The Effects of International Trade on Wage Inequality in the U.S.

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ABSTRACT

We develop several simple general equilibrium models to analyze the effects of increased international trade on the growth of income inequality that occurred in the U.S. during the 1970's and 1980's. We conclude that the expansion of trade has decreased the real wage of unskilled labor by 1 to 3 percent, a relatively small amount.

To obtain this estimate we developed a new measure of skill based on information found in the Directory of Occupational Titles. This skill index and data from the Occupational Employment Survey and Input-Output Information are used to calculate three factor shares for two tradeable and two non-tradeable sectors.

1. Introduction

It is well known from the work of Freeman (1997, Juhn, Murphy and Pierce (1993), Welch (1999) and many others, that wage inequality has increased significantly in the U.S. over the last twenty-five years and that the real wage of many workers, especially unskilled males, has declined during this period. The real earnings of full-time unskilled male workers, located at the 10^{th} percentile of wage distribution, decreased by 25% between 1970 and 1989. In contrast, the earnings of workers at the 90^{th} percentile increased by 10 percent. (Juhn, Murphy and Pierce (1998, p. 416)). Also, earnings of the least skilled decreased by about 10 percent relative to the earnings of the median worker during this period. Freeman (1997, p.71) reports similar results for trends in hourly earnings. The real wage of the least skilled male worker fell by 20 percent while the hourly wage of a worker at the 90% percentile remain unchanged during the period 1979-93.

The large literature on growing income inequality, surveyed by Lawrence (1996) and Cline (1997), offers two primary explanations for this phenomenon. One is the importance of skilled-biased technological change and the growth of investment in equipment, especially in computers. The second is the growth of international trade between high-income industrial nations and more recently between members of the Organization of Economic Co-Operation and Development (OECD) and newly industrialized economies (NIE). Both groups of countries have dismantled trade barriers, reversed statist policies and encouraged foreign investment.

Stolper and Samuelson (1941) used the Hecksher-Ohlin (HO) model of trade to prove that the liberalization of international trade will decrease the real income of a country's scarce factor, absolutely as well as relatively. In this paper we utilize a large country version of the *HO* model, first formulated by Paul Kurgman (1995) and in a preliminary version of this paper,[1] to study numerically the contribution of increased international trade to the growth of wage inequality in the U.S. This approach, which has also been used by Lawrence and Evans (1996), Lawrence (1996) and Cline (1997), assumes that a large "country", such as the OECD or the U.S., experiences a supply shock. Foreign producers increase their supply of goods intensive in the use of unskilled labor. The additional supply of foreign goods is assumed to be exogenous, to be price inelastic, and to be exchanged for skill intensive goods produced in the home country. The effect of increased trade on the absolute and relative wages of skilled and unskilled labor in the large country is estimated numerically, on the basis of estimates of the magnitude of the trade shock and the relative factor intensities of different industries.

Krugman (1995) used a two-factor two-sector model to calculate that the expansion of trade between the OECD and NIE between 1970-1990 decreased the unskilled wage in the OECD by 3% relative to the skilled wage rate. The effects of the increased trade are relatively small as the size of the overall OECD economies, inclusive of non-traded sectors, are large relative to the expansion of trade.[2]

Our paper is novel in a number of respects. We develop a new way of classifying skill by using the requirements of different occupations reported in the Directory of Occupational Titles (DOT). These data and occupational wage information from the census are used to classify skill and to calculate factor shares by industry for the six-digit industrial classification of the 1987 input-output table for the U.S.

We have two reasons for choosing the DOT-based skill measure instead of relying on the more conventional classification of workers according to whether they have a high school or a college degree.[3] The first consideration is that the use of DOT data to rank the skill level of each industry-occupation cell requires the assumption that workers within each cell are equally skilled, a much weaker restriction than taking that workers with the same educational attainment are homogenous. Secondly, our work indicates that the DOT skill index is a very reasonable measure of workers' skills, and its components are good predictors of the actual wages paid in different industry-occupation cells. The DOT skill index is more highly correlated with wages than any alternative skill index.

This index is used to classify the skill of occupations by industry and to calculate factor shares by disaggregated input-output industries. These factor shares are used to classify using various vintages of the input-output table, exports and imports in different time periods in terms

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[1] Kim and Mieszkowski: (1995)

[2] The importance of the size of the non-traded sector is emphasized by Krugman (1994) and Krugman and Lawrence (1994). This consideration stimulated us to formulate a large-country version of the H-O model which explicitly accounts for non-traded sectors.

[3] One of the two conventional measures of skill, the classification of workers into non-production and production workers, is not useful for our purposes as this designation is not available outside of manufacturing.

of the skill intensities of the producing industries. Non-tradeables are also classified according to a two-industry skill designation.[4]

The input-output-table allows factor shares to be calculated in a way that the relative skill intensity of an "industry" producing a specific commodity reflects both the direct and indirect input requirements of a dollar delivered by that industry to final demand. In our analysis the "aircraft" industry includes both firms which assemble various components into an airplane and the portion of industries that produce the intermediate inputs used in the production of the aircraft. Thus, the capital share for this industry includes the capital used to produce the aluminum used to produce the aircraft and the capital used to produce the electricity to produce the aluminum to produce the aircraft, and so on.

The factor shares so calculated are, to the best of our knowledge, the first disaggregative estimates of the relative skill and capital intensives of tradeables and non-tradeables.[5] Interestingly, the calculated factor shares indicate that unskilled-intensive tradeables are capital intensive relative to skilled-tradeables, a confirmation of the Leontief Paradox, and that the two most intensive users of both unskilled and skilled labor are the two non-tradeables sectors.

More significantly, the estimated differences in factor intensities across sectors are quite small. This finding indicates that a small change in relative commodity prices can be associated with a large change in factor prices; we estimate a magnification effect of six. Furthermore, the small difference in factor shares for exportables and importables supports Johnson's (1966) conclusion that supply can be very elastic in general equilibrium models.[6]

We carry out simulation experiments for two specifications of production. The first is the constant-elasticity of substitution (CES) formulation, used by Cline (1997) and Krugman (1995). The second specification adopts a standard two-tier constant elasticity production function and assumes that capital and skill are relative complements (KSC). We were encouraged to allow for KSC by the growing literature in macro and labor economics on this topic, Krusell et.al. (1997), Stokey (1996), Golden and Katz (1998 and Autor, Krueger and Katz (1998). These authors use

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[4] The factor-share calculations involves the matching of the DOT industrial classification with the input-output industrial classification.

[5] Sachs and Shantz (1998) use educational attainment of workers to measure the relative skill intensities of two broad sectors, tradeables and non-tradeables. In their classification they make no allowance for trade in services, and make no provision for capital.

[6] Johnson showed, for a Cobb-Douglas technology, that the production possibility frontier is essentially a straight line except when factor intensities vary considerably between industries.

historical and quantitative evidence on the existence of capital-skill complementarity to explain growing wage inequality.[7]

The simulation results for the two specifications of production are strikingly and surprisingly similar, the expansion of trade has a small effect on the real wage of unskilled labor in the U.S., between 1 to 3 percent. This result, consistent with the findings of Krugman (1995) and Cline (1997), obtains for the standard CES model except when the elasticity of substitution is quite low, less than .3.

For the case of KSC, the results are more complicated and more unusual. But the principal conclusion remains unchanged — the real income loss of unskilled labor due to trade is quite modest. The effect of increased trade is estimated to increase the skilled wage by 13 percent relative to unskilled wage. However, for this case the return to capital falls by 22 percent relative to the skilled wage and so the gains of skilled labor come primarily at the expense of capital, not unskilled labor. If capital is immobile across countries, the decrease in the real unskilled wage is about 1 percent. When capital is assumed to be mobile internationally, the estimated increase in real skilled wage is significantly smaller while the decrease in the real wage of unskilled labor is slightly larger.

We have little basis for choosing between the two basic models of production as the empirical evidence supporting the quantitative importance of KSC is inconclusive. Consequently, we highlight the result that increased trade in the U.S. has had a modest effect on the real wage of unskilled labor, a finding that is consistent across the two specifications of production.

Section 2 of the paper summarizes the previous research that is most germane to this paper on the relationship between wage inequality and the growth of trade. Section 3 discusses the sources and methods of estimating skill indices, factor shares, the classification of industries and the changes over time in the trade levels in the U.S. Section 4 represents the results of the simulation experiments and compares them with earlier work. Section 5 is devoted to

[7] Krusell et.al. use the falling price of capital equipment and the rising rates of investment during the 1980's and 1990's to explain the increased skill premium. We also experiment with a variant of the specific factors model (Jones 1971) in which skilled and unskilled labor are each employed on a different process to fulfill a different function that is necessary for the production of a commodity. This model allows for no direct substitution between skilled and unskilled labor.

concluding remarks.

2. Literature Review

2.1 Estimation of the magnitude of the Foreign Supply Shock

Krugman (1995) divides the world into two groups of countries: high-income industrial nations (members of the OECD), and new industrialized economies (NIE). Trade between the OECD and NIE has expanded rapidly since 1980 and a large portion of this trade is inter-industry rather than the intra-industry trade common between members of the OECD. Krugman measures the growth of trade between the OECD and NIE during 1970-1990 at two percent of the GDP of the OECD.

