International Trade, Multinational Corporations, and American Wages

by

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Abstract

Several economists, politicians, and pundits have recently argued that in the 1980's the American economy became more tightly integrated into the world economy. In particular, they often argue that American labor-market trends have been increasingly driven by this "internationalization" of the economy. Inspired by these arguments, this thesis investigates whether international trade and multinational corporations influenced trends in the American labor market during two periods: the 1980's and the antebellum years. In the 1980's, average real wages grew very sluggishly and the wages of skilled workers grew very sharply relative to those of less-skilled workers. I find that neither international trade through the Stolper-Samuelson process nor outsourcing by multinationals contributed significantly to either of these developments. In antebellum America, the construction of canals and railroads equalized commodity prices between the Northeast and the Midwest. However, I find that because regional production patterns were specialized, this commodity-price equalization across regions did not lead to wage equalization across regions. Thus, the overall finding of the thesis is that in two labor-market episodes where strong *prima facie* evidence pointed to a role for either trade or multinationals, this evidence was not supported by more rigorous empirical analysis. The overall policy implication is that current policies designed to ameliorate the labor-market effects of the "internationalization" of the American economy may be unnecessary.

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Introduction

In the last few years, a number of economists, politicians, and pundits have argued that in the 1980's the American economy became more tightly integrated into the world economy. In particular, they often argue that American labor-market trends have been increasingly driven by this "internationalization" of the economy. This argument is often supported by *prima facie* evidence such as anecdotes and growing trade volumes. In this dissertation I go beyond this *prima facie* evidence to investigate whether international trade and multinational corporations influenced trends in the American labor market during two periods: the 1980's and the antebellum years.

The first chapter, "International Trade and American Wages in the 1980's: Giant Sucking Sound or Small Hiccup?" was co-authored with Robert Lawrence and was published in *Brookings Papers on Economic Activity: Microeconomics 1993*. Two facts about the American labor market in the 1980's motivate this paper. First, average real wages barely grew. Second, the wages of less-skilled Americans fell relative to those of their more-skilled counterparts. The paper investigates the contribution of international trade to these two developments. We first present the standard trade theory on factor returns, and then apply this theory to the data. Our main finding is that trade through the standard channels seems to have contributed nothing to either of these developments: import prices did not rise sufficiently to restrain real wages, and the terms of trade through the Stolper-Samuelson process did not diverge relative wages. Instead, trends in the domestic side of the economy seem to have dominated the wage structure. Sluggish labor-productivity growth in the service sector accounts for most of the sluggish real-wage growth, and skill-biased technological change appears to account for most of the unequal wage growth.

The second chapter, "International Trade, Multinational Corporations, and American Wage Divergence in the 1980's," focuses more closely on the wage-divergence issue addressed in the first chapter. The literature on this wage divergence has demonstrated that a shift in relative labor demand away from the unskilled and toward the skilled was its main cause. However, the literature has not adequately addressed the hypothesis that the "internationalization" of the American economy helped cause the demand shift. This paper evaluates whether international trade or multinational outsourcing contributed to the demand shift and resulting wage divergence. First, the paper articulates the theory of how trade or multinationals can shift relative labor demand. The paper then analyzes the relevant data in light of this theory. My main finding is that neither international trade through the Stolper-Samuelson process nor outsourcing by multinationals contributed significantly to America's wage divergence in the 1980's.

The third chapter, "The Antebellum Transportation Revolution and Factor-Price Equalization," applies the techniques developed in the first two chapters to the antebellum labor market. In antebellum America an extensive network of canals and railroads was constructed which slashed transportation costs between the Northeast and the Midwest. This "transportation revolution" allows an interesting case study of the factor-price equalization (FPE) theorem. The paper documents that the lower transportation costs helped equalize commodity prices across regions. It then presents wage series which surprisingly display no evidence of wage equalization across regions. The interesting question then becomes why FPE didn't arise. The paper argues that regional specialization of production in the Midwest prevented it. To support this argument the paper presents historical evidence that the Midwest was effectively specialized. It then presents a simple model that shows how the nature of regional shifts in factor demands depends on whether the region specializes in production. Thus, the transportation revolution was realizing one of FPE's usual assumptions---zero trade barriers. But the fact that a second assumption--no regional specialization of production--was not being realized prevented the first from equalizing factor prices.

Thus, the overall finding of the thesis is that in two labor-market episodes where strong *prima facie* evidence pointed to a role for either trade or multinationals, this evidence was not supported by more rigorous empirical analysis. The overall policy implication is that current policies designed to ameliorate the labor-market effects of the "internationalization" of the American economy may be unnecessary.

Chapter 1

International Trade and American Wages in the 1980's: Giant Sucking Sound or Small Hiccup?

1 Introduction

The American dream is that each generation should live twice as well as its predecessor. Over the century prior to 1973, real average hourly earnings rose by 1.9 percent per year.[1] At that rate earnings doubled every thirty-six years, and the dream was realized.

The dream no longer holds. Since 1973, the United States has failed to match its historic track record. In 1973, real hourly earnings, measured in 1982 dollars by the Consumer Price Index (CPI), were $8.55. By 1992 they had actually *declined* to $7.43--a level that had been achieved in the late 1960's. Had earnings increased at their earlier pace, they would have risen by 40% to over $12.00. Or consider real hourly compensation. This is a more comprehensive measure of the payments to labor because it includes fringe benefits as well as earnings. Between 1973 and 1991, real hourly compensation rose by only 5%. However one measures labor's income growth, it clearly has slumped since 1973.

A second ominous development in the American economy has accompanied this slump: a dramatic increase in the inequality of earnings. In particular, the earnings of skilled and educated workers have risen sharply relative to those of their less qualified counterparts. Bound and Johnson (1992) have calculated this divergence based on education. They found that between 1979 and 1988, the ratio of the average wage of a college graduate to the average wage of a high school graduate rose by 15%.[2] Steven

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[1]See Johnson and Stafford (1992), page 1.

[2]The education differential has risen most sharply among inexperienced workers. Murphy (1992) found that in 1979, the hourly wage of a college graduate with less than five years of work experience was 30% more than that of a high-school graduate with similar experience. In 1989 this premium had soared

Davis (1992) has calculated this divergence in terms of work experience. He found that between 1979 and 1987, the ratio of weekly earnings of males in their forties to weekly earnings of males in their twenties rose by 25%. Or consider the Employment Cost Index (ECI). Assembled by the Bureau of Labor Statistics (BLS), it classifies workers by occupation, and it indicates that between December 1979 and December 1992, the growth of compensation and earnings of white collar occupations exceeded those of blue collar occupations by 7.9 and 10.9 percent respectively. However one distinguishes the skilled from the unskilled, the sharp rise in wage inequality between the two in the 1980's is clear.(See Appendix A for a brief discussion on making this distinction).

These two developments--sluggish and unequal real-wage growth--have coincided with three major changes in America's international economic relations.

The first was convergence: the change in America's comparative position from global economic preeminence to "first among equals." In the 1950's, output per worker in America was twice that in Europe and six times that in Japan. Today, both Europe and Japan have closed most of the output gap (McKinsey 1992). In addition, foreign stocks of both human and physical capital have since the 1950's been growing more rapidly than in the United States. The result has been a convergence in wage rates. In 1975, a trade-weighted average of foreign compensation rates expressed in U.S. dollars was equal to 64% of US levels. By 1980, this measure stood at 72%, and by 1990, 93%.[3]

The second major change was globalization: the increased volumes of foreign

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to 74%.

[3]This measure includes 24 US trading partners; it excludes Brazil, Mexico, and Israel. When these countries are included, the 1990 trade-weighted foreign manufacturing compensation measure equals 88% of America's. Data come from the BLS (1991).

trade and foreign direct investment in America. Between 1970 and 1990, America's exports plus imports as a percentage of gross national product rose from 12.7% to 24.9%. During the 1980's, the stock of inward foreign direct investment, valued on a historic cost basis, grew from 3% to 8.1%. Since the first oil shock in 1973, Americans have been forced to adjust to foreigners as suppliers of raw materials, as competitors in manufactures (e.g., automobiles), and finally as bankers and bosses.

The third major change was spending: the shift in American spending patterns in the 1980's which produced record trade deficits. The Reagan Administration's combination of expansionary fiscal policy and contractionary monetary policy helped cause an unprecedented appreciation of the U.S. dollar until 1985. This record strength of the dollar priced many American exporters out of the world market, and it made imports a bargain for American consumers. The result was record trade deficits: .5% of GDP in 1980 to nearly 3.5% of GDP in 1987.

The coincidence of America's changed international economic relations with its slow and uneven wage growth makes it scarcely surprising that the former has frequently been advanced as a primary cause of the latter. This connection is often made in policy discussions. Recall Ross Perot, for example. In the 1992 presidential debates he claimed that ratification of the North American Free-Trade Agreement (NAFTA) would generate "a giant sucking sound," with high wages and challenging jobs fleeing to Mexico. This claim struck a nerve with millions, and helped him win 19% of the popular vote.

Many academics as well have linked international factors to wage developments. For example, Johnson and Stafford (1992) argue that the erosion of high returns from American technological leadership has been the principle source of the slow rise in

American real wages since 1973. Similarly, Leamer (1991) claims that increased capital formation abroad is leading inevitably to "factor price equalization" in which American wage rates converge to those in other countries. According to Leamer, this convergence is not benign because it entails not simply a rise in foreign wage levels but also a decline in American wage levels. Reich (1991) argues that global competition has bifurcated American workers--and thereby American society--into two groups: high-earning "symbolic analysts" whose talents are rewarded by globalization, and the mass of ordinary production workers whose earnings are depressed by it. And referring to growing wage disparity, Murphy and Welch (1991) conclude that "The evolving pattern of international trade is perhaps a primary cause of recent wage changes."

Other academics, however, have argued that international factors have played only a small role in recent wage changes. Borjas, Freeman and Katz (1992) argue that trade flows explain at most 15% (i.e., 1.9 percentage points) of the 12.4% increase between 1980 and 1988 in the earnings differential between college-educated workers and their high-school-educated counterparts. Moreover, because the manufacturing trade deficit declined from $106 billion in 1988 to $47 billion in 1991, their method would attribute to trade less than one percentage point of the disparity in relative wage growth that persists today. Davis (1992) finds that increased trade is associated with a convergence across several countries of relative-wage structures. But he concludes that this "factor-price equalization" effect has been more than offset by the growing divergence across countries of relative industry wage structures. Freeman and Needles (1992) find that the college/high school wage differential increased only slightly in Canada during the 1980's. They conclude from this that America's wage divergence was not the result of "an inexorable shift in the economic structure of advanced capitalist countries." Instead, it reflected "specific developments in the U.S. labor market." Berman, Bound and Griliches (1992) do not find much role for trade. Finally, Bound and Johnson (1992) find that trade played basically no role in America's wage changes in the 1980's. Instead, they ascribe these changes to technological change and changes in unmeasured labor quality.

The impact of America's international economic relations on both its real and relative wages is thus a controversial topic. It is also an increasing part of the policy debate. While trade intervention is rarely the ideal instrument for redistributing income, it is often a tempting one. Leamer, for example, argues that liberalizing trade with developing countries such as Mexico costs the U.S. an important mechanism for maintaining the wages of its least fortunate workers.

In this paper, we try to advance the debate by a data analysis which uses insights from theory to investigate the role of international trade on America's recent wage performance. In the first section of the paper, we look at the sluggish growth of average real wages. As a first approximation, we expect the performance of average real wages to mirror the performance of output per worker. Accordingly, we explore reasons for the divergence between real wages and labor productivity. Our main finding is that trade had nothing to do with the slow increase in average compensation. The sluggish rise in real compensation and the accompanying convergence of US and foreign wages reflected slow productivity in the non-traded goods sectors of the American economy. Real *product* compensation increased almost as rapidly as output per worker. Real *consumption* compensation growth lagged behind real product compensation because of a rise in the relative price of housing (which workers consume but do not produce) and a decline in the relative price of investment goods (which workers produce but do not consume).

In the second section of the paper, we consider the rise in the relative wages of non-production workers. Standard international-trade theory, as laid out by Stolper and Samuelson, suggests that changes in the relative returns of factors will reflect changes in the prices of the goods that they produce. Many studies of relative wage performance have ignored this process, however.[4] Instead, they focus on trade volumes and trade deficits. As Bhagwati (1991) has emphasized, trade deficits are not the most suitable measures of the effects of trade because they are not necessarily associated with relative wage behavior. We focus instead on the behavior of traded-goods prices, and we find no evidence that the relative prices of goods which use production labor relatively intensively have declined. From this evidence, we conclude that relative U.S. wages have not been driven by Stolper-Samuelson effects. We do, however, find a positive association between total-factor productivity growth and the intensive use of non-production labor. This points to technological change as the major source of relative wage changes. Indeed, we argue that the pervasive decline in the ratio of production to non-production workers actually employed--despite the decline in the relative wages of production workers--points to a dominant role for technological change which has augmented employment of non-production workers. This accords well with anecdotal evidence of the shift toward computer-controlled flexible manufacturing systems.

In the third section of the paper, we consider and reject two more complex hypotheses about the impact of trade on wages. We analyze models which assume complete specialization and the hypothesis that trade has eroded union rents. We

[4]Leamer (1992) is a noteworthy exception--but see Footnote 24.

conclude with a summary of our major findings and some observations on the important role played by the productivity slowdown outside of manufacturing.

2 Average Wages

What has happened to real average wages of U.S. workers? To answer this question, one must first define "wages." One source of confusion reflects the inconsistent use of conceptually distinct data series. The most commonly cited statistic, real average hourly earnings of production workers, shows a *decline* of almost 11% between 1979 and 1991. By contrast, a second commonly cited series, real hourly compensation in the business sector, shows an *increase* of 1.5% over the same period. These series differ in two ways. First, the average hourly earnings series samples only production or nonsupervisory workers while the hourly compensation series includes all persons engaged in work (including the self employed). Second, the hourly earnings series reflects only wages while the compensation measure includes employers' contributions for social insurance and private benefit plans (including retirement and medical care). Both differences are important, and the series have diverged for two reasons. First, the wages of production workers have risen more slowly than those of non-production workers. Second, fringe benefits for all workers have increased more rapidly than wages.

The ECI offers an indication of the relative roles of these two factors in earnings behavior. It suggests that half of the shortfall between the average hourly series and average compensation reflects the relatively slower increase in the earnings of production workers, and the other half the relatively rapid rise in the costs of employer-provided taxes and fringe benefits (especially medical care). Indeed, between December 1979 and December 1991, the ratio of earnings of blue-collar workers to average earnings in the private sector declined by 5.7%, and the ratio of average compensation to average earnings in the private sector increased by 5.7%.

From a theoretical standpoint, compensation rather than earnings is the relevant measure of "wages" on which we should focus. We expect workers to be hired as long as their compensation cost is less than their marginal revenue product. In equilibrium, therefore, we expect nominal compensation at time t, w_t, to equal labor's marginal revenue product at time t, mrp_t:

$$w_t = mrp_t = P_t \times mpp_t \quad (1).$$

Note that mrp_t is defined as usual as the product price at time t, P_t, and the marginal physical product of labor at time t, mpp_t.

Expressing (1) in logarithms and differentiating (1) with respect to time, we get

$$w_t^* = P_t^* + mpp_t^* \quad (2).$$

Here, w_t^* denotes $d\log(w_t)/dt$, etc. Changes in compensation are the sum of changes in product prices and changes in the marginal physical product of labor.

In the long run in a conventional neoclassical growth model, we also expect changes in the marginal physical product of labor to match changes in the average physical product (app) of labor, which equals output per worker. Thus $mpp_t^* = app_t^*$, and we can write

$$w_t^* = P_t^* + app_t^* \quad (3).$$

This suggests that as a first approximation, we expect changes in real compensation to match the change in output per worker:

$$w_t^* - P_t^* = app_t^* \quad (4).$$

Let us consider what happened in the United States.

The Output-Wage Gap

We focus on the period since 1979, because 1979 is when slow average-wage growth and rising relative wage dispersion-- the two phenomena we are interested in-- became apparent. The growth of output per worker in the U.S. did slow down dramatically after 1973. But Figure 1 indicates that between 1973 and 1979, average real compensation increased in line with output per hour in the US business sector. From 1979 to 1991, however, output per worker grew by 10.5%--a very slow pace by historical standards. Over the same period, however, real compensation (average hourly compensation deflated by the CPI-U, the Consumer Price Index for Urban consumers) grew by only 1.5%. Apparently, real-compensation growth failed to match the slow growth in output per worker. Here, then, is the output-wage gap which needs explaining.

If workers have not seen their real incomes rise as rapidly as output per worker, it is quite natural to assume that someone else has received this discrepancy. One candidate is owners of capital, and a second is foreigners. Indeed, both the decade of greed (Krugman 1992) and the impact of international convergence both in reducing US buying power (e.g., Stafford and Johnson 1992) and in shifting income away from labor (e.g., Leamer 1991) have been cited as explanations of the output-wage gap.

However, these explanations can be rejected in favor of a more straightforward one which involves the basket of goods to which P_t refers. The P_t used in equation 4 measures a basket of goods produced in the United States. The CPI used in calculating real compensation, however, measures a basket of consumption goods typically consumed in the United States. The key point is that the two baskets do not contain the same goods. It follows that nominal compensation deflated by the CPI does not equal nominal compensation deflated by a basket of production goods. Indeed, if we deflate nominal compensation by the output deflator used in the business-output measures of productivity, we find that between 1979 and 1991 real product compensation actually increased by 9.5%--just 1% less than the increase in output per worker (see Table 1). Thus by measuring ($w_t^* - P_t^*$) with the appropriate P_t, we find that equation (4) basically did describe the United States from 1979 to 1991. By deflating wages with the appropriate prices, the output-wage gap disappears.

This means that there has *not* been a shift in the income of the business sector away from wages and towards profits.[5] Indeed, in 1991, the share of total compensation in the value-added by the business sector was 65.6%, less than one percentage point lower than it was in 1979 (see Table 1). The share of compensation tends to rise during slumps and fall during recoveries, and the share in 1991 was higher than in the late 1970's and was close to its 1970-1990 average. What explains the differences between these output data and the more publicized versions based on household and personal income which indicate growing inequality? As convincingly demonstrated by Cutler and Katz (1991), the discrepancies arise because of data definitions. Unlike personal-income data, national-income-accounts data include in the return to capital both reinvested earnings and taxes on corporate earnings, and they exclude capital gains and interest paid on the government debt. The divergence between the output and income measures can

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[5]Define S as labor's share in income, where W nominal compensation rate, L employment, P the price of output and Q the quantity of output:

$$S = WL/PQ.$$

Expressing both sides in logs, taking the derivative with respect to time and rearranging, we get

$$S^* = W^* - P^* - (Q^* - L^*).$$

Here $S^* = dLogS/dt$, etc. So changes in labor's share are equal to the difference between changes in the product wage, ($W^* - P^*$), and changes in output per worker, ($Q^* - L^*$).

be ascribed to these differences. Profits, therefore, did not increase dramatically at the expense of compensation.

Our explanation of the output-wage gap also means that trade developments did *not* shift income away from labor. We will describe below, in greater detail in the context of a two-factor model, how the traditional Stolper-Samuelson model predicts that changes in the terms of trade reduces the real product return of the factor used intensively in the production of the good whose relative price falls. The finding that real product wages have matched productivity growth is an important piece of evidence which contradicts those who use such a model to argue that the poor U.S. average-wage performance reflects trade raising the return to capital and lowering the return to labor. If trade had done this, the real product wage would have declined. Instead it actually rose, which means that trade did not have the impact just described.

Indeed, the behavior of the aggregate U.S. business sector between 1979 and 1989 seems consistent with the predictions of a conventional neo-classical growth model. We have already noted that factor shares were constant, and that real product compensation rose at the rate of growth of output per worker. We should add that the capital-output ratio remained fairly constant. The growth rates of the net capital stock of fixed non-residential capital and business sector were 31.5% and 29.6%, respectively.[6] As a result, the 1989 ratio of business sector profits to net capital stock of 9.1% was similar to the 1979 ratio of 8.7%.

To summarize, we find that if we deflate nominal compensation by production

[6] Capital-stock data are from the January 1992 Survey of Current Business. Business-sector output data are from the 1993 Economic Report of President.

prices rather than consumption prices, workers in the 1980's were basically compensated for their growth in output per worker. If workers had chosen to consume the products they actually produced, they would have raised their real compensation by as much as the improvement in productivity growth. The wage gap illustrated in Figure 1 is thus almost totally due to a discrepancy between the production and the consumption wage. Apparently, the prices of the products that workers consume have risen more rapidly than those which they produce.

Production versus Consumption Compensation

Three major differences in the composition of the deflators for production and consumption compensation merit attention.

First come investment goods. The CPI does not, of course, reflect the prices of investment goods. The prices of the most rapidly growing investment goods, computers, have declined precipitously, and hedonic price series indicate that productivity growth in the computer sector has been particularly rapid. Simply subtracting gross domestic investment from business- sector output provides a measure of consumption goods output.[7] The implicit deflator from this series suggests that between 1979 and 1991, real compensation in terms of consumer goods increased by 5.1% (versus 1.5% using the CPI-U). Thus, about half of the shortfall between consumption- and production-compensation can be explained by the relative price decline of investment goods.

A second major . ompositional difference between consumption and production prices is housing. Output of owner-occupied housing is not included in the BLS's business-sector price measure. However, the cost of owner-occupied housing constitutes

[7]This measure is crude because investment includes expenditures on imported capital goods.

20% of the CPI. Since 1983, this cost has been inflating particularly rapidly: between 1979 and 1991, the index of shelter prices increased 17% more rapidly than did the rest of the CPI. If we deflate hourly compensation by the CPI minus shelter, then real compensation between 1979 and 1991 increased by 5.8%. This estimate is roughly equal to the previous estimate that was calculated using the business deflator minus investment goods.[8]

The third major difference between production and consumption prices involves international trade. Imported goods comprise part of the consumption basket, but not the production basket. There is a widespread view that foreign economic growth necessarily increases aggregate U.S. welfare because it provides increased opportunities for trade (e.g., Williamson 1991). However, as Hicks (1953) pointed out long ago, this is not necessarily correct. Given domestic output, national welfare depends on the terms of trade--the ratio of export to import prices. Foreign growth *will* raise aggregate U.S. welfare if it improves America's terms of trade by providing either larger markets for U.S. products and/or cheaper imports. However, if growth induces foreigners to boost output of U.S. exportables (or to shift out of U.S. importables), U.S. welfare could be reduced.[9] In principle, therefore, the sluggish increase in average U.S. real wages could reflect a decline in America's terms of trade. Johnson and Stafford (1993) have formalized this argument.

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[8]It should be noted that for workers who own their own homes, the deflation of real earnings by the CPI-U provides an unduly pessimistic view of income growth because it neglects the "real" increase in their incomes earned from home-ownership. The fact that housing output (including that imputed to owner-occupied housing) is a component of GDP helps explain why GDP per hour has also increased faster than real compensation.

[9]It should be stressed that simply because the gains from trade have been reduced, it does not follow that protection would be a superior policy.

Given domestic output, real compensation rises when workers must give up fewer resources to obtain a given quantity of imports. Whether real compensation actually rises in this way depends on two factors. The first is the productivity with which factors can be combined to produce domestic products, and the second is the rate at which domestic products can be exchanged for imports--i.e., the terms of trade. If product-wage increases match domestic productivity growth (as our work says they have), then the level of real compensation depends on the nation's terms of trade.

In Figure 2, we depict a fixed-weight measure of the terms of trade over the period of interest. This series actually indicates a small *improvement* in the terms of trade. Indeed, the broadest terms-of-trade measure (which uses GDP deflators for all tradables; this is not shown) shows an increase of 5.2%, while the fixed-weight measure shows an increase of 1.5%.[10] Other things equal, these slightly improved terms of trade meant slightly higher real compensation.

Another measure which shows that the terms of trade actually raised real compensation is the BEA's Command GNP. Designed to capture the impact of America's changed international buying power, Command GNP differs from conventional GNP in that it deflates nominal exports by the import deflator rather than the export deflator. If the terms of trade worsen, Command GNP falls relative to GNP--as does America's international buying power. Figure 3 shows that over the 1980's as a whole, Command GNP actually rose 2% more than GNP did. This means that America's international buying power grew slightly in the 1980's. Therefore, both fixed-weight terms of trade

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[10] As shown in Lawrence (1991), excluding the prices of computers, oil, and agriculture indicates virtually no change in the terms of trade for other goods and services between 1980 and 1990.

and Command GNP indicated that trade--via the terms of trade--has actually been a slightly *positive* factor in the performance of real compensation.

Of course, the terms of trade did fluctuate in the 1980's. A nation's terms of trade can shift for two very different reasons. They can shift because of competitiveness, i.e., if consumers at home or abroad change the quantities they would like to buy at given prices. But they can also shift because of changes in total spending. Domestic spending tends to fall more heavily on domestic products than foreign spending does. Accordingly, when domestic spending rises relative to foreign spending we expect to see rising terms of trade (in addition to a deteriorating current-account balance). Evaluating the impact of competitiveness on terms of trade, therefore, must control for the impact of total spending.

Consider the behavior of the U.S. terms of trade in the 1980's. Notice in Figure 2 how the emergence of the current account deficit in the first half of the 1980's was associated with both an improvement in the terms of trade and an appreciation of the real exchange rate. Also notice how both the terms of trade and the real exchange rate peaked in 1985 and then moved back to roughly their 1980 levels by 1988. The current-account deficit, however, persisted. So the terms-of-trade improvement was associated with a deterioration in the current account. This association implies that improved U.S. competitiveness did not cause this improvement. Instead, it reflected a surge in U.S. spending relative to production.[11]

[11]One mechanism by which America's terms of trade were shifted was changes in the real exchange rate. If firms selling traded goods kept their price fixed in terms of domestic currencies, we would expect the terms of trade and the real exchange rate to move together.

Although the real exchange rate and the terms of trade had nearly returned to their 1980 levels by 1990, the current account still has not. *As yet, therefore, American workers have not paid the price in terms of trade loss required to restore the trade balance in goods and services to its 1980 level.* If historical relationships prevail, in addition to the required reductions in US spending relative to income, a real decline in the dollar on the order of about 10% will be required to restore the trade balance to its 1980's levels (Lawrence 1991). Since imports account for about 13% of U.S. spending, the impact of this change on living standards would probably be on the order of just over 1%.

Productivity Growth

We said that output per worker since 1979 has grown more slowly than it did in previous decades. To analyze this slowdown, we divided the growth in business-sector output per hour into two components: manufacturing and non-manufacturing. Figure 4 displays this breakdown. Here, manufacturing output is measured in 1987 dollars. This tends to bias downward productivity growth prior to 1987 because of the treatment of computer-price weights. Despite this bias, it is striking that Figure 4 indicates that manufacturing in the 1980's actually performed near its historic norms. Measured in 1987 dollars, between 1979 and 1990 output per hour in manufacturing grew 30.7%. During the same period in non-manufacturing, by contrast, output per hour grew by only 4.5%. This weak performance in non-manufacturing productivity is the primary cause of the slump in aggregate productivity growth--and therefore in real wage growth as well.[12]

Some believe that this data reflects considerable mismeasurement.[13] However, it is noteworthy that before 1973, productivity growth in the non-manufacturing portion of the business sector was only slightly slower than that recorded in the manufacturing portion. No historical evidence, therefore, indicates that productivity growth is inevitably slower outside of manufacturing. Moreover, prior to 1973, measurement problems did not prevent the detection of significant productivity increases outside of manufacturing. To attribute the entire slowdown in services productivity to measurement problems, it is necessary to argue not only that productivity in services is difficult to measure--but moreover that this measurement has recently grown more difficult.

Some have argued that trade has kept the U.S. manufacturing sector smaller than it would otherwise have been. As we will emphasize below, it is treacherous to assume that a trade deficit represents foregone domestic output. Closing the trade deficit need not imply growing domestic output. It could simply imply shrinking domestic expenditure. Nonetheless, assume that trade deficits do represent foregone domestic output. More manufacturing activity from a smaller trade deficit would boost manufacturing's share in overall business output. This higher share, in turn, would imply higher overall business productivity. Thus, closing the trade deficit would raise aggregate productivity.

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[12]Gullikson (1992) corroborates our result. He estimates that multifactor productivity in US manufacturing increased by 1.6% per year between 1979 and 1988 -- exactly the same rate recorded between 1948 and 1973. He also demonstrates that manufacturing accounted for *all* of the 0.8% annual increase in multifactor productivity growth in the private business sector.

[13]See Baily and Gordon (1988) for a more complete analysis.

Do the data support this story? In 1991 the manufacturing trade deficit was $47 billion, approximately 5% of manufacturing value added. Had the manufacturing sector been 5% larger thanks to elimination of the trade deficit, it would indeed have carried a larger weight in the business sector. But this larger weight would have increased the level of business-sector productivity growth accumulated between 1979 and 1991 by only 0.3%. Eliminating the trade deficit, therefore, would not have appreciably boosted American productivity.

International Comparisons

Data on productivity and earnings in other countries are difficult to obtain. The BLS, however, does compile data on output and earnings per worker for France, Germany, Japan, and the United Kingdom. These data are reported in Table 2. Several features are worth noting.

First, in contrast to the U.S. experience, real earnings in the four economies grew significantly over the decade. The result has been a convergence of foreign real earnings towards U.S. levels.

Second, the primary source of the difference in earnings behavior between the United States and other countries was the difference in the growth of non-manufacturing output per employee. Table 2 decomposes overall productivity growth between the manufacturing and non-manufacturing sectors of each country. Almost all of the U.S. productivity growth and a high share of the U.K. productivity growth occurred in manufacturing. In contrast, in Japan, France, and Germany productivity growth in non-manufacturing contributed 57%, 67%, and 75% to the overall rise in productivity, respectively. These figures imply that productivity growth outside manufacturing (plus changes in the share of manufacturing in overall output) accounted for 70%, 91% and more than 100% of the differences in overall productivity growth between the U.S. and Japan, France, and Germany, respectively. Differences between the U.S. and the U.K., by contrast, reflected mainly manufacturing performance.

Third, in the three European economies a shift in income distribution towards profits slowed down the growth in product wages, and production- and consumption-wage growth were quite similar. In these two respects, the three economies differed from the U.S. Japan, however, resembled the U.S. There, profit shares remained constant but consumption-wage growth lagged production-wage growth.

As noted in McKinsey (1992), output per hour in the service sector remains higher in the U.S. than in other developed economies. However, this American lead has been shrinking over the past two decades. Since most services are not traded, this improved relative performance abroad is likely to reflect domestic developments there--increased education, increased investment rates, and technological improvements--rather than the removal of barriers to trade.[14]

It is striking how much attention has focused on relative U.S. manufacturing performance and how little on the slowdown in U.S. services-productivity growth.[15] Before the quantitative importance of this productivity development has been taken into account, it is particularly inappropriate to interpret the convergence in international real

[14]Foreign direct investment, on the other hand, may have contributed to this convergence. According to the United Nations (UNCTC, 1991), in 1970 foreign direct investment in services accounted for 25% of the global stock of foreign direct investment. By the late 1980's, the share was close to 50%.

[15]For a focus on services instead, see the paper by Baily in this volume.

wages as evidence of international trade's factor-price equalization (FPE). FPE is a basic result of standard international-trade theory that says that under certain conditions (including identical technology across countries and reasonably similar factor endowments across countries), free trade equalizes factor prices across countries. It is important, therefore, to distinguish international factor-price convergence caused by FPE from international factor-price convergence caused by productivity or technological convergence. This distinction is especially critical because technological catch-up in the non-traded sector of follower nations might well improve rather than reduce real wages in the leading country.[16]

To conclude, we have found that trade played very little role in the performance of average real compensation in the United States in the 1980's. Consumption-deflated compensation lagged production-deflated compensation because of the relative rise in housing prices and the relative decline in investment prices (especially computers). Compensation grew slowly mainly because service-sector productivity grew slowly. These results indicate that the most important determinants of U.S. average compensation in the 1980's lay in the behavior of the *domestic* economy.

3 Relative-Wage Performance

We have calculated that in American manufacturing between 1979 and 1989, the ratio of mean annual wages of non-production workers to production workers rose by nearly 10% (See Figure 5).[17] This fact corroborates the evidence presented in the

[16]Much depends on the impact of foreign income growth on the terms of trade.

[17]In 1979 the mean wage of non-production workers in manufacturing was $19,517, and the mean production worker wage in manufacturing was $12,829. In 1989 these wages were $34,866 and $21,112, respectively. Note that these wages measures do not include non-payroll compensation such as health

introduction on growing wage inequality, and it is worrisome for two reasons. First, the increased wage divergence sharply reverses the trend from 1945 until 1979 of wage convergence between production and non-production workers. Second, sluggish average real wages and diverging relative wages imply that unskilled workers actually suffered real-wage *declines* in the 1980's.

One obvious candidate for explaining this divergence is relative labor supply. All other things held constant, the wage differential between skilled and unskilled labor should grow if the growth of the unskilled-labor supply exceeds that of the skilled-labor supply. However, in the 1980's (as in the 1970's) the growth rates were reversed. Large numbers of college graduates entered the workforce, and the baby boomers aged into experienced workers. While white-collar occupations constituted 67.2% of employment in 1983, they represented 90% of the rise in employment between 1983 and 1990. Similarly, managerial and professional specialty occupations accounted for 24% of employment in 1983 and 45.7% of the growth between 1983 and 1990.[18] Thus, the data do not support labor-supply stories.[19]

Explanations have turned instead to labor demand. If manufacturing shifts its

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insurance. The previous section pointed out that total compensation rather than just wages is the appropriate measure of factor returns. Unfortunately, total-compensation data which distinguish between non-production and production workers do not exist. Therefore, we use the wage data that we have in light of this caveat.

[18]As discussed in Appendix A, the mapping is quite tight between the non-production/production distinction and the white-collar/blue-collar distinction. We define as "white-collar" occupations such as managerial and professional specialty; technical, sales, and administrative support; and service occupations. See the BLS Handbook.

[19]The relative supply of college graduates actually grew more slowly in the 1980's than in the 1970's (Katz and Murphy (1992)). But this deceleration was too small to account for the wage divergence. Bound and Johnson (1992) and Katz and Murphy (1992) elaborate on the inability of relative supply movements to explain the basic facts.

relative-labor-demand mix away from production workers and toward non-production workers, the wage differential between the two groups should grow. A second stylized fact from the data supports this labor-demand story. Figure 6 shows the evolution of the ratio of non-production to production workers employed in manufacturing. The ratio rose 25% between 1979 and 1989, from .35 to .44. This rise was much sharper than the gentle upward trend of the earlier postwar decades.

Thus both the relative wages *and* the relative employment of non-production workers rose in American manufacturing in the 1980's. This combination indicates that the labor-demand mix must have shifted toward non-production labor.[20]

A number of facts support this indication. Between 1983 (the earliest year for which consistent occupation data are available) and 1990, the rise in non-production workers in manufacturing was heavily concentrated in two occupational categories: managers and professional specialties. Over these seven years, employment in these categories grew by 25%. Over the same period, employment in total manufacturing grew by just 4.7%. Growth in these two categories constituted 91.5% of all employment growth in manufacturing during this period. More recently, this trend has continued despite the perception that middle-level managers in manufacturing are being laid off in manufacturing. Between March 1990 and March 1992, overall employment in manufacturing declined by 1.6 million workers, or 7.6%. But during these two years, manufacturing employment of managers and the professional specialties actually increased by 0.7%.

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[20]A simple exercise of drawing relative-supply and relative-demand schedules shows that relative wages *and* relative employment can rise only if the relative-demand schedule shifts toward non-production labor, regardless of what happens to the relative-supply schedule.

Given that the labor-demand mix shifted toward non-production labor, the question becomes why the demand for non-production workers in manufacturing has been so strong.

Framework

To determine the relative contributions of trade and technology to shifts in labor demand, consider a general production function for industry j at time t:

$$Q_{jt} = \Theta_{jt} F^{j}(S_{jt}, U_{jt}, K_{jt}) \quad (5).$$

Q_{jt} is the output of industry j; $F^{j}(.)$ is the time-invariant production function of industry j; and Θ_{jt} is the Hicks-Neutral technology parameter for industry j at time t that boosts the productivity of any given combination of inputs. The factors of production employed at time t are capital (K_t), skilled (or non-production) labor (S_t), and unskilled (or production) labor (U_t).

The demand schedule for each factor is the appropriate first-order condition of the profit-maximization problem. At time t, industry j demands factor i according to

$$w_{ijt} = P_{jt} \times \Theta_{jt} \times F^{j}_{it}(\cdot) \quad (6).$$[21]

Here, w_{ijt} equals factor i's marginal revenue product in industry j at time t. It is the amount that industry j is willing to pay factor i for a unit of its services. In equilibrium, this amount equals the actual wage set by the market. P_{jt} is the exogenously given price of output in industry j at time t, and $F^{j}_{it}(\cdot)$ is the partial derivative of $F^{j}(\cdot)$ with respect to factor i at time t.

To completely specify the labor market, one must add a supply schedule for factor

[21]This equation is derived as was equation (1). Here, however, we distinguish between labor types and among industries. We also represent mpp_{ijt} as the product of Θ_{jt} and $F^{j}_{it}(\cdot)$.

i in industry j. The quantity of factor i supplied to industry j probably depends on at least the wage that factor i can receive both in industry j and elsewhere, i.e., on w_{ij} and $w_{i\sim j}$. Quantity supplied probably does not depend on P_{jt} or Θ_{jt}, however. In this case, shifts in P_{jt} and Θ_{jt} identify the supply schedule as shifts in the demand schedule trace it out. In what follows, we assume that the schedules are parameterized as described. We can therefore study shifts in the demand for labor by studying shifts in P_{jt} and Θ_{jt}. First, we analyze how international trade changes P_{jt}. Then we analyze how technological progress changes Θ_{jt}.

International-Trade Theory and Relative Wages

The classic Hecksher-Ohlin-Samuelson (HOS) trade theory assumes a world of constant returns to scale and perfect competition. One of the basic implications of this theory, typically set in a two-good world with trade, is the Stolper-Samuelson theorem. This theorem states that a rise in the price of a product raises the real return to the factor used relatively intensively in the production of that good, and lowers the real return to the factor used relatively sparsely in the production of that good. International trade thus redistributes income by changing the terms of trade.

To describe the Stolper-Samuelson process, consider a small open economy which produces two products, software and textiles, with two factors, skilled and unskilled labor. "Open" means that this country freely trades both goods with the rest of the world. "Small" means that this country's production and consumption choices do not influence its terms of trade. Instead, these relative prices are determined in the rest of the world.

Furthermore, suppose that software uses skilled labor relatively intensively.[22] Initially, the country settles at some equilibrium output mix of software and textiles. To produce this mix, firms employ the country's skilled and unskilled labor. The labor market generates an equilibrium wage for each type of labor; at this wage the quantity demanded by firms equals the total quantity supplied in the economy.

We can illustrate this equilibrium with unit-value production isoquants for software and textiles that follow from the prices. In Figure 7 these are drawn as SS and TT, respectively. Note that SS lies above and to the left of TT. This indicates that software uses skilled labor relatively intensively. If both goods are produced, both isoquants must be tangent to the line which indicates the ratio of factor prices, (W_s/W_u). These tangency points indicate the ratios of skilled to unskilled labor $(S/U)_s$ and $(S/U)_t$ used to produce software and textiles, respectively.[23]

Now suppose that the international price of software rises. This is depicted in Figure 8 as an outward shift in the relevant textile unit-value isoquant to T'T'. The country will seek to make more software and fewer textiles. Output in textiles declines, releasing some of both factors. Output in software expands, requiring more of both factors. Because software employs skilled labor relatively intensively, the overall economy's relative demand shifts towards skilled labor and away from unskilled labor.

[22]This is an assumption about the technology of production. It means that for any given relative wages, the ratio of skilled to unskilled labor employed in making one unit of software exceeds the ratio of skilled to unskilled labor employed in making one unit of textiles. Since there are only two goods and two factors in this economy, it immediately follows from software using skilled labor relatively intensively that textiles use unskilled labor relatively intensively.

[23]If technological capabilities are the same throughout the world, the unique relationship between goods prices and factor prices leads to FPE.

If factor prices remained constant, however, the factor quantities released by textiles would not match those demanded by software because of the different factor intensities of the goods. The textile industry would release too much unskilled labor and too little skilled labor relative to what the software industry demands.

Wages must therefore change. The nominal unskilled-labor wage falls, and the nominal skilled-labor wage rises. The new equilibrium relative-factor-price ratio is $(W_s/W_u)' > (W_s/W_u)$. This higher ratio induces firms to substitute away from skilled labor and toward unskilled labor, and this substitution lowers the ratio of skilled to unskilled labor employed in each industry (In Figure 8, this substitution is represented as a flattening of each industry's (S/U) ray to (S/U)'). Textiles thus releases less unskilled labor and more skilled labor relative to what it would have released without the wage change. Similarly, software demands more unskilled labor and less skilled labor relative to what it would have released without the wage change. Wages move just enough to reemploy all labor; at this point the economy attains its new equilibrium. At this point, the real wage of unskilled labor has fallen, and the real wage of skilled labor has risen.

In the new equilibrium the economy makes more software and fewer textiles. This new output bundle implies a shift in the economy's relative factor demand toward skilled labor and away from unskilled labor. This shift has two important effects. It *raises* the skilled-labor wage and lowers the unskilled-labor wage. It also *lowers* the ratio of skilled to unskilled labor employed in both industries. Overall, changed terms of trade have translated into changed factor returns and changed factor-employment ratios by shifting the demand for these factors. With reference to equation 6, the w_{ijt}'s change both because the P_{jt}'s change and because the $F^j_{it}(\cdot)$'s also change (because of the new relative employment levels in all industries). Thus it is not trade volumes which matter in the Stolper-Samuelson process. It is the change in prices of traded goods.

We have just presented the Stolper-Samuelson process in a very simple model. One might wonder whether the process still operates in more complicated--yet more realistic-- models. The short answer is that it does, although now with reference to relative-wage changes rather than the real-wage changes predicted in the strong Stolper-Samuelson theorem.

For example, the model can be extended by allowing either or both of the industries to be imperfectly competitive thanks to increasing returns to scale. Helpman and Krugman (1985) lay out the basic imperfect-competition models, and they find that Stolper-Samuelson still operates. Scale economies internal to the firm introduce a second channel by which trade redistributes utility: increased product variety worldwide in the differentiated-product industry benefits consumers (i.e., all factors of production). But this channel does not work through factor returns, and therefore does not alter the relative-wage changes of Stolper-Samuelson--the relative wage changes we are interested in here. The model can also be extended by increasing the number of factors of production and goods. Ethier (1984) studies how Stolper-Samuelson and other theorems generalize in higher dimensions. He finds that a generalized version of Stolper-Samuelson still operates regardless of dimensionality. In this generalized version, relative good-price changes translate into relative factor-price changes. Again, our work here focuses on relative factor-price changes, so this extension applies to our work. Thus, we feel that looking in the data for implications of this generalized Stolper-Samuelson process is the appropriate way to gauge the effects of international trade on the American economy in the 1980's.

Existing Work on Trade and Relative Wages

Did this process help increase the relative wages of skilled workers in the United States in the 1980's? Surprisingly, no study of America's income distribution in the 1980's has explicitly considered this question.[24] Instead, studies of relative wages which look at the role of international trade have focused on either trade volumes and trade deficits or the impact of changes in traded-goods prices on relative *industry* wages.[25]

The studies which calculate the quantities of factors embodied in trade volumes or the trade deficit do not relate precisely to the Stolper-Samuelson theorem. For example, Borjas, Freeman, and Katz (1991)[26] calculate the quantities of skilled and unskilled labor embodied in America's trade deficits up through 1987, and call these quantities the "international factors" which influence wages. Borjas, et al, reason that these embodied labor supplies should be combined with America's endowment of factors to obtain America's "effective" labor supplies. All other things equal, a large effective

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[24]The one exception is Leamer (1992), who does acknowledge the role of terms of trade. His analysis is flawed in another way, however. He attempts to exploit the reciprocity between the Rybczynski and Stolper-Samuelson theorems by first estimating Rybczynski partial derivatives in production functions and then calling these estimates of Stolper-Samuelson partial derivatives. This approach is flawed because reciprocity cannot be applied empirically. Reciprocity requires firms to have a revenue function with well-defined first and second derivatives. Such derivatives exist in higher dimensions if and only if the number of factors of production equals or exceeds the number of goods produced. As discussed earlier, in reality the number of goods probably far exceeds the number of factors. Leamer himself estimates Rybczynski partial derivatives with 3 factors and 37 goods.

[25]On the first focus, see Borjas, Freeman, and Katz (1991); Davis (1992); Katz & Murphy (1992); and Murphy & Welch (1992). On the second, see Ravenga (1992).

