + \bar{\alpha}}{2}$$

So both $A_0$ and $A_1$ will decline when $\bar{\alpha}$ decreases to $\bar{\alpha}'$. Moreover, $A_1 - A_0 = b_1/2$, so it is unaffected by the decline in $\bar{\alpha}$. Intuitively, with a uniform distribution of $a_i$, when $\bar{\alpha}$ increases, both $A_0$ and $A_1$ fall by exactly the same amount, so the composition effects have no influence on the education premium. Clearly, with other distributions of ability, this extreme result will no longer hold, but it remains true that both $A_0$ and $A_1$ will fall, and whether this effect will increase or decrease the education premium is unclear. Overall, therefore, the effects of changes in composition on education premia is an empirical question.

2.3. Evidence on composition effects. Empirically, the importance of composition effects can be uncovered by looking at inequality
changes by cohort (e.g. Blackburn, Bloom and Freeman, or Juhn, Murphy and Pierce). To see this, rewrite equation (2.2) as

\[(2.3) \quad \ln w_{ict} = a_{ic} + \gamma_t h_{ic} + \varepsilon_{cit}\]

where \(c\) denotes a cohort—i.e., a group of individuals who are born in the same year, or a group of individuals who have come to the market in the same year. I have imposed an important assumption in writing equation (2.3): returns to skills are assumed to be the same for all cohorts and ages; \(\gamma_t\)—though clearly they vary over time. We can now define cohort specific education premia as

\[
\ln \omega_{ct} \equiv E(\ln w_{ict} | h_i = 1) - E(\ln w_{ict} | h_i = 0) = \gamma_t + A_{1ct} - A_{0ct}
\]

where \(A_{1ct} \equiv E(a_{ic} | h_i = 1)\) and \(A_{0ct}\) is defined similarly. Under the additional assumption that there is no further schooling for any of the cohorts over the periods under study, we have \(\ln \omega_{ct} = \gamma_t + A_{1c} - A_{0c}\), which implies

\[(2.4) \quad \Delta \ln \omega_{c,t'}-{t} \equiv \ln \omega_{c,t'} - \ln \omega_{ct} = \gamma_{t'} - \gamma_t,\]

i.e., changes in the returns to education within a cohort will reveal the true change in the returns to education.

The assumption that returns to skills are constant over the lifetime of an individual may be too restrictive, however. As we saw above, there are quite different age earning profiles by education. Nevertheless, a similar argument can be applied in this case too. For example, suppose

\[
\ln \omega_{est} = \gamma_{st} + A_{1c} - A_{0c}
\]
for cohort \( c \) of age \( s \) in year \( t \), and that
\[
\gamma_{st} = \gamma_s + \gamma_t
\]
(this assumption is also not necessary, but simplifies the discussion).

Then
\[
\Delta \ln \omega_{c,t-t} = \gamma_{s'} - \gamma_s + \gamma_{t'} - \gamma_t,
\]
where obviously \( s' - s = t' - t \). Now consider a different cohort, \( c'' \) that is age \( s' \) in the year \( t \) and age \( s \) in the year \( t'' \). Then
\[
\Delta \ln \omega_{c'',t-t''} = \gamma_{s''} - \gamma_s + \gamma_{t} - \gamma_{t''}
\]
So, the true change in the returns to skills between the dates \( t'' \) and \( t' \) is
\[
(2.5) \quad \Delta^2 \ln \omega \equiv \Delta \ln \omega_{c,t'-t} - \Delta \ln \omega_{c'',t-t''} = \gamma_{t'} - \gamma_{t''}.
\]

The evidence using this approach indicates that there are large positive changes in the returns to a college degree or this time period.

Juhn, Murphy and Pierce (1993) apply similar methodology to the increase in overall and residual inequality. They also find that these changes cannot be explained by composition effects either. These results suggest that the changes in the structure of wages observed over the past 30 years cannot be explained by pure composition effects, and reflect mainly changes in the true returns to observed and unobserved skills.
### TABLE 3

**Changes in Inequality by Cohort, 1963–89**

**A. 90-10 Differentials for Log Weekly Wages**

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#### Average Changes within Cohorts and Experience Levels

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### B. 90-10 Differentials for Log Wage Residuals

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#### Average Changes within Cohorts and Experience Levels

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CHAPTER 6

The Basic Theory of Skill Premia

The simplest framework for thinking about skill premia (returns to schooling and returns to other skills) starts with a supply-demand framework. The demand for skills is often thought to be generated by the technology possibilities frontier of the economy, but is also affected by international trade, and perhaps by the organization of production.

1. The Constant Elasticity of Substitution Framework

1.1. The aggregate production function. Let me start with the simplest framework where there are two types of workers, skilled and unskilled (high and low education workers), who are imperfect substitutes. Imperfect substitution between the two types of workers is important in understanding how changes in relative supplies affect skill premia. For now, let us think of the unskilled workers as those with a high school diploma, and the skilled workers as those with a college degree, so the terms “skill” and education will be used interchangeably. In practice, however, education and skills are imperfectly correlated, so it is useful to bear in mind that since there are skilled and unskilled workers within the same education group, an increase in the returns to skills will also lead to an increase in within-group inequality.

Suppose that there are $L(t)$ unskilled (low education) workers and $H(t)$ skilled (high education) workers, supplying labor inelastically at
time $t$. All workers are risk neutral, and maximize (the present value of) labor income. Also suppose that the labor market is competitive.

The production function for the aggregate economy takes the form the constant elasticity of substitution (CES) form,

$$(1.1) \quad Y(t) = [(A_l(t)L(t))^{\rho} + (A_h(t)H(t))^{\rho}]^{1/\rho},$$

where $\rho \leq 1$. I also ignore capital. I drop the time argument when this causes no confusion.

The elasticity of substitution between skilled and unskilled workers in this production function is $\sigma \equiv 1/(1 - \rho)$.

Skilled and unskilled workers are gross substitutes when the elasticity of substitution $\sigma > 1$ (or $\rho > 0$), and gross complements when $\sigma < 1$ (or $\rho < 0$). Three noteworthy special cases are:

1. $\sigma \rightarrow 0$ (or $\rho \rightarrow -\infty$) when skilled and unskilled workers will be Leontieff, and output can be produced only by using skilled and unskilled workers in fixed portions;
2. $\sigma \rightarrow \infty$ when skilled and unskilled workers are perfect substitutes
3. $\sigma \rightarrow 1$, when the production function tends to the Cobb Douglas case.

The value of the elasticity of substitution will play a crucial role in the interpretation of the results that follow. In particular, in this framework, technologies either increase the productivity of skilled or unskilled workers, i.e., there are no explicitly skill-replacing or unskilled-labor-replacing technologies. Depending on the value of the elasticity
of substitution, an increase in $A_h$ can act either to complement or to “replace” skilled workers.

As a little digression, at this point we can note that a more general formulation would be

$$Y(t) = [(1 - b_t)(A_l(t)L(t) + B_l(t))^{\rho} + b_t(A_h(t)H(t) + B_h(t))^{\rho}]^{1/\rho},$$

where $B_l$ and $B_h$ would be directly unskilled-labor and skill-replacing technologies, and an increase in $b_t$ would correspond to some of the tasks previously performed by the unskilled being taken over by the skilled. For most of the analysis here, there is little to be gained from this more general production function.

The production function (1.1) admits three different interpretations.

1. There is only one good, and skilled and unskilled workers are imperfect substitutes in the production of this good.

2. The production function (1.1) is also equivalent to an economy where consumers have utility function $[Y_l^{\rho} + Y_h^{\rho}]^{1/\rho}$ defined over two goods. Good $Y_h$ is produced using only skilled workers, and $Y_l$ is produced using only unskilled workers, with production functions $Y_h = A_hH$, and $Y_l = A_lL$.

3. A mixture of the above two whereby different sectors produce goods that are imperfect substitutes, and high and low education workers are employed in all sectors.

Although the third interpretation is more realistic, I generally use one of the first two, as they are easier to discuss.
Since labor markets are competitive, the unskilled wage is

\[
\begin{align*}
    w_L &= \frac{\partial Y}{\partial L} = A_t^\rho \left[ A_t^\rho + A_h^\rho (H/L)^\rho \right]^{(1-\rho)/\rho}.
\end{align*}
\]

This equation implies \( \partial w_L/\partial H/L > 0 \): as the fraction of skilled workers in the labor force increases, the wages of unskilled workers should increase. Similarly, the skilled wage is

\[
\begin{align*}
    w_H &= \frac{\partial Y}{\partial H} = A_h^\rho \left[ A_t^\rho (H/L)^{-\rho} + A_h^\rho \right]^{(1-\rho)/\rho},
\end{align*}
\]

which yields \( \partial w_H/\partial H/L < 0 \); everything else equal, as skilled workers become more abundant, their wages should fall.

Combining these two equations, the skill premium—the wage of skilled workers divided by the wage of unskilled workers—is

\[
\begin{align*}
    \omega &= \frac{w_H}{w_L} = \left( \frac{A_h}{A_t} \right)^\rho \left( \frac{H}{L} \right)^{-(1-\rho)} = \left( \frac{A_h}{A_t} \right)^{(\sigma-1)/\sigma} \left( \frac{H}{L} \right)^{-1/\sigma}.
\end{align*}
\]

Equation (1.3) can be rewritten in a more convenient form by taking logs,

\[
\begin{align*}
    \ln \omega &= \frac{\sigma - 1}{\sigma} \ln \left( \frac{A_h}{A_t} \right) - \frac{1}{\sigma} \ln \left( \frac{H}{L} \right).
\end{align*}
\]

Naturally, the skill premium increases when skilled workers become more scarce, i.e.,

\[
\begin{align*}
    \frac{\partial \ln \omega}{\partial \ln H/L} &= -\frac{1}{\sigma} < 0.
\end{align*}
\]

This is the usual substitution effect, and shows that for given skill bias of technology, as captured by \( A_h/A_t \), the relative demand curve for skill is downward sloping with elasticity \( 1/\sigma = (1 - \rho) \). Intuitively, an increase in \( H/L \) can create two different types of substitutions.
(1) if skilled and unskilled workers are producing the same good, but performing different functions, an increase in the number of skilled workers will necessitate a substitution of skilled workers for tasks previously performed by the unskilled.

(2) if skilled and unskilled workers are producing different goods (because they have different comparative advantages making them useful in different sectors), the greater number of skilled workers will lead to a substitution of the consumption of the unskill-intensive good by the skill-intensive good. In both
cases, this substitution hurts the relative earnings of skilled workers.

1.2. Relative supply of skills, technology, and the skill premium. An interesting case study of the response of the returns to schooling to an increase in the supply of skills is provided by the experience in the West Bank and Gaza Strip during the 1980s. As Angrist (1995) illustrates, there was a very large increase in the supply of skilled Palestinian labor as there opened Palestinian institutions of higher education, which were totally absent before 1972. Angrist shows that premia to college graduate workers (relative to high school graduates) that were as high as 40 percent quickly fell to less than 20 percent.

The extent of substitution was also clear. First, many college graduate workers could not find employment in skilled jobs. Angrist (1995) shows a sharp increase in the unemployment rate of college graduates, and Schiff and Yaari (1989) report that only one in eight Palestinian graduates could find work in his profession, with the rest working as unskilled laborers, mainly in the construction industry. Second, premia for tasks usually performed by more educated workers fell sharply. Between 1984 and 1987, the premium for administrative and managerial jobs (relative to manual laborers) fell from .32 to .12, while the premium for clerical workers fell from .02 to -.08 (see Angrist, 1995, for details).

As equation (1.5) shows, the elasticity of substitution, $\sigma$, regulates the behavior of the skill premium in response to supply changes. The elasticity of substitution is also crucial for the response of the skill
premium to changes in technology. Unfortunately, this parameter is rather difficult to estimate, since it refers to an elasticity of substitution that combines substitution both within and across industries. Nevertheless, there are a number of estimates using aggregate data that give a range of plausible values. The majority of these estimates are between $\sigma = 1$ and $2$. The response of college premium for Palestinian labor reported in Angrist (1995), for example, implies an elasticity of substitution between workers with 16 years of schooling and those with less than 12 of schooling of approximately $\sigma = 2$.

How does the skill premium respond to technology? Differentiation of (1.4) shows that the result depends on the elasticity of substitution. If $\sigma > 1$ (i.e., $\rho \in (0, 1]$), then

$$\frac{\partial \omega}{\partial A_h/A_l} > 0,$$

i.e., improvements in the skill-complementary technology increase the skill premium.

Diagrammatically, this can be seen as a shift out of the relative demand curve, which moves the skill premium from $\omega$ to $\omega''$. The converse is obtained when $\sigma < 1$: that is, when $\sigma < 1$, an improvement in the productivity of skilled workers, $A_h$, relative to the productivity of unskilled workers, $A_l$, shifts the relative demand curve in and reduces the skill premium. This case appears paradoxical at first, but is, in fact, quite intuitive. Consider, for example, a Leontief (fixed proportions) production function. In this case, when $A_h$ increases and skilled workers become more productive, the demand for unskilled workers, who are necessary to produce more output by working with the more productive
skilled workers, increases by more than the demand for skilled workers. In some sense, in this case, the increase in $A_h$ is creating an “excess supply” of skilled workers given the number of unskilled workers. This excess supply increases the unskilled wage relative to the skilled wage.

This observation raises an important caveat. It is tempting to interpret improvements in technologies used by skilled workers, $A_h$, as “skill-biased”. However, when the elasticity of substitution is less than 1, it will be advances in technologies used with unskilled workers, $A_l$, that increase the relative value over marginal product and wages of skilled workers, and an increase in $A_h$ relative to $A_l$ will be “skill-replacing”.

Nevertheless, the conventional wisdom is that the skill premium increases when skilled workers become relatively more—not relatively less—productive, which is consistent with $\sigma > 1$. In fact, as noted above, most estimates show an elasticity of substitution between skilled and unskilled workers greater than 1.

It is also useful to compute average wages in this economy. Without controlling for changes in the educational composition of the labor force, the average wage is

$$w = \frac{Lw_L + Hw_H}{L + H} = \frac{[(A_lL)^\rho + (A_hH)^\rho]^{1/\rho}}{1 + H/L},$$

which is also increasing in $H/L$ as long as the skill premium is positive (i.e., $\omega > 1$ or $A_h^\rho(H/L)^\rho - A_l^\rho > 0$). Intuitively, as the skill composition of the labor force improves, wages will increase.

1.3. Summary. The results I have outlined so far imply that in response to an increase in $H/L$: 
1. Relative wages of skilled workers, the skill premium $\omega = w_H/w_L$, decreases.

2. Wages of unskilled workers increase.

3. Wages of skilled workers decrease.

4. Average wages (without controlling for education) rise.

These results can be easily generalized to the case in which physical capital also enters the production function, of the form

$$F(A_h L, A_h H, K)$$

and the same comparative statics hold even when the economy has an upward sloping supply of capital.

It is also useful to highlight the implications of an increase in $A_h$ on wage levels. First, an increase in $A_h$, with $A_l$ constant, corresponds to an increase in $A_h/A_l$; the implications of this change on the skill premium were discussed above. Moreover if $A_h$ increases, everything else being equal, we expect both the wages of unskilled and skilled workers (and therefore average wages) to increase: technological improvements always increase all wages. This observation is important to bear in mind since, as shown above, the wages of low-skill workers fell over the past 30 years.

2. Why Technical Change Must Have Been Skill Biased?

The most central result for our purposes is that as $H/L$ increases, the skill premium, $\omega$, should fall. Diagrammatically, the increase in supply corresponds to a rightward shift in the vertical line from $H/L$ to $H'/L'$, which would move the economy along the downward sloping demand curve for skills. But this tendency of the skill premium to
fall could be counteracted by changes in technology, as captured by 
\[ \frac{\sigma - 1}{\sigma} \ln(A_h/A_l). \]

As discussed above, the past 60 years, and particularly the past 30 years, have witnessed a rapid increase in the supply of skills, \( H/L \), but no corresponding fall in the skill premium. This implies that demand for skills must have increased to prevent the relative wages of skilled workers from declining. The cause for this steady increase in the demand for skills highlighted by this simple framework is skill-biased technical change. More explicitly, the relative productivity of skilled workers, \( (A_h/A_l)^{(\sigma-1)/\sigma} \), must have increased.

The increase in \( (A_h/A_l)^{(\sigma-1)/\sigma} \) can be interpreted in a number of different ways. In a two-good economy, such skill-biased technical change corresponds to an increase in \( A_h/A_l \) and \( \rho > 0 \) \( (\sigma > 1) \)—i.e., skilled workers become more productive. Skill-biased technical change could also take the form of a decrease in \( A_h/A_l \) and \( \rho < 0 \) \( (\sigma < 1) \). In this case the “physical” productivity of unskilled workers would increase, but their relative wages would fall due to relative price effects. Alternatively, with the one-good interpretation, skill-biased technical change simply corresponds to an increase in \( (A_h/A_l)^{(\sigma-1)/\sigma} \).

If we assume a specific value for \( \sigma \), we can translate these numbers into changes in \( A_h/A_l \) to get a sense of the magnitude of the changes. In particular, notice that the relative wage bill of skilled workers is given by

\[
S_H = \frac{w_H H}{w_L L} = \left( \frac{A_h}{A_l} \right)^{(\sigma-1)/\sigma} \left( \frac{H}{L} \right)^{(\sigma-1)/\sigma}.
\]
Hence, we have

\[
\frac{A_h}{A_l} = \frac{S_H^\sigma/(\sigma - 1)}{H/L}.
\]

We can easily calculate the implied \(\frac{A_h}{A_l}\) values for \(\sigma = 1.4\) and for \(\sigma = 2\) using workers with some college, college graduates, and college equivalents definitions of Autor, Katz and Krueger (1998). In all cases, there is a very large implied increase in \(\frac{A_h}{A_l}\) and \((\frac{A_h}{A_l})^{(\sigma - 1)/\sigma}\). For example, these numbers indicate that, assuming an elasticity of substitution of 1.4, the relative productivity of college graduates, \(\frac{A_h}{A_l}\), was approximately 0.030 in 1960, increased to 0.069 in 1970, and to 0.157 in 1980. Between 1980 and 1990, it increased by a factor of almost three to reach 0.470. As equation (1.4) shows, changes in the demand index

\[
D = (\frac{A_h}{A_l})^{\frac{\sigma - 1}{\sigma}}
\]

may be more informative than changes in \(\frac{A_h}{A_l}\).

