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ABSTRACT

Shifts in US Relative Wages: The Role of Trade, Technology and Factor Endowments*

This paper investigates three hypotheses to account for the observed shifts in US relative wages of less educated workers compared to more educated workers from 1967–92: (i) increased import competition; (ii) changes in the relative supplies of labour of different educational levels; and (iii) changes in technology. Our analysis relies on a basic relationship of the standard general equilibrium trade model, that relates changes in product prices to factor price changes and factor shares, together with information about changes in the composition of output, trade, within-industry factor use and factor supplies. We find support for the hypothesis that the relative increase in the supply of well-educated labour was the dominant economic force that narrowed the wage gap in the late 1960s and early 1970s. Our results also indicate that technical progress rather than increased import competition was the dominant force in the widening of the wage gap among the major education groups after 1980.

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NON-TECHNICAL SUMMARY

There is widespread disagreement among economists concerning the role of international trade in accounting for the wage decline of less-educated compared to more-educated US workers since the late 1970s. A drawback of most of the studies on this subject is their reliance on a partial rather than a general equilibrium framework. This paper utilizes the standard general equilibrium model of trade economists to review the analysis in some of the earlier studies and then to investigate empirically, not only the impact of trade on relative wages, but also the role of changes in technology and in relative factor endowments in bringing about shifts in relative US wages from 1967 to 1992. Two empirical exercises are undertaken in studying these possible causes of shifts in relative wages. One is based on a simple general equilibrium relationship between proportional changes in product prices and proportional changes in factor prices that must hold under the zero-profit condition of perfectly competitive models. A second estimates the effects of changes in trading patterns and factor endowments (with fixed technology) on relative factor prices by analysing changes in the factor content of trade instead of changes in product prices. While this procedure is only appropriate under special assumptions, it serves as a check on the robustness of the underlying trade model.

In a general equilibrium model with perfect competition, unchanged constant returns-to-scale technology and perfect internal factor mobility, changes in relative factor prices take place only in conjunction with changes in relative product prices. In such a model a unique relationship between small changes in factor and product prices exists – for small changes in factor prices, the relative change in the price of any good is equal to the weighted sum of the relative changes in the prices of the productive factors used in producing the good, where the weights are the distributive shares of the respective factors used in producing a unit value of the good. This relationship can be used to estimate proportional changes in factor prices under unchanged technological conditions by regressing observed relative changes in product prices across industries in a given period on known industry factor shares, where the regression coefficients are estimates of the proportional changes in factor prices. In sorting out various hypotheses concerning the main causes of observed changes in factor prices, we also focus on three additional variables: (i) output changes in industries intensively using highly-educated labour compared with output changes in industries intensively using less-educated labour; (ii) changes in the within-industry use in production of highly-educated

compared with less-educated labour; and (iii) changes among highly-educated labour-intensive industries compared with less-educated labour-intensive industries in net exports relative to consumption of an industry's products.

In determining whether increased import competition or changes in the supply of highly-educated relative to less-educated labour could have been the dominant factor influencing relative wages in a particular time period, we test for the consistency of the parameter estimates from the price regressions and changes in the other variables with the predictions from the trade model of how these economic forces are expected to affect relative wages and the other variables. The trade model is also used as a basis for predictions about the effects of domestic technological change on factor prices. Changes in technology can change factor prices without changing product prices, although if product prices change – as they will if the country is large enough that its changes in outputs of traded goods affect international product prices – then these changes in relative product prices will also affect relative factor prices. Consequently, the factor share coefficients estimated from regressions of changes in product prices on factor shares will not be accurate predictors of the actual proportionate changes in nominal wages. However, the biases in the regression coefficients due to various types of technological progress, suggested as important determinants of the actual factor price changes, can be inferred from the trade model, and the factor share coefficients estimated from the price regressions can be checked for consistency with the coefficients theoretically predicted as a consequence of the total influence of assumed changes in domestic technology.

The basic units for empirical analysis are 79 two-digit industries in the input-output tables of the Bureau of Economic Analysis. The prices of the goods and services produced in these industries are from the Bureau of Labour Statistics (BLS). The labour factors of production are classified into three education groups: workers with 1–11, 12 and 13-or-more years of schooling. Factor shares for workers with these education levels are calculated from several sources: the direct and indirect labour coefficients from the input-output tables, the division of value added in each input-output sector between employee compensation and property resources, BLS employment data for each industry, and the education and wages of workers by industry from the March Current Population Survey of the Bureau of the Census. Three time periods are covered: 1968–73, 1973–9 and 1979–91. For each period regressions are estimated for two groups of industries: all goods and services and manufacturing.

The analysis of the 1968–73 period, when real wages increased and the wage gap between less-educated and more-educated workers narrowed, supports the hypothesis that an increase in the supply of more-educated relative to less-educated labour was the dominant factor influencing changes in relative wages and other key variables. Changes in trading patterns were probably operating to widen rather than narrow the wage gap between less-educated and more-educated workers. Finally, there does not seem to be a plausible technological explanation for the narrowing of the wage gap.

In the 1973–9 period the trend in real wages was flat and the wage gap among education groups continued to narrow. Our regression results are not sufficiently clear-cut to conclude that the continued increase in the relative supply of highly-educated labour was again the main factor shaping relative factor prices in this period. It is nevertheless clear that the reduction in the skill differential cannot be explained by increased import competition in products intensively using less-educated labour because this factor tends to increase wage inequality.

Our analysis of the 1979–91 period, in which the gap between less-educated and more-educated workers increased significantly, rejects the hypothesis that increased import competition, by itself, explains the observed increase in wage inequality in the 1980s and 1990s across all three education groups of labour with more education compared with less education. This conclusion is supported by several parts of our analysis: the behaviour of both domestic and import prices, changes in trade ratios, regressions in which industry output is the dependent variable, and changes in relative labour coefficients (which measure the proportions of high- and low-education labour used in producing a unit of industrial output). Increased import competition could have been a contributory factor in decreasing the relative wages of the least-educated individuals, however, specifically those with 1–11 years of schooling (although this group made up only 10% of the full-time labour-force by 1992). Our most strongly supported hypothesis for the 1979–91 period is that biased technical progress, that which utilizes lower quantities of less-educated labour and which is more rapid in those manufacturing industries that intensively use high-educated labour, was the main force widening the wage gaps among the three education groups.

Finally, we implement empirically the Deardorff-Staiger model, which specifies a set of assumptions under which changes in the factor content of trade can be used to indicate the effects of trade on relative factor prices. These results reinforce the conclusion that increased import competition between 1977 and

1987 was not the dominant economic force in bringing about the widening of the wage gap between these years.

I. Introduction

There is considerable disagreement among economists concerning the role of international trade in accounting for the wage decline of less educated compared to more educated U.S. workers since the late 1970s. (The widening gap of wages is described in many studies; see, Kosters (1994), Mincer (1993), and Murphy and Welch (1992).) Deardorff and Hakura (1994) review seven empirical studies and report that the findings range from trade having a major impact on the distribution of wages to having no impact.[1] Five additional studies not included in this review are: Berman, Bound, and Griliches (1994), who conclude that shifts in trading patterns contributed to widening the observed inequality in relative wages but that other forces, particularly biased technological progress in favor of more skilled workers, had a larger impact; Borjas and Ramey (1994), who find that increased international competition explains "much of the increase in wage inequality," (Abstract); Krugman and Lawrence (1993), who argue that the effect of increased international competition on the widening of U.S. income inequality has been "quantitatively minor" (Abstract); and Leamer (1995), who concludes that "a very large percentage of the increased income inequality among workers can be attributed to globalization, but most of this effect came during the 1970s"; and Sachs and Shatz (1994, p. 57) who conclude that "increased trade has contributed . . . to the growing inequality of earnings between low-skilled and high-skilled workers, although the weight of the trade effect is uncertain."

A drawback of most of the above studies (the Leamer and Krugman-Lawrence papers are exceptions) is their reliance on a partial rather than a general equilibrium framework to investigate the causes of the shifts in relative and absolute wages. As argued in Section II, this has led some authors to draw conclusions about the appropriate means of ascertaining the effects of different economic factors on

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[1]The studies reviewed are Borjas, Freeman and Katz (1993), Bound and Johnson (1992), Katz and Murphy (1992), Lawrence and Slaughter (1993), Leamer (1992), Murphy and Welch (1991), and Revenga (1992).

relative wages that are not always warranted under the general equilibrium conditions within which the issue should be analyzed. This paper utilizes the general equilibrium framework of trade economists to study not only the impact of trade on relative wages but also the roles of changes in technology and in relative factor endowments in bringing about shifts in relative wages. Other causes of the variations in relative wages have been suggested, such as the decline in union density, decreases in the real level of the minimum wage, increased immigration and shifts in the pattern of public and private spending, but changes in trade, technology and factor supplies are generally regarded as the most important possible explanations.

Two empirical exercises are undertaken to analyze these possible causes of shifts in relative wages. One utilizes a simple general equilibrium relationship between changes in relative product prices and changes in relative factor prices that must hold under the zero profit condition of perfectly competitive models. This relationship is discussed in Section III, together with the likely general equilibrium effects of changes in trade, technology and factor endowments on relative product and factor prices and on other key economic variables. In Section IV, regression models are used to estimate the relationship between changes in product prices and factor prices in various periods, and their implications for how changes in trade, technology and factor endowments have shaped relative wages are discussed.

In Section V, a second empirical exercise estimates the effects of changes in trading patterns and factor endowments on relative factor prices by analyzing changes in the factor content of trade instead of changes in product prices. While this procedure is only appropriate under special assumptions, such as Cobb-Douglas preference and production functions, it serves as a check on the robustness of the underlying trade model. The paper's main conclusions are summarized in Section VI.

The behavior of real weekly wages from 1967 to 1992 for all U.S. workers by various levels of

education and for all workers combined is depicted in Figure 1.[2] It is useful to divide this period into three parts. From 1967 to 1973 real wages for all education categories increased, with the wages of the groups at the lower end of the wage scale increasing more rapidly than those at the higher end. For example, the ratio of the average weekly wage of workers with 13 or more years of education to those with 1-12 years of education declined from 1.51 in 1967 to 1.45 in 1972 (see Table 1, Part A). After 1973, the trend in average real wages of all workers was slightly downward until 1982. The gap between the most highly educated and least educated continued to narrow through 1980, when the ratio of wages of workers with 13 or more years of education to the wages of those with 1-12 years fell to 1.38.

Average weekly wages of all workers rose between 1982 and 1987 but then fell steadily through 1991. However, wage inequality increased from 1980 through 1992. For example, the ratio of the wages of workers with 13 or more years of education to the wages of those with 1-12 years of education rose to 1.52 by 1992. As Figure 1 indicates, between 1980 and 1992 real wages increased only for workers with 16 or more years of education, and real wages for the other education groups fell.

Table 1 also summarizes the trends over the period of other key economic variables that are important for understanding the causes of changes in wage inequality. A major change has been the relative increase in the supply of highly educated workers. The ratio of the supply of workers (who were in the labor force for 39 weeks or more) with 13 or more years of education to those with 12 years or less of education rose from .34 in 1967 to 1.11 by 1992. Also, the use in production of more educated relative to less educated labor increased steadily across industries throughout the entire period. For example, the weighted (by output) industry average of the ratio of workers with 13 or more years of education used per dollar of industry output to those with 1-12 years rose from .29 in 1967 to .70 in

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[2]These data are taken from the March Current Population Surveys for each year from 1967 to 1992. Wages are measured as average weekly wages for full time workers who were in the labor force 39 weeks or more and are deflated by the implicit price deflator for personal consumption expenditures from the National Income and Product Accounts.

1987. (See the labor-coefficients ratio in Part A of Table 1). The average annual growth rates of workers with 1-11 years of education, 12 years of education, and 13 and more years of education are reported in Part B of Table 1, together with the growth rates of the total labor force and the capital stock. The percentage distribution of the labor force by these three education groups is shown in Part C of Table 1.

The output of all goods and services that intensively use the 13+ group of workers rose appreciably over the period from 1967 to 1987 compared with the output of all goods and services intensively using the 1-12 group of workers. Based on a 1977 division of industries into these two groups (see note 3 in Table 1), the ratio of the output of goods and services intensively using the more educated workers to the output of goods and services intensively using the less educated workers rose from .89 in 1967 to 1.16 in 1987, reaching a peak of 1.25 in 1982 (Part A of Table 1).[3] Also shown in Table 1 is the consumption ratio for these two types of goods, which changes in a manner similar to that of the output ratio. The ratio of domestic prices of these two types of goods (weighted by output) also rose between 1967 and 1987 and remained at roughly the same level through 1992. For manufactured goods only, however, the price ratio was about the same in 1967 as it was in 1987 and 1992. Another source of output changes that is related to education (or skill) inputs is factor productivity. Total factor productivity in manufacturing increased more rapidly in sectors intensive in the use of highly educated labor than in sectors intensive in the use of less educated labor between 1967 and 1977, but then, after decreasing between 1977 and 1980, grew at about the same rate as in sectors intensive in the use of less educated labor.

Two other useful relationships relating to the trade of the United States are shown in Part A of Table 1. One is that a representative bundle of U.S. exports embodies a higher ratio of highly educated to

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[3]This and other ratios in the Table cannot be calculated beyond 1987, since this is the last year for which there is an input-output table published by the Commerce Department.

less educated labor than is embodied in a representative bundle of imports produced domestically. A second is the rapid decline between 1980 and 1987 in the net trade balance as a fraction of domestic consumption.

II. Approaches of Earlier Studies

Katz and Murphy (1992), Murphy and Welch (1991), and Sachs and Shatz (1994) investigate the impact of trade on relative wages by examining the factor content of trade. They estimate the effect of changes in net trade across industries on the number of workers of different education levels that are needed to produce exports or are displaced by imports and then draw conclusions about how these quantitative changes in labor demand may have affected relative wages. They find the impact of trade on the demand for labor to be moderate in the late 1960s and 1970s, but quite significant and adverse, especially for less-skilled employees, in the 1980s.[4] For example, Katz and Murphy (1992) find that between 1979 and 1985, a period when the U.S. trade deficit was large and increasing, changes in trade across industries increased the relative demand for male college graduates by 0.55 percent, while reducing the relative demand for males who dropped out of school with 8-11 years of education by 0.63 percent. They conclude that these trade-induced changes in relative demand moved in the correct direction to help explain the rising education differentials in the 1980s but also note that the changes were quite small relative to the increases in the relative supplies of more educated workers over the period.