[26]Other examples of this approach include Lawrence (1984).

supply of a factor lowers its return. Because America tends to import unskilled-labor-intensive products, larger trade deficits in the 1980's meant a larger relative effective supply of--and therefore a lower relative wage for--unskilled labor.[27]

Borjas, et al, conclude that America's trade deficits accounted for no more than 15% of the growth in inequality of American wages. When one considers with whom America trades, it is not surprising that estimates of the factor supplies embodied in U.S. trade indicate relatively small effects on wages. In 1990, 70% of America's manufacturing imports came from OECD countries--countries with endowments and wage structures very similar to America's. In 1980, hourly compensation in other OECD countries was 83% of U.S. levels. This dropped to 64% by 1985, but then increased to 103% by 1990.[28] In 1981, only 25% of America's manufacturing imports came from developing nations. By 1990, this share had increased to only 30%.[29]

Although the approach of Borjas, et al, enjoys a long tradition, it is rather weakly grounded in standard trade theory. Standard trade theory does discuss effective factor supplies, but it does not develop clear empirical tests for their effect on relative wages. Indeed, it suggests that trade deficits per se have no necessary relationship to factor

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[27]Policymakers sometimes use a particularly egregious version of this approach. They use a rule of thumb that says each billion dollars of manufacturing output represents twenty thousand jobs. With this rule, they argue that a trade deficit of $100 billion represents two million American jobs lost.

[28]EC wages were the same as in the US in 1980, and are 15% higher today. Wages in the Asian NICs were 12% of US levels in 1980 and are 25% today. Overall, on a weighted average with 24 foreign countries, foreign wages have increased from 72% to 88% of US levels.

[29]As a percentage of GDP, however, manufacturing imports from developing nations grew over the 1980's from 1.2% in 1981 to 2.1% in 1990.

returns.[30] The reason is that trade deficits depend on both production and consumption activity: they are the excess of expenditure over production. The Stolper-Samuelson theorem, however, deals only with production activity: shifts in production prompted by shifts in the terms of trade. Changes in the trade deficit that leave the terms-of-trade unchanged do not change relative factor returns.

To clarify this point, return to our small open economy. Suppose that it is at full employment with balanced trade, and that its residents decide to consume more than they produce. They import more, and pay for this trade deficit with a capital-account inflow. Obviously, since the economy remains fully employed, the trade deficit does not cost jobs. Moreover, since the economy is small, the terms of trade do not change--and this means that relative factor returns do not change. Domestic spending is simply exceeding the economy's productive potential.[31] But the trade deficit does change the country's effective factor supplies as defined by Borjas, et al. They would therefore incorrectly conclude that relative factor returns must change.

As Bhagwati (1991) has emphasized, relative price changes are the critical intervening variable in the chain of causation from trade to factor prices. *Ex post* trade

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[30]Some empirical work has used factor endowments to test trade-theory results other than the Stolper-Samuelson theorem. For example, Bowen, Leamer, and Sveikauskas (1987) use effective factor supplies to test the law of comparative advantage. In addition, some theoretical work has linked effective factor supplies to factor returns. Deardorff and Staiger (1988) discuss under what conditions the factor content of trade can relate changes in the factor content of trade to changes in relative factor prices. Unfortunately, when the model does not restrict preferences and technology to be Cobb-Douglas, only average relationships can be derived between factor content and factor returns. Deardorff and Staiger do not lay out an empirical strategy for testing their model's results, so how exactly Borjas, et al relate to their work is unclear. As for the relationship between trade deficits and factor returns, think of the transfer problem. The entire literature on the transfer problem is devoted to determining the direction in which a trade deficit (or the accompanying international transfer of capital) will move the terms of trade--and by implication, the impact that this move will have on relative factor prices.

[31]If the country is large, depending on demand patterns the terms of trade could move in either direction.

volumes are a poor measure of the *ex ante* pressures generated by trade. If international competition forced U.S. workers to lower their wages, domestic firms might be able to hold on to their domestic market shares. By examining only trade flows, however, we might conclude that trade had no impact on wages. In principle, even if trade flows are small, changes in traded goods prices could have large effects on the prices (and thus factor returns) of domestically produced substitutes. All of these considerations suggest that prices rather than quantities provide a better picture of the shocks originating from trade.

Empirical Evidence of Stolper-Samuelson

To explore the implications of the Stolper-Samuelson theorem, we examined the data for relationships consistent with the process working. All other things equal in the Stolper-Samuelson framework, a rising relative wage of skilled labor should manifest itself in two relationships: (1) a *fall* in all industries in the ratio of skilled to unskilled labor employed, and (2) an *increase* in the international price of skilled-labor intensive products relative to those of unskilled-labor-intensive products. We consider each of these propositions in turn. Our data set covers the United States manufacturing sector through 1989. Data on prices and quantities of inputs and outputs come from the National Bureau of Economic Research's Trade and Immigration Data Base. Data on the America's terms of trade come from the Bureau of Labor Statistics' export and import price indexes.[32]

[32]The export and import price indices are generated from quarterly surveys of firms engaged in trade. The NBER data base draws primarily from the Annual Survey of Manufactures; see Abowd & Freeman (1987) for a detailed description of this data base. Recall that in our data set "skilled labor" is defined as non-production labor, and that "unskilled labor" is defined as production labor. S e Appendix A for more on this. In addition, all SIC classifications in this data set come from the revisi #2 scheme. Revision #3 replaced #2 starting in 1988, and it redesignated about 25% of #2's industries. All data from 1988 and 1989 have been concorded back to revision #2.

We have limited ourselves to manufacturing because very little data exits on trade in services. However, since trade in manufactures constitutes nearly 70% of America's total trade, the Stolper-Samuelson process is unlikely to have a large role in overall trade without having a large role in manufacturing trade.

First, we consider whether industries experienced a fall in the ratio of non-production to production labor employed. If the Stolper-Samuelson process alone had influenced American wages in the 1980's, rising relative wages of non-production labor would have compelled all industries to substitute toward production labor. Figure 9 checks whether industries did substitute in this way. It plots the percentage change between 1979 and 1989 of relative wages and relative employment in manufacturing industries disaggregated at the 2-, 3-, and 4-digit SIC levels. Higher relative wages of non-production labor combined with a lower ratio of non-production to production labor employed would move industries in the upper-left quadrant of Figure 9.

Regardless of the level of disaggregation, however, only about 10% of all industries moved this way.[33] Indeed, one of the remarkable features of American manufacturing in the 1980's was a pervasive *increase* in the ratio of non-production to production workers employed--exactly the opposite of the HOS prediction. At every level of disaggregation, at least half of all industries (measured by share of total manufacturing employment) moved to a new equilibrium in the upper-right quadrant of Figure 9. This equilibrium entails both higher relative wages and higher relative employment of non-production labor. Thus, the majority of industries accompanied rising relative wages with rising, not falling, relative employment. So Figure 9 indicates that Stolper-Samuelson

[33]At the 2-digit level, 8.2%; at the 3-digit level, 9.8%; at the 4-digit level, 9.5%.

was not the predominant influence on relative labor demand in the 1980's.

We should emphasize two points. First, we have carried out our analysis at several levels of disaggregation to eliminate the possibility that outsourcing was an important reason for the shifts in relative labor use. By using industry data to explore the Stolper-Samuelson effects, we assume that we can identify each product with a unique industry and each industry with a unique production process. In practice, however, industries may produce products using processes which differ in their factor intensity. For example, the production of semiconductors could involve both research and development which uses skilled labor and assembly which uses unskilled labor. The availability of cheaper foreign labor might result not in the shrinking of entire industries but rather in the international migration of particular production processes within an industry. This outsourcing could be confused with a change in production techniques if the data are analyzed at an aggregate level. The foreign outsourcing of assembly operations in semiconductors, for example, would raise skill intensity in the data for the industry as a whole because of the shrinking assembly activities. However, separate data on R&D and assembly might indicate no shift in relative factor use.[34]

The fact that the rise in ratio of non-production to production workers is as pervasive at the 4-digit level as it is at the 2-digit level suggests that the rise does *not* reflect outsourcing. Berman, Bound and Griliches (1992) corroborate this evidence against outsourcing. They note that the 1987 Annual Survey of Manufacturing reported that in 1987 foreign materials constituted only 8% of all materials purchased in

[34]The BEA collects the most comprehensive data on the activity of multinationals. It does not release all this data by country at the 3-digit SIC level of disaggregation, however, to avoid revealing the identity of individual corporations.

manufacturing. Moreover, only a small fraction of materials purchased typically come from an establishment's own industry: 2% of materials originate in the same 4-digit SIC category, 7% in the same 3-digit. They calculate that replacing all outsourcing with domestic activity would raise manufacturing employment of production workers by just 2.8%.

Our second point is that all we can conclude from examining the relative employment ratios is that the Stolper-Samuelson effect was dominated by some larger effect. The sum of these effects was that most industries employ , relatively more, not relatively less, non-production labor. We cannot yet say anything about the absolute size of the Stolper-Samuelson effect. Perhaps it was large; perhaps it was nonexistent.

To determine the absolute size of this effect, we examine international prices. Figures 10 and 11 graph percentage changes over the 1980's in industries' import prices against the ratio of non-production to production labor employed in these industries in 1980. Figures 12 and 13 replace the import prices with export prices. In each pair of figures, the first classifies industries at the 2-digit SIC level, and the second at the 3-digit SIC level.[35]

Non-production-labor-intensive products are those which employ a high ratio of non-production to production labor.[36] If Stolper-Samuelson had any influence at all, then

[35]Unfortunately, the BLS does not report prices for all industries between 1979 and 1989. The import prices cover 93% of all manufacturing employment at the 2-digit level and 50% at the 3-digit level. The export prices cover 64% of all manufacturing employment at the 2-digit level and 48% at the 3-digit level. We assume that the price movements in these industries are reasonably representative. In addition, a minority of industries were not covered as far back as 1980. Almost all these, however, were covered by 1982, and were therefore included in the diagrams.

[36]To ensure that no factor-intensity reversals occurred during the decade which could change the results, we also plotted changes in the terms of trade against employment ratios calculated for 1985 and 1989. These plots were very similar to Figures 10 through 13; they therefore have not been included.

the international prices of these products should have risen relative to the international prices of production-labor-intensive products. But Figures 10 through 13 do not indicate a rise in the relative price of non-production-labor-intensive goods. Instead, their trend lines suggest that the relative price of non-production-labor-intensive products actually fell.[37]

Weighted-average price increases corroborate this suggestion. For both import prices and export prices at the 3-digit level, we have constructed two price indexes. One weights each industry's price rise by the industry's share in 1980 employment of non-production workers, the other by the industry's share in 1980 employment of production-workers.[38] Table 3 reports that import prices weighted by non-production-labor shares rose by 26% in the 1980's. Weighted by production-labor shares, import prices rose by 28%. Similarly, export prices weighted by non-production-labor shares rose by 26% in the 1980's. Weighted by production-labor shares, they rose by 30%.

Thus, the data suggest that the Stolper-Samuelson process did not have much influence on America's relative wages in the 1980's. In fact, because the relative price of non-production-labor-intensive products fell slightly, the Stolper-Samuelson process

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Incidentally, the data indicate that America has a comparative advantage in non-production-labor-intensive products. In 1979, the exports-weighted ratio of non-production to production labor employed in America's export industries was .501; the analogous ratio for imports was .384. In 1989, these ratios were .539 and .433, respectively. These numbers indicate that America's exports employ non-production labor relatively intensively and that its imports employ production labor relatively intensively. This higher ratio of non-production to production labor employed in exports indicates a comparative advantage in non-production-labor-intensive goods, and a comparative disadvantage in production-labor-intensive goods.

[37]These trend lines plot the estimated percentage price changes obtained from regressing actual percentage price changes on the ratio of skilled to unskilled labor employed and a constant. None of the four regressions estimated a coefficient on the ratio that was significantly negative at even the 10% level of significance.

[38]These price indexes were also calculated using 1989 employment shares as weights. The results were virtually identical, so only the results with 1980 employment shares as weights are presented.

actually nudged relative wages towards greater *equality*. No regression analysis is needed to reach this conclusion. Determining that the relative international prices of America's non-production labor-intensive products actually fell during the 1980's is sufficient.[39]

Technological Change and Relative Wages

We have concluded that changes in the P_{jt}'s prompted by international trade did not contribute to America's growing wage dispersion in the 1980's. This leaves changes in the Hicks-neutral technology parameters, the Θ_{jt}'s. The Θ_{jt}'s, like the P_{jt}'s, are indexed only by industry. Changes in Θ_{jt}'s, therefore, shift the labor-demand equations as do changes in the P_{jt}'s. Industries with rising Θ_{jt}'s attract producers and shift relative factor demands as do industries with rising P_{jt}'s. Thus, *under the assumption of given prices*, Hicks-neutral technological change occurring more rapidly in the non-production-labor-intensive industries should increase the relative wage of non-production labor.

We can therefore test for the influence of Hicks-neutral technical change on relative wages as we tested for the Stolper-Samuelson process. All other things equal, this change should manifest itself in two relationships similar to those analyzed for the Stolper-Samuelson process. First is a fall in all industries in the ratio of skilled to unskilled labor employed, second is greater Hicks-neutral technological progress for skilled-labor-intensive products relative to unskilled-labor-intensive products. Again, we examine each of these propositions in turn.

We measure growth of the Θ_{jt}'s as the total factor productivity (tfp) growth of each industry j. The tfp growth for an industry is calculated as the growth of real output

[39] If we had seen the relative international prices of America's non-production-labor-intensive products rise, regression analysis would have been appropriate to determine the contribution of Stolper-Samuelson to America's wage changes relative to other factors such as technological progress.

minus the cost-share-weighted average of the growth of five real inputs: non-production labor, production labor, capital, energy, and intermediate materials.[40] Transforming the annual changes into decade-long changes allows testing their cumulative impact.

As was the case with international prices, Figure 9 demonstrates that Hicks-neutral technological change was not the predominant influence on relative labor demand in the 1980's. If it had been, industries would have moved into the upper-left quadrant as higher relative wages for non-production labor prompted lower ratios of non-production to production labor employed.

To check the absolute size of the effect of Hicks-neutral technological progress, look at Figures 14 and 15. They graph percentage changes in industries' tfp during the 1980's against the ratio of non-production to production labor employed in these industries in 1980. Figure 14 classifies industries at the 2-digit SIC level; Figure 15 at the 3-digit SIC level. If Hicks-neutral technological change raised the relative wage of non-production labor, it did so by raising tfp more in the non-production-labor-intensive products. Figures 14 and 15 do not display such a change.

However, when we weight technology increases by shares of production and non-production labor we *do* find that technological change has been concentrated in industries using non-production labor intensively. As we did for both import prices and export prices at the 3-digit level, we calculated two different weighted-average tfp increases for

[40]Wayne Gray of Clark University provided these tfp numbers. He assumed that cost shares sum to one, and thereby calculated the cost share of capital as a residual. He also assumed that capacity utilization of capital remains constant over time. Real capital input is therefore a constant proportion of the real capital stock, and the rate of capital-input growth is simply the rate of capital-stock growth.

both export and import industries.[41] Table 3 shows that in the import industries, tfp weighted by skilled-labor shares rose by 20.5% in the 1980's. Weighted by unskilled-labor shares, however, tfp in the import industries rose by only 11.9% in the 1980's. Similarly, in the export industries, tfp weighted by skilled-labor shares rose by 18.6% in the 1980's. Weighted by unskilled-labor shares, tfp in the export industries rose by only 10.7%.

Apparently, technological progress *was* concentrated in the skilled-labor-intensive industries. This helped raise the wages of skilled labor relative to unskilled labor. Indeed, it more than offset the effect on relative wages of the relative international-price decline of non-production-labor-intensive products. To see this, define (P_{jt} x Θ_{jt}) as the "effective price" of good j at time t.[42] The percentage change over time in a good's effective price is simply the sum of the percentage change in its international price and the percentage change in its Hicks-neutral technology parameter. So adding the weighted-average increases in P_{jt} and Θ_{jt} in Table 3 yields the weighted-average increases in effective prices. The concentration of Hicks-neutral technological progress in non-production-labor-intensive industries offsets the concentration of international-price increases in production-labor-intensive industries if and only if the non-production-weighted increase in effective prices exceeds the production-weighted increase.

Table 3 confirms that this was the case. For both exports and imports, the non-

[41]As was done with prices, these tfp indexes were also calculated using 1989 employment shares as weights. The results were virtually identical, so only the results with 1980 employment shares as weights are presented.

[42]Because both P_{jt} and Θ_{jt} are indexed only by industry, we can call the product of the two an effective price. International-trade theorists often use this construction to study simultaneously changes in the terms of trade and in technology.

production-weighted increase in effective price was larger. This means that the combined effect of international prices and Hicks-neutral technology was to shift the labor-demand mix towards non-production labor. This shift helped raise the relative wage of non-production labor.

We can place this result in historical context by looking at the evolution of effective prices before 1980 as well. Unfortunately, terms-of-trade data go back only to 1980, so we use domestic price deflators instead.[43] Table 4 lists effective-price changes (weighted as before) over three decades for all manufacturing industries at the 3-digit SIC level. Notice that the difference between growth in effective prices weighted by non-production labor and growth weighted by production labor was 1.6% over the 1960's, 1.7% over the 1970's, and 4.1% over the 1980's. This sharp rise is consistent with the increased wage dispersion of the 1980's. Notice, too, that in the 1970's the concentration of technology growth in non-production-labor-intensive industries was even larger than in the 1980's. This concentration in the 1970's was overshadowed by the concentration of price increases in production-labor-intensive industries, however--precisely what would have been expected in light of the declining American terms of trade.

So the growth pattern of Hicks-neutral technology offset the growth pattern of international prices. This helped shift the labor-demand mix towards non-production labor, and thereby helped raise the relative wage of non-production labor. The Hicks-neutral technology growth was not the predominant influence on the labor-demand mix, however. As discussed earlier, Hicks-neutral technology growth concentrated in the non-

[43]These calculations assume that changes in these domestic-price deflators tracked changes in international prices. This is a weaker assumption than the law of one price: it allows prices to differ across countries by some fixed constant.

production-labor-intensive industries should lead to a falling ratio of non-production to production labor employed in all industries. Figure 9 shows clearly, however, that in reality this ratio was rising in nearly all industries.

One possible explanation of this relative employment shift is that technological change was "biased" towards the use of non-production labor.[44] Indeed, Berman, Bound, and Griliches (1992), conclude that production-labor-saving technological change is the most likely explanation for the shift in demand towards non-production workers. They support this conclusion with strong correlations between skill upgrading within industries and with increased spending by firms on computers and R & D. Kreuger (1991) corroborates the importance of biased technological progress with his estimate that from one- to two-thirds of the 1984-89 increase in the premium on education was related to the use of computers. Bartel and Lichtenberg (1991) find that industries which use young technologies pay a premium wage.[45]

4 Qualifications

We have been able to reject the simplest theories which assert that international trade has placed downward pressure on the relative wages of unskilled labor. Since the United States tends to import unskilled-labor-intensive products, the problem with these explanations is that they imply an *improvement* in the U.S. terms of trade. As we have demonstrated, however, the terms of trade were basically flat in the 1980's (and actually declined in the 1970's).

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[44]In the framework presented earlier, biased technological progress can be represented by allowing $F^j(\cdot)$ to vary over time.

[45]Berndt and Morrison (1992), however, find a negative association between use of high-technology equipment and total factor productivity.

Complete Specialization

There are theories which break the tight relationship between the terms of trade and relative factor prices by assuming complete specialization. In fact, these theories have the intriguing implication that the difficulties facing U.S. unskilled workers reflect the fact that there are too few of the poorest countries, rather than too many. One version of the argument stresses the impact of international capital flows; another, the international diffusion of technology.[46] In both versions, wage rates in the rich country fall at the same time as its terms of trade decline.

In the version which emphasizes capital mobility there are three types of goods, differentiated by capital intensity. Only the rich country produces the most capital-intensive product (computers), and only the poor country produces the least capital-intensive product (textiles). Both countries produce the midrange product (radios). Initially, the wage-rental ratio is higher in the rich than the poor country. As capital shifts into the poor country, the country increases its production of radios. This process shifts the rich country away from the production of radios and towards computers. It also shifts the poor country away from the production of textiles and towards radios. Within the rich country, therefore, the Stolper-Samuelson mechanism operates by releasing more labor than capital from the shrinking radio industry. This requires a lower wage-rental ratio to restore full employment. In the poor country an analogous effect operates to raise the wage-rental ratio. When the countries have sufficiently similar relative factor endowments, relative factor prices converge. This model has been presented using capital

[46]Leamer (1992) presents the first version. Collins (1985), Johnson and Stafford (1992), and Krugman (1979) present varieties of the second version.

and labor; however, it could readily be presented using skilled and unskilled labor.

Three-good models with technological diffusion can generate a similar result. Consider technological change in a simple Ricardian model. The world is divided into a lead and a follower country.[47] The lead country initially specializes in the two more technologically sophisticated products (computers and radios), while the follower country specializes in the least (textiles). With technological advance in radios in the follower country, production of radios shifts from the lead to follower nation. Again, this process shifts the rich country away from the production of radios and towards computers. It also shifts the poor country away from the production of textiles and towards radios. The result is an increase in the relative price of textiles. Real wages in the lead country fall because the decline in the relative price of now-imported radios is offset by the increase in the relative price of textiles. From the standpoint of the lead country, the problem is too little production of textiles and too much production of radios.

Integrating the effects of labor force growth, technological diffusion and capital mobility in a single model requires considerable fortitude. This has been done by Dollar (1986) in a model with complete specialization. Dollar shows that in the short run, labor- force growth in the South raises the terms of trade and the level of wages in the North. However, this rise in Northern wages increases the rate of diffusion of both technology and capital to the South. This long-run effect, as we have seen, tends to worsen the North's terms of trade and equalize wages between the two regions.

Do these theories provide a better explanation of U.S. developments in the 1980's? Our findings in the previous sections suggest that they do not. First, in the two-

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[47]In Collins (1985) the argument involves three countries.

factor models with capital and labor we expect to see the terms of trade declining, the wage-rental rate falling, and product wages falling behind average productivity growth. We found, in fact, unchanged terms of trade, no decline in the wage-rental ratio, and product wages that matched productivity. Similarly, a two-factor model with non-production and production workers does not predict what we actually found: constant terms of trade, the relatively similar performance of import prices using production and non-production worker shares as weights, and the widespread shift towards the use of non-production workers. Therefore, we reject these models because they do not predict the facts of the 1980's which we actually see.

Union Wage Premia

So far we have assumed that there is perfect competition in the labor market. There is considerable evidence, however, that wages reflect rents due to unions and other factors.[48] One hypothesis is that trade has had a particularly adverse impact on the wages of production workers in unionized manufacturing industries. This effect could operate either by reducing the number of unionized jobs that are available or by reducing the premium earned by unionized workers. Bound and Johnson (1992) find very little impact of changes in the number of union workers on relative wages. We find that the premiums paid to unionized workers in manufacturing have not declined. The ECI reports that between 1979 and 1989, the nominal compensation growth of non-unionized manufacturing production workers exceeded the nominal compensation growth of unionized manufacturing production workers by only 2.31%. This small difference is inconsistent with union wages in traded-goods sectors having been particularly squeezed

[48] See, for example, Katz and Summers (1991).

by international competition in the 1980's.

Non-Traded Goods

The divergence of productivity growth between manufacturing and non-manufacturing may have played an important role in the wage-dispersion story.

Between 1960 and 1980, the share of goods in real spending remained roughly constant (43.5% versus 44.4%) while the share of goods in nominal spending declined (from 49.5% to 45.2%). These two facts imply that the price of goods relative to services was falling. In addition, the long-run income elasticity of demand for goods is less than unity. However, falling relative prices for goods has induced a shift in spending towards goods large enough to offset the tendency for the share of goods in real spending to decline. The price elasticity of aggregate goods demand is also less than unity. Consequently, the share of goods in nominal spending has declined secularly.

Between 1979 and 1989 these effects appear to have operated more powerfully because of the slowdown in services productivity growth. The shift towards spending on goods is in fact a response to the increased disparity between productivity growth in manufacturing and productivity growth in services. While it is difficult to quantify precisely, a variety of measures indicate that the decline in relative goods prices was unusually large in the 1980's. For example, in the 1960's and 1970's the GNP deflator for goods declined relative to the overall GNP deflator by 5.0% and 5.7%, respectively. In the 1980's, this decline increased to 13.1%. Similarly, the commodity-price component of the CPI declined relative to the services component by 16.2% and 13.3% in the 1960's and 1970's but by 23.9% in the 1980's. And while the PPI for finished goods actually rose relative to the GNP deflator in the 1970's and fell by 5.3% in the

1960's, it fell by 10.9% in the 1980's.

If the demand for goods overall is inelastic, a rise in productivity growth which is passed through to final demand will, on balance, reduce the demand for factors of production used in goods production. Although the share of non-production workers has been rising in manufacturing, the ratio of production workers to employment in manufacturing of 61% in 1983 was almost twice as high as the 33% ratio in the overall economy. Accordingly, the divergence in overall productivity growth could be a factor in reducing the relative wages of production workers. In this case, one mechanism for increasing production-labor employment opportunities would be an improvement in non-manufacturing productivity.

5 Conclusions

In this paper we have examined the pressures that stem from trade by emphasizing price rather than quantity behavior. We have found that trade has not been the major source of US average and relative wage performance in the 1980's. The constancy of the US terms over the decade casts doubt on the argument that technological diffusion has robbed US workers of their rents due to technological leadership. Similarly, our finding that workers have on average been compensated for their product wages casts doubt on those who invoke a Stolper-Samuelson mechanism as the source of poor average wage performance. In addition, we doubt the view that a Stolper-Samuelson mechanism has played an important role in placing pressure on production worker wages. Indeed, both import and export prices indicate that the relative price of production-labor-intensive products actually increased slightly over the decade. Both the traditional 2-good and the more sophisticated 3-good models with complete specialization forecast that the relative decline in the wage of US production workers will be associated with an increase in the ratio of production to non-production labor. However, we have found a pervasive shift in US manufacturing toward the increased use of non-production labor despite the rise in its relative wage.

This shift suggests that technological change has been the more important source of wage pressures for production workers. Total-factor productivity growth has been higher in manufacturing industries which use non-production workers relatively intensively. Such a tfp change, however, also implies an increase in the ratio of production to non-production labor, however. This means that in addition to tfp growth, technological progress was probably biased towards non-production labor. Finally, those who focus on real wage behavior without paying attention to productivity growth outside of manufacturing are writing Hamlet without the Prince. The major source of real wage convergence between the United States and other major industrial economies besides the United Kingdom lies in the disparate performance of services productivity. In addition, an important pressure on the relative wages of production workers may have been slow productivity growth in services.

Appendix A: Identifying the Skill Level of Workers

Identifying the skill level of workers is a recurring problem in empirical work. A worker's skill level probably grows with some combination of her education, her on-the-job training, and her work experience. Pinpointing her skill level clearly requires a broad range of data. Unfortunately, most data sets do not contain such breadth. Instead, many distinguish workers based on job classification. For example, the ASM distinguishes non-production from production labor. Similarly, the Current Population Survey distinguishes white-collar workers from blue-collar workers. In each case, the first group usually gets called "skilled."

The obvious concern with these occupational distinctions is that they misclassify too many workers. Consider these two workers: an experienced machine-tool technician with a bachelor's degree in computer science who programs the computers driving these tools, and a recent high-school dropout who files reports and runs mail. If they both work for a manufacturing firm, the non-production/production distinction will classify the technician as unskilled and the office runner as skilled. Clearly, this seems wrong. The worry is that such misclassifications are the rule rather than the exception, i.e., that using either the ASM or the CPS classification to identify skill levels misplaces an unacceptably high number of people.

Berman, Bound, and Griliches (1992) convincingly argue that these methods probably classify most people correctly. They do this by establishing two facts. First, they show that the ASM distinction closely matches the CPS distinction. For the years 1973, 1979, and 1987, the percentage of workers classified as non-production by the ASM is never more than two percentage points away from the percentage of workers classified as white-collar by the CPS. Second, with the educational-attainment data in the CPS they show that white-collar workers average more years of education than blue-collar workers. In 1987, nearly 70% of white-collar workers had some college education, versus only 17% for blue-collar workers. Similarly, less than 5% of white-collar workers had less than a high-school education, versus 30% of blue-collar workers.

Assuming that these two facts were representative of the 1980's as a whole, Berman et al conclude from them that "the relationship between education and occupation is quite tight." Insofar as the more-educated are more skilled, it follows that occupational distinctions do correctly classify most workers' skill levels. In my work in this paper I make this final assumption, and assume that the non-production/production distinction reasonably separates workers across skills.

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TABLE 1

Year	Earnings /CPI (1)	Comp /CPI (2)	Output /Hour (3)	Comp /POut (4)	Comp /POut-I (5)	Comp/ CPI-Sh (6)	FWTOT (7)	Comp Share (8)	GDP87/ Hours (9)
1970	98.0	89.4	87.5	88.5	86.1	88.1	126.5	67.0	89.3
1971	100.4	91.2	90.4	89.7	86.9	89.8	124.2	65.7	92.5
1972	104.3	93.9	93.2	91.8	89.4	92.7	120.0	65.2	93.9
1973	104.5	96.1	95.6	94.0	91.6	94.4	116.9	65.1	95.4
1974	101.4	95.1	93.9	94.3	92.0	93.2	107.1	66.5	94.7
1975	99.1	95.8	96.0	94.3	92.9	94.1	106.9	65.0	97.9
1976	100.7	98.8	98.8	97.3	96.0	96.9	107.3	65.2	100.0
1977	102.1	100.3	100.5	98.7	98.0	98.4	103.8	65.0	100.7
1978	102.7	101.4	101.1	99.4	99.2	100.3	102.0	65.1	100.6
1979	100.0	100.0	100.0	100.0	100.0	100.0	100.0	66.2	100.0
1980	95.2	97.5	99.3	101.0	100.8	99.2	91.7	67.3	100.4
1981	93.9	96.8	100.5	100.4	101.0	98.9	93.9	66.1	101.5
1982	93.8	98.0	100.7	102.1	102.1	100.6	97.6	67.1	101.8
1983	94.9	98.5	102.9	102.4	101.1	100.5	101.5	65.9	103.9
1984	94.3	98.4	105.3	102.6	101.5	100.7	104.4	64.5	104.4
1985	93.8	99.3	106.8	103.7	101.9	102.2	105.7	64.3	105.4
1986	94.1	102.4	109.0	106.6	104.7	106.2	107.6	64.7	107.8
1987	93.2	102.3	110.1	107.5	105.4	106.4	102.5	64.6	107.8
1988	92.4	102.4	111.1	108.2	105.9	106.8	102.7	64.5	108.4
1989	91.8	101.0	110.2	107.1	104.5	105.3	102.0	64.3	108.4
1990	90.3	101.1	110.5	108.8	105.6	105.4	100.2	65.2	109.2
1991	89.4	101.4	110.5	109.5	105.1	105.8	101.5	65.6	110.4

Notes:

Earnings = Average Hourly Earnings
CPI=CPI for All Urban Consumers
Comp=Average Hourly Compensation
CPI-Sh=CPI minus Shelter Component
CompShare=share of compensation in Business Output Value Added

Output=Business Sector Output(Excludes Housing)
POut=Deflator for Output
POut-I=Deflator for Output minus Investment
FWTOT=Ratio of Fixed Weight Price Index of Exports of Goods and Serivces to Price Index of Imports
Hours=Hours worked in Business Sector

TABLE 2

International Changes in Real Earnings
Percentage Change, 1979-1989

		Comp /CPI (1)	Comp /Pout (2)	OutPut /Employe (3)	Due To:	Manu- Facturing (4)	Non Manufact (5)	Share Change (6)
1	US	2.1	5.4	7.6		6.4	2.2	-1
2	JAPAN	24.9	32.4	32.1		13.7	18.1	0.3
3	FRANCE	14.9	16.8	24.1		7.9	21.1	-4.9
4	GERMAN	11.3	9.4	13.8		3.5	12.3	-2
5	UK	14	12.1	17.1		13.2	4.6	-0.7
	Difference from US							
(2-1)	JAPAN	22.8	27	24.5		7.3	15.9	1.3
(3-1)	FRANCE	12.8	11.4	16.5		1.5	18.9	-3.9
(4-1)	GERMAN	9.2	4	6.2		-2.9	10.1	-1
(5-1)	UK	11.9	6.7	9.5		6.8	2.4	0.3

Notes:
CPI=Consumer Price Index
Pout = GDP Deflator
(4) = (7) * 1979 Share of Manufacturing in Output
(5)=(8)* 1979 Share of nonmanufacturing in Output
(6)=(3) - (4+5)

Supplementary Information

		Out/Emp Man (7)	Other (8)	Manufacturing Output/Hour (9)	Labor Share in Income (10) 1979	1989	Manufacturing Real Comp (11) Annual	Hourly
1	US	30.7	2.8	27.3	60.2	59	3.1	0
2	JAPAN	52.2	24.5	30.3	54.2	54.3	19.6	19.7
3	FRANCE	33.8	27.5	42.3	54.9	51.7	13.2	20.3
4	GERMAN	10.5	18.5	18.9	57	54.8	18.3	27.1
5	UK	56.1	5.4	58.9	58.5	56	19.4	21.7
	Differences from US							
(2-1)	JAPAN	21.5	21.7	3			16.5	19.7
(3-1)	FRANCE	3.1	24.7	15			10.1	20.3
(4-1)	GERMAN	-20.2	15.7	-8.4			15.2	27.1
(5-1)	UK	25.4	2.6	31.6			16.3	21.7

Sources. Bureau of Labor Statistics, Office of Productivity and Technology. Underlying Data for Indexes of Output per Hour, Hourly Compensation, and Unit Labor Costs in Manufacturing; Twelve Industrial Countries; 1950-1991 December 2, 1992.

Bureau of Labor Statistics, Office of Productivity and Technology. "Comparative Gross Domestic Product, Real GDP Per Capita, and Real GDP Per Employed Person: Fourteen Countries: 1960-1990." January 1992.

OECD. "National Accounts, Main Aggregates 1960-1991 (Vol. I)." Paris, 1992.

OECD. "National Accounts, Detailed Tables 1978-1990 (Vol. II)." Paris, 1992.

Table #3: Employment-Weighted[1] Percentage Changes in International Prices and Hicks-Neutral Productivity in the 1980's

Import-Producing Industries, 1980-1989

Percentage Change, 1980-1989	Non-Production Weights	Production Weights	Difference Between Non-Prod and Prod
International Prices	26.0	28.1	-2.1
Hicks-neutral Tech.	20.5	11.9	8.6
Effective Prices	46.5	40.0	6.5

Export-Producing Industries, 1980-1989

Percentage Change, 1980-1989	Non-Production Weights	Production Weights	Difference Between Non-Prod and Prod
International Prices	26.3	30.0	-3.7
Hicks-neutral Tech.	18.6	10.7	7.9
Effective Prices	44.9	40.7	4.2

Notes:[1]Non-production weights weigh each industry's price and/or technology change by that industry's share of total manufacturing employment of non-production labor in 1980. Production weights weigh each industry's price and/or technology change by that industry's share of total manufacturing employment of production labor in 1980. All industries are defined at the 3-digit SIC level.

Sources: International-price data comes from the Bureau of Labor Statistics. Employment and technology (i.e., total-factor productivity) data comes from the National Bureau of Economic Research's Trade and Immigration Data Base and Professor Wayne Gray.

Table #4: Employment-Weighted[1] Percentage Changes in Domestic Prices and Hicks-Neutral Productivity from 1960 to 1990

All Manufacturing Industries, 1960-1969

Percentage Change, 1980-1989	Non-Production Weights	Production Weights	Difference Between Non-Prod and Prod
Domestic Prices	13.3	13.4	-0.1
Hicks-neutral Tech.	12.6	10.9	1.7
Effective Prices	25.9	24.3	1.6

All Manufacturing Industries, 1970-1979

Percentage Change, 1980-1989	Non-Production Weights	Production Weights	Difference Between Non-Prod and Prod
Domestic Prices	88.1	93.3	-5.2
Hicks-neutral Tech.	13.4	6.5	6.9
Effective Prices	101.5	99.8	1.7

All Manufacturing Industries, 1980-1989

Percentage Change, 1980-1989	Non-Production Weights	Production Weights	Difference Between Non-Prod and Prod
Domestic Prices	33.1	32.3	0.8
Hicks-neutral Tech.	11.5	8.4	3.1
Effective Prices	44.6	40.7	3.9

Notes:[1]See Table #3

Sources: See Table #3

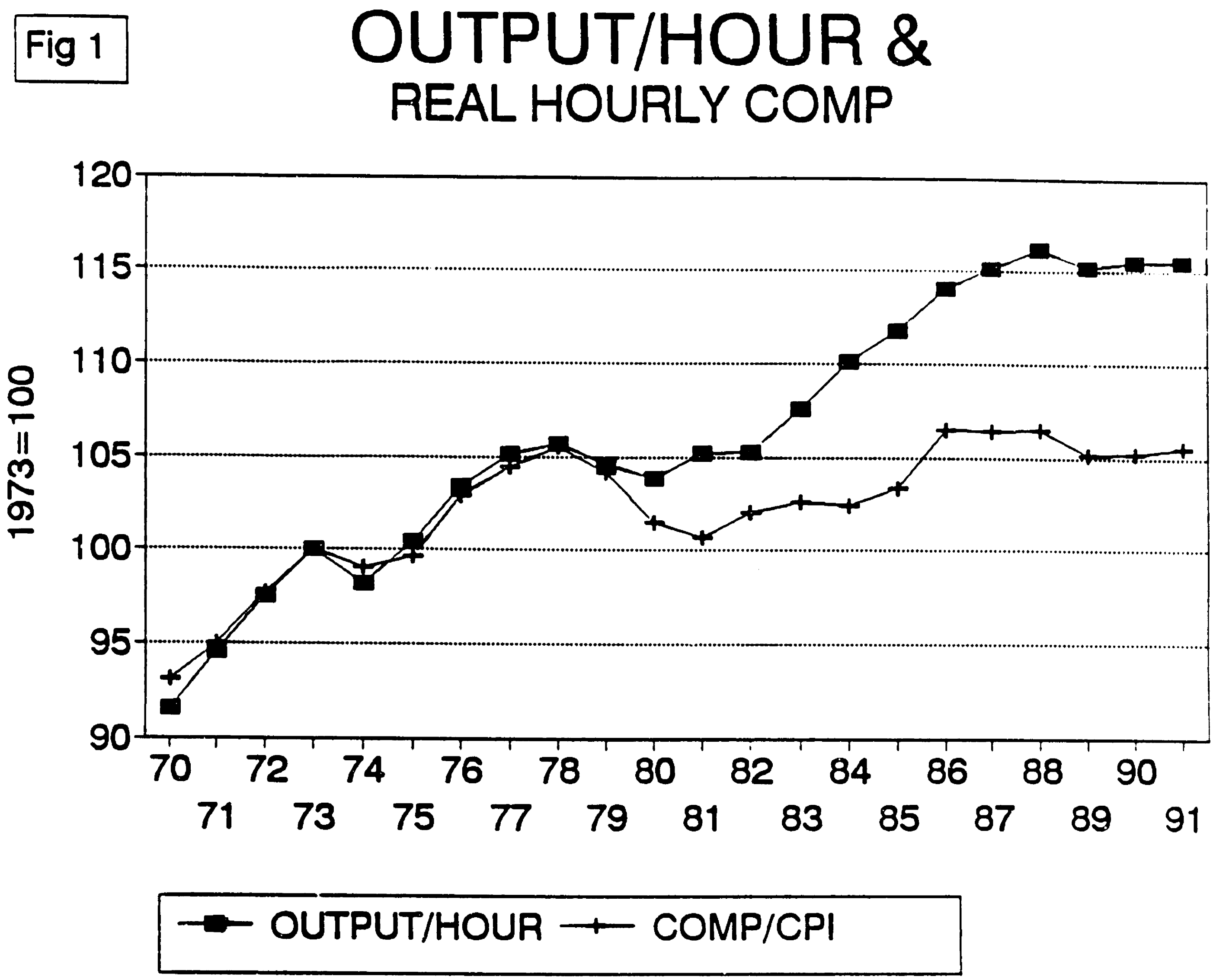


Fig 1
OUTPUT/HOUR &
REAL HOURLY COMP
1973=100
120
115
110
105
100
95
90
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
OUTPUT/HOUR
COMP/CPI

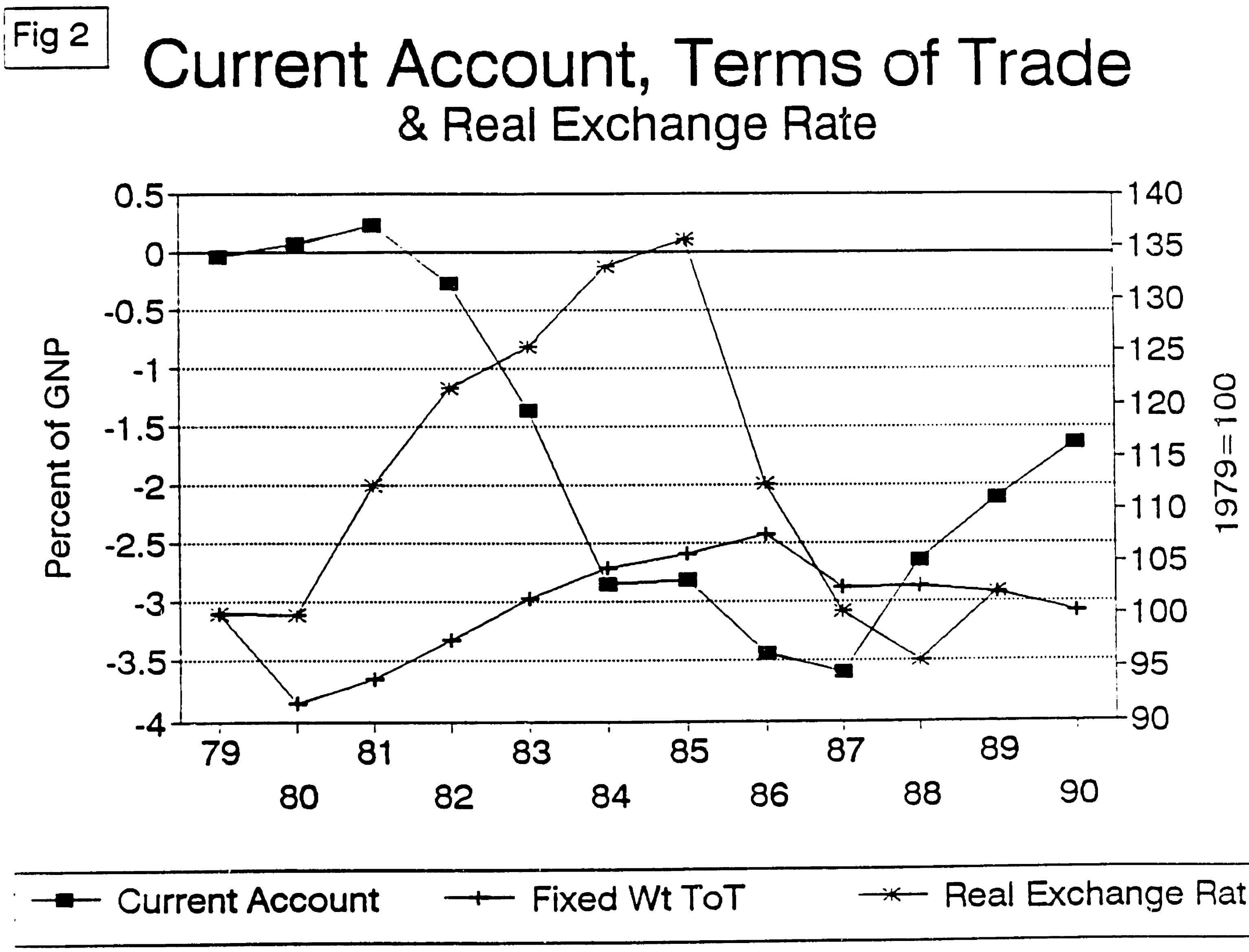


Fig 2
Current Account, Terms of Trade
& Real Exchange Rate
Percent of GNP
1979=100
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
140
135
130
125
120
115
110
105
100
95
90
79
80
81
82
83
84
85
86
87
88
89
90
Current Account
Fixed Wt ToT
Real Exchange Rat

