International Review of Economics and Finance 46 (2016) 136–147

Contents lists available at ScienceDirect

International Review of Economics and Finance

journal homepage: www.elsevier.com/locate/iref

# Multi-sector specific factors model with two mobile factors ☆

Can Dogan [a,*], Gokhan H. Akay [b,c]

[a] Department of Business Administration, North American University, 11929 W. Airport Blvd. Stafford, TX 77477, USA
[b] Department of International Trade, Mahmutbey Dilmenler Caddesi, No:26, 34217 Bağcılar – Istanbul, Turkey
[c] Istanbul Kemerburgaz University, Turkey

A R T I C L E  I N F O

*Article history:*
Received 11 April 2015
Received in revised form
5 September 2016
Accepted 6 September 2016
Available online 9 September 2016

*JEL classification:*
F1
J24
J31

*Keywords:*
Specific factors
Stolper-Samuelson theorem
Skill premium

A B S T R A C T

This paper is an extension of the specific factors model to the study of relative wages by considering a multi-industry model with skilled and unskilled labor as the only mobile factors. We show that for changes in the price of a single industry, the impact on the skill premium is usually modest and sometimes the sign is the reverse of expectations. The elasticity of substitution between factors is critical for single-sector price changes. To generate a Stolper-Samuelson magnification effect, it is necessary to have a large number of price changes across industries intensive in either skilled or unskilled labor.



## 1. Introduction

Wage inequality between skilled and unskilled labor has been increasing since the late 1970s. For example, over the past 35 years, there has been a substantial widening in the difference between pay for workers with a bachelor's degree and pay for those with only a high school diploma. Earned incomes of men and women with college education were 33% and 76% higher, respectively, than men and women with only high school diplomas in 1963. By 2013, however, workers with college education were earning more than twice the incomes of high school graduates.[1] Researchers have studied the skill premium in many different contexts to explore the main causes of the widening wage gap between the two types of labor. In this regard, changes in terms of trade along with the factor movements due to international trade are one of the mainstream explanations for the rise in the skill premium.[2]

Studies suggesting this explanation are mostly built on the Heckscher-Ohlin (H-O from here on) model. According to these studies, assuming perfectly competitive goods and labor markets, international trade affects the relative prices of products which in turn affect the factor prices through relative factor demands. In a model with two factors, say skilled and

☆ We thank Robin Sickles, Chinhui Juhn, Atilla Ciftler, Emin Dinlersoz, and Edward Balistreri for their valuable comments and suggestions.

* Corresponding author.
*E-mail addresses:* dogan@na.edu (C. Dogan), gokhan.akay@kemerburgaz.edu.tr (G.H. Akay).

[1] See *Economic Report of the President-2015* for a detailed discussion and more statistics.

[2] One other common explanation for the skill premium is the skill biased technical change. Technological advances that increase the productivity advantages associated with skill result in a higher increase in the productivity of more-skilled workers compared to less-skilled workers. Due to this change, referred as skill-biased technical change in the literature, demand for skilled labor increases and so does the skill premium.

http://dx.doi.org/10.1016/j.iref.2016.09.002

unskilled labor, in a skill-rich country, like the U.S., the Stolper and Samuelson (1941) predicts that relative price of skill-intensive goods will rise and hence skilled wages rise while unskilled wages fall.

Earlier empirical studies have emphasized factor intensity approach to explain the relationship between trade and wages.[3] Grossman (1987) finds only minor sensitivity of wages to tariff changes and prices of imports in the US. Revenga (1992) estimates the impact of changes in imports on wages in the US and states that the prices of imported goods have small effects on wages. Krugman (1995) shows that American trade with developing countries had only a small impact on prices and wages. Haskel and Slaughter (2001) find that international trade has a negative effect on the wages of unskilled workers in the UK. On the other hand, Lawrence and Slaughter (1993) and Bhagwati (1991) do not find a clear trend in relative prices of goods in the U.S. during the 1980s. Feenstra and Gordon (2002) argue that international trade, mostly in the form of intermediate goods, affects the labor demand and is an important explanation for the increase in the wage gap. Malki and Thompson (2014) investigate the impact in Morocco of its pending free trade agreement with the US in a specific factors model with unemployment and energy imports. In terms of factor substitution, they conclude that factor substitution only impacts the degree of output adjustments. Akay and Dogan (2013) use a generalized form of specific factors model using a single mobile factor and show that output in each industry increases at a different rate when labor supply increases based on the elasticity of substitution between capital and labor in that industry.

It is not surprising to see different conclusions given the fact that each study has a different set of restrictive assumptions. Many researchers have used the H–O model because it is analytically easy to explain how prices affect real wages and it also requires minimal data to test.[4] However as several studies have emphasized, this approach is based on the very restrictive assumption of complete factor mobility between industries. This assumption may not be well-suited to answering questions involving the impact of trade policy on income distribution, at least in the short run. It is likely that some factors are sector specific and thus immobile, and some researchers include immobility in their models. Moreover, it is difficult to generalize the model to describe a multi-industry economy.[5]

The specific factor model, introduced by Jones (1971) and Samuelson (1971), has since been interpreted by many researchers as an alternative to the H–O model. The specific factor model assumes that one factor is mobile between sectors with given supplies of specific factors. As a result, trade tends to lower the factor returns in import-competing industries and increase those in export industries.

The specific factor model is appealing for several reasons. The H–O model implies that factor intensity determines the industry level outputs and the pattern of trade. On the other hand, the specific factors model points out that a comparison of both factor intensities and factor demand elasticities plays a key role in deciding which output grows comparatively more when the size of the corresponding factor increases.[6] Blum (2010) states that the specific factors model allows for tradable and non-tradable sectors not found in the H-O model. One other advantage of the specific factors model is that any number of sectors of the economy can be studied and so it is not necessary to confine oneself to some generalized change in the terms of trade. In the real world, whether trade occurs or not, relative prices are going in different directions even in industries intensive in a given factor.