Let us examine the theoretical underpinnings of these and similar findings. In the standard competitive, constant-returns-to scale trade model with a fixed technology, relative factor prices change

[4] In a later analysis, Murphy and Welch (1992) reversed their conclusion about the impact of trade as a result of their findings that the major source of the rise in wage inequality was within-industry. Reasoning that a trade impact should mainly affect average wage inequality among industries, they concluded that the trade impact was minor. We discuss the issue of within- and among-industry relationships below.

only when relative product prices change. For example, given a simple two-factor (unskilled and skilled labor), two-good (a skilled labor-intensive good, Y, and an unskilled labor-intensive good, X), two-country trade model with homothetic preferences, suppose that the foreign country's offer curve of the unskilled labor-intensive good, X, for the skilled labor-intensive good, Y, shifts outward due to an increase in its endowment of unskilled labor. With a given home country offer curve of Y for X that is less than perfectly elastic, this shift will lower the international price of the unskilled labor-intensive good, X, relative to the skilled labor-intensive good, Y. This, in turn, will cause the home country's output of X to fall and Y to rise. Since, at existing levels of relative wages, the contraction of the X industry tends to release a larger proportion of unskilled labor than the proportion of this type of labor used in the expanding industry, Y, the wages of unskilled labor will fall relative to the wages of skilled labor in order to maintain full employment.[5]

Considerable caution must be used in drawing conclusions about changes in relative factor prices from changes in the factor content of trade.[6] Suppose, for example, in the hypothetical case of increased import competition described above, that the international demand of the home country for the unskilled labor-intensive export good of the foreign country (good X) is inelastic. The outward shift of the foreign country's offer curve will result in a decline in the international price of X relative to Y, and a decline in trade revenue for the foreign country. While the home country's imports of X will rise, its exports of Y will fall, even though its production of Y increases. Following the factor-content methodology leads to the conclusion that the demand for both skilled labor and unskilled labor declines in the home country as increased imports replace domestic production and the volume of exports falls. Since it is quite possible

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[5]For a more detailed diagrammatic explanation of the effects of increased foreign competitiveness, see Baldwin (1995), pp. 38-39.

[6]As explained in Section V, Deardorff and Staiger (1988) specify a set of assumptions under which changes in the factor content of trade can be used to indicate the effects of trade on relative factor prices.

for the demand decline for skilled labor that is associated with the changes in exports and imports to be relatively greater than the demand decline for unskilled labor due to these trade changes, one would erroneously conclude that the outward shift of the foreign country's offer curve lowered (rather than raised) the wages of skilled labor relative to those for unskilled labor. Although this outcome is ruled out if the home country's import demand is elastic, there need be little relationship between the relative magnitudes of the factor content changes and the relative magnitudes of the actual factor price changes.

The failure to take account of any changes in the size of a country's trade deficit or surplus can also result in misleading conclusions under the factor-content approach. Suppose, for example, that a country's citizens borrow funds from abroad and increase their expenditures on both import and export goods, thereby leading to a decrease in exports and increase in imports.[7] A standard result of the literature on such transfers is that there will be no change in the terms of trade if tastes domestically and abroad are identical and homothetic so that the increased domestic spending on these goods is matched by decreased spending on them abroad. However, in calculating changes in the factor content of exports and imports, the relative decrease in the domestic demand for factors used intensively in the export sector will in general differ from the relative decrease in the domestic demand for factors used intensively in the import-competing sector. Thus, on the basis of the factor-content approach, one would conclude that relative factor prices had changed, when, in fact, they need not have changed at all.

The paper by Berman *et al.* (1994) investigates the relative importance of skill-biased technological change, increased trade, and increases in defense spending in explaining the shift in demand away from unskilled and toward skilled labor in U.S. manufacturing over the 1980s. Utilizing skill indexes based on the relationship between hourly earnings and the occupational classifications of

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[7]The existence of the debt and the need to repay the loan will tend, of course, to reduce spending in the future, but the initial effect on expenditures will be positive Murphy and Welch (1991) and Katz and Murphy (1992) take into account the increase in the trade deficit, but Sachs and Shatz (1994) do not. See Deardorff and Hakura (1994, pp.93-94) for a more detailed discussion of this issue.

blue-collar and white-collar workers, Berman *et al* first show that a significant part of the skill upgrading between 1973 and 1987 was due to a shift in the economy from production (blue-collar) workers to nonproduction (white-collar) workers. (They present evidence that shows production workers as less skilled than nonproduction workers.[8]) They then decompose the increase in the proportion of nonproduction workers in U.S. manufacturing into that part due to their increased use within industries and that part due to the shift in production toward industries using high proportions of such workers. For explaining the shift in employment toward nonproduction workers, the authors argue that increases in international trade, as measured by the ratio of imports plus exports of manufactures to manufacturing shipments, and increases in military expenditures affect the skill composition of labor demand primarily by shifting inter-industry labor demand from industries intensive in the use of production workers to those intensive in the use of nonproduction workers. In contrast, they contend that biased technological change shifts the skill composition of labor demand within industries.

Berman *et al* find that the within-industry component of the shifts in the demand for labor dominates the among-industry component. Furthermore, when they allocate employment in each of 450 industries to four sectors (domestic consumption, exports, imports, and defense procurement) and assume that imports replace employment in import-competing sectors, they find that the among-industry contribution of imports and exports to the rise in the share of nonproduction workers is small. Therefore, they conclude that the role of trade in shifting employment away from industries that intensively use production labor has been quite small.

The implications of these findings are best understood by analyzing the possible causes of the shifts in relative wages within a general equilibrium framework. Consider, for example, the effects of an increase in the share of international trade in gross domestic product. While they do not discuss reasons

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[8] Further evidence is presented in Berman, Machin and Bound (1996).

why the ratio of a country's exports and imports to its output can increase, causes that seem to be consistent with what they have in mind are a reciprocal reduction in tariffs among countries or a general decrease in transportation costs. In these situations, trade could expand as a share of a country's gross domestic product without any change in international prices of traded goods.

To examine the effects of such changes, let us again use the standard two-factor (skilled labor and unskilled labor), two-good (a skilled labor-intensive good and an unskilled labor-intensive), two-country trade model with homothetic preferences, in which the home country exports the skilled labor-intensive good and the foreign country exports the other good. The endowments of the two types of labor are assumed to remain fixed in the two countries. Even if the reciprocal reductions of tariffs or the decrease in transportation costs do not change the international prices of the two goods, these changes will increase the relative domestic price of each country's export good. If we further assume that labor coefficients are fixed in each country, each country's output levels for the two goods will not change nor will there be any change in the use of skilled versus unskilled labor within each country. Under these circumstances there will be no within-industry or between-industry effects on the use of skilled versus unskilled labor. However, as the relative domestic prices of the goods change, the real wages of skilled labor will increase relative to the wages of unskilled labor in the home country and fall in the foreign country.[9]

If factor coefficients are not fixed, the output of the skilled labor-intensive good will expand in the home country, and its output of the unskilled labor-intensive good will decline. These shifts tend to increase the demand for skilled labor relative to unskilled labor.[10] At the same time, in response to the

[9]This follows from the Stolper-Samuelson theorem (Stolper and Samuelson, 1941), which holds because of the zero-profit condition that must exist in a perfectly competitive economy. See, for example, Jones and Neary (1984) for an explanation of this theorem,

[10] The opposite will take place in the foreign country. For simplicity, it is again being assumed that the international price ratio does not change.

changes in relative factor prices, there will be a substitution in production of unskilled labor for skilled labor in the home country, thereby decreasing the ratio of skilled labor to unskilled labor in the two industries.[11] The opposite will take place in the foreign country. Thus, as trade expands, there are both within-industry and between-industry shifts in the relative use of skilled and unskilled labor.[12] Both shifts take place concurrently.

Unskilled labor-saving technical progress also brings about relative shifts in labor demand among industries as well as within industries.[13] Consider, for example, the case where technical progress that is saving of unskilled labor takes place to the same extent in both industries in the sense that at unchanged factor prices the relative reduction in unit costs is the same in both sectors.[14] Besides the within-industry shift toward the greater the use of skilled compared with unskilled labor in both sectors, the output of the unskilled labor-intensive industry (the import-competing sector) will increase relative to the output of the skilled labor-intensive industry (the export sector) at given product prices.[15] As long as

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[11]This is possible even though the country's total endowment of each factor remains fixed, since these ratios are weighted averages.

[12]See Baldwin (1995, pp. 27-30) for a more detailed diagrammatic explanation of this case and the example of unskilled labor-saving technical progress discussed in the following paragraph..

[13]The classic article analyzing technological change within a Heckscher-Ohlin-Samuelson trade model is Ronald Findlay and Harry Grubert, (1959), "Factor Intensities, Technological Progress, and the Terms of Trade," Oxford Economic Papers, XI, 111-21. Also see Jones (1970).

[14]In the standard Lerner diagram depicting unit value isoquants for the skilled labor-intensive and unskilled labor-intensive goods, technical progress defined in this manner shifts both unit value isoquants based on constant product prices toward the origin so that the lower constant outlay line that must be tangent to both isoquants in equilibrium has the same slope as the constant outlay line tangent to the initial unit value isoquants. In other words, with this uniform technical progress across sectors, relative factor prices remain unchanged if product prices remain unchanged. Since the technical change is unskilled labor-saving, the ratio of skilled to unskilled labor used in producing both goods is, however, greater at the new tangency points than initially.

[15]In this two-factor, two-good model, the output of the unskilled labor-intensive good must increase relatively more than the skilled labor-intensive good at given product prices in order to fully employ the available endowment of unskilled labor.

the country is too small to affect its terms of trade, these within-industry and between-industry effects will not change relative factor prices. However, if the country is "large" in the sense of being able to affect its trading terms, the relative increase in the supply of the unskilled labor-intensive good will tend to decrease the price of this good, thereby reducing the relative wages of unskilled workers.[16] Nevertheless, if the labor coefficients are fixed under a given technology, there will be no further changes in relative outputs. But if substitution between the two factors is possible, these changes in the relative prices of the goods and factors will lead to further between-industry and within-industry shifts. The lower relative price of the unskilled labor-intensive good will lead to a decrease in the output of this good relative to the skilled labor-intensive good.

The relative decline in the wages of unskilled labor will also lead to a substitution of unskilled labor for skilled labor in each industry. Because of these offsetting forces, both the output of the skilled labor-intensive good relative to the output of the unskilled labor-intensive good and the ratio of skilled to unskilled labor used in producing the two goods could end up lower than their initial levels. These various possible changes from uniform (in the sense defined in footnote 14) unskilled labor-saving technical progress are summarized in row 3 of Table 2, along with the effects in a standard two-factor,

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[16]Since the country exports the skilled labor-intensive good and imports the unskilled labor-intensive product, the ratio of the output of the skilled labor-intensive good to the unskilled labor-intensive good will be higher than the ratio of the consumption of these two goods. Consequently, even though this type of technical progress decreases the total output ratio of the skilled to unskilled labor-intensive good at a given product-price ratio as the country's production-possibilities curve shifts outward, it is possible for the ratio of the increase in the output of the skilled labor-intensive goods to the increase in the output of the unskilled labor-intensive good at a given product-price ratio to be less than the ratio of the increase in the consumption of these two goods. This would result in an increase in the quantity of the skilled labor-intensive good offered for the unskilled labor-intensive good at the given price and, thus, in a decrease in the international price of the skilled labor-intensive goods as the country's offer curve shifts outward. However, we will assume that the unskilled labor-saving nature of the technical change is sufficiently strong so that the relative supply-side effects dominate the price determination process.

two-good trade model of other economic shocks to be discussed later in the paper.[17]

While this general equilibrium analysis supports the authors' conclusion that the increased use of skilled labor relative to unskilled labor within industries is consistent with unskilled labor-saving technical progress playing a dominant role in explaining the shift in relative wages in the 1980, their factor-use findings are not inconsistent with international trade playing an important role in accounting for the increased wage inequality. As explained above, the relative wages of unskilled workers could have fallen due to product-price changes caused by increased trade without any or very little among- or within-industry changes in the use of skilled versus unskilled labor. The increase in the wage gap brought about by increased trade under these circumstances could have been even greater than the increase associated with the within-industry factor-use shifts documented by Berman *et al* that are consistent with the technology hypothesis. As explained in the next section, an investigation of the relationship between the distributive shares of the productive factors and changes in relative product prices, in addition to the factors stressed by Berman *et al*, is helpful in further trying to disentangle the relative importance of trade changes versus technology changes in determining relative wages.

III. Estimating and Interpreting Relative Changes in Factor Prices

In a general equilibrium model with perfect competition, unchanged constant returns-to-scale technology and perfect internal factor mobility, changes in relative factor prices take place only in conjunction with changes in relative product prices. As Jones (1965a) pointed out, in such a model a unique relationship between small changes in factor and product prices follows from cost minimization behavior and the zero-profit condition of perfect competition, namely:

$$\hat{p}_j = \sum_{i=1}^{m} \theta_{ij} \hat{w}_i \,, \qquad (1)$$

[17]Where the signs of the ratio changes are ambiguous, the case where the initial supply-side effects dominate is given first.

where $\hat{p}_j$ is the proportional change in the price of any of the n products, $\hat{w}_i$ is the proportional change in the return to any of the m factors[18], and θ_{ij} is the distributive share of the i^{th} factor in the production of the j^{th} good (where $\sum \theta_{ij}=1$).[19] In words, for small changes in factor prices, the relative change in the price of any good is equal to the weighted sum of the relative changes in the prices of the productive factors used in producing the good, where the weights are the shares of the respective factors used in producing a unit value of the good.

As pointed out in an earlier version of this paper (Baldwin and Cain, 1994), equation (1) can be used to estimate proportional changes in factor prices under unchanged technological conditions by regressing observed relative changes in product prices across industries in a given period on known industry factor shares. The regression equation is:

$$\hat{p}_j = \sum_{i=1}^{m} \hat{w}_i \theta_{ij} + e_j , \qquad (2)$$

where e_j is a well-behaved error term and the other variables are the same as in equation (1).

Several strong assumptions are required to accept equation (2) as a well-specified regression model, but it is argued below that such a model is informative for testing the consistency of its estimation results with several hypotheses suggested by the trade models previously discussed. The units of observation in the regression are industries, the characteristics of which are measured for several key years. It is assumed that the factor prices for given quality-constant factors - - skill groups of workers (measured by education levels) and homogeneous capital - - are constant across all industries at any

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[18]With the perfect mobility assumption, the returns to a particular factor will be the same in all industries so that the change in the return for this factor will be the same across industries.

[19]Among the many sources of a proof of this relationship are Jones (1965a), Ethier (1984) and Deardorff (1994). The relationship also holds under imperfectly competitive conditions if there is a uniform mark-up by producers on unit costs.

time, a relationship that follows from the assumptions of perfect competition and perfect factor mobility within a country. The factor prices are parameters, and changes in nominal factor prices are the parameter values (coefficients) being estimated. The right-hand side variables in the model are the industry factor shares, which, given the initial factor prices, are determined by the industry's constant-returns-to-scale technology. Thus, changes in industry prices are effectively regressed on the industries' technology, which varies across industries and is assumed to be exogenously determined. The share variable is measured at the beginning of the period and contains the beginning period product price, p_0, in its denominator. We assume p_0 is measured without error to avoid any spurious correlation between the presence of p_0 in the measure of the price change (the dependent variable) and in the denominator of the share variable.[20] The aggregate supply of the productive factors is assumed to be fixed and exogenously determined. Changes in factor prices over the time period analyzed are also assumed to be sufficiently small for the relationship in equation (2) to hold. Other aspects of the regression model are explained below.

The empirical specification of equation (2) will include two (or three) labor factors and a capital factor. Because there are more than two factors, we must qualify the assumption previously used in the two-factor model whereby a rise in the relative price of one (labor) factor leads unambiguously to a substitution in production away from that factor and toward the other (labor) factor. To retain this relation between the labor factors, we will assume that with a three-factor model (two labor factors and one capital factor) capital is not so strongly complementary with either of the two labor factors that a change in capital's price would reverse the negative cross-substitution elasticity between the two labor factors.

