Bernardo Blum
Decomposing the US Income Inequality into Trade, Technological, and Factor Supply Components: Theory and Data
Decomposing the U.S. Income Inequality into Trade, Technological, and Factor Supply Components: theory and data *

Bernardo S. Blum †

First Draft October 2000 - This Draft March 2001
preliminary - comments welcome

Abstract

In this paper I see the changes in the income distribution of a country through the lens of the Ricardo-Viner model. Unlike the commonly used Heckscher-Ohlin model, this framework provides a theoretical decomposition of the income inequality changes of a country into components due to international trade, factor-biased and sector biased technological changes, and factor supply changes. This allows a clear separation of trade from technology and thus offers an answer to the important policy question: How much has each of these factors mattered? In order to estimate this model a new data set containing information on the Services, Retail Trade, Wholesale Trade, and Manufacturing sectors is constructed. The main results are: a) trade was an important force pushing for increases in inequality in the 1970’s but played only a minor role in the 1980’s and 1990’s; b) factor biased technological changes that saved unskilled labor relative to skilled labor were the dominant causes of increases in income inequality in the 1980’s after not playing any role in the 1970’s; and c) factor supply changes, mostly through capital accumulation, were always an important force pushing for worsenings of the income distribution.

*I am very grateful to my advisor Ed. Leamer and to Joe Hotz. I also thank Sebastian Edwards, Arnold Harberger, and participants of the Proseminar in International and Development Economics at UCLA. All errors are mine.

† e-mail to: blumb@ucla.edu
1 Introduction

Since the 1970's the U.S. labor market has been experiencing some fundamental changes, of which perhaps the most important one is a very well documented worsening in income inequality. In the search for the causes of such a change international trade, factor supply changes, and skill biased technological changes have always figured as likely suspects. At this point there is a quite reasonable amount of evidence gathered which seem to show that trade must account for a rather small fraction of the observed changes and factor supply changes should have contributed to decreases in income inequality. Technological changes, on the other hand, have been found largely responsible, even though, despite being abundant, the empirical evidence should be regarded as very inconclusive.

In almost every work that followed the trade tradition linking product price variations to changes in factor returns\(^1\), the theoretical framework adopted was the Heckscher-Ohlin (HO from here on) model. Although there is no doubt this framework can be useful in analyzing the issue, in this paper I argue that it may not be the most appropriate one to distinguish among the effects of international trade, factor supply changes, and different types of technological changes on the domestic income distribution.

One of the characteristics of the HO model is that, among other assumptions, it imposes perfect mobility of production factors across the sectors of the economy. In general that makes the model better suited for dealing with long-run effects. In practice, however, this assumption has dramatic consequences for the enterprise of identifying the causes of the recent rise in income inequality. Because of that assumption, factor supply changes as well as factor biased technological changes are condemned \textit{a priori} to have no effect on the income distribution. The burden is then to be split between trade and sector biased productivity changes.

In this paper I see the changes in income distribution of a country through the lens of the Ricardo-Viner model. This model distinguishes itself from the HO model by assuming that at least one of the production factors is sector specific. In practice this framework provides a theoretical decomposition of the income distribution changes into components due to international trade, factor-biased and sector biased technological changes, and factor supply changes. This allows a clear separation of trade from different types of technological changes and thus offers an answer to the important policy question: How much has each of those components mattered?

\(^1\)See Slaughter (1999) for a survey of this literature.
The use of the Ricardo-Viner model (RV from here on) poses some new difficulties. The main one is that according to this model changes in every sector of the economy, irrespective of being a tradable or a non-tradable sector, affect the factor returns. Because of that, differently than what happens in the HO framework, using only manufacturing data would be highly inappropriate. In order to deal with that a new data set is constructed to be used in this paper. It adds to the NBER Manufacturing Productivity Database the analogous information on three non-tradable sectors: Services, Retail Trade, and Wholesale Trade. This new data set covers about 65% of the US labor force and almost 80% of the US labor force employed in the private sector.

The conclusions of the paper are: a) trade was an important force pushing for increases in inequality in the 1970's but played only a minor role in the 1980's and 1990's; b) factor biased technological changes that saved unskilled labor relative to skilled labor were the dominant causes of increases in income inequality in the 1980's, after not playing any role in the 1970's; and c) factor supply changes, mostly through capital accumulation, were always an important force pushing for worsenings of the income distribution throughout the period analyzed.

The paper is organized in six more sections. In section two a general equilibrium framework is used to derive the determinants of the factor returns with perfect (HO framework) and imperfect (RV framework) factor mobility. It is shown that as opposed to what happens when perfect factor mobility is assumed, if factors are imperfectly mobile factor biased technological changes and factor supply changes play determinant roles in setting the income distribution of a country. Section three presents an extension of the RV model with three production factors and $N$ goods, $M$ of which tradables, that is meant to fit the data available and the question addressed in the paper. In this framework the link between income distribution, trade, technology, and factor supplies is derived. In section four some estimation issues are discussed and the methodology applied to measure the variables used in the empirical part is described. Section five presents the data set, section six presents the results, and the seventh and final part concludes.

2 Trade, Technology, Factor Supplies and Income Inequality in HO and RV

In this section the notation developed in Jones (1965) is used to characterize the link between trade, technology, factor supplies and factor returns when
factors are assumed to be perfectly mobile or sector specific. In order to avoid unnecessary complications the simple two factors two goods model is presented\(^2\). The central message of the section is that, differently than the Heckscher-Ohlin model, the Ricardo-Viner model provides a clear theoretical decomposition of the changes in income inequality of a country into components due to trade, factor-biased technological changes, sector-biased technological changes, and factor supply changes. Readers familiar with the determinants of factor returns in the HO and RV models may skip this section and still follow the remaining sections of the paper.

2.1 The Heckscher-Ohlin Model

Suppose the economy is capable of producing two goods, \(x_1\) and \(x_2\), using constant returns to scale technologies and two production factors capital, \((K)\) and labor \((L)\). Prices are assumed to be set internationally and factors are assumed to be fully mobile between sectors. The equilibrium in this economy is fully characterized by the four equations below:

\[
a_{11}x_1 + a_{12}x_2 = L \quad (1)
\]

\[
a_{k1}x_1 + a_{k2}x_2 = K \quad (2)
\]

\[
a_{11}w + a_{k1}r = p_1 \quad (3)
\]

\[
a_{12}w + a_{k2}r = p_2 \quad (4)
\]

where \(a_{ii} = \frac{L_i}{L}\) gives the amount of labor required to produce one unit of good \(i\), \(w\) is the wage rate and \(r\) is the rate of return on capital.

