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Effort and Wages
A New Look at the Interindustry Wage Differentials

Edward E. Leamer and Christopher F. Thornberg

2.1 Introduction

The purpose of this paper is to provide empirical support for the theory of effort in a multisector model developed in Leamer (1999). That theory is built on the familiar idea that a firm can contract with workers regarding both the wage level and the working conditions. Those features of the labor contract that enhance productivity but are disliked by workers are called "effort" and the labor market thus offers a set of wage-effort contracts with higher wages offsetting higher effort. If effort does not affect capital depreciation, the high-effort high-wage jobs occur in the capital-intensive sectors where the capital cost savings from high effort are greatest.

Among the implications of this theory are that communities inhabited by industrious workers who are willing to exert high effort for high wages have high returns to capital, and that minimum wage does not cause unemployment—it forces effort in the low-effort low-wage contracts up enough to support the higher wage. These and many other aspects of the model of endogenous effort are discussed in Leamer (1999). In this paper we focus on two implications: (1) The capital savings from effort are greatest in the capital-intensive sector, which is where the high-wage high-effort contracts occur; and (2) price declines in labor-intensive goods twist the wage-effort offer curve, lowering the compensation for low-effort work,

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but increasing the marginal return for hard work. Thus, increased competition with the developing economies adversely affects the low-effort workers who find themselves having to work harder to maintain their standard of living; high-effort workers may be made better off by the increased marginal compensation for effort in high-wage high-effort jobs in the capital-intensive sectors.

We find empirical support for both of these hypotheses. We show that there is a surprisingly clear relationship among effort, wages, and capital intensity, with the higher capital intensity of the sector associated with both higher wages and higher effort. We find a twisting of the wage-effort offer curve in the 1970s, which we (somewhat casually) associate with increased globalization.

The obvious and possibly insurmountable problem that we face is how to measure effort, the hours of operation multiplied by the intensity of use. We have no measurement of job intensity, which is not merely the speed of operations, but also the attentiveness and willingness of the worker to take risks, and any other intangibles that raise productivity without increasing capital costs. Lacking any obvious measure of job intensity, we take a first step in the direction of least resistance and use production workers' annual hours as our indicator of effort. We are thereby acting as if intensity is not so negatively correlated with hours that there is no relationship between hours and effort.

Given the measurement difficulties, we should not expect much. The big surprise is that there is a remarkably clear relationship among hours, wages, and capital intensity. The capital-intensive sectors have longer annual hours and higher hourly wage rates, exactly what the theory would suggest if hours were a perfect indicator of effort. Not only do we find a wage-effort offer curve; we also find it shifting just as the theory suggests. In the 1960s, with stable relative prices but improving technologies, the curve shifts upward with higher real wages offered at every level of effort. Starting in the mid-1970s, when the relative prices of apparel and footwear and textiles and other labor-intensive goods fell substantially, the offer curve twists, with wages falling for low-effort contracts, but rising for high-effort contracts. In the 1980s, the curve began shifting to the right, with more hours required to attain any given level of earnings. The theory allows this last shift to be due either to the introduction of new machinery (computers) or to a rise in fixed costs other than capital, namely benefits.

The relationship between wages and capital intensity has been discussed in the efficiency wage literature, including papers by Dickens and Katz (1987), Katz and Summers (1989), and Krueger and Summers (1987). We view the correlation between wages and capital intensity through an entirely different theoretical lens. Empirically, the innovation of this paper is the discovery of a strong correlation between weekly hours and capital intensity.

One surprising feature of the U.S. wage-effort offer curve is that it bends backward in the early years of the sample, with the highest wages offered in sectors with relatively low effort (as measured by hours). The two-digit-level names of these unusual sectors are transportation, primary metals, and printing and publishing. These names indicate to us union effects. A union effect on wages can come from market power in the product market, since it allows producers to pass on higher costs to consumers who have nowhere else to go. Beginning in the 1970s, consumers did have somewhere else to go: auto imports from Japan and steel imports from a variety of countries. The erosion of union power seems evident in the wage-effort offer curve as the transportation and primary metal sectors increase their hours to conform more closely to the wage-hour contracts offered in other sectors. But our measure of unionization is not able to account completely for this backward-bending portion of the wage-effort offer curve. This may be due to the poor quality of the unionization data.

The most likely alternative explanation for the correlation between wages and capital intensity is the complementarity of human and physical capital. We include measures of human capital as well as rate of unionization in our equations that explain wages and hours. Unionization and education both have positive simple correlations with weekly wages and weekly hours. Controlling for capital intensity of the sector, both education and union membership have a positive and statistically significant effect on wages, but do not have a measurable effect on hours. Even after controlling for education and unionization, there remains strong evidence of the positive relationship between wages and effort that we are looking for.

Another possible explanation for the apparent wage-effort offer curve is rent sharing, with rents especially high in capital-intensive sectors. We explore this possibility by using an imperfect measure of industry rents and do not find that rents can explain away our findings.

Our analysis could be contaminated by business-cycle effects. The first response to a slowdown in sales is a reduction in hours, and only when the slowdown is judged to be long-lived is there a reduction in employment. Then when sales begin to grow again, the first response is to increase hours, followed later by an increase in employment. The variation in employment causes opposite variation in capital per worker because capital is a very slow moving series. This cycle in hours and capital per worker causes us concern about our choice of years for estimating the wage-effort offer curve, since the movements in the curve over time may be mostly due to the cycle. We control for the cycle by estimating the wage-effort offer curve at business-cycle peaks and business-cycle troughs and then comparing peak with peak and trough with trough.

The theory that drives the data analysis concerns the demand for labor, but the market, of course, has to have a supply side as well. We briefly explore one labor-supply variable, gender. We find what is already rather well known: Females are more likely to be employed in low-effort low-wage sectors.

In section 2.2, we review pertinent aspects of the theory offered in Leamer (1999). Also in section 2.2, we summarize the related literature. We argue that we offer a unique theoretical viewpoint that is distinct from the efficiency-wage literature and that leads us to derive an entirely new equation that explains hours as a function of the capital intensity of the sector. In section 2.3 we discuss graphical displays of the two-digit Standard Industrial Classification (SIC) data on hours and wages. These displays conform remarkably well with the theory. The capital-intensive sectors have long hours and high hourly wage rates. We also present a formal analysis at the four-digit level that backs up what is evident in the two-digit displays. Finally, we offer some summary and concluding remarks in section 2.4.

2.2 Theoretical Two-Sector Model

This section reviews Leamer's (1999) two-sector model with endogenous effort. The key building block is a production function defined as

$$Q = s \cdot h \cdot f(K,L) \equiv e \cdot f(K,L), \qquad (1)$$

where Q is the rate of output per unit of time, K and L are the (timeless) stocks of capital and labor inputs respectively, $f(\cdot,\cdot)$ is a function homogeneous to degree one, s is the intensity of operation, h is the hours of operation, and $e = s \cdot h$ is the overall effort exerted by each worker. Intensity is influenced by speed of operations, but also includes the level of care or attentiveness a worker must exert to reduce the likelihood of breakdowns and other costly delays in the production process.

We make two additional assumptions about effort. First, we assume that labor cares about effort, but capital does not. In other words, long hours at high speed will not wear out equipment any faster than short hours at slow speed. Second, we assume that effort is continuous and completely variable, which is an assumption that affects the details but not the basic message of the model.[1] For generating most of the diagrams, we assume that each sector has fixed input technologies and the production function takes the form

1. There is a substantial literature built on the assumption that capital does care—that increased use causes increased depreciation. A recent working paper by Auernheimer and Rumbos (1996) includes many references, among them Calvo (1975) and Bischoff and Kokkelenberg (1987). This literature typically uses a one-sector model and focuses on intertemporal capital use questions. This paper, instead, emphasizes sectoral differences. Deardorff and Stafford (1976) provide another framework that allows both capital and labor to care about the pace and hours of operation. They write output proportional to the hours of operation and explore the coordination problem between two inputs that have different preferences regarding hours of work.

(2) $$Q_i = e_i \cdot \min\left(\frac{L}{A_{Li}}, \frac{K}{A_{Ki}}\right),$$

where e_i is the effort level in sector i, and K and L are the capital and labor inputs. With the assumption that depreciation does not depend on worker effort, a competitive labor market will award any marginal increase in output from greater effort to the workers. Expressed differently, it is as if the workers rented the capital equipment and received the excess earnings as compensation for the effort they decide to exert. The (net) wage rate $w_i(e_i)$ applicable to effort e can be found from the zero-profit condition $p_i \cdot e_i \cdot f(K,L) = w_i(e_i) \cdot L = r \cdot K$, where r is the rental rate of capital and p_i is the price of the product.[2] Inserting the labor and capital inputs and output levels into the zero-profit condition and dividing by total output determines the set of zero-profit wage-effort contracts in sector i,

(3) $$\frac{w_i}{P} = \frac{p_i \cdot e_i}{P \cdot A_{Li}} - \frac{r \cdot A_{Ki}}{P \cdot A_{Li}},$$

where P is an overall price index. The wage-effort zero-profit lines for two sectors are illustrated in figure 2.1.

Both zero-profit lines in figure 2.1 have negative intercepts, since at very low levels of effort the value of the output is not large enough to cover capital rental costs. Since the capital costs in the capital-intensive sector are higher, the intercept is more negative. As the effort increases, workers can be awarded higher wages in both sectors.[3] The observed labor contracts will lie along the upper envelope of these wage-effort offer curves, highlighted as the heavy curve depicted in figure 2.1. The marginal return to effort has to be lower in the labor-intensive sector, since otherwise there would be no attractive contracts in the capital-intensive sector. These intercepts and slopes dictate that the low-effort low-wage contracts are offered in the labor-intensive sector while high-wage high-effort contracts are offered in the capital-intensive sector. Also depicted in figure 2.1 is an indifference curve tangent to the wage-effort offer curve at two points. This represents an equilibrium with identical workers who are indifferent between the two prevailing contracts, high-effort high-wage and low-effort low-wage.

High effort saves capital costs. These savings are offset by the wage premiums necessary to compensate workers for high levels of effort. Multiple

2. Note that the rental rate of capital could also be considered to include depreciation expenses.

3. Average capital cost is $AC_K = (r \cdot K)/(q \cdot e)$, where q is the level of output when $e = 1$. The capital cost savings of effort is $\partial AC_K/\partial e = -(r \cdot K)/(q \cdot e^2)$, clearly larger at any one specific level of effort e for industries with a greater overall capital cost per worker. These cost savings are offset by the marginal increase in wages necessary to compensate workers' for their additional efforts.

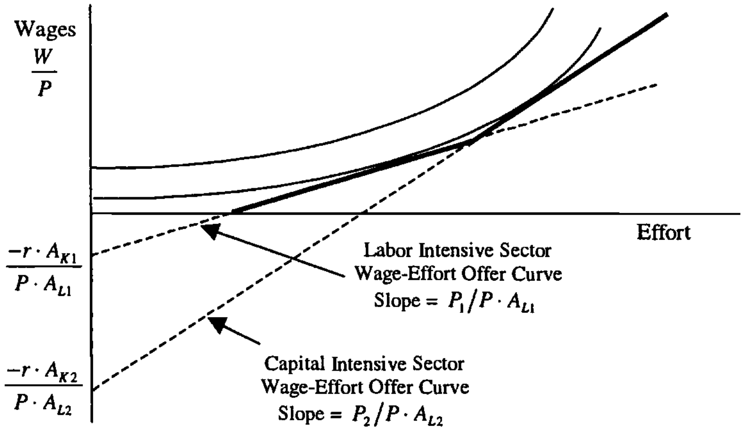

Fig. 2.1 Equilibrium in a two-sector model with fixed input technologies

shifts and other forms of capital sharing can also save capital costs. When two workers share the same capital, the intercept of the zero-profit line for each worker shifts upward toward the origin by a factor of two. This allows firms to offer better wage-effort contracts. But capital sharing does not come without costs. Among the costs of capital sharing are wage premia for the second and graveyard shifts, transitional downtimes, and increased noncapital fixed costs, such as training and benefits, as well as moral hazard problems and coordination costs. Competition among firms will lead to efficient work practices that optimally trade off the gains from capital sharing with the costs.

2.2.1 Endogenous Effort with Cobb-Douglas Technologies

If the capital/labor ratio in a sector is not fixed technologically, the wage-effort offer curve loses its flat segments, but otherwise there is no material change in the model. For example, a Cobb-Douglas production function is

(4) $$q = e \cdot k^{\beta},$$

where q is output per worker, k is the capital used by each worker, and β is the capital intensity. The optimal level of capital is determined by setting the marginal revenue product of capital equal to the capital rental rate r.

(5) $$\beta \cdot p \cdot e \cdot k^{\beta-1} = r \Rightarrow k = \left(\frac{r}{p \cdot e \cdot \beta}\right)^{1/(\beta-1)}.$$

Since capital's marginal rate of productivity changes with the level of effort, the optimal level of capital inputs varies with the level of effort.