Fig3

RATIO OF COMMAND GNP TO GNP

1987 dollars

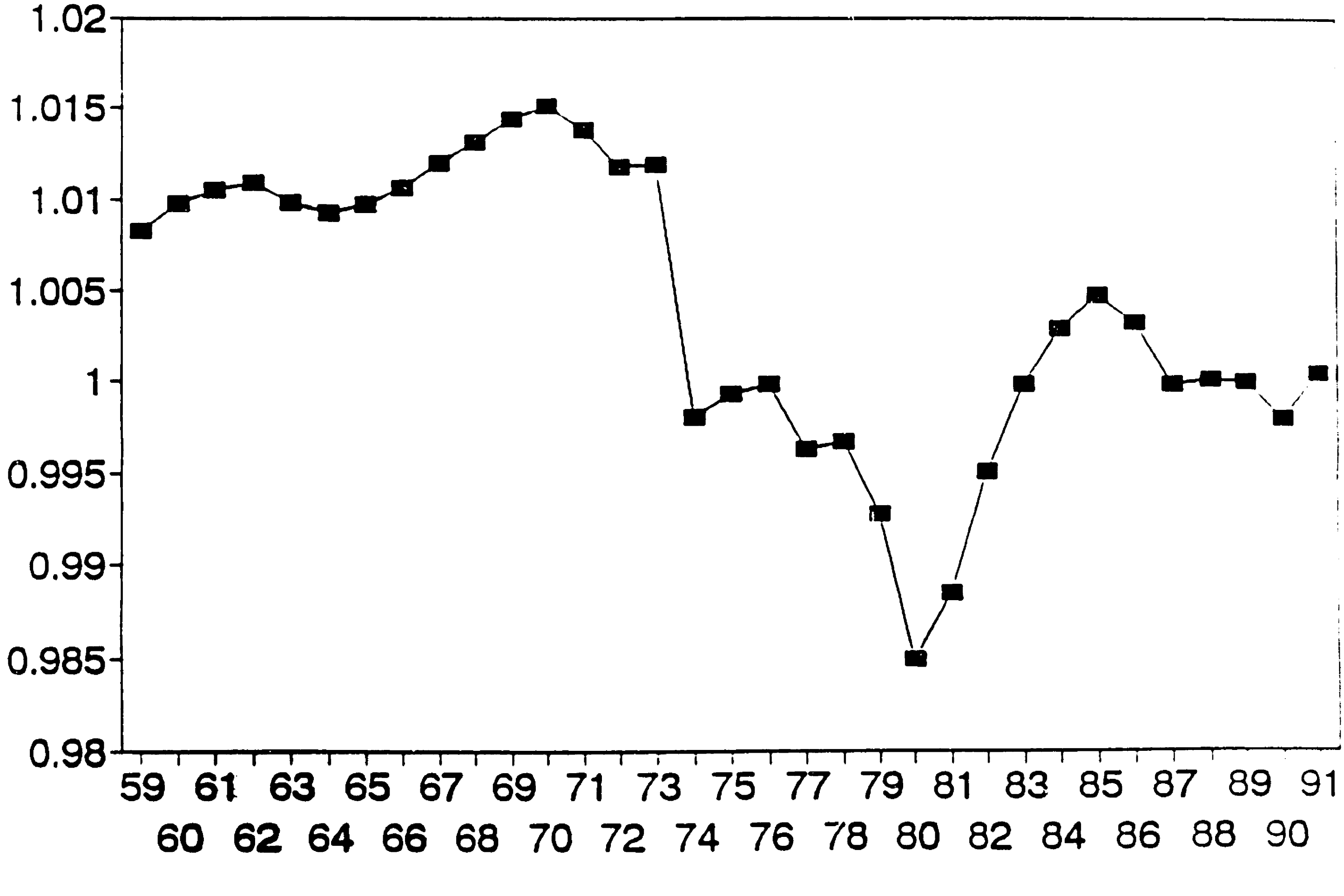


fig 4

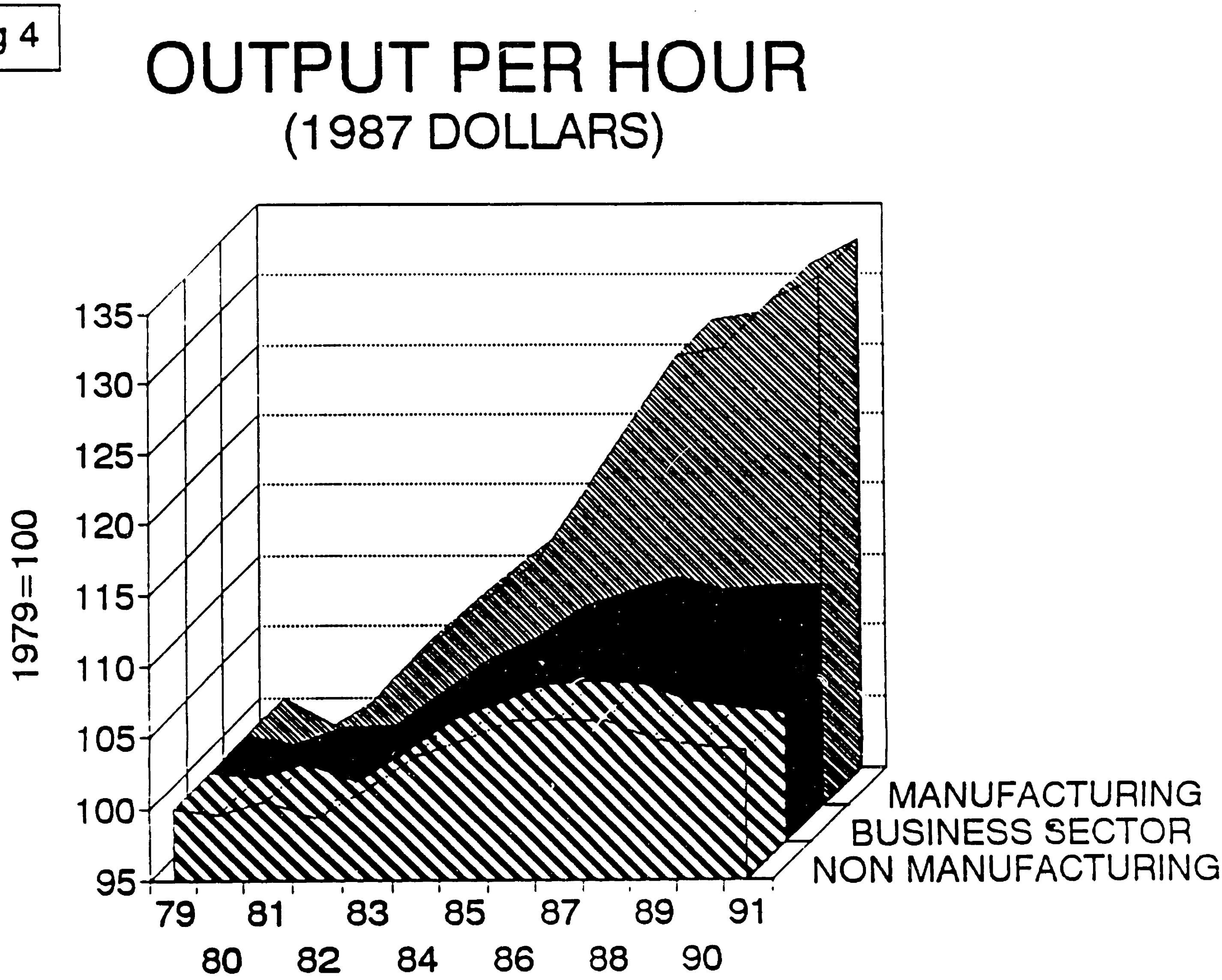
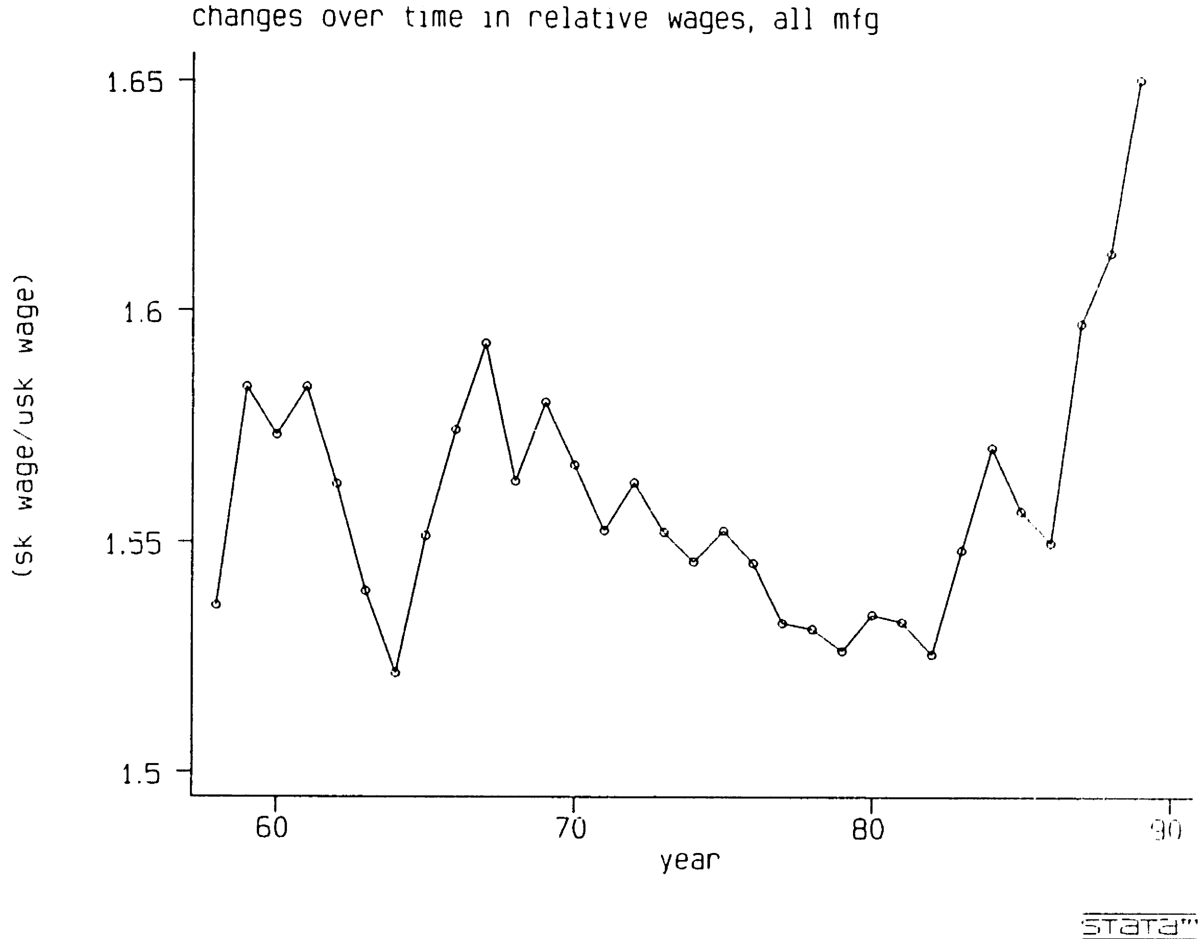
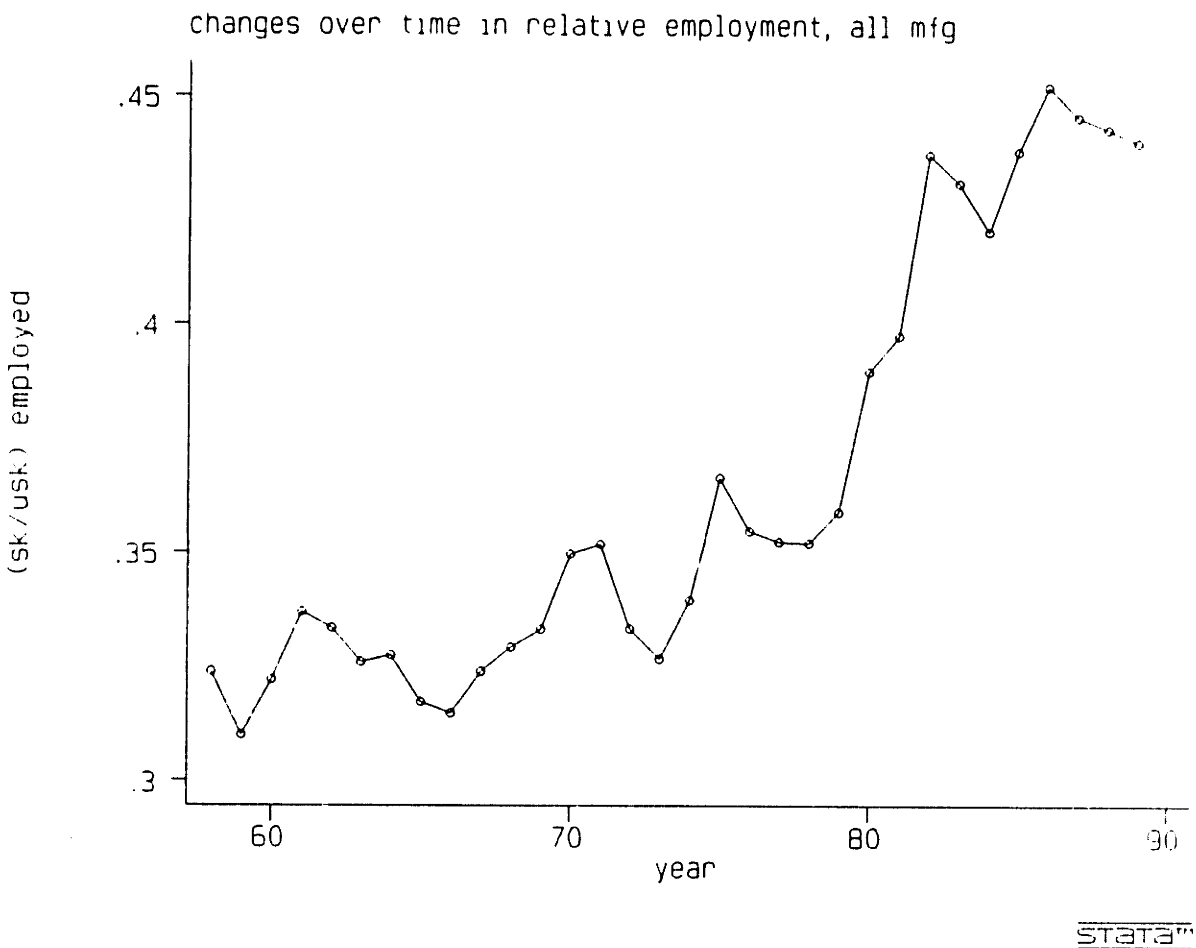

OUTPUT PER HOUR
(1987 DOLLARS)
1979=100
135
130
125
120
115
110
105
100
95
79
80
81
82
83
84
85
86
87
88
89
90
91
MANUFACTURING
BUSINESS SECTOR
NON MANUFACTURING

Figure #5: Evolution of Non-Production Versus Production Wages In Manufacturing



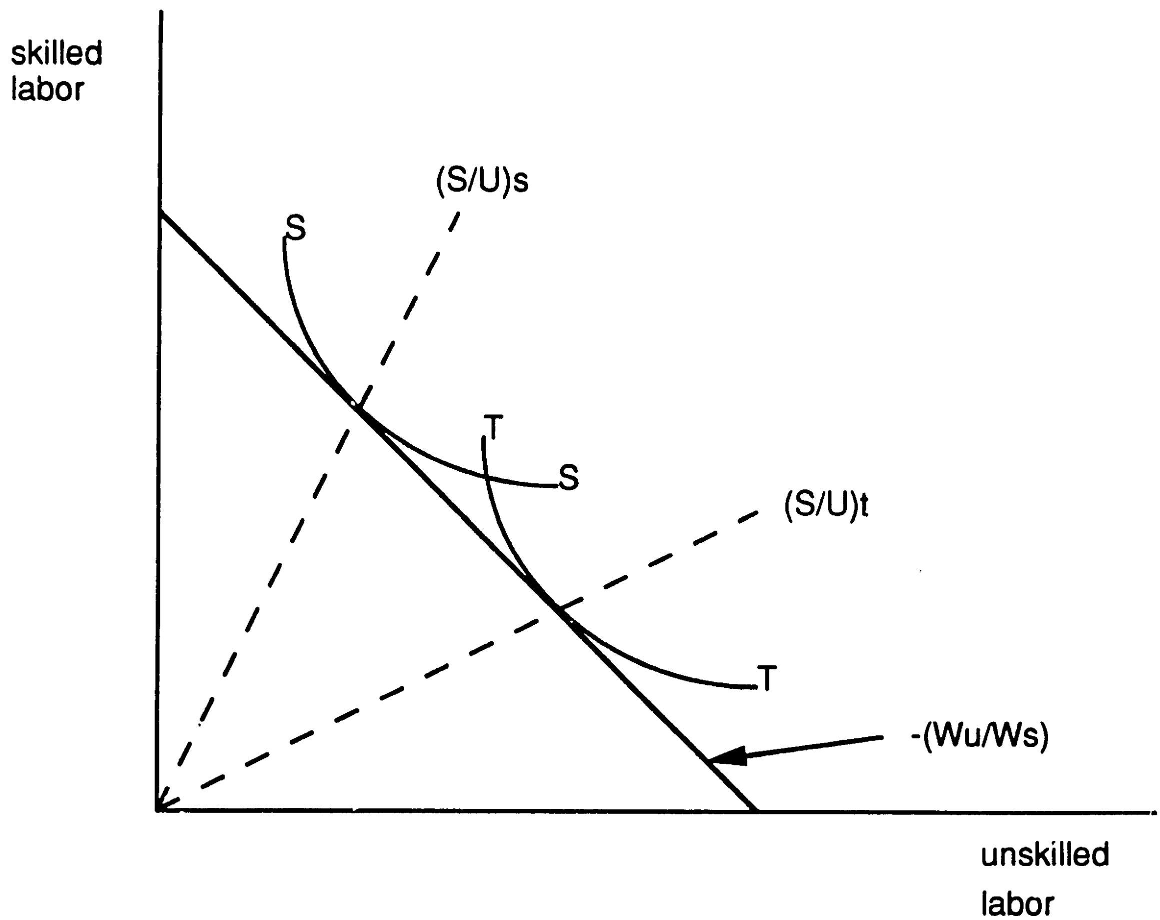
Sources: Wage data comes from the NBER's Trade and Immigration Data Base.
Average wage of non-production workers is "sk wage."
Average wage of production workers is "usk wage."

Figure #6: Evolution of Non-Production Versus Production Employment In Manufacturing



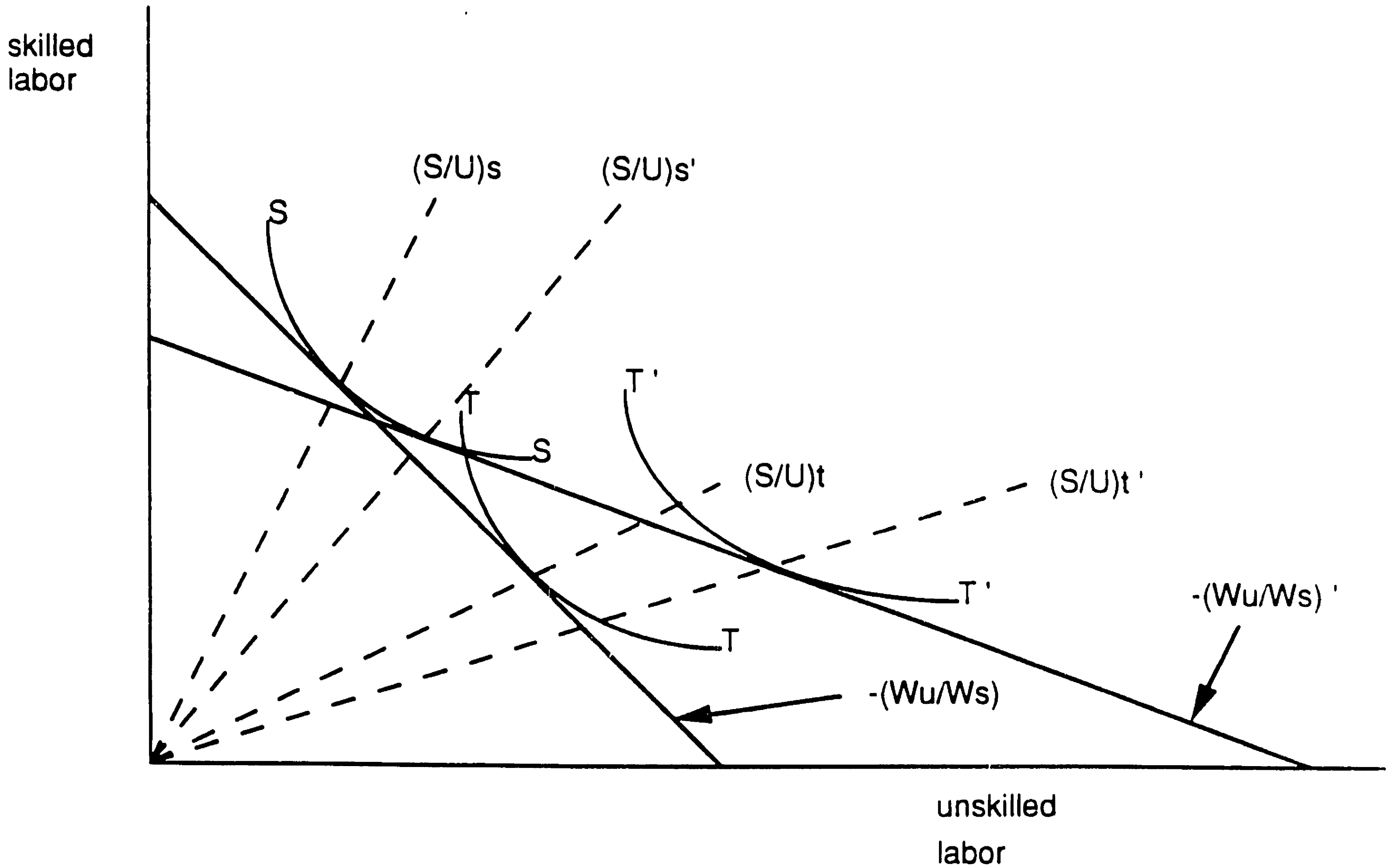
Sources: Employment data comes from the NBER's Trade and Immigration Data Base. Vertical axis plots the ratio of non-production to production labor employed in all manufacturing industries taken together.

Figure #7: Initial Equilibrium of a Small Open Economy



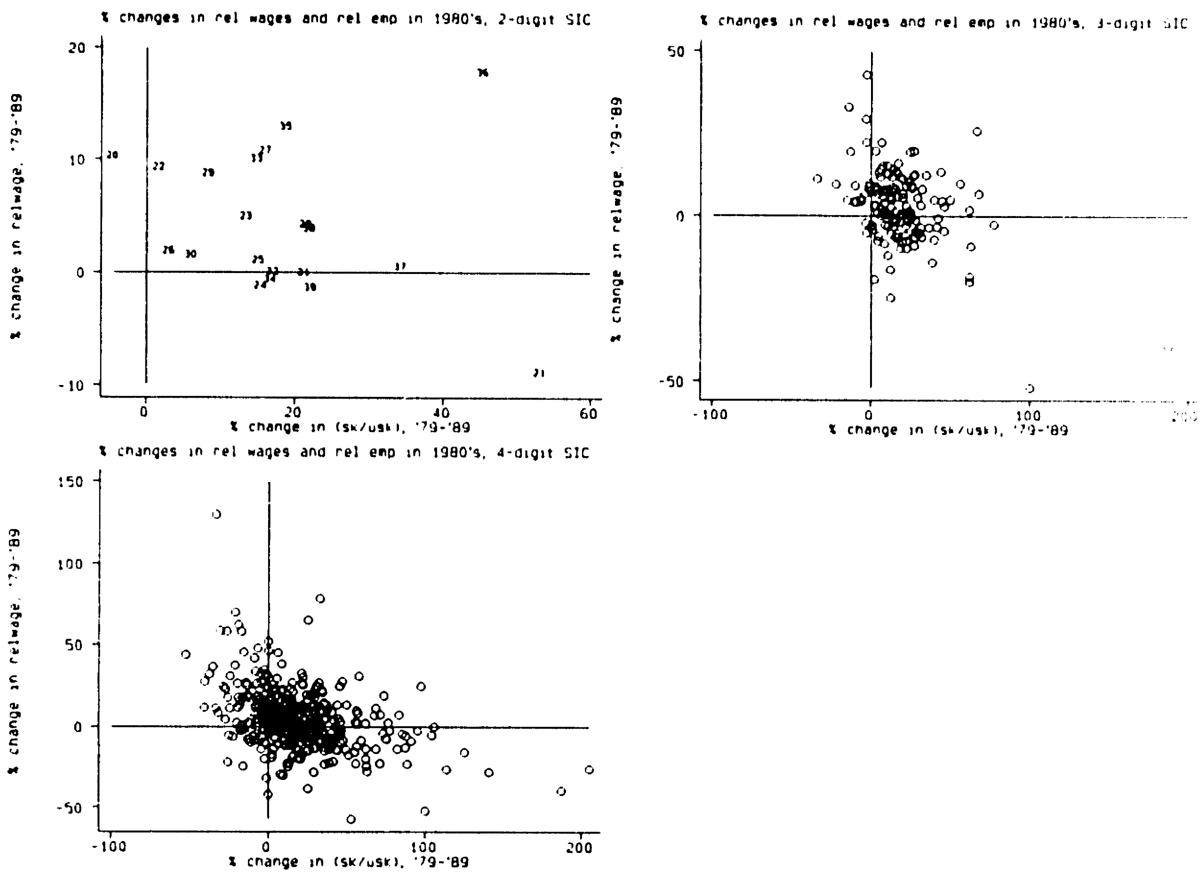
SS and TT are the initial production isoquants of software and textiles, respectively.
-(Wu/Ws) is the negative of the economy's initial relative-wage ratio.
(S/U)s and (S/U)t are the initial ratios of skilled to unskilled labor
employed in software and textiles, respectively.

Figure #8: New Equilibrium of a Small Open Economy



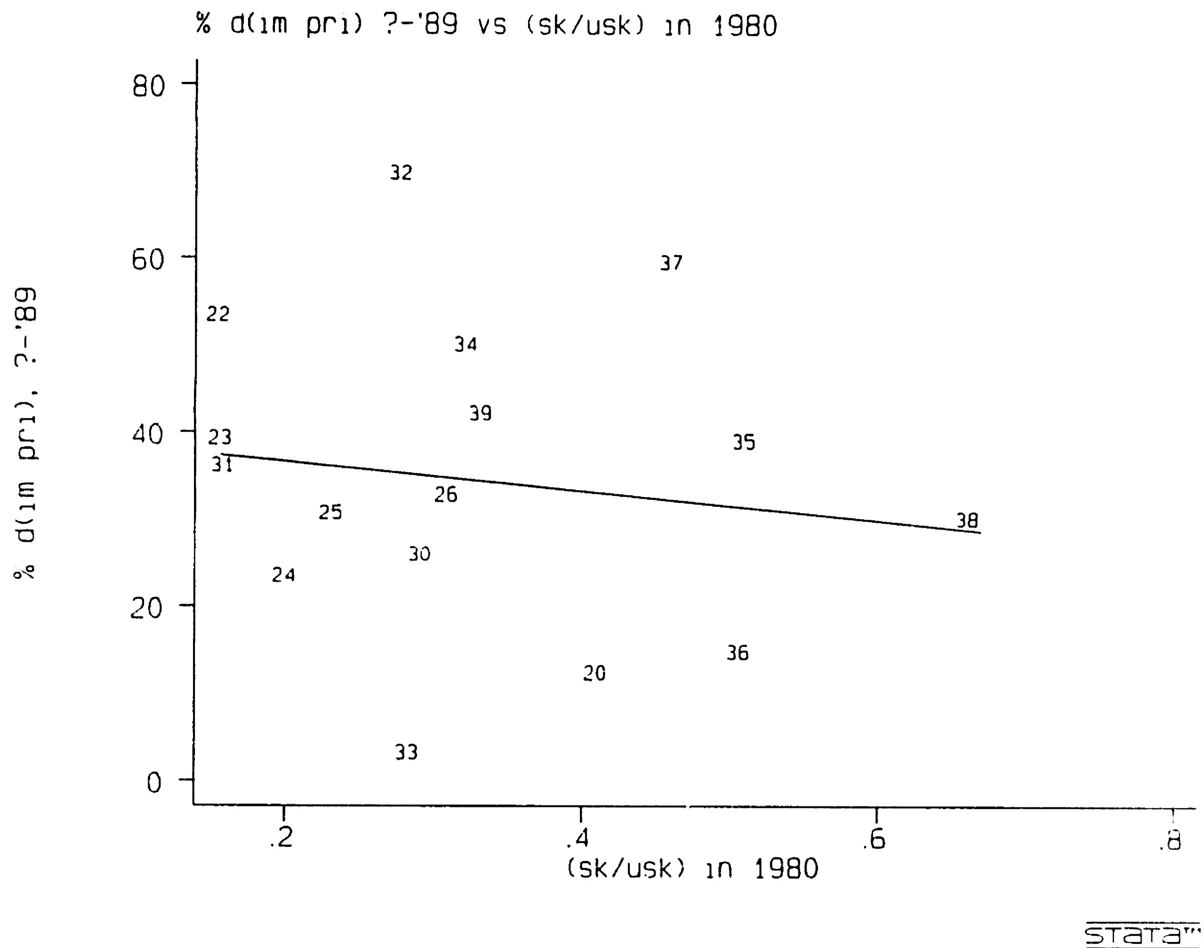
The international price of software has risen. Software output increases, and textile output shrinks.
This is represented as a shift in the textile isoquant to T'T'.
-(Wu/Ws)' is the negative of the economy's new relative-wage ratio:
the wage of skilled labor has risen relative to unskilled labor.
(S/U)s' and (S/U)t' are the new ratios of skilled to unskilled labor
employed in software and textiles, respectively.

Figure #9: Percentage Changes in the 1980's in the Relative Wages and Relative Employment of Non-Production and Production Labor in Manufacturing



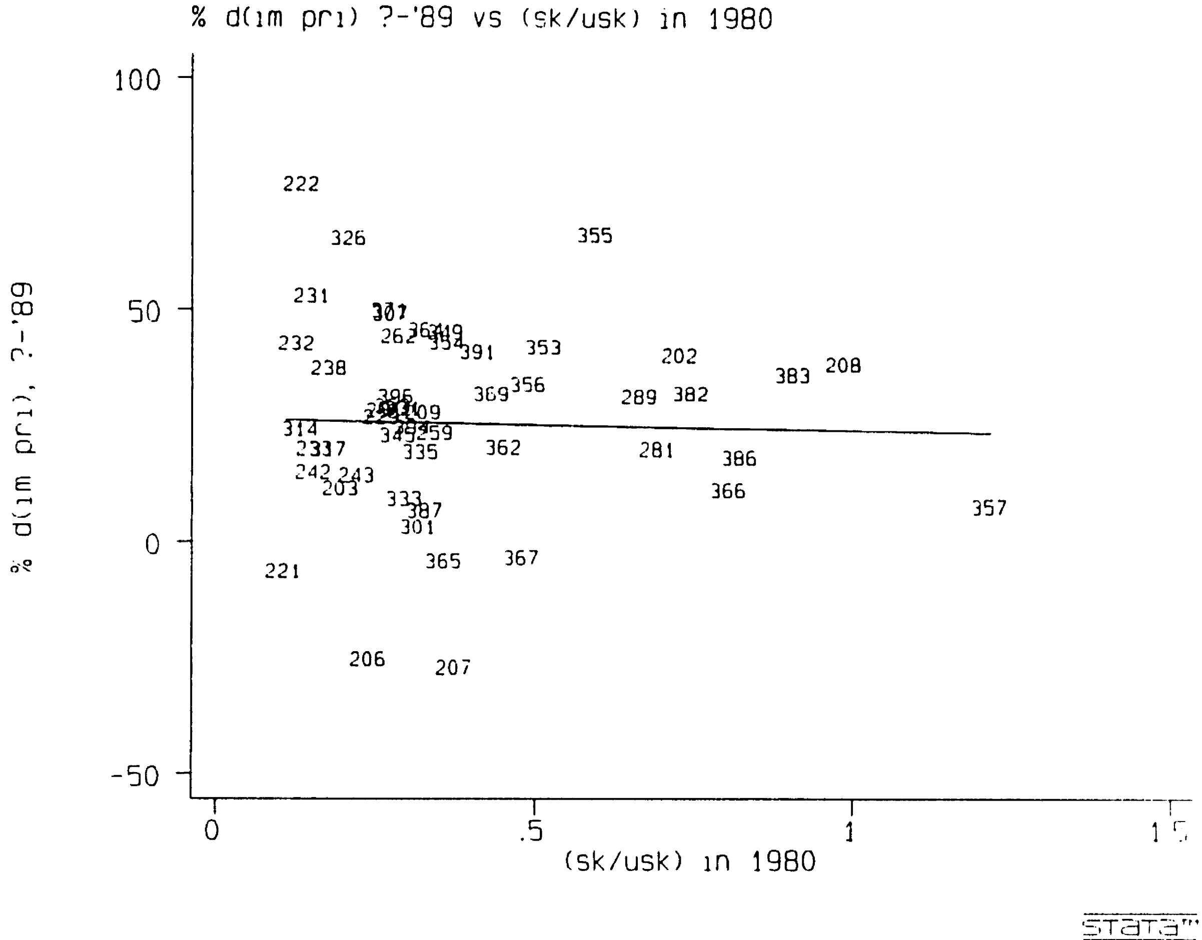
Sources: Employment and wage data come from the NBER's Trade and Immigration Data Base. In each graph, the vertical axis measures the percentage change in each industry's ratio of non-production wages to production wages. The horizontal axis measures the percentage change in each industry's ratio of non-production to production workers employed. Each graph defines an industry at a different level of SIC disaggregation.

Figure #10: Percentage Changes in the 1980's of Import Prices by Industry Versus the Non-Production-Worker Intensity of Industries



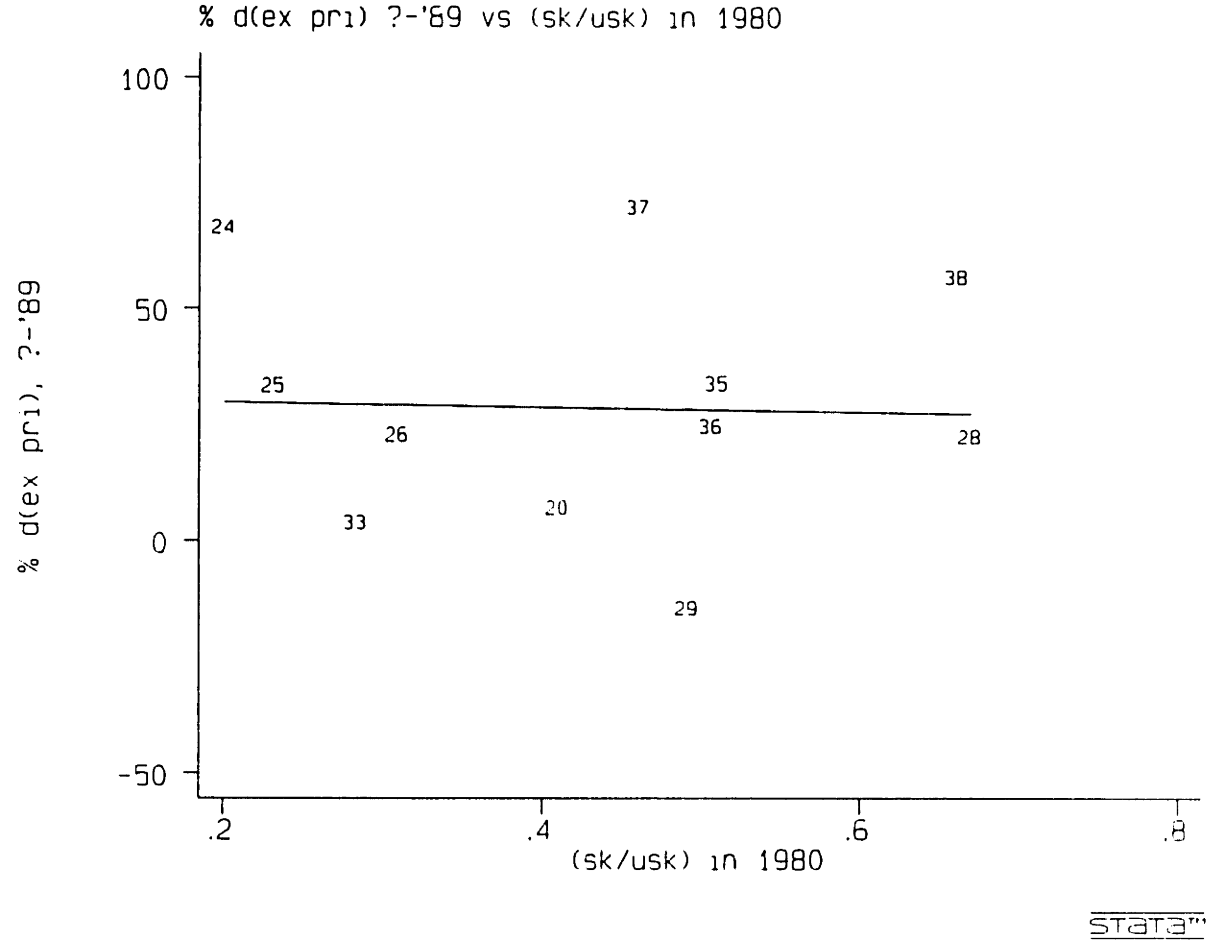
Sources: Import prices come from the Bureau of Labor Statistics;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 2-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure #11: Percentage Changes in the 1980's of Import Prices by Industry Versus the Non-Production-Worker Intensity of Industries



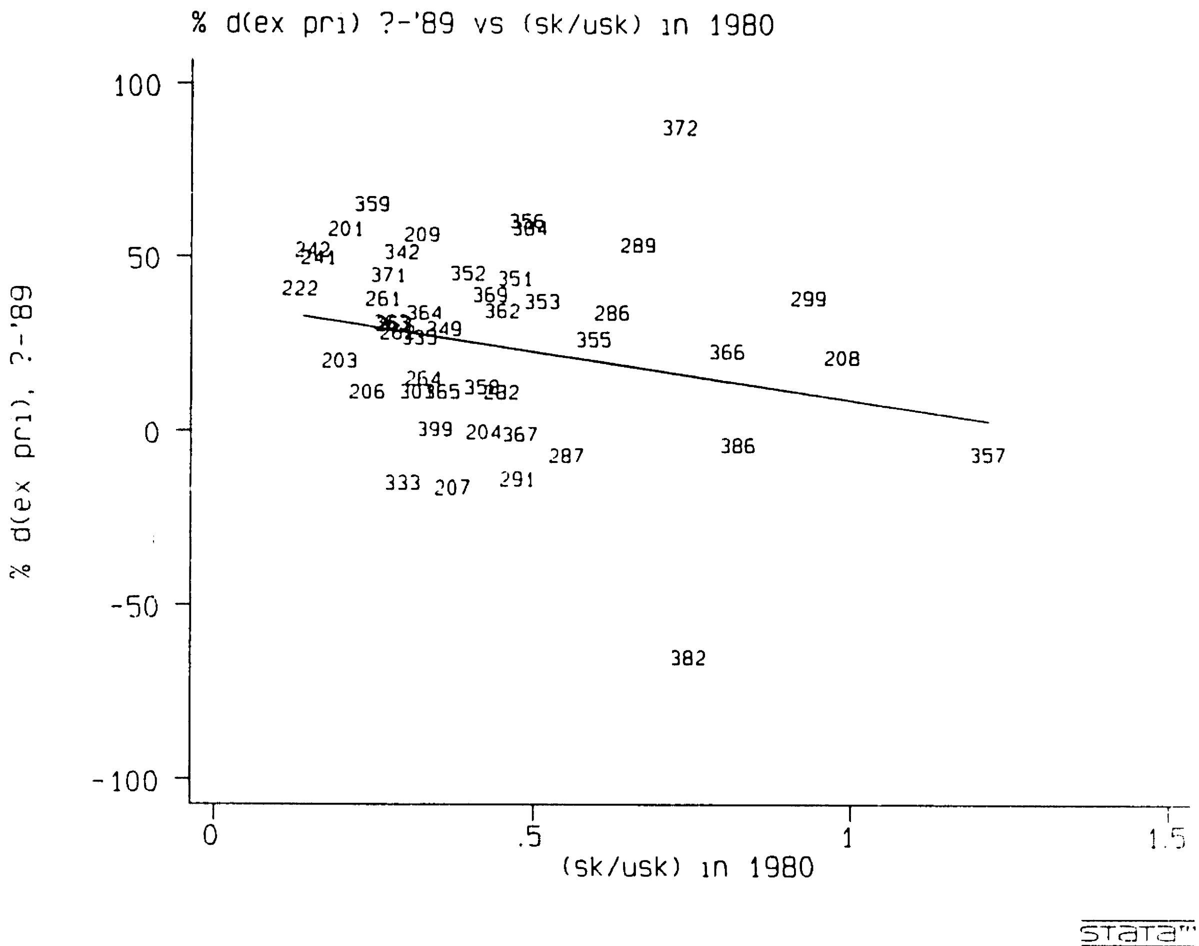
Sources: Import prices come from the Bureau of Labor Statistics;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 3-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure #12: Percentage Changes in the 1980's of Export Prices by Industry Versus the Non-Production-Worker Intensity of Industries



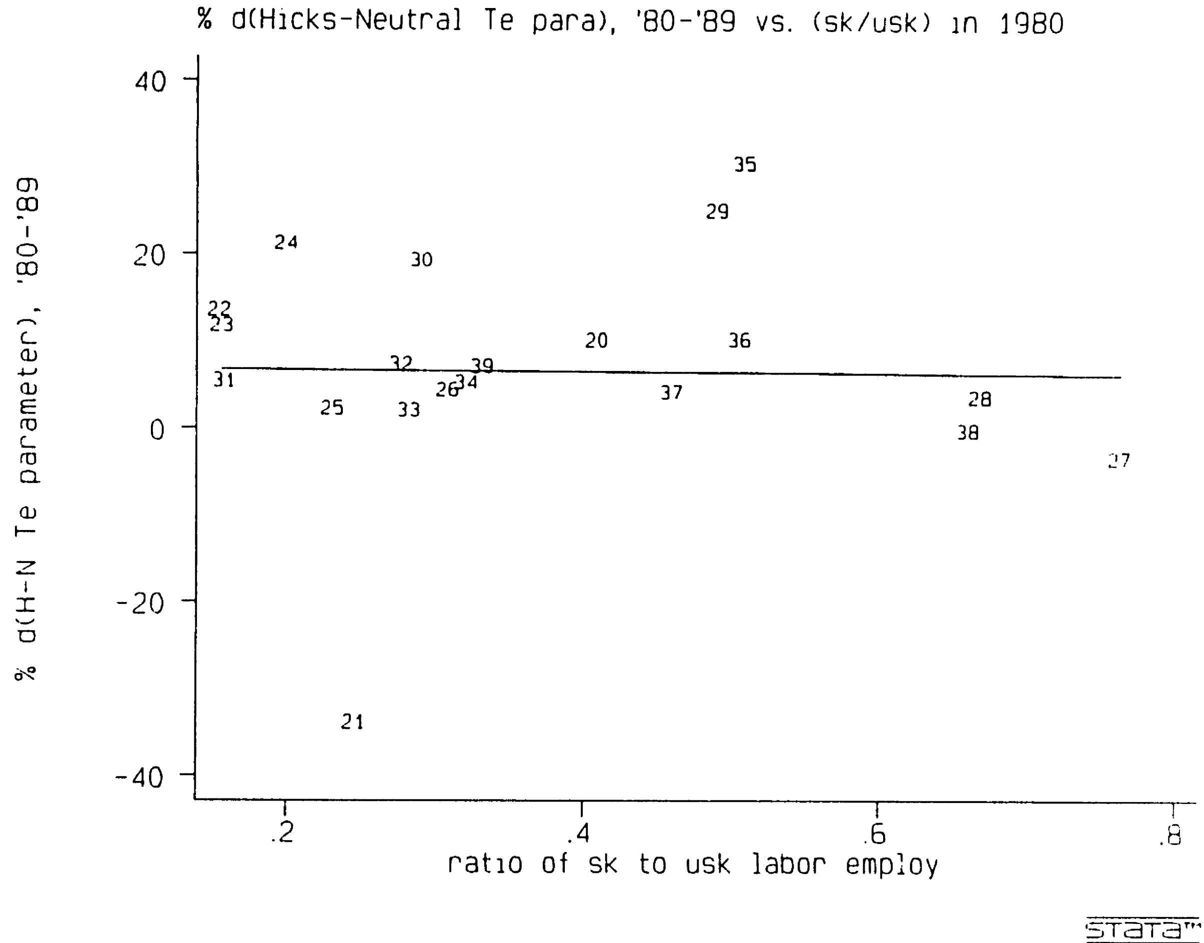
Sources: Export prices come from the Bureau of Labor Statistics;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 2-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure #13: Percentage Changes in the 1980's of Export Prices by Industry Versus the Non-Production-Worker Intensity of Industries



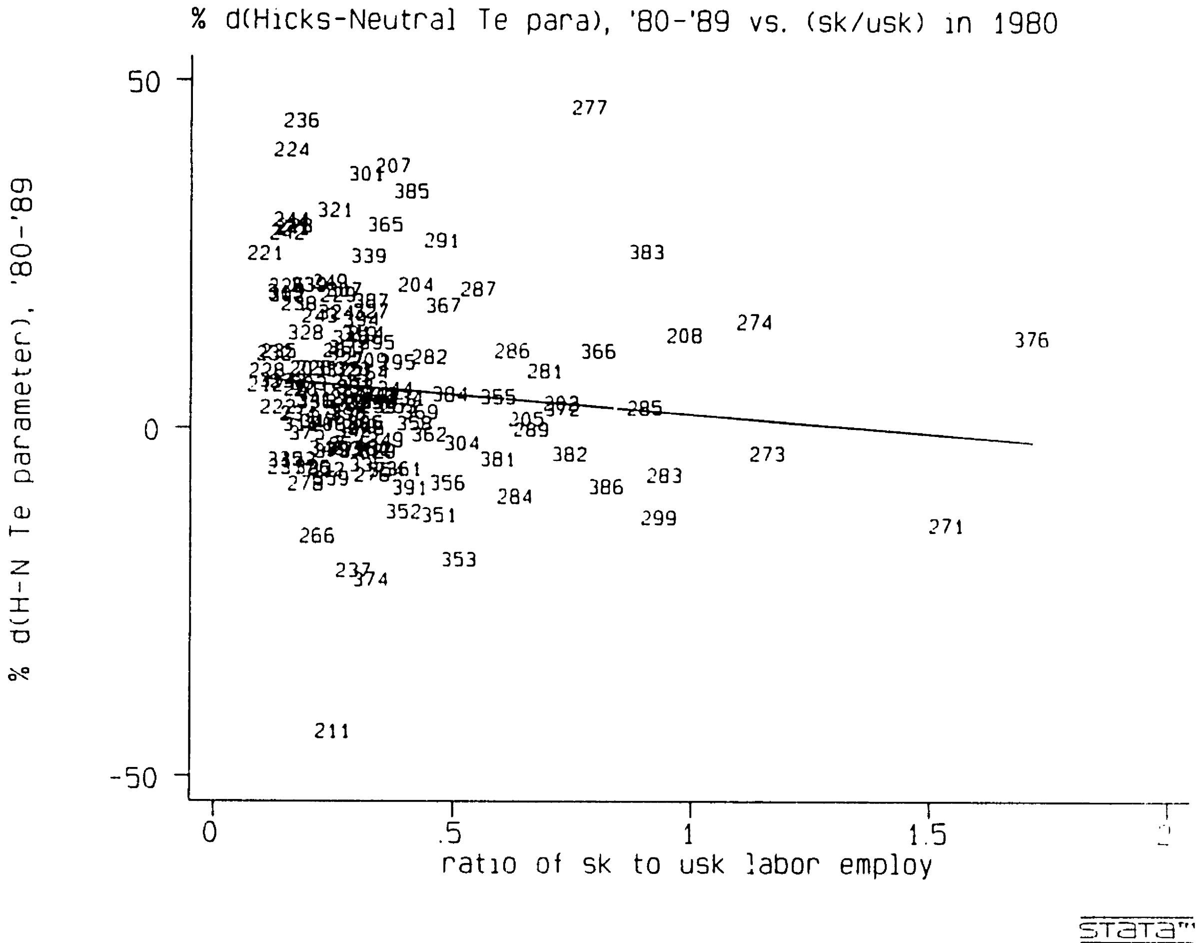
Sources: Export prices come from the Bureau of Labor Statistics;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 3-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure #14: Percentage Changes in the 1980's of Total-Factor Productivity by Industry Versus the Non-Production-Worker Intensity of Industries



Sources: TFP data come from Professor Wayne Gray;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 2-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure #15: Percentage Changes in the 1980's of Total-Factor Productivity by Industry Versus the Non-Production-Worker Intensity of Industries



Sources: TFP data come from Professor Wayne Gray;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 3-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Chapter 2

International Trade, Multinational Corporations, and American Wage Divergence in the 1980's

1 Introduction

The wages of less-skilled Americans fell sharply in the 1980's relative to those of their more-skilled counterparts. Several economists have documented this fall in terms of education, experience, and job classification.[1] Bound and Johnson (1992) find that between 1979 and 1988, the ratio of the averaged wage of a college graduate to the average wage of a high school graduate rose by 15 percent. Davis (1992) finds that between 1979 and 1987, the ratio of weekly earnings of males in their forties to weekly earnings of males in their twenties rose by 25 percent. Finally, Lawrence and Slaughter (1993) find that in manufacturing between 1979 and 1989, the ratio of average annual wages of non-production workers to average annual wages of production workers rose by nearly 10 percent, from 1.52 to 1.65. Figure 1 plots this result.[2]

The literature on this wage divergence has determined that its primary cause was a shift in relative labor demand away from the unskilled and toward the skilled. For example, a comprehensive study by Katz and Murphy (1992) demonstrates that for many measures of skill differentials, relative employment of the skilled rose along with their relative wages. Figure 2 shows this employment rise in the manufacturing sector. It plots

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[1]In this paper, I work primarily with manufacturing data generated from the Annual Survey of Manufactures (ASM). The ASM distinguishes between non-production and production workers by defining production workers as "employees most directly connected with carrying out the manufacturing activities of the business being reported, up to and including working foremen, but excluding other supervisory employees. They [production workers] are those involved in the production of goods, related services (e.g., maintenance and repair), and auxiliary production for the plant's own use (e.g., power plant).". I assume that this division provides a reasonable breakdown between more-skilled and less-skilled workers. Appendix A defends this assumption.