Equations 1 and 2 assure the full employment of production factors while the zero-profit conditions 3 and 4 assure efficiency. The system of equations 1–4 can be totally differentiated to generate the link between changes in the factor returns and changes in the exogenous variables.

\[
\lambda_{11}\dot{x}_1 + \lambda_{12}\dot{x}_2 = \dot{L} - [\lambda_{11}\dot{a}_{l1} + \lambda_{12}\dot{a}_{l2}] \quad (5)
\]

\[
\lambda_{k1}\dot{x}_1 + \lambda_{k2}\dot{x}_2 = \dot{K} - [\lambda_{k1}\dot{a}_{k1} + \lambda_{k2}\dot{a}_{k2}] \quad (6)
\]

\[
\theta_{11}\dot{w} + \theta_{k1}\dot{r} = \dot{p}_1 \quad (7)
\]

\[
\theta_{12}\dot{w} + \theta_{k2}\dot{r} = \dot{p}_2 \quad (8)
\]

\(^2\)References to the results that eventually do not hold in higher or not even dimensions are made when necessary.
where $\lambda_{i1} = \frac{L_1}{L}$ is the share of labor employed in sector one, $\theta_{i1} = \frac{w_i}{p_i x_i}$ is the labor share of sector one revenue, and hats mean rate of change.

The system above has the property of being block-recursive, implying that equations 7 and 8 are enough to fully characterize the determinants of the changes in factor returns. Allowing for technological changes in the equations above means that the coefficients $a_{ij}$ or $\theta_{ij}$ may change not only as a response to changes in relative factor prices (moves along the isoquants) but also for given relative factor prices (moves of the isoquant). The changes in factor returns are then completely specified by the modified version of 7 and 8:

$$\theta_{i1} \dot{w} + \theta_{k1} \dot{r} = \dot{p}_1 + T \dot{F} P_1$$  \hfill (9)  

$$\theta_{i2} \dot{w} + \theta_{k2} \dot{r} = \dot{p}_2 + T \dot{F} P_2$$  \hfill (10)

where $T \dot{F} P$ stands for changes in total factor productivity and it is measured by $T \dot{F} P_1 = -\theta_{i1} \dot{a}_{i1} - \theta_{k1} \dot{a}_{k1}$, where only changes due to technological changes should be accounted.

Equations 9 and 10 above are the basis for the Stolper-Samuelson theorem, and say that changes in factor returns have to be matched either by changes in product prices or sectoral changes in total factor productivity. Under this framework, factor supply changes and skill biased technological changes cannot affect factor returns at all.$^3$

Although it may not be obvious, these results depend crucially on the assumption that the production factors are perfectly mobile between productive sectors. To make this clear consider the adjustment process when the price of good $j$ decreases. At the new price industry $j$ does not break even anymore and has to release production factors that must be absorbed by the other industry. In this process an incipient aggregate excess supply of the factor in which industry $j$ is intensive is generated, together with an incipient aggregate excess demand for the factor in which industry $j$ is less intensive. As a consequence factor returns have to change, and they will until industry $j$ breaks even again. An analogous process will happen if industry $j$ shows sectoral total factor productivity change. In the same way, the irrelevance of factor supply changes and skill biased technological changes also depend on the assumption of perfect factor mobility. Suppose there is an increase in the total supply of labor and the new workers are

---

$^3$In the model presented in this section (same number of goods and production factors) equations 9 and 10 can be solved uniquely for $\dot{w}$ and $\dot{r}$. Notice that this is not true in general. With more goods than factors the HO model may have multiple solutions.
all employed in sector $j$. The marginal productivity of capital in this sector will be higher than in the other sector, so capital will move instantaneously to sector $j$. Such instantaneous factor-mobility will keep the marginal rate of transformation and factor returns equalized in both sectors. The final outcome is that sectoral outputs will change but factor returns will not.

2.2 The Ricardo-Viner Model

What if one of the production factors is sector specific? Suppose the economy still produces two goods, $x_1$ and $x_2$, using constant returns to scale technologies and two production factors capital ($K$) and labor ($L$). Prices continue to be set internationally but now one factor (let’s say capital) is sector specific. In other words, a sewing machine cannot be used to assemble a car. In this case product price and sectoral productivity changes will imply factor intensity changes, and will affect factor returns through different mechanisms. Additionally factor supply changes and skill biased technological changes will also affect factor returns since now those can not be fully absorbed by output-mix changes anymore.

The new conditions characterizing the equilibrium are given by:

\[
\begin{align*}
    a_{l1}x_1 + a_{l2}x_2 &= L \
    a_{k1}x_1 &= K_1 \
    a_{k2}x_2 &= K_2 \
    a_{l1}w + a_{k1}r_1 &= p_1 \
    a_{l2}w + a_{k2}r_2 &= p_2
\end{align*}
\] (11) (12) (13) (14) (15)

As before, equations 11–13 assure full employment of factors and equations 14 and 15 characterize efficiency. The main difference is that, since capital can not move instantaneously to arbitrage the market, the rate of return on capital in both sectors do not have to be permanently equal.

Differently than before the system above is no longer block-recursive, and the zero-profit conditions 14 and 15 are not enough to fully characterize the determinants of the factor returns. Plugging 12 and 13 in 11, totally differentiating the system above, and allowing for technological changes, the link between factor returns changes and price changes, factor supply changes, and different types of technological changes is given by:
\[
\dot{\theta} = \frac{1}{\Delta} \left[ \lambda_{i1} \frac{\sigma_1}{\theta_{k1}} (\hat{p}_1 + \hat{T} \hat{P}_1) + \lambda_{i2} \frac{\sigma_2}{\theta_{k2}} (\hat{p}_2 + \hat{T} \hat{P}_2) + \lambda_{i1} (\hat{K}_1 - FBTC_1) + \lambda_{i2} (\hat{K}_2 - FBTC_2) - \dot{\hat{L}} \right]
\]

(16)

\[
\dot{r}_1 = \frac{1}{\Delta} \left[ (\lambda_{i1} \frac{\sigma_1}{\theta_{k1}} + \lambda_{i2} \frac{\sigma_2}{\theta_{k2}})(\hat{p}_1 + \hat{T} \hat{P}_1) - \left( \frac{\lambda_{i1} \lambda_{i2} \sigma_2}{\theta_{k1} \theta_{k2}} \right) (\hat{p}_2 + \hat{T} \hat{P}_2) \right] + \frac{\theta_{i1}}{\theta_{k1}} (\ddot{L} - \lambda_{i1} (\hat{K}_1 - FBTC_1) - \lambda_{i2} (\hat{K}_2 - FBTC_2))
\]

(17)

\[
\dot{r}_2 = \frac{1}{\Delta} \left[ (\lambda_{i2} \frac{\sigma_2}{\theta_{k2}} + \lambda_{i1} \frac{\sigma_1}{\theta_{k1}})(\hat{p}_2 + \hat{T} \hat{P}_2) - \left( \frac{\lambda_{i2} \lambda_{i1} \sigma_1}{\theta_{k2} \theta_{k1}} \right) (\hat{p}_1 + \hat{T} \hat{P}_1) \right] + \frac{\theta_{i2}}{\theta_{k2}} (\ddot{L} - \lambda_{i1} (\hat{K}_1 - FBTC_1) - \lambda_{i2} (\hat{K}_2 - FBTC_2))
\]

(18)

where \( \sigma_i \) stands for the elasticity of substitution between labor and capital in production in sector \( i \), \( FBTC_i \) stands for factor biased technological changes in sector \( i \) \(^4\), and \( \Delta = \frac{\lambda_{i1} \sigma_1}{\theta_{k1}} + \frac{\lambda_{i2} \sigma_2}{\theta_{k2}} \) is the aggregate elasticity of labor demand.