This paper aims to contribute to the study of trade and relative wages of skilled and unskilled workers by introducing an extension of the specific factors model. It also provides a theoretical explanation for different conclusions drawn by the existing literature. It extends the standard specific factors model to a multi-industry model with skilled and unskilled labor as two types of mobile factors in addition to the capital specific to each industry. The model also introduces elasticity of substitution between these three factors in each industry that turns out to play a significant role in explaining the effect of trade on the skill premium. By estimating the translog cost functions of 27 U.S. industries (covering approximately 65% of the U.S. economy) the model is calibrated to calculate the impact of the change in any commodity price or factor supply on the skill premium. It is shown that for changes in the price of a single industry, the impact on the skill premium is usually quite modest and sometimes the sign is the opposite of expectations. The elasticity of substitution between skilled labor and capital is critical for single-sector price changes. To generate a Stolper-Samuelson magnification effect, it is necessary to have a large number of price changes across industries intensive in either skilled or unskilled labor.

This paper shows that the question of the impact of a change a single price on the skill premium depends very much on whether the skilled labor and capital are complements or substitutes in that industry. If skilled labor and capital are complements, as they are in almost one third of the industries in the data, the impact of an increase in the value of the product has a small but negative impact on the skill premium, even in such a skill-intensive industry as petroleum and coal products.

The model may also be applied to suggest how a tariff or quota might affect factor prices throughout the economy.

[3] Several studies so far have examined factor intensity and the timing of price changes through so-called consistency checks (Lawrence & Slaughter 1993). In other empirical approaches, mandated wage equations have been used to predict changes in wages and price and to check the consistency of Stolper-Samuelson effects (Baldwin & Cain, 2000; Haskel & Slaughter, 2001; Leamer, 1998).

[4] See Leamer (1998).

[5] Redding (2008) states that the use of the H–O model with many goods and production factors are more problematical than in the $2 \times 2 \times 2$ stylized version.

[6] Akay (2012) shows that both factor intensities between industries and the value of elasticity of substitution are important determinants to analyze the impact of commodity prices on rewards of labor and rate of return to specific capital by using data for U.S Economy. See also, Toledo (2011), Thompson and Toledo (2005) and Thompson (1997).

For example, what will be the ripple effect of a tariff or the removal of a tariff or quota on, say, wholesale trade, on returns in other industries or the skill premium? Moreover, it offers a rich set of predictions for determining the effect of endowment changes on factor returns such as migration.

## 2. The model

Jones (1971) developed the algebra of the two sector specific factors model with one mobile factor. This paper builds on Ruffin and Jones (1977) by considering a multi-industry model with two mobile factors and a specific factor for each industry. With three factors in each industry it is possible for any two factors to be complements. From a theoretical point of view, this extension allows for an analysis of different elasticities of substitution for skilled and unskilled labor to capital that is specific to an industry. This feature plays a crucial role on the effect of trade on the skill premium.

Let $S$ be the total supply skilled labor, $U$ be the total supply of unskilled labor, and $K_j$ be the total amount of capital specific to industry $j, j = 1$ to $N$. Production in each industry involves constant returns to scale.

Define the following;

$a_{ij}=$ The amount of type $i$ factor used to produce 1 unit of good $j$. $i = s, u$.

$X_j=$ The amount of good $j$ produced.

$w_i=$ Wage of labor type $i$.

$r_j=$ Return of capital specific to industry $j$.

Given these denotations, full employment conditions are:

$$\sum_{j=1}^{N} a_{sj}X_j = S. \tag{1}$$

$$\sum_{j=1}^{N} a_{uj}X_j = U. \tag{2}$$

The same full employment conditions hold for specific capitals in each industry:

$$a_{kj}X_j = K_j. \tag{3}$$

Assuming perfectly competitive goods and labor markets, prices are driven to costs:

$$a_{sj}w_s + a_{uj}w_u + a_{kj}r_j = P_j. \tag{4}$$

Substituting Eq. (3) into (1) and (2) gives the link between the factors of production:

$$\sum_{j=1}^{N} \left(\frac{a_{sj}}{a_{kj}}\right) K_j = S. \tag{5}$$

$$\sum_{j=1}^{N} \left(\frac{a_{uj}}{a_{kj}}\right) K_j = U. \tag{6}$$

The difference between the elasticity of substitution of capital and unskilled labor and that of capital and skilled labor affects the returns to both labor types and therefore has a direct effect on the skill premium. The partial elasticity of substitution between capital and labor is defined as;

$$\sigma_{uk}^{j}=\frac{\left(\hat{a}_{kj}-\hat{a}_{uj}\right)}{\left(\hat{w}_u-\hat{r}_j\right)} \tag{7}$$

for unskilled labor and;

$$\sigma_{sk}^{j}=\frac{\left(\hat{a}_{kj}-\hat{a}_{sj}\right)}{\left(\hat{w}_s-\hat{r}_j\right)} \tag{8}$$

for skilled labor where a " ^ " over a variable represents a relative change in that variable.

Differentiating (5) and making use of (8) gives:

$$\sum_{j=1}^{N} \left[\lambda_{sj}\sigma_{sk}^{j}\left(\hat{r}_j-\hat{w}_s\right)\right]=\hat{S}, \tag{9}$$

where $\lambda_{ij} = \frac{\frac{a_{ij}}{a_{kj}} K_j}{\sum_{j=1}^{N} \left( \frac{a_{ij}}{a_{kj}} K_j \right)}$ is the fraction of labor type $i$ used in industry $j$. The same applies to the unskilled labor:

$$\sum_{j=1}^{N} \left[ \lambda_{uj} \sigma_{uk}^{j} \left( \hat{r}_j - \hat{w}_u \right) \right] = \hat{U}. \tag{10}$$

These two equations relate changes in factor returns to changes in factor endowments. They imply that a change in factor endowment is equal to the difference in changes of factor returns weighted by the elasticity of substitution of labor and capital in that industry, and the fraction of labor used in that industry. Or, if labor is kept constant, an increase in return to capital in one industry has to be offset by a decrease in returns to specific capitals in other industries adjusted by the elasticity of substitution between labor and capital in each industry.

To be able to solve for equilibrium, it is also necessary to identify the link between prices and the factor returns. Cost minimization requires the selection of the input-output coefficients along the unit-isoquant. This condition implies:

$$\theta_{sj} \widehat{a_{sj}} + \theta_{uj} \widehat{a_{uj}} + \theta_{kj} \widehat{a_{kj}} = 0, \tag{11}$$

where $\theta_{ij} = \frac{a_{ij} r_j}{P_j}$ is the distributive share of factor $i$ in industry $j$.