Substituting equation (4) for q and (5) for k in the zero-profit condition, $w = p \cdot q - r \cdot k$, we find that the sector wage-effort offer curve becomes

$$(6) \qquad w = p^{1/(1-\beta)} \cdot e^{1/(1-\beta)} \cdot r^{-\beta/(1-\beta)} \cdot (\beta^{\beta/(1-\beta)} - \beta^{1/(1-\beta)}).$$

This sets wage offers proportional to effort raised to a power that exceeds one and that increases with the capital intensity of the sector. A two-sector equilibrium with Cobb-Douglas production functions is displayed in figure 2.2. It is very similar to the equilibrium in figure 2.1. In fact, it is easy to demonstrate that if the line tangent to the offer curves was traced back to the y-axis, the intercept would be the negative cost of capital, $r \cdot k$.

2.2.2 Changes in Product Prices

A change in the relative price in the two sectors twists the wage-effort offer curve. Figure 2.3 depicts the initial effect of a simultaneous rise in p_2 and fall in p_1 that leaves the overall price level P constant. What this does is rotate upward the wage-effort offer line in the capital-intensive sector and rotate downward the wage-effort offer line in the labor-intensive sector. These changes render the low-effort low-wage contract in the labor-intensive sector less attractive and cause income and substitution effects in opposite directions for the two contracts. The high-wage workers experience a favorable income effect and a substitution effect in favor of higher effort (steeper wage-effort offer line). The low-wage workers experience an unfavorable income effect and a substitution effect in favor of lower effort.

With identical workers, this cannot be an equilibrium because capital constraints do not allow all workers to operate in the preferred capital-intensive sector. An increase in the capital-rental rate would be needed to ration the consequent excess demand for capital. This rise in the rental rate of capital shifts both wage-effort offer lines downward. Both the initial

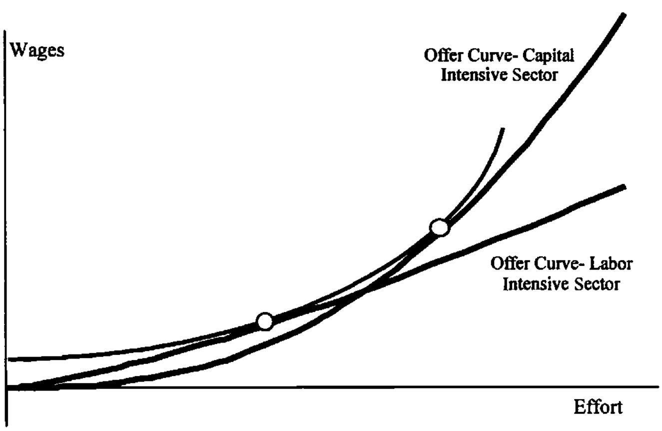

Fig. 2.2 Wage-effort offer curve with Cobb-Douglas production function

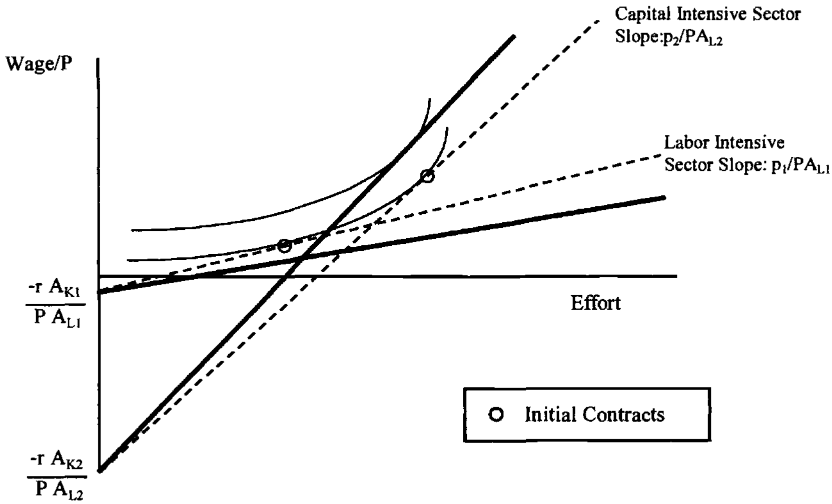

Fig. 2.3 Initial effect of a rise in the relative price of the capital-intensive tradable

rotation and the shift downward worsen the terms of the low-wage low-effort contract, and it follows that the final equilibrium selects a lower worker-indifference curve for the representative worker. The negative income effect that shifts the contracts to a lower indifference curve will also cause lower wages and higher effort in both sectors, provided that both leisure and consumption goods are normal. There is also a substitution effect that tends to drive the contracts in opposite directions; the low-effort low-wage contract shifts in favor of lower effort and lower wages, and the high-effort high-wage contract shifts in favor of higher wages and higher effort. Thus a rise in the relative price of the capital-intensive good makes workers worse off and increases income inequality. Keep in mind that the workers are indifferent between the two contracts and there is no real inequality in the model. The principal message is that the wage-effort offer curve twists, as shown in figure 2.4. We find this kind of twisting in the 1970s.

2.2.3 Heterogeneous Workers

The model presented here can easily be amended to allow for variation in workers' attitudes toward effort. This change has little impact on our empirical work, since we are studying the demand side of the labor market wage-effort offer curve, not the choices that workers make from among the offered contracts. In a model with heterogeneous preferences, materialistic workers who have a relative preference for goods over leisure would take the high-effort high-wage jobs, while humanistic workers who prefer leisure would take the low-effort low-wage work. Heterogeneity in labor

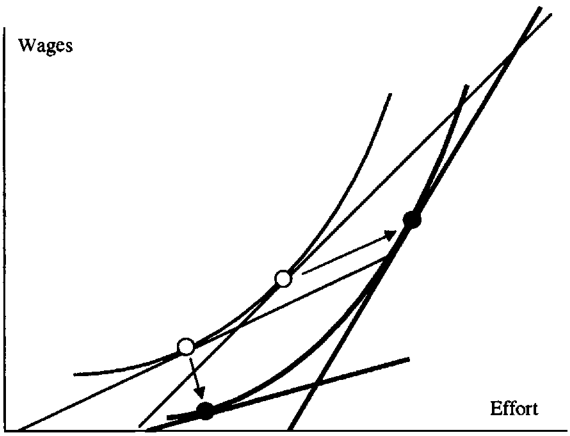

Fig. 2.4 Twisting of the market wage-effort offer curve (market response to relative price change)

supply does not affect how we study the demand side of the market very much, but this form of heterogeneity is important from a policy standpoint. The twisting of the offer curve caused by declines in the relative price of labor-intensive goods may have an adverse affect on the utility level of the humanists, but a favorable effect on the materialists. In other words, the welfare effects of changes in economic fundamentals such as relative prices may vary across groups of workers.

However, heterogeneity in ability is a serious problem for our empirical analysis. If the ability to operate expensive machinery varies across individuals, it is possible to have the more-able workers receiving high wages for low effort in the capital-intensive sectors, while the less-able workers work hard for low pay in the labor-intensive sectors. This would seriously affect our attempts to uncover the offer curve from observed contracts. We partially allow for this by including in the empirical analysis measures of education.

2.2.4 Technological Change

This subsection discusses the effect of technological change on the wage-effort offer curve. The debate regarding the increase in inequality in the United States has focused on two culprits, globalization and technological change. We have shown that globalization, taking the form of price declines for labor-intensive goods, twists the wage-effort offer curve. It is an unfortunate but familiar outcome that technological change can have almost the same effect. We would have liked in this paper to have made a substantial effort to disentangle technological effects from globalization effects, but that task requires direct indicators of both technological

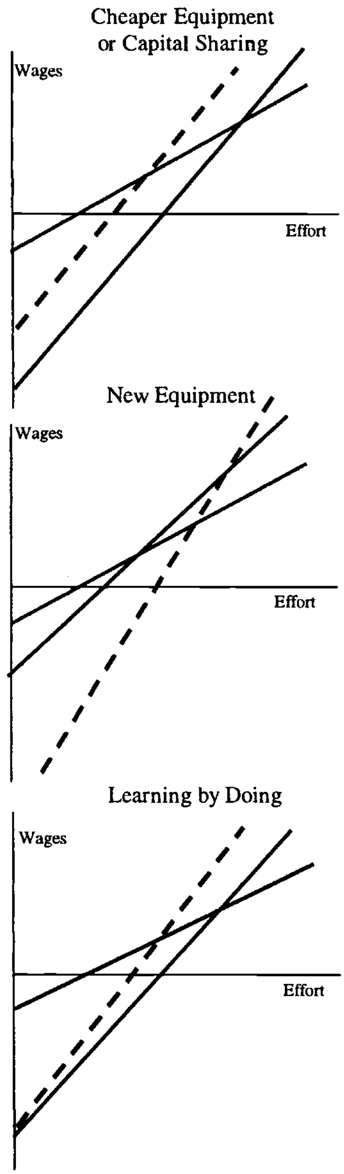

Fig. 2.5 Effect of technological change on wage-effort offer curve

change and globalization. When we occasionally slip into interpreting a certain twist of the wage-effort offer curve as a globalization effect or a technological effect, we do so loosely and based on information not contained in this paper.

Figure 2.5 depicts an initial wage-effort offer curve and the first changes that are induced by three distinct kinds of technological change in the capital-intensive sector: a reduction in the rental cost of existing equipment, the introduction of new, more costly equipment, and learning by doing. A reduction in the rental cost of the existing equipment simply shifts the intercept upward of the wage-effort offer line applicable to the capital-intensive sector, as indicated by the positioning of the new wage-effort offer line (the dashed black line). New more costly equipment creates a new wage-effort offer line that has a lower intercept but a steeper slope—meaning that the rental cost of the equipment is greater, but the productivity is higher. Learning by doing does not affect the rental cost, but it increases the productivity. Thus the intercept stays the same, but the slope increases.

These first effects of new technology create better jobs in the capital-intensive sector, and the economy in each case would have to experience an increase in the capital-rental rates (interest rate) to ration the capital and encourage workers to stick with jobs in the labor-intensive sector. This is the usual general equilibrium story. Capital is helped or hurt depending on whether the technological change is in the capital or labor-intensive sector. Unlike the usual case, labor here has a mixed experience. Before the rental rate of capital is bid up, each of the figures shows an improvement in the high-wage high-effort contracts. When the rental rate of capital is bid up to equilibrate the capital market, the wage-effort offer curve shifts downward across the board. This means that the low-effort low-wage contracts are definitely hurt by whatever kind of technological change may occur in the capital-intensive sector; but it is possible, depending on labor-supply elasticities, to have net improvement in the highest-wage highest-effort jobs remaining in the final equilibrium.

Unfortunately, the twisting of the wage-effort offer curve associated with technological change is essentially the same as the twisting associated with globalization. Thus we will not get very far trying to sort trade from technology by studying only the offer curve.

2.2.5 Previous Literature

There is a substantial previous literature on hours and wages. Unlike this paper, which explores the demand side, much of the discussion of hours in labor economics is concerned with the supply side—the worker's choice of hours. The budget constraint that is often assumed to face workers has earnings proportional to hours worked. An exception is Oi (1962), who assumes that firms experience a fixed training cost for each employee hired. The fixed costs that we emphasize are not training costs, but capital-rental charges. Another fixed cost that has recently increased in importance is worker benefits paid on a per-worker basis instead of a per-hour basis. Of course, nothing theoretically hinges on what the fixed costs are—the message of the model is that both hours and hourly wage rates should be greater the greater the fixed costs.

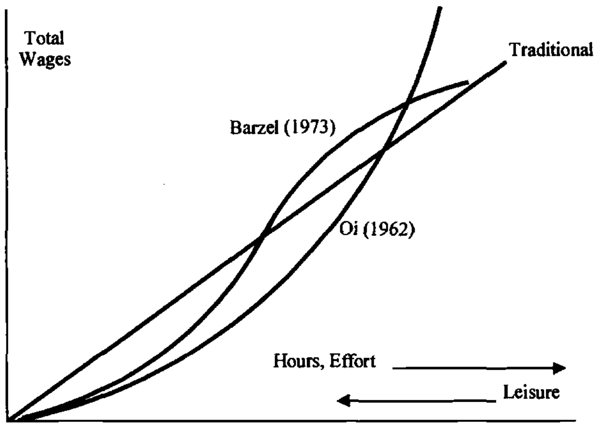

Fig. 2.6 Labor-demand functions in previous literature

Barzel (1973) adds another curved portion to the budget constraint, based on the assumption that labor productivity falls as the number of working hours increases within a fixed period of time, leading to the reversed S-shaped budget constraint cited in such empirical work as Moffit (1984). Barzel's and Oi's budget curves are displayed in figure 2.6.

There has been a substantial amount of empirical work in this field, although again most of this work has been more concerned with labor supply than labor demand. Rosen (1969) was one of the first to investigate the interindustry relationship between wages and hours. His reasoning of the apparent wage-hour trade-off was neatly summarized in his introduction: "Hours of work are an important non-pecuniary aspect of employment, even though 'industry' per se is not. On the other hand, wage and hour differences can persist because firms find certain attributes of their employees more productive and desirable than others and are willing to incur extra costs to obtain them" (250). He divides his analysis into supply and demand sides. On the demand side he, like Oi, correlates hours with the fixed costs of employing labor, including hiring costs, specific training, and unemployment-insurance premiums above the minimum levels. The demand for hours per employee is a decreasing function of the wage rate and an increasing function of these fixed costs. While he has no direct measure of these fixed costs across the industries in his sample, he derives what he believes to be suitable industry proxies from a number of demographic variables including age, education, and race. No mention of capital intensity is included in his work. He also considers short-run adjustments by including a variable to measure the sectoral growth rate and also other external effects, including unions. In general, he has more success measuring the demand side of the equation than the supply side.