Equation (2) can be utilized to help sort out various hypotheses concerning the main causes of

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[20]We are indebted to Wolfgang Keller for pointing out this potential problem.

observed changes in relative factor prices in the three periods described in discussing Figure 1, namely, 1967-73, 1973-1980 and 1980-92. For example, consider the hypothesis that the observed larger increase in the supply of highly educated labor compared to less educated labor was the main cause of the change in the relative wages of these two groups in a particular period. Given the standard general equilibrium trade model, we can determine whether our parameter estimates of the relative changes in factor prices are consistent with the actual (observed) changes in factor prices, in the sense that the direction of the estimated and actual change in the wage gap between these two labor groups is the same. A similar consistency check can be applied to the hypothesis that increased international trade is the determining force in the change in relative wages of the high and low education groups of workers. Note that both the labor supply and trade hypotheses are predicted to change relative factor prices only if relative product prices change.

If, however, domestic technological change caused the change in relative factor prices, then relative product prices would not change if the resulting output changes in traded goods did not affect international prices. If a country's changes in output were large enough to change international prices, then these changes in relative product prices would also affect relative factor prices. In this case, not including a measure of technological change in the regression equations leads to an omitted variable problem in the regression analysis. Some authors, e.g., Leamer(1996) and Feenstra and Hanson(1996) deal with this issue by including measures of technological change by industry in their price regressions. However, these efforts are hampered by the lack of good measures of exogenous technical change and the fact that the components of the empirical measurement of total factor productivity are endogenous to the price setting process. Our alternative is to infer from the general equilibrium trade model the biases in the regression coefficients of the factor shares that would exist with varying types of technological change suggested as important determinants of the actual factor price changes. In other words, we examine the factor share coefficients estimated from the price regressions for consistency with the

coefficients theoretically predicted as a consequence of the total influence of the assumed changes in domestic technology.

Since similar changes in relative factor prices can be caused by different economic forces, the task of identifying which forces are dominant in a particular period should be pursued by examining other economic evidence besides that from the regressions based on equation (2). We will focus on three additional variables: (a) the ratio among industries of the output of goods intensive in the use of highly educated labor to the output of goods intensive in the use of less educated labor; (b) the within-industry ratio of the use in production of highly educated labor to less educated labor, and (c) the ratio among industries of (exports minus imports)/ (output minus exports plus imports). (Note that the denominator equals domestic consumption of the industry's products). The theoretical predictions of change in these ratios are compared with the actual changes. We can thus narrow down the list of plausible sources of the changes in relative factor prices, but we may still reach a conclusion that the various relationships in outcome variables are consistent with more than one possible explanation for the factor price changes.

To illustrate the sorting-out process, suppose that the labor force is divided into two groups, highly educated labor (say, workers with 13 or more years of education) and less educated labor (workers with 12 years or less of schooling) and that regression results based on equation (2) yield a significantly negative sign on the share coefficient for highly educated labor and a significantly positive sign on the share coefficient for less educated labor for a particular period. This means that relative price declines tend to be greatest (or relative price increases least) in industries with high shares of highly educated labor and tend to be least (or relative price increases greatest) in industries with high shares of less educated labor. An interpretation of these results, consistent with the theory underlying the regression model, is that these price changes are associated with a reduction in the wages of the highly educated group relative to the less educated group.

Suppose the following changes also occurred: the supply of highly educated labor increased

relative to less educated labor, wages of highly educated labor fell relative to the wages of less educated labor, the ratio of the use of highly educated relative to less educated labor increased in all goods, and the output of goods intensive in the use of highly educated labor rose relative to goods intensive in the use of less educated labor. In addition, suppose that the country was a net exporter of the former type of goods and importer of the latter type. As explained in the analytical discussion below, these outcomes are consistent with the assumed increase in the endowment of highly educated labor compared to less educated labor being the dominant influence in bringing about the observed relative factor-price changes in the period, in the sense that this relative factor supply change by itself could account for the changes in these economic relationships. In contrast, these outcomes are inconsistent with increased foreign competition being the dominant cause, as the discussion below will make clear.

Consider analytically how an increase in a country's endowment of highly educated labor affects its factor prices in an open economy model with two factors (highly educated labor and less educated labor) and two goods (one intensive in the use of first type of labor and the other intensive in the use of the second type of labor). Suppose that the country, which is assumed to be large enough to affect its terms of trade, exports the good intensive in the use of highly educated labor and imports the good intensive in the use of less educated labor. An increase in the supply of highly educated labor shifts the country's production possibilities curve outward in such a way that, for any given set of product prices at which both goods are initially produced, the output of the highly educated labor-intensive good increases and the output of the other good decreases.[21] This follows from the Rybczynski theorem, the dual of the Stolper-Samuelson theorem (see Samuelson (1953) and Jones (1965b)).

Since the output of the highly educated labor-intensive good increases and that of the less

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[21]If the supply of unskilled labor is also increased, though relatively less than the supply of skilled labor, the output of the unskilled labor-intensive good need not decline absolutely, but the output of the skilled labor-intensive good will increase relatively more than the output of the unskilled labor-intensive good.

educated labor-intensive good decreases at any given set of product prices, the country's offer curve of the highly educated labor-intensive good for the foreign country's less educated labor-intensive good shifts outward (assuming homothetic preferences).[22] With an unchanged and less than perfectly elastic foreign offer curve of the less educated labor-intensive good for the highly educated labor-intensive good, the relative price of the highly educated labor-intensive good declines and the wages of highly educated labor decrease, while the wages of less educated labor rise, in accordance with the Stolper-Samuelson theorem.[23]

If technology is such that labor coefficients are not fixed, the decline in the wage of the highly educated labor leads to a substitution of highly educated for less educated labor and thus an increase in the ratio of highly educated to less educated labor used in producing both goods. In this case, the relative change in product prices causes the output of the highly educated labor-intensive good to decrease and that of the less educated labor-intensive good to increase, compared to the situation without any change in relative product prices. It is even possible for the ratio of the output of the good intensive in the use of highly educated labor to the output of the good intensive in the use of less educated labor to end up lower than initially.[24] These different possible changes in key economic variables resulting from an increase in the endowment of highly educated labor relative to the endowment of less educated labor are summarized in row 1 of Table 2, where for brevity more educated and less educated workers are referred

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[22]The country's offer curve will also shift outward if, with unchanged product prices and homothetic preferences, the output of the good intensive in the use of less educated labor also increases but relatively less than the good intensive in the use of highly educated labor.

[23]If the country is small and faces an infinitely elastic offer curve, there will be no change in product and factor prices as a consequence of the increase in the endowment of highly educated labor. However, the output of the good that intensively use this type of labor will increase and the output of the other good will decrease in order to maintain full employment of both factors.

[24]See Takayama (1964) for a formal analysis of the effects of changes in factor endowments and technology on the different variables in the model.

to as skilled and unskilled labor, respectively. In conclusion, the regression results postulated above, as well as the assumed changes in the other variables, are consistent with an increase in the endowment of highly educated labor relative to less educated labor being the dominant cause of the changes in factor prices and in the other key variables.

In contrast, consider the effects of increased foreign competition, interpreted to mean an outward shift of foreign countries' offers of the less educated labor-intensive good for the highly educated labor-intensive good at various international prices. This shift in the foreign offer curve could be caused by such factors as a relative increase in the foreign endowment of less educated labor or more rapid technological progress abroad in less educated labor-intensive goods. Whatever the cause, the greater outward shift in the foreign offer curve only affects factor prices in the home country in conjunction with a change in the international price of the less educated labor-intensive good relative to the price of the highly educated labor-intensive good. In this case, the outward shift in the offer curve of foreign countries reduces the price of the less educated labor-intensive good in the home country, thereby lowering the wages of less educated labor and raising the wages of highly educated labor in the home country.[25]

These relative price changes, coupled with the possibility of factor substitution, will decrease the output of the less educated labor-intensive good relative to the highly educated labor-intensive good as imports displace domestic production and decrease the ratio of highly educated to less educated labor used in producing both goods as the cheaper less educated labor is substituted for highly educated workers. (These changes in outputs, prices and wages are summarized in row 2 of Table 2.) Thus, the effects of increased foreign competition are not consistent with the findings assumed above with regard to the regression of price changes on factor shares and changes in the other economic variables. This

[25]It is, of course, assumed that the home country does not impose a tariff or import quota to offset the drop in the international price of the unskilled labor-intensive good.

does not mean that increased foreign competition did not occur but, instead, if it did occur, it was dominated by other factors working in the opposite direction on product and factor prices.

The factor-price effects of changes in technology are considerably more complicated, as is evident from the explanation in Section 2 of the effects of uniform technical progress in less educated labor-intensive and highly educated labor-intensive sectors that is biased toward saving less educated labor (see row 3 of Table 2). The effects on factor prices depend not only on the skill bias of the technological changes but on the extent of the technological changes in the sectors intensively using highly educated versus less educated labor. For example, suppose that the home country is exporting the good that intensively uses highly educated labor and that neutral technical progress is greater in this sector than in the sector using less educated labor intensively (see row 4 of Table 2).[26] Neutral technical progress that reduces unit cost more in the highly educated labor-intensive sector causes an increase in the wages of highly educated labor and decline in the wages of less educated labor without any change in the relative prices of the two products. This is due to the relative increase in the demand for highly educated labor as the output of the good intensive in the use of such labor increases relative to the output of the other good in response to the greater profit opportunities in the highly educated labor-intensive sector. However, if less educated labor can be substituted for more educated labor, the relative rise in the wage of highly educated labor will also lead to a relative decline in the use in production of this type of labor.

With an unchanged foreign offer curve and homothetic preferences, the greater increase in the output of the highly educated labor-intensive sector will, however, decrease its relative price (provided

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[26]The technical change is neutral in the sense that, at an unchanged wage ratio of highly educated to less educated labor, the cost-minimizing ratio of using the two factors remains unchanged. Greater or more rapid technical progress in the highly educated labor-intensive sector means that the cost of producing a unit value of this good with the initial factor prices declines relatively more than for the other good.

the country is not "small"), thus moderating or possibly even reversing the relative relationship between the wages of highly educated and less educated labor. This relative price change can also reverse the output and factor-use relationships caused by the neutral technical progress under fixed product prices. These various possible outcomes are also summarized in Table 2.

IV. Data, Empirical Results and Analysis

Data

For the empirical analysis, industries are classified according to the 79 two-digit sectors of the input-output tables prepared by the Bureau of Economic Analysis (BEA), and the prices of the goods and services produced in these industries are those calculated by the Bureau of Labor Statistics (BLS).[27] Factor shares (direct and indirect) for workers with different education levels are calculated from the following sources: the breakdown of value added provided in each input-output sector between employee compensation and property-type income, BLS employment data for each industry, the March Current Population Survey (CPS) that gives the educational level and wages of workers by industry, and direct and indirect labor coefficients calculated from the total requirements coefficients of the input-output tables.[28] Thus, the analysis examines the changes in relative wages in all sectors and not just in manufacturing industries, as in most previous studies.

In the input-output tables prepared by BEA, value-added for factors other than labor, namely, capital and land, is estimated as a residual by subtracting employee compensation from total value added.

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[27]Besides the data available in BLS Bulletin 2018 cited in the References, price data were obtained from disks purchased directly from BLS.

[28]The Census Bureau's industry classification is concorded to BEA's input-output industry classification. Relevant data classified by input-output sectors were obtained from various issues of the Survey of Current Business and various Staff Papers of the Bureau of Economic Analysis. In determining the breakdown of an industry's total labor share into the parts represented by workers with different levels of education, the employment levels of the different education groups are weighted by the average national wage for the different education groups.

Consequently, in estimating the regression model of equation (2), the coefficient of the residual capital-land share will be positively biased, because any random element in the measure of prices will be reflected in (positively related to) the value of the residual measure of the capital-land share. To avoid this problem, we utilize an independently defined proxy variable to measure the capital-land share, specifically, an estimate of the total capital used per unit of output in each industry, which is obtained from the Trade and Immigration data set of the National Bureau of Economic Research (for manufacturing) and the Fixed Reproducible Tangible Wealth data set of the Bureau of Economic Analysis (for agriculture, mining and service industries). Thus, the equation estimated is:

$$\hat{p}_j = \alpha + \sum_{i=1}^{m} \hat{w}_i \theta_{ij} + k_j + e_j , \qquad (3)$$

where $\hat{w}_i$ is the proportional change in the return to any of the m labor groups with different levels of education, θ_{ij} is the distributive share of these labor groups, k_j is the per-unit capital for the j^{th} good (where this is a proxy for the capital-land share for this good), e_j is a well-behaved error term and α is a constant term. Although equation (2) has no constant term, because the thetas sum to unity with the zero profits condition assumed, equation (3) allows for a constant term to capture the change in specification of the capital term and possible trends in the price variables due to "outside" forces.

The regression results from estimating equation (3) are presented in Table 3.[29] Labor shares and

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[29]Three additional sets of regressions were estimated, which show the same general results. In Appendix 1 we present two sets of weighted regressions, with industry employment and with industry output as weights, which allow for the expected heteroskedacity due to the large differences in industry sizes. Leamer (1995, 1996) and Krueger (1995) use weighted regressions with similar data. We focus primarily on the unweighted regression in Table 3 because they show more stable and internally consistent results, and we find them easier to interpret. The coefficients of the weighted regressions sometimes varied in sign as well as in magnitude, depending on which weights (employment or output) were used. A suspected problem with the weights is that the sizes of industry employment and output may themselves be acting as additional determinants of the dependent variables. When we tested for the weights (or industry size) as a separate right-hand side variable, it was usually, but not always, statistically insignificant. Neither did adding this variable systematically change out general findings, but it did contribute to some unexplainable (to us) variability in the results. In any case, we display the

per-unit capital measures are calculated for five benchmark years of the input-output tables, namely, 1967, 1972, 1977, 1982 and 1987.[30] In the first set of regressions in Table 3, workers are divided into those with 12 or fewer years of education and those with 13 or more years of schooling, while in the second set of regressions, workers are split into those with 1-11 and 12 years or more of education. The third set of regressions involves a threefold breakdown into those with 1-11 years of education, those with 12 years of education, and those with 13 or more years of education.

The regressions cover the three time periods, discussed earlier, that correspond to changes in the wages of the education groups of workers. Relative price changes by industry for the 1968-73 period are the differences between the average of industry prices for 1972, 1973 and 1974 and the average of industry prices for 1967, 1968 and 1969 divided by the average of industry prices for 1967, 1968 and 1969.[31] Similarly, relative price changes between 1973 and 1979 are based on the relative differences between the averages of prices for 1978, 1979 and 1980 and for 1972, 1973 and 1974, while those between 1979 and 1991 are based on the averages for 1990, 1991 and 1992 and for 1978, 1979 and 1980. The compound annualized rates of change in prices over each of the three periods are calculated and used in the regression equations. The factor shares for 1967 are used in the regressions for the 1968-73 period, while 1972 and 1977 factor shares are utilized, respectively, for the 1973-79 and 1979-91 periods.