Total differentiation of (4) and using (11) yield (see appendix for derivation):

$$\theta_{sj} \hat{w}_s + \theta_{uj} \hat{w}_u + \theta_{kj} \hat{r}_j = \hat{P}_j. \tag{12}$$

Eq. (12) shows that a change in price is an average of changes in factor returns weighted by their distributive shares in that industry.

Eqs. (9), (10) and (12) characterize the full model and can be solved simultaneously for equilibrium. Writing them in a matrix form:

$$\begin{bmatrix} -\sigma_{sk} & 0 & \sigma_{sk}^{1}\lambda_{s1} & \sigma_{sk}^{2}\lambda_{s2} & .. & \sigma_{sk}^{N}\lambda_{sN} \\ 0 & -\sigma_{uk} & \sigma_{uk}^{1}\lambda_{u1} & \sigma_{uk}^{2}\lambda_{u2} & .. & \sigma_{uk}^{N}\lambda_{uN} \\ \theta_{s1} & \theta_{u1} & \theta_{k1} & 0 & .. & 0 \\ \theta_{s2} & \theta_{u2} & 0 & \theta_{k2} & .. & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \theta_{sN} & \theta_{uN} & 0 & 0 & .. & \theta_{kN} \end{bmatrix} \begin{bmatrix} \hat{w}_s \\ \hat{w}_u \\ \hat{r}_1 \\ \hat{r}_2 \\ \vdots \\ \hat{r}_N \end{bmatrix} = \begin{bmatrix} \hat{S} \\ \hat{U} \\ \hat{P}_1 \\ \hat{P}_2 \\ \vdots \\ \hat{P}_N \end{bmatrix} \tag{13}$$

where $\sigma_{sk} = \sum_{j=1}^{N} \left( \sigma_{sk}^{j} \lambda_{sj} \right)$ and $\sigma_{uk} = \sum_{j=1}^{N} \left( \sigma_{uk}^{j} \lambda_{uj} \right)$ can be considered as the average elasticities of substitution weighted by the labor shares in each industry. Analytically, solutions for $\hat{w}_s$ and $\hat{w}_u$ are too complicated to do comparative statics. Yet the skill premium, $\left( \hat{w}_s - \hat{w}_u \right) / \hat{P}_i$, can be calculated and analyzed by calibrating the model with the estimates of the substitution elasticities.

## 3. Estimation of elasticity of substitutions between capital and two types of labor

Elasticity of substitution between capital and labor is one of the key elements in measuring factor returns and the skill premium in case of a change in the terms of trade. Intuitively, if capital and labor are substitutes, an increase in the rate of return on capital will cause the demand for labor to rise, whereas if they are complements, the demand for labor will fall, thus having an implication for the skill premium.

## 4. Empirical methodology

Suggested by Christensen, Jorgenson, and Lau (1973), we apply the approach of estimating elasticities based on translog cost[7] function by using a disaggregated industry level data for the U.S. which covers the period 1970–2014.The translog cost function is estimated for each industry. With three factors of capital, skilled and unskilled labor, the translog cost function is given by:

[7] Cost functions are more steady, if wages are exogenous. Due to optimizing behavior, cost functions display homogeneity of degree one in price. It advances measurements without making technological assumptions.

$$\ln C = \alpha_o + \sum_{i \in A} \alpha_i \ln P_i + \frac{1}{2} \sum_{i \in A} \sum_{j \in A} \gamma_{ij} \ln P_i \ln P_j + \alpha_y \ln Y + \frac{1}{2} \gamma_{yy} (\ln Y)^2 + \sum_{i \in A} \gamma_{iy} \ln P_i \ln Y \tag{14}$$

where $C$ represents total cost, $Y$ is output, $P_j$ is the price of factor $j$ , and $A = \{k, s, u\}$.

According to Shephard's Lemma, the cost minimizing demand for a factor can be derived through differentiation of the cost function with respect to its price. In case of the translog cost function this equals the cost share of factor $J$, $S_j$:

$$\frac{\partial \ln C}{\partial \ln P_j} = \frac{P_j}{C} \frac{\partial C}{\partial P_j} = \frac{P_j V_j}{C} = S_j. \tag{15}$$

$V_j$ measures the quantity of factor $j$. Monotonicity of the partial derivatives requires the LHS of (15) be positive. For the three factors, capital and two types of labor, differentiation of (14) with respect to $(\ln P_j)$ yields the following cost shares of factors:

$$S_i = \alpha_i + \sum_{j=k,s,u} \gamma_{ij} \ln P_j + \gamma_{iy} \ln Y + \varepsilon_i \tag{16}$$

The cost shares, by definition, sum up to 1, ie. $S_k + S_s + S_u = 1$. The equality of cross derivatives is assured through the imposition of the following symmetry:

$$\gamma_{ks} = \gamma_{sk}, \; \gamma_{ku} = \gamma_{uk}, \; \gamma_{us} = \gamma_{su}. \tag{17}$$

As the cost shares sum up to 1, only two of the three equations are independent. Linear homogeneity is imposed through the following conditions:

$$\sum_{i=s,k,u} \alpha_i = 1 \tag{18}$$

$$\sum_{i=s,k,u,y} \gamma_{ki} + \gamma_{si} + \gamma_{ui} = 0. \tag{19}$$

After the imposition of symmetry, equality (17), and constant returns to scale and implying that N-1 of the share equations in (16) are linearly independent, the two equations to be estimated are:

$$S_s = \alpha_s + \gamma_{ss} \ln \frac{P_s}{P_k} + \gamma_{su} \ln \frac{P_u}{P_k}. \tag{20}$$

$$S_u = \alpha_u + \gamma_{us} \ln \frac{P_s}{P_k} + \gamma_{uu} \ln \frac{P_u}{P_k}. \tag{21}$$

From the estimated coefficients of the system of Eqs. (20) and (21), Allen-Elasticities of substitution[8] can be obtained by:

$$\sigma_{ij} = \frac{\left(\gamma_{ij} + S_i S_j\right)}{\left(S_i S_j\right)}. \tag{22}$$

If the elasticity of substitution is positive then the factors are substitutes, if it is negative then the factors are compliments.