The view that the post-war period is characterized by skill-biased technical change also receives support from the within-industry changes in employment patterns. With constant technology, an increase in the relative price of a factor should depress its usage in all sectors. Since the college premium increased after 1979, with constant technology, there should be fewer college graduates employed in all sectors—and the sectoral composition should adjust in order to clear the market. The evidence is very much the opposite. Berman, Bound and Griliches (1994) and Murphy and Welch (1993) show a steady increase in the share of college labor in all sectors.
This discussion therefore suggests that the past sixty years must have been characterized by skill-biased technical change.

Note however that the presence of steady skill-biased technical change does not offer an explanation for rise in inequality over the past 25 years, since we are inferring that technical change has been skill biased for much longer than these decades, and inequality was stable or even declining during the decades before the 1970s. Moreover, skill-biased technical change by itself is not enough for inequality and skill premia to increase. It will only need to increase in inequality when it outpaces the increase in the relative supply of skills. We will discuss this topic in more detail below.
CHAPTER 7

Non-Technological Explanations For the Changes in the Wage Structure

Armed with a simple framework for analyzing returns to schooling and skill premia, we can now discuss what the potential causes of the changes in the way structures could be. In this section, I start with three non-technological explanations. In the next section, I will discuss theories where the increase in wage and earnings inequality may reflect changes in technologies.

By non-technological explanations I do not mean explanations in which technology plays no role, but simply that there hasn’t been anything unusual in the technology front. Instead some other changes are responsible for the transformation of the wage structure. The three explanations I will discuss are:

(1) The steady-demand hypothesis. According to this view, there has been no major change in the structure of technology, and therefore in the structure of demand for skills. Changes in the returns to schooling and skill premium can be explained by the differential rates of growth in the supply of skills.
(2) The trade hypothesis. According to this view, the increase in international trade, especially trade with less-developed countries, is responsible for the (unusual) increase in the demand for skills over the past twenty-five years.

(3) The labor-market institutions hypothesis. This view assigns changes in the wage structure to the decline of unions, the erosion of the real value of the minimum wage and more generally, to changes in labor market regulations.

Throughout, it is useful to bear in mind that the leading alternative to the non-technology models is a view which sees an acceleration in the skill bias of technology, or some unusual technological developments affecting the demand for skills. So I will be sometimes explicitly or implicitly comparing these three non-technical hypotheses to the technology view

1. The Steady-Demand Hypothesis

In a simple form, this hypothesis can be captured by writing

\[
\ln \left( \frac{A_h(t)}{A_l(t)} \right) = \gamma_0 + \gamma_1 t,
\]

where \( t \) is calendar time. Substituting this equation into (1.4), we obtain

\[
\ln \omega = \sigma \left( \frac{1}{\sigma} \gamma_0 + \frac{1}{\sigma} \gamma_1 t - \frac{1}{\sigma} \ln \left( \frac{H}{L} \right) \right).
\]

According to equation (1.2), the demand for skills increases at a constant rate, but the supply of skilled workers could grow at different rates. Therefore, changes in the returns to skills are caused by uneven growth in the supply of skills. When \( H/L \) grows faster than the rate of
skill-biased technical change, \((\sigma - 1) \gamma_1\), the skill premium will fall, and when the supply growth falls short of this rate, the skill premium will increase. The story has obvious appeal since the 1970s, when returns to schooling fell sharply, were a period of faster than usual increase in the supply of college graduate workers. In contrast, the 1980s were a period of slow increase in the supply of skills relative to the 1970s.

Katz and Murphy (1992) estimate a version of equation (1.2) above using aggregate data between 1963-1987. They find

\[
\ln \omega = 0.033 \cdot t - 0.71 \cdot \ln \left( \frac{H}{T} \right)
\]

This approach does fairly well in capturing the salient features of the changes in the college premium between 1963 and 1987. In fact, Katz and Murphy show that the predicted values from the above equation are quite close to the observed movements in the college premium. This implies that we can think of the U.S. labor market since 1963 as characterized by an elasticity of substitution between college graduate workers and noncollege workers of about \(\sigma = 1/0.71 \approx 1.4\), and an annual increase in the demand for skills at the rate of about 3.3 percent. The increase in the college premium during the 1980s is then explained by the slowdown in the rate of growth of supply of college graduates.

Nevertheless, there are a number of reasons for preferring a cautious interpretation of this regression evidence.

1. The regression uses only 25 aggregate observations, and there is significant serial correlation in the college premium. If the true data were generated by an acceleration in skill bias and a larger value of the elasticity of substitution, this regression
could estimate a smaller elasticity of substitution and no acceleration in the demand for skills. For example, Katz and Murphy show that if the true elasticity of substitution is $\sigma = 4$, a significant acceleration in the skill bias of technical change is required to explain the data.

(2) From the wage bill share data reported above, Autor, Katz and Krueger (1998) conclude that even for the range of the values for the elasticity of substitution between $\sigma = 1$ and 2, skill-biased technical change is likely to have been more rapid during the 1980s than the 1970s. This can also be seen in the numbers reported above, where, for most measures, the increase in $(A_h/A_l)^{\sigma-1}$ appears much larger between 1980 and 1990 than in other decades.

So it is important to undertake a detailed analysis of whether the steady-demand hypothesis could explain the general patterns.

**2. Evidence On Steady-Demand Vs. Acceleration**

The first piece of evidence often put forth in support of an acceleration relates to the role of computers in the labor market. Krueger (1993) has argued that computers have changed the structure of wages, and showed that workers using computers are paid more, and this computer wage premium has increased over time. Although this pattern is striking, it is not particularly informative about the presence or acceleration of skill-biased technical change. It is hard to know whether the computer wage premium is for computer skills, or whether it is
even related to the widespread use of computers in the labor market. For example, DiNardo and Pischke (1997), and Enhorf and Kramartz (1998) show that the computer wage premium is likely to be a premium for unobserved skills. Equally, however, it would be wrong to interpret the findings of DiNardo and Pischke (1997) and Enhorf and Kramartz (1998) as evidence against an acceleration in skill-biased technical change, since, as argued below, such technical change would increase the market prices for a variety of skills, including unobserved skills.

The second set of evidence comes from the cross-industry studies of, among others, Berman, Bound and Griliches (1994), Autor, Katz and Krueger (1998), and Machin and Van Rennan (1998). These papers document that almost all industries began employing more educated workers during the 1970s and the 1980s. They also show that more computerized industries have experienced more rapid skill upgrading, i.e., they have increased their demand for college-educated workers more rapidly. For example, Autor, Katz and Krueger run regressions of changes in the college wage-bill share in three digit industries on computer use between 1984 and 1993. They find, for example, that

\[
\Delta S_{c_{80-90}} = .287 + .147 \Delta cu_{84-93} \\
\quad (.108) \quad (.046)
\]

\[
\Delta S_{c_{90-96}} = -.171 + .289 \Delta cu_{84-93} \\
\quad (.196) \quad (.081)
\]

where \(\Delta S_c\) denotes the annual change in the wage bill share of college graduates in that industry (between the indicated dates), and \(\Delta cu_{84-93}\) is the increase in the fraction of workers using computers in that industry between 1984 and 1993. These regressions are informative since
the college wage bill share is related to the demand for skills as shown by equation (2.2). The results indicate that in an industry where computer use increases by 10 percent, the college wage bill share grows by about 0.015 percent faster every year between 1980 and 1990, and 0.03 percent faster in every year between 1990 and 1996.

Although this evidence is suggestive, it does not establish that there has been a change in the trend growth of skill-biased technology. As pointed out in above, the only way to make sense of post-war trends is to incorporate skill-biased technical change over the whole period. Therefore, the question is whether computers and the associated information technology advances have increased the demand for skills more than other technologies did during the 1950s and 1960s, or even earlier. This question cannot be answered by documenting that computerized industries demand more skilled workers.

Cross-industry studies also may not reveal the true impact of computers on the demand for skills, since industries that are highly computerized may demand more skilled workers for other reasons as well. In fact, when Autor Katz and Krueger (1998) run the above regressions for 1960-1970 college wage bill shares, they obtain

\[
\Delta S_{c_{60-70}} = .085 + .071 \Delta c_{u_{84-93}}
\]

\[
(0.058) \quad (0.025)
\]

Therefore, industries investing more in computers during the 1980s were already experiencing more skill upgrading during the 1960s, before the arrival of computers (though perhaps slower, since the coefficient here is about half of that between 1980 and 1990). This suggests that at least part of the increase in the demand for skills coming from highly
(a) College Graduates

coeff = .152, se = .025, t = 6.12

(b) High School Graduates

coeff = -.301, se = .034, t = -8.96

FIGURE I
Changes in Computer Use and Industry Workforce Educational Shares
computerized industries may not be the direct effect of computers, but reflect an ongoing long-run shift towards more skilled workers. In this light, faster skill upgrading by highly computerized industries is not inconsistent with the steady-demand hypothesis.

The third, and probably most powerful, piece of evidence also comes from Autor, Katz and Krueger (1998). They document that the supply of skills grew faster between 1970 and 1995 than between 1940 and 1970—by 3.06 percent a year during the latter period compared to 2.36 percent a year during the earlier 30 years. In contrast, returns to college increased between 1970 and 1995 by about 0.39 percent a year, while they fell by about 0.11 percent a year during the earlier period. If demand for skills had increased at a steady pace, the skill premium should have also fallen since 1970. Moreover, Autor, Katz and Krueger (1998) document greater within-industry skill upgrading in the 1970s, 1980s and 1990s than in 1960s, which is also consistent with more rapid skill-biased technical change during these later decades.

A simple regression analysis also confirms this point. A regression similar to that of Katz and Murphy for the period 1939-1996 yields similar results:

\[
\ln \omega = 0.025 \cdot t - 0.56 \cdot \ln \left( \frac{H}{L} \right),
\]

(0.01) (0.20)

with an \( R^2 \) of 0.63 and an implied elasticity of substitution of 1.8, which is somewhat larger than the estimate of Katz and Murphy. However, adding higher order terms in time (i.e., time squared, time cubed, etc.) improves the fit of the model considerably, and these higher-order terms
Non-technological explanations for the changes in the wage structure are significant. The next figure shows these higher order trends, which indicate an acceleration in skill bias starting in the 1970s.

Alternative Time Trends for the Relative Demand for Skills

Estimates of time trends from regressions of ln$\omega$ on ln$(H/L)$, year, year$^2$, year$^3$ and year$^4$ between 1939 and 1996 (with observations in 1939, 1949, 1959 from the decennial censuses and observations for 1963-1996 from the March CPSs).

A final piece of evidence comes from the behavior of overall and residual inequality over the past several decades. As argued above, this increase in inequality weighs in favor of a marked change in labor market prices and demand for skills.

Overall, therefore, there is a variety of evidence suggesting an acceleration in skill bias over the past 25 or 30 years. Although not all evidence is equally convincing, the rise in the returns to schooling over the past 30 years, despite the very rapid increase in the supply
of skills, and the behavior of overall and residual inequality since the 1970s suggest a marked shift in the demand for skills over the past several decades.

It is useful to bear in mind, however, that the unusual increase in the demand for skills might be non-technological. It might reflect effect of increased international trade with skill-scarce countries, or it may reflect the collapse of some labor market institutions.

3. Trade and Inequality

3.1. Trade and wage inequality: theory. Standard trade theory predicts that increased international trade with less developed countries (LDCs), which are more abundant in unskilled workers, should increase the demand for skills in the U.S. labor market. Therefore, the increase in international trade may have been the underlying cause of the changes in U.S. wage inequality.

To discuss these issues, consider the two good interpretation of the model above. Consumer utility is defined over \([Y^p_l + Y^p_h]^{1/\rho}\), with the production functions for two goods being \(Y_h = A_h H\) and \(Y_l = A_l L\). Both goods are assumed to be tradable. For simplicity, let me just compare the U.S. labor market equilibrium without any trade to the equilibrium with full international trade without any trading costs.

Before trade, the U.S. relative price of skill intensive goods, \(p_h/p_l\), is given by

\[
(3.1) \quad p^{US} = \frac{p_h}{p_l} = \left[ \frac{A_h H}{A_l L} \right]^{\rho-1}.
\]
The skill premium is then simply equal to the ratio of the marginal value products of the two types of workers, that is,

\begin{equation}
\omega^{US} = p^{US} \frac{A_h}{A_l}
\end{equation}

Next, suppose that the U.S. starts trading with a set of LDCs that have access to the same technology as given by \(A_h\) and \(A_l\), but are relatively scarce in skills. Denote the total supplies of skilled and unskilled workers in the LDCs by \(H\) and \(L\) where \(H/L < H/L\), which simply reiterates that the U.S. is more abundant in skilled workers than the LDCs.

After full trade opening, the product markets in the U.S. and the LDCs are joined, so there will be a unique world relative price. Since the supply of skill-intensive and labor-intensive goods are \(A_h \left( H + \hat{H} \right)\) and \(A_l \left( L + \hat{L} \right)\), the relative price of the skill intensive good will be

\begin{equation}
p^W = \left[ \frac{A_h \left( H + \hat{H} \right)}{A_l \left( L + \hat{L} \right)} \right]^{p-1} > p^{US}.
\end{equation}

The fact that \(p^W > p^{US}\) follows immediately from \(\hat{H}/\hat{L} < H/L\). Intuitively, once the U.S. starts trading with skill-scarce LDCs, demand for skilled goods increases, pushing the prices of these goods up.

Labor demand in this economy is derived from product demands. The skill premium therefore follows the relative price of skill-intensive goods. After trade opening, the U.S. skill premium increases to

\begin{equation}
\omega^W = p^W \frac{A_h}{A_l} > \omega^{US}
\end{equation}
where the fact that $\omega^W > \omega^US$ is an immediate consequence of $p^W > p^US$. Therefore, trade with less developed countries increases wage inequality in the U.S..

The skill premium in the LDCs will also be equal to $\omega^W$ after trade since the producers face the same relative price of skill-intensive goods, and have access to the same technologies. Before trade, however, the skill premium in the LDCs was $\hat{\omega} = \hat{p}A_h/A_l$, where $\hat{p} = \left( A_h\hat{H}/A_l\hat{L} \right)^{\rho-1}$ is the relative price of skill-intensive goods in the LDCs before trade. The same argument as above implies that $\hat{p} > p^W$, i.e., trade with the skill-abundant U.S. reduces the relative price of skill-intensive goods in the LDCs. This implies that $\omega^W < \hat{\omega}$; after trade wage inequality should fall in the LDCs that have started trading more with the U.S. or other OECD economies.

3.2. Evidence. Although this analysis shows that increased international trade could be responsible for the rise in skill premia and inequality in the U.S., most economists discount the role of trade for the reasons discussed briefly in the introduction.

First, as the comparison of equations (3.2) and (3.4) shows, the effect of international trade works through a unique intervening mechanism: free trade with the LDCs increases the relative price of skill-intensive goods, $p$, and affects the skill premium via this channel. The most damaging piece of evidence for the trade hypothesis is that most studies suggest the relative price of skill-intensive goods did not increase over the period of increasing inequality. Lawrence and Slaughter found that during the 1980s the relative price of skill-intensive goods actually
Figure 9. Percentage changes in the 1980s of Export Prices by Industry Versus the Nonproduction-Worker Intensity of Industries

A. Two-digit SIC industries

B. Three-digit SIC industries

Source: Import and export prices come from the Bureau of Labor Statistics; employment data come from the NBER's Trade and Immigration Data Base.
Figure 2: Price Growth versus Average Education Level

Proportionate Growth in Output Prices, 1989-95
Non-technological explanations for the changes in the wage structure fell. Sachs and Shatz found no major change or a slight decline, while a more recent paper by Krueger found an increase in the relative price of skill-intensive goods, but only for the 1989-95 period.

Second, as pointed out above, a variety of evidence suggests that all sectors, even those producing less skill-intensive goods, increased their demands for more educated workers. This pattern is consistent with the importance of skill-biased technical change, but not with an increase in the demand for skills driven mainly by increased international trade.

Third, as noted above, a direct implication of the trade view is that, while demand for skills and inequality increase in the U.S., the converse should happen in the LDCs that have started trading with the more skill-abundant U.S. economy. The evidence, however, suggests that more of the LDCs experienced rising inequality after opening to international trade. Although the increase in inequality in a number of cases may have been due to concurrent political and economic reforms, the preponderance of evidence is not favorable to this basic implication of the trade hypothesis.

Finally, a number of economists have pointed out that U.S. trade with the LDCs is not important enough to have a major impact on the U.S. product market prices and consequently on wages. Krugman illustrates this point by undertaking a calibration of a simple North-South model. Katz and Murphy, Berman, Bound and Griliches and Borjas, Freeman and Katz emphasize the same point by showing that the content of unskilled labor embedded in U.S. imports is small relative to the changes in the supply of skills taking place during this period.
These arguments suggest that increased international trade with the LDCs is not the major cause of the changes in the wage structure by itself.

4. Labor Market Institutions and Inequality

Two major changes in labor market institutions over the past twenty five years are the decline in the real value of state and federal minimum wages and the reduced importance of trade unions in wage determination. Many economists suspect that these institutional changes may be responsible for the changes in the structure of the U.S. labor market.

The real value of the minimum wage eroded throughout the 1980s as nominal minimum wages remained constant for much of this period. Since minimum wages are likely to increase the wages of low paid workers, this decline may be responsible for increased wage dispersion. DiNardo et al. (1995) and Lee (1999) provide evidence in support of this hypothesis.

Although the contribution of minimum wages to increased wage dispersion cannot be denied, minimum wages are unlikely to be a major factor in the increase in overall inequality for a number of reasons:

(1) Only a very small fraction of male workers are directly affected by the minimum wage (even in 1992, after the minimum wage hike of 1990-91, only 8 percent of all workers between the ages of 18 and 65 were paid at or below the minimum wage). Although minimum wages may increase the earnings of some workers who are not directly affected, they are highly unlikely to affect the wages above the median of the wage distribution.
(2) The difference between the 90th percentile and the median mirrors the behavior of the difference between the median and the 10th percentile. (Perhaps with the exception of during the early 1980s when there is a more rapid increase in inequality at the bottom of the wage distribution, most likely due to the falling real value of the minimum wage). This implies that whatever factors were causing increased wage dispersion at the top of the distribution are likely to have been the major cause of the increase in wage dispersion throughout the distribution.

(3) Perhaps most importantly, the erosion in the real value of the minimum wage started in the 1980s, whereas, as shown above, the explosion in overall wage inequality began in the early 1970s.