On the labor-supply side are papers by Moffit (1984), Lundberg (1985), and Biddle and Zarkin (1989). These are primarily concerned with identifying the factors that influence the hours worked by individual workers, and the relationship between hours and wages as measured from the worker's perspective. They all point out that traditional ordinary least squares (OLS) wage regressions, which include hours worked as a right-hand-side variable, will not adequately measure the wage-hour relationship because of the endogeneity of hours. Biddle and Zarkin specifically control for this endogeneity and find the bias to be significant. After controlling for this bias, they find that male wages increase as a function of hours, first at an increasing and then at a decreasing rate. Less in line with our work are papers on the intertemporal behavior of hours and earnings, such as Bernanke (1986) and Abowd and Card (1987, 1989). These papers are concerned again with the supply side. Abowd and Card consider how individuals alter their hours of work over time. Bernanke is interested in how earnings and hours varied in eight industries during the Great Depression.

The efficiency-wage literature has some elements of similarity with our approach, but the differences are substantial and important. Our key variable is the capital intensity of the task—the greater the capital intensity, the greater the effort exerted by the worker. Most of the efficiency-wage theory initiated by Shapiro and Stiglitz (1984) and collected in Akerlof and Yellen (1986) makes no reference at all to the capital intensity of the operation. These efficiency-wage models are all based on the idea that firms can increase profits by raising wages above the market clearing price. These above-market wages reduce monitoring costs, since workers are induced to provide high effort by the threat of termination and thus a wage reduction.

The efficiency-wage conceptual framework is very different from ours. After controlling for ability, our framework has workers either preferring their own job or indifferent between their wage-effort contract and those contracts available to them in other jobs. The efficiency-wage theory, on the other hand, suggests that high wages reflect worker rents needed to coerce workers in the good jobs not to shirk. According to the efficiency-wage theory, workers in low-wage jobs prefer and are able to do the high-wage work, but are prevented from bidding for the better jobs in order to make the threat of firing have force in the high-wage contracts. Another important difference is that our framework has high-effort jobs in capital-intensive sectors and low-effort jobs in labor-intensive sectors. In the efficiency-wage literature, worker effort need not vary across sectors. There can be a high-effort low-wage perfectly monitored job and a high-effort high-wage imperfectly monitored job.

Empirically, the efficiency-wage literature includes one of our two fundamental equations, but not the other. Our framework explains both wages and hours as a function of capital intensity. The first equation is part of the efficiency-wage tradition; the second is not. Indeed, the efficiency-wage literature was partly instigated by the observation of the substantial differences in wages across industries. The correlation of the industry premiums with capital intensity was noted at least as far back as Slichter (1950). This has been empirically investigated in recent years in papers by Dickens and Katz (1987), Katz and Summers (1989), and Krueger and Summers (1987). The interindustry wage pattern has been shown to be steady over time and remarkably consistent across different countries. The wage premiums in the capital-intensive sectors have been attributed to variety of potential causes, including higher costs of monitoring, more inelastic labor demand, and higher cost of worker shirking (close in spirit to our own work). It has been noted that disentangling these various effects can be difficult because of the simultaneity problem, since wages and capital intensity are considered to be jointly determined.

The new empirical finding in this paper is not the well-known correlation between wages and capital intensity, but rather the correlation between weekly hours and capital intensity. This correlation may either contradict, be explained by, or complement the efficiency-wage findings, depending on other assumptions. First, consider the contradiction. The efficiency-wage literature generally assumes that weekly hours are fixed and that intensity of effort is variable and costly to observe. But if hours of work are variable and if workers prefer fewer hours, then an efficiency contract can stipulate both a higher hourly wage rate and also fewer weekly hours than the prevailing market contract. This would make us expect a negative correlation between hours and wage rates.

If, instead, employers are indifferent to the number of hours worked by each individual employee per week (monitoring problems, but no fixed costs), then the relationship between hours and capital intensity could merely be a secondary labor-supply effect caused by the high hourly wages offered in capital-intensive sectors. Workers rationally choose to work more weekly hours because of the higher opportunity cost of leisure. This view, of course, requires the additional assumption that substitution effects outweigh income effects.

Our findings could also complement the efficiency-wage literature. Some monitoring costs are like capital costs in that they are paid per worker rather than per hour. Others may be subject to learning curves and other economies of scale. Then our theory suggests that industries that incur high monitoring costs would also require their workers to exert additional effort. Thus, the interindustry wage differential would be part wage premium, part compensation for higher effort.

Distinguishing between these possibilities is not necessary for our purposes and is clearly outside the scope of this paper. Our whole approach of tracing out the wage-effort offer curve at different times and connecting its movements to changes in product prices, technology, and worker benefits represents a substantial departure from the efficiency-wage literature.

This comes from the very different conceptual frameworks that underlie wages that are determined to solve monitoring problems as opposed to wages that are instead payment for observable effort.

2.3 Empirical Evidence from the Census of Manufactures

The theory of effort can explain a large number of empirical facts, including wage differences across industries, productivity differences across countries, and the limited capital flow from high-wage to low-wage regions. The purpose of this paper is to breathe more life into this theory by showing that the U.S. labor market does seem to have a wage-effort offer curve. Two data sets are employed to this purpose, industry-level data from the Bartelsman-Becker-Gray Manufacturing Productivity database (hereafter NBER)[4] and worker-level data from the March Current Population Surveys (CPS).[5] We will assume initially that all workers are identically productive and that there is a single wage-effort offer curve with higher wages compensating for higher effort levels. This wage-effort offer curve is indexed by the capital intensity of the sector, with the high-effort high-wage contracts occurring in the capital-intensive sectors. Workers may have the same tastes and therefore be indifferent among the wage-effort contracts that are formed, or workers may have different attitudes toward effort, with the industrious (or materialistic) choosing high-effort high-wage contracts and with the slothful (or humanistic) workers choosing low-effort low-wage jobs. Later we will allow ability differences proxied by education levels.

The measurement of intensity of effort is the biggest problem we face. Effort is the product of unobservable intensity times observable hours. Fortunately, since effort is our dependent variable, measurement errors cause noise but not bias. Although we suspect that hours and intensity of work are positively correlated, it is enough that they are not so negatively correlated as to destroy any positive association between effort and hours.

Capital sharing from shift or temp work might cause us serious difficulties, but it does not. If the same capital K is used by two different work-

4. The NBER Manufacturing Productivity database, constructed by Eric Bartelsman and Wayne Gray, contains annual information on 450 manufacturing industries from 1958 to 1991. The industries are those defined in the 1972 Standard Industrial Classification and cover the entire manufacturing sector. The data themselves come from various government data sources, with many of the variables taken directly from the Census Bureau's Annual Survey of Manufactures and Census of Manufactures. The advantages of using the NBER database are that it gathers together many years of data, adjusts for changes in industry definitions over time, and links in a few additional key variables (e.g., price deflators and capital stock). For more information, see the NBER website: www.nber.org.

5. The sample represented in the Current Population Survey March demographic data was further reduced to those workers who worked between 20 and 80 hours in the previous week, who made at least $2.50 per hour in 1987 dollars, who were between the ages of 17 and 75, and who were not self-employed.

ers over the course of a day, then our measure of the capital intensity of the job correctly is equal to $K/2$, since 2 is the number of employees. Likewise, if one worker uses the equipment K for half the year, and another uses it for the other half, then the annual rental cost is also proportional to $K/2$, which we appropriately measure because the number of employees is doubled. Thus both shift work and temp work are compatible with our theory and with our empirical work. What we do not allow for are setup times associated with the handing of the capital from one worker to the next. Nor do we allow for unused capacity that is not charged against labor. But we think both of these are relatively minor concerns.

2.3.1 Evidence of the Wage-Effort Trade-off from Two-Digit Manufacturing Data

Given the potential problems with the use of hours as a measure of effort, it is perhaps remarkable that we are able to find a clear relationship across manufacturing industries between the average number of hours worked per week and hourly wages. Figure 2.7 depicts two-digit SIC data on industry average weekly hours and industry average weekly wages for production workers at six periods of time between 1950 and 1995. All six scatter diagrams have a remarkably clear association between hours and wages, exactly what we are looking for, with printing and publishing being the one outlier, offering a low-hour high-wage contract. Of course it is not surprising that people who work more hours earn more, but figure 2.7 has the increase in wages more than proportional to the average weekly hours, which we take as a reward for saving capital costs. These first data displays leave us excited about the accuracy of the theory. Low-wage low-effort contracts are being offered in the labor-intensive industries such as apparel and leather, while high-wage high-effort contracts are being offered in the capital-intensive sectors such as transport and chemicals.

Another interesting feature of the data displayed in figure 2.7 is the backward bend in the early periods, which is ironed out by 1980. The bend is associated with transportation and primary metals, which offer high wages but lower hours than some of the other sectors. Printing and publishing is on the backward-bending part of the curve in 1950, but separates entirely from the rest of the curve thereafter. We are inclined to think that the backward-bending part of the curve is due to unionization effects. Production workers in transport and primary metals have unionization rates of over 55 percent, compared to a 30 percent overall unionization rate for production workers in manufacturing industries.[6] But printing has

6. These numbers were calculated from the Current Population Surveys and refer to unionization rates in the 1990s. There is every reason to believe that the patterns of unionization, if not the overall numbers, have been roughly constant over time.

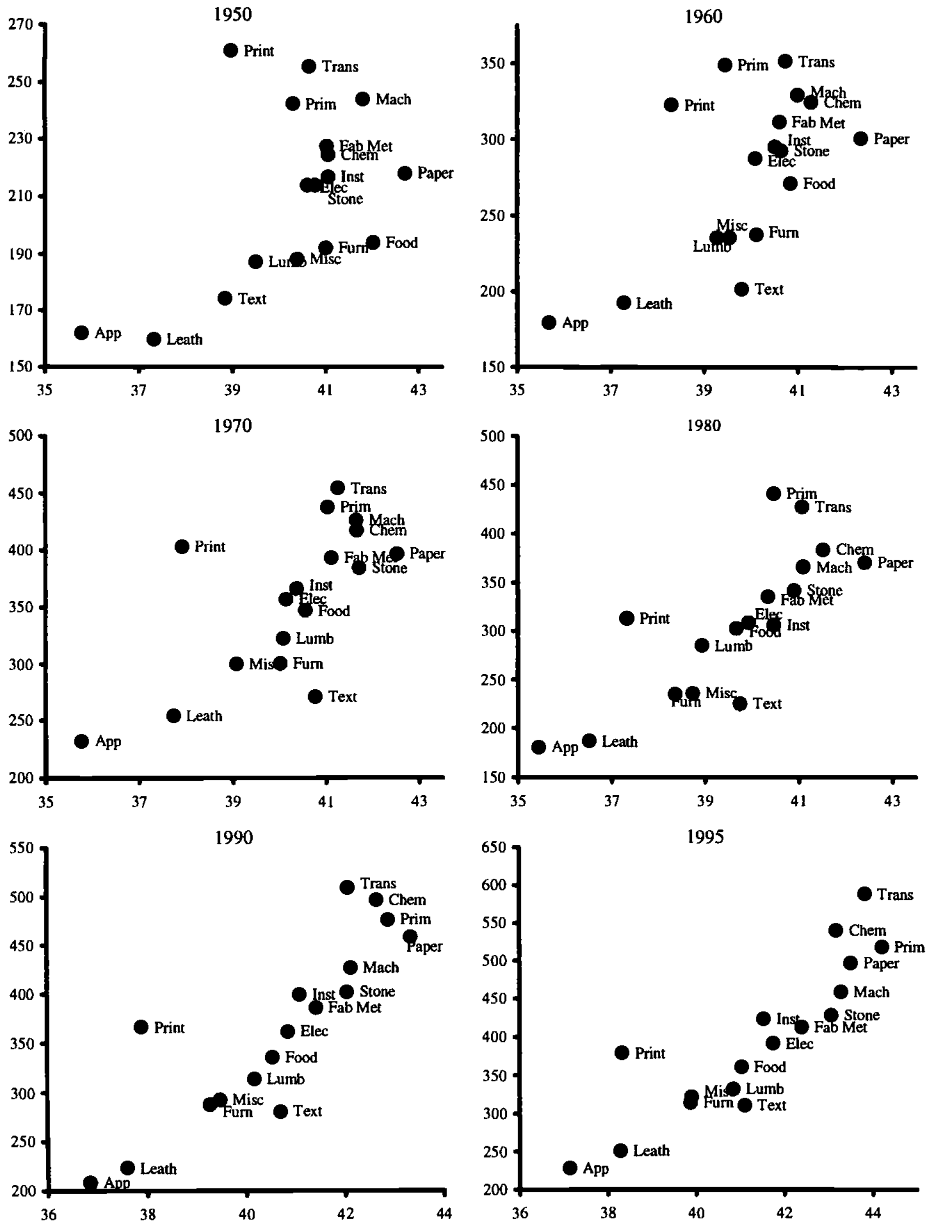

Fig. 2.7 Real weekly wages and weekly hours, 1950–95, by two-digit SIC manufacturing industries

Source: Citibase database.