Regressions for two groups of industries are estimated for each period: (1) all 79 input-output

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weighted regressions in Appendix 1 so readers may make their own judgements, and we indicate in our subsequent discussion of Table 3 those few instances where the weighted regressions show notably different results. A third set of regressions (not shown) used direct factor shares and per-unit capital measures. Again, the results were quite close to those in Table 3.

[30]The last available year for estimating per-unit capital measures is 1986.

[31]Averages for three years are used in this and the other periods to prevent any one year having undue influence in the regression results.

sectors except federal enterprises (I-O sector 78) and state and local government enterprises (I-O sector 79), for which capital coefficients were not available, and eating and drinking places (I-O sector 74), whose definition changed significantly over the period; and (2) industries 13-64, which cover only manufacturing. Regressions for manufacturing industries alone are included for comparative purposes with most earlier studies, which covered only this sector, and also because it is in this sector that one would expect to see the effects of trade changes most clearly. We also estimated a set of regressions for an industry grouping consisting of agriculture, mining and manufacturing industries to focus on the role of natural resource industries in influencing relative wages. The regression results for this grouping, which tended to be similar to those for the All Sectors group, are shown in Appendix 1 as part of the display of weighted regressions, discussed above in footnote 29.

In addition to the regressions in Table 3 with proportional changes in industry prices as the dependent variable, three other regressions are estimated, which also use industry factor shares as independent variables. In Table 4 the dependent variable is the proportionate change in industry output. In Tables 4 and 5, the dependent variables are, respectively, the industry trade ratio and the change in the industry trade ratio. The industry trade ratio is defined as net exports (industry exports less imports) divided by industry consumption (industry output less industry exports plus imports). These regressions are useful to check on the consistency of changes in outputs and trade ratios with those predicted from the basic theoretical model under various hypotheses concerning the dominant force shaping the change in relative wages. The regression model in Table 3 remains basic in the paper because it represents the model specified in equations (1) and (2).

1968-73

As pointed out in Section 1, real wages of workers in all education groups increased absolutely in the 1968-73 period, with the percent increase in wages being greater the lower the group's education (and wage) level. In the separation of workers into two groups (the first two sets of price regressions in

Table 3), the share coefficients of the less educated group are statistically significantly (hereafter, significantly) larger than the share coefficients of the group with more education in all four regressions. Thus, these regressions indicate that relative prices increased more (or decreased less) in industries that were labor intensive in less educated (low-skill) workers. (We will discuss the quantitative magnitude of the coefficients later.) Also supporting this conclusion is the decline from 1967 to 1972 in the price ratio (weighted by output) of goods and services intensive in the use of workers with 13 or more years of education to goods and services intensive in the use of workers with 12 or fewer years of education for All Sectors and Manufacturing (see Table 1, Part A).

The regressions with a three-part education breakdown are weakly consistent with the above pattern of relative sizes of the share coefficients. The coefficient for the 1-11 education group is positive and significantly larger than the coefficients for those with 12 years and 13+ years of education in the regression for All Sectors. For the worker group with 12 years of schooling, however, the coefficient is significantly smaller (more negative) than those for the highest education group, 13+.

In the regression for Manufacturing, the share coefficient for the 1-11 group is smaller than the 12 group, but the difference is small and not significant. The large negative coefficient for the 13+ group, however, is significantly smaller than the other two education groups, and this indicates agreement with the pattern of relatively larger coefficients for the less educated workers. The coefficients of the capital variable are always positive and significant. The constant terms are positive, with one minor exception, and 3 of the 6 are significantly positive.

The regression results in Table 3 are broadly consistent with an increase in the supply of more educated workers relative to the supply of less educated workers being the dominant economic factor shaping changes in the pattern of relative wages and other key variables in this period, as maintained by such investigators as Katz and Murphy (1992). The weighted regressions shown in Appendix 1 also support this general conclusion. As reported in Table 1 (Part B) the supply of workers with 12 years of

education as well as with 13 or more years increased substantially during this period, while the supply of those with 1-11 years of education actually decreased. It is well known that the negative correlation among adults between age and years of schooling completed, which is a result of the trend in rising educational attainment, implies that the average educational attainment of the labor force will rise as young persons enter and older workers retire.

Consider evidence on several other economic variables to help distinguish among alternative explanations for the observed changes in wages among education groups. Between 1967 and 1972, the average industry ratio of the number of workers utilized per dollar of output with at least some college education to those with 12 or fewer years of education rose from .29 to .35 (Part A of Table 1). This is consistent with the substitution effect expected from an endowment change that causes the wages of college-educated workers to decrease relative to the wages of less educated workers. In fact, this ratio increased in all but 2 of the 79 industries in the input-output table between 1967 and 1972 (figures not shown).

As explained earlier and reported in Table 2, an increase in the supply of highly educated relative to less educated labor can result in either a rise or fall in the ratio of the output of goods and services that intensively use well-educated labor to the output of goods and services intensively using less educated labor. In fact, this ratio fell slightly from .89 to .88 between 1967 and 1972, as reported in Table 1, Part A. However, this shift in the output ratio was heavily influenced by sizeable output decreases in the ordinance and aircraft industries, which intensively use highly educated labor and, being closely linked to national defense, tend to be relatively unaffected by market forces. This output ratio shows an increase if these two sectors are excluded (figures not shown).

The regressions shown in Table 4, with relative changes in output as the dependent variable and which exclude the ordinance and aircraft industries, are consistent with the hypothesis of an output shift toward high education-intensive goods and with our interpretation of the price regressions shown in

Table 3.[32] In the regressions with two education groups, the coefficient of the less educated factor share is always significantly less than the coefficient of the more educated factor share. In the threefold breakdown (the last set of regressions in Table 4), there is essentially no difference between the coefficients of the two less educated factor shares, while the coefficients of the 13+ group are, as expected, larger than the other two coefficients and significantly larger than the coefficients of the 1-11 labor group in both regressions.

Next, consider the possible role of technological change as an alternative explanation of the observed wage changes in this period. The absolute increase in the real wages of all education groups is consistent with general technological progress.[33] The relative increase in the wages of less educated relative to more educated workers is consistent with neutral technical progress that takes place to the same extent in both sectors intensive in the use of less educated workers and sectors intensive in the use of highly educated workers. (This case is not covered in Table 2.) The proportionate increase in the output of both set of goods at constant product prices that occurs with this type of technical progress coupled with the proportionate increase in the consumption of these goods at constant product prices (assuming homothetic preferences) results in an outward shift of the country's international offer curve of goods intensive in the use of highly educated labor for goods intensive in the use of less educated labor. With an unchanged foreign offer curve of goods intensively using less educated labor for goods intensively using highly educated labor, this shift will cause the price of goods intensive in the use of highly educated labor to fall relative to goods intensive in the use of less educated labor. Associated

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[32]The regression results are also broadly consistent with this hypothesis when the ordinance and aircraft sectors are included. Data on outputs are taken from the input-output tables and expressed in constant dollars.

[33]The more rapid annual growth rate in the capital stock than in the labor force between 1967 and 1972, namely, 4.4 percent versus 2.4 percent, is another factor contributing to the increase in the real wages of all groups (see Table 1, Part B).

with this change in relative product prices will be a decline in the wages of highly educated workers relative to less educated workers.

While the price regressions and the change in the average within-industry ratio of the labor coefficients for highly educated compared to less educated labor for the 1968-73 period are consistent with this type of technological progress, the output regressions are not. The decline in the price of goods intensive in the use of highly educated labor relative to goods intensive in the use of less educated labor that is associated with this type of technical change will result in a decline in the output of the former type of goods relative to the latter. However, as noted, the output regressions in Table 4 indicate a shift in the opposite direction.

A form of technological change that is consistent with both the price and output regressions as well as the behavior of the labor coefficients is technical progress that is saving on the use of less educated labor in all sectors but is more extensive in those sectors that intensively use highly educated labor. The fact (reported in Table 1, Part A) that increases in total factor productivity were greater in sectors intensively using highly educated labor than in sectors intensively using less educated labor during this period supports the view that technological progress was more rapid in the former than latter sectors. However, the direct effect of this type of technical progress is to raise the wages of highly educated relative to less educated workers. Consequently, unless the increase in the output of goods intensively using of highly educated labor relative to goods intensively using less educated labor that is brought about by this type of technical progress causes the prices of the former set of goods to decline relative to the latter so much that the direct relative wage effect is reversed, the relative wages of highly educated labor rise on balance with this form of technical change. This is, of course, not consistent with the actual behavior of relative wages during the period.

Finally, consider the role of international trade in shaping the changes in relative wages in this period. In Table 5, industry trade ratios are regressed on the same factor shares as in Tables 3 and 4 to

reveal the type of goods and services (in terms of factor intensities) in which the United States has a comparative advantage. The trade ratio for an industry is defined as (industry exports minus industry imports)/(domestic consumption of products produced in the industry, which equals industry output - industry exports + industry imports).[34] (Similar results would be obtained if industry output instead of industry consumption were used). As expected, for the periods 1967-69 and 1972-74, as indeed for all periods shown, the signs of the factor share coefficients in the two level regressions tend to be positive for highly educated workers, negative for less educated workers, and the differences are usually significant. These results indicate a comparative advantage in goods and services intensive in the use of the former workers and a comparative disadvantage in goods intensive in the use of less educated workers. The regressions with three educational groups show similar results, although with less consistency. The sign of the coefficient for capital varies but generally is not significant.

In Table 6, regressions of changes in these trade ratios on factor shares provide an indication of changes in comparative advantage. We focus here only on the 1968-73 period. With two education groups, the coefficients of the higher education group in both sets of industries are positive and significant, and the coefficients of the less educated group are significantly smaller. Using the three education groups, we see that the coefficients of the 13+ group are positive and significantly larger than the 1-11 group. The coefficients of the 12 group lie in between the other two education groups, but these coefficients tend not to be significantly different. The capital coefficient is consistently negative but not significant. Thus, there is evidence that changes in trade during this period tended to raise the relative demand for higher educated workers, which is not consistent with the observed decline in their relative wages. As discussed earlier, one must be cautious in relating such quantitative trade measures to changes in relative factor returns, but even the directions of the changes are not consistent with trade

[34] Data on export, imports and consumption are taken from the input-output tables and are adjusted for inflation.

changes being the dominant factor in shaping changes in relative wages during the period.

Thus far, the analysis of the regression results has focused on whether the coefficients of the labor share variables have conformed qualitatively to the changes predicted from the trade model for various possible explanations for the narrowing of the wage gap in the 1968-73 period. Now consider the quantitative magnitudes of the coefficients.

If the wages of highly educated relative to less educated labor were affected solely by economic forces that changed relative wages only in conjunction with changes in relative product prices (such as changes in the relative supplies of highly educated and less educated labor, increased import competition in products intensive in the use of less educated labor, or uniform technological progress in all sectors), the factor share coefficients in the regressions would be estimates of the actual (observed) proportionate changes in nominal wages. However, if, in addition to such economic forces, technical progress occurs that is not uniform in highly educated labor-intensive versus less educated labor-intensive sectors, relative factor prices will change independently of relative product-price changes. Furthermore, the relative product-price changes caused by the uneven technological progress produce relative factor-price changes that tend to offset the direct factor-price effects of the technological progress. Consequently, the factor share coefficients estimated from regressions of changes in product prices on factor shares will not be accurate predictors of the actual proportionate changes in nominal wages.

The differences between the various labor coefficients in Table 3 are clearly much too large to be considered reasonable estimates of the differences in the growth rates of wages for these labor groups during the 1968-73 period. As indicated in row 1 in Table 1, the actual gap between workers with 13+ years of education and those with 1-12 years of schooling declined from 1.51 to 1.45, or only about 4 percent over the entire period, whereas the estimated narrowing of the gap in Table 3 for these groups is

15 percent annually![35] A number of other estimates yield even more extreme values.

Consider the possible bias in these coefficients because of unequal technological change in highly educated labor-intensive versus less educated labor-intensive sectors. Assume that a variable measuring productivity-enhancing technological change is (i) negatively correlated with the change in product prices, since the cost-reducing effect of the technological change will, other things equal, lower prices[36]; (ii) positively correlated with high education-intensive industries; and (iii) negatively correlated with the less education-intensive industries. (Note that the correlations between technological change and the two labor variables must be of opposite sign, assuming -- for simplicity -- that the capital variable is uncorrelated with the labor share variables and with technological change. These simplifications are assumed to permit us to concentrate on the labor share coefficients.)

Given these assumed correlations, which, by themselves, conform to generally accepted beliefs and are supported by the greater increase in total factor productivity in highly educated-intensive industries than in less education-intensive industries during the period (Table 1, Part A), it can be shown that the coefficients of the high-education group in Table 3 are biased down, and the coefficients of the low-education group are biased up. Thus, the estimated coefficients for the less educated group in the two-group regressions would be smaller than -.01, .06, .08, and .12 if a technological change variable were included in the regression. By the same reasoning, the estimated coefficients for the high-education group would be larger than -.16, -.18, -.10, and -.05 if a technological change variable were included. Accordingly, the biases are part of the explanation for the excessive differences between the coefficients of the labor share variables. Differences in the extent of technological progress across different groups

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[35]In his regressions of price changes between 1989 and 1995 on factor shares, Krueger (1995) also find the estimated change in the wage gap between skilled and unskilled workers to be considerably larger than the actual change, although not nearly as large as in our regressions.

[36]The term "correlation" should be interpreted as a partial correlation, controlling for other variables in the model.

of industries may also be an explanation for the sometimes large differences in coefficients of the All Sectors versus Manufacturing set of industries.

Among other possible causes for these excessive differences are the existence of systematic price rigidities among low education-intensive versus high education-intensive sectors, i. e., the failure of the perfect competition assumption of the model to hold. Perhaps a smaller proportion of the productivity gains in less education-intensive industries were passed on in the form of lower prices than in high education-intensive industries due to greater monopoly power on the part of workers and producers in the former than the latter sectors. It should also be noted that the estimating model used, equation (3), differs from that of equation (2), which would be appropriate if empirical measures were available for the theoretical variables. Finally, regressions of "changes on changes" are notoriously volatile in their coefficient estimates, especially when sample sizes are relatively small and the explanatory power (R-square) of the regressions is low.

Our summary of the regression results in Tables 3-7 returns to the qualitative results, i. e., the ranking of the coefficients for the education groups and differences among them. These results and our interpretation of them provide considerable support for the hypothesis that an increase in the supply of more educated relative to less educated labor was the dominant factor influencing changes in relative wages and other key variables in the 1968-73 period. Changes in trading patterns were probably operating to widen rather than narrow the wage gap between less educated and more educated workers. Finally, while it is possible that technological change could have brought about a narrowing of the wage gap, the evidence for such an explanation is not strong.

1973-79

After 1973 real wages for all education groups declined absolutely, and a slight trend toward greater wage equality between the highest (13+years) and both the lowest (1-11 years) and the middle (12 years) education groups continued through 1978. However, the gap between those with 12 years of

education and those with 1-11 years of schooling increased slightly.

The results of the price regressions for the 1973-79 period (Table 3) only weakly support the hypothesis that the continued increase in the supply of more educated relative to less educated workers was the dominant economic change shaping relative wages in this period. In regressions with two levels of education the larger share coefficients for the less educated group relative to the more educated group that one expects from such an endowment change holds in all four regressions, although only in All Sectors are the differences close to being significant.