Equations 16–18 provide a decomposition of the factor return changes into its possible causes. It is this decomposition scheme that will be used in order to measure the contribution each of the different factors has in every observed change in factor returns.

2.2.1 Non-Tradable Goods

How do the determinants of the factor returns in the RV model derived above change if some goods are not traded internationally?

Suppose last section’s framework still applies but one of the goods (say \( x_2 \)) is not traded internationally. In this case this good’s price is determined endogenously in order to clear the domestic market for \( x_2 \). Equations 11–15 are not enough anymore to characterize the equilibrium in this economy since all they do is to determine the supply function of \( x_2 \). In order to close the model an aggregate demand for the non-tradable good has to be specified.

As shown in appendix A, from equations 11–15 the supply of \( x_2 \) is found to be given by:

\[^4\text{Where these are defined as } FBTC_i = -\frac{\delta_{i}}{\delta_{x_2}} \text{ due to technological changes.}\]
\[\dot{x}_2 = \dot{K}_2 - b_k \frac{\sigma_2 \theta_{l2}}{\Delta \theta_{k2}} \sigma_1 \lambda_{l1}(\dot{p}_2 + T\dot{F}P_2 - \dot{p}_1 - T\dot{F}P_1) + \] 
\[+ \frac{\sigma_2 \theta_{l2}}{\Delta \theta_{k2}} [\dot{L} - \lambda_{l1}(\dot{K}_1 - FBTC_1) - \lambda_{l2}(\dot{K}_2 - FBTC_2)] \] 

(19)

Regarding the demand for \(x_2\) let’s consider three possibilities.

Suppose first the quantity demanded adjusts to the changes in supply such that no changes in the price of the non-tradable good occur. In this case of an infinitely elastic aggregate demand for non-tradables it is just like if \(x_2\) were a tradable good. The results from last section (equations 16–18) hold, and the effects associated to changes on \(p_2\) should be attributed to exogenous changes in the demand for non-tradables.

Alternatively suppose the other extreme where the quantity demanded of the non-tradable good is fixed. In this case \(\dot{c}_2 = \dot{x}_2 = 0\) and equation 19 can be solved for \(\dot{p}_2\) as:

\[\dot{p}_2 = \dot{p}_1 + T\dot{F}P_1 - T\dot{F}P_2 - \frac{\Delta \theta_{k1} \theta_{k2}}{\sigma_2 \theta_{l2} \sigma_1 \lambda_{l1}}(\dot{K}_2 - b_k) - \] 
\[\frac{\theta_{k1}}{\sigma_1 \lambda_{l1}} [\dot{L} - \lambda_{l1}(\dot{K}_1 - FBTC_1) - \lambda_{l2}(\dot{K}_2 - FBTC_2)] \] 

(20)

The link between changes in the price of the tradable good, technological changes, factor supply changes and the factor returns in this economy is given by equations 16–18 plus the price equation 20. Because of the demand specification assumed, changes in the exogenous variables are fully accommodated by changes in factor returns and in the non-tradable price, without leading to output and production factor shifts between the tradable and the non-tradable sectors.

Finally suppose an intermediate case where the elasticity of substitution in consumption between the non-tradable and the tradable goods is equal to one. In this case the market clearing condition is given by \(\dot{c}_2 = \dot{I} - \dot{p}_2 = \dot{x}_2\), where \(\dot{I}\) represents changes in the aggregate income. Using 19 the market clearing condition can be solved for the price of the non-tradable good as:

\[\dot{p}_2 = \frac{\alpha}{1 + \alpha} (\dot{p}_1 + T\dot{F}P_1 - T\dot{F}P_2) + \frac{1}{1 + \alpha} (\dot{I} - \dot{K}_2 + b_k) - \] 
\[- \frac{\sigma_2 \theta_{l2}}{\Delta \theta_{k2}} \frac{1}{1 + \alpha} [\dot{L} - \lambda_{l1}(\dot{K}_1 - FBTC_1) - \lambda_{l2}(\dot{K}_2 - FBTC_2)] \] 

(21)
where $\alpha = \frac{\sigma_2 \theta_2}{\Delta} \frac{\lambda_{11} \sigma_1}{\theta_{k1} \theta_{k2}}$.

The link between changes in the price of the tradable good, technological changes, factor supply changes and the factor returns in this economy is given by equations 16–18, and 21. In this case changes in the exogenous variables cause changes in factor returns, non-tradable good's price, and in the output-mix (tradables and non-tradables) of the economy. As an illustration of the mechanism suppose, for example, that the price of the tradable good ($x_1$) goes down. This causes the value of the marginal productivity of labor in the tradable sector to decrease. Labor (the mobile factor) will flow to the non-tradable sector increasing output and decreasing price in this sector.

In this section it was shown that the existence of non-tradable goods changes just slightly the link between price changes, technological changes, and factor supply changes and factor returns. The only difference is that now part of the effects are carried through endogenous changes in the prices of the non-tradable goods.

3 The 3 Factors \( N \) Goods Ricardo-Viner Model

In this section the over-simplified two by two model presented in the previous section is extended in order to fit the data and the question addressed in the paper.

The economy is assumed to produce \( N \) goods, \( M \) of which are traded internationally, using capital and two types of labor, unskilled and skilled. Markets are competitive, the economy is always in full-employment, technologies exhibit constant returns to scale, and as before capital is assumed to be sector specific. Finally the aggregate demands for non-tradable goods are derived from Cobb-Douglas preferences.

Under this setting the equilibrium is fully characterized by the equations below:

\[
\begin{align*}
    a_{ui} w^u + a_{s1} w^s + a_{k1} r_i &= p_i & i &= 1,2,\ldots,M \\
    a_{ui} w^u + a_{s1} w^s + a_{k1} r_i &= q_i & i &= M+1,M+2,\ldots,N \\
    \sum_{i=1}^{N} a_{ui} x_i &= U \\
    \sum_{i=1}^{N} a_{s1} x_i &= S
\end{align*}
\]
\[ c_i = \frac{\kappa I}{q_i} \quad i = M + 1, M + 2, ..., N \]

where \( p_i \) are the prices of tradable goods, \( q_i \) are the prices of non-tradable goods, \( c_i \) is the quantity demanded of the non-tradable good \( i \), \( I \) is the aggregate income, \( \kappa \) is a constant, and the tradable goods are ordered from \( 1, 2, ..., M \).

Totally differentiating the system above:

\[
\theta_i \dot{\omega}^u + \theta_i \dot{\omega}^s + \theta_i \dot{\tilde{r}}_i = \ddot{p}_i + T \ddot{P}_i \quad i = 1, 2, ..., M
\]
\[
\theta_i \dot{\omega}^u + \theta_i \dot{\omega}^s + \theta_i \dot{\tilde{r}}_i = \ddot{q}_i + T \ddot{P}_i \quad i = M + 1, ..., N
\]
\[
\sum_{i=1}^{N} \lambda_{ui} \dot{\omega}_u^i \dot{r}_i - \dot{\omega}_u^i \sum_{i=1}^{N} \lambda_{ui} \dot{\omega}_u^i = \dddot{U} - \sum_{i=1}^{N} \lambda_{ui} \dddot{K}_i + \sum_{i=1}^{N} \lambda_{ui} \dddot{BTC}_i^u
\]
\[
\sum_{i=1}^{N} \lambda_{si} \dot{\omega}_s^i \dot{r}_i - \dot{\omega}_s^i \sum_{i=1}^{N} \lambda_{si} \dot{\omega}_s^i = \dddot{S} - \sum_{i=1}^{N} \lambda_{si} \dddot{K}_i + \sum_{i=1}^{N} \lambda_{si} \dddot{BTC}_i^s
\]
\[
\dddot{q}_i = \dddot{I} - \dddot{x}_i \quad i = M + 1, M + 2, ..., N
\]

where \( FBTC_i^u \) and \( FBTC_i^s \) represent the changes in factor usage of unskilled and skilled labor relative to capital due to technological changes\(^5\).