Note: Wages are on vertical axis.

a unionization rate of only 14 percent.[7] It may be that printing of newspapers requires intense worker effort during relatively few hours in a day.

Textiles is another unusual sector. Textiles in 1970 and earlier had many more hours but about the same wages as apparel and leather. Relatively high-wage growth in textiles has moved the textile point closer to the rest of the scatter. This change has been accompanied by an increase in the average number of hours worked per week by production workers in this sector.

2.3.2 Trends and Cycles in Hours and Employment

We are concerned that some of these shifts in the wage-effort offer curve may be associated with the business cycle. The unit of time to which the wage-effort offer curve applies is the implicit contract period, which may be a worker's lifetime and which almost certainly covers the business cycle. If a business cycle defines the time unit, then the capital/labor ratio should be the capital stock divided by peak employment. In addition, both earnings and hours should refer to the whole cycle, not to a subset of time within a cycle. When we use annual data, the measured capital intensity is inappropriately high at the trough of the cycle when employment is low. When we use annual data we overestimate the effort level and the wages since we do not account for the idleness of workers at the trough. For these reasons, we worry that when we trace out the apparent wage-effort offer curve over time we may think that we see shifting offers when all that is happening is a business cycle.

Figure 2.8 shows how closely the employment rate and average weekly hours move together over time, with hours worked leading the cycle in employment.[8] Average hours peaked at over 41 hours in the late 1960s when unemployment was down to less than 4 percent. Average hours bottomed out at slightly over 39 hours in the late 1950s and again in the early 1980s when unemployment rates were measured at 7 percent and 10 percent, respectively.[9]

We note the run-up in average hours in the late 1980s and early 1990s to peak levels and the corresponding increase in the rate of employment

7. The most unionized sector inside the printing sector is newspaper publishing, with a unionization rate of 30 percent. It is unlikely that disaggregation is going to resolve this puzzle.

8. Data collected from the Bureau of Labor Statistics (BLS). The employment rate is measured as 1 − Unemployment Rate. Weekly hours are measured for production workers.

9. It is worth noting the distinct difference between average weekly hours as collected in the NBER Productivity database and the data presented here, with the BLS calculating average weekly hours at about 1 hour more than the NBER data. The BLS data were collected from the Current Population Surveys, while the NBER data were collected from the Census of Manufactures. The primary difference between these two data sets is their ultimate source, firms for the Census of Manufacturers and individual respondents for the Current Population Surveys. In the CPS, the data on hours employed per week include those employed at all jobs. Thus the average is dragged up by the set of individuals who take employment at more than one firm as well as by recollection error.

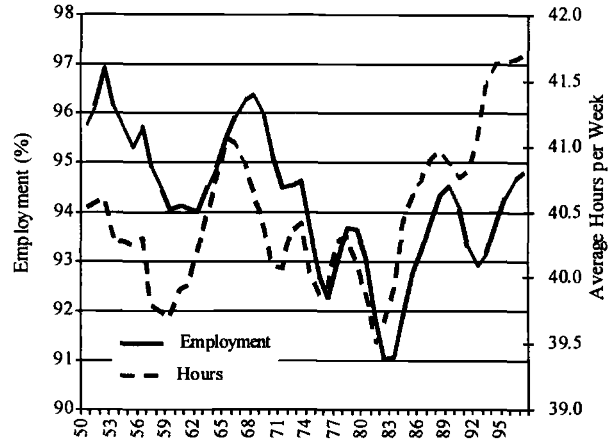

Fig. 2.8 Average employment rates and hours, production workers
Source: Bureau of Labor Statistics.

to high levels, but not to the historically high levels seen in the mid-1960s. This seems to imply that there has been some distinct break between these two series occurring in the early 1980s. We find this increase to be endemic across all industries in the NBER data. We are inclined to attribute this to a reaction to an increase in benefits, which are paid on a per-worker basis, not on a per-hour basis. Firms thus save on the costs of benefits by increasing hours. But the introduction of new, very expensive equipment can have a similar effect.

Cycles and trends are eliminated by subtracting the overall average from the sectoral hours data displayed in figure 2.9. The high-hours sectors in 1993 are displayed in panel *A* and the low-hours sectors in panel *B*. For example, a worker in apparel (in fig. 2.9*B*) worked about 4 hours less than the average production worker. This value has remained steady over the 45 years mapped out in the figure. On the top is the paper industry, where a worker works about 2.5 more hours per week than the average production worker. Notable exceptions to the stability of these results are indicated by thick black lines. They include, especially, transport and primary metals, each of which experienced an increase in average hours of about 3 hours per week. These two industries were the same two that formed the backward-bending portion of the wage-effort offer curve in the 1970s. The increase in the number of hours in these two industries is clearly due to the same reason the backward-bending portion of the wage-effort curve disappeared from the data, that is, the decline of unionization. Those changing in the opposite direction, albeit on a smaller scale, include furniture and food, which both experienced a 2-hour decline. The food sector and the furniture sector experienced a small decline in their relative capital

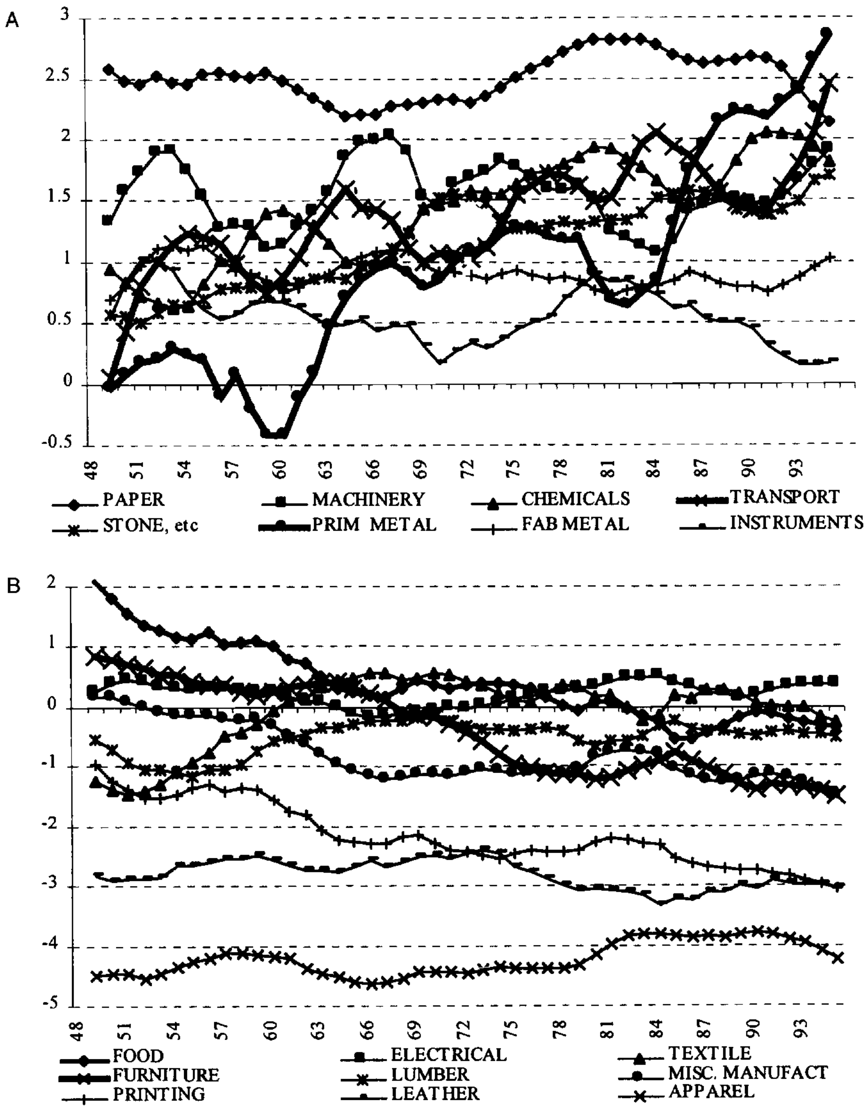

Fig. 2.9 Smoothed variation in two-digit industry hours from manufacturing mean: (*A*) high-hours sectors, (*B*) low-hours sectors

Source: Citibase database.

intensity compared to other manufacturing industries, perhaps explaining the decline in the average number of weekly hours worked in this industry.

2.3.3 Displays of the 1990 Four-Digit Industry Data

The four-digit industry data in the NBER Productivity database are considerably more noisy than the two-digit data, but the same pattern emerges. Capital-intensive sectors pay high wages and have long hours. Figure 2.10 shows the distinctly positive relationship between average weekly hours and average real weekly wages for production workers across the industries included in the NBER data in 1990.[10] Also striking is the strong positive relationship between the capital intensity of the sector, with both average hours worked per week by production workers and weekly wages. Of these two, the relationship between capital and hours is noisier. This is probably due to short-term fluctuations in industry demand that are absorbed more by hours than by wages, as well as due to the existence of greater noise in reported hours than in reported weekly earnings.

We expect a positive relationship to exist between weekly hours and weekly wages in the short run due to the inelasticity of the industry-specific labor supply and normal fluctuations in relative industry demand. This could explain the upward-sloping relationship seen in any one year. Yet as seen in the two-digit data, the pattern of wages and hours across sectors is very stable over time. For example, the correlation of weekly wages across sectors between 1990 and 1960 is 0.83, as can be seen in table 2.1. The table reports the cross-industry correlations of wages and hours at the various sample years, and both remarkably stable even over a 30-year time period. The correlation of weekly hours across sectors in 1960 and 1990 is 0.56.

Some of the association between hourly wages and weekly hours may come from the institutionalized 40-hour workweek and the legal requirement for overtime pay rates for weekly hours beyond 40. But legally mandated overtime need not have any effect even when overtime is observed. If a firm is willing to pay $430 for 42 hours of work, the contract can stipulate 42 hours at $430/42 per hour, or, to comply with the law, the contract can stipulate an hourly rate of $10 with time and a half for over-

10. The data have been smoothed using a three-period weighted average over the time series provided in the NBER data, where the weight is the percentage variation from the 3-year median. The reason we use this particular method is because the hours data in the NBER data are subject to what would appear to be unreasonable fluctuations in hours per production worker and hourly wages. Often hourly wages will increase by 50 percent or more, while hours worked per worker drop by 50 percent. This almost certainly is due to basic errors in the recording of the data. Using the deviation from the median as a weight eliminates the effect of large outliers in the data. It represents between 12 and 14 million production workers separated into 448 distinct manufacturing industries. Only production workers are discussed here because unfortunately data on the average hours per week for nonproduction workers are not provided in the NBER data.

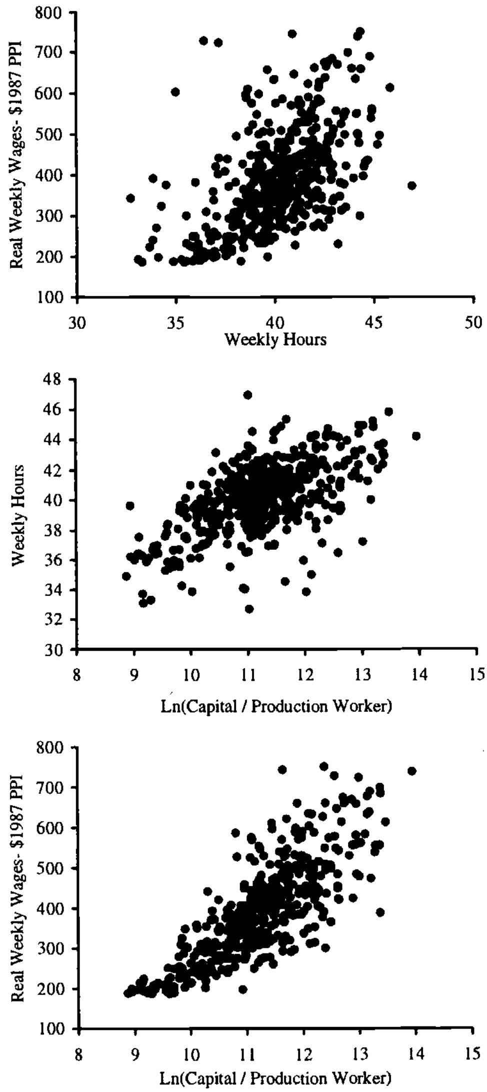

Fig. 2.10 Capital intensity, wages, and hours across four-digit manufacturing industries, 1990

Source: NBER Productivity database.

time. This would not affect the observed wage-effort offer curve. What the mandated overtime law really does is limit the flexibility of contracts over time, and it affects firms that experience variability in the demand for labor. Our focus on the longer-run aspects of the contract that are evident in the cross-sectional comparison of various industries means that man-

Table 2.1 **Correlations of Weekly Wages and Hours by Four-Digit Industry across Sample Years**

	1960	1965	1970	1975	1980	1985	1990	1994
				Wages Correlation				
1960	1.00							
1965	0.97	1.00						
1970	0.95	0.98	1.00					
1975	0.90	0.93	0.95	1.00				
1980	0.86	0.89	0.91	0.97	1.00			
1985	0.84	0.86	0.89	0.94	0.97	1.00		
1990	0.83	0.86	0.88	0.93	0.95	0.97	1.00	
1994	0.82	0.85	0.87	0.91	0.94	0.96	0.98	1.00
				Hours Correlation				
1960	1.00							
1965	0.78	1.00						
1970	0.74	0.85	1.00					
1975	0.64	0.74	0.78	1.00				
1980	0.61	0.64	0.68	0.66	1.00			
1985	0.58	0.59	0.61	0.63	0.57	1.00		
1990	0.56	0.61	0.66	0.62	0.60	0.60	1.00	
1994	0.52	0.62	0.66	0.63	0.61	0.59	0.80	1.00

dated overtime is not a substantial concern. The fact that some industries appear consistently to require that their workers work more than 40-hour workweeks despite mandated overtime pay premiums lends support to this idea.