The price regressions with three labor groups are even less supportive of the factor supply hypothesis. The significant and large negative effects of the highest education group, 13+, for both All Sectors and Manufacturing are consistent with this group's relative wage decline, but these coefficients are significantly larger than those for the 12 group only, and then only in the manufacturing regressions. In contrast, the significant negative coefficient for the 1-11 group in the three-level regression for Manufacturing is not supportive of this hypothesis. This latter result is consistent with the hypothesis that increased import competition began to exert downward wage pressure on the least (or less) educated workers in Manufacturing. The sign pattern of the coefficients in the three labor-group breakdowns for Manufacturing is also consistent with technical change that is labor saving of the 1-11 education group and that is more rapid in sectors intensively using the 13+ group, thereby causing the prices of goods intensively using this latter labor group to decline relative to the goods intensively using labor with 12 years of schooling. However, the more rapid technological progress in sectors intensively using labor with 13+ years of education is likely to increase the wage gap between these two groups, when in fact the gap narrowed. The coefficients on capital are positive in all six regressions but significant in only the three Manufacturing regressions for the 1973-79 period.

As in the 1968-73 period, the differences between the labor share coefficients are "too large" to represent actual annual rates of changes in wages over the 1973-79 period. Again, this may be due to the

biases in the coefficients of the educational groups attributable to the omitting of an explicit variable measuring technological change. More extensive technological progress in industries intensively using highly educated labor than in industries intensively using less educated labor biases the coefficients for the former labor group down and those for the latter group up, thus causing the differences to be biased up.[37]

The output regressions in Table 4 for the period 1973-79 support the finding reported in Table 1 that shows a greater growth in the output of goods that are intensive in the use of higher educated labor than in the output of goods intensive in the use of less educated labor. As in the 1968-73 period, the coefficients for the less educated group in the two-part breakdowns are always significantly less that for the highly educated group. Similarly, in the three group divisions, there is essentially no difference between the coefficients on the two less-educated groups, while the coefficient for the 13+ group is higher than for the other two educational groups and significantly so in comparison with the 1-11 group in both regressions.[38] As indicated in Table 2, an increase in the supply of more educated relative to less educated labor, increased import competition or technical change that is saving of less educated labor can all bring about this change in the composition of output.

The role of trade in influencing relative wages in this period also receives some support from the regressions of changes in trade ratios on factor shares reported in Table 6. In regressions with two education levels the coefficients are negative for less educated and smaller than those for more educated labor, although only the positive coefficient for the 13+ group for All Traded Manufactures is

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[37]As reported in Table 1, Part A, data on cumulative changes in total factor productivity over the period indicate a small decline in the ratio of total factor productivity changes in manufacturing industries intensively using highly educated labor to those intensively using less educated labor. However, between 1972 and 1979, the trend in this ratio was slightly upward.

[38]The weighted output regressions reported in Appendix 1 are quite similar to the unweighted regressions.

statistically significant. The results for the regressions with three education groups are less supportive. The coefficients for the labor groups with 1-11 and 12 years of schooling are negative and virtually the same. The coefficients for the highest educated group are positive and larger than the coefficients for the less educated groups, but, again, only in the regressions for All Traded Manufactures is the coefficient significantly larger than the coefficients for the two less educated groups. In any case, we know that trade could not, by itself, have brought about the observed changes in relative wages and other economic variables in this period, because the evidence for a positive relation between trade and the highest education group (a) would tend to widen the wage gap between the highest education group and the lesser education groups, and (b) would tend to increase the average production coefficient for less educated labor compared to more educated labor. In fact, these relationships moved in the opposite direction, as shown in Table 1, Part A.

In summary, the continued trend toward greater wage equality between the least and most educated groups in the 1973-79 period cannot be explained either by increased import competition in products intensively using less compared with more educated labor or technical progress that is saving of less educated labor and more extensive in sectors intensively using highly educated labor (since these forces tend to increase wage inequality). However, we also conclude that the results from the price regressions (Table 3) are too weak and inconsistent to justify the hypothesis that the observed continued increase in the relative supply of highly educated labor was the dominant force in narrowing the skill (education-based) differential in this period. Various opposing forces seem to be at work during these years. For example, there is some evidence that increased imports of goods intensively using labor with 1-11 years of education were tending to lower the relative wages of this group. There is also some support for the hypothesis that technical change which is saving of the least educated labor and is more rapid in manufacturing sectors using the most educated labor intensively was tending to increase wage inequality. As the following discussion indicates, in the 1980s and 1990s these two sets of forces seem to

have become more important relative to the continued increase in the relative supply of highly educated labor.

1979-91

During the 1980s and early 1990s, real wages continued to decline for all education groups except those with 16 or more years of education, and, in contrast to the earlier period, the wage gap between more educated and less educated workers increased significantly. The gap between workers with 13 or more years of education and workers with 12 years of schooling widened, as did the gap between those with 12 years of education and workers with only 1-11 years of education. These outcomes are not consistent with the continued growth in the supply of highly educated compared to less educated labor being the dominant factor shaping relative wages. Instead, likely sources of the increased wage inequality shift to (a) increased import competition in goods intensive in the use of less educated workers, or (b) technical progress that tends to displace less educated labor and/or is more extensive in sectors intensively using higher educated labor.

Our evidence for the 1979-91 period, contained in Tables 3-7, supports the conclusion that trade, by itself, cannot explain the increased wage inequality in favor of groups of workers with more education, although increased import competition could have been an important contributory factor in the decrease in the absolute and relative wages of those with 1-11 years of education relative to the wages of better educated groups. Our analysis also supports the hypothesis that biased technical progress that was saving in the use of less educated labor and was more extensive in some manufacturing industries intensive in the use of highly educated labor could have been the main force operating not only to decrease the relative wages of the 1-11 education group but also to widen the wage gap between the education groups with 12 and 13+ years of schooling.

We begin with the price and output regressions in Tables 3 and 4. In the price regressions with two education groups none of the coefficient differences between the high education and less education

groups are significant by conventional standards. Looking at the sign differences, we see that the coefficients of the high education groups are larger than the coefficients of the less education groups in the regressions for All Sectors, but the opposite sign pattern is found in Manufacturing.[39] In the All Sectors regressions with three education groups the coefficients of all three groups are small and not significantly different from each other. Only in the three-group regressions for Manufacturing are some of the education coefficients large and significantly different from each other. The positive coefficient for the middle education group (12 years of schooling) is significantly larger than each of the other two education coefficients. The large negative coefficients for the other two groups, 1-11 and 13+, are not significantly different from each other.

Clearly, the price regressions for the 1979-91 period do not show dramatic results nor ones that are consistent across different groups of industries. The most notable result is the apparent negative effect on industry prices in Manufacturing of larger labor shares of highly educated workers (13+). This effect does not show up in the All Sectors regressions, but there may be a straightforward reason for viewing the experience for All Sectors during this period as unusual, due to the very different behavior of the prices of natural resources compared with the prices of services.

Price changes for eight of the ten natural resource industries (I-O industries 1-10) were below the average price increase for all 78 industries, while the price changes in 13 of 14 service industries (I-O industries 65-79, excluding 74) were above the average. (These natural resource and service industries are not included in the Manufacturing sector.) Since natural resource industries tend to use intensively less educated labor, and service industries tend to use highly educated labor intensively, these price changes could well have been responsible for an unusually low coefficient for less educated labor and an

[39]In the weighted price regressions for the two education groups, the coefficients for the less educated labor tend to be significantly lower than the coefficients for the highly educated labor for All Sectors but show no difference in Manufacturing.

unusually high coefficient for highly educated labor in the All Sector price regressions. The relative decline in prices in natural resource products was a cyclical phenomenon of the 1980s.

The output regressions in Table 4 show internally consistent and sharp results, but they are only partly consistent with the results of Table 3. In all regressions in Table 4 that use two levels of education, the high education groups have a positive coefficient on output that is significantly larger than the negative coefficients of the less education group. In the three-level regressions the large positive coefficients for the highest education group (13+) are significantly larger than those for the two less education groups. The positive coefficients of the 13+ group are consistent with their negative coefficients in the Manufacturing sector for Table 3, but not with their positive (but near zero) coefficient in the All Sector regressions using three education groups.

If we focus on Manufacturing, the results from Tables 3 and 4 for the highest and lowest education groups are consistent with technological progress that is relatively saving on the use of less educated workers and is also more extensive in industries intensively using highly educated labor. A greater reduction in unit costs in the more education-intensive industries acts to increase directly the relative wages of highly educated labor without any changes in product prices, while the associated relative increase in the output of industries intensively using highly educated labor has the indirect effect of decreasing their relative product prices. The bias of the technical change toward using more highly educated labor is needed to explain why the increase in the relative wages of highly educated labor did not result in a net decrease in its (relative) use.[40]

The price and output regressions for Manufacturing in which three education groups are included are consistent with the hypothesis that the bias in the technological change was the most labor-saving of

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[40]It must be assumed, of course, that the indirect price effects of the greater cost decline in the sectors utilizing highly educated labor more intensively do not offset the direct relative wage effects and that the output effects of the biased nature of the technical change do not offset the tendency for the prices of more educationally-intensive products to fall relative to less educationally-intensive products.

the least educated group (1-11 years), decreasing their wages, decreasing the prices -- and increasing the outputs -- of products intensively using this labor. Consistent with these relationships, the coefficients for the 1-11 group in the price and output regressions are negative and positive respectively, while the price and output coefficients for the group with 12 years of education are positive and negative, respectively. [41] Finally, the negative coefficient for the 13+ group in the price regression and positive coefficient in the output regressions are consistent with greater technological progress in sectors intensively using this group of workers.[42]

The regressions in Table 3 and 4 for Manufacturing are not supportive of the hypothesis that increased import competition in products intensively using less educated labor was the dominant factor bringing about the widening of the wage gap. Since increased foreign competition in the standard trade model affects relative wages entirely through its impact on relative prices, one should observe larger negative coefficients of the less educated groups in Table 3.[43] However, of the four regressions with two

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[41]The coefficients for 1-11 years and 12 year groups differ from each other in the output regressions are the 1 percent level, but they differ from each other in the price regressions only at the 17 percent level. However, eliminating five outlier sectors, namely, ordinance, tobacco, petroleum refining, computers, and aircraft results in the price regression coefficients for these two labor groups being different from each other at the 5 percent level.

[42]Although there does not seem to have been higher productivity growth in the period over all manufacturing sectors intensively using workers with 13+ years of education compared to those intensively using workers with 12 years or less of education (see Table 1, Part A), the data on total factor productivity assembled by Bartelsman and Gray for 4-digit manufacturing sectors do indicate above-average cumulative increases in total factor productivity for the group of high tech industries associated with the so-called information revolution, in particular, electronic components, computers, communications equipment, and optical and photographic equipment. The scatter diagrams of the price and output regressions indicate that these industries play an important role in accounting for the significant negative coefficient for the 13+ group in the price regressions and significant positive sign in the output regressions.

[43]In the All Sectors price regressions, which include natural resource products and services, the negative coefficient for less educated labor and positive coefficient for higher educated labor are consistent with the increased import competition hypothesis. However, the United States is a net exporter of services, while the price behavior for natural resource products during this period seems mainly a cyclical phenomenon. The output regressions for All Sectors are also similar to those for

educational groups, two show this pattern (in All Sectors) and two do not (in Manufacturing), and none of the differences are statistically significant.[44] In the regressions with three educational groups in Table 3 there is no practical difference in the education coefficients for All Sectors, and although the coefficient for the 1-11 group in Manufacturing is significantly less than that of the 12 group, the coefficient for the 13+ group is the smallest of the three education coefficients. Moreover, if the import competition hypothesis explained the negative coefficient of the 1-11 group relative to the positive coefficient for the 12 group in Manufacturing, one would expect to observe a decline in the output of Manufactured goods intensive in the 1-11 education group relative to that of the 12 group. In fact, the opposite occurred, as Table 4 shows.[45]

Further evidence concerning the import competition hypothesis can be gained from Tables 6 and 7. Utilizing comprehensive import and export price indices calculated by the Bureau of Labor Statistics (BLS) since 1982, Table 7 presents the results of regressing changes in import and export prices on factor shares over the period 1982-1992. If increased foreign competition in Manufacturing was the major source of the increased wage inequality in the 1980s and 1990s, the import prices of goods intensive in the use of less educated labor should have fallen relative to the import prices of goods intensive in the use of more educated labor. However, as with the domestic price regressions covering manufacturing alone, this sign pattern does not emerge from the regressions.

In the two labor-group regressions, the share coefficients of the less educated workers are larger than those of the highly educated workers from 1982-92, 1982-87 and 1987-92, with the differences

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Manufacturing.

[44]In the weighted price regressions for Manufacturing (Appendix 1), none of the two labor-group coefficients even weakly differ from each other.

[45]This is also the case for the weighted output regressions (not included in the Appendix). Furthermore, eliminating the five outliers mentioned in footnote 41, increases the significance level of the positive coefficient for workers with 1-11 years of education in the three labor-group regressions.

being significant between 1987-92 period and nearly significant for the entire period 1982-92.[46] As with the domestic price regressions in Table 3, the three labor-group regressions in Table 7 indicate that a positive share coefficient for the group with 12 years of schooling is the source of the positive sign for the less educated workers in the two-group regressions. In the three group regressions the negative signs on the share coefficient for workers with 1-11 years of schooling are consistent with increased import competition decreasing the relative wages of this group. However, the signs of the other coefficients in the three labor-group regressions are not consistent with increased import competition operating to increase the wages of those with 13+ years of schooling relative to those with 12 years of education. Not surprisingly, the sign pattern in both the two- and three-group regressions of changes in export prices of manufactured goods (Table 7) is the same as in the regressions for import prices and quite similar to the domestic price regressions.

The hypothesis that U.S. markets were faced with an increase in imported products intensively using labor with 1-11 years of schooling during the 1980s period is also supported in the three labor-group regressions with trade ratios as the dependent variable, which are reported in Table 6. The coefficients of products intensively using workers with 1-11 years of education are negative and significantly less for the group with 12 years of education for both sets of industries and significantly less than the 13+ group in All Traded Goods and Services.

A crucial problem with any claim that increased import competition in goods and services intensively using less educated labor, by itself, can account for changes in factor prices in the period is,

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[46]Dropping obvious outlier industries does not change this sign pattern. Indices of BLS import prices weighted by the volume of 1982 imports both for those manufacturing sectors intensively using highly educated labor and those manufacturing sectors intensively using less educated workers (based on a 1977 classification of these sectors) also supports the results of the regression analysis. (These indices are not shown in Table 1.) Import prices rose more for manufactured goods intensively using labor with 12 years or less of education than for manufactures intensively using labor with 13 or more years of schooling between 1982 and 1987 as well as between 1982 and 1992.

as Krugman and Lawrence (1993) point out, that the resulting increase in the relative wages of highly educated workers relative to less educated workers should have led to a substitution in production of less educated workers for highly educated workers. In fact, as indicated in Table 1, the average industry ratio of workers with 13+ years of education used per dollar of industry output to those with 12 years or less of schooling continued to increase significantly across industries. The proportionate changes in the average amounts of labor with 1-11 years of education used per dollar of output relative to the labor with more education indicate, for example, that increased import competition could not have been the dominant factor affecting the use in production of labor with different levels of education. The direct and indirect per dollar amount of labor with 1-11 years of schooling declined by 32 percent between 1980 and 1987 in contrast to only an 11 percent decline for the group with 12 years of education and a 2 percent increase in the use of labor with 13 or more years of education. (These results are not shown in Table 1.) If increased imports had been the main factor affecting these coefficients, there would have been factor substitution in favor of the 1-11 group and thus an increase in its use per dollar of output relative to the per dollar use of more educated groups. However, these changes in factor use are consistent with the biased technical-change hypothesis.