It should be noticed that with three production factors there are three possible types of factor biased technological changes. The first one changes the relative usage of unskilled labor and capital, the second one changes the relative usage of skilled labor and capital, and the last one changes the relative usage of unskilled and skilled labor. The two first cases will be referred to as capital deepening either relative to unskilled labor \( (CAP_i^u) \) or to skilled labor \( (CAP_i^s) \). The last type will be referred to as skill biased technological changes \( (SBTC_i) \). From the expressions above it is clear that \( FBTC_i^u \) and \( FBTC_i^s \) are measures of \( CAP_i^u \) and \( CAP_i^s \) respectively, representing in fact capital deepening in each industry. Additionally it should be noticed that the three types of factor biased technological changes described above are not independent. From any two of them the third one can be readily obtained by \( SBTC_i = CAP_i^u - CAP_i^s \). That is why although every form of factor biased technological change matters for the characterization of the equilibrium, in the conditions above only two of them are present (it could have been any two of them!)

\(^5\)(\( FBTC_i^u = -\frac{\partial \omega_u^i}{\partial \omega_u^i} \)) due to technological changes.
The link between changes in factor returns and changes in the prices of tradable goods, technological changes, and factor supply changes is derived in detail in Appendix B. Equations 22 and 23 below break this link in two parts. The first one (equation 22) gives the direct effects of changes in those variables on the skill premium. These are the effects that do not work through changes in the prices of non-tradable goods, just like if every good were traded internationally. The second one (equation 23) shows how changes in the exogenous variables affect the price of the non-tradable goods. The total effects are given by the sum of the direct effects plus the effects through non-tradable good's prices changes.

\[
(\tilde{\omega}^u - \tilde{\omega}^u) = \frac{1}{\Delta} \left( \sum_{i=1}^{N} \phi_{si} \tilde{\phi}_i - T\tilde{FP}_i \right) - \left( \sum_{i=1}^{N} \phi_{si} \tilde{\phi}_i - T\tilde{FP}_i \right) + \\
+ \left( \sum_{i=1}^{N} \phi_{si} \tilde{\phi}_i - \sum_{i=1}^{N} \phi_{ui} \tilde{\phi}_i \right) \tilde{S} + \\
+ \left( \sum_{i=1}^{N} \phi_{ui} \sum_{i=1}^{N} \lambda_{si} (\bar{K}_i - CAP_i^u) \right) - \left( \sum_{i=1}^{N} \phi_{si} \sum_{i=1}^{N} \lambda_{ui} (\bar{K}_i - CAP_i^u) \right)
\]

\[
\tilde{q}_i = g(\bar{p}, T\tilde{FP}, \bar{K}, CAP^u, CAP^s, \tilde{\phi}, \tilde{S}) \quad i = M + 1, M + 2, ... N
\]

where

\[
\phi_{ui} = \frac{\lambda_{ui} \sigma_u^i}{\theta_{ki}}
\]

\[
\delta_{ui} = \frac{\lambda_{ui} \sigma_u^i}{\theta_{ki}} (1 - \theta_{ki} - \theta_{ui}) = \frac{\lambda_{ui} \sigma_u^i}{\theta_{ki}} \theta_{si}
\]

\[
\Delta = \left( \sum_{i=1}^{N} \phi_{ui} - \delta_{ui} \right) \left( \sum_{i=1}^{N} \phi_{si} - \delta_{si} \right) - \left( \sum_{i=1}^{N} \delta_{ui} \right) \left( \sum_{i=1}^{N} \delta_{si} \right)
\]

The equations above and in appendix B can be used to perform some comparative statics. Although in general \( \Delta \) can be positive or negative, in appendix C it is shown that if in aggregate unskilled and skilled labor are substitutes for capital in production then \( \Delta > 0 \).

Appendix C also calculates the sign of the direct effects of changes in the exogenous variables on the skill premium. Given the prices of the non-tradable goods: a) increases in the supply of unskilled labor increase the skill premium \( \left( \frac{d(\tilde{\omega}^u - \tilde{\omega}^u)}{d\tilde{\phi}_i} \right)_q > 0 \), b) increases in the supply of skilled work-
ers decrease the skill premium \( \frac{d(\hat{w}^s - \hat{w}^u)}{\hat{S}} \bigg| q < 0 \), c) capital deepening relative to unskilled workers increases the skill premium \( \frac{d(\hat{w}^s - \hat{w}^u)}{\hat{CAP}_s} \bigg| q > 0 \), d) capital deepening relative to skilled workers decreases the skill premium \( \frac{d(\hat{w}^s - \hat{w}^u)}{\hat{CAP}_t} \bigg| q < 0 \), and e) skill biased technological changes increase the skill premium \( \frac{d(\hat{w}^s - \hat{w}^u)}{\hat{STC}_t} \bigg| q > 0 \).

The direct effects of changes in the prices of tradable goods, of total factor productivity changes, and of changes in the prices of non-tradable goods may go either way, depending on the sector where those occur. The expressions for these effects are given by:

\[
\frac{d(\hat{w}^s - \hat{w}^u)}{d\hat{p}_i} \bigg| q = \frac{d(\hat{w}^s - \hat{w}^u)}{d(TFP_i)} \bigg| q = \frac{d(\hat{w}^s - \hat{w}^u)}{d\hat{q}_i} = \frac{\left( \sum_{i=1}^{N} \phi_{si} \right) \phi_{ui} - \left( \sum_{i=1}^{N} \phi_{ui} \phi_{si} \right) \phi_{ui}}{\Delta} = \Xi_{ui} \phi_{si} - \Xi_{si} \phi_{ui} \tag{24}
\]

Some intuition can be gained from the formulas above. Let’s focus first on the sector specific components \( \phi_{ui} \) and \( \phi_{si} \)\(^6\). Noticing that \( \frac{1}{\theta_{ti}} = \frac{d\hat{r}_i}{d\hat{q}_i} \), it is not difficult to see that \( \phi_{ui} \) represents the percentage change in the demand for unskilled labor due to changes in the price of good \( i \). Breaking the effect in its components, \( \frac{1}{\theta_{ti}} \) gives by how much \( p_i \) (or \( q_i \)) affects \( r_i \), \( \sigma^i_u \) gives the percentage change in the demand for unskilled labor as a consequence of such a change in \( r_i \), and \( \lambda_{ui} \) makes it proportional to the total unskilled labor force. The interpretation of \( \phi_{si} \) is analogous.