Our model links weekly hours and weekly wages to capital intensity. Table 2.2 reports the average and standard deviation of real log capital per production worker and the average of the percentage of employees who are production workers for the 448 manufacturing sectors included in the sample. The capital intensity for each production worker is measured as total industry capital stock divided by the number of production workers.[11] The numbers in table 2.2 indicate that the average level of capital per production worker has been increasing steadily through the sample period, while the standard error of the log has been decreasing. This growth in capital intensity may be due partly to errors in measurement. For example, it is possible that there has been a shift of capital from pro-

11. This seems to allocate all capital to production workers, but a weaker assumption works. A formula for the total capital is $K = k_n N + k_p P$, where N and P are nonproduction and production workers and k indicates the capital intensity of the job. From this equation we can solve for the capital intensity of the production job as $(K/P) = k_n(N/P) + k_p$. The weaker assumption is that the product of nonproduction capital intensity times the nonproduction share of the workforce $k_n(N/P)$ is adequately constant across sectors. In addition to this problem, no attempt is made to allow for differences in depreciation rates across sectors and real interest rates over time.

Table 2.2 Capital per Production Worker

	Average Log Capital	Standard Deviation Log Capital	Production Workers (%)
1960	10.23	1.01	64.3
1965	10.35	0.98	64.4
1970	10.56	0.92	64.1
1975	10.78	0.85	64.9
1980	10.89	0.85	65.2
1985	11.08	0.85	61.3
1990	11.13	0.84	63.5
1993	11.17	0.85	62.2

Source: NBER database—weight averages for 448 manufacturing sectors.

duction to nonproduction workers, and it is also possible that the depreciation rates do not adequately account for obsolescence in this period of supposed rapid technological advance.

2.3.4 Estimation of the Wage-Effort Offer Curve with Four-Digit Data

To infer the wage-effort offer curve we estimate regressions explaining weekly hours and weekly wages as quadratic and cubic functions of the ratio of capital (K) to production employees (PE).

$$(7)\qquad \log(\mathit{Weekly\ hours})_i = \alpha_{i,t} + \beta_{1,i}\cdot\log\left(\frac{K}{PE}\right)_i + \beta_{2,i,t}\cdot\log\left(\frac{K}{PE}\right)_i^2 + \mu_i,$$

$$(8)\qquad \log(\mathit{Weekly\ wages})_i = \alpha_i + \beta_{1,i}\cdot\log\left(\frac{K}{PE}\right)_i + \beta_{2,i,t}\cdot\log\left(\frac{K}{PE}\right)_i^2 + \beta_{2,i,t}\cdot\log\left(\frac{K}{PE}\right)_i^3 + \mu_i.$$

We exclude the cubic of capital intensity from the hours equation because it is generally statistically insignificant. Data to estimate these equations are 3-year averages centered on the years 1960, 1965, 1970, 1975, 1980, 1985, 1990, and 1993. Observations are weighted by the number of production workers employed in the sector year in order to prevent the small sectors from dragging the coefficients around.

The results of these regressions are presented in table 2.3. The basic patterns of the results are as predicted and are fairly constant over the sample period. Capital intensity explains close to 40 percent of the variation in weekly hours across sectors, but somewhat more of the variation

Table 2.3 **Wage and Hour Regression Results**

Year Variance	Hours Coefficient		Wages Coefficient	
1960				
R^2	0.369		0.5031	
Int	2.1184	(0.0783)*	8.3832	(2.4432)*
(K/L)	0.2840	(0.0156)*	−1.3892	(0.7386)*
$(K/L)^2$	−0.0128	(0.0008)*	0.1722	(0.0737)*
$(K/L)^3$			−0.0061	(0.0024)*
1965				
R^2	0.4466		0.5626	
Int	2.0819	(0.0760)*	12.6155	(2.7216)*
(K/L)	0.2890	(0.0150)*	−2.7023	(0.8125)*
$(K/L)^2$	−0.0127	(0.0007)*	0.3081	(0.0801)*
$(K/L)^3$			−0.0107	(0.0026)*
1970				
R^2	0.433		0.6083	
Int	2.2968	(0.0817)*	16.6675	(3.1310)*
(K/L)	0.2337	(0.0157)*	−3.8122	(0.9069)*
$(K/L)^2$	−0.0097	(0.0008)*	0.4073	(0.0868)*
$(K/L)^3$			−0.0135	(0.0028)*
1975				
R^2	0.3821		0.6422	
Int	2.2975	(0.1007)*	17.9309	(4.0029)*
(K/L)	0.2213	(0.0189)*	−4.2620	(1.1285)*
$(K/L)^2$	−0.0088	(0.0009)*	0.4512	(0.1053)*
$(K/L)^3$			−0.0148	(0.0033)*
1980				
R^2	0.3835		0.6731	
Int	2.1802	(0.0994)*	15.2499	(4.2042)*
(K/L)	0.2406	(0.0184)*	−3.5119	(1.1691)*
$(K/L)^2$	−0.0096	(0.0008)*	0.3770	(0.1077)*
$(K/L)^3$			−0.0122	(0.0033)*
1985				
R^2	0.3884		0.6923	
Int	1.9133	(0.1163)*	9.7820	(4.3422)*
(K/L)	0.2821	(0.0210)*	−2.0616	(1.1779)*
$(K/L)^2$	−0.0111	(0.0009)*	0.2481	(0.1059)*
$(K/L)^3$			−0.0084	(0.0032)*
1990				
R^2	0.3212		0.6751	
Int	2.2617	(0.1266)*	5.2251	(4.4977)
(K/L)	0.2237	(0.0227)*	−0.7699	(1.2132)
$(K/L)^2$	−0.0085	(0.0010)*	0.1275	(0.1085)
$(K/L)^3$			−0.0047	(0.0032)
1993				
R^2	0.2647		0.6534	
Int	2.2208	(0.1367)*	3.2645	(4.3934)
(K/L)	0.2351	(0.0244)*	−0.1503	(1.1794)
$(K/L)^2$	−0.0091	(0.0011)*	0.0651	(0.1050)
$(K/L)^3$			−0.0027	(0.0031)

Note: Standard errors are in parentheses.
*Significant at the 5 percent level.

in weekly wages, 50 percent in 1960 and nearly 70 percent in the 1980s. From the pair of estimated equations (7) and (8), we solve for the wage-effort offer curve by eliminating the capital intensity variable. Segments of these curves corresponding to observed capital intensities are plotted in figures 2.11, 2.12, and 2.13. The capital intensity data have a large right tail, so the capital range was determined as the minimum capital intensity observed in the data up to 2.5 standard deviations above the mean, roughly encompassing all but two outlying sectors of the sample, petroleum refining and blast furnaces. The lower-left portions of the curves represent the wage-effort contracts in the relatively labor intensive sectors, while the upper-right portions represent the contracts in capital-intensive sectors. The eight regressions are divided into three subperiods in which the shift of the curve takes a distinct form: 1960 to 1970, 1970 to 1980, and 1980 to 1993.

The wage-effort offer curves in figure 2.11 for 1960 and 1965 show the distinct backward-bending form of the wage-effort offer curve that was evident in the two-digit data in figure 2.7. The lowest curve in figure 2.11 is the wage-effort offer curve in 1960. Between 1960 and 1970, two changes appear to be happening. First, the backward-bending portion of the wage-effort offer curve has been diminishing, possibly due to the decline in the power that unions had to negotiate favorable contracts in the early 1960s. In addition, the entire curve has been shifting up and to the right.

The rightward shift is most evident in the labor-intensive sectors at the lower-left portion of the curve. This appears to be due to a relative in-

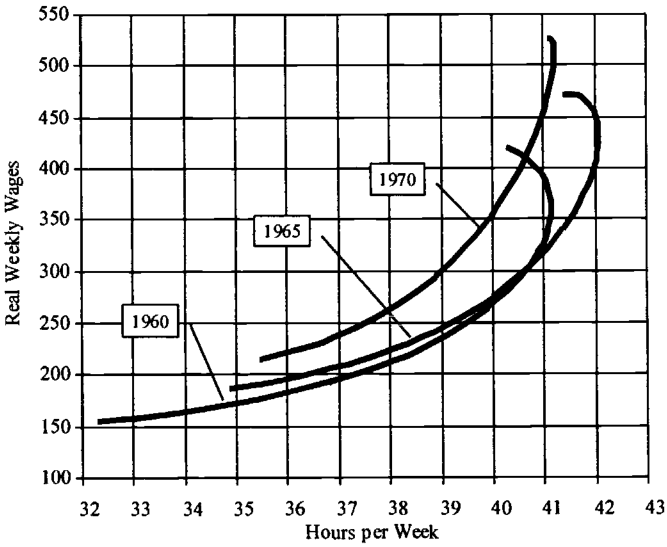

Fig. 2.11 Derived wage-effort offer curves, 1960–70

Table 2.4 **Changes in Capital Intensity**

Capital/Production Worker, 1960 (1987 dollars)	Change 1960–70 (%)
\$0–9,999	56.8
\$10,000–19,999	45.8
\$20,000–29,999	32.5
\$30,000–49,999	30.5
\$50,000+	20.6

Source: NBER database, 1960–70.

Table 2.5 **Pattern of Capital Deepening from Levels Regressions**

Model	Intercept	Slope
(K/L) 1970 on (K/L) 1960	1.705	0.867
	(0.165)	(0.016)
(K/L) 1980 on (K/L) 1970	0.718	0.964
	(0.160)	(0.015)
(K/L) 1990 on (K/L) 1980	0.560	0.976
	(0.187)	(0.017)

Note: Standard errors are in parentheses.

crease in the capital intensity of these sectors. The average increase in capital intensity between 1960 and 1970 was 34 percent according to the NBER data. Yet the largest increases occurred among the labor-intensive industries, as can be seen in table 2.4, which breaks capital growth down by capital intensity in the 1960s. The most capital-intensive industries increased their capital intensity on average only 20 percent compared to over 55 percent in labor-intensive industries. This pattern of change in capital intensities is exclusive to the 1960s. Table 2.5 shows the results from three cross-sectional models regressing log capital intensity across industries on their values from the previous decade. The pattern of capital deepening can be seen in the slope coefficient. If the slope is less than 1, deepening is occurring primarily in the labor-intensive sectors, a slope greater than 1 implies deepening in the capital-intensive sectors. The slope is significantly below 1 in the 1960s, but very nearly 1 in the following 2 decades. These changes may be indicative of technological change. They may also be indicative of the movement of the most labor-intensive subsectors offshore.

The 1970s were very different from the 1960s. Figure 2.12 compares the wage-effort offer curves for 1970, 1975, and 1980. The backward-bending portion of the wage-effort offer curve completely disappeared in the 1970s. In addition, the wage-effort offer curve twisted, with the low-wage low-effort contracts experiencing a 15 percent reduction in wages and the high-

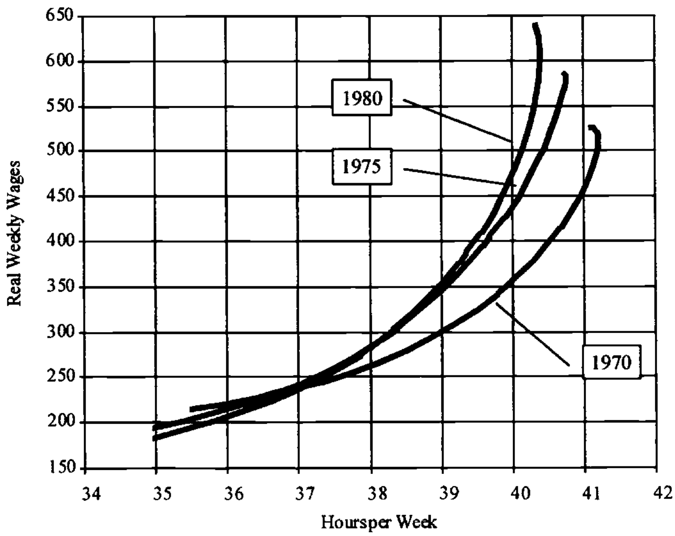

Fig. 2.12 Derived wage-effort offer curves, 1970–80

wage high-effort contracts enjoying a 20 percent increase. The ratio of real hourly wages between the two end points of the curve increased from 2.3 in 1970 to over 3.3 in 1980 and peaked at 3.5 in 1985 before it stabilized at about 3.45. We are inclined to associate this twisting of the curve with the 1970s decline in the relative price of labor-intensive manufactures that is documented in Leamer (1998).