In summary, the analysis here supports the conclusion that increased imports of manufactured products intensively using less educated labor, by itself, cannot explain the observed increase in wage inequality in the 1980s and 1990s among all groups of workers with more education compared with less education. The behavior of domestic and import prices of manufactured products (Tables 3 and 7), the changes in trade ratios (Table 6), the results of the output regressions (Table 4), and changes in relative labor coefficients (Table 1) all support this conclusion. However, increased import competition could have been an important contributory factor to the decrease in the relative wages of the least educated group of workers, specifically, those with 1-11 years of schooling - a group that, however, made up only 10 percent of the labor force by 1992 (Part C, Table 1).

In contrast, our analysis supports the hypothesis that biased technical progress that is saving of the use of less educated labor and is more rapid in some manufacturing sectors intensive in the use of highly educated labor could have been the main force operating to decrease the relative wages of the 1-11 education group and to widen the wage gap between the 12 and 13+ education groups in Manufacturing.[47] Strong demand for the output of education-intensive service sectors also may have contributed to the increasing the wage gap. In other words, while our analysis is not able to rule out import competition as an important contributory factor accounting for the relative decline in the wages of the least educated group, it is able to reject the hypothesis that increased import competition was the dominant force leading to a widening of the wage gap between the 13+ education group and the group with 12 years of schooling.

Leamer (1995, 1996) follows a somewhat similar approach as in this paper in investigating the relative wage issue, but he reaches the conclusion, noted earlier, that, although the influence of globalization dominated that of technology in the 1970s, globalization effects actually tended to reduce income inequality in the 1980s. However, Leamer attributes to "globalization" the residual price variability not accounted for under his assumption that a certain proportion of productivity increases are passed on to consumers in the form of lower prices. As he notes (Leamer, 1996), the price effects of strictly internal U.S. changes, e.g., shifts in the relative endowment of skilled to unskilled labor and changes in product preferences, are included in his measure of globalization in addition to price effects due to changes in foreign demand and supply conditions. Consequently, because of this definition of globalization and his assumption concerning how technological change affects product prices, it is difficult to compare his results with the conclusions reached here.

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[47]As pointed out earlier, by more rapid technical progress in some education-intensive manufacturing sectors, we mean technical change that, at the initial factor prices, reduces unit costs relatively more in these sectors than in other manufacturing sectors.

Some authors, e.g., Martin and Evans (1981) and Wood (1994), maintain that direct estimates of trade effects, such as those undertaken here, significantly understate the impact of trade by failing to account for defensive innovation. According to these authors, increased competition from developing countries induces technical change in countries such as the United States aimed at using labor with high levels of education and skills at the expense of poorly educated, unskilled workers. Since it is not economical for developing countries to copy this form of technological progress because of a relative scarcity of well-educated labor, developed-country producers succeed in slowing down the rate of their market-share losses.

This type of endogenous technical change is possible in imperfectly competitive international markets as well as under conditions in which producers do not seek out all possible profitable opportunities (the so-called X-efficiency literature, see Caves and Krepps (1993)). However, as Wood (1994, p.160) points out, it is very difficult to isolate empirically the causal contribution of foreign competition to this form of defensive innovation.

V. Inferring Relative Factor-Price Changes from Changes in the Factor Content of Trade: The Deardorff-Staiger Model

Deardorff and Staiger (1988) have formulated another means by which factor-price changes can be estimated. They show that, under special conditions, changes in relative product prices and thus changes in relative factor prices can be inferred from changes in the factor content of trade. This analysis can be used to provide another test of the importance of increased foreign competition in accounting for relative wage changes since the early 1980s.

The authors first demonstrate that, under trading conditions with incomplete specialization, there is an equivalent autarky equilibrium associated with each trading equilibrium for a country in the

following sense.[48] If the factors embodied in the country's exports are subtracted from its initial factor endowments and the factors embodied in the country's imports are added to its initial factor supplies (the factors embodied in trade being calculated with the country's own technology), then with the same prices of goods as prevailed in the trading equilibrium, a competitive production equilibrium exits in which consumptions of goods and factor prices are the same as in the trading equilibrium.

As Deardorff and Staiger point out, the insight for this relationship is simply that changing the endowment of factors in this manner provides the country with an endowment equal to the factor content of equilibrium consumption. Thus, the constructed autarky equilibrium merely endows the economy with the factors needed to produce what it had consumed with trade, thereby obviating the need for trade at the prevailing prices of goods and factors. Deardorff and Staiger then proceed by making the strong assumption that both preference and production functions are Cobb-Douglas. Cobb-Douglas production functions imply that each factor earns a constant share of the revenue of each industry, while Cobb-Douglas preferences imply that consumers spend a constant share of their total expenditures, E, on each good. In autarky, where consumers' expenditures on any good equal the revenue of the industry producing the good, the two relationships together imply that each factor's total income (from employment in all industries) is a constant fraction of consumer expenditures. Thus, letting w_i be the return of the i^{th} factor, L_i^a the endowment of this factor under autarky conditions, and c_i the constant fraction for the factor, the following relationship holds:

$$w_i L_i^a = c_i E \qquad (4)$$

Next, consider two equilibria for this country, numbered 1 and 2, that involve trade. With trade, equation (4) does not apply directly. However, equilibrium factor prices with trade can be expressed in

[48] It is not necessary to assume identical technologies across countries.

terms of what they would be without trade in an equivalent autarky equilibrium, the factor endowments of which are B = L (the actual endowments) minus S (the factors needed to produce what is exported less the factors needed to produce replacements for what is imported). Thus, letting L^0 be the actual factor endowments of the country (assumed to be the same in both trading equilibria), the price of factor i in each trading equilibrium, w_i^2 and w_i^1, can be expressed in terms of total expenditures in each trading equilibrium, E^2 and E^1 (consumer preferences are assumed not to change), the unchanged endowment of the factor L_i^0, and the net contents of trade in the factor in the two trading equilibria, S_i^1 and S_i^2, as follows:

$$w_i^t = \frac{c_i E^t}{L_i^0 - S_i^t}, \quad where \quad t=1,2 \qquad (5)$$

If we compare the price of factor i in the two trading equilibria, we have:[49]

$$\frac{w_i^2}{w_i^1} = \frac{E^2(L_i^0 - S_i^1)}{E^1(L_i^0 - S_i^2)} . \qquad (6)$$

If expenditures are the same in the two equilibria, the relationship can be simplified to:

$$\frac{w_i^2 - w_i^1}{w_i^1} = \frac{S_i^2 - S_i^1}{B_i^2} . \qquad (7)$$

Consequently, with unchanged Cobb-Douglas preferences and technologies for a country and unchanged expenditures and factor endowments between two trading equilibria, the relative change in the price of

[49]The c drops out in any ratio of the w's.

any factor can be expressed in terms of the change in the content of trade in the factor and the factor endowment of the equivalent autarky equilibrium of the number 2 trading equilibrium (which equals the factor content of consumption in this equilibrium).

One use of this relationship is to ask the following question: What would the gap in wages between highly educated and less educated workers have looked like in (say) 1987 if, given U.S. factor endowments, preferences, technology, and expenditures of that year, U.S. trade policy had been adjusted to hold the factor content of U.S. net exports (measured in U.S. techniques of production for 1987) at (say) their 1977 levels?[50]

The equation for calculating the change in the wage gap under this hypothesized scenario is:

$$\frac{w_h^{1987'} - w_l^{1987'}}{w_l^{1987'}} = \frac{[1 + \frac{S_h^{1977} - S_h^{1987}}{B_h^{1987'}}]w_h^{1987}}{[1 + \frac{S_l^{1977} - S_l^{1987}}{B_l^{1987'}}]w_l^{1987}} - 1 \qquad (8)$$

where the left side is the hypothetical wage gap between highly educated (h) and less educated (l) labor in 1987 as a ratio of the wages of less educated workers in the hypothetical 1987 economy that still exports in net factor terms what it had in 1977, S_i^t is the observed content of net exports of the i^{th} factor (highly educated or less educated labor) in year t (1977 or 1987) measured in U.S. technologies of year t, and B_i^{1987} is the U.S. endowment of factor i in 1987 minus S_i^{1987}. The difference between the hypothetical wage gap calculated by this formula and the actual wage gap can be interpreted as that part of the gap attributable to the actual change in trade between 1987 and 1977.

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[50]We are grateful to Robert Staiger for suggesting that we use equation (8) to test the effect of changes in the factor content of trade on relative wages.

The results of the calculation for the 1987-77 period as well as for the 1977-67 period are presented in Table 8. As indicated in the table (and in Table 1), in 1987 the wages of workers with 13 or more years of education exceeded those of workers with 12 years or less by 50.3 percent compared to 38.0 percent in 1977. The hypothetical gap in 1987 would have been 48.0 percent if factor trade in 1987 had been the same as in 1977. Thus, the change in trade between these years contributed 2.3 percentage points to the 12.3 percentage point increase (or about 19 percent) in the increase in wage inequality.

If 1977 factor trade had been the same as in 1967, the gap hypothetically would have been 36.4 percent in contrast to the actual wage gap of 38.0. The interpretation is that the actual change in trade between 1967 and 1977 contributed 1.6 percentage points to the 1977 gap. The actual wage gap fell from 51.0 percent in 1967 to 38.0 in 1977, a decline of 13.0 percentage points. The change in trade reduced the narrowing of the wage gap by 11 percent (=1.6/(13.0+1.6). Thus, both the 1977-67 and 1987-77 relationships support the view that changes in trade played a comparatively small role in accounting for changes in the wage gap. However, it is not clear just how sensitive these conclusions are to the assumption of Cobb-Douglas production functions and tastes.

VI. Conclusions

This paper utilizes the standard general equilibrium framework of international trade economists to analyze the role of various economic factors in determining the behavior of relative wages in the United States from the late 1960s to the early 1990s. It is argued that a number of earlier studies, by relying on partial equilibrium techniques, have drawn unwarranted conclusions concerning the appropriate means of determining the effects of the various economic forces operating on wages. The first of the two approaches employed here is based on a simple relationship between proportional changes in product prices and proportional changes in factor prices that holds in the standard competitive, general equilibrium model, while the second relies on a relationship discovered by Deardorff and Staiger between changes in relative wages and changes in the factor content of trade that

holds under special circumstances.

Using the first approach in conjunction with an analysis of the behavior of other relevant variables, we find support for the hypothesis that an increase in the supply of better-educated workers relative to the supply of less educated workers was the dominant economic factor in bringing about the greater degree of wage equality observed during the period of rising wages from the 1960s to early 1970s. Our statistical analysis of the rest of the 1970s, when real wages slumped and during which the wage gap between the least and most educated workers continued to narrow, yields some weak support for the factor supply hypothesis, but it is not sufficiently clear-cut to conclude that the continued increase in the relative supply of highly educated workers was also the main factor shaping relative wages in this period. But, we also know that increased import competition from products intensively using the least-educated labor or technical progress biased toward saving this type of labor could not have been the dominant factors, since these both tend to increase wage inequality.

The significant widening of the wage gap between more educated and less educated workers in the 1980s and early 1990s cannot be explained by the more rapid growth in the supply of highly educated workers than in the supply of less educated workers, since the effects of such growth tend to narrow the wage gap. Sources of the increased wage inequality that have been suggested are increased import competition in goods intensively using less educated labor or technical progress that displaces less educated labor and /or is more extensive in sectors intensively using highly educated labor. We conclude from our regression analysis that the increased import-competition hypothesis cannot, by itself, explain the observed increase in wage inequality among all groups of workers with more education compared with less education. However, this factor could have been an important contributory cause of the decrease in the relative wages of the least educated workers, namely, those with only 1-11 years of education -- a group that made up about 10 percent of the labor force in 1992. In contrast, support is found for the hypothesis that technical progress that is saving on the use of less educated labor and is

more rapid in some manufacturing sectors intensive in the use of highly educated labor could have been the main force operating not only to decrease the relative wages of the 1-11 education group but to widen the wage gap between the other education groups.

Our empirical implementation of the Deardorff-Staiger model reinforces the conclusion that increased import competition between 1977 and 1987 was not the most important economic force in bringing about the widening of the wage gap between these years.

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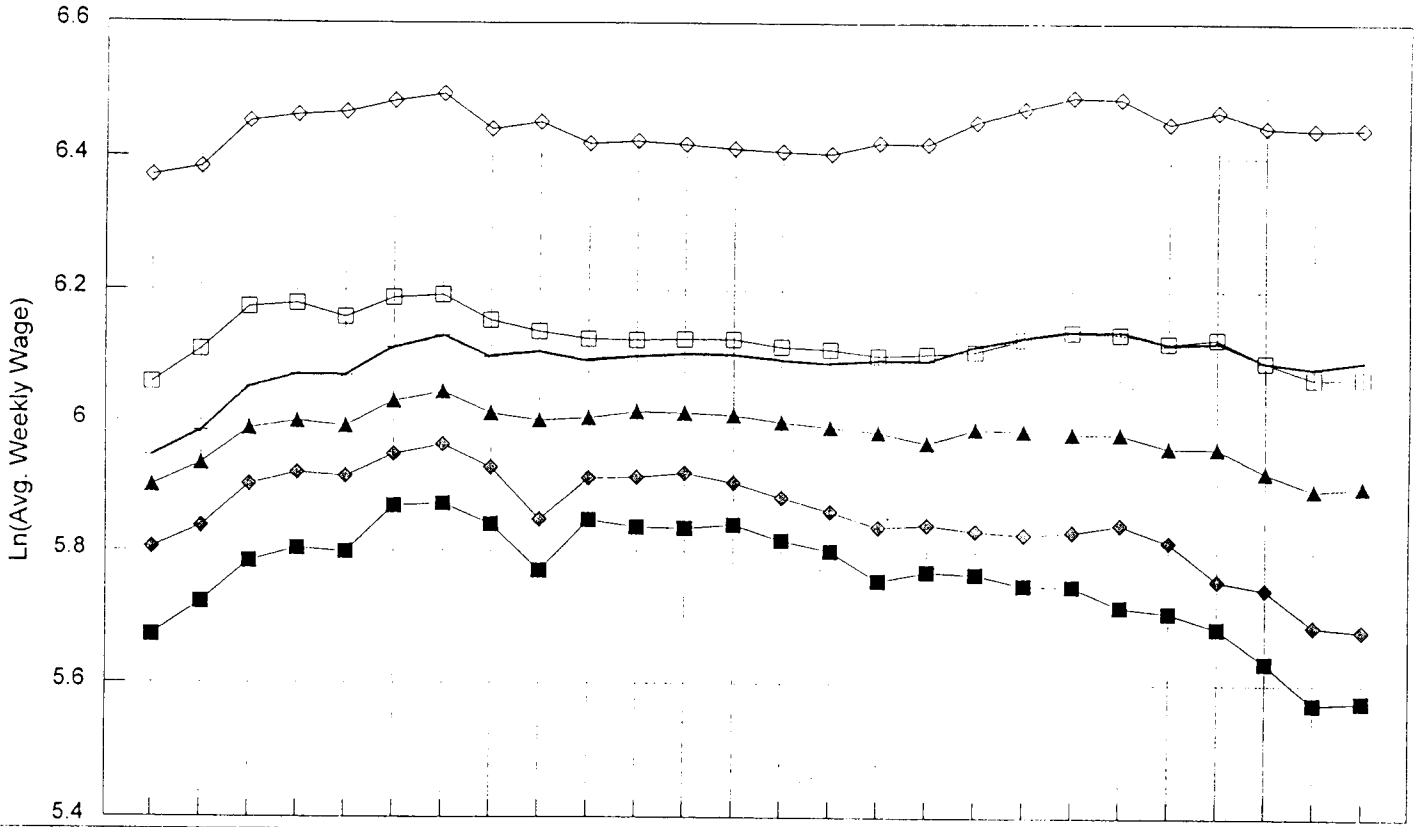
Figure 1.