[2]The ratio rose from 1.52 in 1979 to 1.65 in 1989. In 1979 the mean non-production annual wage in manufacturing was $19,517, and the mean production annual wage was $12,829. In 1989 these wages were $34,866 and $21,112, respectively. Note that this is data on payroll wages. It does not include non-payroll compensation (such as health insurance and company cars) which together with payroll wages constitute total compensation. Thus, this figure of 10% might understate the divergence across skill of total compensation.

the evolution of the ratio of non-production to production workers employed in manufacturing. This ratio rose 25% between 1979 and 1989, from .35 to .44. Taken together, Figures 1 and 2 say that both the relative wages and the relative employment of skilled workers rose in manufacturing. A simple exercise of drawing relative-supply and relative-demand schedules shows that manufacturing could have moved to this equilibrium only if its relative demand shifted toward skilled labor, regardless of what happened to relative supply. This exercise corroborates Katz and Murphy's conclusion "that rapid secular growth in the relative demand for 'more-skilled' workers is a key component of any consistent explanation for rising inequality and changes in the wage structure over the last 25 years."[3]

Given this relative-demand explanation, the question then becomes what factors caused the shift. A number of papers have concluded that "skill-biased" technological progress was the primary cause: Bound and Johnson (1992); Berman, Bound, and Griliches (1992); and Krueger (1991). However, only Krueger (1991) presents evidence which directly links technological progress to rising wage inequality. The other papers link the two primarily by process of elimination: after dismissing the role of factors such as declining union power and the defense build-up, they conclude that the most plausible remaining cause is technology.

This approach has inadequately addressed another potential cause. It can loosely be called the "internationalization" of the American economy. A large number of people in government, the media, and the general public think that the American economy was damaged by its interaction with the world economy in the 1980's. The following quote

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[3]Katz and Murphy (1992), page 37.

from a recent article in *Challenge* synthesizes the spirit of this internationalization argument.

> The internationalization of the domestic economy has depressed wage levels in several ways. The elimination of jobs has increased the supply of semi- and unskilled workers in the economy, relative to demand, and has brought about a depressing effect on U.S. wages. Foreign direct investment by U.S. firms also puts domestic workers into competition with similarly skilled workers in other countries. In addition, low-cost imports put domestic workers into indirect competition with foreign labor in many industries and resulted in stagnant or declining real wages in these sectors as well ... Thus, a substantial share of the decline in the real wages of the poorest segment of the population is directly related to the increased internationalization of the U.S. economy during this period [the 1980's].[4]

Proponents of this position worry about two distinct processes. The first is the international trade of goods and services. Trade, the argument runs, forces American producers to slash workers and wages to stay competitive against foreign competitors. People thus claim that "trade is responsible for a significant portion of the decline in the U.S. manufacturing sector ... and trade has contributed to the decline in real wages and to the stagnation of U.S. living standards."[5]

The second process is often called "outsourcing": a decomposition of existing production techniques and subsequent shift of production-labor-intensive activities to foreign countries. A 1986 *Business Week* special report warned that outsourcing is creating "hollow corporations" in America which will harm the American economy: "By shifting production overseas, U.S. companies are whittling away at the critical mass essential to a strong industrial base. If globalization of industry means that U.S.

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[4]Page 35 of "Flat Earth Economics: Is There a New International Paradigm?" by Robert E. Scott, *Challenge*, September-October 1993.

[5]ibid, p34.

manufacturers will wind up simply licking the labels and sticking them on products that are made abroad, the nation can look forward to a declining standard of living."[6] In particular, many think that outsourcing pits foreign labor against American labor. "In seeking to escape a 'pro-union' or 'anti-business' climate inside the United States, large corporations ... can build, expand, or acquire facilities outside the country altogether. In fact, all the strategic innovations devised by multiplant companies for playing off one group of workers against another ... have become standard operating procedure in the global economy."[7]

Thus, people argue that trade and outsourcing have contributed to America's wage divergence. Two facts underscore the pervasiveness of this position in America. First, it spans the political spectrum: from union halls and publications like *Challenge* to board rooms and publications like *Business Week*. Second, its proponents nearly prevented passage of the North American Free Trade Agreement (NAFTA). Previous rounds of GATT negotiations met only isolated opposition from particular industries. However, with NAFTA a coalition led primarily by Ross Perot and his specter of a "giant sucking sound" rallied sufficient opposition to endanger its approval by the House of Representatives. Proponents of internationalization are a broad group, and are now arguably the most vocal voice in the current policy debate about the American economy.

In theory, trade and outsourcing could have contributed to America's wage

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[6]Page 60, "The Hollow Corporation," *Business Week*, March 3, 1986.

[7]Page 170 *The Deindustrialization of America: Plant Closings, Community Abandonment, and the Dismantling of Basic Industry*, Barry Bluestone and Bennett Harrison, Basic Books, Inc. Publishers, New York, 1982.

divergence. Standard international-economics theory does describe methods by which trade and multinationals shift relative labor demand and thereby shift relative factor returns. The classic Stolper-Samuelson theorem says that changes in the terms of trade translate into changed relative factor demands. And more recent work on the theory of multinational firms says that when these firms spread facilities across countries, they change relative factor demands within these countries.

The issue, therefore, becomes an empirical one. *The Wall Street Journal* and other publications continually write about firms battling their trading competitors and firms moving production facilities abroad. Beyond this anecdotal evidence of internationalization, however, the literature has not provided a more comprehensive analysis. Several papers have focused on trade deficits and trade volumes to determine whether international trade helped shift relative labor demand. However, these measures do not directly map into the Stolper-Samuelson process. Even fewer papers have considered the role of outsourcing, and those that have have used rather narrow definitions of outsourcing. Thus, it remains an open question how much international trade and multinational outsourcing contributed to America's labor-demand shift and resulting relative-wage divergence.

In this paper, I try to answer this question. In doing so, I try to make two contributions. First, I articulate internationalization in the language of standard international-economics theory. In doing this, I identify what the data should indicate if either trade or outsourcing is shifting labor demand. Second, I look in the data for these indications. I focus on the manufacturing sector, primarily because of data limitations. However, this focus should give results which apply to the entire economy. Trade in manufactures constitutes 70% of all U.S. trade, and the large majority of anecdotal cases of outsourcing involve manufacturing firms. If neither trade nor outsourcing plays a large role in the manufacturing sector, then very likely they play no role in the economy as a whole. My primary finding is that internationalists appear to have it wrong. I find that neither international trade through the Stolper-Samuelson process nor outsourcing by multinational corporations contributed significantly to America's labor-demand shift and resulting relative-wage divergence.

The paper contains five additional sections. Section 2 presents the Stolper-Samuelson theorem and its empirical implications. It also explains the problems with previous work that has studied trade volumes and trade deficits. Section 3 presents wage, employment, and terms-of-trade data which indicate that the Stolper-Samuelson process contributed nothing to America's wage divergence. Section 4 presents a simple model of outsourcing which elaborates its empirical implications. Section 5 presents data on employment in subsidiaries of American multinationals which indicate that outsourcing contributed very little to America's wage divergence. Section 6 concludes.

2 The Stolper-Samuelson Theorem

The simple version of Heckshcr-Ohlin-Samuelson (HOS) trade theory addresses a world with two factors of production, two goods, and two countries which share identical constant returns to scale technologies and identical preferences. Despite its simplicity, this framework develops many of the foundational ideas of international-trade theory. One of these is the Stolper-Samuelson theorem. In the simple HOS framework, the theorem says that a rise in the price of a product raises the real return to the factor used relatively intensively in the production of that good, and lowers the real return to the factor used relatively sparsely in the production of that good. International trade thus redistributes income by changing the terms of trade.

In what follows, first I present the Stolper-Samuelson theorem in the simple HOS world. In this framework, I can most clearly identify implications of the theorem working. I then generalize the theorem to more realistic frameworks, and show that this generalized theorem has terms-of-trade shocks changing *relative* wages rather than real wages. Because relative wage divergence is what I want to explain, I conclude that looking in the data for implications of this generalized Stolper-Samuelson theorem is the appropriate way to gauge the effects of international trade on the American economy of the 1980's.

To describe the Stolper-Samuelson process in the HOS world, consider a small open economy whose two goods are software and textiles and whose two factors are skilled labor and unskilled labor. Suppose that software uses skilled labor relatively intensively.[8] Initially, the country settles at some equilibrium output mix of software and textiles. To produce this mix, firms employ the country's skilled and unskilled labor. The labor market generates an equilibrium wage for each type of labor; at this wage, the quantity demanded by firms equals the total quantity supplied in the economy.

This equilibrium can be illustrated with unit-value production isoquants in the Lerner diagram. In Figure 3, the isoquants are SS and TT. Each isoquant plots combinations of skilled and unskilled labor that, given prices of both factors and goods,

[8]I also assume no factor-intensity reversals. Thus, for any given relative wages, the ratio of skilled to unskilled labor employed in making one unit of software exceeds the ratio of skilled to unskilled labor employed in making one unit of textiles. Since there are only two goods and two factors in this economy, it immediately follows from software using skilled labor relatively intensively that textiles use unskilled labor relatively intensively.

produce a unit value of output. Because software uses skilled labor relatively intensively, SS lies above and to the left of TT. The country makes both goods, so both isoquants are tangent to the line which plots the ratio of factor prices, (W_s/W_u). These tangency points indicate the ratios of skilled to unskilled labor $(S/U)_s$ and $(S/U)_t$ used to produce software and textiles, respectively.

Now suppose that the international price of software rises. This is depicted in Figure 4 as an outward shift in the textile unit-value isoquant to T'T'. The country now seeks to make more software and fewer textiles. Output in textiles declines, releasing some of both factors. Output in software expands, requiring more of both factors. Because software employs skilled labor relatively intensively, the overall economy's relative demand shifts towards skilled labor and away from unskilled labor. If factor prices remained constant, however, the factor quantities released by textiles would not match those demanded by software because of the different factor intensities of the goods. The textile industry would release too much unskilled labor and too little skilled labor relative to what the software industry demands.

Wages must therefore change. The nominal unskilled-labor wage falls, and the nominal skilled-labor wage rises. The new equilibrium relative-factor-price ratio is $(W_s/W_u)' > (W_s/W_u)$. This higher ratio induces all firms to substitute away from skilled labor and toward skilled labor, and this substitution lowers the ratio of skilled to unskilled labor employed in each industry. In Figure 8, this substitution is represented as a flattening of each industry's (S/U) ray to (S/U)'. Textiles thus releases less unskilled labor and more skilled labor relative to what it would have released without the wage change. Similarly, software demands more unskilled labor and less skilled labor relative to what it would have released without the wage change. Nominal wages move just enough to reemploy all labor; at this point, the economy attains its new equilibrium. In addition, in the new equilibrium the Stolper-Samuelson process has operated. The price of software has risen, the price of textiles remains unchanged, the nominal wage of skilled labor has risen, and the nominal wage of unskilled labor has fallen. Clearly, the real wage of unskilled labor has fallen. By the "magnification effect," it can be shown that the percentage rise in the nominal skilled-labor wage exceeds the percentage rise in the price of software.[9] Thus, the real wage of skilled labor has risen. These real-wage changes are the Stolper-Samuelson result.

In this simple framework, Stolper-Samuelson manifests itself by changing three things: first the terms of trade, and then real wages across industries and relative employment within industries. Overall, changed terms of trade translate into changed factor returns and changed factor-employment ratios by shifting the demand for these factors. Thus, it is not the trade of goods per se which matters. It is the change in price of these traded goods.

The question now becomes how the Stolper-Samuelson theorem generalizes to more realistic frameworks. I extend the model in two ways. First, I introduce higher dimensions; then I introduce increasing returns to scale.

First, introduce more factors and goods. Ethier (1984) discusses how the results of the simple HOS model extend to higher dimensions. With more than two goods, the

[9]The magnification effect is the fact that the change in each good's price is a convex combination of the changes in the two nominal wages. For each good i, $P^*_i = \Theta_s w^*_s + \Theta_u w^*_u$. Here, X^* denotes the percentage change in variable X, and $\Theta_i \in (0,1)$ is the initial cost share of factor i. Thus, any given price change is "magnified" by the factor-price changes. See Jones (1965) for a full discussion.

Stolper-Samuelson theorem still holds as it does under two goods. But with either more than two factors or many factors and goods, the theorem cannot make unambiguous predictions about real-wage changes. In these cases, some factors' real wages can rise in terms of one good but fall in terms of the other. In the case of many factors and goods, only restrictive assumptions about the nature of technologies permit real-wage predictions about groups of factors.[10]

However, the strong Stolper-Samuelson theorem does have a higher-dimension generalization which makes predictions about *relative* wages without restrictive assumptions. Ethier states it as follows: "there is a tendency for changes in relative commodity prices to be accompanied by increases in the rewards of factors employed most intensively by those goods whose prices have relatively risen the most and employed least intensively by those goods whose relative prices have fallen the most."[11] This generalization follows directly from cost minimization, and therefore requires no restrictions on technology or dimensionality. Moreover, just like the strong Stolper-Samuelson, this generalization involves shifting demands for factors of production across industries and shifting relative employments within industries.

The second extension allows one or more of the industries to produce under increasing returns to scale. Helpman and Krugman (1985) point out that this introduces a second channel through which trade can affect the utility of factors. Notice the use of

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[10]In particular, assumptions need to be made which ensure that the Θ^{-1} technology matrix is Minkowski, i.e., contains positive diagonal elements and negative off-diagonal elements. Also, the "natural friends and enemies" result (Proposition 16 of Ethier (1984)) holds without technology assumptions. But this result deals with only individual, unidentifiable factors of production.

[11]Ethier (1984), page 164.

"utility of factors" rather than factor prices: in a broad class of models summarized in Helpman and Krugman, this second channel does *not* operate on factor prices per se but rather on the utility of the owners these factors through an increase in available product variety. Distinct from this variety effect, Stolper-Samuelson still moves factor prices in these models.

Consider a world with two countries and two industries, one of which (manufacturing) produces under increasing returns to scale internal to the firm that leads to a monopolistically competitive market structure in which each firm makes a different variety of the good. In addition, consumers' (i.e., owners of factors) utility over this manufacturing good takes the Dixit-Stiglitz symmetrical constant elasticity of substitution form. The important aspect of this utility specification is that variety is valued per se: more varieties raise utility. Now allow this world to trade freely. Within manufacturing, each country specializes in a set of manufacturing varieties which both home and foreign consumers demand. Trade thus increases the number of varieties and therefore consumer utility, *ceteris paribus*. However, Stolper-Samuelson still influences utility through its effect on factor prices (and thus available consumption sets). Helpman and Krugman point out that under certain conditions the variety effect can dominate the Stolper-Samuelson effect such that all factors benefit from freer trade.[12]

So increasing returns to scale in a wide class of models does not change the implications of the Stolper-Samuelson process; it simply influences utility in addition to Stolper-Samuelson. In what follows, I assume that this class of models reasonably

[12]See Section III of Helpman and Krugman for a complete discussion of trade models with differentiated products.

describes any actual cases of increasing returns to scale.

Thus, generalizing the HOS framework to allow higher dimensions and increasing returns to scale changes the Stolper-Samuelson theorem only slightly. Instead of predictions about real-wage movements, it now makes predictions about relative-wage movements. The generalized theorem says that a rise in the price of a group of products tends to raise the wage of the factors used relatively intensively in these products relative to the wages of the factors used relatively unintensively in these products. Also, the generalized theorem still operates by shifting demands for factors of production across industries and shifting relative employment within industries. It therefore manifests itself by changing three things: first the terms of trade, and then relative wages across industries and relative employment within industries.

Did this process help increase the relative wages of skilled workers in the United States in the 1980's? Surprisingly, no study of America's income distribution in the 1980's has explicitly considered this question.[13] Instead, studies which look at the influence of international trade on relative wages have focused trade volumes and trade deficits.[14]

Many of these studies focus on the quantities of factors embodied in trade flows. For example, a frequently cited study by Borjas, Freeman, and Katz (1992) calculates

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[13]Leamer (1992) applies Stolper-Samuelson to estimate the impact of the North American Free Trade Agreement on labor and capital in the United States. In particular, he attempts to exploit the reciprocity between the Rybczynski and Stolper-Samuelson theorems by first estimating Rybczynski partial derivatives in production functions and then calling these estimates of Stolper-Samuelson partial derivatives. The logic of this method is clear, but Leamer's assumptions about the empirical applicability of reciprocity are debatable. In particular, trade theory says that Rybczynski partial derivatives are not well-defined when the number of goods exceeds the number of factors.

[14]For example, see Berman, Bound and Griliches (1992); Davis (1992); Freeman and Katz (1991); Katz and Murphy (1992); and Murphy and Welch (1991).

the quantities of skilled and unskilled labor embodied in America's trade deficits up through 1987. They then reason that these embodied labor supplies should be combined with America's endowment of factors to obtain America's "effective" labor supplies. All other things equal, a large effective supply of a factor lowers its return. Thus, embodied labor supplies are the "international factors" which influence wages. Because America tends to import unskilled-labor-intensive products, larger trade deficits in the 1980's meant a larger relative effective supply of--and therefore a lower relative wage for--unskilled labor.[15] Borjas, et al, conclude that America's trade deficits accounted for about 15% of the American wage divergence. When one considers with whom America trades, it is not surprising that estimates of embodied factor supplies indicate relatively small effects on wages. In 1990, 70% of America's manufacturing imports came from OECD countries whose endowments and wage structures are very similar to America's. Between 1980 and 1989, hourly compensation in these countries rose from 83% of U.S. levels to 103%.[16]

Although the approach of Borjas, et al, is often used, it is rather weakly grounded in standard trade theory. Standard trade theory does discuss factor supplies embodied in trade flows, but primarily as a measure of revealed comparative advantage: a country tends to net export its relatively abundant factors and to net import its relatively scarce factors. Trade theory does not make unambiguous links between factors embodied in

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[15]Policymakers sometimes use a particularly egregious version of this approach. They use a rule of thumb that says each billion dollars of manufacturing output represents twenty thousand jobs. With this rule, they argue that a trade deficit of $100 billion represents two million American jobs lost.

[16]EC wages were the same as in the US in 1980, and are 15% higher today. Wages in the Asian NICs were 12% of US levels in 1980 and are 25% today. Overall, on a weighted average with 24 foreign countries, foreign wages have increased since 1980 from 72% to 88% of US levels.

trade and the returns to these factors.[17] Indeed, trade theory says that trade volumes and trade deficits have no necessary relationship to factor returns. The reason is that trade deficits depend on both production and consumption activity: they are the excess of expenditure over production. The Stolper-Samuelson theorem, however, deals only with production activity: shifts in production prompted by shifts in the terms of trade. Changes in the trade deficit that leave the terms-of-trade unchanged do not change relative factor returns.

To clarify this point, return to the small open economy. Initially, it is at full employment with balanced trade. Now, suppose that its residents decide to consume more textiles. They import more textiles, and pay for this trade deficit with a capital-account inflow. Since the economy is small, the terms of trade do not change--and this means that relative factor returns do not change. Domestic spending is simply exceeding the economy's productive potential. But because textiles use unskilled labor relatively intensively, the trade deficit raises the country's effective supply of unskilled labor relative to its effective supply of skilled labor. Borjas, et al, would therefore incorrectly conclude that the relative wage of unskilled labor must fall.

Even in a balanced-trade framework, the Borjas methodology incorrectly predicts relative-wage changes. Again suppose that the small open economy imports more textiles, but that its residents pay for these imports by exporting more software. Like the trade deficit, this balanced increase in trade raises the country's effective supply of unskilled

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[17]A paper which discusses the links is Deardorff and Staiger (1988). They discuss how the factor content of trade can indicate the effects of trade on relative factor prices with reference to "autarky equilibria" constructed by changing factor endowments by the factor content of trade. However, this paper does not directly support the Borjas, et al, methodology. As I discuss in the text, their methodology seems to have serious problems.

labor relative to skilled labor. Borjas, et al, would make the incorrect wage prediction again.[18]

As Bhagwati (1991) has emphasized, relative good-price changes are the critical variable which initiates the chain of causation from trade to factor prices. *Ex post* trade volumes are a poor measure of the *ex ante* pressures generated by trade.

3 Empirical Evidence of Stolper-Samuelson

America's rising wages of skilled labor relative to unskilled labor are consistent with the generalized Stolper-Samuelson process having operated thanks to a rise in the international price of skilled-labor-intensive products relative to those of unskilled-labor-intensive products. All other things equal, this terms-of-trade shock would have raised the relative wages of skilled labor across all industries and lowered the relative employment of skilled labor within all industries.

To see whether the Stolper-Samuelson process did in fact contribute to America's wage divergence, I look in the data for the two implications of the process: (1) a fall in all industries in the ratio of skilled to unskilled labor employed, and (2) an increase in the international price of skilled-labor-intensive products relative to those of unskilled-labor-intensive products. I consider each of these propositions in turn.

The data set covers the United States manufacturing sector from 1979 through 1989. This measure of the decade of the 1980's spans similar peaks in the business cycle, and thereby minimizes the cycle's impact on results. Data on inputs and outputs by

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[18]One can show analytically that with either balanced or unbalanced trade, the Borjas approach breaks down because the elasticity of complementarity between two factors in a closed economy does not equal the elasticity of complementarity between two factors with respect to their effective supplies in an open economy.

industry come from the National Bureau of Economic Research's Trade and Immigration Data Base. Data on America's terms of trade come from the Bureau of Labor Statistics' export and import price indexes. As discussed earlier, in these data skilled labor is defined as non-production labor, and unskilled labor is defined as production labor.[19]

First, I consider whether industries experienced a fall in the ratio of skilled to unskilled labor employed. If the Stolper-Samuelson process alone had influenced American wages in the 1980's, rising relative wages of skilled labor would have compelled all industries to substitute toward unskilled labor. Figure 5 checks whether industries did substitute in this way. It plots the percentage change between 1979 and 1989 of relative wages and relative employment in manufacturing industries disaggregated at the 2-, 3-, and 4-digit SIC levels. Higher relative wages of non-production labor combined with a lower ratio of non-production to production labor employed would move industries in the upper-left quadrant of Figure 5.

Regardless of the level of disaggregation, however, only about 10% of all industries moved this way (at the 2-digit level, 8.2%; at the 3-digit level, 9.8%; at the 4-digit level, 9.5%). Indeed, one of the remarkable features of American manufacturing in the 1980's was a pervasive *increase* in the ratio of non-production to production workers employed within industries--exactly the opposite of the Stolper-Samuelson prediction. At every level of disaggregation, at least half of all industries (measured by

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[19]Again, see Appendix A for more on identifying skill classes. The export and import price indices are generated from quarterly surveys of firms engaged in trade. The NBER data base draws primarily from the ASM; see Abowd & Freeman (1991) for a detailed description of this data base. In addition, all SIC classifications in this data set come from the revision #2 scheme. Revision #3 replaced #2 starting in 1988, and it redesignated about 25% of #2's industries. All data from 1988 and 1989 have been concorded back to revision #2. Table 1 lists the name of each 2-digit SIC industry.

share of total manufacturing employment) moved to a new equilibrium in the upper-right quadrant of Figure 5. This equilibrium entails both higher relative wages and higher relative employment of non-production labor. Thus, the majority of industries accompanied rising relative wages with rising, not falling, relative employment.

So Figure 5 indicates that Stolper-Samuelson was not the predominant influence on relative labor demand in the 1980's. I should emphasize that Figure 5 is consistent with a Stolper-Samuelson effect being dominated by some larger effect. The sum of these effects was that most industries employed relatively more, not relatively less, non-production labor. I cannot yet say anything about the absolute size of the Stolper-Samuelson effect. Perhaps it was large; perhaps it was nonexistent.

To determine the absolute size of this effect, I examine international prices to see whether those of skilled-labor-intensive products rose more than those of unskilled-labor-intensive products. Skilled-labor-intensive products are defined as those which employed a high ratio of non-production to production labor in 1980.[20] Figures 6 and 7 graph percentage changes over the 1980's in industries' import prices against their skill intensity. Figures 8 and 9 replace the import prices with export prices. In each pair of figures, the first figure classifies industries at the 2-digit SIC level, and the second at the 3-digit SIC level.

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[20]I also defined industries based on their relative employment in 1985 and 1989, but the results are very similar for all years. Incidentally, the data indicate that America has a comparative advantage in non-production-labor-intensive products. In 1979, the exports-weighted ratio of non-production to production labor employed in America's export industries was .501; the analogous ratio for imports was .384. In 1989, these ratios were .539 and .433, respectively. These numbers indicate that America's exports employ non-production labor relatively intensively and that its imports employ production labor relatively intensively. This higher ratio of non-production to production labor employed in exports indicates a comparative advantage in non-production-labor-intensive goods, and a comparative disadvantage in production-labor-intensive goods.

There are two caveats about these price data. First, the BLS did not track prices for all industries between 1979 and 1989. The import prices cover 93% of all manufacturing employment at the 2-digit level and 50% at the 3-digit level. The export prices cover 64% of all manufacturing employment at the 2-digit level and 48% at the 3-digit level. I assume that the price movements in these industries are reasonably representative of overall manufacturing. Second, approximately 25% of industries were not covered as far back as 1979. Almost all these, however, were covered by 1982. Assuming that these few industries in these few years did not experience outrageous price movements, I therefore include them in the figures.

If Stolper-Samuelson had any influence at all, then the international prices of skilled-labor-intensive products should have risen relative to the international prices of unskilled-labor-intensive products. But Figures 6 through 9 do not indicate such a rise. Instead, their trend lines suggest that the relative price of skilled-labor-intensive products actually fell.[21]

Weighted-average price increases corroborate this suggestion. For both import prices and export prices at the 3-digit level, I construct two price indexes. One weights each industry's price rise by the industry's share in 1980 employment of non-production workers, the other by the industry's share in 1980 employment of production-workers.[22] Table 2 reports that import prices weighted by non-production-labor shares rose by 26%

[21]These trend lines plot the estimated percentage price changes obtained from regressing actual percentage price changes on the ratio of skilled to unskilled labor employed and a constant. None of the four regressions estimated a coefficient on the ratio that was significantly negative at even the 10% level of significance.

[22]These price indexes were also calculated using 1989 employment shares as weights. The results were virtually identical, so only the results with 1980 employment shares as weights are presented.

in the 1980's. Weighted by production-labor shares, import prices rose by 28%. Similarly, export prices weighted by non-production-labor shares rose by 26% in the 1980's. Weighted by production-labor shares, they rose by 30%.

Thus, the data indicate that the Stolper-Samuelson process did not contribute to America's relative-wage divergence in the 1980's. In fact, because the relative price of skilled-labor-intensive products fell slightly, the Stolper-Samuelson process actually nudged relative wages towards greater *equality*. No regression analysis is needed to reach this conclusion. Determining that the relative international prices of America's skilled-labor-intensive products actually fell during the 1980's is sufficient.[23]

4 A Simple Theory of Outsourcing

Figure 5 demonstrates that the majority of America's shift in labor demand occurred within rather than among industries. For example, at the three-digit SIC level, 124 of 143 industries employed a higher ratio of non-production to production workers in 1989 than in 1979. In principle, manufacturing as a whole can employ relatively more skilled labor either by employing the same labor mix within industries and shifting output towards the skilled-labor-intensive industries, or by producing the same output mix across industries and shifting employment within each industry towards skilled labor. Berman, Bound, and Griliches (1992) corroborate Figure 5. Using the same data as what underlies Figure 5, they decompose the overall shift in relative employment into among- and within-industry components. They find that although there are "both between-industry and within-industry components, the within-industry component dominates the between"

[23]If the relative international prices of America's non-production-labor-intensive products rise, regression analysis would have been appropriate to determine the contribution of Stolper-Samuelson to America's wage changes relative to other contributions such as technological progress.

by accounting for approximately 70% of the overall shift.[24] The pervasiveness of the within-industry demand shift is prima facie evidence that a large number of industries outsourced in the 1980's.

To see this, I present a simple general-equilibrium model of outsourcing. It follows the model in Helpman (1984), but it analyzes the wage and price effects of outsourcing more completely than Helpman does. In the model, multinationals establish foreign subsidiaries to take advantage of lower foreign factor prices.

Consider a world with two countries, home and foreign; two industries, baseballs (B) and food (F); and two factors of production, skilled labor (S) and unskilled labor (U). Food is produced under constant returns to scale with just unskilled labor. Food technology is thus represented by the following production function:

(1) $$F = fU,$$

where $f>0$ parameterizes food productivity.[25]

Making baseballs is a bit more complicated; it combines two distinct activities. One activity is the provision of "headquarters services" (H) such as executive management, finance, and research and development. Headquarters services are provided under constant returns to scale with just skilled labor. This technology is represented by

(2) $$H = hS,$$

where $h>0$ parameterizes headquarters productivity. The second manufacturing activity

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[24]Page 8 of Berman, Bound, and Griliches (1992). Between 1979 and 1987, the overall shift away from production workers rose at .552 percentage points a year. Of this, .387 percentage points--approximately 70%--came from within-industry shifts, and only .165 percentage points came from between-industry shifts.

[25]No results in the model depend on the assumption that food production uses only unskilled labor. I make the assumption purely to simplify things.

is assembling the baseballs. Assembly occurs under constant returns to scale with just unskilled labor. This technology is represented by

(3) $$A = aU,$$

where $a > 0$ parameterizes assembly productivity. Baseball production combines headquarters services and assembly under constant returns to scale according to

(4) $$B = bH^{d}A^{(1-d)}$$

$$= eS^{d}U^{(1-d)}, \text{ where } e \equiv h^{d}a^{(1-d)}c > 0 \text{ and } d \in (0,1).$$

The production technology in equations (1) and (4) can alternative be represented by their cost-function duals. The dual cost functions are equations (5) and (6), respectively.

(5) $$c^{b}(w_{s},w_{u},B) = Kw_{s}^{d}w_{u}^{(1-d)}B$$

(6) $$c^{f}(w_{u},F) = w_{u}F/f$$

In (5) and (6), w_s is the skilled wage, w_u is the unskilled wage, and $K \equiv (1-d)^{(d-1)}d^{(-d)}/e$. Preferences are the same in both countries and are homothetic. Without loss of generality, I assume Cobb-Douglas utility:

(7) $$U(B,F) = B^{g}F^{(1-g)}, \text{ where } g \in (0,1).$$

Finally, each country is endowed with both skilled and unskilled labor: S_h and U_h for home, S_f and U_f for foreign.

First, consider the integrated equilibrium. Five equations can characterize it. Equations (8) and (9) are zero-profit conditions which set average cost equal to price. P represents the price of a baseball, and the price of food is normalized to equal one.

(8) $$Kw_{s}^{d}w_{u}^{(1-d)} = P$$

(9) $$w_{u}/f = 1$$

Next, equations (10) and (11) are factor-market-clearing conditions for skilled and unskilled labor, respectively.

(10) $$dKw_s^{(d-1)}w_u^{(1-d)}B = (S_h+S_f)$$

(11) $$(1-d)Kw_s^{d}w_u^{(-d)}B + F/f = (U_h+U_f)$$

Finally, equation (12) is a goods-market-clearing condition which sets expenditure on baseballs equal to the fraction g of total world income.

(12) $$PB = g(w_u(U_h+U_f)+w_s(S_h+S_f))$$

The endogenous variables are w_u, w_s, P, B, and F. Solving (8)-(12) for these variables yields the following equilibrium values:

(13) $$w_u^* = f$$

(14) $$w_s^* = dfg(1-dg)^{-1}(U_h+U_f)(S_h+S_f)^{-1}$$

(15) $$P^* = (1-d)^{(d-1)}(1-dg)^{-d}e^{-1}fg^{d}(S_h+S_f)^{-d}(U_h+U_f)^{d}$$

(16) $$B^* = (1-d)^{(1-d)}(1-dg)^{(d-1)}eg^{(1-d)}(S_h+S_f)^{d}(U_h+U_f)^{(1-d)}$$

(17) $$F^* = (1-g)f(1-dg)^{-1}(U_h+U_f)$$

Now divide the world into the two countries, home and foreign. First, consider the equilibria which obtain under free trade but no multinationals. The Helpman-Krugman (1985) parallelogram diagram in Figure 10 helps distinguish the two sets of equilibria. One set consists of endowments lying inside the parallelogram, and the other of endowments lying outside the parallelogram. For endowments inside the parallelogram such as point A, trade replicates the integrated equilibrium. In particular, it achieves factor-price equalization (FPE), with relative wages in both countries equal to the relative wages of the integrated equilibrium: $(w_s/w_u)_h = (w_s/w_u)_f = (w_s^*/w_u^*)$. At A, both countries produce both goods, and home exports some baseballs to foreign in exchange for some food.

For endowments lying outside the parallelogram such as point B, trade cannot replicate the integrated equilibrium. At B, for example, home is so well endowed with skilled labor relative to foreign that it has too much skilled labor to fully employ all its endowment using the integrated-equilibrium production techniques. As a result, home makes only baseballs using a different production technique.[26] Foreign makes both baseballs and food, and exports some food to home in exchange for more baseballs.

The following equations characterize this equilibrium. In these equations, the subscripts h and f designate home and foreign values for variables, respectively. Equation (18) is the zero-profit condition for home baseball production.

$$(18) \qquad Kw_{sh}^{d}w_{uh}^{(1-d)} = P$$

Equations (19) and (20) are zero-profit conditions for foreign food and baseball production, respectively.

$$(19) \qquad w_{uf}/f = 1$$

$$(20) \qquad Kw_{sf}^{d}w_{uf}^{(1-d)} = P$$

Equation (21) is the factor-markets clearing condition for home (because home makes only baseballs, one equation for each market can be simplified into this one equation).

$$(21) \qquad w_{uh}/w_{sh} = (1-d)S_h/dU_h$$

Equations (22) and (23) are the two factor-market clearing conditions for foreign.

$$(22) \qquad dKw_{sf}^{(d-1)}w_{uf}^{(1-d)}B_f = S_f$$

$$(23) \qquad (1-d)Kw_{sf}^{d}w_{uf}^{-d}B_f + F_f/f = U_f$$

Finally, equation (24) is the goods-market clearing condition which sets the value of

[26] Clearly, then, $B_h^* = eS_h^dU_h^{(1-d)}$.

world food production equal to the fraction (1-g) of world income.

$$F_f = (1-g)(w_{uh}U_h + w_{sh}S_h + w_{uf}U_f + w_{sf}S_f) \tag{24}$$

These seven equations determine the values for the seven endogenous variables w_{sh}, w_{uh}, w_{sf}, w_{uh}, P, B_f, and F_f. Unfortunately, the non-linearity of the equations do not allow a closed-form analytic solution for these variables. However, any given set of parameters does generate a unique solution. To see this, solve the above system of equations for w_{sf} to obtain the following equation which determines the equilibrium value w_{sf}^*:

$$\{(1-dg)S_f/df\}w_{sf}^* + \{(1-g)(1-d)^{(d-1)}d^{-d}f^{-d}S_h^{\,d}U_h^{\,(1-d)}\}w_{sf}^{*d} = gU_f. \tag{25}$$

The non-linearity of this equation in w_{sf}^* prevents solving it explicitly for w_{sf}^*. But it can be shown that a unique solution for w_{sf}^* exists. Given the assumptions about the parameters, both terms in the brackets are positive; in addition, d lies in the unit interval. It therefore follows that the left-hand side is monotonically increasing in w_{sf}^*. Thus, for any value of $gU_f > 0$, a unique value of w_{sf}^* satisfies equation (25). With this w_{sf}^*, the equilibrium values of the six other endogenous variables can be found. Despite this inability to find a closed-form analytic solution, intuition makes clear that in equilibrium, $(w_{sh}/w_{uh}) < (w_s^*/w_h^*) < (w_{sf}/w_{uf})$. The wage of skilled labor relative to unskilled labor is lower in skilled-rich home than it is in the integrated equilibrium, and it is higher in unskilled-rich home than it is in the integrated equilibrium.

Thus two types of equilibria obtain in a world with trade but no multinationals. For sufficiently similar endowments, trade achieves FPE. For sufficiently dissimilar endowments, the wage of skilled labor relative to unskilled labor is lower in the skilled-rich country.

Now introduce multinationals into the world. Following Helpman (1984), I do this by giving headquarters services a special feature: the services need *not* be located in the same country as the unskilled labor with which they are combined in equation (4). Inputs such as those listed as examples of headquarters services have this feature in many industries. In a baseball manufacturer, for example, it seems unlikely that the chief financial officer must work in the same country as those who sew the leather covers onto the cores. Firm-specific assets whose internalization may create the firm itself often have this feature as well.[27] Such assets include a brand name--Rawlings, for example--or a firm's entrepreneurial culture.

With this production structure, baseball producers have an incentive to become multinational firms when relative wages differ across countries. They will want to outsource: i.e., to locate their headquarters services in the country with the lower skilled-labor wage, and assembly subsidiaries in the country with the lower unskilled-labor wage. In home, relative demand for labor in the baseball industry shifts towards skilled labor. In foreign, it shifts towards unskilled labor. Within each country, then, the desire to outsource changes the within-industry relative demand. This in turn changes each country's overall relative demand, and thereby changes each country's relative wages. Thus, outsourcing actually expands the FPE set that was attainable under trade alone.

The parallelogram diagram in Figure 11 shows this. With multinationals, the production rays for baseballs are no longer O_hQ and O_fQ'. These rays assume that the skilled and unskilled labor which make the baseballs must be located in the same country.

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[27]See Dunning (1988) for a firm's internalization advantage and its relationship to ownership and location advantages.

Multinationals can separate baseball production into its headquarters and assembly components. Thus, the effective production ray for baseballs splits into two rays: one for headquarters and one for assembly. Given the assumptions about headquarters and assembly technology in equations (2) and (3), these rays lie on the edge of the diagram's box. With outsourcing, the world's effective FPE set expands to include all endowments.[28]

Reconsider endowments A and B in this world where multinationals can emerge. Figure 11 plots the possibilities. At endowments such as A, no multinationals emerge. They have no incentive to, because trade alone achieves FPE. But multinationals do emerge at endowments such as B. Baseball producers want to locate headquarters in home and assembly in foreign. These desires increase the demand for skilled labor in home and reduce it in foreign, and they increase the demand for unskilled labor in foreign and reduce it in home. The equilibrium production point which emerges is point B'. Here, home is again involved in only baseballs, as it was at point B without multinationals. But now home's endowment of skilled labor, OS_h, can be combined with foreign unskilled labor. Home-based multinationals therefore combine OS_h with S_hB unskilled labor located in home and BB' unskilled labor located in foreign subsidiaries. Foreign continues to make all the world's food, and it devotes O_fQ unskilled labor to food. QB unskilled labor remains to assemble baseballs. Of this QB, BB' work for home-

[28] If either headquarters or assembly requires both types of labor, the FPE set will not expand to include *all* endowments. In this case, for some endowments multinationals will emerge but will not alter factor demands in each country sufficiently to generate FPE. Helpman (1984) clarifies the possible outcomes. However, in all these cases multinationals do change relative factor demands within countries. I therefore chose the extreme technologies without loss of generality, but merely to explain the effect of multinationals as clearly as possible.

owned subsidiaries. The remaining B'Q unskilled labor combines with foreign's entire skilled-labor endowment to assemble baseballs in entirely foreign baseball firms.[29]

Trade flows are more complicated in this equilibrium. Multinationals have created a new tradable good: headquarters services. Home now exports these services intrafirm from the headquarters, at a price w_s^*, to the foreign subsidiaries. The subsidiaries then combine the services with assembly to produce baseballs. Foreign then exports both baseballs and food back to home. Trade remains balanced: the value of headquarters services sent abroad just equals the amount needed to import the desired baseballs and food.