This twisting of the observed wage-effort offer curves is not compatible with a representative worker model with a stable utility function, since the contracts in the capital-intensive sectors have unambiguously improved while those in the labor-intensive sectors have unambiguously deteriorated. This twisting of the curve could be an equilibrium if workers have heterogeneous preferences. Differences in adversity to effort may also explain a portion of the apparent rigidity of the labor market to changes in relative wages across sectors: despite the shift in the wage-effort offer curve, the distribution of production workers across sectors has remained fairly stable. This is illustrated in table 2.6, which reports employment by quintile of capital intensity. The sectors with the lowest capital/labor ratios experienced an 8.5 percent reduction in employment between 1970 and 1980. The third and fourth quintiles experienced the greatest gains, while there was actually a decline in employment in the most capital-intensive sectors.

In the 1980s the wage-effort offer curve began to shift to the right, a movement that is depicted in figure 2.13. In words, for the same wage levels, workers were required to work more hours. The increase in weekly hours was between 2 and 3 hours during this 13-year period, more at the upper end of the wage-effort offer curve than at the lower end. One pos-

Table 2.6 Changes in Employment of Production Workers by Quintiles of Capital Intensity, 1970–80

Capital Intensity	Employment 1970 (× 10^3)	Employment 1980 (× 10^3)	Change (%)
First quintile	2,589.9	2,379.4	−8.5
Second quintile	3,172.6	3,281.6	3.4
Third quintile	2,619.2	2,771.7	5.7
Fourth quintile	2,712.9	3,050.4	11.7
Fifth quintile	2,545.1	2,406.5	−5.6

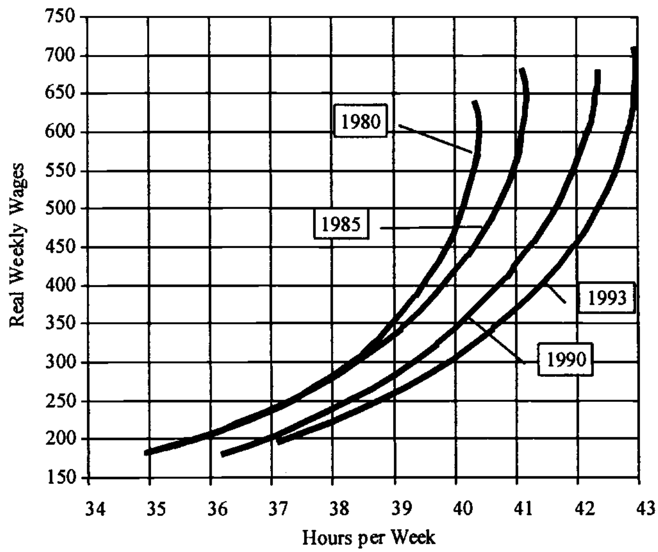

Fig. 2.13 Derived wage-effort offer curves, 1980–93

sible explanation for this shift is the increasing real capital rental costs coming from the rise in the demand for capital induced by the economic liberalizations in Asia and Latin America. Another possible explanation is the introduction of new more expensive equipment (computers and robots), which shifts the curve as illustrated in the middle panel of figure 2.5. A third possibility is the business cycle. There was a four-point decline in unemployment after the peak during the recession in 1983. The strong correlation between employment and weekly hours was highlighted in figure 2.8. Yet there are a number of reasons to doubt the business-cycle role in the sharp increase in weekly hours. One reason is the magnitude of the change. The larger change in unemployment between 1969 and 1983 (a reduction of 5.5 points) only led to a 1.25-hour decrease in average weekly hours, much smaller than the 2-hour increase seen after 1983.

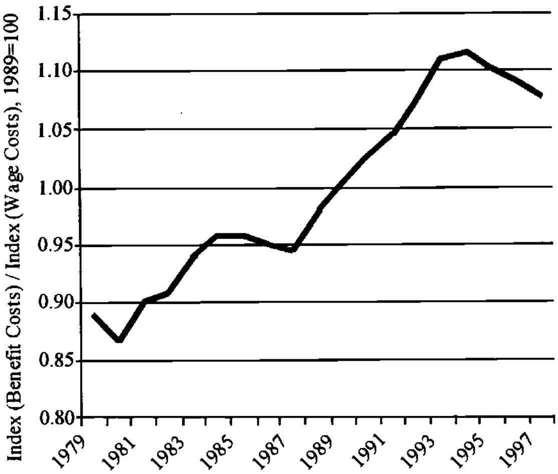

Fig. 2.14 Benefit to wage costs in manufacturing, 1989 = 100
Source: BLS Labor Cost Indexes, Manufacturing.

We think that a likely cause for part of the shift in the wage-effort offer curve since 1980 was an increase in the quasi-fixed labor costs emphasized by Oi (1962): training, payroll taxes, and worker benefits. Whether it is capital or benefits, firms can save costs paid on a per-worker basis by getting more work out of each worker; thus more benefits for more hours. Figure 2.14 plots the ratio of a BLS employee-benefits index relative to wages per worker in manufacturing in the 1980s. Between 1980 and 1996, this index increased about 25 percent. Note that the majority of this increase occurred after 1986. Unfortunately, the data do not go back beyond 1979, so there is no way to compare this trend to earlier periods.

2.3.5 Controlling for Business Cycles

According to our estimates, the wage-effort offer curve has varied systematically over time, shifting up, then twisting, and finally shifting right. The 1970 and 1980 dates at which we estimate the wage-effort offer curve were selected to conform with Leamer's (1998) claim that the 1970s were the Stolper-Samuelson decade in which there was a significant decline in the relative prices of labor-intensive tradables. But these years and the other 5-year intervals at which we estimate the wage-effort offer curve select different points in the business cycle, and some of the observed shifting may be due to the cycle rather than the fundamentals. In this section we show that in fact the timing is not essential. Comparisons, peak-to-peak and trough-to-trough, show the same shifting of the wage-effort offer curve.

We use the employment rate to define the cycle. As is evident in figure 2.8, weekly hours lead the employment rate, a feature we attribute to a delay between an increase or reduction in product demand and the actual hiring or firing of workers. To capture the cycle in demand, we use the smoothed forward rate of employment as the indicator of the business cycle, and we compare peak-to-peak and trough-to-trough changes in the wage-effort offer curve. Using smoother year-ahead rate of employment again as our guide, we set our trough years as 1961–62, 1970–71, 1975–76, 1981–82, and 1991–92. The peak years were set at 1958–59, 1967–68, 1972–73, 1977–78, 1988–89, and 1993–94. The results of these peak and trough regressions are displayed in table 2.7.

These regressions can be used to solve for the wage-effort offer curves such as those displayed in figures 2.11–2.13. When we do so, the peak-to-peak and the trough-to-trough comparisons are completely in line with our first results, which ignored the business cycle. In the 1960s, the wage-effort offer curve moved up and to the right, in the 1970s it twisted, and in the 1980s it shifted sharply to the right. In addition, when we put consecutive peak and trough years next to each other, such as 1970, 1971–72, 1973 and 1977, 1978–81, 1982, we find very little difference between the shapes of these curves. The trends we see in the wage-effort offer curves tend to be long term and appear to occur exogenous to cyclical effects.

2.3.6 Evaluation of Alternative Explanations of the Wage-Effort Offer Curve

We are excited by how well these results conform with the theory, but we need to be alert to the possibility that these findings are driven by some third factor that has nothing to do with effort. Our primary concern is that human capital is correlated with physical capital and with hours, and that what we are observing is not compensation for effort, but compensation for skill and skilled workers choosing longer hours. Unionization is also a concern. Unions might be able to bargain for a wage-effort contract above the competitive market curve. A strong union effect might account for the outlying sectors observed in the two-digit-level data. Even without unions, profit sharing may help to explain the pattern of wages. The realized returns to capital vary widely across sectors and also across time. Firms in the less competitive sectors may collect positive rents and may share those rents with workers.

The NBER data set does not include information on unionization or education. We have formed industry estimates of production worker education from the Current Population Surveys. To do this, we had to match the 71 three-digit CPS manufacturing industries with the 448 industries in the NBER productivity database.[12] Data from Kokkelenberg and Sockell (1985) on union status were used for the 1973–81 period while data from

12. CPS industry data at the three-digit level are available between 1971 and 1994, so the 1971 data were matched with the earlier NBER data for the regressions.

Table 2.7 Wage and Hour Regressions at the Cyclical Peaks and Troughs

	Trough					Peak					
	1961–62	1970–71	1975–76	1981–82	1991–92	1958–59	1967–68	1972–73	1977–78	1988–89	1993–94
					Hours Regressions						
R^2	.394	.445	.370	.332	.293	.359	.422	.450	.474	.365	.255
Int	2.038*	2.284*	2.356*	2.427*	2.299*	2.257*	2.193*	2.092*	2.096*	2.061*	2.190*
(K/L)	.298*	.235*	.210*	.196*	.219*	.259*	.261*	.264*	.253*	.258*	.241*
$(K/L)^2$	−.0133*	−.0097*	−.0082*	−.0077*	−.0084*	−.0117*	−.0112*	−.0108*	−.0099*	−.0100*	−.0094*
					Wage Regressions						
R^2	.518	.626	.649	.692	.674	.484	.540	.635	.661	.668	.646
Int	9.031*	17.448*	17.406*	12.350*	4.197	7.263*	11.239*	21.654*	18.875*	7.299	2.975
(K/L)	−1.599*	−4.045*	−4.117*	−2.667*	−.448	−1.032	−2.243*	−5.296*	−4.565*	−1.353	−.056
$(K/L)^2$	.195*	.430*	.437*	.295*	.095	.135	.260*	.550*	.480*	.182	.056
$(K/L)^3$	−.0069*	−.0142*	−.0143*	−.0096*	−.0036	−.0049*	−.0090*	−.0180*	−.0156*	−.0064	−.0024

*Significant at the 5 percent level.

Hirsch and Macpherson (1993) were used for the later years. These measures are also created from the CPS data, so they match with the NBER data in the same way that the education measures do.

Industry rents are particularly difficult to measure. The NBER data provide a measure of value added. Theoretically this variable represents employee wages; other employee benefits such as social security, which are not directly included in the wage bill;[13] ex ante capital-rental costs; industry rents, if any; and firm-specific rents that accrue to the owners of the capital:

$$(9) \quad VA_i = w \cdot Emp_i + w_B \cdot Emp_i + r \cdot Capital_i + Rent_i + \mu_{it}.$$

With the admittedly suspicious assumption that capital-rental rates and worker benefit rates are constant across industries, we can extract from value added that which is due to capital intensity and treat the residual as rent:

$$(10) \quad \frac{VA_i - w \cdot Emp_i}{Emp_i} = \alpha + \beta \cdot \frac{Capital}{Emp} + \varepsilon_i.$$

The coefficient α represents the per-worker cost of nonwage benefits plus average rents, β represents the capital-rental costs, and ε is the rent residual. Since it is impossible to separate from the constant that part which represents average rents, we use only the estimated rent residuals smoothed over seven periods to form estimates of sectoral long-run rents.[14]

Table 2.8 reports a number of basic statistics for the additional data. The average education level for production workers was slightly less than 12 years in 1993, up from only 10 years in 1960. There are distinct differences in the educational attainment of workers across sectors. In 1990 the average years of schooling varied across sectors from 9 years to 13.5 years. Around 20 percent of production workers were actively enrolled in unions or covered by a union contract in 1993, a significant decrease from the 42 percent enrollment in 1960. Again there appears to be a fairly large variation in union participation across sectors, with a maximum of 60 percent to a minimum of 2 percent in 1993. In 1960 this range stretched between 12 percent and 82 percent. The bottom of table 2.8 provides basic statistics on the computed industry rents. Note that these data have been converted to real values by dividing by the producer price index (PPI) deflator. The average rent is close to zero in each period, a function of the regression technique employed to construct this measure. Interestingly, there has been a sharp increase in the variance of rents since 1980.

Except for the percentages of unionization rate and females, all these

13. The wage data in the NBER data do not include some worker benefits.

14. For the purpose of the regression analysis, rents were also put into log form by taking the log of 100 times the absolute value and multiplying by the sign of the initial value. Values between 0.01 and −0.01 were set to 0.

Table 2.8 **Additional Explanatory Variables for Wage and Hour Regressions Computed per Production Worker**

	1960	1965	1970	1975	1980	1985	1990	1993
Education								
Mean	10.2	10.2	10.2	10.6	11.0	11.3	11.5	11.6
Standard deviation	0.8	0.8	0.8	0.7	0.7	0.6	0.7	0.7
Minimum	7.5	7.5	7.5	8.7	8.3	9.4	8.9	9.5
Maximum	11.8	11.8	11.8	12.4	12.6	13.0	13.5	13.7
Union Status (%)								
Mean	42.0	42.5	41.9	39.7	36.8	27.5	22.6	20.4
Minimum	12.3	12.3	12.3	5.6	4.1	4.5	2.4	2.1
Maximum	81.8	81.8	81.8	76.6	75.4	62.5	58.6	59.4
Rents								
Mean	−0.3	−0.3	−0.4	−0.5	−0.8	−0.9	−1.0	−1.0
Standard deviation	4.6	5.6	6.6	7.3	8.7	11.9	16.7	18.0
Minimum	−9.4	−13.7	−22.8	−27.6	−37.3	−44.2	−39.0	−53.8
Maximum	37.4	58.8	73.0	74.5	87.1	139.5	256.7	286.1

variables will be entered into our equation in logarithmic form. Table 2.9 reports the correlations between different variables within a data set and also between the same variables from the CPS data and the NBER data. The correlation between average weekly hours and average weekly wages across the two data sets are respectively 0.55 and 0.75, implying that the patterns seen in the NBER data are in part replicated in the CPS data despite the large differences in the collection techniques employed by the two sources.