The \( \Xi \) coefficients are not sector specific, but relates to the structure of the whole economy. Looking at equations 27 and 28 in appendix B we see that the aggregate own-price elasticity of demand for unskilled and skilled labor are given respectively by:

\[
\frac{dU}{dw^u} = \frac{-\Delta}{\left( \sum_{i=1}^{N} (\phi_{si} - \delta_{si}) \right)}
\]

\[
\frac{dS}{dw^s} = \frac{-\Delta}{\left( \sum_{i=1}^{N} (\phi_{ui} - \delta_{ui}) \right)}
\]

The aggregate cross-price elasticity of those demands are given by:

\[
\frac{dU}{dw^s} = \frac{-\Delta}{\left( \sum_{i=1}^{N} \delta_{si} \right)}
\]

\(^6\phi_{ui} = \frac{\lambda_{ui}}{\theta_{ti}} \phi_{si} \phi_{ui} = \frac{\lambda_{ui}}{\theta_{ti}} \phi_{ui}^i \phi_{si}^i\)
\[
\frac{dS}{dw^u} \frac{w^u}{S} = \frac{\Delta}{(\sum_{i=1}^{N} \delta_{ui})}
\]

It is easy to see from 24 that \( \Xi_u \) is the inverse of the aggregate elasticity of demand for unskilled labor, and \( \Xi_a \) is the analogous measure for the skilled labor.

Given the structure of the economy, a fall in product price in sector \( i \) will tend to increase the skill premium if: a) unskilled labor is relatively more substitutable for capital than skilled labor, and b) the fraction of unskilled labor employed in sector \( i \) is relatively big compared to the fraction of skilled labor employed in \( i \). Both of these conditions imply that the demand for unskilled labor is more sensitive to price variations than the demand for skilled labor.

But how does the structure of the economy affect the final outcome? Since both skilled and unskilled labor are assumed to be fully mobile between sectors, changes in the demand for those factors in sector \( i \) will be transmitted to every other sector. The final effect on wages will depend on the labor demand elasticities in every sector, or in other words on the aggregate elasticities of demands.

Once the direct effects are calculated, the only part missing is how factor supply changes, technological changes, and changes in the price of tradable goods affect the price of the non-tradable goods. Appendix B shows that \( \frac{d\delta}{dU} < 0, \frac{d\delta}{dS} < 0, \frac{d\delta}{d(CAP_i)} < 0, \frac{d\delta}{dN_i} > 0, \frac{d\delta}{d(TFP_i)} < 0 \). The intuition of these results is pretty clear. Suppose for example the price of a tradable good increases. This causes the value of the marginal productivity of labor (both types) in this sector to be greater than in the rest of the economy. Labor will then flow in from the other sectors of the economy in order to arbitrage the markets. As a consequence the non-tradable output will decrease and non-tradable prices will increase. The same logic applies to the other variables.

Before moving to the empirical part of the paper it should be noticed that the model developed in this section brings up a mechanism, different than the Stolper-Samuelson effect, through which product price changes can affect the income distribution of a country. The idea is that a price fall in industry \( j \) will increase the ratios \( \frac{w^u}{r_j} \) and \( \frac{w^s}{r_j} \) because the immobile factor bears most of the cost. As a consequence industry \( j \) will substitute away from both types of labor. The type of labor with the biggest (in absolute value) elasticity of substitution is the one to have its demand decreased proportionally the most. In this way the Ricardo-Viner model provides a modified version of the Stolper-Samuelson theorem where price declines in
sectors where unskilled labor is very substitutable for capital and skilled labor is not leads to increases in the skill premium, and vice-versa.

4 Variable Definitions and Estimation Issues

4.1 The Elasticity of Substitution

In performing the decomposition proposed by identities 22, and 23 all the information required but the elasticity of substitution parameters $\sigma_u^i$ and $\sigma_s^i$ are available in standard industry level data sets. The only parameters that need to be estimated are those elasticities. In this section I discuss issues related to the definition and estimation of these parameters.

Before jumping to estimation procedures it is important to understand what it is being estimated. Theoretically $\sigma_s^i = \frac{d\left(\frac{\omega}{\omega_s}\right)}{d\left(\frac{\omega}{\omega_s}\right)} \left(\frac{\omega}{\omega_s}\right)$ is supposed to measure the slope of sector's $i$ isoquant. It happens though that in the case of more than two production factors there are an infinity of directions in which this slope (and the elasticity of substitution parameters $\sigma_u^i$ and $\sigma_s^i$) can be calculated. Although ideally one would like to estimate the whole curvature of the isocuant (or the slope in every direction) empirically that is not feasible.

Nevertheless the literature has offered a few options to deal with this issue. The most popular one is to use a modified definition of $\sigma_s^i$ and $\sigma_u^i$ called the Allen's elasticity of substitution. However, as Blackorby and Russel (1989) show, for more than two factors Allen's definition has no relation to the slopes of the isocquants. Another possibility is to impose an arbitrary direction and calculate the elasticity of substitution parameters for factor price variations in this direction only. Blackorby and Russel (1989) propose the so called Morishima's elasticity of substitution, where the return on capital ($r$) is kept constant and changes in the ratios $\frac{w^a}{r}$ and $\frac{w^u}{r}$ occur as a consequence of changes in $w^a$ and $w^u$ only. The choice for this specific direction is justified by computational reasons, since as those authors show the Morishima's elasticity of substitution can be written as:

$$\sigma_s^i = \epsilon_{ks}^i - \epsilon_{ss}^i$$

(25)

where $\epsilon_{ks}$ is the constant output cross-price elasticity of factor demand and $\epsilon_{ss}$ is the constant output own-price elasticity of factor demand.

---

7For a discussion on Allen's and Morishima's elasticity of substitution see Blackorby and Russel (1989)
For the reasons mentioned above, in this paper I use the Morishima’s elasticity of substitution concept to calculate $\sigma^i_s$ and $\sigma^i_u$.

As equation 25 above shows, in order to obtain estimates of $\sigma^i_s$ and $\sigma^i_u$ it is enough to have estimates of the own-price and cross-price factor demand elasticities. Hamermesh(1993) discusses many methods for estimating demand elasticities. One that has been widely used and has provided reasonable and consistent results\(^8\) is based on assuming a cost function $C = C(w, Y)$, linearly homogeneous on the vector of factor returns $w$. Applying the Shephard’s lemma the set of factor demands is given by:

$$L = \frac{dC}{dw} = L(w, Y)$$

The factor demand elasticities are then empirically obtained by estimating the system of linear equations below\(^9\):

\[
\begin{align*}
ln(S)^i &= b_{s1}^i ln(w_{us}) + b_{s2}^i ln(w_{st}) + b_{s3}^i ln(r_i) + ln(y_i) + \xi_i^s \\
ln(U)^i &= b_{u1}^i ln(w_{us}) + b_{u2}^i ln(w_{st}) + b_{u3}^i ln(r_i) + ln(y_i) + \xi_i^u \\
ln(K)^i &= b_{k1}^i ln(w_{us}) + b_{k2}^i ln(w_{st}) + b_{k3}^i ln(r_i) + ln(y_i) + \xi_i^k
\end{align*}
\]

(26)

where $\epsilon_{ks}^i = b_{ks}^k$, $\epsilon_{ku}^i = b_{ku}^k$, $\epsilon_{su}^i = b_{su}^s$, and $\epsilon_{uu}^i = b_{uu}^u$.