We estimate the growth of trade for the U.S. with all countries — and calculate the size of the supply shock relative to the U.S. GDP at two points in time, 1967 and 1992. We restrict ourselves to the U.S as we use detailed data on inter-industry trade and international trade for this nation. All trade is considered because the U.S. is a large net importer of automobiles and other consumer products produced by unskilled assemblers in other OECD countries and because trade in these commodities increased significantly throughout the 1970's and 1980's. Moreover, Juhn, Murphy and Pierce (1993) found that the ratio of wages at the 90th percentile of the wage distribution to the 10th percentile increased significantly during both the 1970's and 1980's. Consequently, by examining a longer time period, rather than concentrating on the late 1970's and 1980's as Lawrence and Slaughter (1993) and Sachs and Shatz (1994,1998) have done, we allow for the possibility that the expansion of trade affected relative wages during the 1970's as well.

2.2 Skill-Biased Technological Change and Capital-Skill Complementarity

Skill-biased technological change (SBTC) can be represented as a shift in the unit isoquant so that at unchanged factor prices the demand for skilled labor will increase relative to unskilled. Goldin and Katz (1998) characterize SBTC as a change in the type of production process. Suppose that an assembly process using machinery and large numbers of unskilled workers is replaced by a new batch process. This new process consists of a machine-installation and maintenance stage requiring skilled machinists, and a production stage during which the machines are operated by unskilled labor. This change in technology is an example of SBTC if the relative employment of skilled labor increases per unit of output.[8]

In contrast, the capital skill complementarity explanation of the increase in the demand for skill requires an increase in the supply of capital so that the increase in the capital output ratio increases the relative demand of skilled labor. If in an open economy the contracting sector is capital intensive, relatively more capital will be set free. As capital needs to be employed with more skilled labor, a trade-induced change in the home country's production structure will increase the demand for skill.

Griliches (1969) was the first to estimate capital and skill to be price complements. Hamermersh (1993 p.135), upon reviewing estimates of disaggregative studies of labor demand, concludes: "We are fairly sure that: (1) capital and skill are price-complements, (2) that technological change is a quantity-complement with skill, and (3) that the own-wage demand elasticity decreases as the skill embodied in a group of workers increases."[9]

Krussell, Ohanian, Rios-Rull and Violante (1997) present time-series evidence that KSC explains the growing inequality of wages. They stress that with KSC, growth in the stock of equipment increases the marginal product of skilled labor and decreases the marginal product of unskilled labor, and they report that since 1975 the growth rate in equipment investment has

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[8] Berman, Bound and Machin (1998) present a very clear exposition of the effects of SBTC on trade and relative commodity prices in their article on whether SBTC is pervasive across countries.

[9] Unfortunately, as noted by Cline (1997, p.16), the estimates of the elasticity of substitution between skilled and unskilled labor are based largely on the questionable nonproduction-production labor classification, and they are quite varied. Of the eighteen studies surveyed by Hamermesh (1993, p.109), fourteen are estimated to be positive, a substantial number of these well above 1 in value. A times-series study by Katz and Murphy (1992) of substitution between college and high school labor assumes separability between labor inputs and capital and estimates the elasticity of substitution between skilled and unskilled labor to be 1.41.

accelerated. Also, they note that the price of equipment has fallen relative to non-durables and services, accentuating the complementary effects of the accelerated investment spending. As the price of equipment falls, more machines are used, the demand for skilled labor will increase and fewer unskilled workers will be used. They go on to emply these facts to construct a multi-sector growth model with production characterized by KSC and conclude "that changes in observables can account for nearly all the variation in the skill premium over the last 30 years" (Krusell et.al. 1997, abstract)[10]

2.4 Classification and measurement of skill

In order to estimate the effects of trade on relative wages, we need a reliable measure of skill. One of the two measures traditionally used to classify the skill intensity of tradeable goods is the ratio of non-production workers to production workers, a classification available only for manufacturing.[11] A second measure of skill is education. Unskilled workers are reclassified as those with high school or less and skilled workers with at least some college education.[12]

Sachs and Shantz (1994) present evidence that these two measures of skill are correlated over time for total manufacturing; but they are not equivalent. Cline (1997, pp. 19-20) shows that the ratio of non-production (NP) to production (P) wages in manufacturing was relatively constant from 1960 on, before increasing by five percent in the late 1980's. In comparison, the wages of college graduates increased by 18% relative to the earnings of high school graduates between 1979-1993.

Leamer (1994) and Hamermesh (1993) are dubious of the NP-P skill classification as many P workers are skilled and many NP workers are unskilled. Hamermesh (1993, p.65) argues that the earnings overlap between the two groups is so large that knowing the degree

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[10] Their reasoning is at odds with Berman, Bound and Griliches (1994 p. 386) who conclude that investment in U.S. manufacturing was not large enough to explain the change in relative wage for estimated values of the elasticity of substitution.

[11] Berman, Bound and Griliches (1994) investigate the shift in demand away from production workers toward non-production labor in U.S. manufacturing, Sachs and Shatz (1994) assign imports and exports by skill decile by means of the production worker/non-production worker designation.

[12] Factor content analyses by Murphy and Welch (1991), Borjas, Freeman, and Katz (1992), and Wood (1994) use the educational classification to measure the skills embodied in imports and exports and to estimate the "change" in the effective supply of unskilled labor that occurred as a result of the expansion of trade. Also Sachs and Shatz (1998) use educational attainment to measure the skill intensity of tradeables and nontradeables.

substitution between them is of little policy interest. Leamer (1998, p.185) makes a similar point: "In 1971, for example, there was a sector where the average production worker had earnings of $3,660 and another with average earnings of $11,860. In the same period average earnings of non-production workers varied across sectors from a low of $4,930 to a high of $15,250" (p. 185). The wide variation in earnings casts doubt on the value of the NP-P labor classification. Wage differentials also indicate that skill for the same general occupation may vary significantly across industries. Assemblers of aircraft are more skilled than assemblers of plastic boxes. Furthermore, workers outside of manufacturing are not classified by the NP-P designation. Skill intensities constructed for manufacturing either must be applied to the whole economy[13] or skill must be measured in terms of workers' educational attainment. As discussed in the next section, we have opted for an alternative approach to the measure of skill.

3. Definition of Skill Groups and Estimation of Factor Shares[14]

3.1 Measuring the Skill of Workers

We develop a new, alternative, multidimensional measure of skill based on information contained in the Directory of Occupational Titles (DOT), data on occupation by industry, and 1989 census information on the wages, education and experience of workers. This continuous measure of skill permits us to rank the skill level of each industry-occupation cell. Workers within each cell are assumed to be equally skilled, a much weaker restriction than the assumption that workers with the same educational attainment are homogenous.[15] Moreover, as the skill

[13] This approach is adopted by Krugman (1995) who adapts educational skill-intensities estimated for export-manufacturing by Wood (1994) and applies them to the whole economy. Krugman does not explicitly consider non-tradeables but does express the increase in trade between the OECD and NIE economies relative to the total GDP of the OECD.

[14] These procedures are discussed in greater detail in an appendix.

[15] The within-group variance of earnings has increased over time, and during the 1980's the value of unmeasured skill and institutional factors was slightly larger than the combined influence of schooling and work experience (Juhn, Murphy and Pierce, 1992). Pryor and Schaffer (1999) have used data from the 1992 National Adult Literacy Survey to document the within-group heterogeneity of workers. They classify occupations by the average educational attainment of persons working in these occupations in 1971. In tier 4 jobs (skilled) 80 percent of the workers had college educations. Pryor and Schaffer argue that some college graduates, whose percentage grew rapidly during the 1970's and 1980's, have been forced to accept jobs in the lower-level occupational tiers as the supply of college graduates increased faster than the growth of college-type jobs in tier 4. As expected, the college educated labor working lower-level occupational tiers in 1992 had lower functional literacy scores. This fact is taken as evidence that the college wage premium increased in the 1980's and 1990's because of shortage of college

level is continuous, investigators are free, subject to the objectives of their projects, to chose any number of skill levels.

The Dictionary of Occupation Titles (DOT) contains information on required skills for 12,741 occupations. It includes 4 categories of general educational requirement, 11 categories of aptitude, and others. Although the unit of observation in the DOT is occupation, the actual values of the skill variables will differ among the same occupation depending on industry. Thus, the skill information is available for each occupation/industry cell in the DOT data. We focus on the 15 categories of skill requirements – general educational and aptitude variables — and attempt to construct the linkage between the requirements and average wages paid in each occupation.

The four general educational variables are reasoning ability, mathematical skills, language proficiency and the extent of specific vocational training necessary to carry out the task. The first three variables are coded in 6 levels from 1 to 6, of which a higher number indicates a higher skill level. The average value of these variables exceeds 4 for managerial and professional occupations and varies between 1 and 3 for the production worker occupations. The last educational variable – the extent of specific training – is coded in 9 levels from 1 to 9, and tends to have a higher average value among managerial and professional jobs as well as for some production jobs. The average value for the training variable tends to be smaller for clerical and unskilled labor.