Of the other variables, education appears to be significantly correlated with both wages and hours. Not surprisingly, educated workers are also overrepresented in capital-intensive sectors. Unionization is highly correlated with wages and positively correlated, albeit weakly, with weekly hours. This surprising result may be linked to the high positive correlation between union activity and the capital intensity of the industry. Rents are also positively correlated with capital intensity. These correlations make it possible that what we are seeing in the initial set of wage and hour regressions is only omitted variable bias and not a wage-effort offer curve. These new variables will now be included in another set of regressions.

Although the percentage of females is reported in table 2.9, we exclude this from our equations because we think it represents, at least partly, the supply side. Proper econometric estimation of the joint (supply and demand) determination of the wage-effort offer curve with heterogeneous workers is beyond the scope of this paper. The data do indicate that females tend to be employed in labor-intensive (i.e., low-wage low-effort) sectors.

Proper treatment of the human capital variable is another delicate task, which has been discussed more fully in Leamer (1999). Here we note that the model depicted in figure 2.1 is based on the assumptions that workers are fully charged for the capital they use and that the wage we observe is total earnings net of all capital charges. To put it another way, we assume that workers do not bring their own tools to the workplace, and we assume also that workers have no other sources of wealth that can be used to finance consumption. Both of these assumptions are violated by human capital, first because the wage that we observe is not net of the implicit human capital rental costs[15] and second because human capital acquired in formal education is partly financed by the government and by the worker's parents. Without these two problems, we could simply combine human and physical capital into a single capital aggregate.

This is illustrated in figure 2.15, which depicts three different jobs with differing fixed levels of human capital inputs and the same fixed level of physical capital inputs. One job uses physical capital only, the second job

15. An exception is firm-specific training, financed by the firm. The education variable we use merely counts the years of formal schooling, those that create human capital owned by the worker, not the firm.

Table 2.9 **CPS and NBER Data Correlation Statistics (1990 data)**

	Hhr	WW	KE	Chrs	CWW	Edu	Uni	Rent	Fem
NBER Data									
Hhr	1.00								
WW	0.57	1.00							
KE	0.54	0.81	1.00						
CPS Data									
Chrs	0.55	0.55	0.38	1.00					
CWW	0.45	0.75	0.55	0.66	1.00				
Edu	0.35	0.67	0.49	0.62	0.83	1.00			
Uni	0.23	0.51	0.33	0.40	0.67	0.19	1.00		
Rent	−0.01	0.26	0.34	−0.05	0.19	0.22	−0.02	1.00	
Fem	−0.39	−0.47	−0.38	−0.80	−0.75	−0.40	−0.39	0.07	1.00

Note: Correlations computed with all variables in log form.

Abbreviations: Chrs, CPS hours per week; CWW, CPS wage per week; Edu, education; Fem, female; Hhrs, NBER hours per week; KE, capital; Rent, rents; Uni, Union; WW, NBER wage per week.

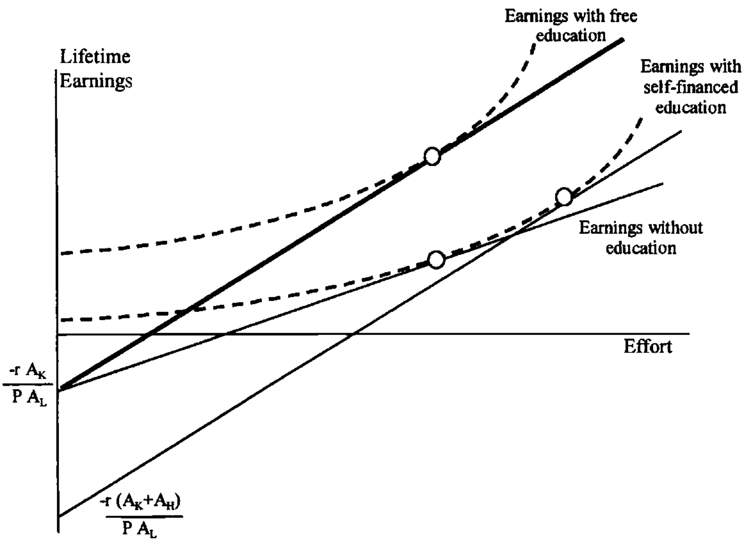

Fig. 2.15 Wage-effort offer curves by level of education

uses the same physical capital but also self-financed human capital, and the third job is the same as the second except that the human capital is provided without cost to the worker. The envelope of preferred contracts without free education is the heavy wage-effort offer curve in figure 2.15, which has the same character as the wage-effort offer curves that we have been discussing—namely, the high-effort high-(net) wage contracts are intensive in human capital. If the human capital is provided free of charge, then the offer line facing the educated worker has the slope of the original educated worker line but the intercept of the no-education line. This line of contracts with free education completely dominates the contracts if education is charged to the workers.[16]

Empirically, there are a number of directions in which this discussion of education could lead. One is nowhere. If education is free and everyone has the same ability, then the regressions of wages and hours on capital

16. As a side note, this resulting equilibrium suffers from two kinds of inefficiencies, too much education and too little effort. It is efficient to have some workers operating without human capital investments, but, once it is free, everyone opts for the education. It is efficient to have educated workers supplying a high level of effort, but the wealth transfer to them in the form of free human capital affords them the opportunity to take it easy and still earn high wages. The economic inefficiency here is not caused simply by some workers opting to take it easy. The inefficiency is caused by workers taking it easy while they use expensive capital. This inefficiency would not occur if human capital were transferable among workers. For example, if the wealth transfer to workers were financial or physical capital, then these wealthy workers could efficiently opt to supply low levels of effort, but they would then take jobs that did not require much capital.

intensity define the wage-effort offer curve. It may be that the educational requirements vary along the curve, but that is entirely immaterial because workers do not incur a cost for the education. If education is free, but ability is heterogeneous (and unobservable) and interacts with education, then we are in a lot of trouble and do not want to talk about it. If human capital is self-financed, then ideally we would amend equations (7) and (8) by aggregating human with physical capital and by subtracting from weekly wages a term that is proportional to human capital and that represents the human capital rental charges. We do not know how to aggregate years of education with dollars of physical capital and we do not know the implicit rental rate of human capital to net from wages. What we do is add the human capital variable to our equations and hope for the best, recognizing that our wage equation is gross of human capital rental charges but net of physical capital rent. We plan on revisiting the issues of educational financing and heterogeneity in ability in subsequent work.

Keeping all these concerns in mind, the wage and hour regressions are reestimated using the same functional forms as before, but with three new variables: the percentage of employees with union status, the log of average education, and the measure of industry rents. The variable for percentage of females was not included in these regressions, as we believe that this is a supply-side rather than a demand-side variable. Also included were two interactive variables, between union status and capital intensity and between industry rents and capital intensity. These interaction terms allow for the greater market power that employees may have in capital-intensive industries. The inclusion of the interactive term between education and capital made the results highly unstable and increased the standard errors significantly; thus it was dropped from the regressions.

We draw your attention to the set of supplemental regressions presented in table 2.10. The adjusted R^2 for each of the regressions has increased, although more so for the wage regressions than the hours regressions. The signs on the additional variables in the wage regression are mostly as would be expected, and mostly significant. The capital-intensity variable has retained a significant positive impact on both hours and wages despite the inclusion of the other variables, including education. When we include the interactive coefficients, the magnitudes are quite similar to those of the initial regressions, although additional formal analysis will be performed to verify this.

The average education of production workers has a significant effect on average weekly wages that increases over time. There was a particularly sharp rise between 1980 and 1985, a result that conforms to the literature on changes in the returns to education over this period. Holding all else equal, the average relative wage difference between a worker with 2 years of college and a high school dropout with 10 years of education increased from 31 percent in 1970 to 39 percent in 1980 to 55 percent in 1985, and

Table 2.10 **Supplementary Log Wage and Log Hour Regressions**

	1960	1965	1970	1975	1980	1985	1990	1993
Hours								
R^2	.401	.467	.463	.392	.390	.429	.368	.327
Int	1.774*	1.890*	2.263*	2.186*	1.994*	1.493*	2.014*	1.963*
(K/L)	.323*	.342*	.280*	.263*	.268*	.327*	.266*	.238*
$(K/L)^2$	−.0142*	−.0151*	−.0115*	−.0106*	−.0103*	−.0132*	−.0105*	−.0091*
Edu	.0369*	−.0486*	−.1097*	−.0573*	−.0106	.0659*	.0055	.0837*
Union	.1895*	−.0199	.0483	.0079	.2364*	−.0329	−.3577*	.0766
Union × (K/L)	−.0169*	.0039	−.0037	.0010	−.0217*	.0080	.0328*	−.0021
Rent	−.0194*	−.0192*	−.0104*	−.0092*	−.0095*	−.0126*	−.0071*	−.0091*
Rent × (K/L)	.0019*	.0018*	.0009*	.0009*	.0008*	.0010*	.0004	.0006
Wages								
R^2	.655	.667	.690	.748	.768	.803	.787	.783
Int	−.235	−.387	.257	−.785	−.385	−4.237*	−3.324*	−1.843*
(K/L)	.439*	.594*	.552*	.641*	.546*	.909*	.810*	.542*
$(K/L)^2$	−.0186*	−.0245*	−.0218*	−.0261*	−.0220*	−.0330*	−.0275*	−.0149*
Education	1.417*	1.111*	.932*	1.138*	1.176*	1.655*	1.440*	1.416*
Union	−2.300*	−1.827*	−2.225*	−3.151*	−4.161*	−1.310*	−.925	.493
Union × (K/L)	.2331*	.1945*	.2256*	.3218*	.4135*	.1724*	.1464*	.0277
Rent	−.0220*	−.0217	−.0175	.0036	.0421*	−.0306*	−.0549*	−.0339*
Rent × (K/L)	.0020*	.0021*	.0018	.0000	−.0034*	.0029*	.0049*	.0031*

Note: All variables in log form except union status.

*Significant at the 5 percent level.

then dropped back slightly to 48 percent in 1993. Interestingly, at the same time there was also a substantial change in the impact of education on effort. In 1970 the worker with 14 years of education worked on average 1.5 hours less than the high school dropout. By 1993 this had reversed, so that the college educated worked 1 hour more per week on average than the high school dropout. This empirical fact sets us to thinking about possible explanations. One explanation we like is that new very productive jobs emerged in the 1980s that required both high amounts of human capital and high inputs of physical capital (computers). But maybe it is the decline in the marginal tax rates, or the increasing cost of higher education, or something else entirely. Work is under way to answer this important question: Why are the educated working so much harder today than they did 30 years ago?

The interactive terms make it difficult to clearly see the impact of rents and union status on wages and hours. To facilitate the discussion of these interaction terms, table 2.11 displays the estimated impact of a 1 percent increase in union participation and in industry rents separately for a labor-intensive industry and a capital-intensive industry.[17] The impact of union status on weekly hours is very small in magnitude, but its impact on wages is significant. Not surprisingly, the presence of unions tends to raise wages in the capital-intensive sectors more than in the labor-intensive sectors. But up until 1985, unions seemed to have a negative effect on wages in labor-intensive industries. This result is possibly caused by another potential endogeneity problem, this time between capital intensity and unions. When unions successfully raise wages, firms naturally become more capital intensive. The overall decline of union presence from 39 percent in 1975 to 20 percent in 1993 may explain why this odd result has dissipated. Another interpretation is that unions seek preferred contracts in terms of both wages and effort level. In the capital-intensive sectors, where the cost of cutting effort is very high, unions opt for higher wages and perhaps not much change in effort. In the labor-intensive sectors, unions pursue the effort dimension of the contract more aggressively and end up opting for a contract that has greatly reduced effort and also somewhat reduced wages. (Here we are speaking about effort in the form of pace rather than in the total number of hours.)

We are uncomfortable with both the theory of rent sharing and also our measurement of rents, and we consequently do not place a great deal of faith in the rent results in table 2.11. According to these estimates, industry rents seem to reduce hours in labor-intensive sectors, but raise hours in capital-intensive sectors. Rents have a mixed effect over time on wages in the labor-intensive sectors, but consistently raise wages in the capital-

17. These industries are defined at the minimum and maximum levels of capital intensity for each time period, respectively.

Table 2.11 **Variation in Union and Rents Effects (%)**

	Hours			Wages			
	Low (K/L)	Average (K/L)	High (K/L)	Low (K/L)	Average (K/L)	High (K/L)	Variable Average
Unions							
1960	.07	.02	−.02	−.72	.09	.65	42.0
1965	.01	.02	.03	−.36	.19	.65	42.5
1970	.02	.01	.00	−.39	.16	.66	41.9
1975	.02	.02	.02	−.43	.32	.98	39.7
1980	.05	.00	−.04	−.59	.34	1.19	36.8
1985	.04	.06	.07	.22	.60	.95	27.5
1990	−.07	.01	.07	.37	.71	1.00	22.6
1993	.06	.05	.05	.74	.80	.86	20.4
Rents							
1960	−.63	.03	.50	−.87	−.20	.27	−1.82
1965	−.56	−.05	.37	−.60	−.02	.47	−1.72
1970	−.28	−.06	.15	−.30	.14	.53	−1.81
1975	−.19	.02	.20	.36	.37	.37	−1.94
1980	−.23	−.04	.13	1.32	.56	−.13	−1.94
1985	−.39	−.18	.02	−.50	.14	.73	−2.48
1990	−.32	−.22	−.13	−1.17	−.05	.94	−3.11
1993	−.39	−.26	−.14	−.67	.02	.64	−3.23

Note: Impact of a 1 percent increase in rents and union status on weekly hours and wages by capital intensity.

intensive sectors, reflecting the potential for profit sharing within an industry that is not fully competitive.