Log of U.S. Real Wages by Educational Groups, 1967-92



Year	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
■ 1-8 Years of Ed.	5.67	5.72	5.78	5.80	5.80	5.87	5.87	5.84	5.77	5.85	5.84	5.84	5.84	5.82	5.80	5.76	5.77	5.77	5.75	5.75	5.72	5.71	5.68	5.63	5.57	5.57
◆ 9-11 Years of Ed.	5.81	5.84	5.90	5.92	5.92	5.95	5.96	5.93	5.85	5.91	5.91	5.92	5.91	5.88	5.86	5.84	5.84	5.83	5.83	5.83	5.84	5.82	5.76	5.74	5.69	5.68
▲ 12 Years of Ed.	5.90	5.94	5.99	6.00	5.99	6.03	6.05	6.01	6.00	6.01	6.01	6.01	6.01	6.00	5.99	5.98	5.97	5.99	5.99	5.98	5.98	5.96	5.96	5.92	5.90	5.90
□ 13-15 Years of Ed.	6.06	6.11	6.17	6.18	6.16	6.19	6.19	6.15	6.14	6.13	6.13	6.13	6.13	6.11	6.11	6.10	6.10	6.11	6.13	6.14	6.14	6.12	6.13	6.09	6.07	6.07
◇ 16+ Years of Ed.	6.37	6.38	6.45	6.46	6.47	6.48	6.49	6.44	6.45	6.42	6.42	6.42	6.41	6.41	6.41	6.42	6.42	6.45	6.47	6.49	6.49	6.45	6.47	6.45	6.44	6.44
All	5.95	5.98	6.05	6.07	6.07	6.11	6.13	6.10	6.11	6.09	6.10	6.10	6.10	6.09	6.09	6.09	6.09	6.12	6.13	6.14	6.14	6.12	6.12	6.09	6.08	6.09

The logs of average weekly real wages are tabulated separately below the graph.

Table 1
Key U.S. Economic Relationships, 1967-1992

A	1967	1972	1977	1980	1982	1987	1992
Ratio of workers (who were in the workforce for 39 weeks or more) with 13 or more years of education to workers with 12 years or less with respect to:							
Wages	1.51	1.45	1.38	1.38	1.42	1.50	1.52
Supply of Workers	.34	.43	.56	.62	.67	.79	1.11
Labor Coefficients[1]	.29	.35	.45	.52	.57	.70	-
Labor Embodied in imports[2]	.22	.26	.34	.39	.42	.54	-
Labor Embodied in exports[2]	.26	.32	.41	.47	.51	.65	-
Output ratio of all goods intensive in higher educated to less educated workers[3] (1977= 1.00)	.89	.88	1.00	1.18	1.25	1.16	-
Consumption ratios of all goods intensive in higher educated to less educated workers[3] (1977 = 1.00)	.88	.87	1.00	1.17	1.23	1.11	-
Domestic Price ratio of goods intensive in higher educated to less educated workers[3] (1977 = 1.00)							
All Sectors	1.06	1.05	1.00	1.00	1.04	1.20	1.22
Manufacturing	1.02	.95	1.00	1.08	1.11	1.02	1.01
Total factor productivity ratio of manufactured goods intensive in higher educated to less educated workers[3] (1977=1.00)	.90	.98	1.00	.96	.96	.95	.96
Ratios of (Exports Less Imports) / Consumption	-.015	-.023	-.012	.012	-.003	-.047	-.010

[1]For each industry the direct and indirect labor coefficients (that is, the number of workers used to produce each dollar's worth of industry output, including the workers involved in producing the intermediate goods and services used in producing the final industry output) for both education groups are weighted by the outputs of each of the 79 industries in the two-digit input-output tables.

[2]The ratio of the direct and indirect number of workers in each educational group embodied in a representative one-million-dollar bundle of import-competing and exported goods and services.

[3]Goods and services intensive in the use of higher educated (13 years and above) and less educated (12 years and below) workers are defined as those industries above and below the median industry ratio of the direct and indirect labor coefficients of these two educational groups for the year 1977.

Table 1 -(continued)

B	1967-1972	1972-1980	1980-1992
Average Annual Percentage Change in the Endowment of:			
Workers with more than 12 years of education	6.2	5.8	4.2
Workers with 12 years of education	4.2	2.8	0.2
Workers with 1-11 years of education	-3.0	-2.2	-3.6
Labor Force	2.4	2.6	1.4
Physical Capital	4.4	3.8	2.

C

Percent Distribution of Labor Force by Education Levels	1967	1972	1977	1980	1982	1987	1992
1-11 Years of Education	36	28	22	19	18	14	10
12 Years of Education	39	42	42	43	42	42	37
13 or more Years of Education	25	30	36	38	40	44	53

Sources: Data on wages and proportions of workers by education groups are from the March Current Population Surveys. Data on the value of output, consumption, exports and imports are from the 79 industry (the two-digit level of classification) input-output tables published by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. These data are expressed in real terms, using the consumer price deflator. Employment and price data are from from the Output and Employment Database of the Office of Employment Projections, Bureau of Labor Statistics. Total factor productivity data are from the Productivity Database assembled by Eric Bartelman and Wayne Gray, which is available from the National Bureau of Economics. Data for the labor force and physical capital (equipment and structures) data are from the Economic Report of the President and BEA's Fixed Reproducible Tangible Wealth in the United States, 1925-89.

Table 2
Effects in Standard Two-Factor, Two-Good Trade Model of Economic Shocks in Country Exporting Skilled Labor-Intensive Good[1]

Changes in:

	$\frac{P_{sk}}{P_{un}}$		$\frac{O_{sk}}{O_{un}}$		$\frac{L_{sk}\text{ coefficient}}{L_{un}\text{ coefficient}}$		$\frac{W_{sk}}{W_{un}}$	
	Fixed Labor Coefficients	Factor Subst.	Fixed Labor Coefficients	Factor Subst.	Fixed Labor Coefficients	Factor Subst.	Fixed Labor Coefficients	Factor Subst.
Increase in L_{sk} relative to L_{un}	-	-	+	+ or -	0	+	-	-
Increased Import Competition in Unskilled Labor-Intensive Sector	+	+	0	+	0	-	+	+
Uniform Unskilled Labor-Saving Technical Progress	+	+	-	- or +	+	+ or -	+	+
Greater Neutral Technical Progress in Skilled Labor-Intensive Sector	-	-	+	+ or -	0	- or +	+ or -	+ or -

[1]It is assumed that the country is large enough to influence its terms of trade and that its preferences are homothetic.

Table 3
Changes in Industry Product Prices Related to Factors Shares, 1968-1973, 1973-79 and 1979-91

Productive Factors	1968-73		1973-79		1979-91	
Labor by level of education	All Sectors	Manufac-turing	All Sectors	Manufac-turing	All Sectors	Manufac-turing
1-12 years	-.01 (.03)	.06* (.03)	-.03 (.04)	-.03 (.06)	-.04* (.02)	-.03 (.03)
13+ years	-.16*** (.05)	-.18*** (.05)	-.15** (.06)	-.15* (.09)	.01 (.03)	-.11** (.05)
Capital	.004 (.003)	.02*** (.01)	.002 (.003)	.03** (.01)	-.003* (.002)	.009 * (.005)
Constant	.07*** (.02)	.02 (.02)	.13*** (.03)	.09* (.04)	.06*** (.01)	.09*** (.02)
R-squared	.22	.45	.10	.20	..08	.12
F Statistic	6.92	12.84	2.71	4.01	1.95	2.23

Labor by level of Education	All Sectors	Manufac-turing	All Sectors	Manufac-turing	All Sectors	Manufac-turing
1-11 years	.08* (.04)	.12*** (.04)	.02 (.07)	-.05 (.09)	-.07* (.04)	-.02 (.05)
12+ years	-.10*** (.03)	-.05 (.03)	-.10** (.04)	-.06 (.06)	-.01 (.02)	-.06** (.03)
Capital	.004 (.003)	-.018** (.007)	.002 (.003)	.03** (.01)	-.003* (.002)	-.008 (.005)
Constant	.07*** (.02)	.02 (.03)	.13*** (.03)	.08* (.05)	.06*** (.01)	.08*** (.02)
R-squared	.28	.36	.10	.17	.07	..09
F Statistic	9.36	8.87	2.58	3.39	1.80	1.60

Labor by level of Education	All Sectors	Maufac-turning	All Sectors	Manufac-turing	All Sectors	Manufac-turing
1-11 years	.14*** (.05)	.04 (.06)	-.02 (.10)	-.30** (.12)	-.04 (.06)	-.13* (.08)
12 years	-.21*** (.06)	.08 (.07)	-.04 (.10)	.25** (.12)	-.04 (.05)	.05 (.07)
13+ years	-.01 (.09)	-.36** (.14)	-.14* (.08)	-.35*** (.12)	.01 (.04)	-.18*** (.07)
Capital	.005* (.003)	.02*** (.01)	.002 (.003)	.03*** (.01)	-.003* (.002)	.010* (.005)
Constant	.06*** (.02)	.00 (.02)	.13*** (.03)	.10** (.04)	.06*** (.01)	.09*** (.02)
R-squared	.29	.41	.10	.30	..07	.08
F Statistic	7.31	8.21	2.01	4.96	1.44	2.19
Number of Observations	76	52	76	52	76	52

Standard error in parentheses; *, **, *** indicates 10%, 5% and 1% significance level

Table 4
Changes in Outputs Related to Factor Shares, 1968-1973, 1973-79 and 1979-86

Productive Factors	1968-73		1973-79		1979-86	
Labor by Level of Education	All Sectors	Manufac-turing	All Sectors	Manufac-turing	All Sectors	Manufac-turing
1-12 years	-.04 (.03)	-.10* (.05)	-.06 (.04)	-.11 (.08)	-.10** (.05)	-.13 (.08)
13+ years	.15*** (.06)	.27*** (.10)	.23*** (.07)	.42*** (.12)	.33*** (.07)	.47*** (.12)
Capital	-.003 (.003)	-.003 (.011)	.003 (.004)	-.006 (.015)	-.002 (.004)	-.017 (.013)
Constant	.01 (.02)	.02 (.04)	.01 (.03)	.01 (.06)	-.01 (.03)	.00 (.06)
R-squared	.14	.26	.16	.29	.28	.36
F Statistic	3.68	5.44	4.59	6.43	9.13	9.19

Labor by Level of Education	All Sectors	Manufac-turing	All Sectors	Manufac-turing	All Sectors	Manufac-turing
1-11 years	-.11** (.05)	-.21*** (.07)	-.23*** (.07)	-.34*** (.12)	-.27*** (.10)	-.28* (.14)
12+ years	.07* (.04)	.07 (.06)	.12** (.05)	.18** (.08)	.13** (.05)	.14 (.09)
Capital	-.003 (.003)	-.003 (.011)	.003 (.004)	-.006 (.015)	-.003 (.004)	-.024* (.014)
Constant	.02 (.02)	.04 (.04)	.01 (.03)	.02 (.06)	.00 (.03)	.03 (.06)
R-squared	.14	.22	.17	.25	.16	.21
F Statistic	3.78	4.26	5.05	5.45	4.52	4.29

Labor by level of Education	All Sectors	Manufac-turing	All Sectors	Manufac-turing	All Sectors	Manufac-turing
1-11 years	-.11* (.06)	-.16 (.10)	-.18* (.11)	-.15 (.17)	.10 (.13)	.30* (.18)
12 years	.07 (.07)	-.02 (.13)	.06 (.11)	-.06 (.18)	-.26** (.11)	-.50*** (.16)
13+ years	.14 (.11)	.27 (.28)	.16* (.09)	.39** (.17)	.41*** (.09)	.76*** (.16)
Capital	-.003 (.003)	-.005 (.011)	.003 (.004)	-.006 (.015)	-.001 (.004)	-.012 (.012)
Constant	.02 (.02)	.05 (.04)	.01 (.03)	.01 (.06)	.02 (.03)	.04 (.06)
R-squared	.14	.22	.18	.29	.30	.44
F Statistic	2.84	3.13	3.83	4.75	7.61	9.37
Number of Observations	74	50	76	52	76	52

Standard error in parentheses
*, **, *** indicates 10%, 5% and 1% significance levels

Table 5
Revealed Comparative Advantage: Trade Ratios Related to Factor Shares[1]

Productive Factors	All Traded Goods and Services[2]				All Traded Manufactures[2]			
Labor by Education Level	1967-69[3]	1972-74	1978-80	1985-87	1967-69	1972-74	1978-80	1985-87
1-12 years	-.12[x] (.07)	-.12 (.09)	-.26[x] (.14)	-.35[xx] (.09)	-.11 (.13)	-.14 (.14)	-.32 (.19)	.56[xxx] (.14)
13+ above years	.14 (.11)	.12 (.13)	.07 (.19)	.27[xx] (.13)	.47[xxx] (.17)	.75[xxx] (.20)	1.07[xxx] (.26)	.73[xxx] (.21)
Capital	.009 (.86)	.004 (.010)	-.003 (.013)	.017 (.011)	.033 (.029)	.006 (.029)	.029 (.031)	.045[xx] (.021)
Constant	.01 (.05)	.04 (.07)	.11 (.09)	.00 (.06)	-.08 (.11)	-.09 (.12)	-.13 (.15)	-.10 (.10)
R-Squared	.10	.05	.07	.24	.22	.28	.33	.35
F-Statistic	2.21	1.16	1.70	6.73	4.48	6.08	9.41	8.80

Labor by Education Level	1967-69	1972-74	1978-80	1985-87	1967-69	1972-74	1978-80	1985-86
1-11 years	-.16[x] (.15)	-.28 (.25)	-.68 (.43)	-1.41[xxx] (.45)	-.17 (.20)	-.25 (.26)	-.43 (.43)	-1.17[xx] (.48)
12 years	-.05 (.17)	.05 (.27)	.07 (.35)	.27 (.27)	-.02 (.28)	.00 (.32)	-.21 (.39)	-.09 (.38)
13+ above years	.17 (.38)	-.02 (.24)	-.21 (.33)	-.17 (.21)	.79 (.49)	.64[xx] (.31)	.98[xx] (.40)	.39 (.33)
Capital	.008 (.069)	-.004 (.010)	-.007 (.014)	.011 (.011)	.029 (.029)	.007 (.029)	.027 (.032)	.039[x] (.022)
Constant	.02 (.05)	.05 (.07)	.15 (.10)	.07 (.07)	-.03 (.10)	-.09 (.12)	-.12 (.16)	-.06 (.10)
R-Squared	.10	.06	.09	.31	.28	.27	.37	.38
F-Statistic	1.65	.98	1.53	6.91	3.26	4.54	6.95	7.14

Standard errors in parentheses below the coefficients; [x], [xx], [xxx], indicate significance levels at 10%, 5%, and 1%, respectively.