The declining importance of unions may be another important factor in the increase in wage inequality. Unions often compress the structure of wages and reduce skill premia. Throughout the postwar period in the U.S. economy, unions negotiated the wages for many occupations, even indirectly influenced managerial salaries. Unions also explicitly tried to compress wage differentials. This suggests that the decline of unions may be a major cause of the changes in the structure of wages.

But once again, deunionization does not appear to be the major cause of the increase inequality.

(1) Wage inequality increased in many occupations in which prices were never affected by unions (such as lawyers and doctors).
(2) Perhaps more important, in the U.S., deunionization started in the 1950s, a period of stable wage inequality. During the 1970s, though unionization fell in the private sector, overall unionization rates did not decline much because of increased unionization in the public sector. Overall union density was approximately constant, around 30 percent of the work force, between 1960 and 1975. It was the anti-union atmosphere of the 1980s and perhaps the defeat of the Air-traffic Controllers’ Strike that led to the most major declines of the unions, dating the sharp declines in unionization after the rapid increase in inequality during the early 1970s. Evidence from other countries also paints a similar picture. For example, in the UK, wage inequality started its sharp increase in the mid 1970s, while union density increased until 1980 and started the rapid decline only during the 1980s. In Canada, while unionization rates increased from around 30 percent in the 1960s to over 36 percent in the late 1980s, wage inequality also increased.
CHAPTER 8

Acceleration in Skill Bias

By the process of elimination, we have arrived at an acceleration skill bias as the most likely cause of the increase in inequality over the past 25-30 years.

There is also a variety of direct evidence that also suggests that the technological developments of the past 30 years may have increase the demand for skills considerably. Most observers agree that many computer-based technologies require a variety of abstract and problem-solving skills, thus increasing the demand for college education and related skills. The evidence in Autor, Katz and Krueger indicates that industries that have invested in computer technology have increased their demand for skills substantially. They also show that this correlation is not driven by some omitted factors, such as R&D investment or capital intensity.

1. Exogenous Acceleration Skill Bias

The most popular view in the literature is that the past 25 years experienced an acceleration in skill bias because of exogenous technological developments, and link these technological developments to a “technological revolution,” most likely associated with the microchip, the computer technology, and improvements in communications technology.
I would like to distinguish between 3 different approaches here.

1.1. “Black-Box” exogenous acceleration. This is the simplest view, and claims that for some (unknown/exogenous) reason there has been a more rapid increase in $A_h/A_l$ during this period, translating into greater skill premia. This may be linked to the introduction of computer technology, but in this view there is no explicit theory of why it would be so. In other words, new technologies just happened to be more skill-biased and increase $A_h/A_l$.

The advantage of this theory is its simplicity, and the disadvantage is that by a similar approach we could explain anything that happens. So for this theory to make progress, that has to be more empirical work somehow documenting that $A_h/A_l$ has increased. Cross-industry regressions that explain the demand for skills by computer investment come close to this, but are not entirely satisfactory or easy to interpret.

An interesting attempt in this direction is made by Autor, Levy and Murnane. They argue that the recent increase in the skill bias is an outcome of improvements in computer technology resulting from the fact that computers substitute for routine tasks, while at the same time increasing the demand for problem-solving skills. Using data from the Dictionary of Occupational Titles and decennial censuses, they show that in industries with greater computerization, there has been a shift away from occupations specializing in routine tasks towards occupations with a heavy problem-solving component. Therefore, this approach gives some empirical content to the otherwise exogenous and hard-to-observe skill bias. It also suggests that the recent acceleration
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n is 140 consistent CIC industries. Standard errors are in parentheses. Weighted mean of Δ computer use 1984 - 1997 is 0.252. Estimates are weighted by mean industry share of total employment (in FTEs) over the endpoints of the years used to form the dependent variable. Computer use is the change in fraction of industry workers using a computer at their jobs estimated from October 1984 and 1997 CPS samples. Samples used are Census IPUMS for 1960, 70, and 80 and CPS MORG 1980, 90, and 98 samples.
Figure 1. Economy-Wide Measures of Routine and Non-Routine Task Input: 1959 - 1998 (1959 = 0)
in the demand for skills maybe the outcome of the nature of computers, which by construction replaced routine, easy-to-replicate tasks.

1.2. Capital-skill complementarity. An interesting fact uncovered by Gordon is that the relative price of equipment capital has been falling steadily in the postwar period. Moreover, this rate of decline of equipment prices may have accelerated sometime during the mid to late 1970s.

Krusell, Ohanian, Rios-Rull and Violante, using this fact, argue that the demand for skills accelerated as a result of the more rapid decline in the relative price of capital equipment. They build on an idea first suggested by Griliches that capital is more complementary to skilled rather than unskilled labor. Combining this insight with the relatively rapid accumulation of equipment capital due to the decline its relative price, they offer an explanation for why the demand for skills may have increased at a faster rate during the past 25 years than before.

More explicitly, these authors consider the following aggregate production function

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

where \( K_s \) is structures capital (such as buildings), and \( K_e \) is equipment capital (such as machines). The parameter \( \sigma_1 = 1/(1 - \lambda) \) is the elasticity of substitution between equipment and skilled workers, and \( \sigma_2 = 1/(1 - \mu) \) is the elasticity of substitution between unskilled workers and the equipment-skilled worker aggregate.
If $\sigma_1 > \sigma_2$ (i.e., $\mu > \lambda$), equipment capital is more complementary to skilled workers than unskilled workers, and as a result, an increase in $K_e$ will increase the wages of skilled workers more than the wages of unskilled workers.

The skill premium in this model is

$$\omega = \frac{w_H}{w_L} = \frac{(1 - b_2)(1 - b_1) H^{\lambda-1} \left(b_2 K_e^\lambda + (1 - b_2) H^\lambda \right)^{(\mu-\lambda)/\lambda}}{b_1 L^{\mu-1}}$$

Differentiation shows that as long as $\mu > \lambda$, $\partial \omega / \partial K_e > 0$. So provided that equipment capital is more complementary to skilled workers than unskilled workers, an increase in the quantity of equipment capital will increase the demand for skills. Since the post-war period has been characterized by a decline in the relative price of equipment goods, there will be an associated increase in the quantity of equipment capital, $K_e$, increasing the demand for skills steadily.

Nevertheless, there are serious difficulties in adjusting capital prices for quality. This suggests that we may want to be cautious in interpreting this evidence. Another problem comes from the fact that, as I will discuss in more detail below, a variety of other evidence does not support the notion of faster technological progress since 1974, which is a basic tenet of this approach.

Finally, one would presume that if, in fact, the decline in the relative price of equipment capital is related to the increase in the demand for skills, then in a regression of equation (1.2) as in the work by Katz and Murphy (1992), it should proxy for the demand for skills and perform better than a linear time trend.
But, the evidence suggests that the relative quantity of equipment capital or its relative price never does as well as a time trend. When entered together in a time-series regression, the time trend is significant, while there is no evidence that the relative price of equipment capital matters for the demand for skills.

This evidence casts some doubt on the view that the relative price of equipment capital is directly linked to the demand for skills and that its faster decline since 1970s indicates an acceleration in skill bias.

1.3. Technological revolutions and the Schultz view of human capital. Recall that according to Schultz/Nelson-Phelps view of human capital, skills and ability are more useful at times of rapid change (at times of “disequilibrium” as Schultz called it). So if indeed there has been a technological revolution, we might expect this may have increased the demand for skills.

This view has been advanced by a number of authors, including Greenwood and Yorukoglu (1997), Caselli (1999), Galor and Moav (2000). For example, Greenwood and Yorukoglu (1997, p. 87) argue:

“Setting up, and operating, new technologies often involves acquiring and processing information. Skill facilitates this adoption process. Therefore, times of rapid technological advancement should be associated with a rise in the return to skill.”

Let me give a brief formalization of this approach built on Galor and Moav (2000) adapted to the above framework. Suppose that in
terms of the CES framework developed above

\( A_l = \phi_l(g)a \) and \( A_h = \phi_h a \)

where \( a \) is a measure of aggregate technology, and \( g \) is the growth rate of \( a \), i.e., \( g \equiv \dot{a}/a \). The presumption that skilled workers are better equipped to deal with technological progress can be captured by assuming that \( \phi_l' < 0 \). Galor and Moav (2000) refer to this assumption as the “erosion effect,” since it implies that technical change erodes some of the established expertise of unskilled workers, and causes them to benefit less from technological advances than skilled workers do.

Substituting from (1.1) into (1.3), the skill premium is

\[
\omega = \frac{w_H}{w_L} = \left( \frac{A_h}{A_l} \right)^{(\sigma-1)/\sigma} \left( \frac{H}{L} \right)^{-1/\sigma} = \left( \frac{\phi_h}{\phi_l(g)} \right)^{(\sigma-1)/\sigma} \left( \frac{H}{L} \right)^{-1/\sigma}
\]

Therefore, as long as \( \phi_l' < 0 \), more rapid technological progress, as captured by a higher level of \( g \), will increase the skill premium.

This approach therefore presumes that the recent past has been characterized by faster than usual technological progress, and explains the acceleration in skill bias by the direct effect of more rapid technical change on the demand for skills.

1.4. Are we in the midst of a technological revolution? This is not an easy question to answer, but a relevant one to judge many of the theories discussed in this section. Here I will simply give my own view, which is: no.

There is little direct evidence that the decades between 1970 and 1995 have been a period of rapid technical change. First, this period
ACCELERATION IN SKILL BIAS

has experienced sluggish TFP and output growth relative to earlier periods. Although some authors argue that the slow TFP growth itself may be an outcome of the more rapid technical change, this is not entirely convincing. According to this argument, new revolutionary technologies first reduce productivity growth as firms and workers spend their time learning to use these technologies. Relatedly, following a suggestion by Griliches, many have argued that our ability to measure TFP growth may have deteriorated following a change in technological regime. Neither of these arguments are very convincing, however.

It is difficult to imagine how a new and radically more profitable technology will first lead to twenty five years of substantially slower growth. Although, in an influential paper, Paul David (1990) argues that the spread of electricity to American manufacturing was also slow and productivity gains from electrification were limited until the 1920s, the parallel with the recent productivity slowdown should not be overstated.

(1) Though productivity growth from electrification was sluggish during the early 1900s, the U.S. economy overall had a much higher level of output growth than growth levels experienced over the past three decades. Output growth between 1899 and 1909 in the U.S. economy was 4.2 percent a year, while between 1909 and 1919, it was 3 percent, and between 1990 and 1929, output grew by 3.6 percent a year.

(2) As noted by Oliner and Sichel (1994), computers and other advanced office equipment have only been a trivial part of the aggregate capital stock of the U.S. economy until the mid
1. EXOGENOUS ACCELERATION SKILL BIAS

1990s. It is therefore unlikely that the whole of the U.S. economy has been adapting to the changes in this relatively small part of the capital stock

(3) As shown by Brendt, Morrison and Rosenblum (1994), more computerized sectors did not perform any better in terms of labor productivity growth over this period, and this pattern is also difficult to reconcile with a computer-led technological revolution.

Finally, it is not even the case that historical evidence supports the notion that times of rapid technical change increase inequality. The major technological changes of the nineteenth century appear to have been largely unskilled-biased and to have reduced inequality, even though they seem as radical as computer technology. This suggests that it is the skill bias of technology, not merely its rapid arrival, that is important for the demand for skills.

A final problem for all of the approaches based exogenous technological developments is the coincidence in the timing of this change, and the rapid increase in the supply of skilled workers. Recall that there was a very large increase in the supply of college graduate workers during the late 1960s and early 1970s. So the acceleration in skill bias is either concurrent with, or immediately follows, this large increase in the supply of skills. There is no a priori reason to expect the acceleration in skill bias to coincide with the rapid increase in the supply of skills. Those who want to subscribe to the exogenous technological progress view have to explain this as a chance event.
2. Endogenous Acceleration in Skill Bias

The theories discussed so far presume technical change to be skill-biased by nature. A different perspective is to link the type of technologies that are developed and adopted to (profit) incentives.

The basic idea is that the development of skill-biased technologies will be more profitable when they have a larger market size—i.e., when there are more skilled workers. Therefore, the equilibrium degree of skill bias, which will be determined endogenously, could be an increasing function of the relative supply of skilled workers. An increase in the supply of skills will then lead to skill-biased technical change. Furthermore, an acceleration in the supply of skills can lead to an acceleration in the demand for skills.

2.1. A basic model. Imagine that the production functions above are modified to:

\[
Y_L = \frac{1}{1-\beta} \left( \int_0^{N_L} x_L (j)^{1-\beta} \, dj \right) L^\beta,
\]

and

\[
Y_H = \frac{1}{1-\beta} \left( \int_0^{N_H} x_H (j)^{1-\beta} \, dj \right) H^\beta,
\]

where \( x_L (j) \) and \( x_H (j) \) denote machines used in the production of the labor-intensive and skill-intensive goods. This formulation with the use of these machines replaces the exogenous technology terms \( A_l \) and \( A_h \) above.

\( N_L \) and \( N_H \) denote the range of machines that can be used in these two sectors. As is standard in Dixit-Stiglitz-type models (for example endogenous technical change models), these ranges of machines will
be measures of productivity in the two sectors. Therefore, change in $N_H/N_L$ will change the skill bias of technology.

Assume that machines to both sectors are supplied by “technology monopolists”.

Each monopolist sets a rental price $\chi_L (j)$ or $\chi_H (j)$ for the machine it supplies to the market.

The marginal cost of production is the same for all machines and equal to $\psi \equiv 1 - \beta$ in terms of the final good.

Price taking by the producers of the labor-intensive goods implies

$$\max_{L,(x_L(j))} p_L Y_L - w_L L - \int_0^{N_L} \chi_L (j) x_L (j) dj,$$

This gives machine demands as

$$x_L (j) = \left[ \frac{p_L}{\chi_L (j)} \right]^{1/\beta} L.$$

Similarly

$$x_H (j) = \left[ \frac{p_H}{\chi_H (j)} \right]^{1/\beta} H,$$

Since the demand curve for machines facing the monopolist, (2.4), is iso-elastic, the profit-maximizing price will be a constant markup over marginal cost. In particular, all machine prices will be given by

$$\chi_L (j) = \chi_H (j) = 1.$$

Profits of technology monopolists are obtained as

$$\pi_L = \beta p_L^{1/\beta} L \text{ and } \pi_H = \beta p_H^{1/\beta} H.$$

Let $V_H$ and $V_L$ be the net present discounted values of new innovations. Then in steady state:

$$V_L = \frac{\beta p_L^{1/\beta} L}{r} \text{ and } V_H = \frac{\beta p_H^{1/\beta} H}{r}.$$
The greater is $V_H$ relative to $V_L$, the greater are the incentives to develop $H$-complementary machines, $N_H$, rather than $N_L$.

This highlights the two effects on the direction of technical change that I mentioned above:

1. The price effect: a greater incentive to invent technologies producing more expensive goods.
2. The market size effect: a larger market for the technology leads to more innovation. The market size effect encourages innovation for the more abundant factor.

Substituting for relative prices, relative profitability is

$$
\frac{V_H}{V_L} = \left( \frac{1 - \gamma}{\gamma} \right)^{\frac{\sigma}{\sigma}} \left( \frac{N_H}{N_L} \right)^{-\frac{1}{\sigma}} \left( \frac{H}{L} \right)^{\frac{\sigma-1}{\sigma}}.
$$

where

$$
\sigma \equiv \varepsilon - (\varepsilon - 1)(1 - \beta).
$$

is the (derived) elasticity of substitution between the two factors. When $V_H/V_L$ there will be more research towards inventing new skill-complementary varieties, and $N_H/N_L$ will increase. This is the essence of the model of endogenous skill bias. Greater profitability of skill-complementary technologies leads to more innovations that are skill complementary.

As discussed above, in the case of substitution between skilled and unskilled workers, a high elasticity is reasonable. So here I presume that $\sigma > 1$. Then equation (2.8) immediately implies that the higher relative supply of skills, $H/L$, increases $V_H/V_L$, and via this channel, it induces an increase in $N_H/N_L$, creating skill-biased technical change.

Also note that relative factor prices are
First, the relative factor reward, $w_H/w_L$, is decreasing in the relative factor supply, $H/L$, this is simply the usual substitution effect, making the short-run (exogenous-technology) relative demand for for skills downward sloping.

Second, greater $H/L$ leads to a greater $N_H/N_L$, which is biased toward skilled workers, and therefore increases $w_H/w_L$. In other words, an increase in the relative supply of skills causes skill-biased technical change.

Next, the question is whether this induced skill bias effect could be strong enough to outweigh the substitution effect, and lead to an upward sloping relative demand curve.

To answer this question, we need to specify the production function for the creation of new varieties of machines. Suppose that new varieties are created as follows:

\begin{equation}
\dot{N}_L = \eta_L X_L \quad \text{and} \quad \dot{N}_H = \eta_H X_H,
\end{equation}

where $X$ denotes R&D expenditure.

This gives the following “technology market clearing” condition:

\begin{equation}
\eta_L \pi_L = \eta_H \pi_H.
\end{equation}

Then, relative physical productivities can be solved for

\begin{equation}
\frac{N_H}{N_L} = \eta^\sigma \left( \frac{1 - \gamma}{\gamma} \right)^\xi \left( \frac{H}{L} \right)^{\sigma - 1}.
\end{equation}
Substituting for (2.12) into (2.9), endogenous-technology factor rewards are obtained as

\[ w_H \eta^\sigma - 1 \left( \frac{1 - \gamma}{\gamma} \right) \varepsilon \left( \frac{H}{L} \right)^{\sigma - 2}. \]  

Comparing this equation to the relative demand for a given technology, we see that the response of relative factor rewards to changes in relative supply is always more elastic in (2.13) than in (2.9).

This is simply an application of the LeChatelier principle, which states that demand curves become more elastic when other factors adjust—that is, the relative demand curves become flatter when “technology” adjusts.

The more important and surprising result here is that if \( \sigma \) is sufficiently large, in particular if \( \sigma > 2 \), the relationship between relative factor supplies and relative factor rewards can be upward sloping.

2.2. Implications. If \( \sigma > 2 \), then the long-run relationship between the relative supply of skills and the skill premium is positive.

Why is this interesting? Three important facts about demand for skills are:

1. Secular skill-biased technical change increasing the demand for skills throughout 20th century.
2. Possible acceleration in skill-biased technical change over the past 25 years.
3. Many skill-replacing technologies during the 19th century.
With an upward sloping relative demand curve, or simply with the degree of skilled bias endogenized, we have a natural explanation for all of these patterns.