The 11 aptitude variables are largely for physical skills, and are coded in 5 levels from 1 to 5. They are: general learning ability, verbal expression ability, numerical calculation ability, spatial perception, form perception, clerical ability, motor coordination, finger dexterity, manual dexterity, eye-hand coordination, and color discrimination. Unlike the general educational variables, a lower value of these aptitude variables indicates a higher level.

We match the occupation/industry skill data from the DOT to the Public Use Micro Series file of 1980 Census data on individual wages and demographic variables. The matching is based on the occupation/industry cell to which each individual worker belongs. In the process, the occupation and industry variables in both data sets are converted into standard occupation

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educated labor with college level cognitive skills. The demand for highly qualified college graduates is growing because of rapidly growing demand for medical and legal services and skill-bias technical change (Pryor and Schaffer, 1999, p.218).

and industry codes (SOC and SIC). The resulting wage-skill data consist of information on average wages, the demographic composition and skills for 62,106 occupation/industry cells.

To obtain the continuous skill index for occupation/industry cells, we run a simple wage regression as below.

$$\log(W) = X\beta + I\delta + \varepsilon$$

Where *W* is the average wages of each cell, X represents the demographic and skill variables, and I is the vector of industry affiliation. ε is the error term that is orthogonal to the regressors and has a zero mean.

Two demographic variables, the share of men in each cell and average (imputed) market experience, are included in X. Market experience is measured in years and is imputed as age-years of schooling, that is 6. Industry dummy variables are added to the regression in an attempt to capture any non-competitive rents paid at industry level, and the gender variable is also interpreted as a non-competitive element. In the regression the value of each aptitude variable is set equal to 7 minus its original values so that a higher value of each variable indicates a higher level of skill. The estimates are reported in the following table.

Table 1 : Wage-Skill Regression

Regressors	Coefficient (Standard Errors)	Standard Deviation
Constant	5.702 (0.036)	
Share of Men	0.550 (0.002)	
Average Market Experience	0.010 (0.000)	
Reasoning Ability	0.159 (0.005)	1.056
Mathematical Ability	0.010 (0.003)	1.048
Language Proficiency	-0.087 (0.003)	1.255
Specific Vocational Training	0.004 (0.002)	1.614
General Learning Ability	0.012 (0.006)	0.732
Verbal Expression	0.106 (0.006)	0.828
Numerical Calculation Ability	-0.017 (0.004)	0.679
Spatial Perception	0.043 (0.004)	0.615
Form Perception	-0.036 (0.004)	0.537
Clerical Ability	0.008 (0.002)	0.629
Motor Coordination	-0.205 (0.005)	0.364
Finger Dexterity	0.160 (0.005)	0.524
Manual Dexterity	-0.087 (0.004)	0.482
Eye-Hand Coordination	0.060 (0.003)	0.376
Color discrimination	-0.012 (0.003)	0.429
50 Industry Dummy Variables	Included	
R-Squared	0.823	
Number of Observations	62,106	

Most of the skill variables have a positive coefficient, implying that higher wages are paid in occupations requiring a high level of such skills. However, a few exceptions arise. First, although higher wage managerial and professional occupations require higher levels of language proficiency, the sign of this variable is negative, indicating a lower wage, other things equal. Our interpretation of this result is that wages tend to be lower in occupations requiring language proficiency once other skills such as reasoning ability and especially verbal expression ability (one of the aptitude variables) are held constant. In other words, language proficiency does not appear to be valuable for high wage occupations that require high levels of abilities in reasoning and verbal expression. Second, a few aptitude variables, most of them skills expected from production workers, are also found to be associated with a lower wage. They are perception, motor-coordination, and manual dexterity. The small coefficient for numerical calculation is also estimated to be negative. This variable is highly correlated with one of the general educational variables, mathematical skills, and it appears that once mathematical skills are held constant, numerical calculation ability is not an important skill.

The skill index is calculated as the predicted wage by means of an estimated regression which includes a gender variable (share of men in the industry-occupation cell) and an experience variable. The estimated index accounts for a large share of total wage variations among industry-occupation cells. The weighted correlation coefficient, where the weights are employment shares of industry-occupation cells, between the skill index and actual wages is .902. In terms of *R*-square, the predicted wages are found to account for 82% of total wages variations.

To compare the predictions of the DOT skill index and alternative measures which are based on more conventional measures of skill, we carried out a number of experiments. The results most comparable to those of the DOT index are for a predicted wage regression based on years of education, experience and the gender variable. The correlation between the predicted wage based on this regression and the prediction based on DOT variables and gender and experience is .873. The consistency between the two sets of estimates for the predicted wage, one based on DOT variables, the other based on education, is reassuring.

The two approaches yield quite similar results when gender and experience are also included as regressors with the DOT version yielding marginally better results. For the education version, the correlation coefficient between the predicted and the actual wage is .872 (versus .902 for the DOT version) and the predicted wage accounts for 76% of total wage variations (versus 82% for the DOT variant). However, the DOT variables alone are relatively better predictors of actual wages.

The correlation coefficient for this experiment between predicted and actual wages is .6076 (versus .4449 for education alone) and the *R*-square is .45 (versus .26 for education).

These results indicate that the predicted wages from the DOT skill regression are a very reasonable measure of worker skills, and probably are a better measure than the conventional skill variables. The DOT skill index is much more highly correlated with wages than any single skill variable. Even when both education and experience are jointly considered, they account for a smaller share of total wage variation than the DOT skill index by itself. The value-added is generated by the additional information on the skills required to carry out tasks on each occupation.

The skill index, based on predicted wages, is used to classify skill categories of labor. In principle any number of skill levels could be created. Factor shares are then calculated for the different groups of workers. Predicted wages for each industry-occupation cell are used to create a single measure for that cell Z_{oj} , workers within each industry-occupation cell assumed to be equally skilled. Each Z_{oj} is matched to the corresponding occupation industry cell in the Occupational Employment Survey (OES).[16] To define two skill groups, we array employment in ascending order of proficiency. The occupation/industry cells in the lower-half of this distribution are designated as unskilled and those in the upper half as skilled jobs.

Next, the distribution of skilled and unskilled workers in each industry is calculated by "collecting" all the occupations in each industry. Then by using mean wages calculated from CENSUS for each industry/occupation cell we estimate for each industry the distribution of total wages between skilled and unskilled labor. These labor shares are then applied to the information on total wage compensation reported in the 1987 Benchmark Input-Output Table (IOT) to estimate the value-added factor shares for each industry.

3.2 Calculation of Composite Factor Shares

The composite factor shares for a specific industry represent the cost shares of skilled and unskilled labor and capital which are used directly and indirectly to produce the intermediate inputs and the final commodity that is delivered to final demand. If the aircraft industry is to produce an additional airplane valued at $1.0, the value of gross output will have to increase by approximately $2.0 as a wide variety of intermediate inputs, direct and indirect, will have to be produced. Each intermediate input consists of a value-added component and material inputs. The sum of all of the value-added components including the value added in the aircraft industry will add up to $1.0.

Input-Output tables prepared by the Bureau of Economic Analysis (BEA 1994) contain information on the input-out relationships across industries in the U.S., the share of value-added for each industry, the distribution of value-added between workers' compensation, profit income, and excise taxes; and exports and imports by industry. The BEA also inverts the input-output table to obtain a total requirement matrix for deliveries of final demand by each industry. Each row of the resulting total requirements matrix represents the amounts of each industry's output needed for the delivery of an industry's finished product to final demand. The composite factor shares are calculated by the matrix multiplication:

$$CFS = TR * FS$$

where composite factor shares (CFS) are an *I* by *4* matrix, with *I* equal to the number of industries. The first two columns of this matrix are the composite shares of skilled and unskilled labor in the output of each industry, and the final two columns are the shares of capital and indirect tax payments. *TR* is an *I* by *I* matrix of total requirements, and its p - q^{th} element represents the output requirement of industry *q* for the delivery of one dollar of final demand by industry *p*. FS is an *I* by 4 matrix representing the factor shares in the valued-added of each industry. The columns of FS are the same as those of CFS.

3.3. Estimated factor share for four industries groups

We aggregate the six-digit input-output industries into four industry groups, two tradeable sectors, T_1 and T_2, and two non-tradeable sectors, NT_1 and NT_2. The subscript *1* designates the unskilled industry, *2* indicates the skilled one. Industries are classified as unskilled if the ratio of composite factor shares, skilled/unskilled, varies between .25 to 1.5. Industries with a factor ratio exceeding 1.5 are classified as skilled.