## 5. Data

To estimate the translog cost function, data on factor inputs, number of skilled workers, number of unskilled workers, amount of capital and their returns, and total output are required. Two different sources are used to compile the data set. BEA releases estimates on number of full time employees and compensation of employees in each industry. Compensation of employees is defined as the sum of employee wages and salaries and supplements to wages and salaries. BEA's Chain-type quantity indexes for net stock of private fixed assets which include equipment, software and structures are used for capital stock in each industry. The estimates provide measures of the value of assets in the prices of the given period, which are end of year for net stocks and annual averages for depreciation.[9] The index uses 2009 as the base year. Rental rates are calculated by dividing gross operating surplus by the net stock quantity index.[10] Gross operating surplus includes corporate profits, proprietor's income, rental income, net interest, private capital consumption allowances, business transfer payments, and government consumption of fixed capital. Gross product by industry is used as the measure of output.

[8] See Christev and Featherstone (2009) for a derivation of elasticity of substitution in translog cost functions.

[9] See BEA's Concepts and Methods of the US National Income and Product Accounts (2015) for detailed definitions and methodology to calculate indices.

[10] See Balistreri, McDaniel and Wong (2002).

**Table 1**
Summary statistics.

| INDUSTRY | $\lambda_{si}$ | $\lambda_{ui}$ | $\theta_{si}$ | $\theta_{u_i}$ | $\theta_{ki}$ |
|---|---|---|---|---|---|
| Farms | 0.009 | 0.021 | 0.057 | 0.118 | 0.825 |
| Construction* | 0.064 | 0.115 | 0.239 | 0.443 | 0.318 |
| Wood products | 0.006 | 0.015 | 0.233 | 0.477 | 0.290 |
| Nonmetallic mineral products | 0.006 | 0.013 | 0.257 | 0.430 | 0.313 |
| Primary metals | 0.008 | 0.018 | 0.258 | 0.461 | 0.281 |
| Fabricated metal products | 0.029 | 0.024 | 0.436 | 0.285 | 0.279 |
| Machinery | 0.035 | 0.029 | 0.427 | 0.289 | 0.284 |
| Motor vehicles, bodies and trailers, and parts | 0.013 | 0.019 | 0.283 | 0.372 | 0.345 |
| Furniture and related products | 0.005 | 0.012 | 0.244 | 0.537 | 0.219 |
| Food and beverage and tobacco products | 0.017 | 0.040 | 0.190 | 0.378 | 0.433 |
| Textile mills and textile product mills | 0.005 | 0.017 | 0.250 | 0.526 | 0.224 |
| Paper products | 0.007 | 0.013 | 0.245 | 0.382 | 0.374 |
| Petroleum and coal products | 0.003 | 0.002 | 0.195 | 0.164 | 0.641 |
| Chemicals products | 0.020 | 0.015 | 0.276 | 0.178 | 0.547 |
| Plastic and rubber products | 0.010 | 0.017 | 0.291 | 0.403 | 0.306 |
| Wholesale trade* | 0.102 | 0.090 | 0.373 | 0.302 | 0.325 |
| Retail trade* | 0.189 | 0.285 | 0.283 | 0.436 | 0.281 |
| Air transportation | 0.014 | 0.007 | 0.519 | 0.258 | 0.223 |
| Rail transportation | 0.004 | 0.007 | 0.265 | 0.429 | 0.306 |
| Water transportation | 0.002 | 0.003 | 0.262 | 0.343 | 0.395 |
| Pipeline transportation | 0.001 | 0.000 | 0.222 | 0.108 | 0.669 |
| Federal Reserve banks and credit intermediation | 0.055 | 0.030 | 0.324 | 0.151 | 0.525 |
| Insurance carriers and related activities | 0.050 | 0.022 | 0.434 | 0.187 | 0.379 |
| Real estate | 0.032 | 0.018 | 0.040 | 0.025 | 0.935 |
| Educational services* | 0.054 | 0.014 | 0.723 | 0.196 | 0.081 |
| Health care and social assistance* | 0.226 | 0.096 | 0.550 | 0.243 | 0.207 |
| Arts, entertainment, and recreation* | 0.021 | 0.017 | 0.298 | 0.331 | 0.371 |

* Represents two digit industries while the rest are three digit industries.

Educational attainment and annual earnings by education are derived from the Current Population Survey through the use of microdata at the Integrated Public Use Microdata Series – USA (IPUMS – USA) Database (Ruggles, 2015). Microdata is converted to industry level aggregate data to group workers as either skilled or unskilled according to their educational attainment. High school graduates, high school dropouts, and workers who have lower levels of education are classified as unskilled while workers with some college, associate, bachelors' or advanced degrees are classified as skilled labor.

The BEA dataset is compiled based on the 2007 NAICS code and merged with Current Population Survey data. It covers 6 two-digit and 21 3-digit non-overlapping industries from 1970 to 2014. Considering datasets exploited by the majority of the previous studies, data coverage is superior and sufficiently high to represent the economy as a whole. The industries in the data count for approximately 65% of GDP by private industries and 60% of the total labor force of private industries of the U.S. Economy. (Table 1) shows a summary of the data.

### 5.1. Estimation and calibration

The translog cost function and the system of cost share equations characterized by Eqs. (14), (20), and (21) form a system of multiple equations with cross-equation parameter restrictions (restrictions (17), (18), and (19)). This system is estimated for each industry using Zellner's[11] seemingly unrelated regressions (SUR) method. A time trend is added in the estimation to capture for productivity growth in each industry. Because the SUR estimates are not invariant to the

[11] See Zellner (1962).

dropped equation, by using iterative Zellner efficient method (ISUR) neutral parameter estimates are obtained. Seemingly Unrelated Regression is run for a system of 3 equations. There are 45 observations for each regression. All coefficients are significant at the 5% level.

All wages are scaled by the price of the specific capital in that industry to solve the problem of singularity of the disturbance covariance matrix of the cost share equations. Table 3 reports Im, Pesaran and Shin (IPS, Im, Pesaran & Shin, 2003), and the cross-sectionally augmented (CIPS, Peseran, 2007) type panel unit root tests. The tests are conducted including only constant as well as a constant and a deterministic trend. Table 3 shows that the null of unit root hypothesis could be rejected according to the IPS and the CIPS type panel unit root tests. It is, therefore, concluded that the series are stationary.