(1) The increase in the number of skilled workers that has taken place throughout 20th century is predicted to cause steady skill-biased technical change.

(2) Acceleration in the increase in the number of skilled workers over the past 25 years is predicted to induce an acceleration in skill-biased technical change.

(3) Large increase in the number of unskilled workers available to be employed in the factories during the 19th century could be expected to induce skill-replacing/labor-biased technical change.

In addition, this framework with endogenous technology also gives a nice interpretation for the dynamics of the college premium during the 1970s and 1980s. It is reasonable to presume that the equilibrium skill bias of technologies, \( \frac{N_h}{N_l} \), is a sluggish variable determined by the slow buildup and development of new technologies. In this case, a rapid increase in the supply of skills would first reduce the skill premium as the economy would be moving along a constant technology (constant \( \frac{N_h}{N_l} \)) curve in the figure. After a while the technology would start adjusting, and the economy would move back to the upward sloping relative demand curve, with a very sharp increase in the college premium. This approach can therefore explain both the decline in the college premium during the 1970s and the subsequent large surge, and relates both to the large increase in the supply of skilled workers.
If on the other hand we have $\sigma < 2$, the long-run relative demand curve will be downward sloping, though again it will be shallower than the short-run relative demand curve. Then following the increase in the relative supply of skills there will be an initial decline in the skill premium (college premium), and as technology starts adjusting the skill premium will increase. But it will end up below its initial level. To explain the larger increase in the 1980s, in this case we need some exogenous skill-biased technical change. The next figure draws this case.

The dynamics of the relative wage of skilled workers in response to an increase in the supply of skills with limited endogenous skill-biased technical change.
3. A Puzzle: The Decline in the Wages of Low-Skill Workers

A common shortcoming of all the pure technology approaches discussed in this section is that they do not naturally predict stagnant average wages and/or falling wages for unskilled workers. In the basic framework above, average wages should always increase when the supply of educated workers increases, and all wages should rise in response to an increase in the productivity of skilled workers, $A_h$. Yet, over the past 30 years the wages of low-skill workers have fallen in real value during, which contrasts with their steady increase in the 30 years previous.

3.1. Basic issues. Models of faster technological progress would naturally predict that unskilled workers should benefit from this faster progress. The endogenous technology approach discussed above, on the other hand, predicts that there may be no improvements in the technologies for unskilled workers for an extended period of time because skill-biased innovations are more profitable than labor-complementary innovations. Yet in that case, their wages should be stagnant, but not fall.

Some of the studies mentioned above have suggested explanations for the fall in the wages of low-skill workers. For example, recall that Galor and Moav (2000) argue that faster technological change creates an “erosion effect”, reducing the productivity of unskilled workers. Using equation (1.2) from above, in the simplified version of their model discussed above, the wages of unskilled workers is $w_L = \phi_l (g) a [1 + \phi_h^e (H/L)^{\rho}]^{(1-\rho)/\rho}$, so the rate of growth of unskilled wages
will be \( \dot{w}_L / w_L = g (1 + \varepsilon_\phi) \), where \( \varepsilon_\phi \) is the elasticity of the \( \phi \) function which is negative by the assumption that \( \phi' < 0 \). If this elasticity is less than -1, an acceleration in economic growth can reduce the wages of low-skill workers due to a powerful erosion effect.

### 3.2. Allocation of capital between sectors and workers

As an alternative, Acemoglu (1999a) and Caselli (1999) derive a fall in the wages of less skilled workers because the capital-labor ratio for low education/low-skill workers falls as firms respond to technological developments. In Caselli’s model this happens because the equilibrium rate of return to capital increases, and in my paper, this happens because firms devote more of their resources to opening specialized jobs for skilled workers.

Consider the following simple example to illustrate this point. There is a scarce supply of an input \( K \), which could be capital, entrepreneurial talent or another factor of production. Skilled workers work with the production function

\[
Y_h = A_h^\alpha K_h^{1-\alpha} H^\alpha
\]

while unskilled workers work with the production function

\[
Y_l = A_l^\alpha K_l^{1-\alpha} L^\alpha,
\]

where \( K_l \) and \( K_h \) sum to the total supply of \( K \), which is assumed fixed. For simplicity, \( Y_l \) and \( Y_h \) are assumed to be perfect substitutes. In equilibrium, the marginal products of capital in two sectors have to be equalized, hence

\[
\frac{K_l}{A_l L} = \frac{K - K_l}{A_h H}
\]
3. A PUZZLE: THE DECLINE IN THE WAGES OF LOW-SKILL WORKERS

Therefore, an increase in $A_h$ relative to $A_l$ will reduce $K_l$, as this scarce factor gets reallocated from unskilled to skilled workers. The wages of unskilled workers, $w_L = (1 - \alpha) A_l^\alpha K_l^{1-\alpha} L^{\alpha-1}$, will fall as a result.

An innovative version of this story is developed by Beaudry and Green (2000). Suppose that equation (3.2) above is replaced by $Y_l = A_l^\eta K_l^{1-\eta} L^\eta$, with $\eta < \alpha$, and $K$ is interpreted as physical capital. This implies that unskilled workers require more capital than skilled workers. Beaudry and Green show that an increase in $H/L$ can raise inequality, and depress the wages of low-skill workers. The increase in $H/L$ increases the demand for capital, and pushes the interest rate up. This increase in the interest rate hurts unskilled workers more than skilled workers because, given $\eta < \alpha$, unskilled workers are more “dependent” on capital.

A potential problem with both the Beaudry and Green and Caselli stories is that they explicitly rely on an increase in the price of capital. Although the interest rates were higher during the 1980s in the U.S. economy, this seems mostly due to contractionary monetary policy, and related only tangentially to inequality. Perhaps, future research will show a major role for the increase in the interest rates in causing the fall in the wages of low education workers over the past twenty-five years, but as yet, there is no strong evidence in favor of this effect.

Overall, a potential problem for all of these models based on technical change is to account for the decline in the wages of low-skill workers. The effect of technical change on the organization of the labor market may provide an explanation for this decline.
4. Organizational Change

A variety of evidence suggests that important changes in the structure of firms have been taking place in the U.S. economy over twenty-five years. Moreover, it seems clear that a major driving force for this transformation is changes in technologies.

For example, team production and other high-performance production methods are now widespread in the U.S. economy (e.g., Ichinowski, Prennushi, and Shaw, 1997, or Applebaum and Batt, 1994). Similarly, Cappelli and Wilk (1997) show that there has been an increase in the screening of production workers, especially from establishments that use computer technology and pay high wages.

Murnane and Levy (1996) report case study evidence consistent with this view. From their interviews with human resource personnel at a number of companies, they describe the change in the hiring practices of U.S. companies. A manager at Ford Motor company in 1967 describes their hiring strategy as follows: “If we had a vacancy, we would look outside in the plant waiting room to see if there were any warm bodies standing there. If someone was there and they looked physically OK and weren’t an obvious alcoholic, they were hired” (p. 19). In contrast, comparable companies in the late 1980s use a very different recruitment strategy. Murnane and Levy discuss the cases of Honda of America, Diamond Star Motors and Northwestern Mutual Life. All three companies spend substantial resources on recruitment and hire only a fraction of those who apply.
Model of organizational change are interesting in part because they often predict a decline in the wages of low-skill workers as a result of organizational change. Moreover, such models can explain both the changes in the organizational work that we observe, and also make some progress towards opening the black-box of “skill-biased technical change).

4.1. A simple model. I will first outline a simple model, inspired by Kremer and Maskin (1999) and Acemoglu (1999a), that captures the effect of the changes in technologies on the organization of production. The basic idea is simple. As the productivity of skilled workers increases, it becomes more profitable for them to work by themselves in separate organizations rather than in the same workplace as unskilled workers. This is because when the skilled and unskilled work together, their productivities interact, and unskilled workers may put downward pressure on the productivity of skilled workers.

Specifically, suppose that firms have access to the following production functions

\[
\text{the old-style production function : } Y = B_p \left[ (A_l L)^\rho + (A_h h_O)^\rho \right]^{1/\rho},
\]

\[
\text{the new-organization production function : } Y = B_s A_h^\beta h_N.
\]

Intuitively, skilled and unskilled workers can either be employed in the same firm as with the old-style function, \( h_O \), or high skill workers can be employed in separate firms, \( h_N \). The fact that when they are employed in the same firm, these two types of workers affect each other’s productivity is captured by the CES production function. This formulation implies that if the productivity (ability) of unskilled workers, \( A_l \),
is very low relative to $A_h$, they pull down the productivity of skilled workers. In contrast, when they work in separate firms, skilled workers are *unaffected* by the productivity of unskilled workers. Moreover, $\beta > 1$, which implies that improvements in the productivity of skilled workers has more effect on the productivity of new style organizations. The parameters $B_p$ and $B_s$ capture the relative efficiency of old and new style production functions.

The labor market is competitive, so the equilibrium organization of production will maximize total output, given by $B_p \left[ (A_l L)^\rho + (A_h h_O)^\rho \right]^{1/\rho} + B_s A_h^\beta (H - h_O)$, where $h_O \in [0, H]$ is the number of skilled workers employed in the old-style organizations. For all cases in which $h_O > 0$, the solution to this problem will involve

$$w_H = B_p A_h^\rho h_O^{\rho-1} \left[ A_l^\rho L^\rho + A_h^\rho h_O^{(1-\rho)/\rho} \right]^{(1-\rho)/\rho} = B_s A_h^\beta,$$

i.e., skilled workers need to be paid $B_s A_h^\beta$ to be convinced to work in the same firms as the unskilled workers. The unskilled wage is

$$w_L = B_p A_l^\rho L^{\rho-1} \left[ A_l^\rho L^\rho + A_h^\rho h_O^{(1-\rho)/\rho} \right]^{(1-\rho)/\rho} < w_H$$

Now consider an increase in $A_h$. Differentiating (4.1) yields $\partial (A_h h_O) / \partial A_h < 0$, which, from (4.2), implies that $\partial w_L / \partial A_h < 0$. Therefore, skill-biased technical change encourages skilled workers to work by themselves, and as a result, unskilled wages fall. Intuitively, since, in the old-style organizations, the productivity of skilled workers depends on the ability of unskilled workers, when the skilled become even more productive, the downward pull exerted on their productivity by the unskilled workers becomes more costly, and they prefer to work in separate organizations. This reduces the ratio $h_O / L$ and depresses unskilled wages. As a result,
improvements in technology, which normally benefit unskilled workers as discussed above, may actually hurt unskilled workers because they transform the organization of production.

An increase in $B_s/B_p$, which raises the relative profitability of the new organizational form, also leads to further segregation of skilled and unskilled workers in different organizations. This last comparative static result is useful since Bresnahan (1999) and Autor, Levy and Murnane. (2000) argue that by replacing workers in the performance of routine tasks, computers have enabled a radical change in the organization of production. This is reminiscent to a technological change that makes the new-organization production function more profitable.

4.2. A more detailed model of the changes in the organization of production. Now consider a somewhat more structured model which also tries to get to the same issues. The basic idea is that when either the productivity gap between skilled and unskilled workers is limited or when the number of skilled workers in the labor force is small, it will be profitable for firms to create jobs that to employ both skilled and unskilled workers. But when the productivity gap is large or that are a sufficient number of skilled workers, it may become profitable for (some) firms to target skilled workers, designing the jobs specifically for these workers. Then these firms will wait for the skilled workers, and will try to screen the more skill once among the applicants. In the meantime, there will be lower-quality (low capital) jobs specifically targeted at the unskilled.
Suppose that there are two types of workers. The unskilled have human capital (productivity) $1$, while the skilled have human capital $\eta > 1$. Denote the fraction of skilled workers in the labor force by $\phi$.

The firms choose the capital stock $k$ before they meet a worker, and matching is assumed to be random, in the sense that each firm, irrespective of its physical capital, has exactly the same probability of meeting different types of workers. Once the firm and the worker match, separating is costly, so there is a quasi-rent to be divided between the pair. Here, the economy is assumed to last for one period, so if the firm and worker do not agree they lose all of the output (see Acemoglu, 1999, for the model where the economy is infinite-horizon and agents who do not agree with their partners can resample). Therefore, bargaining will result in workers receiving a certain fraction of output, which I denote by $\beta$.

The production function of a pair of worker and firm is

$$y = k^{1-\alpha} h^\alpha,$$

where $k$ is the physical capital of the firm and $h$ is the human capital of the worker.

Firms choose their capital stock to maximize profits, before knowing which type of worker will apply to their job. For simplicity, I assume that firms do not bear the cost of capital if they decides not to produce with the worker who has applied to the job. I also denote the cost of capital by $c$.

Their expected profits are therefore given by

$$\phi x^H (1 - \beta) (k^{1-\alpha} \eta - ck) + (1 - \phi) x^L (1 - \beta) (k^{1-\alpha} - ck),$$
where $x^j$ is the probability, chosen by the firm, that it will produce with a worker of type $j$ conditional on matching that type of worker. Therefore, the first term is profits conditional on matching with a skilled worker, and the second term gives the profits from matching with an unskilled worker.

There can be two different types of equilibria in this economy:

1. A pooling equilibrium in which firms choose a level of capital and use it both of skilled and unskilled workers. We will see that in the pooling equilibrium inequality is limited.

2. A separating equilibrium in which firms target the skilled and choose a higher level of capital. In this equilibrium inequality will be greater.

In this one-period economy, firms never specifically target the unskilled, but that outcome arises in the dynamic version of this economy.

Now it is straightforward to characterize the firms profit maximizing capital choice and the resulting organization of production (whether firms will employ both skilled and unskilled workers). It turns out that first choose the pooling strategy as long as

$$\eta < \left( \frac{1 - \phi}{\phi^\alpha - \phi} \right)^{1/\alpha}$$

Therefore, a sufficiently large increase in $\eta$ (in the relative productivity of skilled workers) and/or in $\phi$ (the fraction of skilled workers in the labor force) switches the economy from pooling to separating).
Such a switch will be associated with important changes in the organization of production, an increase in inequality, and a decline in the wages of low-skill workers.

Is there any evidence that there has been such a change in the organization of production? This is difficult to ascertain, but some evidence suggests that there may have been some important changes in how jobs are designed and organized now.

First, firms spend much more on recruiting, screening, and are now much less happy to hire low-skill workers for jobs that they can fill with high skill workers.

Second, as already mentioned above, the distribution of capital to labor across industries has become much more unequal over the past 25 years. This is consistent with a change in the organization of production where rather than choosing the same (or a similar) level of capital with both skilled and unskilled workers, now some firms target
the skilled workers with high-capital jobs, while other firms go after unskilled workers with jobs with lower capital intensity.

Third, evidence from the CPS suggests that the distribution of jobs has changed significantly since the early 1980s, with job categories that used to pay “average wages” have declined in importance, and more jobs at the bottom and top of the wage distribution. In particular, if we classify industry-occupation cells into high-wage the middle-wage and low-wage ones (based either on wages or residual wages), there are many fewer workers employed in the middle-wage cells today as compared to the early 1980s, or the weight-at-the-tales of the vob quality distribution has increased substantially as the next figure shows.
The evolution of the percentage of employment in the top and bottom 25 percentile industry-occupation cells (weight-at-the-tails of the job quality distribution).

This framework also suggests that there should be better “matching” between firms and workers now, since firms are targeting high skilled workers. Therefore, measures of mismatch should have declined over the past 25 or so years. Consistent with this prediction, evidence from the PSID suggests that there is much less over- or under-education today than in the 1970s.

4.3. Alternative stories. Other possible organizational stories could also account for the simultaneous changes in the organization of production and inequality. One possibility is that the introduction of computers has enabled firms to reorganize production, giving much more power to skilled workers, and therefore increasing their productivity. Caroli and Van Reenen provide evidence consistent with this view.
from British and French establishments. They show that measures of organizational change, such as decentralization of authority, have a strong predictive power for the demand for skills at the establishment level, even after controlling for other determinants of the demand for skills, such as computers.

Another possibility, suggested by Thesmar and Thoenig, is that firms have been gradually changing their organization from mechanistic organizations, which are highly productive at a given task, but not adaptable to changing environments, towards more adaptive organizations, which may be less efficient at a given task, but can quickly and adapt to changes. They link this switch in organizational form to globalization and to the increased availability of skilled workers (as in the above story). Because adaptive organizations require more skilled workers, this change in organizational form increases the demand for skills.