Composite factor shares divide the value of each dollar of an industry's deliveries to final demand, i.e., its contribution to GDP. The shares measure the contributions of each factor in the value-added of the industry, plus the contributions of the three factors in the value-added of the intermediate input requirements of each commodity. If imports of a particular commodity are large, as in the case of crude petroleum, the contribution of that industry to GDP will be

[16] The basis for matching the information in the different data sets is discussed in the appendix.

negative. This negative contribution to aggregate factor payments will net out the factor payments of this industry embedded in the value of other industries in which crude petroleum is used as an intermediate input.

We stress that the aggregation of commodities into a small group of industries may conceal important differences between the factor content of domestic industries displaced by additional imports and the overall factor content of the broad industry group to which these imports are assigned. This problem arises as industries are classified in terms of skill level and whether their products are tradeable—not according to whether particular industries are net importers or net exporters. This distinction is important as in the aggregation procedure the contribution of each six-digit industry is weighted by an industry's contribution to GDP. Therefore, the larger the level of imports relative to the level of final demand, the smaller will be the weight given to the import-competing industry.[17]

[17] The classification of industries according to net trade balance—and alternative to the classification by skill intensity—was attempted and rejected as it produced estimates of skill intensity that were virtually the same for exportable and importables. In part, this result reflects the fact that in 1987 the U.S. ran a large trade deficit.

Table 2

Factor payments and factor shares for tradeables and non-tradeables[18]

(annual data for 1987, in millions of dollars)

	Tradeable Unskilled T_1	Tradeable Skilled T_2	Non-tradeables Unskilled NT_1	Non-tradeables Skilled NT_2
Wages skilled Labor	218,670	401,918	358,727	667,791
Wages unskilled labor	217,032	185,946	452,887	203,549
Returns to capital	349,765	319,276	400,813	470,839
Total factor payments	**785,457**	**907,140**	**1,212,427**	**1,352,179**
Share of skilled labor	.2784	.4431	.2959	.5013
Share of unskilled labor	.2763	.2050	.3735	.1505
Share of capital	.4453	.3519	.3306	.3482

We are not aware of other estimates of factor payments and factor shares for tradeables and non-tradeables.[19] It is of interest that the total size of the non-traded sector is 50 percent larger than the tradeable one. This confirms the importance of non-tradeables in determining the effects of trade on relative factor prices. Also, the unskilled non-traded sector is 57% larger than the unskilled tradeable sector.

Note also that NT_1, the non-traded unskilled-intensive sector uses slightly more unskilled labor per unit of output than T, its traded counterpart. Also, it is a non-traded sector, NT_2 that is most intensive in the use of skilled labor. These findings are important as they imply that both types of labor each have a "friendly sector" in which to seek employment should they be released

[18] In calculating this table we have excluded indirect tax. The estimated total output of each sector is exclusive of indirect taxes.
[19] Industries are assigned on the basis of international trade data presented in the input-output table. Non-traded industries are those for which exports and imports are either negligible or very small.

from traded industries as the result of trade adjustments. For example, unskilled labor that is released from a shrinking tradeable sector can be absorbed in a relatively large unskilled intensive non-tradeable sector as well as in skill-intensive tradeables.

Since the tradeable unskilled sector is capital-intensive relative to skilled tradeables, the contraction of T_1 as the result of trade and the expansion of T_2 will lower the return to capital and increase the skilled wage. The fall in the return to capital will accentuate the increase in the demand for skilled labor if the technology is capital-skill complementary.

Table 3 shows for the years for which input-output tables are available, and for 1998, the level of merchandise trade, goods and services, as a percent of GDP.

Table 3
Trends in Foreign Trade of U.S.

	Exports/GDP x100	Imports/GDP x100	Exports of Manufactured Goods / GDP x100	Imports of Manufactured Goods / GDP x100
1967	5.19	4.87	2.91[1]	2.30[1]
1972	5.35	6.00	2.95	3.21
1977	7.83	9.00	4.39	3.97
1982	8.72	9.35	4.98	4.87
1987	7.79	10.83	4.26	6.91
1992	10.24	10.71	5.90	6.96
1998	10.97[2]	12.70[2]	6.80[2]	9.05[2]

Sources: U.S. Foreign Trade Highlights, U.S. Department of Commerce, International Trade Administrations, August 1997.

1. Calculated from input-output table for 1967. Survey of Current Business, U. S. Department of Commerce, February 1974, pp. 38-42
2. electronic data base, U.S. Department of Commerce

Table 3 shows that during the last 30 years the international trade of the U.S. increased continuously relative to GDP. During the 1970's a large portion of the increase in the imports reflects an increase in the price of mineral fuels. The value of the imports of fossil fuels increased from virtually zero in 1970 to 2% of GDP by 1982. Imports of manufactured goods have increased faster than GDP, especially during the early 1980's and the late 1990's.[20]

Trade between the U.S. and NIE has expanded rapidly, especially in recent years. While in 1987 the U.S. share of imports of manufactured goods from high-income industrial countries, including Canada, Japan and Europe was 69%,[21] by 1998 this share had fallen to 55 percent. The U. S. imports large amounts of unskilled intensive goods such as apparel, shoes and toys from NIE. Especially noteworthy is the growth of imports of transportation equipment, semi-conductors, computers, and various parts for these commodities from eight NIE in Asia[22] and Mexico. In 1998 the U.S. ran a trade deficit of $64 billion with these countries in the trade category transportation equipment and machinery.

The growth of this trade creates a problem in the classification of the skill-intensity of high-tech imports. The overall production of computers and office equipment in the U.S. is highly skill-intensive. If the imports of computers and computer parts from Malaysia, the Philippines and so on represent unskilled labor-intensive processes producing components or assembly, the assumption that these imports are close substitutes for production activities in the U.S. will overstate the skill intensity of these goods and underestimate the effects of trade on relative wages in the U.S.

Table 4 presents additional information on changes in the level and pattern of U.S. trade for selective years over a 25-year period. The 500 commodity groups available in input-output tables are classified into tradeables and non-tradeables and each of the two general commodity groups is divided into 4 labor-skill categories. The skill classification is based on the ratio of the share of skilled labor to the share of unskilled labor of composite factor shares calculated for each commodity for 1987. In skill group 1 (unskilled) the skill ratio varies from .25 to .95, and

[20] The U.S. had an export surplus in trade of manufactured goods until 1982 but by 1987 ran a deficit of 2.5% of GDP in these commodities. The deficit in manufactures narrowed and then widened again in the 1990's, a period of rapid economic growth in the U.S. Between 1967 and 1998 the U.S. exports of services increased from 1 to 3 percent of GDP. In 1998 the surplus in the trade of services was equal to 1% of GDP.

[21] Manufactured goods are defined as beverages and tobacco, chemicals manufactured goods classified directly by material, machinery and transport equipment, and miscellaneous manufactured articles.

[22] China, Indonesia, South Korea, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

for group 2 the range is .95 to 1.5. For groups 3 and 4, the range of the skill ratios is 1.5 to 2.0 and 2 plus respectively. The tabulations for exports and comparable imports — commodities which are produced in the U.S.[23] — by skill category and the contribution of each traded goods sector to GDP are reported in Table 4.

[23] We do not consider non-comparable imports such as bananas, coffee, minerals and other raw materials not produced in the U.S.

Table 4

Trade in Four Commodity Groups Classified by Skill

Billions of Nominal Dollars

		Group 1	Group 2	Group 3	Group 4
	X	4.5	14.2	6.3	3.0
1967	M	6.4	7.8	4.8	.7
	GDP	65.3	89.7	45.7	43.0
	X	7.3	23.7	13.6	7.5
1972	M	19.3	27.4	6.6	2.4
	GDP	114.5	154.5	121.5	81.8
	X	20.3	57.4	35.0	18.6
1977	M	35.7	56.3	50.5	5.6
	GDP	203.1	288.6	192.3	107.2
	X	28.7	88.5	57.6	24.2
1982	M	48.9	91.6	70.3	9.8
	GDP	232.2	385.1	323.0	165.6
	X	36.7	102.1	93.6	58.4
1987	M	104.1	194.0	65.3	46.4
	GDP	309.7	535.6	572.3	425.8
	X	66.7	182.9	129.6	100.1
1992	M	129.6	238.5	45.1	76.4
	GDP	437.6	668.4	638.8	788.4

Note: Commodity groups are classified according to the ratio of skilled to unskilled labor. For Group 1, which includes textiles and footwear, the ratio varies between .25 and .95. The skill ratios for groups 2 and 3 are .95 to 1.5 and 1.5 to 2.0 respectively. Group 4 has a skill ratio greater than 2. Examples of commodities assigned to each of the four skill groups are found in Appendix II.

The data presented in Table 3 indicate that in 1967 the U.S. had a small trade deficit in the lowest skilled category, group 1, but an overall trade surplus for group 1 and group 2, confirming that during the 1960's international trade had a negligible effect on the distribution of income in the U.S. The trade deficit in group 1 commodities increased by 1972 to 10 percent of GDP originating in this sector and remained at this level through 1982. Trade in group 2 was essentially in balance between 1972 and 1982. The overall deficits in group 1 plus group 2 relative to overall GDP varied between 1.2 percent in 1972 to .7 percent in 1977 and 1982.