To flesh out how multinationals change the equilibrium for endowments such as B, I present a numeric example. Parameterize the model with the following assumptions: $a=b=c=e=f=1$; $d=g=3/4$; $S_h=U_f=9$; $U_h=S_f=1$. Now I can compare the equilibrium at B without multinationals to the equilibrium at B with multinationals. Table 3 presents the results.

The table highlights four important differences between the equilibria. First, multinationals equalize relative wages across countries at a level that is both less than relative wages in foreign without multinationals and more than relative wages in home without multinationals. Second, multinationals employ some assembly labor abroad. Employment in foreign subsidiaries of home-headquartered baseball firms rises from zero to 2.86 when multinationals emerge. Third, this ability to outsource assembly of baseballs lowers the international price of baseballs relative to food. The ability of

[29]Actually, at B' several multinational configurations are possible. Following Helpman (1984), I choose the configuration which involves the least amount of multinational activity. This choice can be justified as a long-run equilibrium of an adjustment process which involves a cost to shifting facilities abroad.

baseball firms headquartered in home to assemble their product in foreign with the cheaper foreign unskilled labor lowers the price of baseballs. Fourth, outsourcing creates a new tradable product: headquarters services. Home-based multinationals export intrafirm 6.67 units of services to their foreign subsidiaries.

This model formalizes the outsourcing arguments of globalists in a very simple way. Multinationals are vertically integrated, and they trade headquarter services intrafirm. The model can be expanded in a number of ways. Helpman and Krugman (1985) introduce intermediate inputs into baseball production. Factor-price differentials still induce outsourcing, but the new trade flows now include visible trade in intermediate inputs. Ethier and Horn (1990) introduce a convex administrative cost of controlling operations which is larger when the operation is located abroad. Firms contemplating foreign expansion must then trade off factor-price advantages against the cost of control, and both one-way and two-way multinational penetration is possible. Brainard (1993) introduces transportation costs in trade and both plant-level and firm-level economies of scale. In this framework multinationals can emerge even in the absence of factor-price differences (when firm-level scale economies are large and/or transportation costs are low relative to plant-level scale economies), and two-way multinational penetration is possible. All these models share the common feature that multinationals' desire to employ different factors in different countries can change the relative demand for labor within countries.

5 Empirical Evidence on Outsourcing

The model just presented can explain how outsourcing contributed to America's wage divergence. In a large number of industries, firms outsourced production-labor-intensive activities to foreign subsidiaries. Within these industries, relative demand shifted towards non-production labor. For manufacturing as a whole, these within-industry shifts led to both rising relative wages and rising relative employment for skilled labor. Figure 5 and the calculations by Berman, Bound, and Griliches are consistent with this story.

Very little empirical work has tried to assess the empirical relevance of this outsourcing story. Katz and Murphy (1992) comment that "Important sources of within-industry shifts [in labor demand] include factor non-neutral technological change, changes in prices of non-labor inputs (e.g., computer services), and 'outsourcing' (shifts of portions of industry production out of the United States)."[30] But they do not check the contribution of outsourcing to this shift.

Berman, Bound, and Griliches (1992) look for economy-wide evidence of outsourcing in the 1987 Census of Manufactures. In this census, a question asked each establishment to report what amount of materials it purchased from foreign sources. The total came to $104 billion: 8% of all materials purchased, and 30% of all imported manufactures. BBG note that only 7% of this $104 billion came originated from the same 3-digit industry as the establishment itself. They conclude from this small percentage that a negligible amount of outsourcing occurred. However, this conclusion assumes two things. First, it assumes that the output of outsourced activities must return to America; second, that this output must return as material for further processing. My model of outsourcing does not fit either of these assumptions. First, some of the baseballs assembled in foreign for home-owned multinationals might get consumed in foreign.

[30]Katz and Murphy, page 54.

These baseballs do embody outsourced unskilled labor, but Berman's methodology would miss counting them. Second, some of the baseballs which home imports from foreign do embody outsourced unskilled labor. However, because they return as a final good the Berman methodology would miss counting them. Because Berman, et al, look for evidence of only one particular manifestation of outsourcing, their conclusion that very little outsourcing occurred seems premature.

My method of looking for empirical evidence of outsourcing parallels my method of looking for evidence of the Stolper-Samuelson theorem. I first check the data for basic facts that are implied by outsourcing having occurred. If I do not find these facts in the data, I can conclude that widespread outsourcing did not contribute to America's wage divergence.

The model presented in the last section gives at least three empirical implications of outsourcing. Outsourcing creates new tradable goods; it lowers the relative price of the goods whose production involves outsourcing; and it generates employment abroad within subsidiaries of multinationals.

Neither trade nor terms-of-trade data offers a very good first pass at the extent of outsourcing. First, very disaggregated (i.e., 10-digit level) trade data does exist. In principle, "newly traded" goods can be identified: either as goods whose classification did not exist before 1979, or as goods whose trade increased from very low levels. However, I do not know of a method to distinguish increased trade flows caused by outsourcing from increased trade flows caused by other factors such as changed preferences. Second, terms-of-trade data might in principle help identify outsourcing industries: they should see their prices decline relative to non-outsourcing industries.

However, America's terms-of-trade data which I presented earlier are almost certainly too aggregated to yield any information about outsourcing. Even the three-digit SIC level most likely masks any relative-price movements generated by outsourcing.

In light of these problems, I look for evidence of outsourcing in data on multinational employment. All other things equal, outsourcing by American multinationals should appear in their subsidiaries showing rising employment levels of production labor.

Table 4 lists manufacturing employment by year to give an idea of the orders of magnitude involved. Between 1979 and 1982, production employment fell by 2.3 million. Thereafter, it stayed basically flat. Non-production employment was basically flat throughout the decade. The recession clearly contributed a lot to the '79-'82 drop in production employment. The question then becomes why production employment stayed flat during the seven-year expansion after 1982. If outsourcing was occurring, then some of the flatness was caused by rising production employment in foreign subsidiaries of multinationals.

To evaluate this hypothesis, I have assembled data on the employment between 1977 and 1989 of foreign subsidiaries of American multinationals. These data come from the Bureau of Economic Analysis (BEA). Through legally mandated annual surveys, the BEA tracks the activity of foreign affiliates of American persons. A person is defined broadly as an individual or a group such as a trust, corporation, or partnership. A foreign affiliate is defined as a foreign business enterprise in which there exists American foreign direct investment (FDI). In turn, FDI is defined as direct or indirect ownership or control by a single US person of at least 10% of either the voting securities of an incorporated foreign business enterprise or an equivalent interest in an unincorporated foreign business enterprise.

In 1977, 1982, and 1989 the BEA surveyed every subsidiary of every American multinational. In these three benchmark surveys, the BEA had subsidiaries report their employment mix between non-production and production workers. Unfortunately, in the survey years of 1983-1988 the BEA did not ask for this employment breakdown. So I have data on multinationals' employment mix which more than spans the 1980's. The question then becomes whether I should use 1977 or 1982 as the start of the decade. As explained in the Stolper-Samuelson section, defining the 1980's as running from 1979 to 1989 makes sense because 1979 and 1989 were both peaks of the business cycle. Using the criterion of picking which year was closest to the 1979 peak, I choose 1977 because 1982 was the trough of a severe worldwide recession. The data support this choice. In Figures 1 and 2, manufacturing relative wages and relative employment in 1977 and 1979 are nearly identical. Thus for the multinational data, I span the 1980's using 1977 and 1989.

The BEA covers 32 major industries in manufacturing.[31] Some are 3-digit SIC industries; others are the sum of several 3-digit industries; and still others are one or even two 2-digit SIC industries. I construct data for these 32 industries in America by aggregating up from the 4-digit SIC level. Together, they constitute about 80% of

[31]The BEA classifies at the enterprise level, not the establishment level like the ASM. This does pose a problem for comparing the two data sets by industry, as I do in what follows. I cannot do anything about this difference, other than assume that relatively few establishments are owned by enterprises whose industry classification differs from that of the establishments. The introduction to the 1989 Benchmark Survey supports this assumption when it writes that "the bias is not too bad, primarily because [foreign] affiliates are much less diversified than their U.S. parents."

American manufacturing in terms of sales and employment. Figure 12 plots the relative employment and wage developments in these industries in America between 1977 and 1989. As in figure 5, the majority of the industries in Figure 12 display both rising relative employment and rising relative wages of skilled labor. Weighted by 1977 employment, the 32 industries together experienced an average rise in the ratio of non-production to production labor employed of 18.4%.

The BEA also reports data by country. Unfortunately, to prevent disclosure of individual firms' activities, it does not publicly reveal data grouped both by industry and by country except at very high levels of aggregation. Therefore, the BEA reports subsidiary employment in two ways: within countries across industries, and within industries across countries. Table 5 lists production-employment levels within countries for majority-owned non-bank affiliates; Table 6 within industries for the same group of affiliates.[32]

All other things equal, outsourcing should manifest itself in rising employment levels of production labor. Tables 5 and 6 do not display this rise, however. The first four columns of Table 5 show a worldwide *loss* of 495,300 production workers between 1977 and 1989. The loss is spread across almost all major groups of countries: Europe (-370,700), Central and South America excluding Mexico (-75,300), and South-East Asia (-6,100). Within these groups, only five countries employed more production workers

[32]Unfortunately, the BEA reports these data only for majority-owned non-bank affiliates. The numbers therefore miss affiliates whose foreign stake lies between 10% and 50%. However, data from majority-owned affiliates do constitute approximately 75% of total affiliate data for variables such as total employment and sales. Moreover, I have no reason to believe that non-majority-owned affiliates had markedly different employment patterns. For these two reasons, I assume that the numbers in these tables accurately reflect the employment patterns of all affiliates.

in 1989: Mexico (+80,900), Malaysia (+15,600), Singapore (+10,400), South Korea (+3,900), and Thailand (+11,700). The first four columns of Table 6 show that this cross-country decline was spread across almost all industries. 22 of the 32 industries employed fewer production workers in 1989 than in 1977. Weighting each industry by its 1977 production employment, I find that overall subsidiary employment of production workers fell by 21.2%.

These data on production levels do not control for industry scale. Employment levels--both production and non-production--in an industry might rise or fall simply as the industry grows or contracts worldwide. As a rough control for the overall size of industries, I calculate ratios of non-production to production employment. Insofar as industry rescaling changes employment of both labor types in the same percentage, this ratio is constant across scale. However, outsourcing should lower it as production employment rises. Thus, I have a second implication of outsourcing to look for in the data: falling ratios of non-production to production employment.

The last three columns of Tables 5 and 6 do not display this implication. Instead, they show rising employment ratios both within countries and within industries for majority-owned non-bank affiliates. Within countries, only Mexico's ratio declined; the worldwide ratio rose 23.6%. Within industries, 26 of 32 industries had rising ratios. Weighted by industry employment in 1977, the overall subsidiary ratio rose 23.3%.

It is worth reemphasizing that the data in Tables 5 and 6 present stocks of employees at various points in time, and that outsourcing is only one flow that may have contributed to these stocks. Given this caveat, however, the data are still strongly inconsistent with outsourcing having been a widespread phenomenon in America in the

1980's. Outsourcing should manifest itself in rising production-worker employment in American subsidiaries, or at least in a falling ratio of non-production to production employment. The data do not display either of these trends. Instead, across the majority of countries and industries they display falling levels of production employment and rising ratios of non-production to production employment. Indeed, these two facts from the data mirror the trends seen in America. The similarity between employment trends in subsidiaries and in America is consistent with the same force(s) operating worldwide--for example, skill-biased technological change.

This is not to say that outsourcing did not occur in America in the 1980's. Five countries did experience rises in subsidiary employment levels. And three industries experienced both rising employment levels and falling relative employment ratios: tobacco products (SIC code 21; +4,000 and -15.7%), other chemical products (SIC codes 285, 288, and 289; +10,900 and -25.4%), and computers and office equipment (SIC code 357; +37,400 and -27.4%). The changes in these three industries are consistent with outsourcing having occurred in them in America.[33] Moreover, the changes in production employment constitute non-negligible percentages of production employment in these industries in America in 1979: 8.6% in tobacco, 13.9% in other chemicals, and 21.7% in computers.

However, the magnitudes involved in these groups are very small compared with the 2.3 million production jobs lost in America. Except for Mexico and computers, no country or industry gained more than 20,000 production employees. The magnitudes

[33]A good deal of anecdotal evidence indicates that the computer industry outsourced heavily in the 1980's. The fact that my approach finds both rising employment levels and falling employment ratios for this industry is support that my approach is looking at the right numbers.

appear even smaller when productivity differentials are factored in. Insofar as facilities are more production-labor intensive and/or technologically advanced in subsidiaries, a production worker in a subsidiary is probably less productive than his/her counterpart in the United States. Thus, even if all 81,400 production employees gained in Mexico came from outsourcing, fewer than 81,400 production jobs were probably lost in the United States in the process. Similarly, the 52,300 production jobs gained in the three industries which most likely outsourced probably cost far fewer than 52,300 American production jobs.

Taking together the employment levels, employment ratios, and productivity considerations, I conclude that outsourcing contributed basically nothing to America's wage divergence in the 1980's. Only three of 32 industries seem to have outsourced to any noticeable degree.

In fact, the data make one question whether the outsourcing story accurately represents the majority of American multinational activity. On balance, do American multinationals substitute foreign production labor for home production labor? The outsourcing model says that they do. But other models (such as Ethier and Horn (1990)) say that home and foreign production labor can complement each other: activity abroad can stimulate activity at home and thereby dominate any outsourcing effect.

To test whether multinationals tend to substitute between home and foreign production labor, I have estimated price elasticities of demand for these two factors by estimating the cost functions of American multinationals. Hammermesh (1993) defines the partial price elasticity of demand for factor i with respect to factor j as

(26) $$\eta_{ij} \equiv \partial \ln X_i / \partial \ln w_j,$$

where X_i is the employment level of factor i and w_j is the price of factor j. This elasticity holds constant both output and all other factor prices, and it tells how employment of factor i responds to changes in factor j. Factors i and j are defined as price substitutes when $\eta_{ij} > 0$, and as price complements when $\eta_{ij} < 0$. I formalize the outsourcing hypothesis as follows: outsourcing says that home and foreign production labor are price substitutes for American multinationals.

(27) H_o: $\eta_{hf} \equiv \partial \ln X_h / \partial \ln w_f > 0$ and $\eta_{fh} \equiv \partial \ln X_f / \partial \ln w_h > 0$

Here, h denotes home production labor and f foreign production labor. This hypothesis says that when foreign (home) production wages fall, American multinationals lower home (foreign) production employment as they substitute production into the now-cheaper foreign (home) country. The alternative hypothesis is that these two factors are price complements.

To test the null hypothesis, I have assembled a panel of 32 multinational industries across 9 years. Each multinational industry covers one of the 32 industries defined by the BEA, and it consists of activity in America combined with activity in subsidiaries of American multinationals. The BEA data cover 9 years: 1977, and 1982-1989. As mentioned earlier, the surveys from 1983-1988 report only total employment in subsidiaries. To maximize the number of observations, I use the data from these survey years by reformulating the outsourcing hypothesis in terms of home and foreign labor overall. Thus, in (27) h now denotes home labor overall and f foreign labor overall. If I do not aggregate labor in this way, I am left with only three years of observations--potentially too few to generate meaningful results.[34]

With this panel, I have estimated cost-share equations of a translog cost function. Following Hamermesh (1993), I choose cost functions rather than production functions. Hamermesh emphasizes that the more disaggregated the units of observation, the more reasonable the assumption that prices are exogenously given and that quantities are chosen. At my level of disaggregation, nearly all papers on production behavior work with cost functions rather than production functions.[35] The translog cost function can be thought of as a second-order Taylor's series approximation in logarithms to an arbitrary cost function. I choose this specification because it does not impose any restrictions on the pairwise elasticities of substitution, and thus on the implied pairwise elasticities of demand. In contrast, a Cobb-Douglas specification restricts all pairwise elasticities of substitution to equal one, and a CES specification restricts all of them to equal some constant (not necessarily one).

The translog cost function can be written as follows.

$$\text{(28)} \qquad \ln C_{at} = \alpha_o + \sum \alpha_i \ln P_{iat} + \tfrac{1}{2} \sum_i \sum_j \beta_{ij} \ln P_{iat} \ln P_{jat} + \alpha_y \ln Y_{at} + \tfrac{1}{2}\beta_{yy}(\ln Y_{at})^2 + \sum_i \beta_{iy} \ln P_{iat} \ln Y_{at}$$

Here, C_{at} is total cost in industry a at time t, P_{iat} is the price of factor i in industry a at time t, and Y_{at} is output in industry a at time t. The symmetry of this function implies the following restrictions: $\beta_{ij} = \beta_{ji} \ \forall \ (i,j)$. Log-differentiating this function with respect

[34]Currently, I am estimating cost functions using just these three years and the finer disaggregation of labor to see if the results corroborate the ones presented here.

[35]To ensure no misspecification due to simultaneity between prices and quantities of factors, I could estimate both as a simultaneously determined system. I may do this in the future; however, at this point I am simply following the precedent in the literature.

to factor prices and invoking Shephard's lemma generates the following cost-share equations.

(29) $$S_{iat} = \alpha_i + \sum_j \beta_{ij} \ln P_{jat} + \beta_{iy} \ln Y_{at}$$

Here, S_{iat} is the share of factor i in total cost for industry a at time t, with $S_{iat} \in (0,1)$. Estimating (29) as a system of equations with the symmetry restrictions imposed across equations yields greater efficiency than estimating (28) alone. However, this system must omit one factor's cost-share equations: since the sum of all cost shares for an observation (industry-time unit) sum to one, only (n-1) share equations in a system with n factors are linearly independent. After estimating this system, estimates of the β_{ij}'s can be transformed into estimates of the η_{ij}'s with the following formula.

(30) $$\eta_{ij} = (\beta_{ij} + S_i S_j)/S_j$$

Here, S_i is the cost share of factor i averaged across all observations. Unfortunately, because the η_{ij}'s are a non-linear transformation of the β_{ij}'s, standard errors for the η_{ij}'s are nearly impossible to calculate. In what follows, I report standard errors for only the β_{ij}'s.

I specify (28) with three factors of production: capital, foreign labor, and home labor. I aggregate home and foreign captial into one factor because I have only one cost-of-capital series. Foreign wage, employment, captial stock, and output data come from the BEA. Home wage, employment, capital stock, and output data come from the NBER. The cost-of-capital series comes from Yolanda Kodzrycki at the Federal Reserve Bank of Boston; it uses a standard Hall-Jorgensen framework to calculate the annual cost-of-capital for American industries. The BEA does not track data on energy and materials used by subsidiaries, so I cannot include these factors. As a result, I measure output as value-added rather than value of shipments. I estimated the system of equations in (29) three times, each time dropping a different factor. As expected, the results do not depend on which factor is dropped. To control for the cross-industry variation in cost structure, I also included industry dummies in my specification.

Table 7 presents the results. My specification appears to be well-behaved. It retains the restrictions necessary for the cost function to be homogeneous of degree one in factor prices[36]; all the estimated own-price elasticities of demand are negative; and all but one parameter estimate is significant at the 95% level. The first two lines of Table 7 show estimates of η_{hf} and η_{fh} which are negative, not positive: -.092 and -.448, respectively. Negative elasticities reject the null hypothesis, and imply that home and foreign labor are price complements, not price substitutes. For example, η_{hf} = -.092 indicates that a 1% drop in foreign wages tends to *raise* home employment by nearly 0.1%. This price complementarity between home and foreign labor is further evidence that outsourcing was not the predominant form of American multinational activity in the 1980's.

6 Conclusion

Existing empirical work has determined that the primary cause of America's wage divergence in the 1980's was a shift in the relative-labor-demand mix away from the unskilled and toward the skilled. However, this work has not adequately addressed the hypothesis that the "internationalization" of the American economy contributed to this shift. This paper has tried to do so by assessing the role of both international trade and multinational outsourcing. International-economics theory says that in theory, both trade

[36]These restrictions are that $\sum \alpha_i = 0$; $\sum_j \beta_{ij} = 0$ for every i; and $\sum_i \beta_{iy} = 0$.

and outsourcing could have contributed to the labor-demand shift. But the data say that in fact, they did not. The international prices of skilled-labor-intensive products did not rise relative to those of unskilled-labor-intensive products, and only three of 32 industries experienced both rising production-employment levels and falling relative employment in foreign subsidiaries of American multinationals. Thus, I conclude that neither international trade through the Stolper-Samuelson process nor outsourcing by multinationals contributed significantly to America's labor-demand shift and resulting relative-wage divergence. This finding does not imply that international-economic theory needs improving. It simply means that the international economy was not driving America's wage divergence in the 1980's, and therefore that the primary causes lay in the domestic side of the economy.

Appendix A: Identifying the Skill Level of Workers

Identifying the skill level of workers is a recurring problem in empirical work. A worker's skill level probably grows with some combination of her education, her on-the-job training, and her work experience. Pinpointing her skill level clearly requires a broad range of data. Unfortunately, most data sets do not contain such breadth. Instead, many distinguish workers based on job classification. For example, the ASM distinguishes non-production from production labor. Similarly, the Current Population Survey distinguishes white-collar workers from blue-collar workers. In each case, the first group usually gets called "skilled."

The obvious concern with these occupational distinctions is that they misclassify too many workers. Consider these two workers: an experienced machine-tool technician with a bachelor's degree in computer science who programs the computers driving these tools, and a recent high-school dropout who files reports and runs mail. If they both work for a manufacturing firm, the non-production/production distinction will classify the technician as unskilled and the office runner as skilled. Clearly, this seems wrong. The worry is that such misclassifications are the rule rather than the exception, i.e., that using either the ASM or the CPS classification to identify skill levels misplaces an unacceptably high number of people.

Berman, Bound, and Griliches (1992) convincingly argue that these methods probably classify most people correctly. They do this by establishing two facts. First, they show that the ASM distinction closely matches the CPS distinction. For the years 1973, 1979, and 1987, the percentage of workers classified as non-production by the ASM is never more than two percentage points away from the percentage of workers classified as white-collar by the CPS. Second, with the educational-attainment data in the CPS they show that white-collar workers average more years of education than blue-collar workers. In 1987, nearly 70% of white-collar workers had some college education, versus only 17% for blue-collar workers. Similarly, less than 5% of white-collar workers had less than a high-school education, versus 30% of blue-collar workers.

Assuming that these two facts were representative of the 1980's as a whole, Berman et al conclude from them that "the relationship between education and occupation is quite tight." Insofar as the more-educated are more skilled, it follows that occupational distinctions do correctly classify most workers' skill levels. In my work in this paper I make this final assumption, and assume that the non-production/production distinction reasonably separates workers across skills.

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Table 1: SIC Numbers, Descriptions, and Skill-Intensity at the 2-Digit Level

SIC Code	Description	(sk/usk) 1979
20	food and kindred products	.41
21	tobacco products	.25
22	textile mill products	.16
23	apparel products	.16
24	lumber and wood products	.20
25	furniture and fixtures	.23
26	paper and allied products	.31
27	printing and publishing	.76
28	chemicals & allied products	.67
29	petroleum refining	.49
30	rubber and plastic products	.29
31	leather products	.16
32	stone, clay, and glass prods	.28
33	primary metal industries	.28
34	fabricated metal products	.32
35	industrial machinery	.51
36	electronic equipment ex computers	.51
37	transportation equipment	.46
38	measuring & controlling equipment	.66
39	miscellaneous industries	.33

Notes: Skill-intensity of each industry is defined as the ratio of non-production to production workers employed in the industry in 1979.

Sources: Data comes from the NBER's Trade and Immigration Data Base

Table 2: Employment-Weighted Percentage Changes in International Prices

Percentage Change, 1980-1989	Non-Production Weights	Production Weights	Difference Between Non-Prod and Prod
International Prices of U.S. Imports	26.0	28.1	-2.1
International Prices of U.S. Exports	26.3	30.0	-3.7

Notes: Non-production weights weigh each industry's price by that industry's share of total manufacturing employment of non-production labor in 1980. Production weights weigh each industry's price by that industry's share of total manufacturing employment of production labor in 1980. All industries are defined at the 3-digit SIC level.

Sources: Employment data comes from the NBER's Trade and Immigration Data Base and Wayne Gray. Price data comes from the Bureau of Labor Statistics.

Table 3: Equilibrium Values With and Without Multinationals

Endogenous Variable	Without Multinationals	With Multinationals
w_{sh}^*	1.69	1.29
w_{uh}^*	5.06	1.00
(w_{sh}^*/w_{uh}^*)	0.33	1.29
w_{sf}^*	2.89	1.29
w_{uf}^*	1.00	1.00
(w_{sf}^*/w_{uf}^*)	2.89	1.29
P^*	3.89	2.12
U_{fh}^*	0.00	2.86
Exports of HQ	0.00	6.67

Notes: These values come from a numeric simulation of the outsourcing model presented in Section 4. The model solves for an endowment such as point B in Figure 11 both without and with multinationals. $U_{fh}^* \equiv$ Unskilled labor located in foreign employed by home-headquartered multinationals.

Table 4: Manufacturing Employment in the 1980's

Year	Production Workers	Non-Production Workers	Non-Prod/Prod Ratio
1979	14,533,600	5,216,500	.359
1980	13,889,000	5,411,400	.390
1981	13,536,800	5,380,500	.397
1982	12,403,000	5,425,600	.437
1983	12,203,000	5,262,000	.431
1984	12,580,800	5,290,600	.421
1985	12,170,700	5,332,000	.438
1986	11,765,100	5,321,300	.452
1987	12,253,700	5,461,400	.456
1988	12,416,900	5,550,600	.443
1989	12,356,200	5,438,100	.440

Sources: These data come from the NBER's Trade and Immigration Data Base and Wayne Gray.

Table 5: Employment by Country of Foreign Subsidiaries of United States Multinationals

Country	1977 Prod Employees	1989 Prod Employees	Level Change	1977 (NP/P)	1989 (NP/P)	Percent Change
World	2370.7	1875.4	-495.3	.59	.73	+23.6
Europe	1201.8	831.1	-370.7	.62	.81	+30.0
Canada	358.2	271.2	-77.0	.57	.66	+16.5
Mexico	103.1	184.0	+80.9	.66	.59	-11.1
Other Am	344.3	269.0	-75.3	.57	.67	+19.0
SE Asia	203.0	196.9	-6.1	.34	.54	+57.9
Hkong	24.1	23.1	-1.0	.21	.40	+88.2
India	19.3	3.5	-15.8	.77	1.83	+136.9
Indonesia	8.4	3.8	-4.6	.42	.74	+76.8
Malaysia	19.0	34.6	+15.6	.35	.47	+32.8
Philipp	44.7	36.5	-8.2	.37	.47	+28.4
Singapore	27.4	37.8	+10.4	.19	.53	+184.3
S Korea	9.8	13.7	+3.9	.20	.58	+182.6
Taiwan	45.3	27.2	-18.1	.29	.62	+116.5
Thailand	5.0	16.7	+11.7	.58	.60	+3.2

Notes: These data are for majority-owned non-bank affiliates of US-owned multinationals. The data for production employees are in thousands of employees. (NP/P) is the ratio of employment of non-production to production workers. "Other Am" consists of all Central- and South-American countries other than Mexico. "SE Asia" consists of all South-East Asian countries listed below its line in the table.

Sources: These data come from the Bureau of Economic Analysis.

Table 6: Employment by Industry of Foreign Subsidiaries of United States Multinationals

Industry (SIC #)	1977 Prod Employees	1989 Prod Employees	Level Change	1977 (NP/P)	1989 (NP/P)	Percent Change
204+	48.5	45.8	-2.7	.54	.59	+9.9
208	23.5	15.7	-7.8	.99	1.16	+16.9
206+	176.3	122.4	-53.9	.45	.64	+41.7
281+	85.6	65.6	-20.0	.71	1.05	+47.4
283	73.3	65.6	-7.7	1.14	1.33	+16.3
284	47.7	54.5	+6.8	1.25	1.28	+2.8
287	8.1	4.8	-3.3	.80	.96	+19.4
285+	18.5	29.4	+10.9	1.11	.83	-25.4
331+	21.3	5.9	-15.4	1.85	.49	-73.4
333+	21.7	17.8	-3.9	.29	.40	+35.2
34	115.0	93.0	-22.0	.46	.56	+21.1
352	31.2	17.1	-14.1	.62	.53	-14.9
353	75.2	34.8	-40.4	.66	1.02	+56.0
357	65.4	102.8	+37.4	1.90	1.38	-27.4
359	98.8	99.5	+0.7	.60	.67	+11.8
363	58.5	50.1	-8.4	.63	.51	-20.1

Notes and Sources: See bottom of next page.

Table 6 (Continued): Employment by Industry of Foreign Subsidiaries of United States Multinationals

Industry (SIC #)	1977 Prod Employees	1989 Prod Employees	Level Change	1977 (NP/P)	1989 (NP/P)	Percent Change
365+	147.5	22.7	-124.8	.54	.67	+22.5
367	135.2	155.8	+20.6	.37	.54	+46.7
361+	80.5	58.9	-21.6	.50	.73	+45.5
371	494.6	346.4	-148.2	.45	.62	+37.4
372+	12.5	19.0	+6.5	.70	.80	+13.6
21	22.5	26.5	+4.0	.63	.53	-15.7
22 + 23	80.3	58.5	-21.8	.26	.40	+50.2
24 + 25	29.9	27.2	-2.7	.32	.36	+11.1
261+	68.6	81.5	+12.9	.44	.58	+31.3
27	13.9	16.5	+2.6	.96	.96	+0.0
301+	82.3	52.2	-30.1	.76	.79	+2.8
308	20.0	28.6	+8.6	.40	.55	+39.0
321+	27.2	21.4	-5.8	.36	.37	+2.5
324+	41.0	23.6	-17.4	.43	.52	+21.1
38	86.9	76.2	-10.7	.79	1.10	+40.6
39	59.2	28.1	-31.1	.39	.57	+46.8

Notes: These data are for majority-owned non-bank affiliates of US-owned multinationals. The data for production employees are in thousands of employees. (NP/P) is the ratio of employment of non-production to production workers. A "+" after an industry's 3-digit SIC code indicates that additional 3-digit SIC industries within that industry's 2-digit SIC code help comprise it.

Sources: These data come from the Bureau of Economic Analysis.

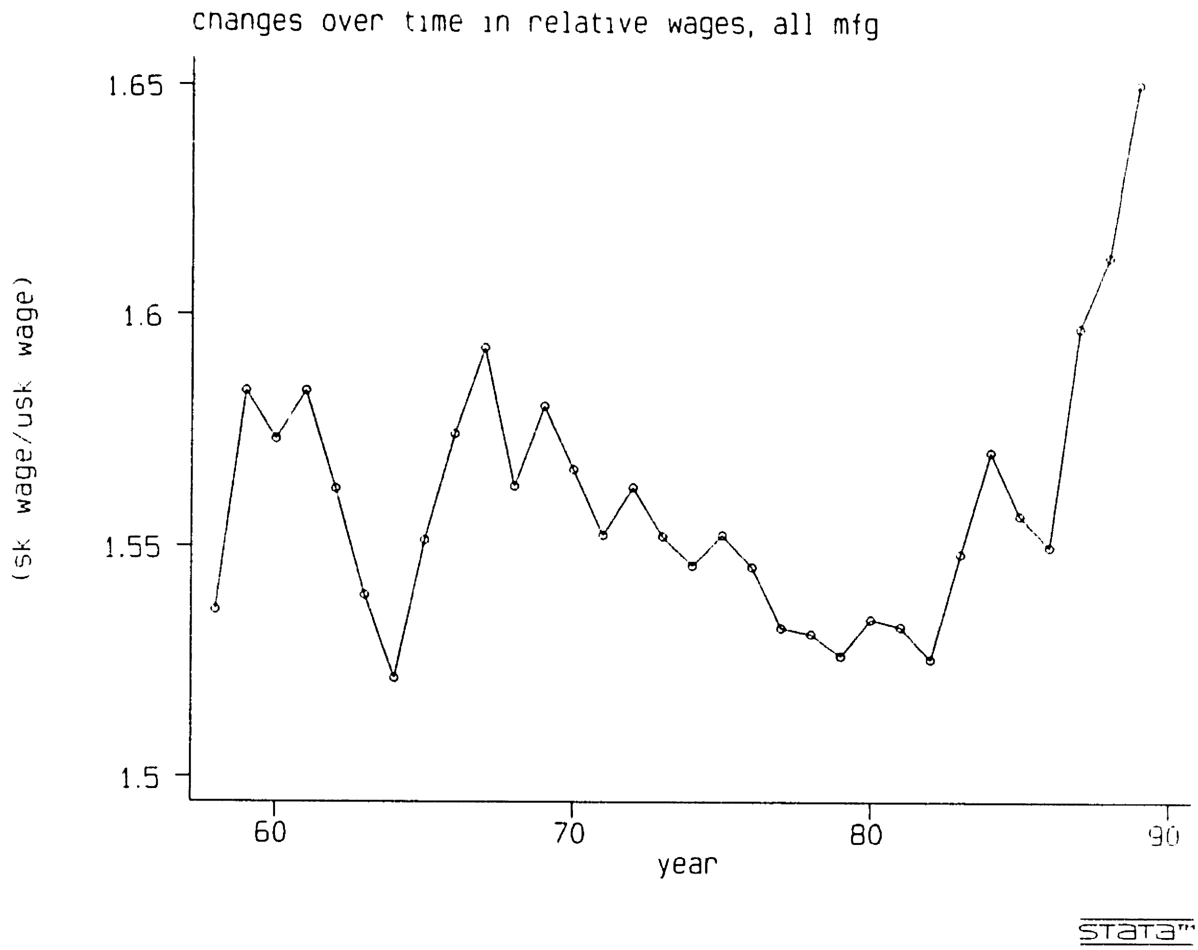
Table 7: Results of Estimating a Translog Cost Function For American Multinationals

Regression Parameter	Parameter Estimate	Standard Error	Implied Elasticity	Elasticity Estimate
$\beta_{hf} = \beta_{fh}$	-.060	.017	η_{hf}	-.092
			η_{fh}	-.448
$\beta_{hr} = \beta_{rh}$	-.104	.027	η_{hr}	.058
			η_{rh}	.171
$\beta_{fr} = \beta_{rf}$	-.037	.027	η_{fr}	-.063
			η_{rf}	-.036
β_{hh}	.103	.017	η_{hh}	-.190
β_{ff}	.060	.007	η_{ff}	-.489
β_{rr}	.141	.021	η_{rr}	-.249

Notes: These results are for fitting a translog cost function to a panel of 32 American multinationals over 9 years.
The specification contains 3 factors of production: capital, foreign labor, and home labor.
The specification also contains industry dummies.
Estimation was done on the system of cost-share equations with the cross-equation symmetry restrictions imposed.

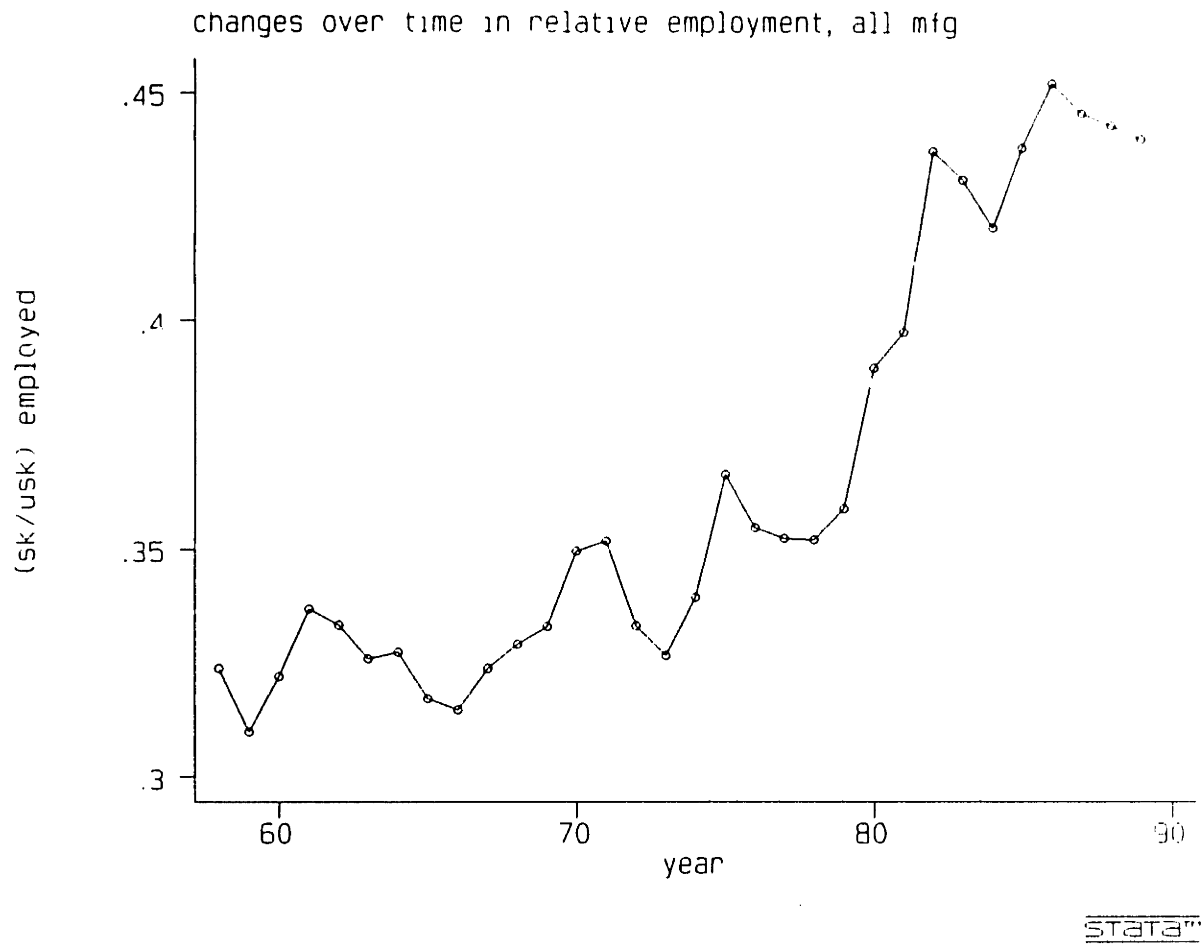
Sources: Subsidiary wage, employment, captial stock, and output data come from BEA.
Home wage, employment, capital stock, and output data come from the NBER.
The cost-of-capital series comes from Yolanda Kodzrycki at the Federal Reserve Bank of Boston.

Figure 1: Evolution of Non-Production Versus Production Wages In Manufacturing



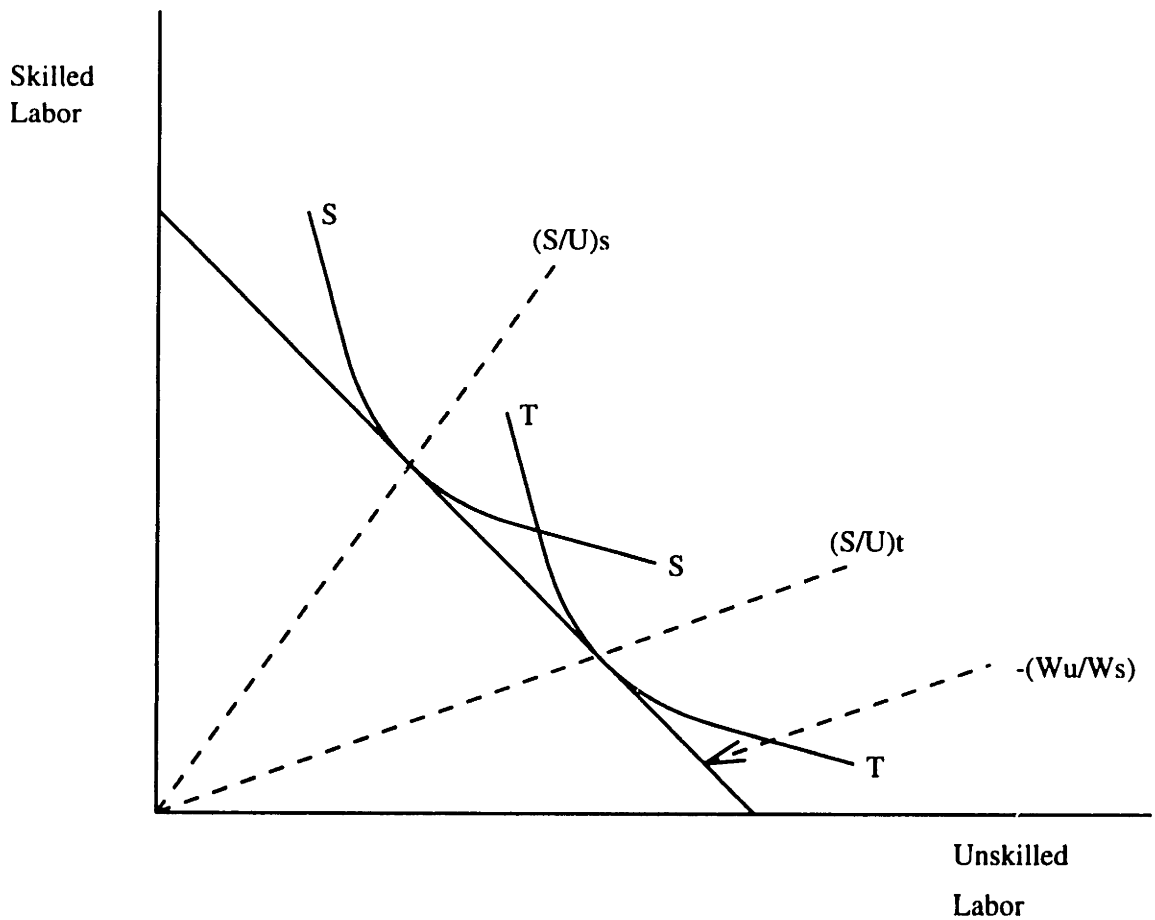
Sources: Wage data comes from the NBER's Trade and Immigration Data Base.
Average wage of non-production workers is "sk wage."
Average wage of production workers is "usk wage."

Figure 2: Evolution of Non-Production Versus Production Employment In Manufacturing



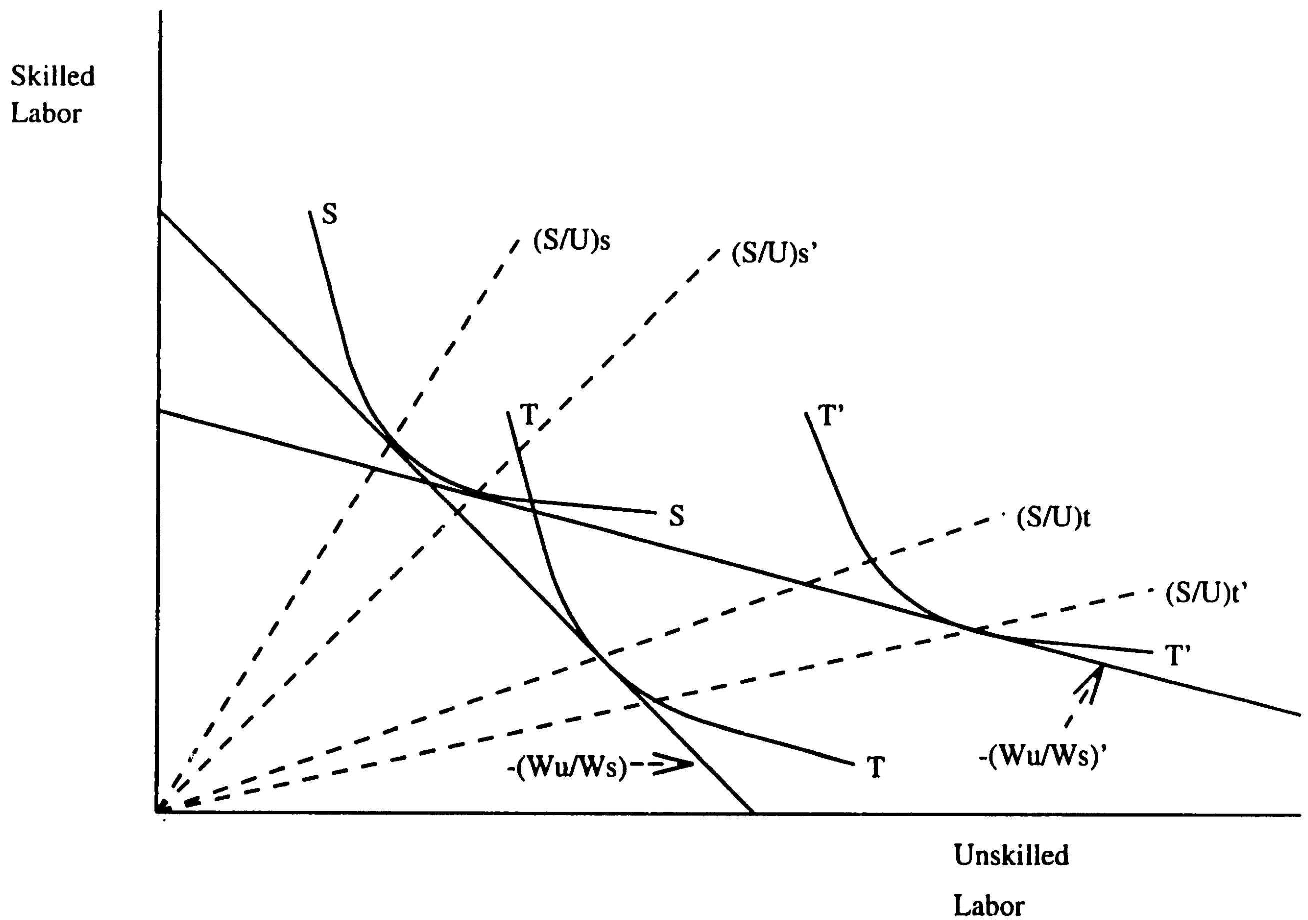
Sources: Employment data comes from the NBER's Trade and Immigration Data Base. Vertical axis plots the ratio of non-production to production labor employed in all manufacturing industries taken together.