5. Technical Change and Institutional Change

The above discussion of the effect of labor market institutions on inequality suggested that these are unlikely to be the main reason for the change in inequality. But this still leaves the question of how come labor market institutions started to change shortly after the changes in the structure of wages. Moreover, other major changes in the labor market, including the explosion in the pay of the CEOs, indicate that the organization of the labor market has changed substantially. Are these changes totally unrelated to the changes in technology favoring skilled workers?
Table II
Changes in Wage Bill Shares in Britain: Effects of Organizational and Technological Change

<table>
<thead>
<tr>
<th>Mean of dependent variable</th>
<th>1984–1990 Change in wage bill share of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unskilled manuals</td>
</tr>
<tr>
<td>A. Basic controls</td>
<td>-.012</td>
</tr>
<tr>
<td>OC</td>
<td>-.047</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
</tr>
<tr>
<td>B. Basic controls and technology</td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>-.049</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
</tr>
<tr>
<td>TECH</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
</tr>
<tr>
<td>(\Delta IND_{TECH})</td>
<td>-0.028</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
</tr>
<tr>
<td>(\Delta COMP)</td>
<td>-0.023</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
</tr>
<tr>
<td>C. Extended controls and technology</td>
<td></td>
</tr>
<tr>
<td>OC</td>
<td>-0.056</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
</tr>
<tr>
<td>TECH</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td>(0.039)</td>
</tr>
<tr>
<td>(\Delta IND_{TECH})</td>
<td>-0.004</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
</tr>
<tr>
<td>(\Delta COMP)</td>
<td>-0.019</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
</tr>
</tbody>
</table>

Standard errors are in parentheses. Each column presents the results from a separate regression where the left-hand-side variable is the change in the wage bill share between 1984 and 1990 of the indicated skill group. Each panel (A,B,C) corresponds to a different specification. OC indicates whether the plant introduced organizational change between 1981–1984. Basic controls include ten regional and nine industry dummies, the change in the log of total employment in the establishment between 1984–1990, and the 1984 share of all skill groups. Technology controls are the average proportion of workers using microelectronic technologies introduced in the establishment over the period 1981–1984 (TECH), the change in the average proportion of workers using microelectronic technologies in the two-digit industry between 1985–1990 (\(\Delta IND_{TECH}\)), and the change in a dummy indicating whether plants had microcomputers (\(\Delta COMP\)). Extended controls include the 1984 values of union recognition, financial performance above/below average, U.K. ownership, presence of Joint consultative committee, and lagged size of the establishment. Estimation by weighted OLS—the weights are establishment size and sampling frequency. The number of observations is 378 in all panels.
### TABLE IV
**Changes in Wage Bill Shares in France: Effects of Organizational Change (Delayering) and Technical Change**

<table>
<thead>
<tr>
<th>Mean of dependent variable</th>
<th>Unskilled manuals</th>
<th>Skilled manuals</th>
<th>Clerical workers</th>
<th>Middle Managers &amp; Technicians</th>
<th>Senior managers</th>
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</thead>
<tbody>
<tr>
<td>1992–1996 Change in wage bill share of:</td>
<td>0.026</td>
<td>0</td>
<td>-0.008</td>
<td>0.022</td>
<td>0.012</td>
</tr>
<tr>
<td>A. Basic controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( OC )</td>
<td>-0.015</td>
<td>0.017</td>
<td>-0.002</td>
<td>0.003</td>
<td>-0.003</td>
</tr>
<tr>
<td>(0.007)</td>
<td>(0.009)</td>
<td>(0.004)</td>
<td>(0.005)</td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>B. Basic controls + technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( OC )</td>
<td>-0.015</td>
<td>0.016</td>
<td>-0.001</td>
<td>0.003</td>
<td>-0.002</td>
</tr>
<tr>
<td>(0.007)</td>
<td>(0.009)</td>
<td>(0.004)</td>
<td>(0.006)</td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>( TECH )</td>
<td>-0.001</td>
<td>0.015</td>
<td>-0.007</td>
<td>0.006</td>
<td>-0.013</td>
</tr>
<tr>
<td>(0.014)</td>
<td>(0.018)</td>
<td>(0.008)</td>
<td>(0.011)</td>
<td>(0.008)</td>
<td></td>
</tr>
<tr>
<td>C. Extended controls + technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( OC )</td>
<td>-0.016</td>
<td>0.016</td>
<td>-0.003</td>
<td>0.003</td>
<td>-0.001</td>
</tr>
<tr>
<td>(0.007)</td>
<td>(0.009)</td>
<td>(0.004)</td>
<td>(0.006)</td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>( TECH )</td>
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<td>0.015</td>
<td>-0.005</td>
<td>0.005</td>
<td>-0.012</td>
</tr>
<tr>
<td>(0.014)</td>
<td>(0.018)</td>
<td>(0.008)</td>
<td>(0.011)</td>
<td>(0.008)</td>
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</tr>
<tr>
<td>D. Capital/value added (Extended controls + technology)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( OC )</td>
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<td>0.015</td>
<td>-0.003</td>
<td>0.006</td>
<td>0.001</td>
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<tr>
<td>(0.007)</td>
<td>(0.009)</td>
<td>(0.004)</td>
<td>(0.006)</td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>log ( (K/value added) )</td>
<td>-0.044</td>
<td>0.028</td>
<td>-0.010</td>
<td>-0.002</td>
<td>0.029</td>
</tr>
<tr>
<td>(0.025)</td>
<td>(0.031)</td>
<td>(0.013)</td>
<td>(0.020)</td>
<td>(0.014)</td>
<td></td>
</tr>
<tr>
<td>E. Technology * ( OC ) interaction (Extended controls + technology + ( K/value added) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( OC )</td>
<td>-0.034</td>
<td>0.034</td>
<td>0.005</td>
<td>-0.011</td>
<td>0.006</td>
</tr>
<tr>
<td>(0.013)</td>
<td>(0.016)</td>
<td>(0.007)</td>
<td>(0.010)</td>
<td>(0.007)</td>
<td></td>
</tr>
<tr>
<td>( OC * TECH )</td>
<td>0.034</td>
<td>-0.042</td>
<td>-0.017</td>
<td>0.037</td>
<td>-0.012</td>
</tr>
<tr>
<td>(0.023)</td>
<td>(0.029)</td>
<td>(0.012)</td>
<td>(0.015)</td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>F. Change in employment shares (Extended controls + technology + ( K/value added) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean of dependent variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( OC )</td>
<td>-0.020</td>
<td>0.03</td>
<td>-0.007</td>
<td>0.011</td>
<td>0.013</td>
</tr>
<tr>
<td>(0.008)</td>
<td>(0.009)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td></td>
</tr>
</tbody>
</table>

Standard errors are in parentheses. Each column presents the results from a separate regression where the left-hand-side variable is the change in the wage bill share between 1992 and 1996 of the indicated skill group (except row F where the dependent variable is the change in the employment share of the skill group). \( OC \) indicates whether the plant introduced organizational change—delayering—between 1989–1992. Basic controls include twelve industry and eleven regional dummies, a dummy for proximity to the German border, the initial 1989 proportion of all skill groups, and the change in the log of total employment in the establishment between 1989 and 1992. Technology controls include the proportion of workers using new technologies in the establishment over the period 1988–1992 (\( TECH \)). Extended controls are the following establishment characteristics dated 1989: plant employment size, demand conditions, the existence of a union representative at the plant level, and a public sector dummy. Panel D adds changes in log (capital/value added). Panel E has the interaction between \( OC \) and the \( TECH \) variable in the most general specification including extended controls, technology and (capital/value added). The specification in panel F is equivalent to that in D except the dependent variable is the change in the proportion of the skill group in total employment, rather than changes in the wage bill share. All estimations by weighted OLS—the weights are establishment size and sampling frequency. The number of observations in all panels is 515.
One possible view is that changes in technology have also contributed to the changes in labor market institutions, and as a result, we have witnessed the decline of unions, increased power (and pay) of the CEOs etc.

There can be a number of different reasons for why changes in technology may affect the organization of labor market and the form of “equilibrium” institutions. Here I will mention only two:

(1) New technologies may directly make certain institutions harder to maintain. For example, if new technologies require a lot of job switching, this might make unions less sustainable. There may be a lot to a story like this, but probably not because there is more frequent job switching today, since as discussed above, the evidence does not support greater churning in the labor market. Such a story linking organizational forms to technology has not been developed yet, but may be a fruitful area for future research.

(2) New technologies may increase inequality, and greater inequality may make certain organizational forms harder to maintain.

Now I will develop a simple story of deunionization along lines of the second explanation. The same reasoning may apply to other dimensions of wage setting policies and labor market institutions as well as to deunionization.

To see the basic argument suppose that production can be carried out either in unionized or nonunionized firms. In nonunionized firms, workers receive their marginal products, which I denote by $A_h$ and $A_l$ for skilled and unskilled workers. Assume that unions always compress
the structure of wages—i.e., they reduce wage differentials between skilled and unskilled workers. This wage compression could be driven by a variety of factors.

Acemoglu, Aghion and Violante (2000) argue that unions encourage productive training, and such training is incentive compatible for firms only when the wage structure is compressed. Alternatively, collective decision making within a union may reflect the preferences of its median voter, and if this median voter is an unskilled worker, he will try to increase unskilled wages at the expense of skilled wages. It is also possible that union members choose to compress wages because of ideological reasons or for social cohesion purposes. The empirical literature supports the notion that unions compress wages. I capture this in a reduced form way here using the equation

\[ \omega = \frac{w_H}{w_L} \leq \psi \frac{A_h}{A_l}, \]  

where \( \psi < 1 \). Unions could never attract skilled workers unless they provide some benefits to them. Here I simply assume that they provide a benefit \( \beta \) to all workers, for example, because unions increase productivity, or because they encourage training. Alternatively, \( \beta \) could be part of the rents captured by the union. The zero profit constraint for firms would be:

\[ (w_H - \beta)H + (w_L - \beta)L \leq A_hH + A_lL \]

(in the case where \( \beta \) stands for rents, the zero profit ensures that the firm does not wish to open a non-union plant). Combining this equation
with (5.1), and assuming that both hold as equality, we obtain

\[ w_H = \frac{(A_h + \beta) H + (A_l + \beta) L}{A_h H + \psi^{-1} A_l L} A_h. \]

Skilled workers will be happy to be part of a union as long as \( w_H \) given by (5.2) is greater than \( A_h \). As \( A_h / A_l \) increases—i.e., as there is further skill-biased technical change—, \( w_H \) will fall relative to \( A_h \). Therefore, skill-biased technical change makes wage compression more costly for skilled workers, eventually destroying the coalition between skilled and unskilled workers that maintains unions.

There are two important points:

1. the change in technology potentially leads to a significant change in the organization of the labor market. In particular, after the skill bias of technology passes a certain threshold, workers are no longer organizing unions and the wage compression comes to an end.

2. deunionization causes a decline in the wages of unskilled workers from

\[ w_L = \frac{(A_h + \beta) H + (A_l + \beta) L}{A_h H + \psi^{-1} A_l L} \psi A_l \]

to \( A_l \). Unskilled workers, who were previously benefiting from wage compression imposed by unions, experience a fall in real earnings as a result of deunionization. Therefore, in this model, technical change not only affects wage inequality directly, but also induces a change in labor market institutions. Interestingly, the effect of this change in institutions on inequality could be potentially larger than the direct effect of technical change, and explain the decline in the real wages
of less skilled workers. Whether this is the case or not is an empirical question.
CHAPTER 9

Changes in Residual Inequality

A major issue that most models discussed so far failed to address is the differential behavior of returns to schooling and residual inequality during the 1970s. I argue in this section that an explanation for this pattern requires models with multi-dimensional skills.

1. A single index model of residual inequality

The simplest model of residual inequality is a single index model, in which there is only one type of skill, though this skill is only imperfectly approximated by education (or experience). Expressed alternatively, in a single index model observed and unobserved skills are perfect substitutes. Consider, for example, the model developed above, but suppose that instead of skills, we observe education, e.g. whether the individual is a college graduate, which is imperfectly correlated with skills. A college graduate has a probability $\phi_c$ of being highly skilled, while a noncollege graduate is high skill with probability $\phi_n < \phi_c$. Suppose that the skill premium is $\omega = w_H/w_L$. The college premium in this case is

$$\omega^c = \frac{w_C}{w_N} = \frac{\phi_c w_H + (1 - \phi_c) w_L}{\phi_n w_H + (1 - \phi_n) w_L} = \frac{\phi_c \omega + (1 - \phi_c)}{\phi_n \omega + (1 - \phi_n)}.$$
while within-group inequality, i.e., the difference between high wage college graduates (or noncollege graduates) and low-wage college graduates (or noncollege graduates), is $\omega_{\text{within}} = \omega$. It is immediately clear that both $\omega_{c}$ and $\omega_{\text{within}}$ will always move together—as long as $\phi_{c}$ and $\phi_{n}$ remain constant. Therefore, an increase in the returns to observed skills—such as education—will also be associated with an increase in the returns to unobserved skills.

This framework provides a natural starting point, linking between and within-group inequality, but it predicts that within and between-group inequality should move together. However, as discussed above, during the 1970s, returns to schooling fell while residual group inequality increased sharply. We can only account for this fact by positing a decline in $\phi_{c}$ relative to $\phi_{n}$ of a large enough magnitude to offset the increase in $\omega$; this would ensure that during the 1970s the college premium could fall despite the increase in within group inequality. A large decline in $\phi_{c}$ relative to $\phi_{n}$ would predict a very different behavior of the college premium within different cohorts, but the above analysis showed that there was little evidence in favor of such sizable composition effects. I therefore conclude that the single index model cannot explain the changes in residual inequality during the 1970s and 1980s.

2. Sorting and residual inequality

Another approach would combine educational sorting with an increase in the demand for skills. Suppose, for example, wages are given by $\ln w_{it} = \theta_{t} a_{i} + \gamma_{t} h_{i} + \varepsilon_{it}$ where $h_{i}$ is a dummy for high education, $a_{i}$ is unobserved ability, and $\varepsilon_{it}$ is a mean zero disturbance term. Here $\gamma_{t}$
is the price of observed skills, while \( \theta_t \) is the price of unobserved skills. The education premium can be written as

\[
\ln \omega_t \equiv E(\ln w_{it} | h_{it} = 1) - E(\ln w_{it} | h_{it} = 0) = \gamma_t + \theta_t(A_{1t} - A_{0t})
\]

where \( A_{1t} \equiv E(\ln w_{it} | h_{it} = 1) \) and \( A_{0t} \) is defined similarly. Residual (within-group) inequality can be measured as \( \text{Var}(A_{it} | h = 0) \) and \( \text{Var}(A_{it} | h = 1) \).

Under the assumption that there is perfect sorting into education, i.e., that there exists a threshold \( \overline{\alpha} \) such that all individuals with unobserved ability \( \overline{\sigma} \) obtain education, within-group inequality among high and low education workers will move in opposite directions as long as the price of observed skills, \( \theta \), is constant. To see this, note that when \( \theta \) is constant and \( \overline{\alpha} \) declines (i.e., average education increases), \( \text{Var}(A_{it} | h = 1) \) will increase, but \( \text{Var}(A_{it} | h = 0) \) will fall. Intuitively, there are more and more “marginal” workers added to the high education group, creating more unobserved heterogeneity in that group and increasing within-group inequality. But in contrast, the low education group becomes more homogeneous. Therefore, without a change in the prices for unobserved skills, this approach cannot account for the simultaneous increase in inequality both among low and high education groups.

A natural variation on this theme would be a situation in which \( \gamma \) and \( \theta \) move together. However, this will run into the same problems as the single index model: if \( \gamma \) and \( \theta \) always move together, then such a model would predict that within-group inequality should have fallen during the 1970s. Therefore, models based on sorting also require a
mechanism for the prices of observed and unobserved skills to move differently during the 1970s.

### 3. Churning and residual inequality

Another approach emphasizes that workers of all levels of education may face difficulty adapting to changes. According to this approach, an increase in inequality also results from more rapid technical change, not because of skill bias but because of increased “churning” in the labor market. Recent paper by Aghion, Howitt and Violante, for example, suggest that only some workers will be able to adapt to the introduction of new technology, and this will increase wage inequality.

Here I present a simple aversion to give the basic idea. Suppose that the production function of the economy is

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

where \( H \) denotes skilled workers, who have productivity \( A_h \), and \( L \) denotes unskilled workers who have productivity \( A_l \). As in our baseline model, the skill premium, \( \omega \), is given by the standard equation as above, which I repeat here:

\[ \omega = \frac{w_H}{w_L} = \left( \frac{A_h}{A_l} \right)^{\rho} \left( \frac{H}{L} \right)^{-(1-\rho)} = \left( \frac{A_h}{A_l} \right)^{(\sigma-1)/\sigma} \left( \frac{H}{L} \right)^{-1/\sigma} \]

Note that as before, the skill premium is decreasing in \( H/L \).

Workers are not permanently skilled or unskilled, but instead switch between being skilled and unskilled stochastically. For concreteness, suppose that a worker becomes skilled at the flow rate \( \lambda \) (in continuous time), and loses his skills at the flow rate \( \mu \). Then in steady state, we
have

\[ L = \frac{\mu}{\mu + \lambda} \quad \text{and} \quad H = \frac{\lambda}{\mu + \lambda}. \]

Now consider a change in technology such that both \( A_l \) and \( A_h \) increase proportionately, but because this technology is different from existing technologies, \( \mu \)—the rate at which skilled workers lose their skills—increases. This change in adaptability will increase \( L \) and reduce \( H \). As a result, the skill premium \( \omega \), as given by equation (3.1), will also increase.

Therefore, in this theory it is the temporary increase in “churning” or dislocation that is responsible for the increase in inequality. This approach also predicts that as workers adapt to the new technology, inequality should fall. Although there is some evidence that residual inequality is no longer growing (see the figure above), there is as yet no evidence of a fall in inequality, despite the very large increase in the supply of skills.

An advantage of this approach is that it is in line with the increased earnings instability pointed out by Gottschalk and Moffit. However, as pointed out a number of times above, there is relatively little evidence other than this increase in earnings instability that supports the notion that there is more churning in the labor market. Also theories based on churning do not naturally predict a divergence between returns to educations and residual inequality during the 1970s. Therefore, a mechanism that could lead to differential behavior in the prices to observed and unobserved skills is still necessary.
4. A two-index model of residual inequality

Since models based on a single index of skill (or models where different types of skills are perfect substitutes) are inconsistent with the differential behavior of returns to schooling and within-group inequality during the 1970s, an obvious next step is to consider a two-index models, somewhat reminiscent of the view of human capital consisting of a number of different attributes is in the Gardener view. In addition, these different dimensions of skills have to correspond loosely to observed and unobserved skills, and be imperfect substitutes (see Acemoglu, 1998). In particular, suppose that there are four types of workers, differentiated by both education and unobserved skills. The economy has an aggregate production function

\[
Y = \left[ (A_{lu} L_u)^\rho + (A_{ls} L_s)^\rho + (A_{hu} H_u)^\rho + (A_{hs} H_s)^\rho \right]^{1/\rho},
\]

where \( L_u \) is the supply of low-skill low education workers, and other terms are defined similarly. Within-group inequality corresponds to the ratio of the wages of skilled low education workers to those of unskilled low education workers, and/or to the ratio of the wages of skilled high education workers to those of unskilled high education workers. A natural starting point is to presume that the fraction of high skill workers in each education group is constant, say at \( \phi_l = L_s/L_u \) and \( \phi_h = H_s/H_u > \phi_l \), which implies that there are more high ability workers among high education workers. With this assumption, within-group inequality measures will be

\[
\frac{w_{Ls}}{w_{Lu}} = \left( \frac{A_{ls}}{A_{lu}} \right) \phi_l^{-(1-\rho)} \quad \text{and} \quad \frac{w_{Hs}}{w_{Hu}} = \left( \frac{A_{hs}}{A_{hu}} \right) \phi_h^{-(1-\rho)}.
\]
The college premium, on the other hand, is

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

Using this framework and the idea of endogenous technology, we can provide an explanation for the differential behavior of returns to schooling and within-group inequality during the 1970s. Recall that according to the endogenous technology approach, it is the increase in the supply of more educated workers that triggers more rapid skill-biased technical change. Because technology adjusts sluggishly, the first effect of an increase in the supply of educated workers, as in the 1970s, will be to depress returns to schooling, until technology has changed enough to offset the direct effect of supplies. This change in returns to schooling has no obvious implication for within-group inequality in a multi-skill set up since it is the education skills that are becoming abundant, not unobserved skills—in fact in equation (4.1) within-group inequality is invariant to changes in the supply of educated workers unless there is a simultaneous change in $\phi_h$ and $\phi_l$.