The situation changed significantly between 1982 and 1987, a period during which large trade deficits in both commodity groups 1 and 2 developed. In 1987 the combined deficit in trade for these commodities was 20 percent of GDP originating in these sectors and 3.5% of national GDP. However, by 1992 the combined deficit had fallen to 1.9 percent of total GDP.

From Table 3 it is apparent that the increase in the relative wage of skilled labor during the 1970's cannot be attributed to a trade deficit in commodities intensive in the use of unskilled labor. The potential effects of trade on wage structure were at their peak during the 1980's when the trade deficit in unskill-intensive goods, without accounting for outsourcing, was equal to 3.5 percent of national GDP.

4. Results of the Simulations

4.1 General Considerations.

In carrying out the simulations we concentrate on the time interval 1982-87, a period of growing wage inequality and expanding trade. The alternative is to consider changes between 1982-92, years for which input-output tables are available. However, as the trade deficit in unskill-intensive goods narrowed, temporarily, in 1992, we believe that the changes between 1982-87 better represent the changes in trade flows that occurred after 1982.

A small deficit in the trade of T_1 in 1982 increased to $160 billion by 1987. This change is approximated in the simulation as a supply shock of $150 billion, 3.25% of 1987 GDP. _By assuming that all of the proceeds from additional foreign exports are spent on skill-intensive tradeables produced in the U.S, we overstate the effects of trade on distribution of income.[24]

Between 1982-87, private savings in the U.S. fell by 3 percent of GDP, an amount exactly equal to the trade deficit. Foreign countries supplied the additional goods and savings that made possible an additional $100 billion of consumption and $50 billion of investment in the U.S. Some portion of this additional spending, perhaps a third, was made on commodities produced by the unskilled, labor-intensive sectors, T_1 and NT_1 which includes new construction. Nevertheless, in order to simplify the interpretation of the results and to facilitate comparison with earlier work, we retain the assumption of balanced trade.

4.2. Results for a standard CES three-factor model.

Our baseline model, a three factor, four sector model, consists of two tradeable commodities T_1 and T_2 and two non-tradeables NT_1 and NT_2. T_1, the unskilled good, is imported on balance while T_2, the skill-intensive good, is exported.[25]

Initially, the demand structure is assumed to be Cobb-Douglas, with expenditures on each of the four goods a constant proportion of total income. In this section the production functions are assumed to be of the constant elasticity of substitution (CES) form for which the partial elasticities of substitution are equal for pairs of factors. The basic technology is assumed to be the same in all four sectors.

In the initial equilibrium overall trade is in balance and for simplicity it is assumed that there is no net exchange of either T_1 or T_2. An increase in foreign supply is assumed to occur; foreign suppliers produce an additional $150 billion of T_1 for sale in the U.S and, for straight forwardness, it is assumed that all of the income earned by foreigners from the additional sale of X_1 in the U.S. is spent on X_2. So $P_1 X_1^f = P_2 X_2^f$ where X_1^f is the additional foreign supply of X_1, X_2^f is the additional foreign demand of X_2 and P_1 and P_2 are the two new equilibrium prices,

[24] During the mid-1980's the U.S. ran a substantial trade deficit. So part of the proceeds from additional exports to the U.S. were saved by foreigners and lent to the U.S. to finance additional consumption or investment. As both types of expenditures involve some spending on unskill-intensive goods, we overstate the effects of additional trade by assuming that foreigners spend all of their proceeds on skill-intensive exports from the U.S.

[25] Recall that for the two-industry skill classification an industry is classified as unskilled if the ratio of composite factor shares, skilled/unskilled, varies between .25 to 1.5. Industries with a factor ratio exceeding 1.5 are classified as skilled.

after the foreign supply shift has occurred. Although the primary adjustments to the foreign supply occur between the traded goods sectors, the simulations allow for shifts of resources and demand among all four industries of the economy.

Three basic results are obtained for the CES model:

(1) For a Cobb-Douglas technology, the effects of an increase in trade on relative factor prices is quite modest. The skilled wage rate increases by 2.5 percent relative to the unskilled wage, and there is virtually no change between the unskilled wage and the return to capital.

(2) The change in the relative wage of skilled and unskilled labor is approximately proportional to the elasticity of substitution (ES) in production. A decrease in this production parameter from 1.0 to .50 increases the estimate of the trade-induced change in relative wages from 2.5 to 4.8 percent. For a low value of the ES, equal to .1, the skilled wage rate is estimated to increase by 20 percent.

(3) A decrease in the elasticity of substitution in demand from 1, in the Cobb-Douglas case, to .50 increases the relative wage effect by a very small amount. From results (2) and (3), we conclude that it is much more important to accurately estimate substitution possibilities in production than in consumption.

4.3 A model with capital-skill complementarity

The model presented in this section allows capital and skilled labor to be relative complements. The production relation in all sectors is assumed to be a nested CES function consisting of two factors of production, i.e., a composite factor, capital-skilled labor, (KL_s), and unskilled labor, L_u.

The output of any commodity X is

$$X = c[f_{ks}(KL_s)^{-a} + f_u L_u^{-a}]^{-1/a}$$

where $KL_s = A_{ks}[g_k K^{-b} + g_s L_s^{-b}]^{-1/b}$

where the elasticity of substitution between the composite factor KL_s and L_u is equal to $\frac{1}{1+a}$ and the elasticity of substitution between K and L_s is equal to $\frac{1}{1+b}$

For the same values of the partial elasticity of substitution, the results of this model are consistent with those estimated for the standard CES model. For example, when the elasticities of substitution between K and L_s and between the composite factor KL_s and L_u are small and all equal to .1, the skilled wage increased by 20 percent relative to the unskilled wages, just as it did in the standard model.

The principal result obtained for this model is that increased trade will have a larger effect on relative wage rates. When the elasticity of substitution between the composite factor KL_s and unskilled labor is set equal to 1, and capital and skilled labor are assumed to be relative complements—the elasticity of substitution between these factors is equal to 0.1—the skilled wage increases by 22 percent relative to the return on capital and 12 percent relative to the unskilled wage. The relative complementarity between skilled labor, L_s, and capital, *K*, is the key explanation of these results.

When foreign trade expands, T_1, the capital intensive sector, contracts and T_2, the skill intensive sector, expands; skilled labor, L_s, will be in excess demand and there will be an excess supply of capital, *K*. The limited substitutability between L_s and K can produce a large change in the market-clearing values of these two factors, as the estimate indicates.

The change in relative wages is quite large relative to the estimate obtained for the standard CES model. This result can also be explained by the existence of KSC and the consequent large change between the skilled wage and the return to capital. The cost of the composite factor KL_s depends on the prices of its two components. A large increase in the skilled wage accompanied by an offsetting decrease in the return to capital will result in a small change in the cost of the composite factor. Thus, a relatively large elasticity of substitution between L_u and the composite, KL_s, does not rule out a significant increase in the skilled wage relative to the unskilled rate as a concurrent decrease in the return to capital sustains the demand for skilled labor.

For this formulation, as for the standard model of Section 5.2, the magnitude of the assumed demand response has a small effect on the results. Halving the elasticity of substitution in demand from 1 to .5 raises the increase of the skilled wage relative to the unskilled from 12 to 14 percent. This result obtains as the increase in foreign demand and supply is assumed to be price inelastic. Foreigners supply a predetermined additional amount of T_1 and spend all of the additional proceeds on T_2. Moveover, the factor intensities of the four sectors are quite similar and the change in relative commodity prices is small– the price of exportables, T_2, increases by only 3 percent relative to importables, T_1.

The large increase in the wage of skilled labor, relative to the unskilled, obscures an important result for this model that is also obtained for the formulation in which the partial elasticities of substitutions are equal for pairs of factors. When the ES between skilled and unskilled labor is equal to 1, the decrease in the real wage of labor will be small, approximately equal to one percent.

For the Cobb-Douglas version of the CES model, the skilled wage, p_s, increases by 3 percent while p_u and p_k remain unchanged. As commodity prices change by little relative to the price of capital—the numeraine— the real wage of unskilled labor falls by 1 percent. For the two-tier model with KSC, the skilled wage increases by 22 percent relative to the numeraine and the unskilled wage increases by 10 percent. As commodity prices increase by 11 percent, the real decrease in the unskilled wage is 1 percent.

The real wage of skilled labor increases by 1.5 percent for the Cobb-Douglas version and by 11 percent for the two-tier formulation. Capital loses a correspondingly larger amount in the latter case. The introduction of KSC increases the gains of skilled labor at the expense of capital while the estimate of the real income loss of unskilled labor remains unchanged at one percent.

4.4 A specific factors model of production

This model does not allow for direct substitution between skilled and unskilled labor. The two types of labor each work on a specific task or process required for the production of each good. For example, skilled labor working with capital may be involved in management, design, quality control, finance and marketing. In contrast, unskilled labor and capital are engaged in the production of components, assembly, and the shipment of the good. The two processes are used in fixed proportions.