In order to assure that the equations estimated are indeed demand equations rather than equilibrium points two identification devices are used, both of them suggested by Hamermesh(1993). The first one says that the system of equations above should be estimated at a fairly desegregated level, such that the economic unit can be considered small enough to take factor returns as given. Second, as pointed out by Nickell and Symons (1990), it is not clear that there is an identification problem estimating those equations. The reason is that the real factor returns entering in the factor demand functions should be the ones deflated by the industry product price while the real factor returns entering in the factor supply functions should be the ones deflated by some consumer price index. As long as there is enough variation in the ratio of industry prices to consumer prices, the demand functions above will be identified.

\(^8\)See Hamermesh (1993) chapter 2 for a methodological discussion and chapter 3 for the empirical evidence.

\(^9\)Slaughter (1997) estimates the same equations obtaining reasonable results.
4.2 Technological Changes

Although measures of sectoral total factor productivity changes are available, the same does not happen for factor biased technological changes. In calculating those the main issue is how to distinguish from the equilibrium relative factor usage changes the part due to technological changes.

One way of doing it is assuming that each sector is small enough such that changes in this sector do not affect factor returns. In this case the changes in factor usage that are not due to relative factor returns changes can be attributed to factor biased technological changes:

\[ CAP_i^u = \Delta b_{i u} - \Delta b_{ki} = \left( \frac{\tilde{U}_i}{K_i} \right) + \sigma_u^i (\tilde{w}^u - r_i) \]

\[ CAP_i^d = \Delta b_{i d} - \Delta b_{kd} = \left( \frac{\tilde{S}_i}{K_i} \right) + \sigma_d^i (\tilde{w}^d - r_i) \]

4.3 Trade

In the RV model developed trade can affect factor returns in many ways. The first one is through changes in internationally given prices of tradable goods. By this channel competition with low-wage foreign sources of supply would affect domestic factor returns only to the extent that it changes the international prices of tradable goods.

A second way trade can possibly affect the income distribution is through changes in the aggregate demand for non-tradable goods. Large and persistent imbalances in the current account is one example of how trade can affect the aggregate demand for non-tradables.

Finally trade can affect the degree of competition faced by domestic firms. As argued in Slaughter (2001) this can change the firms optimal behavior and affect, among other things, the elasticities of factor demand.

In this paper only the trade effects that work through changes in the prices of tradable goods are considered. Other types of trade effects will be addressed in future research.

5 Data

The manufacturing data used in this paper comes from the NBER Manufacturing Productivity Database. The fact that this data base has been
extensively used in the trade literature exempts me from providing a detailed
description of it.\textsuperscript{10}

The data on non-manufacturing sectors was constructed to be used in
this paper and a detailed description of it is provided in appendix D. It
covers the period from 1964 to 1996 and contains information on three sec-
tors: Retail Trade, Wholesale Trade, and Services.\textsuperscript{11} These three sectors
together with manufacturing represent 65% of the US nonfarm labor force,
80% of the private sector labor force, and 55% of GDP.

Table 1 and graphs 1-8 describe the main characteristics of the data set.
Graph 1 shows the capital to labor ratio in every sector and graphs 2-5
break this measure into equipment per worker and structure per worker in
every sector. Graph 6 shows the average production worker hourly wage\textsuperscript{12}
in every sector. Graph 7 depicts the ratio of production workers to non-
production workers and graph 8 shows the skill premium, measured as the
ratio of the average production wage to the average non-production wage.

6 Results

Before presenting the results a couple of definitions are necessary:

First, throughout the analysis production workers are used as a proxy
for unskilled labor while non-production workers are used as a proxy for
skilled labor. Leamer(1998), among others, discusses for the manufactur-
ing industries the appropriateness of those proxies in trying to distinguish
between skilled and unskilled workers. For the non-manufacturing sectors
the usefulness of those proxies have not been accessed yet. My expectation
is that for the Wholesale Trade and Retail Trade sectors this classification
should do no worse than for the manufacturing sector.\textsuperscript{13} Nevertheless, for
some sub-sectors of the Services sector this classification may be quite mis-
leading. For the Health Services, Legal Services, and Educational Services
sectors characterizing a non-supervisory worker as unskilled does not seem
to be appropriate. In order to deal with this possible problem a sub-sector
of the Services sector excluding Health and Legal Services is constructed.\textsuperscript{14}

\textsuperscript{10}For detailed information see Bartelsman and Gray (1994) and Leamer(1998).
\textsuperscript{11}A second definition of the Service sector excluding Health Services and Legal Services
(labeled Services but H&L) is also built being available starting at 1972.
\textsuperscript{12}As discussed in appendix D, in the non-manufacturing sectors the workers labeled as
production workers are the ones performing non-supervisory or non-managerial jobs.
\textsuperscript{13}It may in fact do better since office personnel that are classified as non-production
workers in manufacturing are labeled as production workers in non-manufacturing sectors.
\textsuperscript{14}Lack of data prevents the exclusion of Educational Services as well. Nevertheless
Second, neither the NBER dataset nor any other database provide measures of the rate of return on capital by industry. Following Slaughter (2001) the price of capital is measured by the nominal value added per capital deflated by the shipments-price index. Notice that this is the definition suggested by the constant returns to scale assumption which says that from the value added whatever is not paid to workers should be considered return on capital.

6.1 Elasticity of Substitution

The elasticity of substitution parameters $\sigma_u^i$ and $\sigma_s^i$ are estimated using equations 25 and 26 following closely the procedure proposed by Slaughter (2001). Value added, average annual returns of production workers, non-production workers, and capital are deflated by the industry price deflator in order to represent $w^n, w^r, r,$ and $Y$ respectively.

Industries in the same 2-digit SIC classification or in the non-manufacturing sectors are assumed to have the same elasticities of substitution. Equations 25 and 26 are estimated in differences, what takes care of fixed effects and scale problems.

Table 2 shows the estimated $\sigma_u^i$ and $\sigma_s^i$ parameters and the number of observation in each industry. It also shows in the last row the weighted average elasticities of substitution, or in other words the aggregate elasticity of substitution between production, non-production workers, and capital. Graph 9 pictures those values in a scatter plot where the big dot is the aggregate elasticity pair. It should be noticed that all the estimated values are well in accordance with previous results reported by Hamermesh (1993), including the fact that for the economy as a whole unskilled workers are relatively more substitutable for capital than skilled workers.

6.2 Trade, Technological, and Factor Supplies Effects

The effects of trade (measured as the effects of changes in product prices of tradable goods), technological changes (factor biased or not), and factor supply changes on the skill premium from 1970 to 1994 are shown in graph 10. Graph 11 breaks the technological effects into $TFP$ and factor biased changes while graph 12 breaks the factor supply effects into the effects of labor supply changes and the effects of capital accumulation.

This sub-sector is relatively small employing only about 2 million workers out of about 40 million in the Services sector as a whole and about 10 million in the Health Services sector.
Finally graph 13 shows the average trade, technology, and factor supply effects for every half decade in the period, so the relative importance of each factor can be easily compared.