The estimated coefficients are used to calibrate the generalized multi-industry specific factors model. The matrix (13) composed of 29 equations (27 specific factors for each industry and 2 mobile factors) is inverted to solve for the general

**Table 2**
The Skill premium and substitution elasticities.

| INDUSTRY | $\hat{w}_s/\hat{P}_i$ | $\hat{w}_u/\hat{P}_i$ | $\frac{(\hat{w}_S - \hat{w}_S)}{\hat{P}_i}$ | $\lambda_s/\lambda_u$ | $\sigma^j_{sk}$ | $\sigma^j_{uk}$ | $\sigma^j_{us}$ |
|---|---|---|---|---|---|---|---|
| Farms | 0.036 | 0.038 | -0.003 | 0.42 | 1.32 | 0.81 | 1.04 |
| Construction* | 0.239 | 0.575 | -0.336 | 0.56 | 0.42 | 1.03 | -0.31 |
| Wood products | 0.023 | 0.054 | -0.031 | 0.37 | 0.41 | 0.66 | 0.85 |
| Nonmetallic mineral products | -0.006 | 0.032 | -0.038 | 0.48 | -0.18 | 0.63 | -0.44 |
| Primary metals | 0.003 | 0.032 | -0.030 | 0.43 | 0.01 | 0.36 | -3.08 |
| Fabricated metal products | 0.115 | 0.011 | 0.104 | 1.21 | 0.46 | -0.21 | -0.1 |
| Machinery | 0.173 | 0.070 | 0.103 | 1.21 | 0.58 | 0.12 | -0.27 |
| Motor vehicles, bodies and trailers, and parts | 0.003 | 0.013 | -0.010 | 0.70 | 0.02 | 0.16 | -2.68 |
| Furniture and related products | -0.014 | 0.051 | -0.065 | 0.38 | -0.35 | 0.75 | 0.24 |
| Food and beverage and tobacco products | -0.082 | 0.059 | -0.141 | 0.43 | -0.91 | 0.68 | -0.27 |
| Textile mills and textile product mills | -0.018 | 0.065 | -0.083 | 0.27 | -0.46 | 0.71 | 0.45 |
| Paper products | -0.032 | 0.025 | -0.057 | 0.55 | -0.72 | 0.73 | -0.21 |
| Petroleum and coal products | -0.002 | 0.003 | -0.005 | 1.24 | -0.17 | 0.79 | 0.16 |
| Chemicals products | 0.025 | 0.036 | -0.011 | 1.29 | 0.26 | 0.75 | -2.45 |
| Plastic and rubber products | -0.004 | 0.034 | -0.038 | 0.63 | -0.08 | 0.49 | -0.33 |
| Wholesale trade* | 0.247 | 0.225 | 0.022 | 1.14 | 0.31 | 0.4 | -0.35 |
| Retail trade* | -1.254 | 0.615 | -1.869 | 0.66 | -0.81 | 0.74 | 0.19 |
| Air transportation | 0.103 | 0.019 | 0.085 | 2.01 | 0.7 | -0.33 | -0.51 |
| Rail transportation | -0.031 | 0.004 | -0.036 | 0.54 | -1.06 | 0.45 | 0.48 |
| Water transportation | 0.002 | 0.004 | -0.002 | 0.70 | 0.14 | 0.33 | 0.05 |
| Pipeline transportation | 0.000 | -0.001 | 0.001 | 1.54 | 0.16 | -1.2 | -3.9 |
| Federal Reserve banks and credit intermediation | 0.230 | 0.037 | 0.194 | 1.84 | 0.92 | -0.46 | -1.5 |
| Insurance carriers and related activities | 0.171 | -0.060 | 0.231 | 2.26 | 0.56 | -1.45 | -0.96 |
| Real estate | 0.052 | 0.028 | 0.024 | 1.73 | 0.63 | 0.46 | -8.54 |
| Educational services* | 0.725 | -0.301 | 1.026 | 3.80 | 0.47 | -2.24 | -0.8 |
| Health care and social assistance* | 0.264 | -0.728 | 0.992 | 2.35 | 0.12 | -1.3 | -0.3 |
| Arts, entertainment, and recreation* | 0.033 | 0.059 | -0.026 | 1.18 | 0.22 | 0.78 | 0.12 |

* Represents two digit industries while the rest are three digit industries.

**Table 3**
Unit root tests.

| Variables | IPS | | CIPS | |
|---|---|---|---|---|
| | $\eta_\mu$ | $\eta_\mu$ | $\eta_\mu$ | $\eta_\tau$ |
| Value Added | -3.269*** | -1.557 | -2.176** | -2.588* |
| Return to Specific Factor | -2.092*** | -2.496*** | -2.328*** | -2.695** |
| Skilled Labor Wage | -1.807** | -2.802*** | -3.677*** | -4.047*** |
| Unskilled Labor Wage | -2.357*** | -3.527*** | -3.597*** | -4.306*** |
| Total Cost | -4.001*** | -1.436 | -2.082* | -2.424 |

Notes: $\eta_\mu$, $\eta_\tau$ are the two statistics for the null of stationarity around a constant and the null of stationarity around a constant and a deterministic trend, respectively.

* Indicates rejection of the unit root hypothesis at the 10%, significance level.
** Indicates rejection of the unit root hypothesis at the 5% significance level.
*** Indicates rejection of the unit root hypothesis at the 1% significance level.