This construct is extreme and unrealistic as it assumes that there is no direct substitution between skilled and unskilled labor. There may be little scope for substituting the labor services of an unskilled laborer for those of a scientist or manager. However, in a more general multi-skill model with many classes of labor, there will be considerable scope for substituting between adjacent labor grades. In addition, a skilled worker is capable of performing unskilled tasks. This section focuses on the extent to which the degree of substitution between capital and the two types of labor can affect the results.

X_1 units of commodity *1* consists of Z_1^1 units produced by process *1* and $\theta_1 Z_2^1$ units produced by process *2*

$$X_1 = \min Z_1^1, \theta_1 Z_2^1 \text{ where}$$
$$Z_1^1 = c_1 [f_1^1 \; {}^1K_1^{-a_1^1} + f_{s1}^1 \; {}^1L_s^{-a_1^1}]^{-1/a_1^1}$$
$$\text{and} \quad Z_2^1 = c_2 [f_{k2}^1 \; {}^1K_2^{-a_2^1} + g_{s2}^1 \; {}^1L_u^{-a_1^1}]^{-1/a_2^1}$$

where ${}^1K_1, {}^1K_2$ are the inputs of capital in processes *1* and *2* used in the production of commodity *1*, ${}^1L_2$ is the amount of skilled labor used on process 1 in the production of commodity *1*, ${}^1L_1$ is the amount of unskilled labor used on process *2* used in the production of commodity *1*. This specification of production is adopted for all the commodities.

For the case where the degree of substitution between capital and both types of labor is substantial, a = .1 in both processes, so the elasticity of substitution is an approximation of Cobb-Douglas, (ES = .91). The unskilled wage, p_u, is estimated to fall by 7% relative to the skilled wage, p_s, and by 2 percent relative to the return on capital. Although there is no direct substitution between labor types, the change in relative wages is moderate as there is indirect substitution between labor types since capital is freely substitutable for skilled and unskilled labor.

When capital and skilled labor are assumed to be relative complements, the ES between *K* and L_s is taken to be equal to .1, while the ES between *K* and L_u remains equal to .91, an expansion of trade increases the skilled wage by 34 percent relative to the price of the other two factors. The combination of KSC and the non-substitutability between skilled and unskilled labor greatly increases the real income of skilled labor at the expense of the other two factors.

4.5 Summary of Results and Comparisons with Earlier Contributions

Table 5 reports the base results for the two primary models of production and adds results of experiments where capital is allowed to be quite mobile.

Table 5

Summary of Simulation Results

Case	Percentage change for skilled labor		Percentage change for unskilled labor		Percentage change for capital	
	Relative Wage	Real Wage	Relative Wage	Real Wage	Relative Return	Real Return
1. CES ES = .91 capital immobile	2.5%	1.5%	-0-	-1.0%	-0-	-1.0
2. CES ES = .333 capital immobile	7.0%	4.5%	-0-	-2.50	-0-	-2.50
3. CES ES=.1 capital immobile	22.0%	12.0%	3.0%	-6.0%	-0-	-9.0%
4. CES ES= .1 capital mobile	7.8%	7.2%	-9.3%	-8.7%	-0-	-0.6%
5. KSC Sigma 1 = .91 Sigma 2 = .1 capital immobile	22.3%	11.4%	9.8%	-1.0%	-0-	-10.9%
6. KSC Sigma l =.91 Sigma 2 =.1 capital mobile	6.0%	4.0%	-0-	-2.1%	-0-	-2.1%

Note: Real wages are calculated by weighing the change in the price of each good relative to the numeraine, the return to capital by its share in GDP and subtracting the price change from the nominal wage change.

Sigma 1 is the ES between the composite factor KL_s and unskilled labor L_u.
Sigma 2 is the ES between K and L_s in the formation of the composite factor.

For the CES model we have already noted when capital is mobile the principal result is that trade will have a large effect on the relative and real wages of skilled and unskilled labor only when the ES is quite low. Also, capital bears a somewhat larger share of the burden of trade-induced redistribution relative to unskilled labor.

These results are fully consistent with the findings of Krugman (1995) and Cline (1997). Krugman uses a two-factor, two-sector, two-country model in which OECD countries export a commodity intensive in the use of skilled labor to NIE in exchange for a good intensive in the use of unskilled labor. He estimates that during 1970-1990, trade between these two large countries increased by an amount equal to 2% of GDP of the OECD. Krugman assumes a Cobb-Douglas technology and estimates factor shares for the two sectors from information found in Wood (1994) and Balassa (1979)[26]. He calculates that the expansion of trade between OECD and NIE decreases the unskilled wage by 3% relative to skilled compensation very close to the 2.5 percent estimate we obtain for a three-factor, four-sector model of U.S. trade with <u>all</u> countries. Our estimate of the difference in the skill intensities between the two tradeable sectors is smaller than the one derived by Krugman, but our estimate of the increase in trade is larger, 3.25 % of GDP.

Both studies indicate that for Cobb-Douglas technologies trade-induced changes in a country's production structure result in a small change in relative factor prices and will bring about a <u>very</u> small change in relative commodity prices. The latter result confirms Johnson's (1966) result that a production possibility curve for a Cobb-Douglas economy can be approximated by a straight line.

Cline (1997, p. 158) reformulates Krugman's model by adopting a more flexible constant-elasticity-of-substitution (CES) production function. He performs a number of sensitivity tests by varying the elasticity-of-substitution (ES) and finds that decreasing this parameter from 1 to .5 doubles the estimated increase in the skilled wage—a result consistent with our results for a three-factor CES model.[27]

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[26] Krugman uses Wood's estimates that the initial ratio of skilled to unskilled wages is 2 and that the employment share of skilled workers in the export industry is equal to .50. As Woods does not provide information for the import industry, Krugman uses the fact found in Balassa that wages in the U.S. industries exporting to developing countries are 28 percent higher than in the industries competing with imports from these industries. The numerical estimates are made "internally consistent" by assigning a share of 20 percent for skilled employment in the import industry. This produces an approximation of the inter-industry wage differential reported by Balassa.

[27] Cline also develops a three-factor inter-temporal model to track the world economy, divided into 13 regions over the period of 1973-93. Skill is measured in terms of level of education so the increase in educational levels throughout the world has a strong equalizing effect on relative wages. Cline estimates that the skilled/unskilled wage ratio would have fallen by 40 percent in the absence of other changes. Among the unequalizing influences in the U.S. are "Stolper-Samuelson effects" arising from greater specialization in skill-intensive goods, which are estimated to increase the wage ratio by 7 percent. In deriving this estimate Cline assumes differences in factor intensities between industries which are in line with those assumed by Krugman, but which are somewhat larger than those estimated in this paper. Cline attributes the larger estimate of the effects of the trade to the fact that the

Wood (1994), Sachs and Shatz (1998) and Cline (1997 p.161), among others, discuss how the effects of trade on income distribution are sensitive to the elasticity of substitution (*ES)* between skilled and unskilled labor. They point out that many estimates of the *ES* between college and high school graduates exceed one and discuss various reasons why they may be biased upwards. However, no one has argued that the *ES* between skilled and unskilled might be less than .33.

One of the virtues of working with a three-factor model is that it allows for changes in the return to capital. This is especially important for the model of KSC with immobile capital. For this case there is a significant increase in the relative wage of skilled labor relative to unskilled, but the real income gains are primarily at the expense of capital.

Empirical evidence for the implied decline in the real return to capital, however, is non-existent as the share of capital has been constant over time in the U.S. and rates of return on capital have changed largely in response to cyclical changes, investment opportunities and productivity growth (Poterba 1997).[28] The constancy in labor's share throughout the larger period and during the 1980's, a time when the U.S. developed a large trade deficit in goods intensive in the use of unskilled labor, is compelling evidence that the return to capital has not been significantly affected by an expansion of trade.[29]

To reconcile our results with the observed constancy of the share of capital, we allow for international capital mobility. Before considering the implications of this modification, we note that there is considerable disagreement about the degree of international capital mobility (See Harberger (1995), Feldstein and Horioka (1980), Gordon and Bovenberg (1996)). Furthermore, the analysis of this paper is based on trade data for a large country, the U.S.. The larger the

model over predicts the amount of trade between developed and less developed countries at the end of the period and to the disaggregative nature of the model.

[28] The constancy of the share of capital is well known (Krugman {1995}, Cline {1997}), but the implications of this fact have not been exploited.

[29] We estimate that if trade affects relative wages by a significant amount, the real return on capital will fall by at least 10 percent. This is equivalent to an increase of 3 percentage points in labor's share. A change of this magnitude or even a change of one-third of this amount is not found in the data for labor's share during the 1980's.

The rate-of-return on non-financial corporate capital was relatively high during the high growth periods of the mid 1960's (12 percent) and in the late 1990's (10 percent) and relatively low during the stagflation period of the late and early 1980's (6 percent) (Poterba 1997, Table 1). During the 1980's, as the economy moved out of the recession, the rate of return increased from 6 to 8 percent. It might be argued that the increase in this factor price would have been even larger if an expansion of trade had not occurred, resulting in an increase in the share of capital.

country the smaller will be the effect of international capital mobility on its rate of return on capital.