Figure 3: Initial Equilibrium of a Small Open Economy



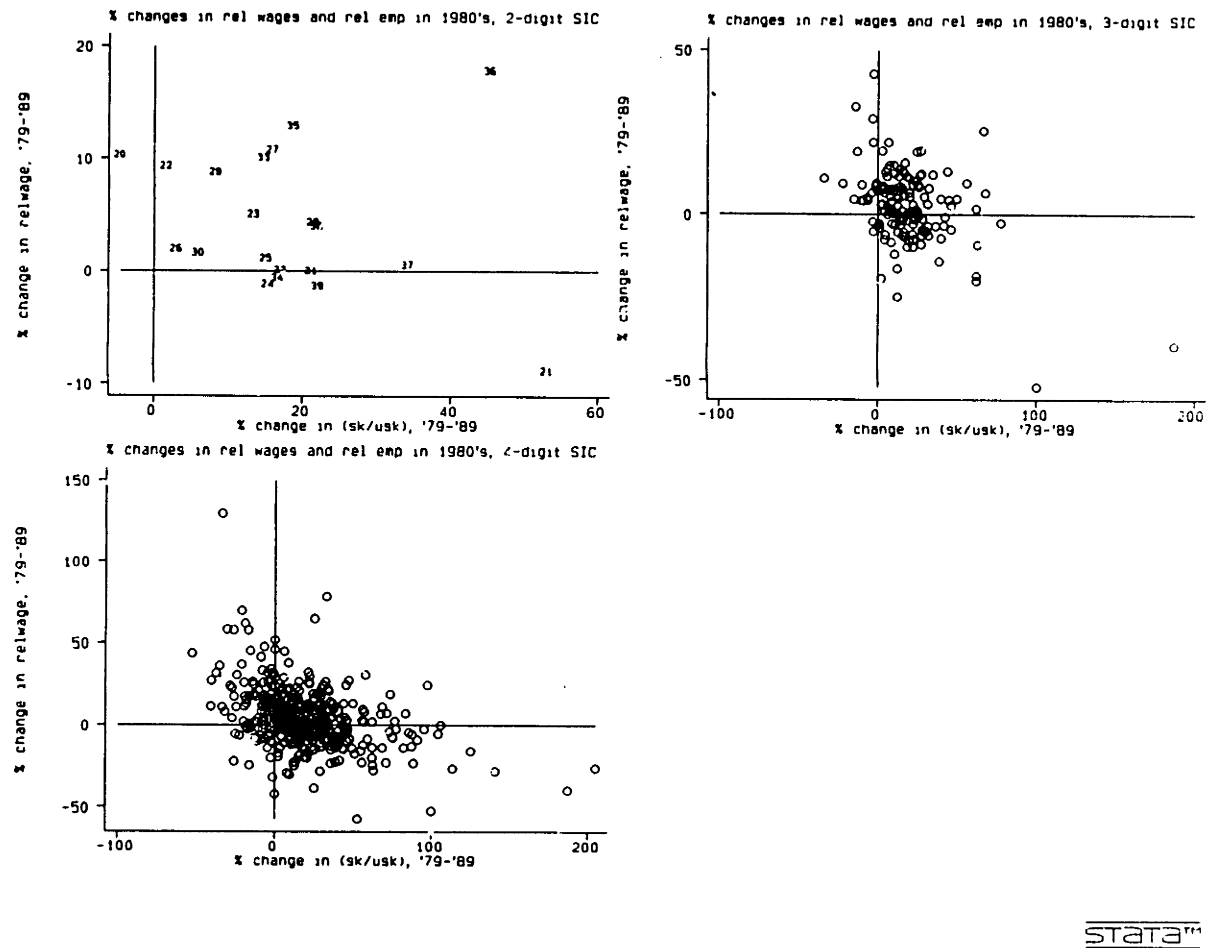
SS and TT are the initial unit-value production isoquants of software and textiles, respectively.
-(Wu/Ws) is the negative of the economy's initial relative-wage ratio.
(S/U)s and (S/U)t are the initial ratios of skilled to unskilled labor
employed in software and textiles, respectively.

Figure 4: New Equilibrium of a Small Open Economy



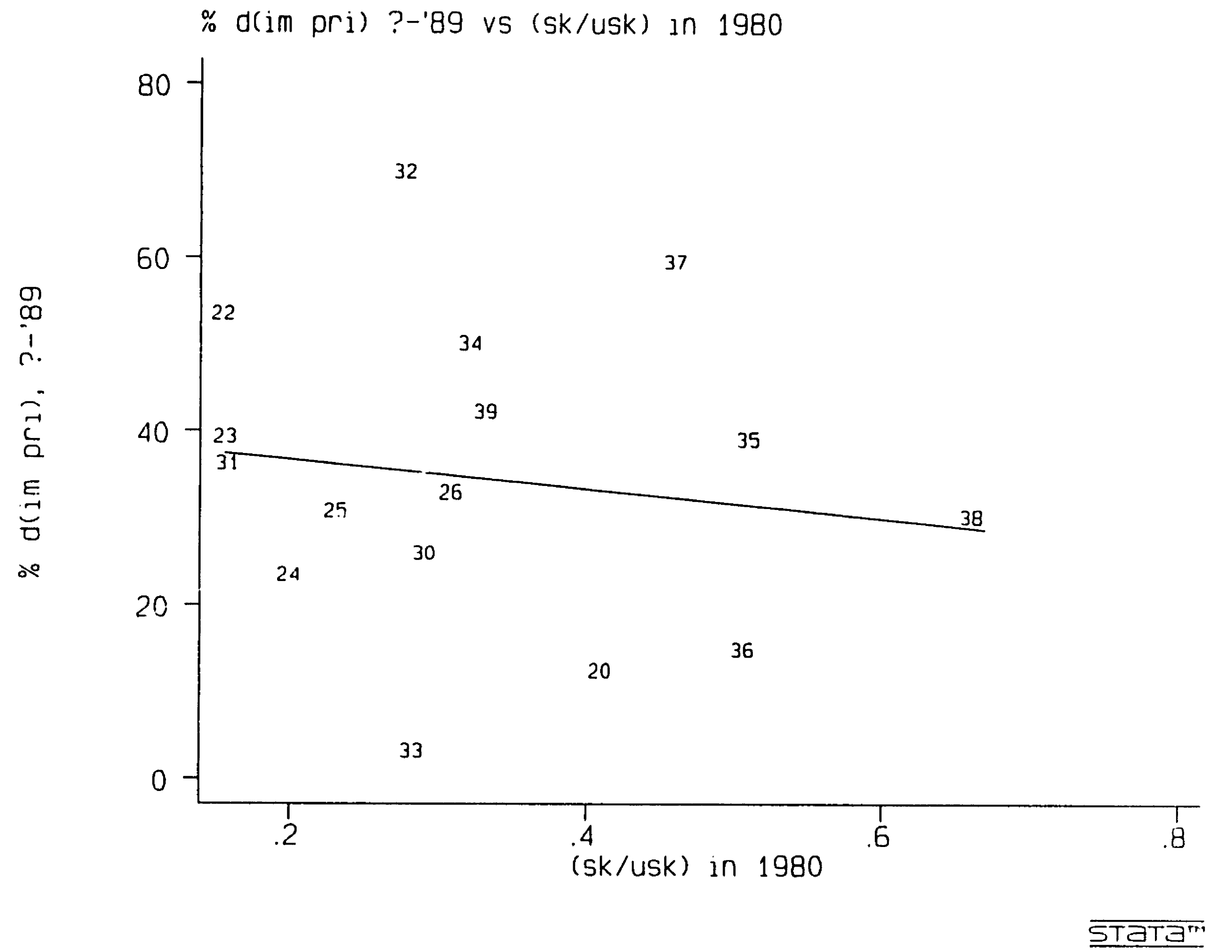
The international price of software has risen.
This is represented by an outward shift in the textile unit-value production isoquant.
Software output increases, and textile output shrinks.
-(Wu/Ws)' is the negative of the economy's new relative-wage ratio:
the wage of skilled labor has risen relative to unskilled labor.
(S/U)s' and (S/U)t' are the new ratios of skilled to unskilled labor
employed in software and textiles, respectively.

Figure 5: Percentage Changes in the 1980's in the Relative Wages and Relative Employment of Non-Production and Production Labor in Manufacturing



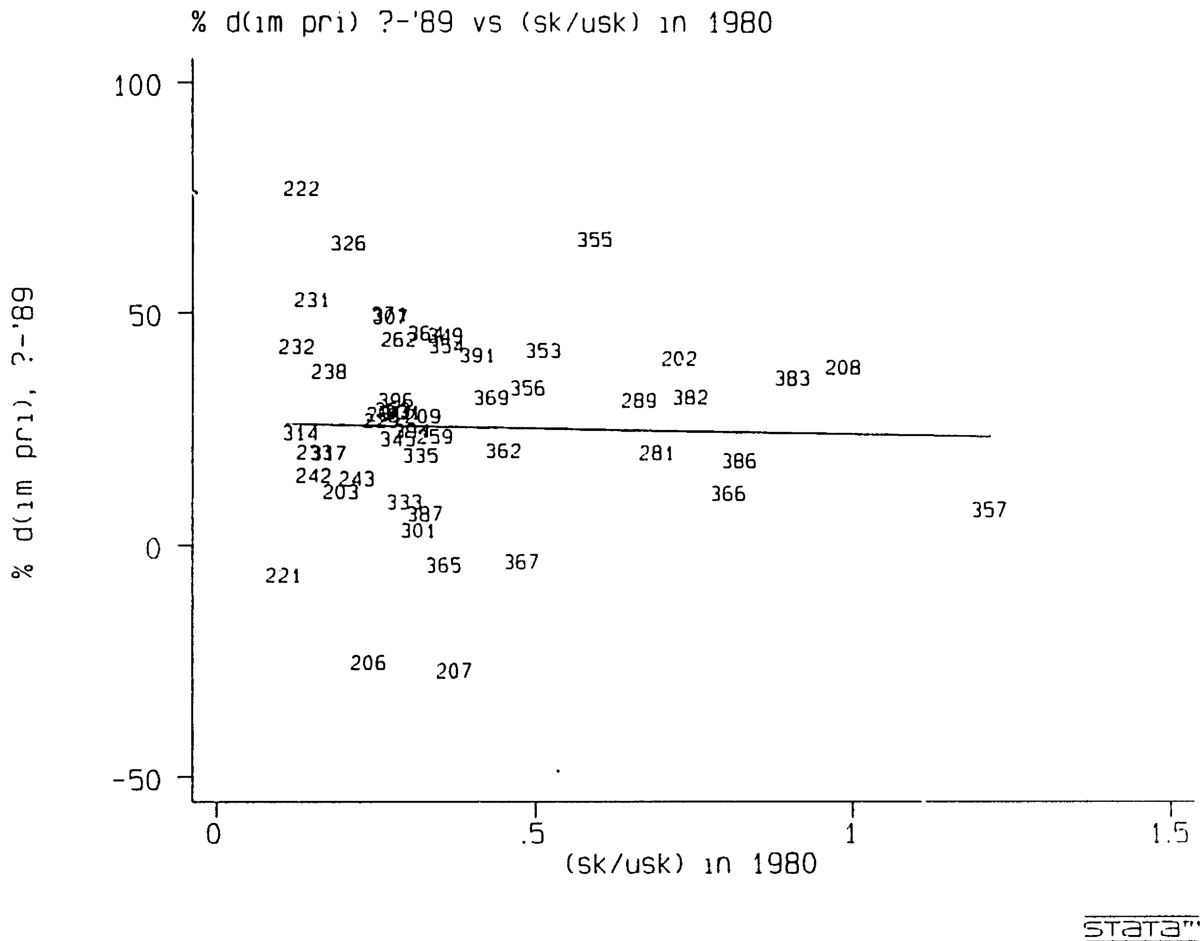
Sources: Employment and wage data come from the NBER's Trade and Immigration Data Base. In each graph, the vertical axis measures the percentage change in each industry's ratio of non-production wages to production wages. The horizontal axis measures the percentage change in each industry's ratio of non-production to production workers employed. Each graph defines an industry at a different level of SIC disaggregation.

Figure 6: Percentage Changes in the 1980's of Import Prices by Industry Versus the Non-Production-Worker Intensity of Industries



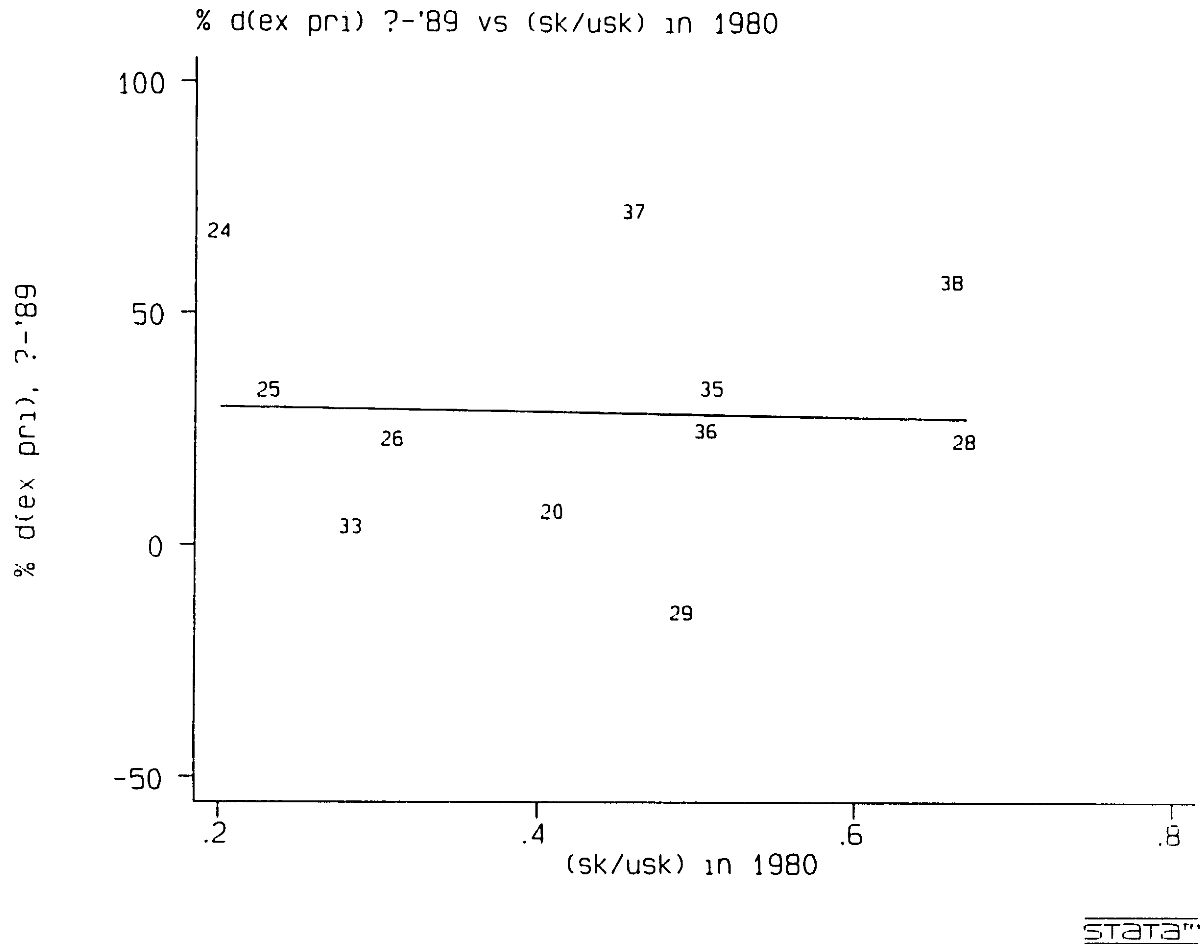
Sources: Import prices come from the Bureau of Labor Statistics;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 2-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure 7: Percentage Changes in the 1980's of Import Prices by Industry Versus the Non-Production-Worker Intensity of Industries



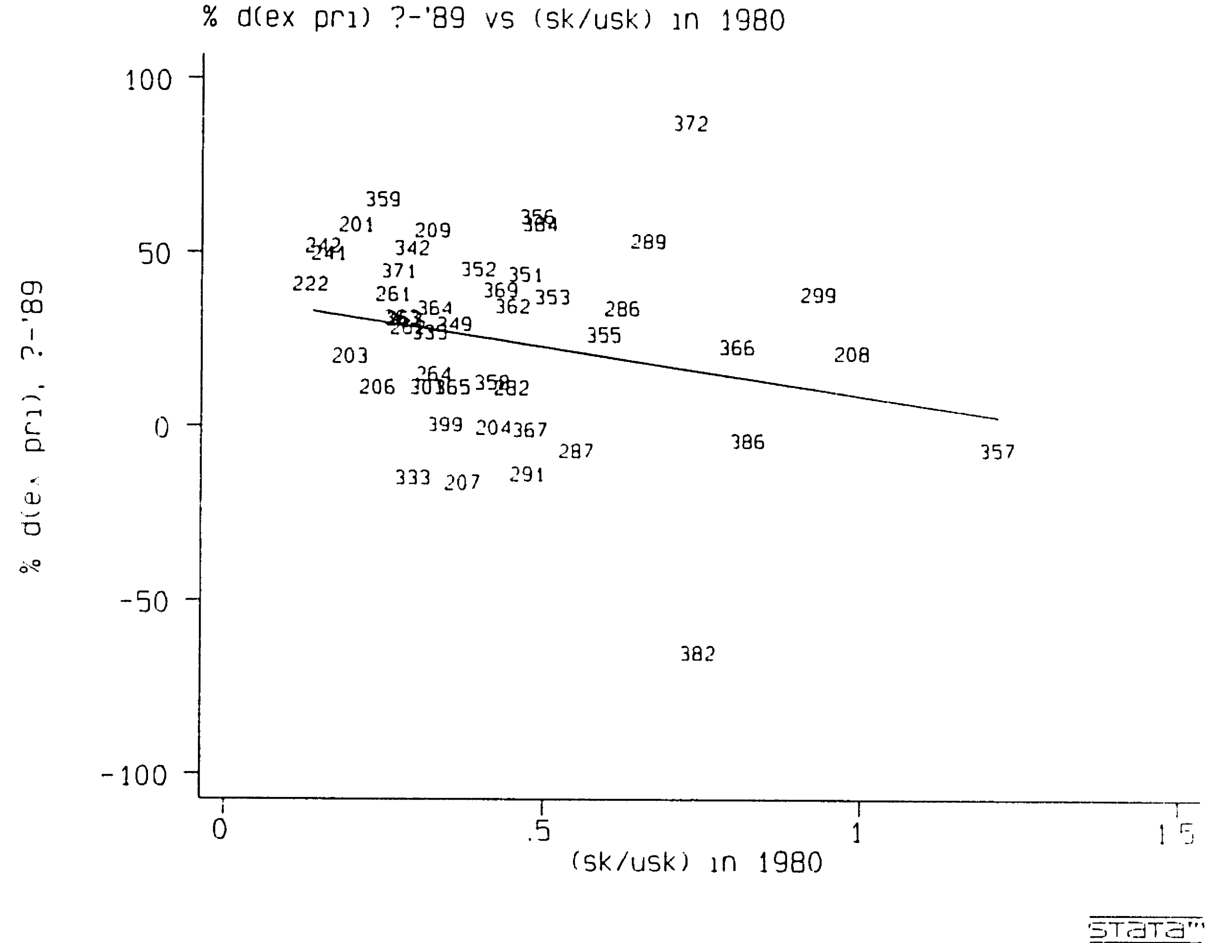
Sources: Import prices come from the Bureau of Labor Statistics; employment data come from the NBER's Trade and Immigration Data Base. Each number represents its 3-digit SIC industry. The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure 8: Percentage Changes in the 1980's of Export Prices by Industry Versus the Non-Production-Worker Intensity of Industries



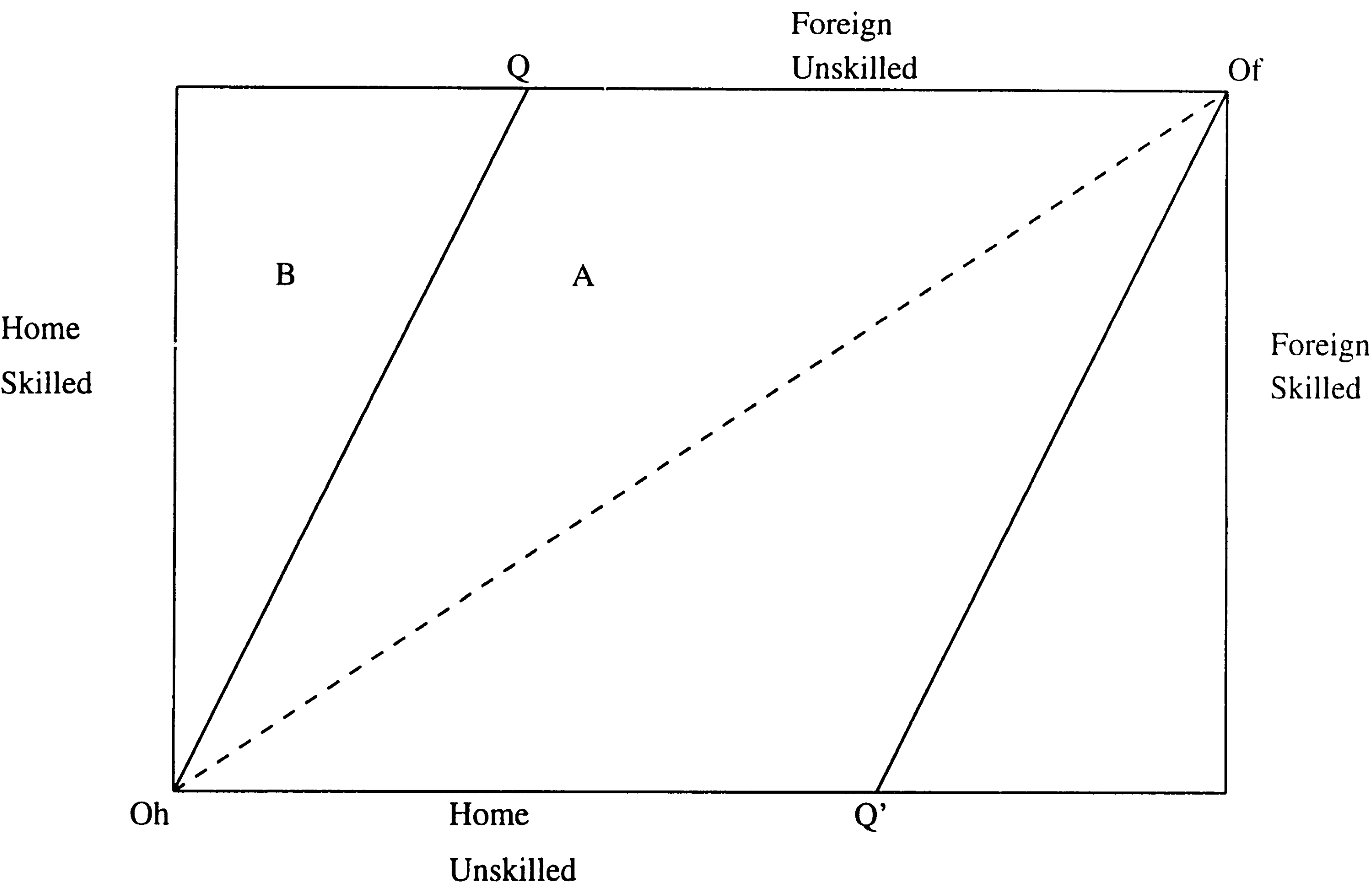
Sources: Export prices come from the Bureau of Labor Statistics; employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 2-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure 9: Percentage Changes in the 1980's of Export Prices by Industry Versus the Non-Production-Worker Intensity of Industries



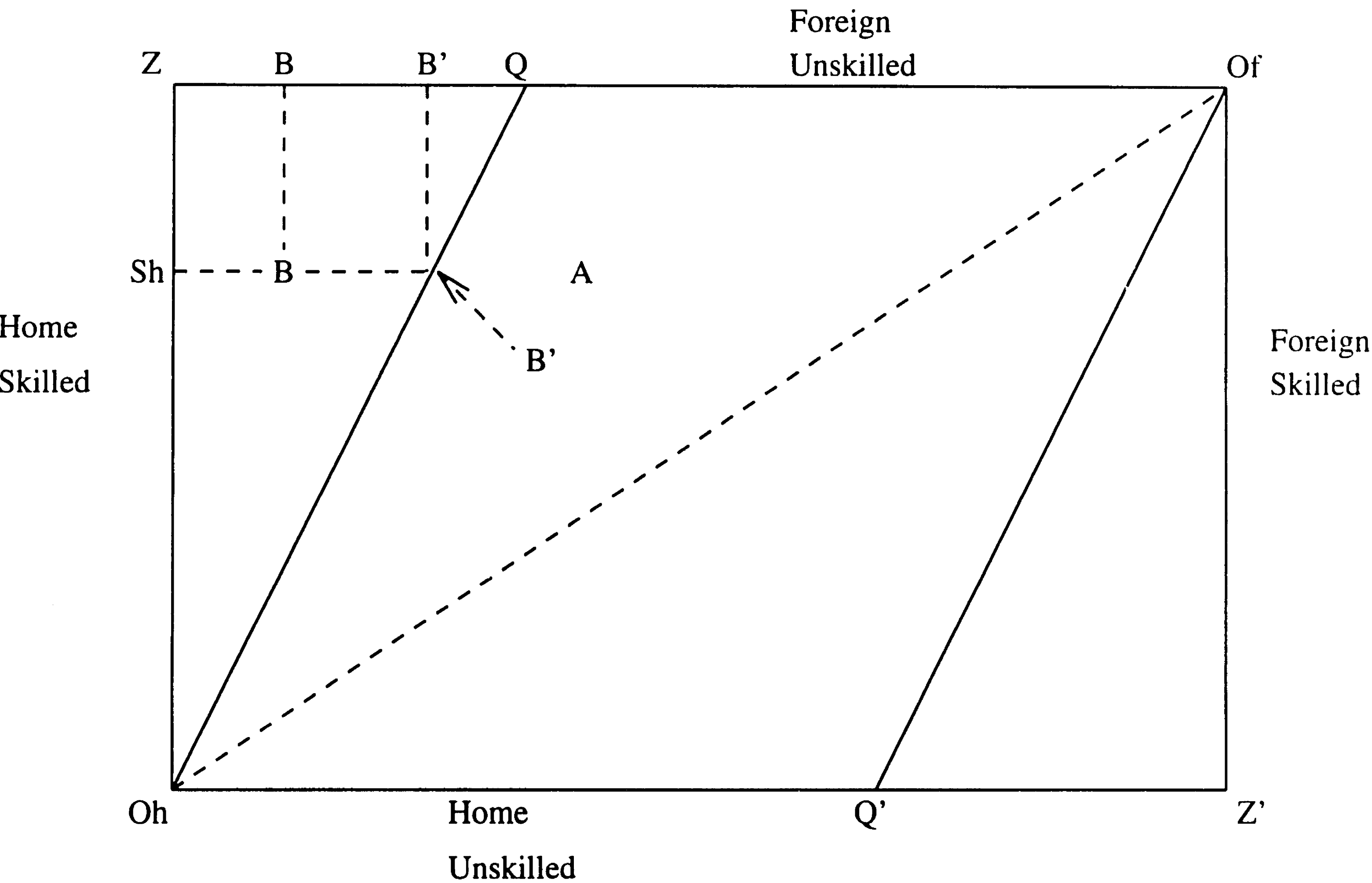
Sources: Export prices come from the Bureau of Labor Statistics;
employment data come from the NBER's Trade and Immigration Data Base.
Each number represents its 3-digit SIC industry.
The horizontal axis measures the ratio of non-production to production workers employed in 1980.

Figure 10: Possible Equilibria Without Multinationals



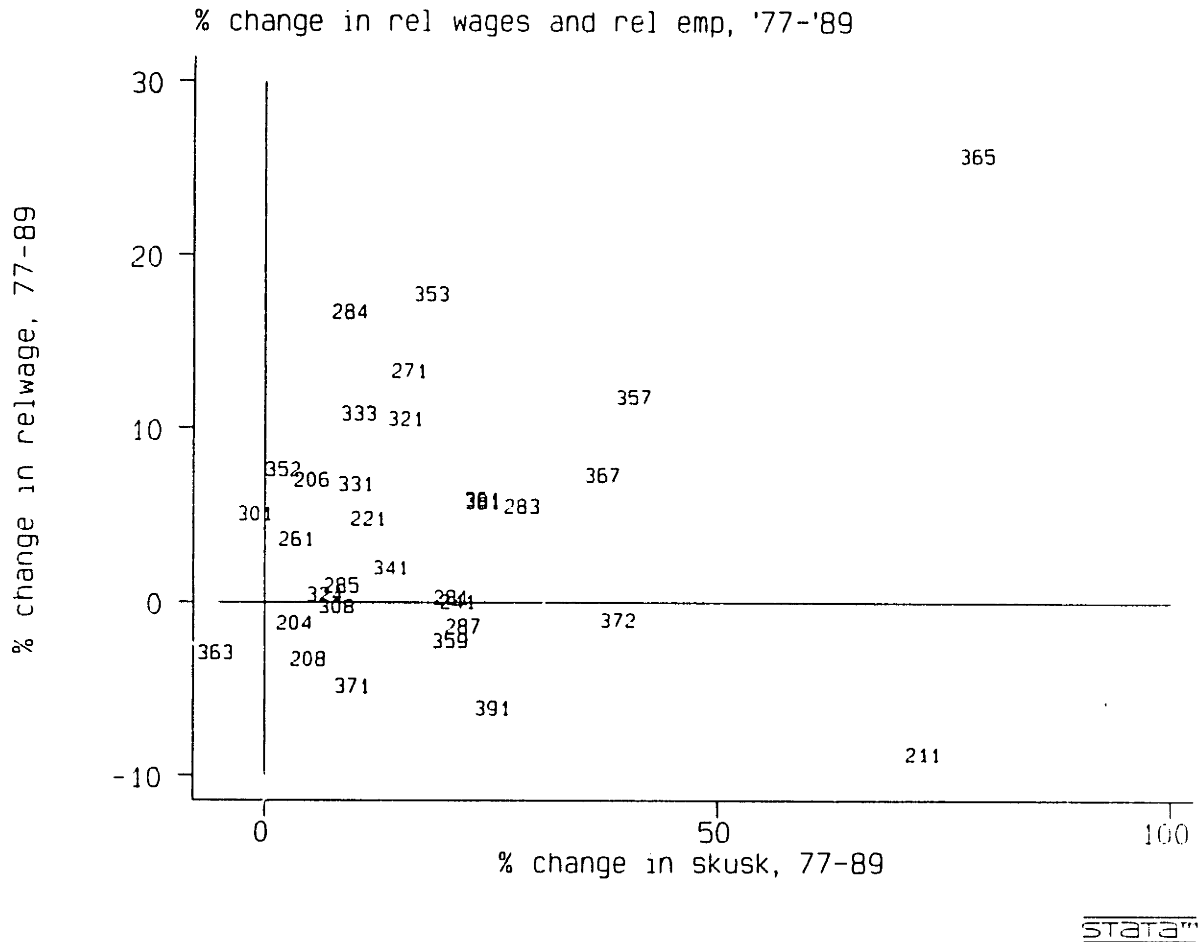
A and B are two representative endowment points between home and foreign.
O_hQ and O_fQ' are the production rays for baseballs in the integrated equilibrium.
QO_f and $Q'O_h$ are the production rays for food in the integrated equilibrium.

Figure 11: Possible Equilibria With Multinationals



A and B are two representative endowment points between home and foreign.
B' is the production point that multinationals settle at when the endowment is B.
O_hZ and O_fZ' are the production rays for headquarter services in the multinational equilibrium.
ZQ and Z'Q' are the production rays for assembly in the multinational equilibrium.
QO_f and $Q'O_h$ are the production rays for food in the multinational equilibrium.

Figure 12: Percentage Changes in the 1980's in the Relative Wages and Relative Employment in America of Non-Production and Production Labor in the 32 BEA Industries



Sources: Employment and wage data come from the NBER's Trade and Immigration Data Base. In each graph, the vertical axis measures the percentage change in each industry's ratio of non-production wages to production wages. The horizontal axis measures the percentage change in each industry's ratio of non-production to production workers employed.

Chapter 3

The Antebellum Transportation Revolution and Factor-Price Equalization

1 Introduction

International-trade economists have historically had a rather schizophrenic attitude toward the factor-price-equalization (FPE) theorem. In theoretical work the FPE theorem has been studied for decades, and it has been shown to be a robust idea which holds in a wide variety of models. Heckscher (1992) and Ohlin (1933, 1992) are usually credited with first arguing that as freer trade equalizes commodity prices among regions, producers respond by shifting resources across industries such that factor prices equalize across regions as well. Samuelson (1948, 1949) rigorously proved conditions under which free trade generates complete FPE in a two good, two factor, two country model. After these papers by Samuelson, he and numerous others generalized this work to determine in what other contexts FPE arises. More recently, new trade theorists have developed a number of models with increasing returns to scale that also exhibit equilibria with FPE. For example, Helpman and Krugman (1985) develop at least three such models: one with increasing returns to scale at the industry level, one with increasing returns to scale at the firm level with contestable markets, and one with increasing returns to scale at the firm level with monopolistically competitive markets.

In empirical work, however, the FPE theorem has been largely ignored. Deardorf's (1984) chapter in the *Handbook of International Economics* on empirical work does not discuss FPE even once, and browsing through Econlit confirms that he did not overlook much. Thus, while decades of work has studied FPE theoretically, almost no work has studied FPE empirically.

One possible explanation of this schizophrenia is that people have thought about FPE only as an equilibrium outcome in isolation from the assumptions which generate it. From this perspective, the appropriate empirical test for FPE is simply whether factor prices are equal across regions. On this criterion, FPE is a spectacular failure. For example, Leamer (1984) finds that in a sample of 32 countries in 1972, hourly wage rates paid to agricultural labor ranged from $.046 in India to $2.80 in Sweden--a wage differential of 61 times. Thus, perhaps people have thought little about FPE other than "In the data, factor prices are not equal." In this spirit, Caves (1960) writes that "One may well wonder why the factor-price equalization theorem has attracted so much attention ... In light of the data, the whole discussion [of FPE] is, for better or for worse, a supreme example of non-operational theorizing."

If this explanation is correct, then I argue that people have been evaluating FPE against too strict a criterion. The criterion should consider not only FPE but also its motivating assumptions, because in most models it requires stringent assumptions which almost certainly do not all hold in reality. For example, Samuelson (1949) requires eight stringent assumptions to hold jointly for FPE to result: these include zero trade barriers, linear homogeneous technology and preferences identical across countries, and perfect factor mobility across industries within each country. When even one of the eight does not hold, factor prices need not equalize. Thus, FPE almost certainly fails empirically because the assumptions needed to generate FPE fail empirically. In this light, Leamer's results seem rather unsurprising.

Thinking about FPE as not only an equilibrium outcome but also as a set of stringent assumptions motivates an alternative empirical approach to FPE. One can look for a *tendency* towards FPE that is motivated by a *tendency* towards realizing its stringent assumptions. The focus thus switches from factor prices alone at one point in time to the interaction between trends over time in the assumptions needed to equalize factor prices and trends over time in the prices themselves.

Some authors have agreed with this alternative approach. Kindleberger (1968) argues that "while full factor-price equalization may be an intellectual curiosity rather than a significant proposition for the real world, the tendency toward factor-price equalization is much more meaningful ... this repercussion of trade on factor prices is vastly important, politically as well as economically." Similarly, Davis (1992) concludes from data such as Leamer's that appropriate tests of FPE "formulate hypotheses that preserve the central logic of the factor-price equalization theorem while also holding some prospect of surviving a confrontation with the data."

Thus, a reasonable method to test FPE is to see whether a tendency towards realizing FPE assumptions leads to a tendency towards FPE itself. In this paper, I follow this method by studying whether the construction of canals and railroads in antebellum America equalized regional wages. This "transportation revolution" is a good case study for FPE for at least three reasons.

First, the revolution made much more realistic one of the essential assumptions for FPE: zero trade barriers among trading regions. Keep in mind that a trade barrier is *any* impediment--political or technological--which prevents commodity-price equalization and thus FPE across regions. People often think only of the political variety: tariffs, voluntary export restraints, etc. However, there is a ubiquitous technological variety as well: transportation costs. Antebellum canals and railroads slashed transportation costs, especially for bulky agricultural products. Second, the country's regions shared a common currency.[1] Looking at regions within a common-currency area avoids the question of the appropriate exchange rates for converting factor prices into a common currency.[2] Third, the necessary factor-price data exist. From the records of U.S. Army posts throughout the country, Margo and Villaflor (1987) and Goldin and Margo (1992) have assembled regional wage series for different types of labor which enable tracing falling trade barriers through to factor prices.

So antebellum America appears to be a prime place to look for FPE: the country had regions on a common currency which experienced a clear trade-barrier shock whose effects can be looked for in regional wage data. In this paper I look for FPE in antebellum America, and my surprising result is that I do not find it.

First, I document how canals and railroads slashed transportation costs and thereby helped equalize commodity prices across regions. I then present regional wage series which surprisingly display no evidence of wage equalization. I explain this puzzle by arguing that regional specialization of production in the Midwest prevented it. To support this argument, I present historical evidence that the Midwest was effectively specialized. I then present a simple model that shows how the nature of shifts in regional factor demands depends on the region's production mix. Specialization prevents

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[1]This statement has received a lot of scrutiny from historians because in antebellum America currency was issued by many banks, not by one central bank. The consensus seems to be that the notes of different banks maintained their relative values except in crises when the banks' solvency was in danger. Thus, the work of Cole (1938), Margo and Villaflor (1987), Goldin and Margo (1992), and many others uses one national currency. In this paper I follow this convention.

[2]Different answers to this question yield different FPE results. For example, suppose that on 4/1/94 American engineers earned an hourly wage of $100 and Japanese engineers earned an hourly wage of Y1250. The spot-market $-Y rate that day was approximately Y105 per dollar. At this rate, full FPE was not attained. But suppose that the consensus PPP rate that day was Y125 per dollar. At this rate, full FPE was attained. Thus, work on FPE which analyzes the levels of factor prices across countries must address this exchange-rate question.

commodity-price equalization from leading to FPE because it permits wages in the specialized Midwest to move in the same direction as wages in the non-specialized Northeast. Thus, the transportation revolution was realizing one of FPE's usual assumptions--zero trade barriers. But the fact that a second assumption--no regional specialization of production--was not being realized prevented the first from equalizing factor prices.

The paper has four additional sections. Section 2 summarizes existing empirical work on FPE. Section 3 presents the relevant data for antebellum America. It documents the fall in transportation costs and subsequent commodity-price equalization, and then it presents the wage data which document wage rigidity. Section 4 presents my model which explains this rigidity. Section 5 concludes.

2 Previous Studies of FPE

As mentioned in the introduction, very little empirical work has studied FPE. Dollar, Wolff, and Baumol (1988) test FPE only as an equilibrium outcome at a point in time. They start from the fact FPE under linear homogeneous production technology in all industries implies equal average productivity in each industry across countries. Dollar, et al, test this implication by seeing whether the value added per employee in 28 various industries was equal across 13 industrialized countries in 1980. Not surprisingly, they find large cross-country variation: the median ratio across industries of highest to lowest value added per employee was 2.12. From this evidence, they conclude that factor-price equalization does not hold across industrial countries. As argued in the introduction, this conclusion is not surprising. More interesting work would try to link trends over time in value added per employee to trends over time in trade liberalization or technology diffusion.

Mokhtari and Rassekh (1989) test whether increased "trade openness" among 16 OECD countries between 1961 and 1984 led to FPE across these countries. They measure factor prices as each country's average real manufacturing wages; their measure of cross-country wage convergence is then the coefficient of variation of the countries' wages.[3] They measure "trade openness" for each country as the sum of its exports plus imports divided by GDP; their measure of cross-country openness is then the weighted average of each country's openness. With these data, Mokhtari and Rassekh regress the coefficient of variation of wages on openness and a set of controls, and they find that increases in openness are associated with a statistically significant decrease in wages' coefficient of variation. This correlation, they argue, is empirical evidence of FPE.

This conclusion is premature. In standard trade models, FPE is not driven by trade openness. It is driven by commodity-price convergence, which is not necessarily the same thing as greater trade openness. As Slaughter (1993) discusses, there is no necessary relationship between a country's volume of trade and its terms of trade. In particular, a country's trade volumes can shift without having any effect on its terms of trade. But without shifts in the terms of trade, pressures toward FPE do not shift. Thus, because Mokhtari and Rassekh have not established an empirical relationship between terms of trade and trade openness, they have *not* found evidence of FPE. Their link between trade openness and wage convergence is interesting in itself. But it is not necessarily the same thing as FPE.

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[3]Mokhtari and Rassekh demonstrate that wage convergence by factor type usually implies manufacturing-wage convergence as well. A variable's coefficient of variation is defined as its standard deviation divided by its mean. A declining coefficient is usually interpreted as second-moment convergence.

Davis (1992) follows this approach of regressing trends in industry wages against trends in trade openness, and thus is open to the same critique. His data set contains annual observations from 1975 to 1989 on mean gross hourly compensation costs for production workers in 41 industries in 14 advanced economies and five middle-income countries. Calculating the average deviation of each country's relative industry wages from the worldwide average relative industry wage structure, Davis then regresses these deviations on the countries' trade openness (again, measured as each country's exports plus imports divided by GDP) and other variables. He finds that increases in trade openness are associated with a statistically significant convergence of industry relative wages toward the worldwide average wage structure. Again, because Davis does not link openness to the terms of trade, the relationship of his results to FPE is unclear.

Leamer (1992) presents evidence of what he calls "wage equalization" between 1960 and 1989. For 1960, 1978, and 1989 he collects data on the real (i.e., in 1985 dollars) industrial hourly wage for a number of countries. Between 1960 and 1978 wages grew more in countries that had lower wages in 1960. Similarly, between 1978 and 1989 wages in initially higher-wage countries actually fell slightly while wages in initially lower-wage countries continued to grow. Leamer conjectures that both FPE tendencies and international factor mobility were causing this wage equalization. He does not attempt to distinguish the relative contribution of these two causes, however.

Finally, Ben-David (1993) presents rather convincing evidence of trade liberalization leading to income convergence across countries. Like Mokhtari and Rassekh and Davis, Ben-David uses countries as his unit of observation. Unlike them, however, his cases consist of well-documented episodes of tariff and quota reductions among particular sets of countries. For each episode he documents trends in income dispersion among the participating countries, and then compares these trends with pre-episode patterns.

Ben-David's benchmark case is the initial round of tariff and quota reductions that followed the 1957 formation of the European Economic Community (EEC). Between January 1, 1959 and July 1, 1968, the six original members[4] formed a customs union which abolished all internal tariffs, set common external tariffs, and expanded the limits on existing intra-EEC quotas. This customs union greatly reduced the trade barriers among these members, and thus should have created a tendency towards FPE among them. This tendency appears in the data as a decline in the annual standard deviation in per capita incomes of the member countries from .26 in 1957 to .15 by 1968. This decline contrasts with no convergence in these standard deviations between 1870 and 1957.