**Table 4**
Factor Returns*.

| | | $\hat{S}$ | $\hat{U}$ | $\hat{P}_1$ | $\hat{P}_2$ | $\hat{P}_3$ | $\hat{P}_4$ | $\hat{P}_5$ | $\hat{P}_6$ |
|---|---|---|---|---|---|---|---|---|---|
| | $\hat{w}_s$ | -2.430 | -0.089 | 0.036 | 0.239 | 0.023 | -0.006 | 0.003 | 0.115 |
| | $\hat{w}_u$ | -0.754 | -1.368 | 0.038 | 0.575 | 0.054 | 0.032 | 0.032 | 0.011 |
| 1 | Farms | 0.276 | 0.201 | 1.204 | -0.098 | -0.009 | -0.004 | -0.005 | -0.010 |
| 2 | Construction* | 2.872 | 1.970 | -0.080 | 2.163 | -0.092 | -0.040 | -0.047 | -0.102 |
| 3 | Wood products | 3.190 | 2.321 | -0.091 | -1.137 | 3.340 | -0.048 | -0.055 | -0.111 |
| 4 | Nonmetallic mineral products | 3.026 | 1.948 | -0.081 | -0.984 | -0.093 | 3.152 | -0.047 | -0.110 |
| 5 | Primary metals | 3.471 | 2.328 | -0.095 | -1.163 | -0.109 | -0.047 | 3.505 | -0.125 |
| 6 | Fabricated metal products | 4.572 | 1.538 | -0.095 | -0.962 | -0.091 | -0.023 | -0.037 | 3.395 |
| 7 | Machinery | 4.427 | 1.530 | -0.092 | -0.946 | -0.089 | -0.023 | -0.037 | -0.185 |
| 8 | Motor vehicles, bodies and trailers, and parts | 2.809 | 1.548 | -0.070 | -0.816 | -0.077 | -0.029 | -0.037 | -0.107 |
| 9 | Furniture and related products | 4.570 | 3.461 | -0.133 | -1.680 | -0.158 | -0.072 | -0.082 | -0.157 |
| 10 | Food and beverage and tobacco products | 1.723 | 1.233 | -0.049 | -0.607 | -0.057 | -0.025 | -0.029 | -0.060 |
| 11 | Textile mills and textile product mills | 4.483 | 3.312 | -0.129 | -1.617 | -0.152 | -0.068 | -0.079 | -0.155 |
| 12 | Paper products | 2.362 | 1.456 | -0.062 | -0.744 | -0.070 | -0.029 | -0.035 | -0.087 |
| 13 | Petroleum and coal products | 0.933 | 0.376 | -0.021 | -0.220 | -0.021 | -0.006 | -0.009 | -0.038 |
| 14 | Chemicals products | 1.471 | 0.489 | -0.030 | -0.307 | -0.029 | -0.007 | -0.012 | -0.062 |
| 15 | Plastic and rubber products | 3.305 | 1.884 | -0.084 | -0.984 | -0.093 | -0.036 | -0.045 | -0.125 |
| 16 | Wholesale trade* | 3.494 | 1.374 | -0.076 | -0.809 | -0.076 | -0.023 | -0.033 | -0.143 |
| 17 | Retail trade* | 3.612 | 2.208 | -0.095 | -1.131 | -0.106 | -0.043 | -0.053 | -0.134 |
| 18 | Air transportation | 6.532 | 1.791 | -0.127 | -1.222 | -0.115 | -0.023 | -0.044 | -0.281 |
| 19 | Rail transportation | 3.164 | 1.998 | -0.084 | -1.014 | -0.095 | -0.040 | -0.048 | -0.116 |
| 20 | Water transportation | 2.266 | 1.247 | -0.057 | -0.658 | -0.062 | -0.024 | -0.030 | -0.086 |
| 21 | Pipeline transportation | 0.929 | 0.251 | -0.018 | -0.172 | -0.016 | -0.003 | -0.006 | -0.040 |
| 22 | Federal Reserve banks and credit intermediation | 1.719 | 0.449 | -0.033 | -0.313 | -0.030 | -0.005 | -0.011 | -0.074 |
| 23 | Insurance carriers and related activities | 3.151 | 0.777 | -0.059 | -0.557 | -0.053 | -0.009 | -0.019 | -0.137 |
| 24 | Real estate | 0.124 | 0.041 | -0.003 | -0.026 | -0.002 | -0.001 | -0.001 | -0.005 |
| 25 | Educational services* | 23.510 | 4.100 | -0.409 | -3.523 | -0.334 | -0.022 | -0.103 | -1.055 |
| 26 | Health care and social assistance* | 7.320 | 1.838 | -0.139 | -1.307 | -0.123 | -0.021 | -0.045 | -0.318 |
| 27 | Arts, entertainment, and recreation* | 2.626 | 1.290 | -0.063 | -0.704 | -0.066 | -0.024 | -0.031 | -0.103 |