The point of this lengthy discussion of additional variables is primarily to determine if our initial estimate of the wage-effort offer curve is substantially contaminated by the omission of all these effects. Since we are now treating human capital as self-financed, in principle we want to trace out the wage-effort offer curve after aggregating human and physical capital and after removing from wages the implicit rental cost of human capital. This is not easily done, and what we do instead is to trace out the curve in the same way as before, using the new coefficients on the capital-intensity variables and holding fixed all the other variables at their sample averages. The results are displayed in figure 2.16. Although the shape of the wage-effort offer curves is altered slightly, the same basic patterns of change can be seen in the three periods.

2.4 Conclusion

We have provided in this paper substantial evidence that the U.S. labor market offers a set of wage-effort contracts, with effort measured by annual hours. This curve is uncovered by estimating two equations using

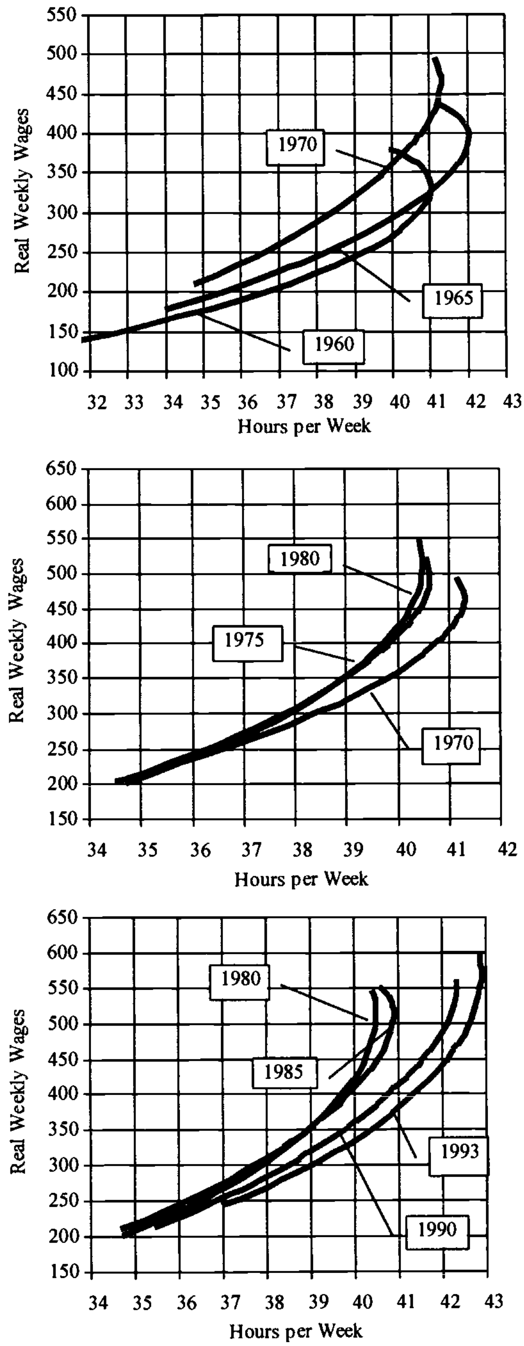

Fig. 2.16 Derived wage-effort offer curves, 1960–93, controlling for education, unions, and industry rents

industry-level data. One equation explains wages as a function of capital intensity and the other equation explains hours also as a function of capital intensity. By eliminating capital intensity from these two equations, we form a wage-hour offer curve.

We have found that this offer curve shifts in three distinctly different ways. Between 1960 and 1970, the wage-effort offer curve shifted up, with higher wages offered at every level of effort. Between 1970 and 1980, the wage-effort offer curve twisted, with the best contracts getting better and the worst contracts getting worse. Since the 1980s, the wage-effort offer curve has shifted to the right, requiring more effort for the same wage level. The upward shift in the 1960s is consistent with capital deepening, the twisting in the 1970s with price declines of labor-intensive tradables, and the rightward shift after 1980 either with the introduction of new equipment or with increases in government-mandated benefits.

The weakest link in our empirical analysis is probably the use of hours as a measure of effort. Despite problems with hours as a measure of effort, we find a consistent and significant relationship among wages, effort as measured by hours, and capital intensity. This relationship stands up even when we control for the business cycle, education, unionization, and estimated industry rents.

This is, of course, not the end of the story by any means. We should be studying tasks, not industries. We should be looking at individual-level data and data outside of manufacturing. We should be allowing more completely for heterogeneity in ability and tastes. We should have a better measure of unionization. We should explicitly link changes in the wage-effort offer curve to the fundamental drivers such as globalization, technological change, and worker benefits. Most of all, we need a better measure of effort.

Although this is not the end of the story, it is a very good beginning.

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Comment Alan V. Deardorff

This paper follows up another paper of Leamer's alone (Leamer 1999) that I have had the pleasure of discussing twice on other occasions. I've said before, and I will repeat here, that I very much like the theoretical model. It adds a dimension—effort—to the two-sector production model that yields a surprising list of interesting and plausible implications. These implications are at least consistent with a number of stylized facts, including the relationship across industries between wages and capital intensity that Leamer documents empirically in his earlier paper.

This paper goes a few steps further toward estimating ("estimate, don't test") the model empirically, primarily by measuring effort by observable hours of work and asking whether the combined relationships among hours, wages, and capital intensity are consistent with the model. To a considerable (and, to me, surprising) extent, they are. Furthermore, by repeating the empirical analysis eight times at 5-year intervals since 1960, Leamer and Thornberg are able to observe how this relationship has changed over time in ways that are at least in some cases consistent with what one would have expected from the model in response to, first, capital accumulation and, then, globalization. The findings are striking and they do, as intended, lend even greater credibility to the model. I can see nothing particularly wrong with what they do, and on the contrary I am impressed with the way they anticipated many of my concerns with additional regressions controlling for variables that they initially left out.

My comments, then, will be mostly requests for amplification and extension, as is customary for a discussant who does not actually have to do the work. I have five of these to mention, after which I will ask whether there may not be some other explanation for the patterns that they have found in the data.

This paper, like Leamer (1999), assumes fixed-coefficient technologies. That was fine for making the theoretical points in the earlier paper, but as the basis for an empirical analysis it raises the question of whether factor substitution could alter the story in ways that matter. I suspect the answer is no, but I'd like to see it addressed. I presume that factor substitution would cause what are now linear zero-profit constraints to become nonlinear. But in my own thinking, I have been unable to visualize how they would curve, and I wonder whether they could curve in such a way as to cross one another more than once. I presume that, if one had factor-intensity reversals in the more usual isoquant diagram, that would happen. For a given set of prices, it would probably not matter if they did cross more than once. An industry's zero-profit curve would be part of the enve-

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lope for all industries only in one place, most likely. But as things change over time, where the curve hits the envelope might change and we could see the ordering of industries by capital intensity change. The remarkable charts in figure 2.7 suggest that this did not happen, but if one does allow for factor-intensity reversals as I've suggested, this becomes that much more surprising.

A related issue is that the theoretical model never allows for more than two goods, yet the empirical work, of course, includes many. I do not think that having multiple goods would change the story here at all, but it would somewhat change the emphasis. As told here, the story of a change in, say, relative prices seems to be mostly about how the zero-profit curves of the two industries shift and rotate, leading to shifts and, as they put it, twisting of the offer curve. But with many goods, it becomes clear that what matters most is not really the shape of the industry curves at all. In market equilibrium these must all be tangent to a single worker's indifference curve. Thus it is the indifference curves that ultimately constitute the offer curve, and that is where one should look to understand changes in its shape.

This makes it easier, I think, to understand the twisting of the offer curve that Leamer and Thornberg attribute to relative price changes. As they explain with figure 2.4, twisting is a rather mysterious phenomenon that includes changes in the curve's slope in opposite directions in different places. But what has really happened is that changes in relative prices have moved workers to a lower indifference curve, and the new offer curve reflects its shape entirely. With Leamer's assumed form for the utility function, which includes a maximum level of effort, lower indifference curves are squeezed down toward the corner formed by the horizontal axis and this maximum, and they do indeed become flatter along their bottom portions and steeper further up.

The one place where the data do not seem to conform to the model is in the backward-bending shape of this offer curve. If it really were an indifference curve, as it should be from the model, then it could not look like this, since presumably workers are unambiguously better off working fewer hours for more (total) pay. Leamer and Thornberg attribute the backward bend to the presence of unions, although as far as I can see, accounting for unions in their regressions does not remove this feature. And while I do understand the intuition that unions in some sectors might both raise wages and reduce hours, I am uncomfortable with the disconnection between this suggestion and the treatment of unions in Leamer's earlier paper. One of the nice features of that model was its treatment of collective bargaining, and I cannot see that it looked anything like this. I would prefer to see unions handled in a way that we know to be at least consistent with the model.

Another concern that I have is the employment of workers in shifts.

This issue is mentioned repeatedly in the paper, mainly to acknowledge its importance and the difficulty of addressing it. I agree with both, as well as with the suggestion that their findings are all that much more impressive given that they did not deal with it. That is, the true capital intensity of an industry is probably the ratio of capital to labor that needs to be employed simultaneously, not the ratio that may in fact be employed over a week. If a machine requires one worker to operate it, then the correct ratio is one machine per worker, even if shift operation permits it to run continuously over a week with three or four workers in staggered shifts. Thus the measured capital/labor ratios in these industries may not correctly reflect differences in these true capital/labor ratios if shift operations are feasible in some and not feasible in others. Leamer and Thornberg's response to this is to say, Yes, that's right, so isn't it impressive that we get the results that we do, even with such noisy data on capital/labor ratios. I agree.

But I also wonder if shifts could not also account for one of their findings that they find difficult to explain, namely the backward-bending offer curve. As Frank Stafford and I (Deardorff and Stafford 1976) argued years ago, as industries become more capital intensive, they first reconcile the conflicting desires of labor to get some sleep and of capital to work 24 hours a day by gradually lengthening the workday, exactly as Leamer and Thornberg find. But at some point the costs of this compromise become too great, and it becomes cheaper to add shifts and reduce hours, even though the less-popular shifts require greater pay. Is it not possible that Leamer and Thornberg's backward-bending offer curve just reflects that the most capital-intensive industries are doing exactly that—reducing hours but adding shifts? Shifts, then, together with the story that Frank and I told years ago about balancing the interests of labor and capital, may provide another alternative explanation for Leamer and Thornberg's findings that they have not addressed.

Which brings me to my final point. As I thought about their findings and wondered where they might have come from, I did not at first think of the shift explanation that I have just mentioned. Rather, as I looked at figure 2.7 and heard it described as showing backward-bending offer curves, I could not help but think I was seeing backward-bending labor-supply curves. The trouble with that, however, is that you do not expect to see all the points on a labor-supply curve at once. With only one wage paid, you will only observe one point, and if more than one wage were paid, workers would all take the highest. But if workers are not the same in all industries in terms of their productivities, but are the same in terms of their willingness to trade off labor and leisure, then one might observe exactly this pattern of low-wage workers working short hours, medium-wage workers working a bit more, and high-wage workers working a bit less.

How do we get the workers to be different? Leamer and Thornberg already allow for the possibility of differences in education, and the backward bend does not go away when they control for that. But suppose that workers differ in other ways that are not fully captured by education? Suppose that they are differently endowed with innate abilities, and that these abilities are complementary with physical capital. Then capital-intensive industries will attract these workers by paying them more, and they in turn will select their hours worked in accord with their preferences. This, it seems to me, would account for the backward-bending pattern of the data, but with a much different interpretation of what it represents. Most importantly, it would not then be the case that all those dots in a panel of figure 2.7 represent workers at the same level of utility, or that workers are indifferent between employment in transport or apparel. Instead, we would have some workers who are meaningfully better off than others, and changes in the economy such as globalization would have real, not just apparent, implications for true inequality.

I suppose that if these differences in innate ability were sufficiently correlated with education, then Leamer and Thornberg's inclusion of education in their later regressions would capture it. But if the correlation is less than perfect, would this do the trick? Leamer is the econometrician, not I, and I'm sure he can answer this. But even if the answer is yes, I suspect that there are many differences in innate ability that are not correlated with education, but that do matter for a worker's productivity in, say, fabricating metals versus stitching apparel.

So my bottom line here is that I love the model, and I am very impressed and intrigued with the empirical results of this paper. But I am not yet ready to believe that this is the main story that we should be telling about recent changes in the world economy. In particular, the notion that apparent increases in inequality are illusory—that the workers who are earning more are not really any better off, but just working harder—strikes me as both doubtful and dangerous.

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