[1]The measure of revealed comparative advantage (the dependent variable in the regressions) is the ratio of (exports less imports)/industry consumption in each two-digit industry averaged over the years indicated. Industry consumption is defined as industry output - exports + imports. The regressors are weighed by employment.

[2]All Traded Goods and Services include 67 two-digit industries: 1-10, 13-64, 65, 68, 70, 73, 76; and Traded Manufactures cover 52 industries: 13-64.

[3]In the regressions for the periods for 1967-69, 1972-74, 1978-80, and 1985-87, the factor shares and employment weights utilized are for 1967, 1972, 1977, and 1982, respectively.

Table 6
Changes in Trade Ratios Related to Factor Shares[1]

	All Traded Goods and Services			All Traded Manufactures		
Productive Factors	1968-73	1973-79	1979-91	1968-73	1973-79	1979-91
Labor by Level of Education						
1-12 Years	-.01 (.06)	-.15^{xxx} (.05)	-.15^{x} (.08)	.02 (.09)	-.14^{xx} (.07)	-.19^{x} (.11)
13+ Years	.16^{x} (.08)	-.05 (.07)	.35^{xxx} (.11)	.54^{xxx} (.12)	.29^{xxx} (.10)	-.02 (.15)
Capital	.000 (.007)	-.004 (.005)	.029^{xxx} (.008)	-.003 (.021)	.024^{x} (.013)	.057^{xxx} (.01)
Constant	-.01 (.04)	.09^{xx} (.03)	-.12^{xx} (.05)	-.09 (.08)	-.02 (.06)	-.08 (.09)
R-squared	.07	.12	.32	.39	.31	.35
F-Statistic	1.55	2.92	9.74	10.44	7.21	8.52
No. of Observations	67	67	67	52	52	52

Productive Factors	1968-73	1973-79	1979-86	1968-73	1973-79	1979-86
Labor by Level of Education						
1-11 Years	-.07 (.12)	-.14 (.13)	-.53^{xx} (.24)	-.08 (.15)	-.12 (.13)	-.48^{xx} (.24)
12 Years	.06 (.13)	-.15 (.14)	.15 (.20)	.12 (.21)	-.16 (.15)	.07 (.21)
13 Years	.11 (.30)	.04 (.13)	.09 (.19)	.72^{x} (.37)	.31^{xx} (.15)	-.25 (.22)
Capital	-.002 (.007)	-.004 (.005)	.025^{xxx} (.008)	-.011 (.076)	.024^{x} (.014)	-.051^{xxx} (.018)
Conatant	.01 (.06)	.09^{xx} (.04)	-.08 (.05)	-.01 (.08)	-.02 (.06)	.-05 (.09)
R-squared	.05	.12	.35	.32	.31	.37
F-Statistic	.87	2.16	8.18	5.63	5.30	7.01
No. of Observations	67	67	67	52	52	52

Standard errors are in parentheses; ^{x}, ^{xx}, ^{xxx} indicate significance levels of 10%, 5% and 1%, respectively.

[1]The trade ratio changes in the 1968-73 period are equal to the average ratio by industry of (exports-imports)/consumption between 1972-1974 minus the average ratio by industry of (exports-imports)/consumption between 1967-1969. The 1973-79 and 1979-86 changes are based on 1978-1980 and 1972-1974 trade-ratio averages and 1985-1987 and 1978-1980 averages, respectively. The regressors are weighted by employment.

Table 7
Changes in Import and Export Prices Related to Factor Shares, 1982-1992

	Import Prices[1]			Export Prices[1]		
Productive Factors	1982-92	1982-87	1987-92	1982-92	1982-87	1987-92
Labor by Level of Education						
1-12 Years	.88** (.38)	.64** (.24)	.15 (.12)	.53* (.31)	.33* (.18)	.16 (.19)
13 Years	-.42 (.64)	-.10 (.41)	-.46** (.21)	-.64 (.46)	-.26 (.28)	-.39 (.28)
Capital	-.045 (.055)	-.021 (.035)	-.02 (.02)	-.080** (.039)	.012 (.023)	-.081*** (.023)
Constant	.19 (.24)	.07 (.16)	.24*** (.08)	.37** (.18)	.00 (.11)	.36** (.11)
R-squared	.13	.16	.12	.15	.10	.25
F-Statistic	1.97	2.76	2.05	2.30	1.34	4.32
No. of Observations	49	49	49	42	42	42

	Import Prices			Export Prices		
Productive Factors						
Labor by Level of Education						
1-11 Years	-2.04* (1.10)	-.76 (.73)	-.82** (.36)	-1.21 (1.01)	-.25 (.63)	-.89 (.61)
12 Years	3.07*** (.85)	1.69** (.57)	.88*** (.28)	1.52** (.62)	.65* (.39)	.76** (.37)
13+ Years	-2.02*** (.82)	-.66 (.55)	-.99*** (.27)	-1.24** (.56)	-.46 (.35)	-.75** (.34)
Capital	-.057 (.051)	-.028 (.034)	-.025 (.017)	-.082** (.038)	.011 (.023)	-.083*** (.023)
Constant	.32 (.23)	-.01 (.15)	.29** (.08)	.44** (.18)	.03 (.11)	.40*** (.11)
R-squared	.25	.23	.26	.22	.12	.32
F-Statistic	3.68	3.23	3.79	2.65	1.23	4.26
No. of Observations	49	49	49	42	42	42

Standard errors in parentheses; *, **, *** indicates 10%, 5% and 1% significance levels, respectively.

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[1]Import prices cover 49 manufacturing sectors of the two-digit input-output table. Import prices are not available for sectors 13 (ordinance), 60 (aircraft), and 61 (other transportation equipment). Export prices cover 42 manufacturing sectors. They are not available for industries 17 (miscellaneous textile goods), 18 (apparel), 19 (miscellaneous textile products), 20 (lumber and wood products), 21 (wood containers), 31 (petroleum refining), 33 (leather tanning), and 34 (footwear). Note that the price changes in this table are not measured on an annual compound basis.

Table 8

The Effect of Changes in Trade on the Highly Educated/Less Educated Labor Wage Gap, 1967-1977 and 1977-1987

	1977= Year t 1967= Year t-1	1987= Year t 1977= Year t-1
Hypothetical Wage Gap in Year t, Holding Factor Trade at Year t-1 Level	.364	.480
Actual Wage Gap in Year t	.380	.503
Gap in Year t Attributable to Change in Trade Between Year t and Year t-1	.015	.023

Sources: The sources cited in Table 2 provide the data needed for these estimates that are based on Equation (8) of the text.

Appendix 1
Factor Price Changes Associated with Changes in Product Prices, 1968-1973
(Weighted Regressions)

Productive Factors	All Sectors		Agriculture, Mining & Manufacturing		Manufacturing	
Labor by level of education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-12 years	-.07*** (.02)	-.01 (.02)	-.04 (.03)	-.01 (.02)	.03 (.04)	.00 (.03)
13+ years	-.06* (.03)	.01 (.03)	-.26*** (.05	-.26*** (.05)	-.10** (.05)	-.13*** (.04)
Capital	.001 (.003)	.002 (.002)	.001 (.004)	.003 (.004)	.025*** (.008)	.019 *** (.007)
Constant	.10*** (.02)	.06*** (.01)	.11*** (.02)	.10*** (.02)	.02 (.03)	.04 (.02)
Adjusted R^2	.07	-.00	.31	.34	.34	.36
F Statistic	2.97	.93	10.54	11.61	9.78	10.42
Labor by level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-11 years	-.05 (.03)	.02 (.03)	.03 (.04)	.08** (.04)	.05 (.05)	.04 (.04)
12+ years	-.07*** (.02)	-.02 (.02)	-.16*** (.03)	-.15*** (.03)	-.03 (.04)	-.06** (.03)
Capital	-.00 (.003)	-.002 (.002)	.001 (.004)	.002 (.005)	.025 *** (.008)	.018*** (.007)
Constant	.10*** (.02)	.06*** (.01)	.11*** (.02)	.10*** (.02)	.01 (.03)	.04* (.02)
Adjusted R^2	.08	.01	.32	.38	.30	.32
F Statistic	3.16	1.34	10.83	13.73	8.17	9.13
Labor by level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-11 years	.00 (.03)	.07* (.04)	.05 (.06)	.14** (.06)	-.02 (.06)	-.02 (.05)
12 years	-.14*** (.04)	-.09** (.04)	-.20** (.09)	-.28*** (.08)	.11 (.08)	.04 (.07)
13+ years	-.02 (.04)	.04 (.05)	-.24 (.18)	-.08 (.16)	-.30** (.14)	-.28** (.12)
Capital	.000 (.03)	.002 (.002)	.001 (.004)	.002 (.005)	.03*** (.008)	.021*** (.007)
Constant	.09*** (.02)	.06*** (.01)	.10*** (.02)	.09*** (.02)	-.00 (.03)	.03 (.02)
Adjusted R^2	.11	.05	.30	.37	.34	.34
F Statistic	3.29	2.01	7.62	10.25	7.54	7.65
Number of Observations	76	76	64	64	52	52

Standard error in parentheses; *, **, *** indicates 10%, 5% and 1% significance level

Appendix 1 - continued
Factor Price Changes Associated with Changes in Product Prices, 1973-1979
(Weighted Regressions)

Productive Factors	All Sectors		Agriculture, Mining & Manufacturing		Manufacturing	
Labor by Level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-12 years	.03 (.04)	.01 (.03)	.05 (.06)	-.10* (.06)	.00 (.06)	-.06 (.04)
13+ years	-.01 (.05)	.00 (.05)	-.08 (.11)	.05 (.13)	-.01 (.08)	.12 (.08)
Capital	.001 (.004)	.012*** (.004)	.001 (.006)	.003 (.009)	.03*** (.01)	.040*** (.008)
Constant	.07*** (.03)	.07*** (.02)	.08** (.04)	.14*** (.04)	.03 (.05)	.02 (.03)
R-squared	.01	.10	.02	.07	.21	.40
F Statistic	.29	2.65	.33	1.61	4.26	10.86

Labor by level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-11 years	.09* (.05)	.07 (.06)	.05 (.09)	-.16 (.10)	-.06 (.07)	-.19*** (.07)
12+ years	-.01 (.04)	-.02 (.03)	-.00 (.06)	-.03 (.07)	.02 (.06)	.05 (.05)
Capital	.000 (.004)	.011** (.004)	.001 (.006)	.003 (.009)	.036*** (.011)	.040*** (.009)
Constant	.08*** (.02)	.07*** (.02)	.08** (.04)	.14*** (.04)	.03 (.05)	.04 (.03)
R-squared	.04	.11	.01	.07	.23	.44
F Statistic	1.12	3.03	.11	1.53	4.65	12.75

Labor by level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-11 years	.16** (.07)	.18* (.09)	-.09 (.15)	-.09 (.19)	-.26*** (.10)	-.29** (.11)
12 years	-.10 (.07)	-.15 (.09)	.23 (.19)	-.13 (.22)	.34*** (.12)	.18 (.12)
13+ years	.04 (.05)	.07 (.06)	-.22 (.18)	.07 (.22)	-.27** (.11)	-.08 (.12)
Capital	.001 (.004)	.013*** (.004)	.002 (.006)	.003 (.009)	.036*** (.010)	.04*** (.008)
Constant	.07*** (.02)	.07*** (.02)	.09 (.04)	.14*** (.04)	.03 (.04)	.04 (.03)
R-squared	.08	.14	.03	.07	.35	.46
F Statistic	1.44	2.92	.51	1.19	6.25	10.00

Number of Observations 76 76 64 64 52 52
Standard error in parentheses; *, **, *** indicates 10%, 5% and 1% significance levels

Appendix 1 - continued
Factor Price Changes Associated with Changes in Product Prices, 1979-1991
(Weighted Regressions)

Productive Factors	All Sectors		Agriculture, Mining & Manufacturing		Manufacturing	
Labor by Level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-12 years	-.08*** (.02)	-.07*** (.02)	.00 (.03)	-.01 (.02)	-.01 (.03)	-.01 (.02)
13+ years	.06** (.03)	.06** (.02)	.05 (.05)	.11** (.05)	-.01 (.04)	.04 (.04)
Capital	.001 (.002)	.000 (.002)	.002 (.003)	-.001 (.003)	-.002 (.005)	-.010** (.004)
Constant	.05*** (.02)	.05*** (.01)	.01 (.02)	.02 (.01)	.04 (.03)	.05*** (.02)
R-squared	.33	.28	.02	.08	.00	.20
F Statistic	11.92	9.17	.43	1.77	.05	3.88

Labor by Level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-11 years	-.18*** (.04)	-.18*** (.04)	-.03 (.06)	-.08 (.06)	-.03 (.05)	-.04 (.04)
12+ years	.01 (.02)	.01 (.01)	.03 (.03)	.06** (.03)	-.00 (.03)	.02 (.02)
Capital	.000 (.02)	-.001 (.002)	.003 (.003)	-.001 (.003)	-.002 (.005)	-.010** (.004)
Constant	.06*** (.02)	.06*** (.01)	.01 (.02)	.02 (.01)	.04* (.03)	.05*** (.02)
R-squared	.25	.25	.03	.09	.01	.21
F Statistic	7.87	7.98	.55	1.87	.19	4.25

Labor by Level of Education	Employment Weights	Output Weights	Employment Weights	Output Weights	Employment Weights	Output Weights
1-11 years	-.07 (.05)	-.10* (.06)	-.06 (.10)	-.06 (.10)	-.14** (.07)	.07 (.07)
12 years	-.09** (.04)	-.06 (.04)	.06 (.09)	.04 (.09)	.11* (.06)	.05 (.06)
13+ years	.07** (.03)	.06* (.03)	.00 (.08)	.07 (.08)	-.12* (.07)	.00 (.05)
Capital	.002 (.002)	.000 (.002)	.002 (.003)	-.001 (.003)	.004 (.005)	-.010*** (.004)
Constant	.05*** (.02)	.05 (.01)	.01 (.02)	.02 (.01)	.06** (.03)	.05*** (.02)
R-squared	.33	.28	.03	.09	.09	.21
F Statistic	8.83	6.86	.44	1.40	1.11	3.20
Number of Observations	76	76	64	64	52	52

Standard error in parentheses
*, **, *** indicates 10%, 5% and 1% significance levels