He provides further evidence of trade liberalization inducing FPE in two other cases. First, he documents a decline in the annual standard deviation in per capita incomes among Denmark, Ireland, and the United Kingdom starting in 1973, the year they joined the EEC and adopted its trade policies. This decline contrasts with no convergence in these standard deviations before 1973. Second, he documents a decline in the difference in the per capita incomes between the United States and Canada starting in 1968, the year the Kennedy Round of GATT negotiations was implemented. This decline contrasts with no convergence in this difference between 1950 and 1968. In addition, Ben-David also calculates rates of income convergence for these liberalization

[4]Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany.

episodes. Most interestingly, he finds that the annual rate of convergence in his benchmark case was slightly higher than the annual rate of convergence among the 50 United States between 1931 and 1984: 5.1% versus 4.4%.

From all this evidence of per capita income convergence, Ben-David concludes that episodes of trade liberalization do induce FPE. The one problem with Ben-David's analysis is that the FPE theorem addresses factor prices, which may or may not be related to per capita incomes. Suppose that labor and capital are the only factors, and full FPE is attained. Then the more capital a country has for a given amount of labor, the higher the country's per capita income. Thus even with full FPE, different capital stocks between two countries implies different per capita incomes. This example discusses levels of prices and incomes, not trends as Ben-David addresses. But the point still stands that the link between trends in the two needs to be established, not assumed--especially for periods during which capital is being accumulated.

To summarize, very little empirical work has been done on FPE. Moreover, in the existing body of work people have often linked factor-price trends to trends that are not necessarily trends towards more complete realization of FPE assumptions. Ben-David is an exception to this point, and my analysis follows his method of first documenting the trends towards more complete realization of FPE assumptions.

3 Antebellum America

Transportation Costs

The construction of canals and railroads in antebellum America has received a lot of attention from economic historians. Many hail this undertaking as a cornerstone of American development. For example, Taylor (1951, p175) writes that "[t]he tremendous development of America during the forty-five years ending in 1860 was, of course, the result of many interacting factors. Fundamental was the adoption of the new instruments of transportation: canals, steamboats, and railroads." Others such as Fogel (1964) argue that this infrastructure did not contribute as much to American growth as is commonly believed. Whatever its myriad effects, it did slash transportation costs and thereby contribute to strong commodity-price equalization across regions.

Table 1 documents the explosion of transportation mileage in the decades before the Civil War. Clearly, the transportation revolution began with canals. In 1816 the country had barely 100 miles of operating canals, and only three canals were longer than two miles. The construction of the Erie Canal from 1818 to 1825 changed all this. "The success of the Erie Canal provided the spark which set off a nation-wide craze for canal building. With the need for improved transportation so great and the financial and economic benefits to be secured from artificial waterways now apparently assured, a veritable canal-building fury gripped the country" (Taylor, p34). Steamboats, whose commercial viability had been demonstrated as early as 1807 by Robert Fulton, flourished on these canals. The spread of railroads followed that of canals. As technical difficulties with track and steam engines were steadily overcome, the miles of track steadily grew. By 1850 most major problems had been solved, and in the 1850's America nearly quadrupled its track mileage. In light of the numbers in Table 1, most historians date the start of the transportation revolution at approximately 1820. I have followed this convention by gathering data back at least that far.

This revolution slashed transportation costs throughout the country. The data on these costs are largely anecdotal because record keeping was sporadic and because different modes of transportation evolved at different rates and to different degrees. Thus, economic historians acknowledge that "the long-term movement between 1800 and 1860 may not be measured with a high degree of accuracy. Indeed, there was more than one such movement, since rates on different classes of commodities did not fall in the same degree" (Berry, 1943, p87). Nevertheless, the available data taken together demonstrate a sharp fall nationwide in transportation costs.

Taylor's survey of various markets and modes concludes that the fall in costs was on the order of 95% for some goods. Berry provides dozens of interesting cases. For example, in New York state over the 1850's alone, the cost for a ton-mile of first-class railroad freight fell from 9.04 cents in 1850 to 2.2 cents in 1860 (p71). Similarly, between Baltimore and Cincinnati the rate for one hundred pounds of "direct rates" fell from $2.50 in 1821 to $1.05 in 1860 (p87). Berry also describes the falling costs in terms of time. In 1817 it took 52 days to ship "a load of freight" from Cincinnati to New York City. This trip required a combination of wagons and riverboats. In 1852 it took only six days to ship the same freight, all via the Erie Railroad and connecting lines (pp88-92). Finally, others describe the falling costs in terms of productivity gains. Williamson and Lindert (1980) estimate that overall American transportation productivity rose 4.68% per year between 1815 and 1859.

Commodity Prices

Standard trade models predict that the drastic fall in transportation costs should have helped equalize commodity prices across regions. The literature on the transportation revolution points out that commodity prices in the South moved very little in response to canals and railroads because natural waterways (the Mississippi River and the Atlantic Ocean) were already providing low-cost transportation. Thus, the most drastic commodity-price equalization occurred between the Northeast and the Midwest.

The price data come from Cole (1938), the definitive source of antebellum prices. Cole collected monthly wholesale prices from hundreds of newspapers for dozens of commodities at six cities (Boston, New York, Philadelphia, Charleston, New Orleans, and Cincinnati) between 1700 to 1861. Surprisingly, Cole devotes almost no attention to regional variation in prices. Instead, he focuses almost entirely on constructing within-city aggregate price indices. Nevertheless, his data provide raw material for documenting regional commodity-price equalization.

To do this, I assembled and then compared regional commodity price series. Geographically, I chose Cincinnati to represent the Midwest and New York and Philadelphia to represent the Northeast.[5] I assumed that trends in these cities matched trends elsewhere in their respective regions; I did this primarily because of data limitations--Cole's data are the only source--but I also had no prior reasons to doubt this assumption. I needed commodities which met three criteria. First, the commodities needed coverage in both Midwest and Northeast cities. Second, they needed continuous coverage from 1860 back to at least 1820. Third, they needed to maintain the same description over the entire period. For example, for Philadelphia Cole surveyed tallow-mould candles up until 1844 and sperm candles thereafter. Because I do not know the quality difference between these two varieties, I could not track candles. Together, these criteria limited the number of trackable commodities to four: two food agricultural and two manufactured. The agricultural goods are flour ("superfine" quality) and pork (mess

[5]Boston records were too sporadic to use.

variety). The manufactured goods are iron bars ("unspecified" variety) and nails (cut, of various sizes). Nail prices ran back to 1820; the prices of the other three commodities ran back to 1816.[6] For each commodity, I constructed an annual price series by averaging each year's 12 monthly prices into an annual price quote.

Assuming that food was the comparative-advantage good in the Midwest and manufactures in the Northeast, *ceteris paribus* one would expect rising food prices and falling manufactures prices in Cincinnati and vice versa in New York and Philadelphia. Figures 1 through 4 graph the price trends in all three cities for flour, pork, iron, and nails, respectively. The prices between 1816 and 1820 were extremely volatile because the country was experiencing a nationwide financial panic in the aftermath of the War of 1812. Thus, in what follows I ignore the prices before 1820. The actual price trends between 1820 and 1860 differ from the *ceteris paribus* expectations. Iron and nail prices fell in all three cities; pork prices rose in all three cities; and flour prices rose in Cincinnati while falling in New York and Philadelphia.

These trends do not imply that prices were not equalizing, however. They just imply that all else was not equal. Most importantly, technological progress was probably driving down manufacturing prices. Consider iron, for example. In 1840 producers began switching from charcoal-fueled blast furnaces to ones fueled by anthracite and bituminous coal. Most observers contend that this switch tended to lower the price of iron.[7] Adding

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[6]Nail prices are in cents per pound. Iron prices are in dollars per ton. Flour prices are in dollars per flour barrel (196 pounds). Pork prices are in dollars per pork barrel (200 pounds).

[7]Swank (1892, pp352-353), for example, writes that "this innovation at once caused a revolution in the whole iron industry of the country. Facilities for the manufacture of iron were increased; districts which had been partly closed to this industry because of a scarcity of timber for the supply of charcoal were now fully opened to it; *and the cheapening of prices was made possible by the increased production and increased competition* ... This introduction [of mineral fuel] marked such radical changes in our iron

this technology effect to the effect of regional price equalization should mean even lower iron prices in Cincinnati and less high or even lower prices in New York and Philadelphia. The data are consistent with this story: Figure 3 shows that iron prices did indeed fall in New York and Philadelphia. Therefore, actual trends in iron prices depicted in Figure 3 are consistent with technological progress reinforcing commodity-price equalization in the Midwest and offsetting it in the Northeast.

Since within-region trends in price levels do not indicate price equalization, I constructed cross-region price ratios: if technology's price effects occurred nationwide, then these ratios can isolate price equalization.[8] For each agricultural commodity in each year, I constructed the ratio of its price in Cincinnati to its price New York and to its price in Philadelphia. Similarly, for each manufactured commodity in each year I constructed the ratio of its price in New York and Philadelphia to its price in Cincinnati. Thus, I ended up with eight price-ratio series that by construction measure the price of each commodity in its comparative-disadvantage region divided by the price in its comparative-advantage region--and that therefore should converge down towards one under regional commodity-price equalization. Figures 5 and 6 graph these series. The vertical axis of each graph measures the price ratios, and the line in each graph plots the ratios' underlying trend as the predicted price ratios calculated from a regression of the actual ratios on time.

The price ratios in all eight graphs converge markedly towards one. There is

industry, that we are amply justified in referring to it as a revolution" (italics mine).

[8]Assuming nationwide technological progress seems reasonable. The majority of Americans spoke English, the learned class which generated innovations was probably quite mobile, and the transportation revolution was quickening communication.

some year-to-year variability, probably caused by the sporadic nature of transportation developments and by city-specific shocks like the weather. This variability aside, the graphs present strong evidence of extensive commodity-price equalization across regions. Flour and pork display the strongest equalization. For both commodities, the price premium in the Northeast fell from about 75% in 1820 to less than 10% in 1860. Similarly, the price premium for iron in the Midwest fell from over 100% in 1820 to just over 10% in 1860. The results for nails are slightly more difficult to interpret because after 1845, nail prices were actually lower in Cincinnati than they were in either New York or Philadelphia. Nevertheless, nail-price ratios between 1820 and 1845 fell gradually.

Within each region, this extensive commodity-price equalization helped raise the terms of trade. Figure 7 graphs this rise in each region in terms of flour and iron: Northeast terms of trade are (P_{iron}/P_{flour}), and Midwest terms of trade are (P_{flour}/P_{iron}). Clearly, commodity-price equalization between the two regions helped raise each's terms of trade.[9]

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[9]The one city for which Cole constructs several terms-of-trade indices is Cincinnati. His indices display the same trend as Figure 8: rising Midwest terms of trade. Recall that in the Northeast, the price of both agricultural goods and manufactures was falling. Northeast terms of trade nevertheless rose because the percentage decline in agriculture prices exceeded the percentage decline in manufactures prices.

I should note that if I replace flour with pork, then the Northeast terms of trade decline rather than rise because pork prices in the Northeast were rising rather than falling. There are two reasons--one empirical, one theoretical--to believe that this particular terms-of-trade index is not representative of overall Northeast terms of trade. First, Cole's exposition on Northeast and Midwest prices indicates that the prices of most agricultural products in the Northeast were falling. Thus, pork seems a bit of an outlier, and I assume that the (iron/flour) terms of trade more accurately represent the Northeast's price trend across more comprehensive product baskets. Second, the terms of trade presented here do not account for technological progress. As discussed above, many manufacturers in the antebellum Northeast experienced significant technological progress. Dixit and Norman (1980,p138) point out that Hicks-neutral technological progress has the same effects on resource allocation as a price rise: "Obviously, then, a one per cent change in [the Hicks-neutral parameter] has the same effect on revenue and other variables as a one percent change in [price]." Thus, for products like iron it may be more appropriate to think of the "effective" terms of trade which consider both technology and prices. In this light, the effective price of iron--and thus the

Thus, the data indicate two clear developments in antebellum commodity prices. The first is commodity-price equalization between the Northeast and the Midwest, and the second is a rise in each region's terms of trade.

Factor Prices

Standard trade models predict that antebellum commodity-price equalization should have equalized factor prices as well. Until very recently, however, antebellum regional factor-price data did not exist. Margo and Villaflor and Goldin and Margo fill this void. They assemble antebellum regional wage series from records of United States Army posts. Quartermasters at these posts hired civilian employees for a wide variety of jobs, and each month the quartermasters prepared a standardized report which documented pay rates, job descriptions, etc. Margo and Villaflor and Goldin and Margo sample an extensive collection of these reports from 1820 to 1856 to build a data set of more than 40,000 observations. They argue both that the Army's demand for civilian labor was to small to affect local labor markets and that the Army did not systematically overpay its hires. Given this, they conclude that the data reflect market wages. From hedonic wage regressions, they then construct an annual series of nominal daily wages for three different types of labor--artisans, clerks, and laborers--over four regions--Northeast, Midwest, South Atlantic, and South Central.[10]

Margo and Villaflor report three initial findings from these data. First, they belie the idea that capital accumulation increased the wages of skilled labor relative to

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Northeast (iron/pork) terms of trade--may very well have been rising.

[10]The clerk series goes back to 1820, the laborer series to 1821, and the artisan series to 1822. All end in 1856.

unskilled labor. Second, they argue that real wage growth in the Northeast was more erratic than previously believed. Finally, they infer from declining real wages in the Midwest that westward migration was indeed forging a national labor market. Goldin and Margo estimate the persistence of shocks to antebellum real wages by looking for unit roots in regional real-wage series. They conclude that shocks moved real wages only in the short run.

Neither study looks for evidence of FPE, however. To do this, I look at cross-region trends in nominal wages. It is important to emphasize that I analyze nominal, not real, wages. As producers respond to equalizing commodity prices by reallocating resources, their new factor demands move *nominal* factor prices. In a wide variety of trade models (for example, Samuelson (1948, 1949)), complete FPE equalizes across regions the level of nominal factor prices. Clearly, equalized commodity prices implies that real factor prices equalize as well. But adjustment towards FPE works through nominal factor prices, so I look at nominal wages. (Appendix A discusses this point further.)

To do this, I constructed a wage-ratio series across regions for each type of labor. I did not construct a wage-level series within each region because I did not have strong priors about each region's relative factor abundance. For each labor type in each year, I constructed the ratio of its wage in the Northeast to its wage in the Midwest. Figure 8 graphs the three wage-ratio series. The vertical axis in each graph measures the wage ratio, and the line in each graph plots the ratios' underlying trend as the predicted price ratios calculated from a regression of the actual ratios on time. With FPE, these ratios should trend over time towards one.

All three wage-ratio series show very little, if any, evidence of FPE. First, none of the figures displays a statistically significant trend line towards one. Indeed, the clerical-wage ratio displays the most convergence (i.e., its trend has the largest slope), but this is extremely sensitive to the endpoints chosen. If one ignores 1820, 1855, and 1856--arguable, given the degree to which these years seem to be outliers--then convergence disappears. Over the entire antebellum period, artisan and laborer wages were approximately 20% higher in the Midwest while clerical wages were approximately 40% higher in the Northeast. Second, the coefficients of variation for subsamples of each ratio do not decline uniformly for any of the ratios. Table 2 reports the coefficients of variation for the three 12-year periods of each ratio.[11] For artisans the coefficient rose and then fell back to barely below its original level. For clerks the coefficient fell and then rebounded to just above its original level. And for laborers the coefficient rose and then fell to finish somewhat below its original level. Thus not only did the means of the wage ratios not converge, but the variances of them did not decline as well. These data indicate that antebellum wages were not equalizing across regions.

Unfortunately, I cannot corroborate this finding with data for rental rates on either land or capital because these data do not exist. Land-price data date back to only 1850, when the United States Department of Agriculture was founded (see Lindert (1988)). Similarly, only nationwide capital stock estimates have been assembled, and they date back to only 1840 (see Gallman (1985)). However, antebellum regional interest-rate data

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[11]A variable's coefficient of variation is defined as its standard deviation divided by its mean. A declining coefficient is usually interpreted as second-moment convergence. I also calculated the trend in each ratio's coefficient of variation for subsamples of five, six, and ten years. Like the 12-year sub-samples, these trends are not uniformly decreasing. Because of this similarity, I report only the 12-year results.

do exist. Bodenhorn and Rockoff (1992) construct an interest rate, the rate of return on banks' earning assets, from financial records that were kept by state legislatures. They find that the antebellum level premium of Midwest rates over New York City rates was growing: 2.86% in 1835, 2.03% in 1840, 2.44% in 1845, 3.83% in 1850, and 5.02% in 1859. Insofar as interest rates are a reasonable proxy for capital-rental rates, these data indicate regional divergence of capital prices. Thus, the lack of regional wage convergence may have been representative of all factor prices.

Before moving on to explain why regional wages were not converging, it is worthwhile to look at the trend across regions in real wages to underscore the distinction just made between nominal and real wages. To do this, for each labor type in each region I constructed a consumption-deflated real wage by dividing the nominal wage by the price of flour; I then constructed the ratio of the Midwest real wage to the Northeast real wage.[12] Figure 9 shows that all three real-wage-ratio series converge markedly towards one. Given the nominal-wage rigidity, this real-wage equalization came almost entirely from commodity-price equalization. This result can be explained by people migrating from the Northeast to the Midwest to take advantage of higher Midwest real wages. Table 3 demonstrates that people were in fact migrating. It reports data from Weiss (1994) on the total, agricultural, and non-agricultural labor forces (free and slave, 10 years old and up) in both regions. The growth rate for the total labor force in the

[12]Clearly, flour was not the only consumption good. But Goldin and Margo (1992) cite Hoover's (1960) finding that flour constituted 15% of the average family's total expenditure--the largest share of any food product. Insofar as trends in other foodstuff prices matched those of flour, deflating with the flour price alone reasonably approximates deflating with broader baskets of goods. Also, for the Northeast I used the flour price of New York rather than Philadelphia. Using Philadelphia prices gives almost identical real-wage series, so I only report New York results.

Midwest between 1820 and 1860 was more than double what it was in the Northeast. These data underscore what several historians have long contended: people moved West in part because of its higher real wages, and this helped equalize real wages nationwide.

Thus, the data indicate that commodity-price equalization between the Northeast and the Midwest was not leading to factor-price equalization between the regions. Instead, nominal wages between the Northeast and the Midwest maintained large and roughly constant differentials. The next section offers an explanation for this puzzle.

4 Explaining Factor-Price Rigidity Across Regions

The transportation revolution was realizing one of the essential assumptions for FPE--zero trade barriers among trading regions. As expected, falling trade barriers did equalize commodity prices across regions. But it did not equalize factor prices across regions. I argue that the most likely explanation of this puzzle is that the antebellum Midwest was effectively specialized in producing only agricultural goods. Regional specialization of production violated another standard assumption for FPE--regional diversification of production--and thereby prevented equalizing commodity prices from equalizing factor prices. This explanation is most likely both because the assumption of Midwest specialization is empirically supported and because the model that follows from this assumption is theoretically sound. I first present the empirical evidence on specialization, and then present the model.

Empirical Evidence of Midwest Specialization

The empirical evidence of Midwest specialization consists of both production patterns implied by actual shocks and production patterns actually observed.

First, consider the Midwest's shocks. The first was improving terms of trade. At the very least, this shock should have concentrated the region's output mix more heavily in agriculture. The second shock was factor accumulation. Thanks to migration (documented in Table 3) and subsequent land settlement, Midwest land and labor supplies were growing. The question is whether the Midwest's relative endowment of labor to land fell sufficiently to induce specialization (or whether it did not rise sufficiently to move back into the cone of diversification if the Midwest was already specialized in 1820). Unfortunately, no land data exist to compare with the employment data. But Table 3 shows that the Midwest ratio of agricultural labor to non-agricultural labor rose between 1820 and 1860 from just under 4 to just over 4. This ratio is prima facie evidence that the Midwest was becoming even more agricultural. Thus, it seems that the Midwest's rising terms of trade and factor accumulation were inducing or even maintaining specialization.

The second line of support for the specialization assumption is the literature: many historians speak of the antebellum Midwest as a region which was specialized in 1820 and which became more so over time. Taylor (p169) marvels at "the growing territorial specialization upon which rested the striking growth of American domestic commerce during the period of this study [1815-1860]." Similarly, North (1961, p136) argues that "During these surges of westward expansion, their primary importance for American economic growth ... was that he [the Midwest farmer] became more specialized ... Throughout the period of study [1790 to 1860], the region's factor endowments provided an obvious comparative advantage for agricultural products, specifically wheat and corn." And Berry (p226) argues that transportation triggered this specialization. "Railroads ... encouraged the direct shipment of hogs to eastern markets.

This development, which parallels the growth of long-distance traffic in wheat and corn, wrought steady if gradual effect of specialization."

Historians do not claim that specialization meant zero manufacturing output. Several point out that pockets (especially major cities like Cincinnati) were developing manufacturing industries. But even in these pockets, manufacturing output seems to have been dwarfed both by local agricultural output and by Northeast manufacturing output. Berry (p256) evaluates Cincinnati's manufacturing development thus: "In spite of this [Cincinnati industrial] progress, however, the leadership of Pittsburgh and other Eastern cities in the metal trades was not seriously challenged ... Cincinnati was dependent upon Pennsylvania for its iron during the period under survey [pre-1861], especially after improvements in domestic [i.e., non-foreign] production and transportation." And if urban manufacturing output in the Midwest seemed negligible, then its overall manufacturing output was probably negligible as well. Given this, one might ask what the nearly 500,000 non-agricultural workers that moved to the antebellum Midwest (see Table 3) did for a living. Historians answer that they supported agriculture in lots of non-manufacturing, non-agricultural tasks. North (p167) argues that "It was necessary to have substantial investment in transportation and other social overhead facilities in order to increase the supply of western staples. Canals, railroads, warehouses ... [and] retail trade all expanded."

Historians also do not claim that resource reallocation was particular to the Midwest. Thanks to its rising terms of trade and other factors, the Northeast was concentrating output in manufactures. North (p187) contends that "Concentration of manufacturing in the Northeast stemmed from a number of factors ... The growth of large urban centers, the development of a capital market, social overhead investment in transportation facilities, and the growing supply of labor--first from agriculture and then from immigrants." But although the Northeast was concentrating in manufactures, it does not appear to have specialized in them. In 1820 the Northeast had a significant agriculture industry, in large part because the Midwest was so small at the time. Although Northeast agriculture did not grow as fast as manufactures, it seems not to have shrunk enough relative to manufacturing for the Northeast to be considered specialized in manufactures.

To conclude, it seems reasonable to assume that the antebellum Midwest was specialized in agriculture. It should be pointed out, however, that this specialization was a temporary phenomenon. With the exploitation of Connellsville coal in the 1850's and of Lake Superior iron ore in the 1860's, the postbellum Midwest developed into America's manufacturing center.

A Model of Factor-Price Rigidity Across Regions

Midwest specialization can explain why antebellum factor prices were not equalizing. The essence of the explanation runs as follows. The data indicate that falling transportation costs improved the terms of trade in the Northeast and the Midwest: in the Northeast agricultural prices fell by more than manufacturing prices, and in the Midwest agricultural prices rose and manufacturing prices fell. In the Northeast, rising terms of trade led to rising wages and falling land rents--a standard application of the Stolper-Samuelson theorem. In the Midwest, the theorem would predict rising land rents and falling wages. But because Midwest production was specialized, the theorem does not apply there. Instead, rising agriculture prices led to both rising rents and rising wages.

Thus wages rise in both regions, and the observed wage rigidity can result. Because of specialization, commodity-price equalization does not induce the standard shifts in regional factor demands needed to equalize factor prices as well.

To elaborate this explanation, I will frame the analysis in a 2x2x2 model because it is the simplest framework which captures the essential aspects of the analysis. The model has two regions, Northeast (E) and Midwest (W); two goods, agriculture (A) and manufactures (M); and two factors, labor (L) and land (K), with respective factor prices w and r. Production technology for each good employs both factors under linear homogeneity; moreover, A employs K relatively intensively and M employs L relatively intensively. This production technology can be represented with unit-cost-function duals, $C_A(w,r)$ and $C_M(w,r)$. Transportation technology takes the form of "iceberg" shipping costs for food (see Samuelson (1954)).[13] When an amount m of agriculture is shipped, some of it "melts" in transit to pay for the shipping such that only a fraction tm arrives. Good A is non-tradable when t = 0, and it is freely traded when t = 1. Thus, the antebellum transportation revolution can be represented by $dt>0$. Given this transportation technology, arbitrage in goods trade ensures the following two equilibrium conditions.

$$(1)\quad P_{AW} = tP_{AE}$$

$$(2)\quad P_{MW} = P_{ME} = 1 \text{ by normalizing}$$

Finally, in light of the above discussion, assume that W specializes in A. Region E is endowed with L_E labor and K_E land; similarly, W is endowed with L_W labor and L_W

[13]Another transportation cost could also be applied to M, but it adds nothing to the analysis. Thus, for simplicity all transportation costs are subsumed into A. Empirically, falling transportation costs probably moved prices in agriculture more than manufactures because agricultural products were more bulky.

land. The specialization assumption requires that W's relative endowment lie outside the "cone of diversification" determined by the two production technologies. This means that (K_W/L_W) is sufficiently large that W cannot fully employ all its land using the integrated-equilibrium production techniques, and thus that W makes only A. In contrast, (K_E/L_E) lies within the cone of diversification such that E produces both goods.

Given this framework, the equilibrium production configuration in each region can be represented with the dual of the Lerner-Pearce diagram (see Mussa (1979) for a complete discussion of this diagram's versatility). Initially, consider the equilibrium in each region in 1820 at the start of the transportation revolution.

Figure 10 plots the initial equilibrium for region E in (w_E, r_E) space. The curve labeled "AA" is E's zero-profit locus for A which traces out combinations of w_E and r_E along which $P_{AE} = C_{AE}(w,r)$.[14] A rise in P_{AE} shifts the locus proportionately outward along every ray through the origin. Similarly, the curve labeled "MM" is E's zero-profit locus for M which traces out combinations of w_E and r_E along which $P_{ME} = 1 = C_{ME}(w,r)$. The MM locus has a steeper slope because M uses L relatively intensively. For each locus, the absolute value of its slope at a point equals the ratio of labor to land employed in that industry given that point's factor prices.

Because production technologies involve no factor-intensity reversals, the two loci intersect once and only once. The intersection point X determines the levels of w_E and

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[14]The equation which defines the $P_{AE} = C_{AE}(w,r)$ locus is given by $a_{LA}w_E + a_{KA}r_E = P_{AE}$. Here, a_{LA} and a_{KA} represent the amounts of labor and land needed to produce one unit of A. Where substitutability among factors is possible, these amounts are themselves functions of the factor prices. In particular, with linear homogeneous technology, they depend only on the ratio of factor prices. Thus, the curve is convex to the origin because as the wage-rental ratio rises A producers employ a higher mix of land to labor.

r_E which are consistent with positive production in both industries. At X, the relative-employment ratios in A and M are given by the rays $-(L/K)_A$ and $-(L/K)_M$, respectively. These rays form two cones which radiate in either direction from X; together they are the cone of diversification. If region E's aggregate relative endowment drawn through X lies within this cone, then E can produce both goods and still fully employ E's total endowment. In this case, X represents the equilibrium factor prices. E's endowment ray is drawn as $-(L_E/K_E)$, and because it does lie within the cone of diversification X represents E's equilibrium.

Figure 11 plots the initial equilibrium for region W in (w_W, r_W) space on the assumption that W was already specialized in agriculture in 1820. The AA locus represents combinations of w_W and r_W along which $P_{AW} = tP_{AE} = C_{AW}(w,r)$. Similarly, the MM locus represents combinations of w_W and r_W along which $P_{MW} = P_{ME} = 1 = C_{MW}(w,r)$. The main difference from the previous figure is that here, W's endowment ray $-(L_W/K_W)$ lies outside the cone of diversification. This means that production of both goods is inconsistent with full employment: W has too much K. To fully employ all this K, W must specialize in the K-intensive good, A. In this situation X does not represent the equilibrium factor prices. Instead, equilibrium is determined by the point Y at which the slope of the AA locus equals $-(L_W/K_W)$.

The effect of the transportation revolution on regional factor prices can be analyzed in these diagrams. Canals and railroads can be modeled as a rise in t towards one. Under very general technology and preference conditions in the model, this rise generates commodity-price equalization by raising $P_{AW} = tP_{AE}$ and lowering P_{AE}--just as was observed in the data.

The expenditure-revenue framework of Dixit and Norman (1980) can help demonstrate the generality of these conditions. Let there be one representative consumer and producer in each region, so that each region's consumption and production can be summarized in a single expenditure and revenue function, respectively. Moreover, thanks to identical preferences and technology across regions, functional forms are the same in both regions. Let the revenue function be given by r(prices, endowments), and the expenditure function by e(prices, utility). These functions are assumed to have standard properties (see Dixit and Norman, chapter 2). Let $v \equiv$ W's endowment vector, $V \equiv$ E's endowment vector, $u \equiv$ W's utility, $U \equiv$ E's utility, and $P \equiv P_{AE}$. Three equations (not four, thanks to Walras' law) can characterize the antebellum general equilibrium. First, expenditure equals revenue in W.

$$(3) \quad e(tP,1,u) = r(tP,1,v)$$

Here, values are measured in units of M. An analogous equation holds for E.

$$(4) \quad e(P,1,U) = r(P,1,V)$$

Finally, the system needs one goods-market clearing condition; without loss of generality, take good A. The point to remember when equating world supply and world demand for A is that some of it gets used up in transit from W to E as transportation costs. To quantify how much, let $m(tP,u) \equiv r_{tP}(tP,1,v) - e_{tP}(tP,1,u)$ be the amount of A that W exports to E. Then the fraction (1-t)m gets used up as transportation costs and cannot be consumed. The goods-market clearing condition which accounts for this amount looks like this:

$$(5) \quad e_{tP}(tP,1,u) + e_P(P,1,U) = r_{tP}(tP,1,v) + r_P(P,1,V) - (1-t)m(tP,u)$$

Again, the transportation revolution can be represented as $dt>0$. The question then becomes under what conditions does this $dt>0$ lead to $dP<0$. The conditions can easily be determined by totally differentiating equations (3)-(5) and solving them for dP. Appendix B does this, and it finds that $dP<0$ if and only if $e_P(\cdot)>r_P(\cdot)$, and moreover that this condition holds over a non-trivial range of P for any $e(\cdot)$ and $r(\cdot)$. Lower transportation costs allows trade to both lower the agricultural price in E and raise it in W. Thus, the historical fact that canals and railroads lowered P_{AE} and raised tP_{AE} is a result that holds in theory under quite general preference and technology conditions.

Figure 12 traces the effects in E of the fall in P_{AE}. The AA locus moves in to A'A'. The A'A' and MM loci intersect at X'; tangents of each locus drawn through this point form E's new cone of diversification. E's endowment ray $-(L_E/K_E)$ through X' lies within this cone, so E remains diversified and X' represents E's new equilibrium. At X', r_E has fallen to r_E' and w_E has risen to w_E'. This is the standard Stolper-Samuelson result: resources shift across industries as relatives prices move, and this shifts relative factor demands and thus factor prices. Regionwide, the demand for the factor used relatively intensively in manufacturing, labor, increases and the demand for the factor used relatively unintensively in manufacturing, land, decreases.

Figure 13 traces the effects in W of the rise in tP_{AE}. The AA locus moves out to A'A'. A'A' intersects MM at X', but W's aggregate endowment ray $-(L_W/K_W)$ lies outside the cone of diversification at X'. Thus, W remains specialized in agriculture, and its new equilibrium is determined by the point Y' at which the slope of the A'A' locus equals $-(L_W/K_W)$.[15] At Y', both factor prices are have risen: r_W to r_W', and w_W to w_W'.

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[15]Because the production technology underlying the various AA loci is linear homogeneous, slopes of these loci are constant along rays extended along rays from the origin. Thus, because the endowment ray has the same slope at Y and Y', Y' can be found along A'A' by extending a ray from the origin through

Because of specialization, the rise in tP_{AE} does not induce a Stolper-Samuelson shift in factor demands away from labor and toward land. Instead, demand for both factors rises and thus the price of both factors rises. To see this algebraically, remember that each factor in Midwest A production receives a price equal to its marginal revenue product, which equals tP_{AE} multiplied by the factor's marginal physical product (mpp). Across equilibria, the mpp's are fixed because total W endowment is always employed in agriculture and because linear-homogeneous agriculture technology implies that mpp's depend only on relative factor employment (see Appendix A on this point). So a higher tP_{AE} immediately raises the price of both factors.

Thus, figures 12 and 13 demonstrate that the transportation revolution raises nominal wages in both E and W. As a result, the ratio (w_E/w_W) can remain constant. Thus, the puzzle of why commodity-price equalization did not lead to factor-price equalization is explained by specialization in W.

Extensions of the Model

At least three other empirical facts about antebellum America can be incorporated into this framework as well.

First is the regional differences in the levels of wages. The data indicate that artisan and laborer wages were approximately 20% higher in the Midwest while clerical wages were approximately 40% higher in the Northeast. The model assumes that $(K_W/L_W) > (K_E/L_E)$: W is relatively well endowed in land while E is relatively well endowed in labor. This endowment difference implies that before the transportation revolution starts (i.e., under autarky), $w_W > w_E$ and $r_W < r_E$. The fact that artisan and

Y. In Figure 13, the ray extended from the origin demonstrates this point.

laborer wages are initially higher in the Midwest is consistent with this model. However, the model cannot explain why clerical wages were higher in the Northeast rather than the Midwest.

A second antebellum fact which can be explained in this framework is the fact that regional interest rates were diverging. In the Lerner-Pearce diagrams, r can be interpreted as a rate of return on all bank assets. The diagrams predict that canals and railroads should raise r_W and lower r_E, and initial regional endowments predict that in 1820 $r_E > r_W$. Together, these predictions imply that regional interest rates should have been converging. However, Bodenhorn and Rockoff (1992) give reason to believe that in 1820 $r_W > r_E$. Their data indicate that as far back as 1830, $r_W > r_E$, not vice versa. They call this premium a "frontier effect," and attribute it in part to the greater monitoring costs of Midwestern investments. Thus, if $r_W > r_E$ initially, then the Lerner-Pearce diagrams predict that canals and railroads should have triggered even greater divergence. This is exactly what the Bodenhorn and Rockoff data show.

The third empirical fact of antebellum America which can be incorporated into the Lerner-Pearce framework is the production implications factor accumulation. As (K_W/L_W) changes, the $-(L_W/K_W)$ ray in Figure 13 rotates. When drawn through X, if the ray moves back into the cone of diversification, manufacturing production begins. I have assumed that this did not occur--i.e., that land accumulation was sufficient to keep the $-(L_W/K_W)$ ray below the cone of diversification. Thus, specialized production continues at points such as Y'. As unbalanced accumulation occurs, however, Y' shifts. For example relatively greater labor accumulation would steepen the $-(L_W/K_W)$ ray and thereby slide Y' up and to the left. This would dampen the rise in w_W and would reinforce the rise in r_w. The geometry of Figure 13 makes clear that given the shift in the AA locus out to A'A' caused by the transportation revolution, there exists a range of shifts in (K_w/L_w) which will be insufficient to completely offset either of the factor-price rises triggered by the shift to A'A'. Thus, although no land-supply data exist to determine the nature of Midwest factor accumulation, the Lerner-Pearce framework clarifies how unbalanced factor accumulation can be consistent with all Midwest factor prices rising.

5 Conclusion

This paper has tried to fill a gap in the empirical international-trade literature by studying whether the construction of canals and railroads in antebellum America equalized factor prices between the Northeast and the Midwest. My primary finding is that canals and railroads generated strong commodity-price equalization across regions, but that this equalization did not lead to FPE. This result can be explained by the fact that the Midwest was specialized in agriculture production. Thus, the transportation revolution was realizing one of the FPE theorem's usual assumptions, zero trade barriers. But a second assumption, no regional specialization of production, was not being realized, and this prevented factor prices from equalizing.

This result does not ratify Caves' claim that the FPE theorem is "a supreme example of non-operational theorizing." Instead, it underscores the theorem's complexity. Several assumptions, not just one, need to hold empirically to realize FPE. This complexity should be remembered for policy considerations as well. When Ross Perot forebodes that NAFTA will equalize American and Mexican hourly wages at $5.00, he is almost certainly oversimplifying things. Indeed, relative to each other Mexico and

America are each specialized in a large number of goods. The patterns of integration in antebellum America may therefore be very relevant for post-NAFTA North America in a way that proves Ross Perot wrong.

Appendix A: FPE and Convergence of Nominal Wages Across Regions

The FPE theorem is often stated in terms of real factor prices. For example, Samuelson's (1949) definitive statement of the FPE theorem talks about real returns: "Under these [aforementioned] conditions, real factor prices must be exactly the same in both countries." But both the body of his paper and its mathematical proof of the theorem deal with nominal returns, not real ones. For empirical work on FPE, it is important to understand that in a wide class of models, the theorem implies cross-country equalization of nominal factor prices.

This appendix proves one (of many) set of standard conditions under which equalization in levels of commodity prices across regions leads to equalization in levels of nominal factor prices across regions. Consider two regions, 1 and 2; two goods, A and B; and two factors of production, L and K, which receive respective factor payments w and r and which are perfectly mobile across industries within each region. Production technology for each good is identical across both regions and is linear homogeneous in the inputs. Linear homogeneity implies two crucial facts for the proof (see Varian's (1984) mathematical appendix for a discussion of linear homogeneity). The first is that the slopes of production isoquants in (L,K) space are constant along rays extending from the origin. This actually requires only that the production functions be homothetic, but all homogeneous functions are homothetic as well. The second is that marginal physical productivities for each good depend only on the ratio of factors employed and not their levels. This is a simple application of Euler's Theorem.

This setup is a standard one under which FPE is proved: for example, it is used in Samuelson (1948, 1949) and several undergraduate and graduate texts. However, references often times do not clearly prove the issue at hand. To do so, start with the claim that under sufficient assumptions, free trade's equalization of relative commodity prices across 1 and 2 implies equalization of relative factor prices across 1 and 2: $(w/r)_1 = (w/r)_2$. Samuelson (1949) proves this one-to-one mapping from relative commodity prices to relative factor prices diagrammatically; Jones (1965) proves it algebraically. But this statement in and of itself is not what is trying to be proved.

This statement needs to be combined with the two technology facts. $(w/r)_1 = (w/r)_2$ plus the first fact implies that relative factor employment in each industry is equalized across 1 and 2: $(K/L)_{1A} = (K/L)_{2A}$ and $(K/L)_{1B} = (K/L)_{2B}$.[16] This statement plus the second fact implies that the levels of marginal physical productivities (mpp) for each factor in each industry are equalized across 1 and 2: $mpp_{ij1} = mpp_{ij2}$ for $i = L,K$ and $j = A, B$. Each factor's nominal wage in industry j is its marginal revenue product in that industry: $P_j \times mpp_{ij}$. It is now known that the mpp_{ij}'s are equalized across regions, and it is also known that free trade equalizes the P_j's across regions. It immediately follows that nominal wages in each industry are equalized across regions. And thanks to perfect inter-industry factor mobility, nominal wages in each region are equalized across industries. Thus, one world nominal wage and one world nominal rental rate result under free trade.

This proof demonstrates that one reasonable empirical test for FPE is whether nominal factor prices are equalizing across regions. This is the test used in Section 2.

[16]This statement plus the fact that average productivity in each industry depends only on relative factor employment (thanks to linear homogeneity of technology) leads to equalized average productivities in each industry across 1 and 2. This result is what Baumol, Dollar, and Wolff (1988) test. See Section 1 for a description of their work.

Appendix B: Transportation Costs in General Equilibrium

As discussed in the text, the fall in transportation costs triggered by canals and railroads did in fact lead to lower food prices in the Northeast and higher food prices in the Midwest. This appendix completes the demonstration laid out in the text that this empirical fact holds in theory under very general conditions. Equations (3)-(5) describe the general-equilibrium conditions between the two regions.

$$(3) \quad e(tP,1,u) = r(tP,1,v)$$

$$(4) \quad e(P,1,U) = r(P,1,V)$$

$$(5) \quad e_{tP}(tP,1,u) + e_P(P,1,U) = r_{tP}(tP,1,v) + r_P(P,1,V) - (1-t)m(tP,u)$$

To show under what conditions $dt>0$ leads to $dP>0$, totally differentiate (3)-(5) and solve for dP. Total differentiation yields the following equations.

$$(3') \quad e_{tP}(tdP+Pdt) + e_u du = r_{tP}(tdP+Pdt)$$

$$(4') \quad e_P dP + e_U dU = r_P dP$$

$$(5') \quad e_{tPtP}(tdP+Pdt) + e_{tPu}du + e_{PP}dP + e_{PU}dU =$$

$$r_{tPtP}(tdP+Pdt) + r_{PP}dP + (t-1)m_{tP}(tdP+Pdt) + (t-1)m_u du + mdt$$

Equations (3')-(5') contain three endogenous variables: du, dU, and dP. Solving for dP generates the following expression.

$$dP=\frac{dt*P(r_{tPtP}-e_{tPtP})+dt*\frac{Pe_{tPu}(e_{tP}-r_{tP})}{e_u}+dt*P(t-1)m_{tP}+dt*\frac{P(t-1)m_u(r_{tP}-e_{tP})}{e_u}+dt*m}{t(e_{tPtP}-r_{tPtP})+(e_{PP}-r_{PP})+\frac{te_{tPu}(r_{tP}-e_{tP})}{e_u}+\frac{e_{Pu}(r_P-e_P)}{e_u}+t(1-t)m_{tP}+\frac{t(1-t)m_u(r_{tP}-e_{tP})}{e_u}}$$

The expenditure and revenue functions have the following properties: $e_P > 0$, $e_{PP} > 0$, $e_u > 0$, $e_{Pu} > 0$, $r_P > 0$, and $r_{PP} > 0$. Moreover, differentiating m(·) and using these properties shows that $m_{tP} = (r_{tPtP} - e_{tPtP}) < 0$ and $m_u = -e_{tPu} < 0$. With this information, the expression for dP can be signed. It can be shown that $dP > 0$ if and only if $e_P > r_P$. Because e(·) is concave in P and r(·) is convex in P, this condition clearly holds over some range of P for any functional form of e(·) and r(·). Thus, $dt > 0$ leads to $dP < 0$ under these very general conditions. The only remaining point to demonstrate is that the Midwest price of agriculture, $P_{AW} \equiv tP$, declines. Totally differentiating this expression yields $dP_{AW} = tdP + Pdt$. On the right-hand side, the first term is negative and the second term is positive. Thus, $dP_{AW} < 0$ requires $Pdt > (-tdP)$.

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Table 1: American Canal and Railroad Mileage by Decades

Year	Canal Mileage	Railroad Mileage
1830	1277	73
1840	3326	3328
1850	3698	8879
1860	4000+	30,636

Source: Taylor (1951).

Table 2: Coefficients of Variation for the Wage-Ratio Series

Period	Artisan-Ratio C.V.	Clerical-Ratio C.V.	Laborer-Ratio C.V.
1820-1832	.146	.126	.135
1833-1844	.152	.066	.144
1845-1856	.142	.128	.061

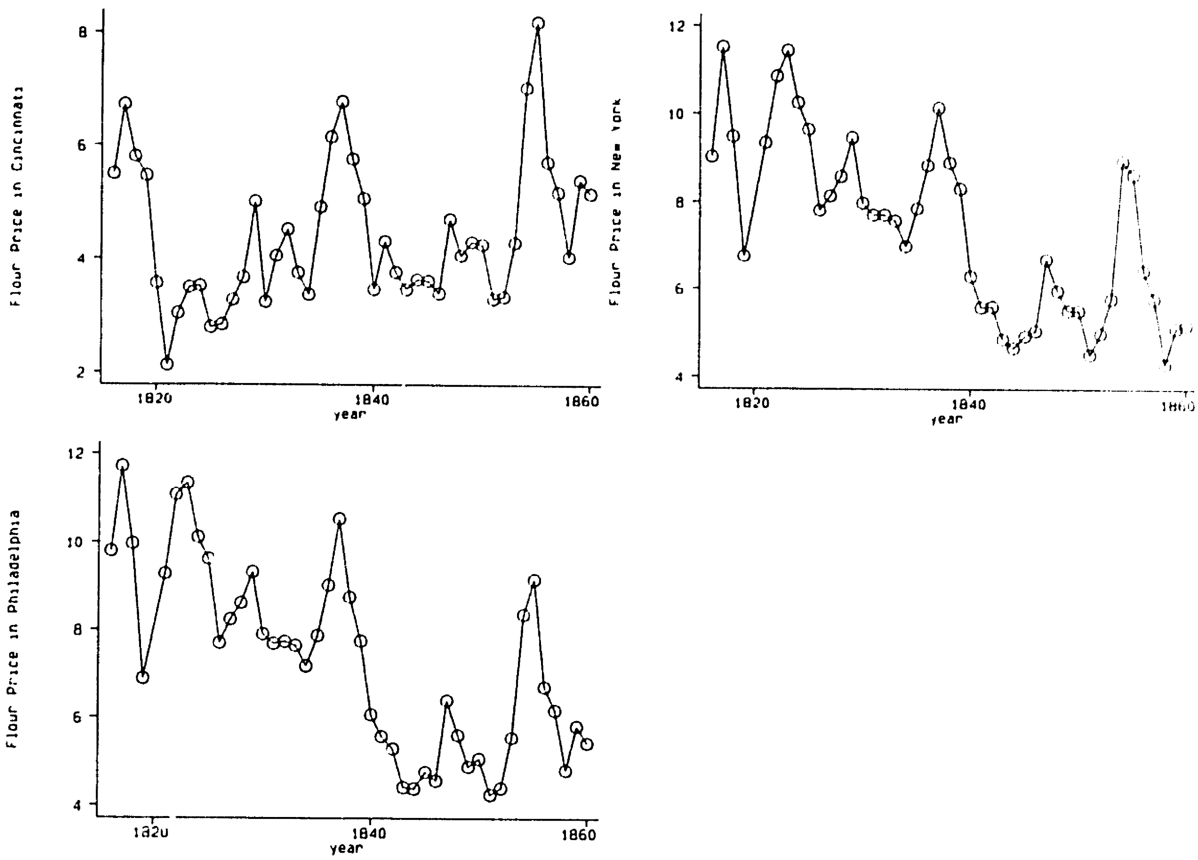
Source: Margo and Villaflor (1987), Goldin and Margo (1992).
The wage-ratio series are plotted in Figure 8.