Under the plausible assumption that more skilled workers within each education group also benefit from skill-biased technical progress, technical change spurred by the increase in the supply of educated workers will immediately start to benefit workers with more unobserved skills, raising within-group inequality. Therefore, an increase in the supply of educated workers will depress returns to schooling, while increasing within-group inequality. After this initial phase, technical change will increase both returns to schooling and within-group inequality.
CHAPTER 10

Cross-Country Inequality Trends

As noted above, inequality increased much less in continental Europe than in the U.S. and other Anglo-Saxon economies. There is currently no consensus for why this has been so. There are a number of candidate explanations. These include:

1. Traditional Explanations

1.1. Basic ideas. The first explanation claims that the more rapid increase in the relative supply of skills in Europe accounts for the lack of increase in inequality there. The second explanation, on the other
hand, emphasizes the role of European wage-setting institutions. According to this explanation, it is not the differential growth of skilled workers in the population, but the differential behavior of skilled employment that is responsible for differences in inequality trends across countries. More specifically, firms respond to wage compression by reducing their demand for unskilled workers, and the employment of skilled workers (relative to that of unskilled workers) increases in Europe compared to the U.S. As a result, the market equilibriates with a lower employment of unskilled workers compensating for their relatively higher wages in Europe.

The figure illustrates the first explanation using a standard relative-supply-demand diagram, with relative supply on the horizontal axis and the relative wage of skilled workers, $\omega$, on the vertical axis. For simplicity, I drew the relative supply of skills as vertical. The diagram shows that an increase in the demand for skills, for a given supply of skills, will lead to higher wage inequality. At a simple level, we can think of this economy as corresponding to the U.S., where the consensus is that because of skill-biased technical change or increased trade with less skill-abundant countries, the relative demand for skills grew faster than the relative supply during the recent decades. As a result of the increase in the relative demand for skills, the skill premium rises from $\omega^{\text{Pre}}$ to $\omega^{\text{US-Post}}$. 
Now imagine that continental Europe is also affected by the same relative demand shifts, but the relative supply of skills also increases. This captures the essence of the first explanation, where the supply of skills increases faster in continental Europe than in the U.S. Then the “European” equilibrium will be at a point like E which may not exhibit greater inequality than before. In fact, the next figure depicts the case in which there is no change in the skill premium in Europe.

Probably the more popular explanation among economists and commentators is the second one above (e.g., Krugman, 1994, OECD, 1994, Blau and Kahn, 1996). To capture this story, imagine that wage-setting institutions in Europe prevent wage inequality from increasing—for example, because of union bargaining, unemployment benefits, or minimum wages that keep the earnings of low-skill workers in line with those of high-skill workers. This can be represented as an institutional
wage-setting line different from the relative supply curve as drawn in the next figure. (To make the story stark, I drew the institutional wage-setting line as horizontal). The equilibrium now has to be along this institutional wage-setting line, and consequently off the relative supply curve, causing unemployment. Now, even in the absence of an increase in the relative supply of skills, the skill premium may not increase; instead there will be equilibrium unemployment. In the figure, relative unemployment caused by the increase in the demand for skills is shown as the gap between the relative supply of skills and the intersection between relative demand and institutional wage-setting line. Notice that in the simplest version of the story, there is full employment of skilled workers, and the indicated gap simply reflects unskilled unemployment. The fact that unemployment increased in Europe relative to the U.S. is often interpreted as evidence in favor of this explanation.
But in this context note that in contrast to the prediction of this simple story, unemployment in Europe increased for all groups, not simply for the low-education workers. See, for example, Nickell and Bell (1994), Card, Kramartz and Lemieux (1996) and Krueger and Pischke (1998). Nevertheless, some of the increase in unemployment among the high-education workers in Europe may reflect the effect of wage compression within education groups on job creation (e.g., if firms are forced to pay the same wages to low-skill college graduates as the high-skill college graduates, they may stop hiring the low-skill college graduates, increasing unemployment among college graduates).

Notice that both of these explanations are “supply-side”. Firms are along their relative demand curves, and different supply behavior
or institutional characteristics of the European economies pick different points along the relative demand curves. This observation gives us a way of empirically investigating whether these explanations could account for the differential inequality trends, while assuming that relative demand shifts have been similar across countries—that is, that all OECD countries have access to more or less a common set of technologies.

1.2. Empirical investigation. Suppose that the aggregate production function for economy $j$ is

$$Y^j (t) = [(A^j_H (t) L^j (t))^\rho + (A^j_H (t) H^j (t))^\rho]^{1/\rho},$$

which is a multi-country generalization of our above framework.

Suppose that wages are related linearly to marginal product: $w^j_H (t) = \beta MP^j_H (t)$ and $w^j_L (t) = \beta MP^j_L (t)$. The case where $\beta = 1$ corresponds to workers being paid their full marginal product, with no rent sharing. Irrespective of the value of $\beta$, we have

$$\omega^j (t) \equiv \frac{w^j_H (t)}{w^j_L (t)} = \frac{MP^j_H (t)}{MP^j_L (t)}.$$  

That is, in this specification firms will be along their relative demand curves. Then, we can write

$$\ln \omega^j (t) = \frac{\sigma - 1}{\sigma} \ln \left( \frac{A^j_H (t)}{A^j_L (t)} \right) - \frac{1}{\sigma} \ln \left( \frac{H^j (t)}{L^j (t)} \right).$$

This equation shows that the skill premium is decreasing in the relative supply of skilled workers, $H^j (t) / L^j (t)$, except in the special case where $\sigma \to \infty$ (where skilled and unskilled workers are perfect substitutes).
Let us start with a relatively weak form of the common technology assumption. In particular, suppose that

\[
A^j_h (t) = \eta^j_h \theta^j (t) A_h (t) \quad \text{and} \quad A^j_l (t) = \eta^j_l \theta^j (t) A_l (t).
\]

This assumption can be interpreted as follows. There is a world technology represented by \(A_h (t)\) and \(A_l (t)\), which potentially becomes more or less skill-biased over time. Countries may differ in their ability to use the world technology efficiently, and this is captured by the term \(\theta^j (t)\). Although the ability to use world technology is time varying, it is symmetric between the two sectors. In addition, countries may have different comparative advantages in the two sectors as captured by the terms \(\eta^j_h\) and \(\eta^j_l\) (though these are assumed to be time invariant).

Substituting (1.3) into (1.4), we obtain

\[
\ln \omega^j (t) = c^j + \ln a (t) - \frac{1}{\sigma} \ln \left( \frac{H^j (t)}{L^j (t)} \right),
\]

where \(\ln a (t) \equiv \frac{\sigma - 1}{\sigma} \ln (A_h (t) / A_l (t))\) is the measure of skill-biased technical change, and \(c^j \equiv \frac{\sigma - 1}{\sigma} \eta^j_h / \eta^j_l\).

Then, using U.S. data we can construct an estimate for the change in \(\ln a (t)\), denoted by \(\Delta \ln \hat{a} (t)\), using an estimate for the elasticity of substitution, \(\sigma\) as:

\[
\Delta \ln \hat{a} (t) = \Delta \ln \omega^0 (t) + \frac{1}{\sigma} \Delta \ln \left( \frac{H^0 (t)}{L^0 (t)} \right),
\]

where \(j = 0\) refers to the U.S.

Now define \(\Delta_k\) as the \(k\)-period difference operator, i.e.,

\[
\Delta_k x \equiv x (t) - x (t - k).
\]
Then, predicted changes in the skill premium for country \( j \) between \( t - k \) and \( t \) are given by:

\[
\Delta_k \ln \hat{\omega}^j (t) = \Delta_k \ln \hat{\alpha} (t) - \frac{1}{\sigma} \Delta_k \ln \left( \frac{H^j (t)}{L^j (t)} \right). 
\]

The implicit assumption in this exercise is that there is no delay in the adoption of new technologies across countries. Instead, it is quite possible that some of the new skill-biased technologies developed or adopted in the U.S. are only introduced in continental Europe with a lag. That is, instead of (1.3), we would have

\[
A_h^j (t) = \eta_h^j \theta^j (t) A_h (t - k^j) \quad \text{and} \quad A_l^j (t) = \eta_l^j \theta^j (t) A_l (t - k^j),
\]

implying that there is a delay of \( k^j \) periods for country \( j \) in the adoption of frontier technologies.

Motivated by the possibility of such delays, as an alternative method I use U.S. data from 1974 to 1997 to recover estimates of \( \Delta \ln \hat{\alpha} (t) \), and calculate the average annual growth rate of \( \ln \hat{\alpha} (t) \), denoted by \( \bar{g} \). I then construct an alternate estimate for the predicted change in the skill premium in country \( j \) between dates \( t - k \) and \( t \) as:

\[
\Delta_k \ln \hat{\omega}^j (t) = \bar{g} k - \frac{1}{\sigma} \Delta_k \ln \left( \frac{H^j (t)}{L^j (t)} \right).
\]

In this exercise, I use 1974 as the starting point, since it is five years prior to the earliest observation for any other country from the LIS data, and five years appears as a reasonable time lag for diffusion of technologies among the OECD countries. I use 1997 as the final year, since this is the final year for which there is LIS data for a country in my sample.
Whether the relative-supply-demand framework provides a satisfactory explanation for cross-country inequality trends can then be investigated by comparing the predicted skill premium changes, the $\Delta_k \ln \hat{\omega}^j(t)$’s from (1.5) and the $\Delta_k \ln \tilde{\omega}^j(t)$’s from (1.7), to the actual changes, the $\Delta_k \ln \omega^j(t)$’s.

![Graphs showing observed vs. predicted skill premium for Australia, Canada, and United Kingdom.](image)

Actual skill premia and predicted skill premia from equation (1.5) for $\sigma = 1.4$ and $\sigma = 2$. 
Actual skill premia and predicted skill premia from equation (1.5) for 
\[ \sigma = 1.4 \] and \[ \sigma = 2. \]
Actual skill premia and predicted skill premia from equation (1.5) for
\[ \sigma = 1.4 \text{ and } \sigma = 2. \]
Actual skill premia and predicted skill premia from equation (1.7) for
\[ \sigma = 1.4 \text{ and } \sigma = 2. \]
Actual skill premia and predicted skill premia from equation (1.7) for

$$\sigma = 1.4$$ and $$\sigma = 2.$$
Actual skill premia and predicted skill premia from equation (1.7) for \( \sigma = 1.4 \) and \( \sigma = 2 \).

2. Differential Changes in the Relative Demand for Skills

2.1. Basic idea. An alternative to the traditional explanations involves differential changes in the relative demand for skills across countries. These differential changes could reflect four distinct forces:

1. Different countries could develop their own technologies, with different degrees of skill bias.
2. Some countries could be lagging behind the world technology frontier, and may not have adopted the most recent skill-biased technologies.
(3) While all countries face the same technology frontier, some may have adopted more skill-biased technologies from this frontier.

(4) Different countries have experienced different degrees of trade opening, affecting the demand for skills differentially.

We have already seen that increased international trade is probably not the major cause of the increase in inequality. This leaves us with the first three options. Plausibly, many advanced economies develop some of their own technologies. Nevertheless, it appears plausible that most OECD economies have access, and even relatively rapid access, to the same set of technologies. This suggests that the most likely reason why the relative demand for skills may have behaved differently in continental Europe is not differential development of new technologies or slow technology diffusion, but different incentives to adopt available technologies.

Let me here briefly summarize how the interaction of technology adoption and differences in labor market institutions may induce differential skill-biased technical change in different countries. I will provide a full model of this once we see the general equilibrium search and matching models later in the class.

The basic idea of the theory I propose is to link the incentives to adopt new technologies to the degree of compression in the wage structure, which is in part determined by labor market institutions. In particular, institutional wage compression in Europe makes firms more willing to adopt technologies complementary to unskilled workers,
inducing less skill-biased technical change there. This theory is based on three premises:

1. There is some degree of rent-sharing between firms and workers, for example, because of bargaining over quasi-rents.
2. The skill bias of technologies is determined by firms’ technology choices.
3. A variety of labor market institutions tend to increase the wages of low-skill workers in Europe, especially relative to the wages of comparable workers in the U.S.

The new implication of combining these three premises is that firms in Europe may find it more profitable to adopt new technologies with unskilled workers than their American counterparts. This is because with wage compression, firms are forced to pay higher wages to unskilled workers than they would otherwise do (that is, greater than the “bargained” wage). This creates an additional incentive for these firms to increase the productivity of unskilled workers: they are already paying high wages, and additional investments will not necessarily translate into higher wages. Put differently, the labor market institutions that push the wages of these workers up make their employers the residual claimant of the increase in productivity due to technology adoption, encouraging the adoption of technologies complementary to unskilled workers in Europe.

A simple numerical example illustrates this point more clearly. Suppose that a worker’s productivity is 10 without technology adoption, and 20 when the new technology is adopted. Assume also that wages are equal to half of the worker’s productivity, and technology adoption
costs 6 (incurred solely by the firm). Now without technology adoption, the firm’s profits are equal to \( \frac{1}{2} \times 10 = 5 \), while with technology adoption, they are \( \frac{1}{2} \times 20 - 6 = 4 \). The firm, therefore, prefers not to adopt the new technology because of the subsequent rent-sharing.

Next suppose that a minimum wage legislation requires the worker to be paid at least 9. This implies that the worker will be paid 9 unless his productivity is above 18. The firm’s profits without technology now change to \( 10 - 9 = 1 \), since it has to pay 9 to the worker because of the minimum wage. In contrast, its profits with technology adoption are still 4. Therefore, the firm can prefer to adopt the new technology. The reason for this change is clear: because of the minimum wage laws, the firm was already forced to pay high wages to the worker, even when his marginal product was low, so it became the effective residual claimant of the increase in productivity due to technology adoption.

This reasoning implies that there may be greater incentives to invest in technologies complementing workers whose wages are being pushed up by labor market institutions. Since European labor market institutions increase to pay of low-skill workers, technology may be endogenously less skill biased in Europe than in the U.S.

2.2. A simple formalization. Leaving a more fully developed model to later, let me now present a simple formalization. Suppose the productivity of a skilled worker is \( A_h = a\eta \), whereas the productivity of an unskilled worker is \( A_l = a \), where \( a \) is a measure of aggregate technology in use, and \( \eta > 1 \). Suppose that wages are determined by rent sharing, unless they fall below a legally mandated minimum wage,
in which case the minimum wage binds. Hence, \( w_j = \min \{ \beta A_j, w \} \), where \( j = l \) or \( h \), and \( \beta \) is worker’s share in rent sharing. Note that the cost of upgrading technology does not featuring in this wage equation, because rent sharing happens after technology costs are sunk.

To capture wage compression, suppose the minimum wage is binding for unskilled workers in Europe. Now consider technology adoption decisions. In particular, firms can either produce with some existing technology, \( a \), or upgrade to a superior technology, \( a' = a + \alpha \), at cost \( \gamma \). The profit to upgrading the technology used by a skilled worker is \( (1 - \beta)\alpha \eta - \gamma \), both in the U.S. and Europe. The new technology will therefore be adopted as long as

\[
\gamma \leq \gamma^S \equiv (1 - \beta)\alpha \eta.
\]

Note that there is a holdup problem, discouraging upgrading: a fraction \( \beta \) of the productivity increase accrues to the worker due to rent sharing (Grout, 1984, Acemoglu, 1996).

The incentives to upgrade the technology used by unskilled workers differ between the U.S. and Europe. In the U.S., this profit is given by \( (1 - \beta)\alpha \eta - \gamma \). So, the new technology will be adopted with unskilled workers if

\[
\gamma \leq \gamma^U \equiv (1 - \beta)\alpha.
\]

Clearly, \( \gamma^U < \gamma^S \), so adopting new technologies with skilled workers is more profitable. In contrast, the return to introducing the new technology is different in Europe because minimum wages are binding for unskilled workers. To simplify the discussion, suppose that even after the introduction of new technology, the minimum wage binds, i.e.,
2. DIFFERENTIAL CHANGES IN THE RELATIVE DEMAND FOR SKILLS

$w > \beta(A + \alpha)$. Then, the return to introducing the new technology in Europe with unskilled workers is $\alpha - \gamma$, and firms will do so as long as $\gamma < \alpha$. Since $\alpha > \gamma^U$, firms in Europe have greater incentives to introduce advanced technologies with unskilled workers than in the U.S.
Part 3

Theories of Unemployment (Notes)
In this last part of the class I will discuss theories of unemployment. Notice that these notes are less detailed than the previous chapters (I have run out of steam!).

A couple of introductory remarks are in order:

(1) The simplest approach to unemployment is to ignore it, and lump it together with non-participation, under the heading of nonemployment. Then the supply and demand for work will determine wages and nonemployment. This is a very useful starting place. In particular, it emphasizes that often unemployment (nonemployment) is associated with wages above the market clearing wage levels.

(2) However, the distinction between voluntary and involuntary unemployment is sometimes useful, especially since many workers claim to be looking for work rather than being outside the labor force. Moreover, when there are very high levels of nonemployment among prime-age workers, the nonemployment framework may no longer be satisfactory. Therefore, three questions important in motivating the theories of unemployment are:
   (a) Why do most capitalist economies have a significant fraction, typically at least around 5 percent, of their labor forces as “unemployed”?
   (b) Why does unemployment increase during recessions?
   (c) Why has unemployment in continental Europe has been extremely high over the past 25 years?
CHAPTER 11

Some Basic Facts About Unemployment

(1) The unemployment rate in the U.S. fluctuates around six percent, and is strongly countercyclical.

(2) There is almost always higher unemployment among younger and less educated workers.

(3) The unemployment rate in continental Europe was lowered in the U.S. throughout the postwar period, but rose above the U.S. level in the late 1970s or early 1980s, and has been consistently higher there than the U.S. level.

(4) The unemployment rate in some countries, notably Spain, has reached, and for a long while stayed at, 20 percent.

(5) High unemployment in Europe reflects low rates of employment creation—that is, unemployed workers leave unemployment only slowly compared to the U.S. Rates at which employed workers lose their jobs and become unemployed are higher in the U.S. than in Europe.

(6) Wage growth and the behavior of the labor share in GDP indicate that there was a disproportionate wage growth in continental Europe compared to the U.S., but the labor share data indicate that much of this may have been reversed during the 1980s.
(7) Unemployment in continental Europe increased both among the less and more educated workers.