To allow for capital mobility, we allow for the overall supply of capital to decrease as a function of a decrease in the real return to capital. The magnitude of this response is increased so that the resulting change in the return to capital is quite small.

For the CES model we consider the effects of capital for only the case of a very small elasticity of substitution, *ES = .1*. The results for this case are the expected ones; as capital flows become more responsive to the real rate of return, the estimated gains to skilled labor decrease while both the relative and real wage of unskilled labor decreases relative to the benchmark results of the case of immobile capital.

The introduction of capital mobility to the model of KSC significantly diminishes the estimated effects of trade expansion on relative factor prices. In this model there is little substitutability between capital and skilled labor. A decrease in the supply of capital decreases the demand for skilled labor. As the price of capital increases, the skilled wage rate must fall in order for the composite factor, capital/skilled labor, to remain competitive with unskilled labor. The real wage gain of skilled labor of 11 percent when capital is immobile is reduced to 4 percent with capital mobility. The real wage loss to unskilled labor increases from 1 percent to 2 percent, a modest absolute change.

5. Concluding remarks

The key ingredient of this paper is the multi-dimensional, occupationally based measure of skill obtained from information contained in the Dictionary of Occupational Titles. The continuous measure of skill and input-output data are used to estimate the factor shares for disaggregated commodity groups, and trade data from input-output tables are used to divide commodities into tradeable and non-tradeables groups and to measure net trade in four commodity groups classified by skill level. The estimated factor shares and changes in the pattern of trade are used to simulate the effects of trade on relative and absolute factor prices.

We believe— the considerable range in the estimates for the partial elasticities-of-substitution notwithstanding — that the most likely range for the trade-induced decrease in the real wage of unskilled labor is between 1 to 3 percent. Only when all three partial elasticities-of-substitution are very small, 0.1, is the decrease in the unskilled real wage large, equal to 6 percent—or even 9 percent when capital is mobile.

No estimates are available of the elasticity of substitution between skilled and unskilled labor for the task-oriented occupationally based measure of skill developed in this paper. We are inclined, a priori, towards a moderate to low elasticity well below 1. However we agree with the broad consensus in the literature that a very low *ES* between broad skill classes of labor is very unlikely.[30] The possibility that capital and skilled labor are relative compliments strengths the case that the effects of trade on the real wage of unskilled labor are quite small. For this case the possible range for the change in the relative skilled/unskilled wage is quite large when capital is immobile. But as the unskilled wage increases relative to the return to capital, the real income gains of unskilled labor are primarily at the expense of capital. When capital mobility is allowed for in the KSC model, the gains of skilled labor diminish significantly, though the decrease in the real wage of unskilled labor increases from 1 to 2 percent.

Another result which supports the position that the growth of trade has a modest effect on growing wage inequality is our finding that the U.S. did not have a significant deficit in the trade of unskill-intensive goods during the 1970's, a period of growing wage inequality (Juhn, Murphy and Pierce, 1993).

Also noteworthy are three interrelated findings. Estimated differences in factor intensities across sectors are relatively small. This indicates a small change in relative commodity prices in relation to the change in factor prices, a magnification effect of six.[31] The small change in relative commodity prices explains why changes in assumed demand elasticities have a small effect on the estimated change of factor prices.

[30] Wood (1994, p.132) criticizes the estimates of the elasticity of substitution between highly educated and less educated, mostly in excess of one, as being reduced form estimates reflecting wage-induced changes in product mix and quality. In carrying out a net-factor-content study of trade, he adopts a value of .5 for this *ES*. Other assumed values for this parameter found in the literature are 1 (Lawrence 1996, p. 46), between .5 and .9 (Cline 1997, p.163) and .33 and .5 (Sachs and Shatz 1998, p. 233). All these authors measure skill by the level of education classification.

[31] Compared to a magnification effect of 3 found in Krugman (1995).

No attempt is made to account for outsourcing despite the growing importance of this phenomenon. In 1998 the U.S. imported from low-wage Asian countries and Mexico $160 billion worth of goods classified as machinery and transportation equipment, or 1.7 percent of GDP. Hypothetical adjustments for the misclassification of trade flows by skill intensity can be made on the basis of these numbers. Our guess is that the downward bias of our estimates due to outsourcing of trade effects is not greater than 25 percent. But the bias may be nil.[32]

[32] The last input-output table is for 1992 a year which is not representative of the 1990's. It is difficult to know how much of the high-tech imports from NIE represents outsourcing and how much is integrated production in native and foreign-based companies. Cline (1997, p 181) has noted that the supply of skilled labor has been growing rapidly in NIE so the growth of exports of commodities by NIE that are skill intensive in the U.S. reflects, in part, these changes in factor endowments. Furthermore, as shown in Kim-Mieszkowski (1995), a decline in the relative wage of unskilled labor due to outsourcing need not imply a decrease in its real wage. Foreign workers may be highly productive relative to the wage they are paid when employed by foreign multinationals because these firms possess superior technological and organizational knowledge relative to native enterprises and the multinationals pay the going wage. If the benefits of the "arbitraging" of the productivity differences are passed on to consumers, the fall in the prices of outsourced traded goods will offset the fall of the unskilled wage in terms of non-traded goods. The real unskilled wage can even be increased by outsourcing if the productivity gains are large enough and expenditures by this labor group on trade goods are sufficiently large.

Bibliography

Autor, David H., Lawrence F. Katz, and Alan B. Krueger. "Computing Inequality: Have Computers Changed the Labor Markets?" The Quarterly Journal of Economics 108, no 4 (November 1998): 1169-1214.

Balassa, Bela. "The Changing International Davision of Labor in Manufactured Goods." Banca Nazionale del Lavoro Quarterly Review 130 (September 1979): 243-85.

Berman, Eli, John Bound, and Stephen Machin. "Implications of Skill-Biased Technological Change: International Evidence." The Quarterly Journal of Economics 108, no 4 (1998): 1245-80.

Berman, Eli, John Bound, and Zvi Griliches. "Changes in the Demand for Skilled Labor within US Manufacturing: Evidence from Annual Survey of Manufacturers." Quarterly Journal of Economics 109, no. 2 (May 1994): 367-97.

Borjas, George J., Richard B. Freeman, and Lawrence F. Katz, eds. Immigration and the Work Force: Economic Consequences for the United States and Source Areas. Chicago: University of Chicago Press, 1992.

Borjas, George J., and Valerie A. Ramey. "The Relationship between Wage Inequality and International Trade." In The Changing Distribution of Income in an Open US Economy, Amsterdam: North-Holland, ed. by Jeffrey H. Bergstrand et al., (1994a).

Cline, William R. "Trade, Immigration, and Wage Distribution." Paper prepared for the conference on Increasing Inequality in America: the Causes and Implications. Texas A&M University (March 1999).

Cline, William R. Trade and Income Distribution. Washington, DC: Institute for International Economics, (1997).

Feldstein, Martin, and C. Horioka. "Domestic Savings and International Capital Flows", The Economic Journal 90, (1980): 314-329.

Freeman, Richard B., When Earnings Diverge, Washington D.C., National Policy Association, (1997).

Golden, Claudia, and Lawrence F. Katz. "The Origins of Technology-Skill Complementarity." Quarterly Journal of Economics 108, (1998): 693-732.

Gordon, Roger H., and A. Lans Bovenberg, "Why is Capital So Immobile Internationally? Possible Explanations and Implications for Capital Income Taxation." American Economic Review 86, No. 5, (December 1996): 1057-1075.

Griliches, Zvi. "Capital-Skill Complementarity." Review of Economics and Statistics 51, (1969): 465-68.

Hamermesh, Daniel S. "Labor Demand." Princeton, NJ: Princeton University Press (1993).

Harberger, Arnold C. "The ABC's of Corporation Tax Incidence: Insights into the Open-Economy Case." Tax Policy and Economic Growth, American Council for Capital Formation Center for Policy Research, Washington, D.C. (1995)

Johnson, H.G. "Factor Market Distortions and the Shape of the Transformation Curve." Econometrica 34, (1966): 686-698.

Jones, Ronald W. "A Three-Factor Model in Theory, Trade, and History." In Trade, Balance of Payments, and Growth: Essays in Honor of C.P. Kindleberger, Amsterdam: North-Holland: ed. by Jagdish Bhagwati et.al., 1971.

Juhn, Chihui, Kevin M. Murphy, and Brooks Pierce. "Wage Inequality and the Rise of Returns to Skill." Journal of Political Economy 101, no.3 (June 2, 1993): 410-42.

Katz, Lawrence F., and Kevin M. Murphy. "Changes in Relative Wages, 1963-1987: Supply and Demand Factors." Quarterly Journal of Economics 107, no. 428 (February 1992): 35-78.

Kim, Dae Il, and Peter Mieszkowski. "The Effects of International Trade and Outsourcing on Relative Factor Prices," paper prepared for International Seminar on Public Economics, University of Essex, (May, 1995)

Krueger, A.B. "How Computers Have Changed the Wage Structure: Evidence from Microdata, 1984-1989." Quarterly Journal of Economics, 107, (1993): 35-60.