| | | $\hat{P}_7$ | $\hat{P}_8$ | $\hat{P}_9$ | $\hat{P}_{10}$ | $\hat{P}_{11}$ | $\hat{P}_{12}$ | $\hat{P}_{13}$ | $\hat{P}_{14}$ |
|---|---|---|---|---|---|---|---|---|---|
| | $\hat{w}_s$ | 0.173 | 0.003 | -0.014 | -0.082 | -0.018 | -0.032 | -0.002 | 0.025 |
| | $\hat{w}_u$ | 0.070 | 0.013 | 0.051 | 0.059 | 0.065 | 0.025 | 0.003 | 0.036 |
| 1 | Farms | -0.022 | -0.002 | -0.006 | -0.003 | -0.008 | -0.001 | 0.000 | -0.007 |
| 2 | Construction* | -0.227 | -0.019 | -0.060 | -0.020 | -0.077 | -0.011 | -0.004 | -0.069 |
| 3 | Wood products | -0.254 | -0.023 | -0.072 | -0.031 | -0.092 | -0.015 | -0.004 | -0.079 |
| 4 | Nonmetallic mineral products | -0.237 | -0.019 | -0.058 | -0.013 | -0.074 | -0.008 | -0.003 | -0.070 |
| 5 | Primary metals | -0.273 | -0.023 | -0.070 | -0.021 | -0.090 | -0.011 | -0.004 | -0.082 |
| 6 | Fabricated metal products | -0.342 | -0.017 | -0.030 | 0.069 | -0.038 | 0.025 | -0.001 | -0.076 |
| 7 | Machinery | 3.194 | -0.017 | -0.031 | 0.064 | -0.039 | 0.023 | -0.001 | -0.074 |
| 8 | Motor vehicles, bodies and trailers, and parts | -0.217 | 2.884 | -0.043 | 0.004 | -0.055 | 0.000 | -0.002 | -0.059 |
| 9 | Furniture and related products | -0.365 | -0.034 | 4.467 | -0.053 | -0.139 | -0.025 | -0.007 | -0.116 |
| 10 | Food and beverage and tobacco products | -0.137 | -0.012 | -0.038 | 2.296 | -0.049 | -0.008 | -0.002 | -0.042 |
| 11 | Textile mills and textile product mills | -0.357 | -0.032 | -0.103 | -0.046 | 4.333 | -0.023 | -0.006 | -0.112 |
| 12 | Paper products | -0.185 | -0.015 | -0.043 | -0.006 | -0.054 | 2.672 | -0.002 | -0.053 |
| 13 | Petroleum and coal products | -0.071 | -0.004 | -0.009 | 0.010 | -0.011 | 0.003 | 1.560 | -0.017 |
| 14 | Chemicals products | -0.110 | -0.005 | -0.009 | 0.022 | -0.012 | 0.008 | 0.000 | 1.805 |
| 15 | Plastic and rubber products | -0.256 | -0.019 | -0.053 | 0.001 | -0.068 | -0.002 | -0.003 | -0.071 |
| 16 | Wholesale trade* | -0.264 | -0.015 | -0.031 | 0.040 | -0.040 | 0.014 | -0.001 | -0.062 |
| 17 | Retail trade* | -0.282 | -0.022 | -0.064 | -0.008 | -0.082 | -0.006 | -0.004 | -0.081 |
| 18 | Air transportation | -0.483 | -0.021 | -0.026 | 0.124 | -0.033 | 0.047 | 0.000 | -0.100 |
| 19 | Rail transportation | -0.248 | -0.020 | -0.059 | -0.011 | -0.075 | -0.007 | -0.003 | -0.072 |
| 20 | Water transportation | -0.175 | -0.013 | -0.035 | 0.003 | -0.044 | 0.000 | -0.002 | -0.048 |
| 21 | Pipeline transportation | -0.069 | -0.003 | -0.004 | 0.018 | -0.005 | 0.007 | 0.000 | -0.014 |
| 22 | Federal Reserve banks and credit intermediation | -0.127 | -0.005 | -0.006 | 0.034 | -0.008 | 0.013 | 0.000 | -0.026 |
| 23 | Insurance carriers and related activities | -0.232 | -0.009 | -0.009 | 0.065 | -0.011 | 0.025 | 0.000 | -0.046 |
| 24 | Real estate | -0.009 | 0.000 | -0.001 | 0.002 | -0.001 | 0.001 | 0.000 | -0.002 |
| 25 | Educational services* | -1.711 | -0.054 | 0.002 | 0.592 | 0.004 | 0.229 | 0.006 | -0.309 |
| 26 | Health care and social assistance* | -0.540 | -0.022 | -0.022 | 0.149 | -0.028 | 0.057 | 0.000 | -0.108 |
| 27 | Arts, entertainment, and recreation* | -0.201 | -0.013 | -0.034 | 0.014 | -0.043 | 0.004 | -0.002 | -0.052 |

| | | $\hat{P}_{15}$ | $\hat{P}_{16}$ | $\hat{P}_{17}$ | $\hat{P}_{18}$ | $\hat{P}_{19}$ | $\hat{P}_{20}$ | $\hat{P}_{21}$ | $\hat{P}_{22}$ |
|---|---|---|---|---|---|---|---|---|---|
| | $\hat{w}_s$ | -0.004 | 0.247 | -1.254 | 0.103 | -0.031 | 0.002 | 0.000 | 0.230 |
| | $\hat{w}_u$ | 0.034 | 0.225 | 0.615 | 0.019 | 0.004 | 0.004 | -0.001 | 0.037 |
| 1 | Farms | -0.005 | -0.049 | -0.001 | -0.010 | 0.002 | -0.001 | 0.000 | -0.021 |
| 2 | Construction* | -0.044 | -0.498 | 0.085 | -0.103 | 0.018 | -0.007 | 0.001 | -0.224 |

**Table 4** (*continued* )

| | | $\hat{P}_{15}$ | $\hat{P}_{16}$ | $\hat{P}_{17}$ | $\hat{P}_{18}$ | $\hat{P}_{19}$ | $\hat{P}_{20}$ | $\hat{P}_{21}$ | $\hat{P}_{22}$ |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Wood products | -0.053 | -0.568 | -0.005 | -0.113 | 0.018 | -0.008 | 0.001 | -0.245 |
| 4 | Nonmetallic mineral products | -0.043 | -0.511 | 0.185 | -0.110 | 0.020 | -0.007 | 0.001 | -0.239 |
| 5 | Primary metals | -0.052 | -0.596 | 0.143 | -0.125 | 0.022 | -0.008 | 0.001 | -0.272 |
| 6 | Fabricated metal products | -0.028 | -0.617 | 1.333 | -0.180 | 0.045 | -0.007 | 0.000 | -0.398 |
| 7 | Machinery | -0.028 | -0.602 | 1.261 | -0.174 | 0.043 | -0.007 | 0.000 | -0.384 |
| 8 | Motor vehicles, bodies and trailers, and parts | -0.033 | -0.446 | 0.367 | -0.105 | 0.021 | -0.006 | 0.001 | -0.229 |
| 9 | Furniture and related products | -0.079 | -0.829 | -0.109 | -0.161 | 0.025 | -0.011 | 0.002 | -0.348 |
| 10 | Food and beverage and tobacco products | -0.028 | -0.305 | 0.012 | -0.061 | 0.010 | -0.004 | 0.001 | -0.133 |
| 11 | Textile mills and textile product mills | -0.075 | -0.804 | -0.045 | -0.159 | 0.025 | -0.011 | 0.002 | -0.343 |
| 12 | Paper products | -0.032 | -0.392 | 0.193 | -0.087 | 0.016 | -0.005 | 0.001 | -0.188 |
| 13 | Petroleum and coal products | -0.007 | -0.133 | 0.225 | -0.036 | 0.008 | -0.002 | 0.000 | -0.080 |
| 14 | Chemicals products | -0.009 | -0.198 | 0.433 | -0.058 | 0.014 | -0.002 | 0.000 | -0.128 |
| 15 | Plastic and rubber products | 3.227 | -0.531 | 0.385 | -0.123 | 0.024 | -0.007 | 0.001 | -0.268 |
| 16 | Wholesale trade** | -0.027 | 2.586 | 0.870 | -0.136 | 0.032 | -0.006 | 0.000 | -0.299 |
| 17 | Retail trade* | -0.049 | -0.597 | 3.864 | -0.132 | 0.025 | -0.008 | 0.001 | -0.289 |
| 18 | Air transportation | -0.030 | -0.836 | 2.209 | 4.225 | 0.068 | -0.009 | 0.000 | -0.579 |
| 19 | Rail transportation | -0.044 | -0.530 | 0.223 | -0.115 | 3.292 | -0.007 | 0.001 | -0.251 |
| 20 | Water transportation | -0.027 | -0.359 | 0.297 | -0.084 | 0.017 | 2.527 | 0.001 | -0.185 |
| 21 | Pipeline transportation | -0.004 | -0.118 | 0.317 | -0.037 | 0.010 | -0.001 | 1.494 | -0.082 |
| 22 | Federal Reserve banks and credit intermediation | -0.007 | -0.218 | 0.598 | -0.069 | 0.018 | -0.002 | 0.000 | 1.753 |
| 23 | Insurance carriers and related activities | -0.012 | -0.394 | 1.131 | -0.127 | 0.034 | -0.004 | 0.000 | -0.282 |
| 24 | Real estate | -0.001 | -0.017 | 0.037 | -0.005 | 0.001 | 0.000 | 0.000 | -0.011 |
| 25 | Educational services* | -0.044 | -2.749 | 9.709 | -0.965 | 0.270 | -0.026 | 0.000 | -2.145 |
| 26 | Health care and social assistance* | -0.029 | -0.918 | 2.602 | -0.295 | 0.078 | -0.009 | 0.000 | -0.653 |
| 27 | Arts, entertainment, and recreation* | -0.027 | -0.399 | 0.461 | -0.099 | 0.021 | -0.005 | 0.001 | -0.218 |