(8) Unemployment in continental Europe increased especially among young workers, and nonemployment has affected prime-age males little. It is the young, the old or the women (in some countries) who do not work in Europe.
Figure 20-3. Unemployment rates in the European Union and the United States, 1970-1995
Chart 2.3.  Employment and real wages
Index 1970 = 100

1. Total compensation per employee deflated by the GDP deflator.
Source: OECD Economic Outlook database.
Chart 1.5

Employment/population ratios by age group, 1979-1993

- Australia
- Canada
- Finland
- France
- Germany
- Ireland
- Italy
- Japan
- Norway


a) Refers to 14-19 in Italy and 16-19 in Norway, Spain, Sweden, the United Kingdom and the United States.
b) Refers to 25-59 in Italy and Norway.
Employment/population ratios by age group, 1979-1993

Portugal

Spain

Sweden

United Kingdom

United States

--- 15-19
--- 20-24
--- 25-54

a) Refers to 14-19 in Italy, and 16-19 in Norway, Spain, Sweden, the United Kingdom and the United States.
b) Refers to 25-59 in Italy and Norway.

Efficiency Wage Theories and Evidence

1. The Shapiro-Stiglitz Model

The Shapiro-Stiglitz model is one of the workhorses of macro/labor. In this model, unemployment arises because wages need to be above the market clearing level in order to give incentives to workers. In fact, it is the combination of unemployment and high wages that make work more attractive for workers, hence the title on the paper “unemployment as a worker-discipline device”.

1.1. The basic model. I will simply sketch the model here: the model is in continuous time and all agents are infinitely lived.

Workers have to choose between two levels of effort, and are only productive if they exert effort.

\[
\begin{align*}
\text{effort} & \quad \rightarrow 0 \\
\text{cost} & \quad = 0, \text{ not productive} \\
\text{effort} & \quad \rightarrow 1 \\
\text{cost} & \quad = e, \text{ productive}
\end{align*}
\]

Without any informational problems firms would write contracts to pay workers only if they exert effort. The problem arises because firms cannot observe whether a worker has exerted effort or not, and cannot induced from output, since output is a function of all workers’ efforts. This introduces the moral hazard problem.

However, if a worker “shirks”, there is effort = 0, then there is probability (flow rate) \( q \) of getting detected and fired. [...For example,
the worker’s actions affect the probability distribution of some observable signal on the basis of which the firm compensates him. When the worker exerts effort, this signal takes the value 1. When he shirks, this signal is equal to 1 with probability $1 - q$ and 0 with probability $q$...

All agents are risk neutral, and there are $N$ workers

$b = \text{exogenous separation rate}$

$a = \text{job finding rate}$, which will be determined in equilibrium

$r = \text{interest rate/delay factor}$

Denote the PDV of employed-shirker by $V_{E}^{S}$ (recall we are in continuous time)

\begin{equation}
(1.1) \quad rV_{E}^{S} = w + (b + q)(V_{U} - V_{E}^{S})
\end{equation}

where I have imposed $\dot{V}_{E}^{S} = 0$, since here I will only characterize steady states. The intuition for this equation is straightforward. The worker always receives his wage (his compensation for this instant of work) $w$, but at the flow rate $b$, he separates from the firm exogenously, and at the flow rate $q$, he gets caught for shirking, and in both cases he becomes unemployed, receiving $V_{U}$ and losing $V_{E}^{S}$.

Denote the PDV of employed-nonshirker by $V_{E}^{N}$

\begin{equation}
(1.2) \quad rV_{E}^{N} = w - e + b(V_{U} - V_{E}^{N}),
\end{equation}

which is different from (1.1) because the worker incurs the cost $e$, but loses his job at the slower rate $b$.

PDV of unemployed workers $V_{U}$ is

\begin{equation}
V_{U} = z + a(V_{E} - V_{U}),
\end{equation}
where
\[ V_E = \max \{ V^S_E, V^N_E \} \]

and \( z \): utility of leisure + unemployment benefit

Non-shirking condition is an incentive-compatibility constraint that requires the worker to prefer to exert effort. Combining these equations, we obtain it as
\[ V^N_E > V^S_E \Rightarrow w > z + e \left[ r + b + a \right] \frac{e}{q} \]

Steady state requires that
\[ \text{flow into unemployment} = \text{flow out of unemployment} \]

In equilibrium, no one shirks because the non-shirking condition holds
\[ bL = aU \]

where \( L \): employment, \( U \): unemployment.

\[ \Rightarrow a = \frac{bL}{U} = \frac{bL}{N - L} \]

Now substituting for this we get the full non-shirking condition as
\[ NSC : w \geq z - e + \left[ r + \frac{bN}{N - L} \right] \frac{e}{q} \]

Notice that a higher level of \( \frac{N}{N-L} \), which corresponds to lower unemployment, necessitate a higher wage to satisfy the non-shirking condition. This is the sense in which unemployment is a worker-discipline
device. Higher unemployment makes losing the job more costly, hence encourages workers not to shirk.

Next consider Labor Demand: $M$ firms with production function

$$AF(L)$$, maximize static profits (no firing/hiring costs - but see below).

$$AF'(L) = w, F'' < 0$$, concave prod. function

Agg Labor Demand given by

$$AF'\left(\frac{L}{M}\right) = w$$

Set $M = 1$, then equilibrium given as

$$z + e + \left[ r + \frac{bN}{N - L} \right] \frac{e}{q} = AF'(L)$$

$A \downarrow \implies L \downarrow$: lower prod. $\implies$ high unemployment

$z \uparrow \implies L \downarrow$: high reservation wages $\implies$ high unemployment

$q \downarrow \implies L \downarrow$: bad monitoring $\implies$ high unemployment

$r \uparrow \implies L \downarrow$: high interest rates $\implies$ high unemployment

$b \uparrow \implies L \downarrow$: high turnover $\implies$ high unemployment

One attraction of the efficiency wage model is that it has the same source of informational problems as other models we used to study training, organizational structure etc..
Second-best: Workers paid average product.
1.2. Welfare. Welfare question: is the level of unemployment too high? It depends what notion of welfare we are using and whether firms are owned by nonworkers.

What are the externalities?

(1) By hiring one more worker, the firm is reducing unemployment, and forcing other firms to pay higher wages $\rightarrow$ unemployment is too low.

(2) By hiring one more worker, the firm is increasing the worker’s utility at the margin, since each worker is receiving a rent (wage $>$ opportunity cost) $\rightarrow$ unemployment is too high.

The diagram shows that the second effect always dominates. The unemployment is too high. A subsidy on wages financed by a tax on profits will increase output.

So can there be a Pareto-improving tax-subsidy scheme?

Not necessarily. If firms are owned by capitalists, the above policy will increase output, but will not constitute a Pareto improvement. If firms are owned by workers, the above policy will constitute a Pareto improvement. But in this case workers have enough income. Why didn’t they already enter into “bonding” contracts?

1.3. Other solutions to incentive problems. Are firms behaving optimally? No. Backloaded compensation will be more effective in preventing shirking.

This is one of the main criticisms of the shirking model: the presence of the monitoring problem does not necessarily imply “rents” for
workers, and it is the rents for the workers that lead to distortions and unemployment.

Moreover, if workers have wealth, they can enter into bonding contracts where they post a bond that they lose if they are caught shirking.

Problems: firm-side moral hazard—firms may claim workers have shirked and fire them either to reduce labor costs when to worker’s wage has increased enough (above the opportunity cost), or to collect the bond payments.

In any case, this discussion highlights that there are two empirical questions:

(1) Are monitoring problems important?
(2) Do more severe monitoring problems lead to greater rents for workers?

2. Evidence on Efficiency Wages

There are two types of evidence offered in the literature in support of efficiency wages.

The first type of evidence shows the presence of substantial inter-industry wage differences (e.g., Krueger and Summers). Such wage differentials are consistent with efficiency wage theories since the monitoring problem \( q \) in terms of the model above is naturally more serious in some industries than others.

Nevertheless, this evidence does not establish that efficiency wage considerations are important, since there are at least two other explanations for the inter-industry wage differentials:
(1) These differentials may reflect compensating wages (since some jobs may be less pleasant than others) or premia for unobserved characteristics of workers, which differ systematically across industries because workers select into industries based on their abilities.

It seems to be the case that a substantial part of the wage differentials are in fact driven by these considerations. Nevertheless, it also seems to be the case that part of the inter-industry wage differences do in fact correspond to “rents”. Workers who move from a low wage to a high wage industry receive a wage increase in line with the wage differential between these two sectors (Krueger and Summers; Gibbons and Katz), suggesting that the differentials do not simply reflect unobserved ability. Compensating wage differentials also do not seem to be the whole story, since high wage jobs attract significantly more applicants (Holzer, Katz, and Krueger), and workers are less likely to quit such jobs (Krueger and Summers).

(2) Inter-industry wage differentials may correspond to differential worker rents in different industries, but not because of efficiency wages, but because of differences in unionization or other industry characteristics that give greater bargaining power to workers in some industries than others (e.g., capital intensity).
Therefore, the inter-industry wage differentials are consistent with efficiency wages, but do not prove that efficiency wage considerations are important.

The second line of attack looks for direct evidence for efficiency wage considerations. A number of studies find support for efficiency wages. These include:

1. Krueger compares wages and tenure premia in franchised and company-owned fast food restaurants. Krueger makes the natural assumption that there is less monitoring of workers in a franchised restaurant. He finds higher wages and steeper wage-tenure profiles in the franchised restaurants, which he interprets as evidence for efficiency wages.

2. Cappelli and Chauvin look at the number of disciplinary dismissals, which they interpret as a measure of shirking, in the different plants located in different areas, but all by the same automobile manufacturer. The firm pays the same nominal wage everywhere (because of union legislation). This nominal wage translates into greater wage premia in some areas because outside wages differ. They find that when wage premia are greater, there are fewer disciplinary dismissals. This appears to provide strong support to the basic implication of the shirking model.

3. Campbell and Kamlani survey 184 firms and find that firms are often unwilling to cut wages because this will reduce worker effort and increase shirking.
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<th>Assistant and shift managers</th>
<th>Full-time crew workers</th>
<th>Part-time crew workers</th>
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<td></td>
<td>(0.013)</td>
<td>(0.012)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Log population density</td>
<td>-0.057</td>
<td>-0.062</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>(0.030)</td>
<td>(0.030)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>Assistant manager b</td>
<td>0.178</td>
<td>0.177</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(0.064)</td>
<td>(0.062)</td>
<td></td>
</tr>
<tr>
<td>Job task dummies (11)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Parent company dummies (3)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Census region dummies (8)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>$\sigma^2_a$</td>
<td>0.012</td>
<td>0.012</td>
<td>0.007</td>
</tr>
<tr>
<td>$\sigma^2$</td>
<td>0.005</td>
<td>0.004</td>
<td>0.001</td>
</tr>
</tbody>
</table>
## TABLE II

**Regression Results for Rates of Disciplinary Layoffs Across Plants**

<table>
<thead>
<tr>
<th></th>
<th>Weighted least squares</th>
<th></th>
<th>Elasticity*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.071</td>
<td>-1.20</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(0.96)</td>
<td>(1.16)</td>
<td></td>
</tr>
<tr>
<td>WPREM</td>
<td>-0.21**</td>
<td>-0.24*</td>
<td>0.547</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.13)</td>
<td></td>
</tr>
<tr>
<td>UE</td>
<td>-0.03</td>
<td>-0.012</td>
<td>0.330</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.045)</td>
<td></td>
</tr>
<tr>
<td>LAIDOFF</td>
<td>-0.009*</td>
<td>-0.008*</td>
<td>0.207</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td></td>
</tr>
<tr>
<td>SEN</td>
<td>0.007*</td>
<td>0.008*</td>
<td>0.285</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>VOICE</td>
<td>-0.14***</td>
<td>-0.14***</td>
<td>0.908</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.05)</td>
<td></td>
</tr>
<tr>
<td>ASSEMBLY</td>
<td>1.008***</td>
<td>1.02***</td>
<td>0.210</td>
</tr>
<tr>
<td></td>
<td>(0.182)</td>
<td>(0.18)</td>
<td></td>
</tr>
<tr>
<td>MICHIGAN</td>
<td>0.09</td>
<td>0.289</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>(0.238)</td>
<td>(0.24)</td>
<td></td>
</tr>
<tr>
<td>SOUTH</td>
<td>0.054</td>
<td>-0.057</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.336)</td>
<td>(0.36)</td>
<td></td>
</tr>
<tr>
<td>UIBEN</td>
<td>-0.00004</td>
<td>-0.00006</td>
<td>0.178</td>
</tr>
<tr>
<td></td>
<td>(0.00009)</td>
<td>(0.00009)</td>
<td></td>
</tr>
<tr>
<td>WPREM'70</td>
<td></td>
<td></td>
<td>0.291</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.54)</td>
</tr>
<tr>
<td>S.E.E. =</td>
<td>0.62</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>F =</td>
<td>6.43</td>
<td>6.32</td>
<td></td>
</tr>
<tr>
<td>n =</td>
<td>78</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

* = significant at 10 percent.
** = significant at 5 percent.
*** = significant at 1 percent (two-tailed tests).

All of the values for DISL lie between zero and one. Standard errors are in parentheses. The proportion of the variance in DISL explained by regressions 1 and 2 is 46 and 49 percent, respectively.

a. Evaluated at the mean from the weighted regression in equation (2).
### TABLE IV

**Average Score Received for Each Statement (4 = Very Important, 3 = Moderately Important, 2 = Of Minor Importance, 1 = Not Important) and Percentage of Respondents Rating Each Statement as the Most Important Reason (rank is in parentheses)**

<table>
<thead>
<tr>
<th></th>
<th>Average score</th>
<th>Percentage ranking each statement as most important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall</td>
<td>Business Week</td>
</tr>
<tr>
<td>a. Labor union contracts prevent wages from being cut.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-collar\textsuperscript{a}</td>
<td>1.35</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>(9)</td>
<td>(9)</td>
</tr>
<tr>
<td>Blue-collar\textsuperscript{a, b, c}</td>
<td>2.40</td>
<td>2.64</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(5)</td>
</tr>
<tr>
<td>Less skilled\textsuperscript{a, b, c}</td>
<td>2.05</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>(8t)</td>
<td>(6)</td>
</tr>
<tr>
<td>b. Workers dislike unpredictable changes in income. Therefore, workers and firms reach an implicit understanding that wages will neither fall in recessions nor rise in expansions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-collar\textsuperscript{a, b}</td>
<td>2.59</td>
<td>2.72</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(9)</td>
</tr>
<tr>
<td>Blue-collar</td>
<td>2.79</td>
<td>2.76</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>Less skilled</td>
<td>2.60</td>
<td>2.69</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>c. If your firm were to cut wages, people in the community would hear about it, making it more difficult to hire workers in the future.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-collar\textsuperscript{a}</td>
<td>2.30</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(7)</td>
</tr>
<tr>
<td>Blue-collar\textsuperscript{a}</td>
<td>2.36</td>
<td>2.53</td>
</tr>
<tr>
<td></td>
<td>(8)</td>
<td>(6)</td>
</tr>
<tr>
<td>Less skilled\textsuperscript{a}</td>
<td>2.20</td>
<td>2.47</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(5)</td>
</tr>
</tbody>
</table>
d. A cut in wages would decrease workers’ effort, resulting in less output or poorer service.

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Business Week</th>
<th>Non-Business Week</th>
<th>Percentage ranking each statement as most important</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-collar</td>
<td>2.77</td>
<td>2.77</td>
<td>2.77</td>
<td>10.3%</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
</tr>
<tr>
<td>Blue-collar*</td>
<td>2.99</td>
<td>2.94</td>
<td>3.12</td>
<td>15.4%</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>(2)</td>
<td>(1)</td>
<td>(3)</td>
</tr>
<tr>
<td>Less skilled</td>
<td>2.88</td>
<td>2.86</td>
<td>2.92</td>
<td>15.4%</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

e. A cut in wages would increase number of workers who quit, increasing the cost of hiring and training new workers in the future.

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Business Week</th>
<th>Non-Business Week</th>
<th>Percentage ranking each statement as most important</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-collar**</td>
<td>2.96</td>
<td>2.95</td>
<td>2.97</td>
<td>11.6%</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Blue-collar</td>
<td>2.73</td>
<td>2.68</td>
<td>2.85</td>
<td>11.7%</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(4)</td>
<td>(3t)</td>
<td>(4t)</td>
</tr>
<tr>
<td>Less skilled*</td>
<td>2.56</td>
<td>2.56</td>
<td>2.55</td>
<td>9.4%</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
</tbody>
</table>

f. If your firm were to discharge some of its current workers and to hire new workers at a lower wage, the workers who remain would harass and refuse to cooperate with the newly hired workers.

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Business Week</th>
<th>Non-Business Week</th>
<th>Percentage ranking each statement as most important</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-collar</td>
<td>1.82</td>
<td>1.77</td>
<td>1.91</td>
<td>0.7%</td>
</tr>
<tr>
<td></td>
<td>(8)</td>
<td>(8)</td>
<td>(7)</td>
<td>(9)</td>
</tr>
<tr>
<td>Blue-collar**</td>
<td>2.16</td>
<td>2.20</td>
<td>2.09</td>
<td>1.1%</td>
</tr>
<tr>
<td></td>
<td>(9)</td>
<td>(9)</td>
<td>(7)</td>
<td>(9)</td>
</tr>
<tr>
<td>Less skilled**</td>
<td>2.05</td>
<td>2.11</td>
<td>1.94</td>
<td>1.7%</td>
</tr>
<tr>
<td></td>
<td>(8t)</td>
<td>(8)</td>
<td>(7)</td>
<td>(8t)</td>
</tr>
</tbody>
</table>
g. If your firm were to cut
wages, your most productive
workers might leave,
whereas if you lay off
workers, you can lay off the
least productive workers.

<table>
<thead>
<tr>
<th></th>
<th>Average score</th>
<th>Percentage ranking each</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall</td>
<td>Business Week</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-collar</td>
<td>3.27 (1)</td>
<td>3.35 (1)</td>
</tr>
<tr>
<td>Blue-collar</td>
<td>3.13 (1)</td>
<td>3.16 (1)</td>
</tr>
<tr>
<td>Less skilled\textsuperscript{a,s}</td>
<td>3.10 (1)</td>
<td>3.13 (1)</td>
</tr>
</tbody>
</table>

h. Workers who have been
with the firm for a long time
have learned how the firm
operates and have formed
relationships with coworkers
and clients. A cut in wages
may cause some of your
long-time employees to
leave, and their
replacements would not
have this inside knowledge
of the firm.