Krugman, Paul R. "Competitiveness! A Dangerous Obsession." Foreign Affairs, (March/April 1994).

Krugman, Paul R., and Robert Z. Lawrence. "Trade, Jobs and Wages." Scientific American 270, (April 1994): 44 - 49.

Krugman, Paul R. "Growing World Trade: Causes and Consequences." Brookings Papers on Economic Activity, (1995): 327-77.

Krusell, Per, Lee E. Ohanian, José-Víctor Ríos-Rull, and Giovanni L. Violante. "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis." Federal Reserve Bank of Minneapolis Research Department Staff Report 239 (1997).

Lawrence, Robert Z., and Matthew J. Slaughter. "Trade and US Wages: Great Sucking Sound or Small Hiccup?" Brookings Papers on Economic Activity no.2, (1993): 161-226.

Lawrence, Robert Z., and Carolyn Evans. "Trade and Wages: Insights from the Crystal Ball." Working Paper 5633. National Bureau of Economic Research, (1996) Cambridge, MA.

Lawrence, Robert Z. Single World Divided Nations? International Trade and OECD Labor Markets. Brookings Institution Press (1996).

Leamer, Edward E. "Trade, Wages, and Revolving Door Ideas." Cambridge, MA: National Bureau of Economic Research (April 1994).

Leamer, Edward E. "In Search of Stolper-Samuelson Linkages between International Trade and Lower Wages." In Imports/Exports and the American Worker, Washington, DC: Brookings Institution Press, ed. by Susan M. Collins, (1998).

Murphy, Kevin M., and Finis Welch. "The Role of International Trade In Wage Differentials." In Workers and Their Wages: Changing Patterns in the United States, Washington: American Enterprise Institute, ed. by Marvin Kosters, (1991).

Murphy, Kevin M., and Finis Welch. 'The Structure of Wages." Quarterly Journal of Economics 107,(February 1992): 285-326.

Poterba, James M. "The Rate of Return to Corporate Capital and Factor Shares: New Estimates Using Revised National Income Accounts and Capital Stock Data." National Bureau of Economic Research, (November 1997).

Sachs, Jeffrey D., and Howard J. Shatz. "International Trade and Wage Inequality in the United States: Some New Results." In Imports/Exports and the American Worker, Washington: Brookings Institution Press, ed. by Susan M. Collins, (1998).

Sachs, Jeffrey D., and Howard J. Shatz. "Trade and Jobs in US Manufactures." Brookings Papers on Economic Activity, no. 1 (1994): 1-84.

Stokey, N.L., "Free Trade, Factor Returns, and Factor Accumulation." Journal of Economic Growth, 1 (4), (1996): 421-47.

Stolper, Wolfgang, and Paul A. Samuelson. "Protection and Real Wages." Review of Economic Studies 9, (November 1941): 58 - 73.

U.S. Department of Commerce International Trade Administration (Washington D.C.) U.S. Foreign Trade Highlights, (1996).

U.S. Department of Commerce International Trade Administration (Washington D.C.) U.S. Foreign Trade Highlights, (1990).

U.S. Department of Commerce International Trade Administration (Washington D.C.) U.S. Foreign Trade Highlights, (1984).

U.S. Department of Labor, (Washington D.C.), Dictionary of Occupational Titles. Fourth Edition, 1991.

Welch, Finis. "Industrial Change and the Demand for Skill." Paper prepared for the conference on Increasing Inequality in America: the Causes and Implications. Texas A&M University (March 1999).

Wood, Adrian. North-South Trade, Employment and Inequality: Changing Fortunes in a Skill-Driven World. New York: Oxford University Press, 1992

Appendix I

Data sources for the Calculation of Skill Groups and Estimation of Factor Shares

A. Description of Data Sources

A.1 Dictionary of Occupational Title.

DOT reports a set of skill measures for 12741 occupations (in 9 digits) which are grouped in three categories: educational skills, aptitude for work, and physical conditions. The educational skill category includes 4 components: reasoning, mathematical, language skills and requirement of specific vocational training. The aptitude category includes 11 components: general learning ability, verbal ability, calculating ability, spacing ability, form perception skills, clerical perception skills, motor coordination skills, finger dexterity, manual dexterity, eye-hand coordination, and color discrimination. The physical-condition category includes 21 components: strength, climbing, balancing, stooping, kneeling, crouching, crawling, reaching, handing, fingering, feeling, talking, hearing, tasting/smelling, near acuity, far acuity, depth perception, accommodation, color vision, and field of vision. Most of these variables are step-variables which take on 4 to 5 values.

DOT data also report the following information for each occupation. First, a 4-digit standardized occupation code (SOC) is given to each occupation, which permits a degree of matching of these data with other data sets. Second, four industries reported as the major employers of the occupation are coded by their character names not in numeric values. Moreover, DOT comes with a table matching its occupations and the occupations in The Occupational Employment Survey (OES). DOT reports a 4-digit standardized occupation code (SOC) for each occupation. In the matching table between DOT occupations and the occupations in (OES), 12,683 DOT occupations are allocated to 745 OES occupations.

A.2 Occupational Employment Survey (OES).

OES reports the distribution of occupations among various industries. It has information on 745 occupations which are (coded in 5 digits, and industries are coded in 4-digit Standardized

Industrial Classification code (SIC). For each occupation/industry, the code reports the number of workers by industry. We use 1989-1994 SIC data for the analysis.

A(3). Census of Population and Housing (Census).

Census reports demographic and labor market information for each individual in the labor force. Specifically, the education, gender, experience, weekly labor earnings, occupation and the industrial affiliation of individuals are reported. Industrial and occupational information is coded in 3 digits for industries and for occupations. The educational information is translated into years of schooling, and experience is measured in years.

A.4. The 1987 Benchmark Input-Output Accounts (IOT)

The 1987 IOT is used to calculate composite factor shares for the industries producing nearly 500 commodities classified according to a six-digit input-output designation. The matching of IOT information with data on occupation and skill is facilitated by the fact that many of the IOT industries delivering the commodities to intermediate use or final demand correspond to a single 4-digit SIC industry.

B. Matching the Data Sets

In matching the various data sets, we use as common denominators the standardized Industrial and Occupational Codes, SIC and SOC. The first step is to use the matching table presented in DOT to convert the occupational codes in OES into DOT codes. The resulting match is then converted into the SOC using the matching information between SOC and DOT. We end up with occupations coded in terms of SOC. Matching information between the industrial and occupational codes of census, (IND3DLW) and OCC3DLW and SIC and SOC, allows us to match census data with the other data sets. Finally, the IOT provides matching information between input-output codes and the SIC classification.

Appendix II

This appendix reports skill ratios for a sample of 6-digit input-output industries and commodity groups. The skill ratio is defined as the share of skilled labor relative to the share of unskilled labor. Two skill ratios are presented in Table II-1. One is based on the factor shares in the value added of the industry. The second reflects value-added shares and the shares of skilled and unskilled labor embodied in the value added of the intermediate input requirements.

Table II-1
Skill ratios for selected industries
Share of skilled labor/Share of unskilled labor

Industry	Shares in Value Added	Shares of direct and indirect labor requirements
Narrow fabrics	.35	.66
Glass products	.38	.63
Footwear	.42	.65
Apparel	.43	.58
Coal mining	.45	.65
Stone and clay	.47	.69
Non metalic minerals	.49	.71
Food	.52	.81
Misc. fabricated textiles	.54	.70
Rubber	.55	.82
Textile floor coverings	.57	.83
Lumber and wood	.59	.81
Retail Trade	.60	.76
Furniture	.64	.84
Tobacco	.64	.89
Metal mining	.70	.92
Primary steel	.72	.92
Farm machinery	.72	.97
Construction	.77	.83
Primary non-ferrous metals	.78	.98

Household appliances	.79	.97
Service industry machinery	.87	1.03
Cars and trucks	.94	1.05
Personal repair service	.94	.93
Fabricated metal products	.95	1.02
Miscellaneous electrical machinery	1.11	1.22
Miscellaneous manufacturing	1.18	1.14
Agricultural, fisheries, forestry	1.30	1.18
Transportation	1.32	1.13
Other transportation equipment	1.33	1.28
Electrical industrial machinery	1.40	1.33
Crude petroleum, natural gas	1.72	1.60
Chemicals	1.74	1.45
Wholesale Trade	1.78	1.63
Communications	1.78	1.65
Photographic equipment	1.83	1.52
Utilities-electrical services, gas	1.96	1.54
Machinery and equipment	2.01	1.62
Printing and publishing	2.02	1.71
Engines	2.03	1.47
Audio, video, communications, electronic components	2.56	1.90
Business and professional services	2.81	1.92
Aircraft	3.09	2.35
Scientific equipment	3.62	2.32
Computers and other equipment	3.94	2.31
Finance	4.08	2.58
Ordinance	5.60	3.33
Insurance	5.65	3.54
Radio and TV broadcasting	11.60	3.20