The conclusions from these graphs are: a) trade was an important force pushing for increases in inequality in the 1970’s but played only a minor role in the 1980’s and 1990’s; b) factor biased technological changes that saved unskilled labor relative to skilled labor were the dominant causes of increases in income inequality in the 1980’s after not playing any role in the 1970’s; and c) factor supply changes, mostly through capital accumulation, were always an important force pushing for worsenings of the income distribution throughout the period analyzed.

7 Conclusions

This paper sees the recently observed changes in the American income distribution through the lens of the Ricardo-Viner model of international trade.

It is found that international trade played an important role only in the 1970's, a result that confirms previous findings in the literature. Factor biased technological changes, on the other side, were the dominant force causing increases in the skill premium in the first half of the 1980’s, and still a very important factor in the second part of 1980’s and in the 1990’s. Finally, factor supply changes proved to be a very important factor causing increases in income inequality. This should be regarded as an unexpected result since because in the last forty years the supply of unskilled labor has decreased relatively to the supply of skilled labor, the general impression is that factor supply changes must not have caused the observed rises in income inequality. As this paper shows, this argument neglects completely capital accumulation, and the effects it can have in income distribution. When accounted for that, factor supply changes were a major force pushing for increases in inequality throughout the period.
References


Feenstra, Robert C., Gordon H. Hanson, Globalizationm Outsourcing, and Wage Inequality, NBER Working Paper 5424, January 1996.


Slaughter (a), Matthew J., What are the Results of Product-Price Studies and What Can We Learn From Their Differences?, in Robert C. Feenstra (eds), International Trade and Wages, National Bureau of Economic Research Conference Volume, 1999.

Slaughter (b), Matthew J., Globalization and Wages: A Tale of Two Perspectives, mimeo, February 1999.


A Supply Function of the Non-Tradable Good
B  Factor Returns Determinants in the $N$ by 3 Model

$$\hat{\omega}^u = \frac{1}{\Delta} \left[ \left( \sum_{i=1}^{N} (\phi_{si} - \delta_{si}) \right) \sum_{t=1}^{N} \phi_{it} (\hat{p}_i - T\hat{F}_i P_t) - \left( \sum_{i=1}^{N} \delta_{ui} \right) \sum_{t=1}^{N} \phi_{si} (\hat{p}_i - T\hat{F}_i P_t) + \right. $$

$$+ \left( \sum_{i=1}^{N} \delta_{ui} \right) \hat{S} - \left( \sum_{i=1}^{N} (\phi_{si} - \delta_{si}) \right) \hat{U} + $$

$$\left. + \left( \sum_{i=1}^{N} (\phi_{si} - \delta_{si}) \right) \sum_{t=1}^{N} \lambda_{ui} (\hat{K}_i - CAP_t^u) - \left( \sum_{i=1}^{N} \delta_{ui} \right) \sum_{t=1}^{N} \lambda_{si} (\hat{K}_i - CAP_t^s) \right] \tag{27}$$

$$\hat{\omega}^s = \frac{1}{\Delta} \left[ \left( \sum_{i=1}^{N} (\phi_{ui} - \delta_{ui}) \right) \sum_{t=1}^{N} \phi_{st} (\hat{p}_i - T\hat{F}_i P_t) - \left( \sum_{i=1}^{N} \delta_{si} \right) \sum_{t=1}^{N} \phi_{ut} (\hat{p}_i - T\hat{F}_i P_t) + \right. $$

$$+ \left( \sum_{i=1}^{N} \delta_{si} \right) \hat{U} - \left( \sum_{i=1}^{N} (\phi_{ui} - \delta_{ui}) \right) \hat{S} + $$

$$\left. + \left( \sum_{i=1}^{N} (\phi_{ui} - \delta_{ui}) \right) \sum_{t=1}^{N} \lambda_{st} (\hat{K}_i - CAP_t^s) - \left( \sum_{i=1}^{N} \delta_{st} \right) \sum_{t=1}^{N} \lambda_{ut} (\hat{K}_i - CAP_t^u) \right] \tag{28}$$

$$\hat{r}_i = \frac{1}{\theta_{st}} \left[ \hat{p}_i - T\hat{F}_i P_t - \theta_{ut} \hat{\omega}^u - \theta_{st} \hat{\omega}^s \right] \tag{29}$$
C Marginal Effects in the $N$ by 3 Model

Theorem 1: If skilled labor and unskilled labor are substitutes for capital in the economy as a whole, and each type of labor's share represents less than 50 percent of the total sector revenue then: $\Delta > 0$, $\frac{d\bar{w}_u}{d\bar{U}} < 0$, $\frac{d\bar{w}_u}{d\bar{S}} > 0$, $\frac{d\bar{w}_s}{d\bar{S}} < 0$, and $\frac{d\bar{w}_s}{d\bar{U}} > 0$.

proof:
With capital being sector specific the aggregate elasticity of substitution between unskilled labor and capital is given by the weighted average of the sectoral elasticities of substitution, where the weights are the proportion of unskilled workers employed in each sector. Algebraically we can define that to be equal to $\sigma_{uk}^a = \sum_{i=1}^N \lambda_{ui} \sigma_{ui}^i$.

Analogously the aggregate elasticity of substitution between skilled labor and capital is given by $\sigma_{sk}^a = \sum_{i=1}^N \lambda_{si} \sigma_{si}^i$.

If both types of labor are substitutes for capital in aggregate then $\sigma_{uk}^a = \sum_{i=1}^N \lambda_{ui} \sigma_{ui}^i > 0$, and $\sigma_{sk}^a = \sum_{i=1}^N \lambda_{si} \sigma_{si}^i > 0$. This implies that $\sum_{i=1}^N \phi_{ui} > 0$, $\sum_{i=1}^N \phi_{si} > 0$, $\sum_{i=1}^N \delta_{ui} > 0$, and $\sum_{i=1}^N \delta_{si} > 0$.

$\Delta > 0$:
rewriting $\Delta > 0$ as

$$
\Delta = (\sum_{i=1}^N \phi_{ui}(1 - \theta_{si}))(\sum_{i=1}^N \phi_{si}(1 - \theta_{ui})) - (\sum_{i=1}^N \phi_{ui}\theta_{si})(\sum_{i=1}^N \phi_{si}\theta_{ui})
$$

it becomes clear that $\theta_{ui} < 0.5$ and $\theta_{si} < 0.5$ is a sufficient condition for $\Delta > 0$. Alternatively, remembering that $\theta_{si} + \theta_{ui} + \theta_{ki} = 1$ it is straightforward to see that $\theta_{ui} < \theta_{si} + \theta_{ki}$ and $\theta_{si} < \theta_{ui} + \theta_{ki}$ is also sufficient for $\Delta > 0$.