<table>
<thead>
<tr>
<th></th>
<th>Average score</th>
<th>Percentage ranking each</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Business Week</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-collar\textsuperscript{a,**}</td>
<td>2.85 (3)</td>
<td>2.81 (3)</td>
</tr>
<tr>
<td>Blue-collar\textsuperscript{a,sm,*}</td>
<td>2.50 (5)</td>
<td>2.35 (8)</td>
</tr>
<tr>
<td>Less skilled\textsuperscript{a,sm}</td>
<td>2.24 (5)</td>
<td>2.05 (9)</td>
</tr>
</tbody>
</table>
2. Below is a list of some things that economists believe may be important in keeping workers from slacking off on the job.

a. high unemployment  
b. high wages  
c. good management-worker relationships  
d. good working conditions  
e. close supervision by supervisors

Please indicate below which of these factors are the most important in keeping your workers from slacking off on the job.

<table>
<thead>
<tr>
<th></th>
<th>Average score</th>
<th>% responding most important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WC</td>
<td>BC</td>
</tr>
<tr>
<td>High unemployment</td>
<td>1.27</td>
<td>1.21</td>
</tr>
<tr>
<td>High wages</td>
<td>2.92</td>
<td>3.10</td>
</tr>
<tr>
<td>Good management-worker relationships</td>
<td>4.39</td>
<td>3.96</td>
</tr>
<tr>
<td>Good working conditions</td>
<td>2.82</td>
<td>2.74</td>
</tr>
<tr>
<td>Close supervision by supervisors</td>
<td>0.53</td>
<td>0.86</td>
</tr>
</tbody>
</table>
These various pieces of evidence together suggest efficiency wage considerations are important. Nevertheless they do not indicate whether these efficiency wages are the main reason why wages are higher than market-cleaning levels and unemployment is high either in the U.S. or in Europe. Such investigation requires more aggregate evidence.

3. Efficiency Wages, Monitoring and Corporate Structure

Next consider a simple model where we use the ideas of efficiency wages for think about the corporate structure.

3.1. Basic model. For simplicity, take corporate structure to be the extent of monitoring (e.g., number of supervisors to production workers).

Consider a one-period economy consisting of a continuum of measure $N$ of workers and a continuum of measure 1 of firm owners who are different from the workers.

Each firm $i$ has the production function $AF(L_i)$.

Differently from the Shapiro-Stiglitz model, let the probability of catching a shirking worker be endogenous. In particular,

$q_i = q(m_i)$ where $m_i$ is the degree of monitoring per worker by firm $i$;

the cost of monitoring for firm $i$ which hires $L_i$ workers is $sm_iL_i$.

[...For example, $m_i$ could be the number of managers per production worker and $s$ as the salary of managers...].

Since there is a limited liability constraint, workers cannot be paid a negative wage, and the worst thing that can happen to a worker is to receive zero income. Since all agents are risk-neutral, without loss
of generality, restrict attention to the case where workers are paid zero when caught shirking.

Therefore, the incentive compatibility constraint of a worker employed in firm $i$ can be written as:

$$w_i - e \geq (1 - q_i)w_i.$$ 

If the worker exerts effort, he gets utility $w_i - e$, which gives the left hand side of the expression. If he chooses to shirk, he gets caught with probability $q_i$ and receives zero. If he is not caught, he gets $w_i$ without suffering the cost of effort. This gives the right hand side of the expression.

Notice an important difference here from the Shapiro-Stiglitz model. Now if the worker is caught shirking, he does not receive the wage payment.

Firm $i$’s maximization problem can be written as:

$$\max_{w_i, L_i, q_i} \Pi = AF(L_i) - w_iL_i - sm_iL_i$$

subject to:

$$w_i \geq \frac{e}{q(m_i)}$$

$$w_i - e \geq u$$

The first constraint is the incentive compatibility condition rearranged. The second is the participation constraint where $u$ is the ex ante reservation utility (outside option) of the worker; in other words, what he could receive from another firm in this market.
The maximization problem (3.1) has a recursive structure: $m$ and $w$ can be determined first without reference to $L$ by minimizing the cost of a worker $w + sm$ subject to (3.2) and (3.3); then, once this cost is determined, the profit maximizing level of employment can be found. Each subproblem is strictly convex, so the solution is uniquely determined, and all firms will make the same choices: $m_i = m$, $w_i = w$ and $L_i = L$. In other words, the equilibrium will be symmetric.

Another useful observation is that the incentive compatibility constraint (3.2) will always bind [...] If the incentive compatibility constraint, (3.2), did not bind, the firm could lower $q$, and increase profits without affecting anything else. This differs from the simplest moral hazard problem with fixed $q$ in which the incentive compatibility constraint (3.2) could be slack...]

By contrast, the participation constraint (3.3) may or may not bind—hence there can be rents for workers as in the Shapiro-Stiglitz model. The comparative statics of the solution have a very different character depending on whether it does. The two situations are sketched in the figures.

(1) When (3.3) does not bind, the solution is characterized by the tangency of the (3.2) with the per-worker cost $w + sm$.

Call this solution $(w^*, m^*)$, where:

$$\frac{eq'(m^*)}{(q(m^*))^2} = s \text{ and } w^* = \frac{e}{q(m^*)}.$$  

(3.4)

In this case, because the participation constraint (3.3) does not bind, $w$ and $m$ are given by (3.4) and small changes in $u$ leave these variables unchanged.
(2) In contrast, if (3.3) binds, \( w \) is determined directly from this constraint as equal to \( u + e \), and an increase in \( u \) causes the firm to raise this wage. Since (3.2) holds in this case, the firm will also reduce the amount of information gathering, \( m \).

Participation Constraint is Slack.
Participation Constraint is Binding.
Participation Constraint is Slack.
Participation Constraint is Binding.

What determines whether (3.3) binds?

Let $\hat{w}$ and $\hat{m}$ be the per-worker cost minimizing wage and monitoring levels (which would not be equal to $w^*$ and $m^*$ when (3.3) binds). Then, labor demand of a representative firm solves:

$$AF'(\hat{L}) = \hat{w} + \hat{m}.$$  

(3.5)

Next, using labor demand, we can determine $u$, workers’ *ex ante* reservation utility from market equilibrium. It depends on how many jobs there are. If aggregate demand $\hat{L}$ is greater than or equal to $N$, then a worker who turns down a job is sure to get another. In
contrast, if aggregate demand $\hat{L}$ is less than $N$, then a worker who turns down a job may end up without another. In particular, in this case, $u = \frac{\hat{L}}{N}(\hat{w} - e) + (1 - \frac{\hat{L}}{N})z$, where $z$ is an unemployment benefit that a worker who cannot find a job receives.

When $\hat{L} = N$, there are always firms who want to hire an unemployed worker at the beginning of the period, and thus $u = \hat{w} - e$. If there is excess supply of workers, i.e. $\hat{L} < N$, then firms can set the wage as low as they want, and so they will choose the profit maximizing wage level $w^*$ as given by (3.4). In contrast, with full employment, firms have to pay a wage equal to $u + e$ which will generically exceed the (unconstrained) profit maximizing wage rate $w^*$. Therefore, we can think of labor demand as a function of $u$, the reservation utility of workers: firms are “utility-takers” rather than price-takers. The figures show the two cases; the outcome depends on the state of labor demand. More important, the comparative statics are very different in the two cases.

3.2. Comparative statics. First, consider a small increase $A$ and suppose that (3.3) is slack. The tangency between (3.2) and the per worker cost is unaffected. Therefore, neither $w$ nor $m$ change. Instead, the demand for labor shifts to the right and firms hire more workers. As long as (3.3) is slack, firms will continue to choose their (market) unconstrained optimum, $(w^*, m^*)$, which is independent of the marginal product of labor. As a result, changes in labor demand do not affect the organizational form of the firm.
3. EFFICIENCY WAGES, MONITORING AND CORPORATE STRUCTURE

If instead (3.3) holds as an equality, comparative static results will be different. In this case, (3.2), (3.5), and \( L = N \) jointly determine \( \hat{q} \) and \( \hat{w} \). An increase in \( A \) induces firms to demand more labor, increasing \( \hat{w} \). Since (3.2) holds, this reduces \( \hat{q} \) as can be seen by shifting the PC curve up. Therefore, when (3.3) holds, an improvement in the state of labor demand reduces monitoring. The intuition is closely related to the fact that workers are subject to limited liability. When workers cannot be paid negative amounts, the level of their wages is directly related to the power of the incentives. The higher are their wages, the more they have to lose by being fired and thus the less willing they are to shirk.

Next, suppose that government introduces a wage floor \( w \) above the equilibrium wage (or alternatively, unions demand a higher wage than would have prevailed in the non-unionized economy). Since the incentive compatibility constraint (3.2) will never be slack, a higher wage will simply move firms along the IC curve in the figure and reduce \( m \). However, this will also increase total cost of hiring a worker, reducing employment.

Can this model be useful in thinking about why the extent of monitoring appears to be behaving differently in continental Europe and the U.S.?
3.3. Welfare. Consider the aggregate surplus $Y$ generated by the economy:

\begin{equation}
Y = AF(L) - smL - eL,
\end{equation}

where $AF(L)$ is total output, and $eL$ and $smL$ are the (social) input costs.

In this economy, the equilibrium is constrained Pareto efficient: subject to the informational constraints, a social planner could not increase the utility of workers without hurting the owners. But total surplus $Y$ is never maximized in laissez-faire equilibrium. This is because of the following reason: if we can reduce $q$ without changing $L$, then $Y$ increases. A tax on profits used to subsidize $w$ relaxes the incentive
constraint (3.2) and allows a reduction in monitoring. Indeed, the second-best allocation which maximizes \( Y \) subject to (3.2) would set wages as high as possible subject to zero profits for firms. Suppose that the second-best optimal level of employment is \( \tilde{L} \), then we have:

\[
\tilde{w} + sq^{-1}\left(\frac{e}{\tilde{w}}\right) = \frac{AF(\tilde{L})}{\tilde{L}}
\]

In this allocation, all firms would be making zero-profits; since in the decentralized allocation, due to decreasing returns, they are always making positive profits, the two will never coincide.

A different intuition for why the decentralized equilibrium fails to maximize net output is as follows: part of the expenditure on monitoring, \( smL \), can be interpreted as “rent-seeking” by firms. Firms are expending resources to reduce wages — they are trying to minimize the private cost of a worker \( w + sm \) — which is to a first-order approximation, a pure transfer from workers to firms. A social planner who cares only about the size of the national product wants to minimize \( e + sm \), and therefore would spend less on monitoring. Reducing monitoring starting from the decentralized equilibrium would therefore increase net output.
1. The Basic Search Model

An alternative approach is the search-matching model, or the flow approach to the labor market. Here the basic idea is that there are frictions and the labor market, making it costly (time-continuing) for workers to find firms and vice versa. This will lead to what is commonly referred to as “frictional unemployment”. However, as soon as there are these types of frictions, there are also quasi-rents in the relationship between firms and workers, and there will be room for rent-sharing. In the basic search model, the main reason for high unemployment may not be the time costs of finding partners, but bargaining between firms and workers which leads to non-market-clearing equilibrium prices.

Here is a simple version of the basic search model.

1.1. The matching side. The first important object is the matching function, which gives the number of matches between firms and workers as a function of the number of unemployed workers and number of vacancies.

Matching Function: \[ \text{Matches} = x(U, V) \]

We typically assume that this matching function exhibits constant returns to scale (CRS), that is,
Matches \( = xL = x(uL, vL) \)
\[ \implies x = x(u, v) \]

\( U = \) unemployment; \( u = \) unemployment rate
\( V = \) vacancies; \( v = \) vacancy rate (per worker in labor force)
\( L = \) labor force

Existing aggregate evidence suggests that the assumption of \( x \) exhibiting CRS is reasonable (Blanchard and Diamond, 1989, Pissarides, 1986)

Using the constant returns assumption, we can express everything as a function of the tightness of the labor market.

Therefore; \( q(\theta) \equiv x \left( \frac{u}{v}, 1 \right) \);

where \( \theta \equiv v/u \) is the tightness of the labor market

\( q(\theta) : \) Poisson arrival rate of match for a vacancy
\( q(\theta)\theta : \) Poisson arrival rate of match for an unemployed worker

Take a short period of time \( \Delta t \)

\[ \implies 1 - \Delta t q(\theta) : \text{probability that a worker looking for a job will not find one during } \Delta t \]

\[ \implies \text{depends on } \theta, \text{thus a key to externality—the search behavior of others affects my own job finding rate.} \]

Job creation: \( u.\theta q(\theta).L \)
Job Destruction: \( \rightarrow \text{Adverse Shock} \rightarrow \text{destroy} \)
Exogenous Job Destruction: Adverse shock = $-\infty$ with "probability" $s$

Steady State:

flow into unemployment = flow out of unemployment

Therefore:

\[ s(1 - u) = \theta q(\theta)u \]

This gives the steady-state unemployment rate as

\[ u = \frac{s}{s + \theta q(\theta)} \]

This relationship is sometimes referred to as the Beveridge Curve.

1.2. The production side. $AF(K, L)$: where the production function $F$ is assumed to exhibit constant returns.

$Af(k) \equiv AF\left(\frac{K}{L}, 1\right)$

Two interpretations $\rightarrow$ each firm is a "job" hires one worker each firm can hire as many worker as it likes

Hiring: Vacancy costs $\gamma_0$: fixed cost of hiring $r$: cost of capital $\delta$: depreciation

ASSUMPTION: Capital Perfectly Reversible

Asset Value Equations
\(J^V\): PDV of a vacancy

\(J^F\): PDV of a "job"

\(J^U\): PDV of a searching worker

\(J^E\): PDV of an employed worker

Worker utility: \(EU_0 = \int_0^\infty e^{-Rt} U(c_t)\)

Utility \(U(c) = c\) Linear utility, so agents are risk-neutral

Perfect capital market gives the asset value for a vacancy (in steady state) as

\[rJ^V = -\gamma_0 + q(\theta)(J^F - J^V)\]

Intuitively, there is a cost of vacancy equal to \(\gamma_0\) at every instant, and the vacancy turns into a filled job at the flow rate \(q(\theta)\).

Notice that in writing this expression, I have assumed that firms are risk neutral. Why?

\[\rightarrow\] workers risk neutral, or

\[\rightarrow\] complete markets

Endogenous Job Creation : Free Entry \(\Rightarrow J^V \equiv 0\)

Note: No limit to fast job creation except through matching

Alternative would be: \(\gamma_0 = \Gamma_0(V)\) or \(\Gamma_1(\theta)\), so as there are more and more jobs created, the cost of opening an additional job increases.

Free entry implies that

\[J^F = \frac{\gamma_0}{q(\theta)}\]
Next, we can write another asset value equation for the value of a field job:

\[ r(J^F + k) = Af(k) - \delta k - w - s(J^F - J^V) \]

Intuitively, the firm has two assets: the fact that it is matched with a worker, and its capital, \( k \). So its asset value is \( J^F + k \) (more generally, without the perfect reversability, we would have the more general \( J^F(k) \)). Its return is equal to production, \( Af(k) \), and its costs are depreciation of capital and wages, \( \delta k \) and \( w \). Finally, at the rate \( s \), the relationship comes to an end and the firm loses \( J^F \).

Perfect Reversability implies that \( w \) does not depend on the firm’s choice of capital

\[ \implies \text{equilibrium capital utilization } f'(k) = r + \delta \implies \text{Modified Golden Rule} \]

[...Digression: Suppose \( k \) is not perfectly reversible. Then the wage depends on the capital stock of the firm.

\[ w(k) = \beta Af(k) \]

\[ Af'(k) = \frac{r + \delta}{1 - \beta} ; \text{capital accumulation is distorted} \]

...]

Now

\[ Af(k) - (r - \delta)k - w - \frac{(r + s)}{q(\theta)} \gamma_0 = 0 \]
Now returning to the worker side, the risk neutrality of workers gives

\[ rJ^U = z + \theta q(\theta)(J^E - J^U) \]

where \( z \) is unemployment benefits. The intuition for this equation is similar. We also have

\[ rJ^E = w + s(J^U - J^E) \]

Solving these equations we obtain

\[
\begin{align*}
    rJ^U &= \frac{(r + s)z + \theta q(\theta)w}{r + s + \theta q(\theta)} \\
    rJ^E &= \frac{sz + [r + \theta q(\theta)] w}{r + s + \theta q(\theta)}
\end{align*}
\]

1.3. **Wage determination.** Wage Determination is given by Nash Bargaining over a quasi-rents due to frictions.

For pair i:

\[
\begin{align*}
    rJ_i^F &= Af(k) - (r + \delta)k - w_i - sJ_i^F \\
    rJ_i^E &= w_i - s(J_i^E - J_i^U) \\
    \max(J_i^E - J_i^U)^\beta(J_i^F - J^V)^{1-\beta} \\
    \beta &= \text{bargaining power of the worker}
\end{align*}
\]

Linear Utility \( \implies \) transferable utility

\[
\begin{align*}
    \implies J_i^E - J_i^U &= \beta(J_i^F + J_i^E - J^V - J^U) \\
    \implies w &= (1 - \beta)z + \beta[Af(k) - (r + \delta)k + \theta \gamma_0]
\end{align*}
\]
Here \([Af(k) - (r + \delta)k + \theta \gamma_0]\) is the quasi-rent created by a match that the firm and workers share.

1.4. Steady-state equilibrium. Steady State Equilibrium is given by four equations

\[ (1) \quad u = \frac{s}{s + bq(\theta)} \]

\[ (2) \quad Af(k) - (r + \delta)k - w - \frac{(r+s)}{q(\theta)} \gamma_0 = 0 \]

\[ (3) \quad w = (1 - \beta) z + \beta [Af(k) - (r + \delta)k + \theta \gamma_0] \]

\[ (4) \quad Af'(k) = r + \delta \]

These four equations define a recursive system

\[ (4) + r \rightarrow k \]

\[ k + r + (2) + (3) \rightarrow \theta, v \]

\[ \theta + (1) \rightarrow u \]

Alternatively, combining three of these equations we obtain the zero-profit locus, the VS curve, and combine it with the beverage curve. More specifically,

\[ (2), (3), (4) \Rightarrow \text{the VS curve} \]

\[ (1 - \beta) [Af(k) - (r + \delta)k - z] - \frac{r + \delta + \beta \theta q(\theta)}{q(\theta)} \gamma_0 = 0 \]

Steady State Comparative Statistics

\[ s \uparrow \quad U \uparrow \quad V \uparrow \quad \theta \downarrow \quad w \downarrow \]
Question: how is the decline in unemployment as a result of the increase in $A$ consistent with balanced growth?