Table 3: Labor Forces in the Northeast and the Midwest

Labor Force	1820 Size	1860 Size	Annual Growth (%)
NE Total	929,558	2,778,745	2.74
MW Total	219,246	2,727,847	6.30
NE Agricultural	572,684	967,994	1.31
MW Agricultural	172,297	2,206,254	6.37
NE Non-agr.	356,874	1,810,751	4.06
MW Non-agr.	46,949	521,593	6.02

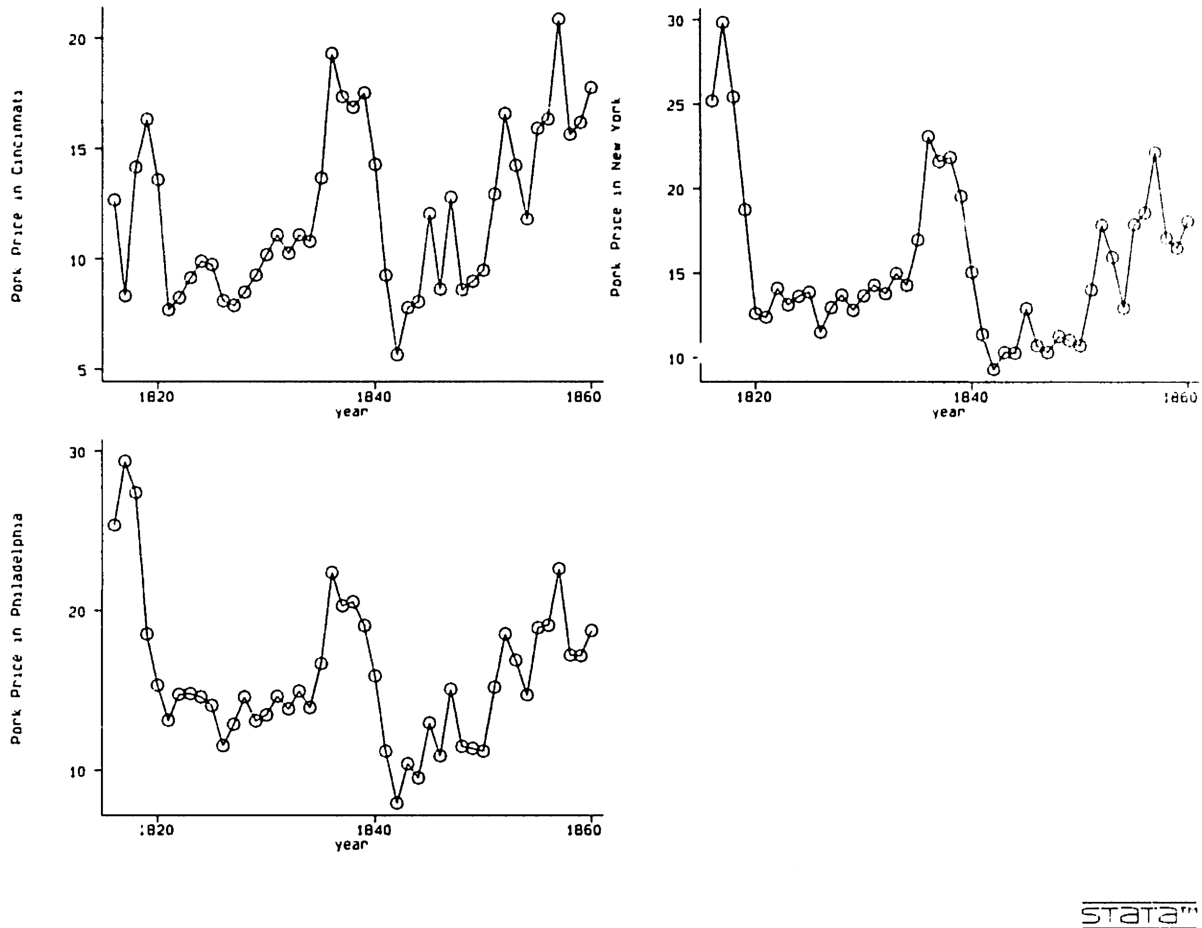
Source: Weiss (1994).

Figure 1: Nominal Flour Prices in Three Cities



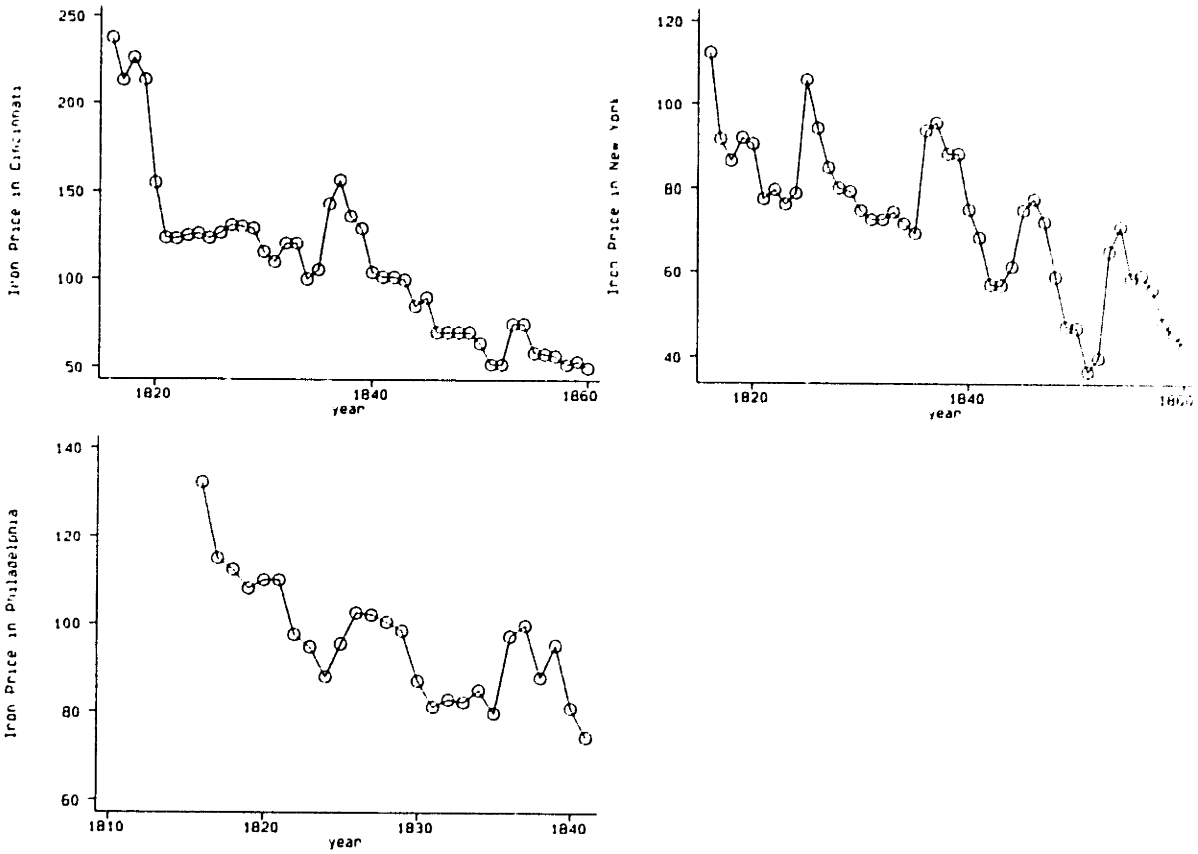
Source: Cole (1938)

Figure 2: Nominal Pork Prices in Three Cities



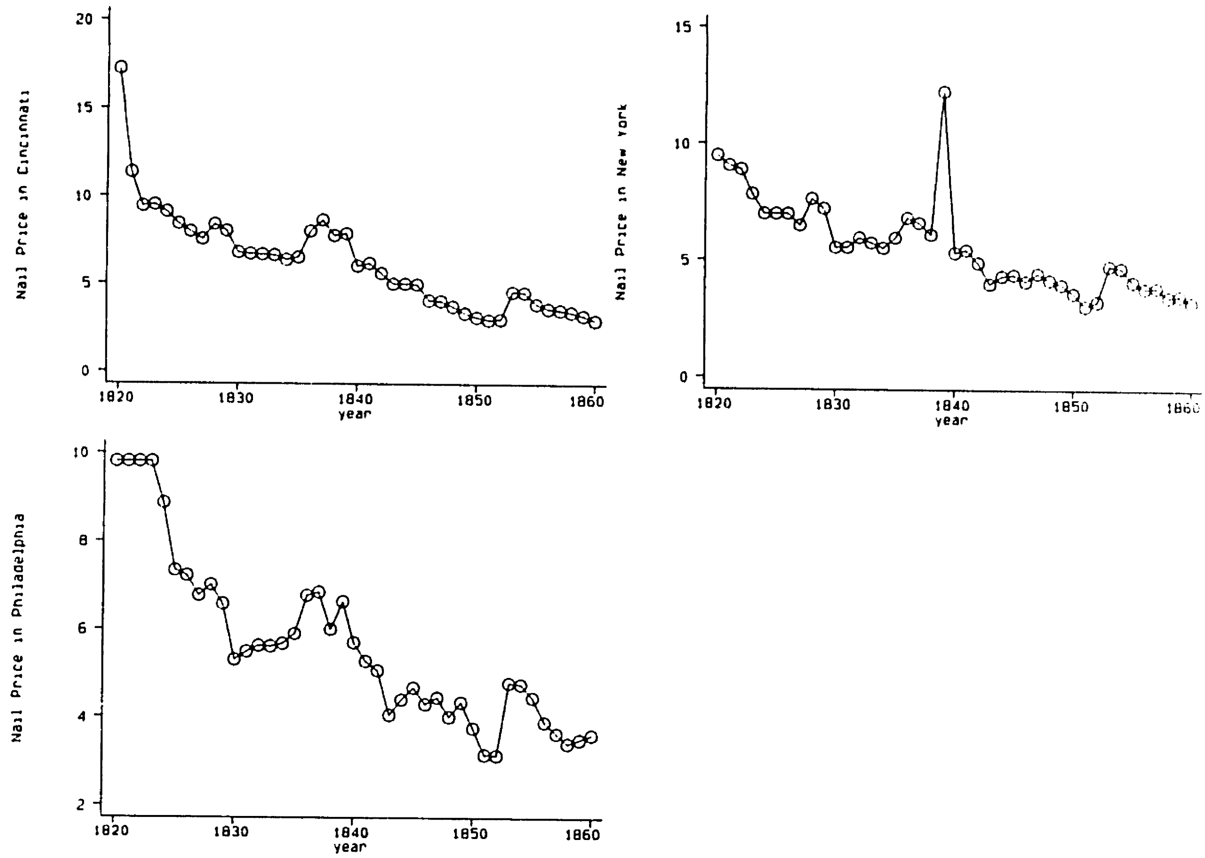
Source: Cole (1938)

Figure 3: Nominal Iron Prices in Three Cities



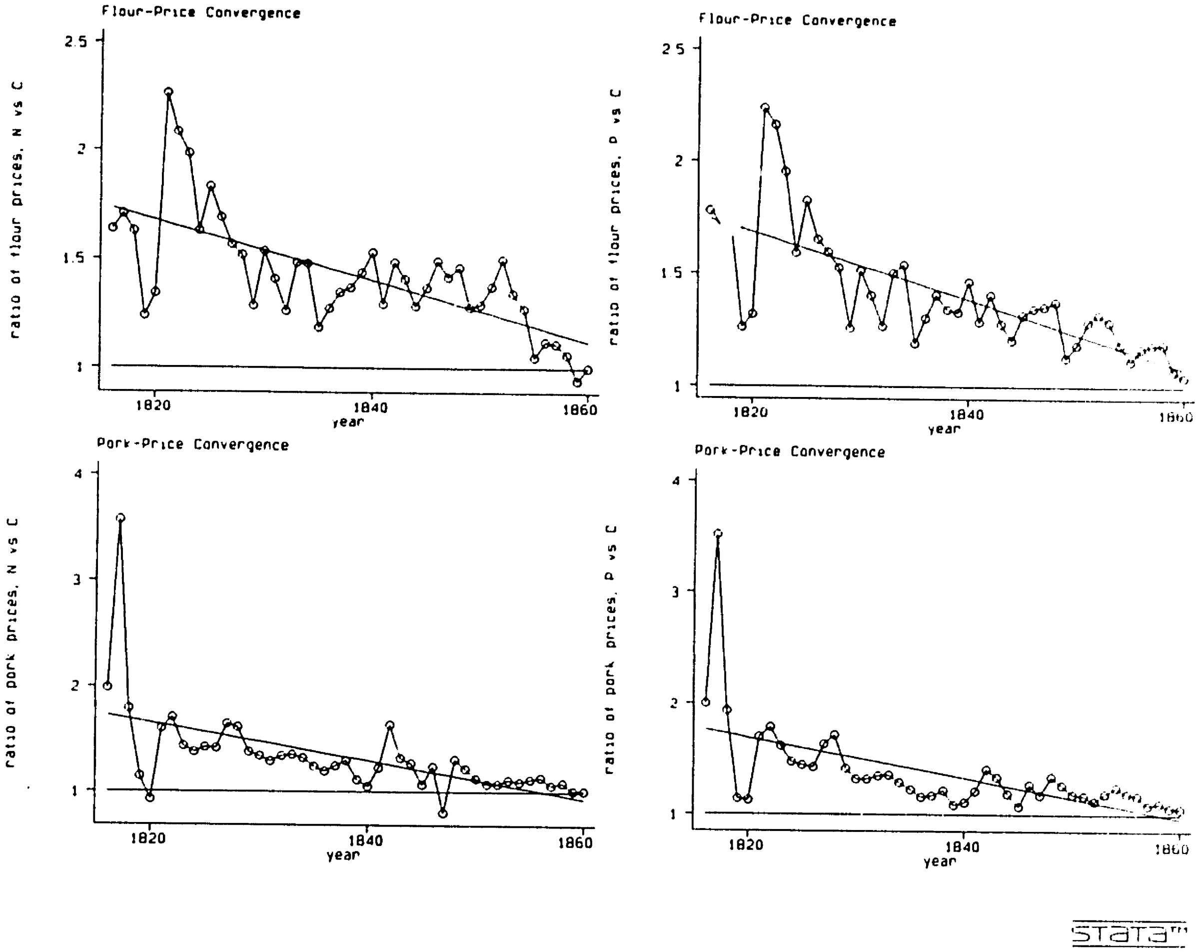
Source: Cole (1938)

Figure 4: Nominal Nail Prices in Three Cities



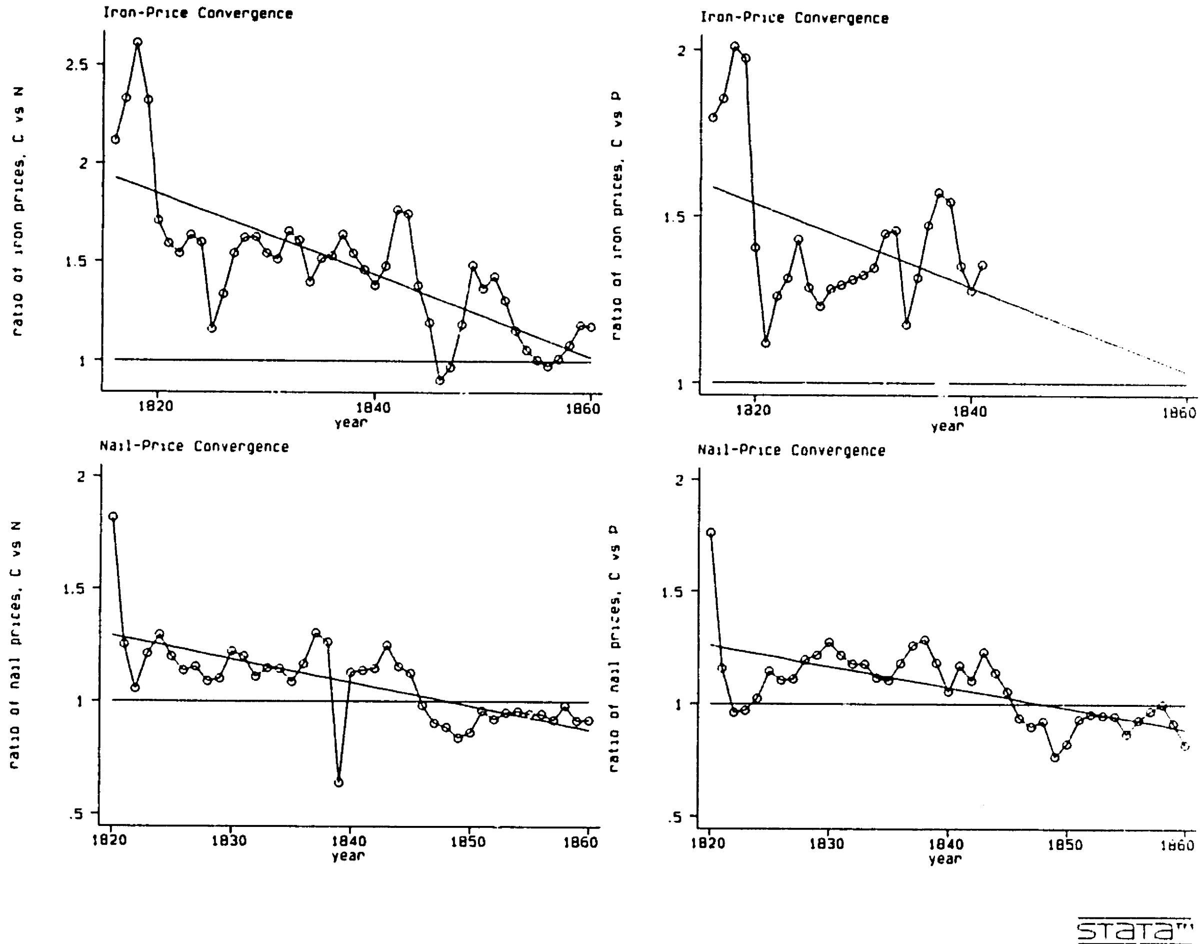
Source: Cole (1938)

Figure 5: Agricultural-Price Convergence Between Northeast and Midwest



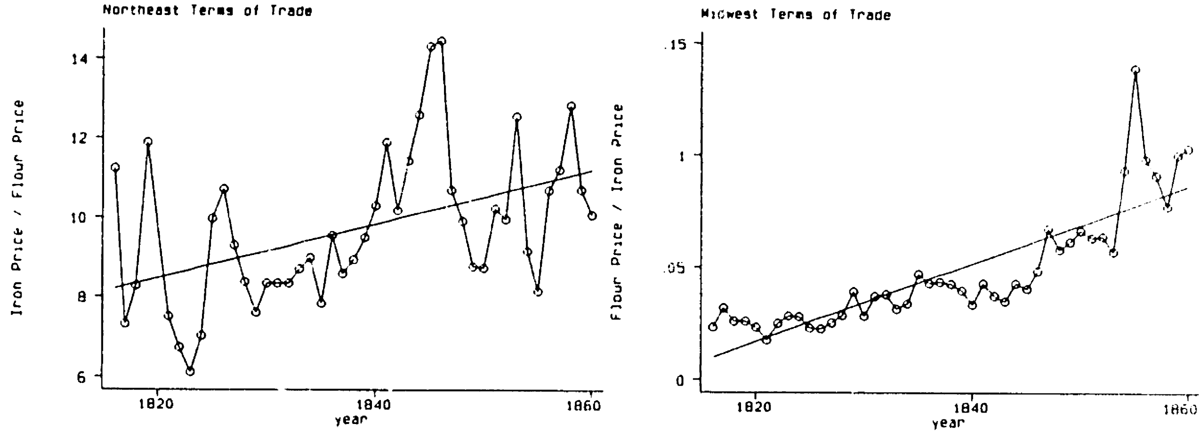
Source: Cole (1938)

Figure 6: Manufacturing-Price Convergence Between Northeast and Midwest



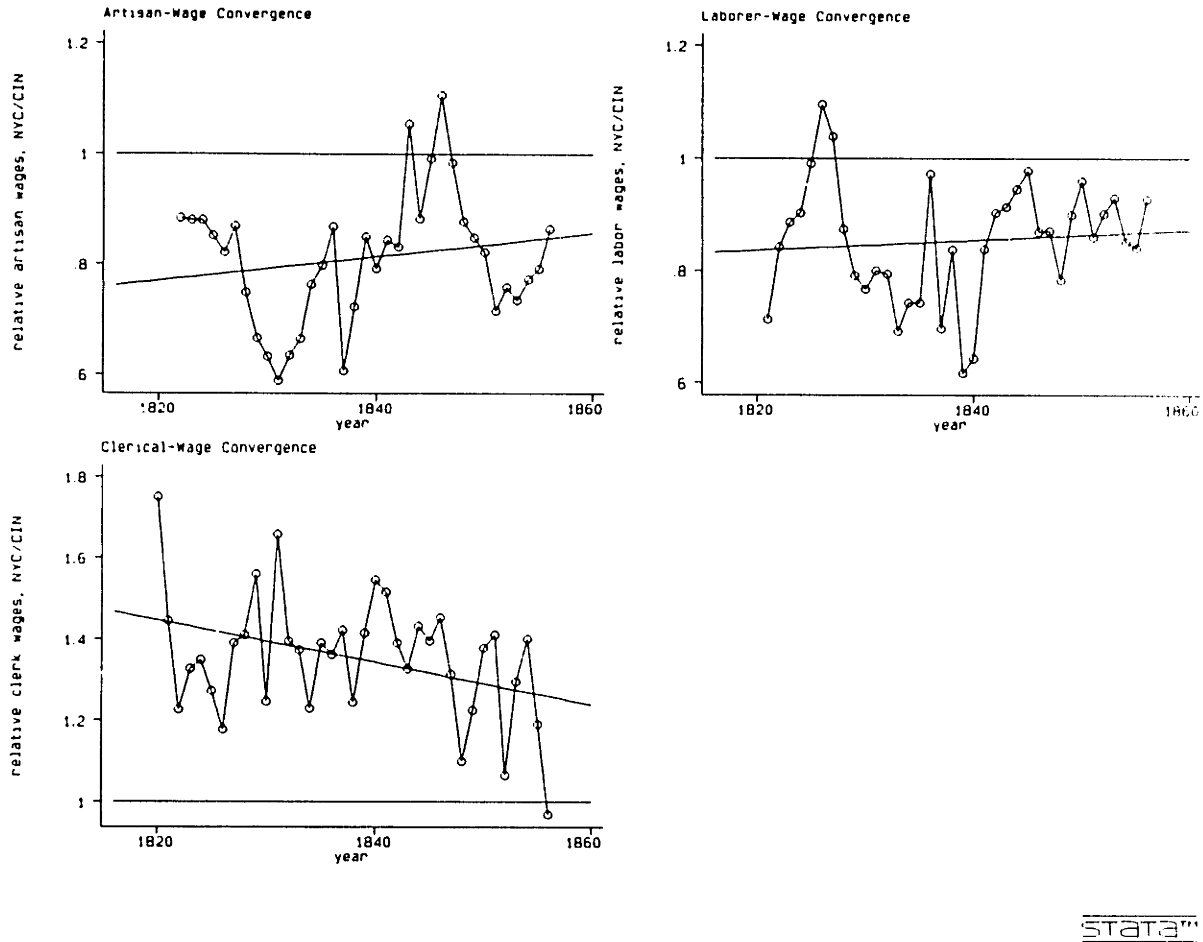
Source: Cole (1938)

Figure 7: Regional Terms of Trade



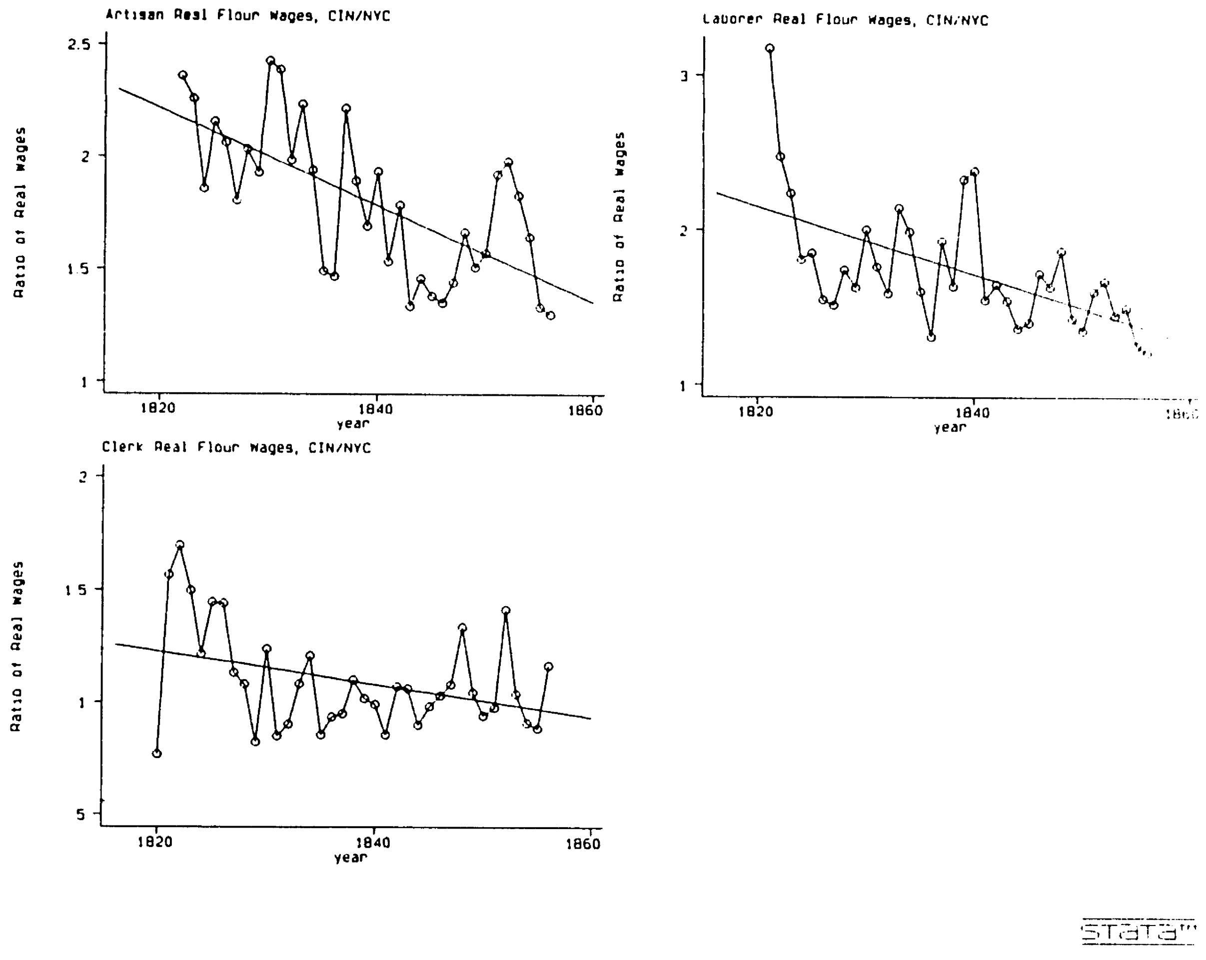
Source: Cole (1938)

Figure 8: Nominal-Wage Rigidity Between Northeast and Midwest



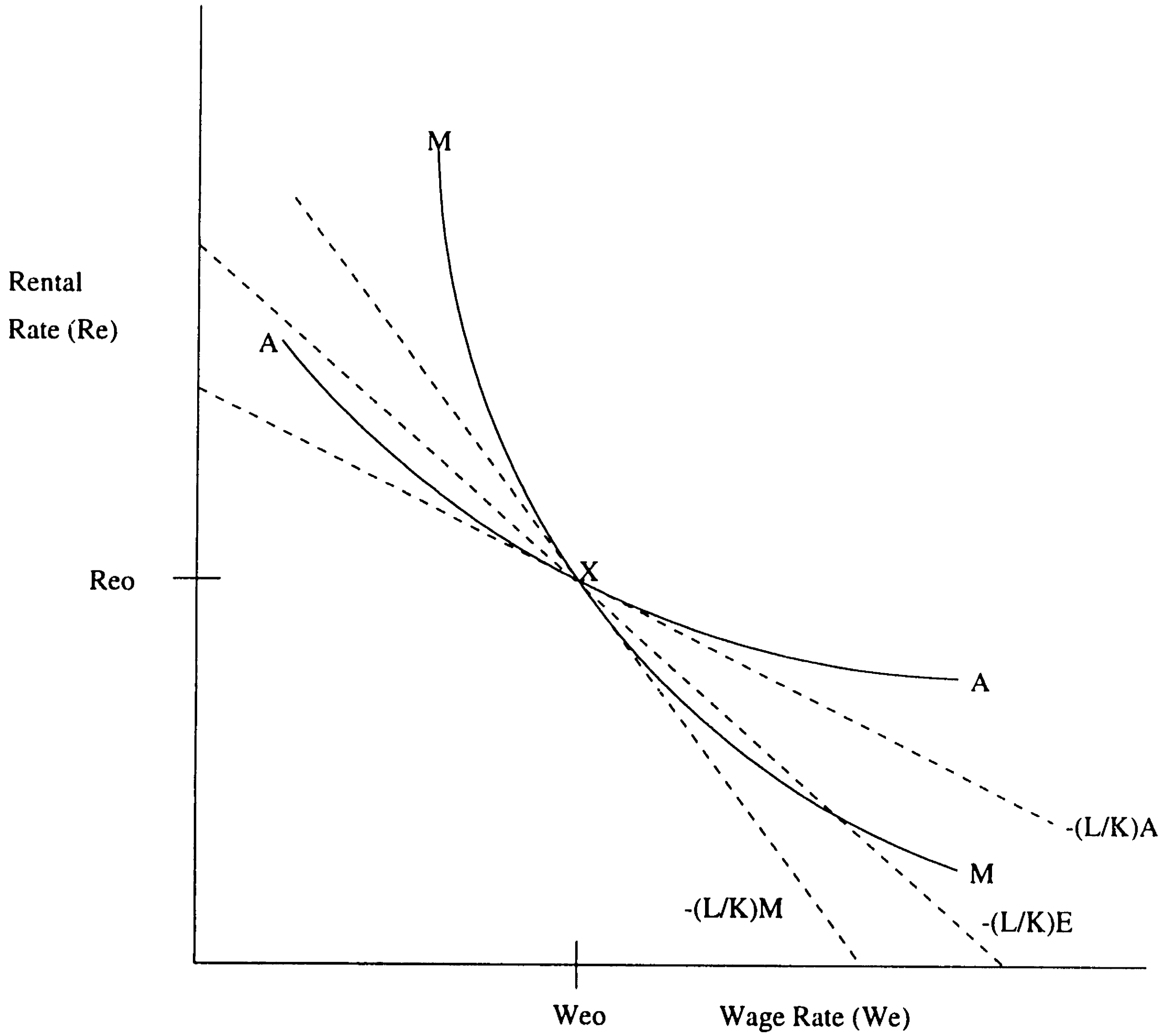
Source: Margo and Villaflor (1987), Goldin and Margo (1989)

Figure 9: Real-Wage Convergence Between Northeast and Midwest



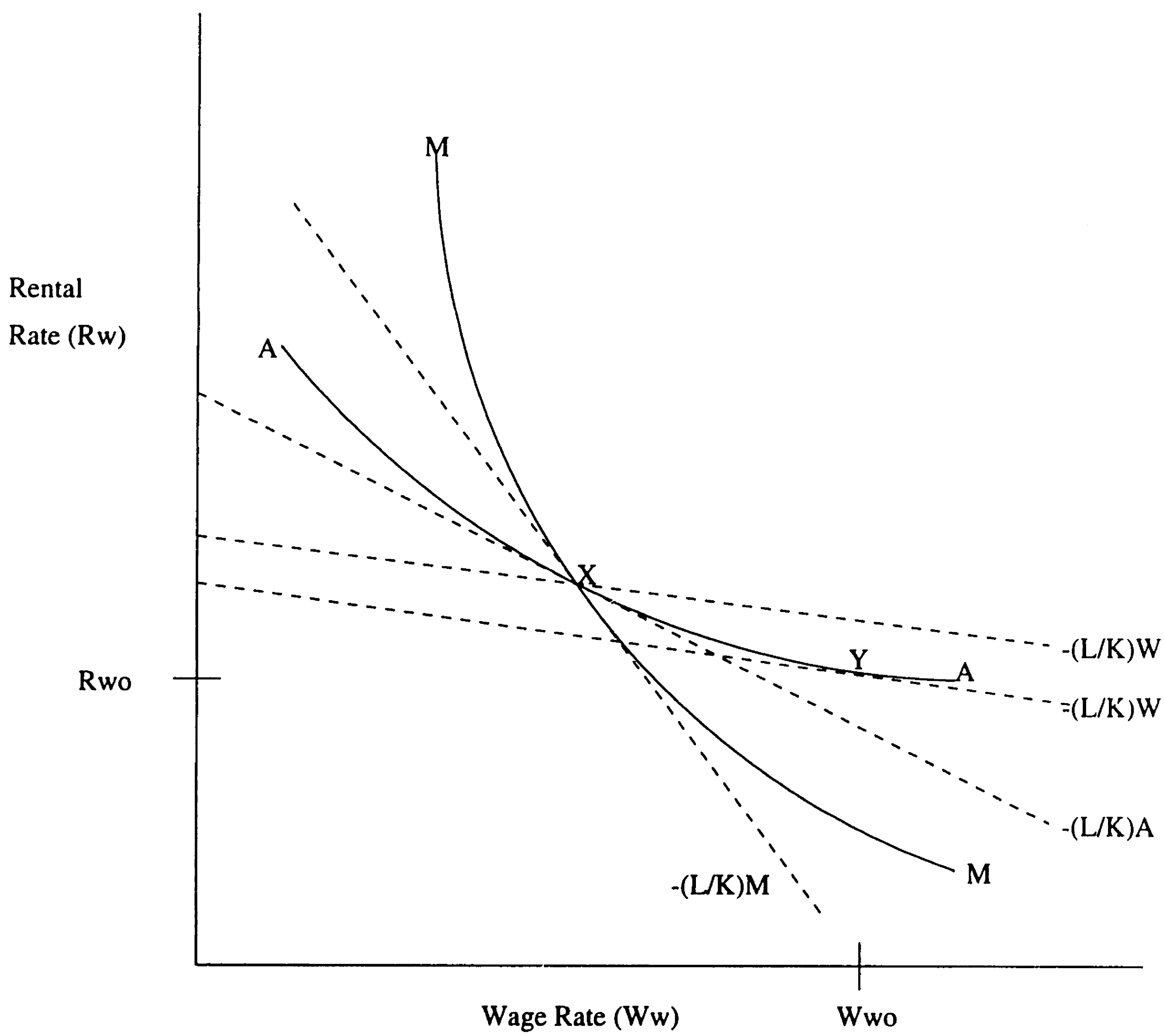
Source: Cole (1938), Margo and Villaflor (1987), Goldin and Margo (1989)

Figure 10: Lerner-Pearce Diagram of Initial Northeast Equilibrium



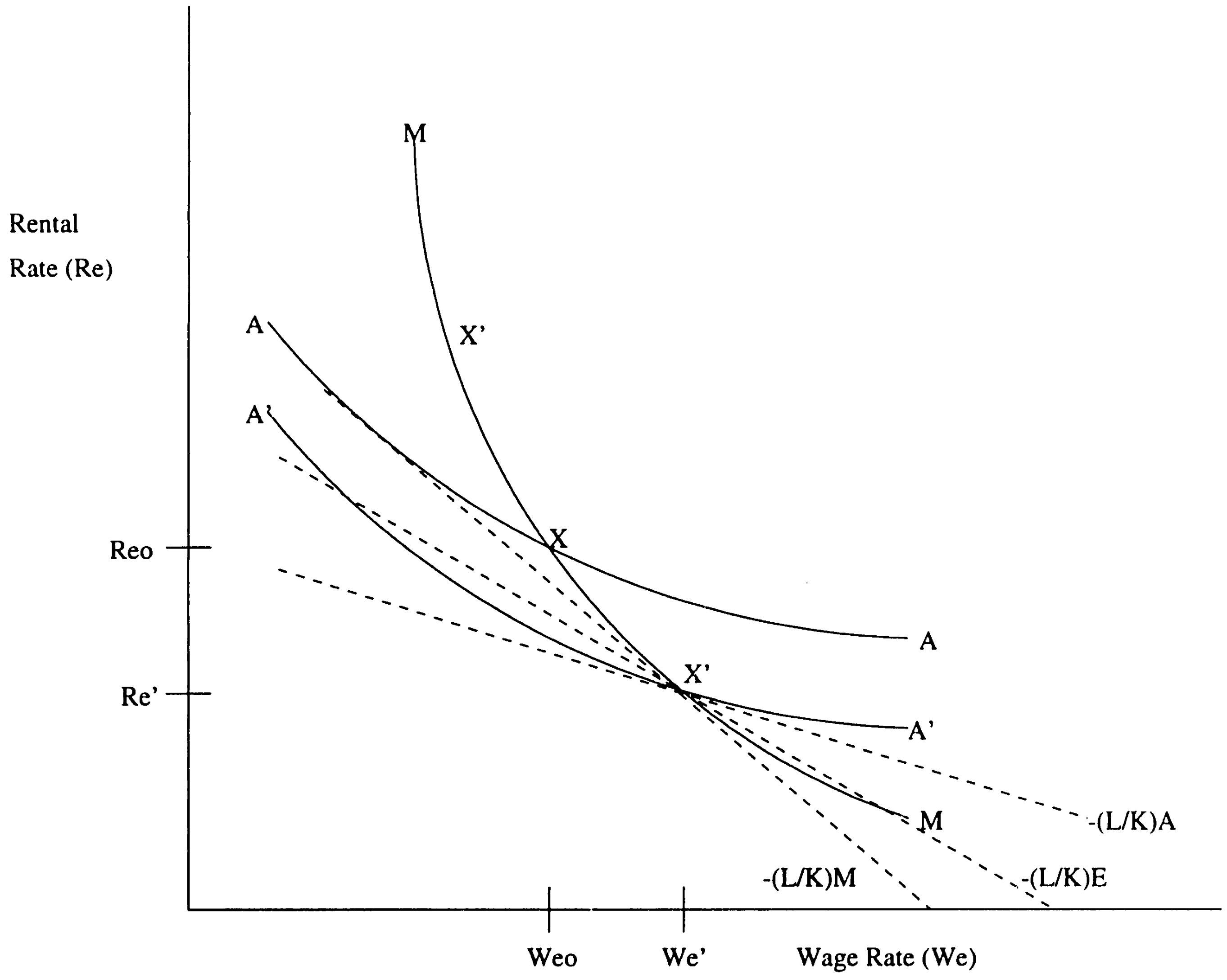
AA is the zero-profit locus for agriculture.
MM is the zero-profit locus for manufacturing.
Because the endowment ray $(L/K)_E$ lies within the cone of diversification, the initial equilibrium lies at point X.

Figure 11: Lerner-Pearce Diagram of Initial Midwest Equilibrium



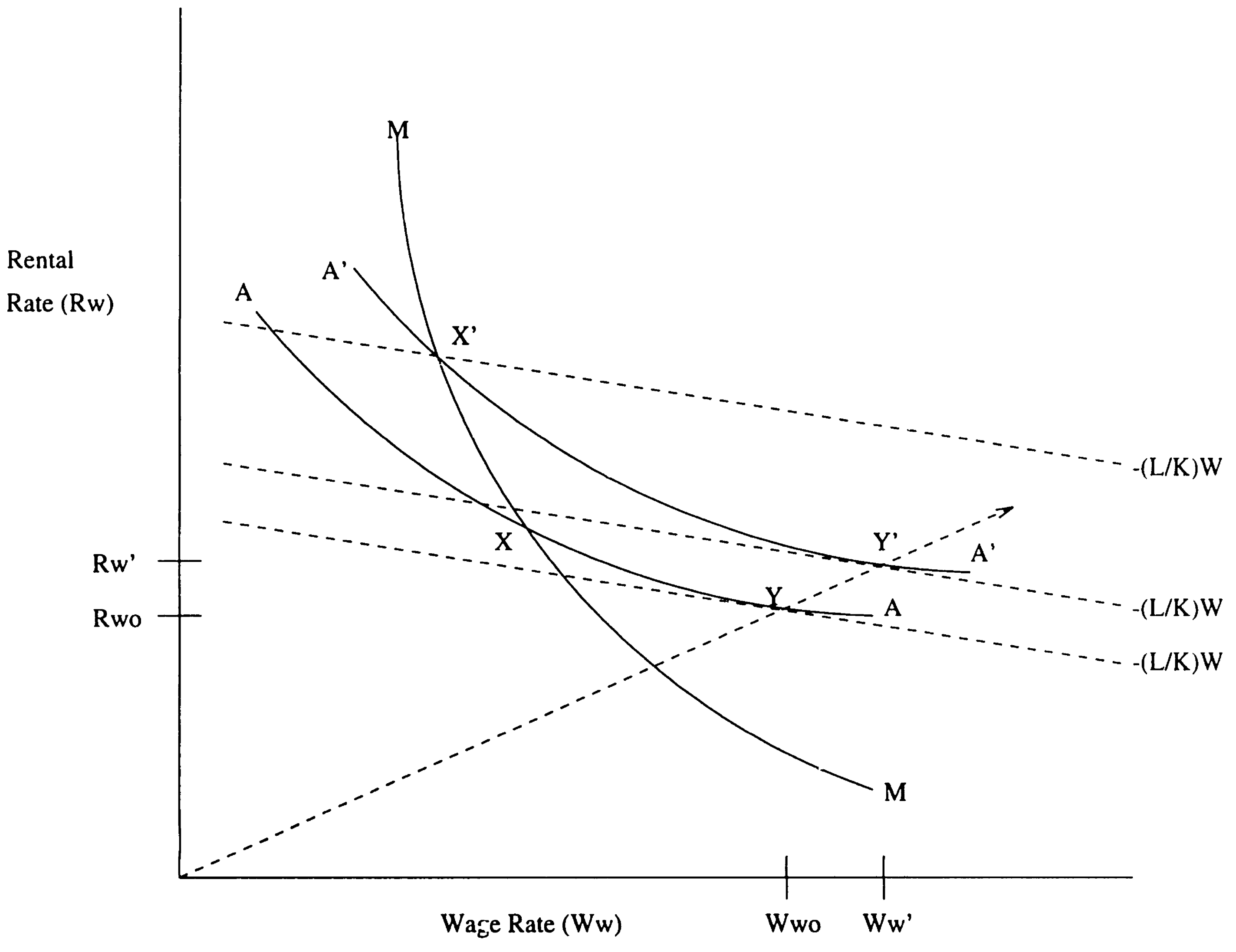
AA is the zero-profit locus for agriculture.
MM is the zero-profit locus for manufacturing.
Because the endowment ray $(L/K)_E$ lies outside the cone of diversification, the initial equilibrium lies at point Y.

Figure 12: Lerner-Pearce Diagram of Final Northeast Equilibrium



The fall in Northeast agriculture prices shifts the AA locus in to A'A'.
The new equilibrium is at point X': the rental rate falls, and the wage rate rises.

Figure 13: Lerner-Pearce Diagram of Final Midwest Equilibrium



The rise in Midwest agriculture prices shifts the AA locus out to A'A'.
The new equilibrium is at point Y': both the rental rate and the wage rate rise.