$\frac{d\bar{w}_u}{d\bar{U}} < 0$, $\frac{d\bar{w}_u}{d\bar{S}} > 0$, $\frac{d\bar{w}_s}{d\bar{S}} < 0$, $\frac{d\bar{w}_s}{d\bar{U}} > 0$:

Once established the signs of $\Delta$, $\sum_{i=1}^N \phi_{ui} > 0$, $\sum_{i=1}^N \phi_{si} > 0$, $\sum_{i=1}^N \delta_{ui} > 0$, and $\sum_{i=1}^N \delta_{si} > 0$, equations 27 and 28 are enough to show that:

$$
\frac{d\bar{w}_u}{d\bar{U}} = -\frac{(\sum_{i=1}^N (\phi_{si} - \delta_{si}))}{\Delta} < 0, \quad \frac{d\bar{w}_u}{d\bar{S}} = \frac{(\sum_{i=1}^N \delta_{ui})}{\Delta} > 0
$$

$$
\frac{d\bar{w}_s}{d\bar{S}} = -\frac{(\sum_{i=1}^N (\phi_{ui} - \delta_{ui}))}{\Delta} < 0, \quad \frac{d\bar{w}_s}{d\bar{U}} = \frac{(\sum_{i=1}^N \delta_{si})}{\Delta} > 0
$$
D  Data Appendix
<table>
<thead>
<tr>
<th>year</th>
<th>Value Added (millions of current dollars)</th>
<th>Manufacturing</th>
<th>Wholesale Trade</th>
<th>Retail trade</th>
<th>Services</th>
<th>Services but H&amp;L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td></td>
<td>594948</td>
<td>71980</td>
<td>100683</td>
<td>120890</td>
<td>82175</td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>1594799</td>
<td>196861</td>
<td>245401</td>
<td>378896</td>
<td>242356</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>3281802</td>
<td>376144</td>
<td>507771</td>
<td>1071525</td>
<td>674507</td>
</tr>
<tr>
<td></td>
<td>Capital (billions of 1987 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td>788</td>
<td>96</td>
<td>222</td>
<td>290</td>
<td>247</td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>1061</td>
<td>194</td>
<td>323</td>
<td>476</td>
<td>406</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>1226</td>
<td>347</td>
<td>455</td>
<td>668</td>
<td>534</td>
</tr>
<tr>
<td></td>
<td>Equipment (billions of 1987 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td>383</td>
<td>53</td>
<td>64</td>
<td>129</td>
<td>115</td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>594</td>
<td>107</td>
<td>100</td>
<td>249</td>
<td>221</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>748</td>
<td>181</td>
<td>141</td>
<td>327</td>
<td>273</td>
</tr>
<tr>
<td></td>
<td>Structure (billions of 1987 dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td>405</td>
<td>43</td>
<td>158</td>
<td>161</td>
<td>131</td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>467</td>
<td>87</td>
<td>223</td>
<td>227</td>
<td>185</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>478</td>
<td>166</td>
<td>314</td>
<td>341</td>
<td>261</td>
</tr>
<tr>
<td></td>
<td>Employment (1000's of workers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td>18408</td>
<td>4006</td>
<td>11034</td>
<td>11548</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>19300</td>
<td>5292</td>
<td>15018</td>
<td>17890</td>
<td>12114</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>17579</td>
<td>6173</td>
<td>19601</td>
<td>27934</td>
<td>19212</td>
</tr>
<tr>
<td></td>
<td>Production Workers (1000's of workers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td>13640</td>
<td>3340</td>
<td>10034</td>
<td>10481</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>13889</td>
<td>4328</td>
<td>13484</td>
<td>15921</td>
<td>10782</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>12128</td>
<td>4959</td>
<td>17358</td>
<td>24387</td>
<td>16691</td>
</tr>
<tr>
<td></td>
<td>Average Hourly Earnings of Production Workers (current dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td>3.43</td>
<td>3.43</td>
<td>2.44</td>
<td>2.81</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>7.41</td>
<td>6.95</td>
<td>4.88</td>
<td>5.86</td>
<td>5.86</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>11.19</td>
<td>10.79</td>
<td>6.75</td>
<td>9.83</td>
<td>9.39</td>
</tr>
</tbody>
</table>

Table 1
<table>
<thead>
<tr>
<th>Industry</th>
<th>Sigma U</th>
<th>Sigma S</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOOD</td>
<td>0.258471</td>
<td>0.602386</td>
</tr>
<tr>
<td>TOBACCO</td>
<td>0.764663</td>
<td>0.44117</td>
</tr>
<tr>
<td>TEXTILE</td>
<td>0.741662</td>
<td>0.790086</td>
</tr>
<tr>
<td>APPAREL</td>
<td>0.983423</td>
<td>0.874075</td>
</tr>
<tr>
<td>LUMBER</td>
<td>0.710661</td>
<td>0.387328</td>
</tr>
<tr>
<td>FURNITURE</td>
<td>0.621706</td>
<td>0.783559</td>
</tr>
<tr>
<td>PAPER</td>
<td>0.730265</td>
<td>0.531218</td>
</tr>
<tr>
<td>PRINTING &amp; PUBLISH</td>
<td>0.481314</td>
<td>0.699169</td>
</tr>
<tr>
<td>CHEMICALS</td>
<td>0.208198</td>
<td>0.570911</td>
</tr>
<tr>
<td>PETROLEUM</td>
<td>0.131064</td>
<td>0.474158</td>
</tr>
<tr>
<td>RUBBER &amp; PLASTIC</td>
<td>0.385223</td>
<td>0.399006</td>
</tr>
<tr>
<td>LEATHER</td>
<td>0.784997</td>
<td>0.655018</td>
</tr>
<tr>
<td>STONE, CLAY, GLASS</td>
<td>0.458395</td>
<td>0.457607</td>
</tr>
<tr>
<td>PRIMARY METAL</td>
<td>0.500146</td>
<td>0.298174</td>
</tr>
<tr>
<td>FABRICATED METAL</td>
<td>0.551472</td>
<td>0.563622</td>
</tr>
<tr>
<td>MACHINERY</td>
<td>0.761907</td>
<td>0.671676</td>
</tr>
<tr>
<td>ELECT. EQUIPMENT</td>
<td>0.661154</td>
<td>0.772685</td>
</tr>
<tr>
<td>TRANSPORT. EQUIP</td>
<td>0.699822</td>
<td>0.873373</td>
</tr>
<tr>
<td>INTRUMENTS</td>
<td>0.568632</td>
<td>0.670023</td>
</tr>
<tr>
<td>MISC. MANUFACT.</td>
<td>0.865097</td>
<td>0.509648</td>
</tr>
<tr>
<td>WHOLESALE TRADE</td>
<td>0.670769</td>
<td>0.432393</td>
</tr>
<tr>
<td>RETAIL TRADE</td>
<td>0.670769</td>
<td>0.432393</td>
</tr>
<tr>
<td>SERVICES</td>
<td>0.670769</td>
<td>0.432393</td>
</tr>
<tr>
<td>Aggregate</td>
<td>0.654732</td>
<td>0.551674</td>
</tr>
</tbody>
</table>

Table 2
Manufacturing Sector

Graph 2: Thousands of 1987 dollars versus years from 1958 to 1996. The graph shows the trends of equipment/worker and structure/worker in the manufacturing sector over time.
Average Production Worker Hourly Wage  
(GDP Deflated)

1987 Dollars

year

64 65 66 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 93 94

graph 6
Trade, Technology, and Factor Supply Effects on the Skill Premium

graph 10
Trade, Technology, and Factor Supply Effects on the Skill Premium

graph 13