| | | $\hat{P}_{23}$ | $\hat{P}_{24}$ | $\hat{P}_{25}$ | $\hat{P}_{26}$ | $\hat{P}_{27}$ |
|---|---|---|---|---|---|---|
| | $\hat{w}_s$ | 0.171 | 0.052 | 0.725 | 0.264 | 0.033 |
| | $\hat{w}_u$ | -0.060 | 0.028 | -0.301 | -0.728 | 0.059 |
| 1 | Farms | -0.003 | -0.008 | -0.007 | 0.085 | -0.011 |
| 2 | Construction* | -0.045 | -0.079 | -0.126 | 0.814 | -0.107 |
| 3 | Wood products | -0.039 | -0.089 | -0.088 | 0.985 | -0.124 |
| 4 | Nonmetallic mineral products | -0.059 | -0.082 | -0.183 | 0.781 | -0.108 |
| 5 | Primary metals | -0.059 | -0.095 | -0.173 | 0.952 | -0.127 |
| 6 | Fabricated metal products | -0.207 | -0.111 | -0.827 | 0.331 | -0.112 |
| 7 | Machinery | -0.197 | -0.108 | -0.785 | 0.345 | -0.110 |
| 8 | Motor vehicles, bodies and trailers, and parts | -0.076 | -0.074 | -0.272 | 0.568 | -0.091 |
| 9 | Furniture and related products | -0.045 | -0.128 | -0.072 | 1.493 | -0.182 |
| 10 | Food and beverage and tobacco products | -0.023 | -0.048 | -0.055 | 0.520 | -0.066 |
| 11 | Textile mills and textile product mills | -0.051 | -0.125 | -0.103 | 1.414 | -0.176 |
| 12 | Paper products | -0.051 | -0.063 | -0.168 | 0.570 | -0.082 |
| 13 | Petroleum and coal products | -0.037 | -0.023 | -0.144 | 0.105 | -0.025 |
| 14 | Chemicals products | -0.067 | -0.036 | -0.268 | 0.103 | -0.036 |
| 15 | Plastic and rubber products | -0.085 | -0.087 | -0.295 | 0.706 | -0.109 |
| 16 | Wholesale trade* | -0.141 | -0.087 | -0.554 | 0.373 | -0.093 |
| 17 | Retail trade* | -0.080 | -0.097 | -0.264 | 0.861 | -0.125 |
| 18 | Air transportation | -0.330 | -0.155 | -1.341 | 0.227 | -0.145 |
| 19 | Rail transportation | -0.065 | -0.085 | -0.206 | 0.793 | -0.111 |
| 20 | Water transportation | -0.062 | -0.059 | -0.220 | 0.457 | -0.073 |
| 21 | Pipeline transportation | -0.047 | -0.022 | -0.192 | 0.030 | -0.020 |
| 22 | Federal Reserve banks and credit intermediation | -0.089 | -0.041 | -0.362 | 0.046 | -0.037 |
| 23 | Insurance carriers and related activities | 2.471 | -0.074 | -0.681 | 0.057 | -0.067 |
| 24 | Real estate | -0.006 | 1.067 | -0.023 | 0.008 | -0.003 |
| 25 | Educational services* | -1.386 | -0.537 | 6.595 | -0.598 | -0.436 |
| 26 | Health care and social assistance* | -0.384 | -0.172 | -1.569 | 4.973 | -0.156 |
| 27 | Arts, entertainment, and recreation* | -0.085 | -0.067 | -0.316 | 0.436 | 2.616 |

* Table 4 shows the ripple effects of a 1% price increase in one industry on the returns of the factors of other industries.

equilibrium. Table 2 shows the summary of the data with elasticities of substitution of factor inputs in all industries. All consistency checks to see if the calibrated model well behaves hold and support the calibration.[12]

## 6. Results

The solution obtained is rich enough to do all comparative statics of interest. The effect of terms of trade changes in each industry on the wages of skilled and unskilled workers is reported in the appendix (Table 4). One of the main differences of these results compared to the ones in the literature is that Table 4 shows the percentage change in skill and unskilled wage not just in one industry but in the entire economy when a price of good *j* increases by 1%. For example, if prices in furniture and related products industry increase by 1% then the wage of skilled labor in all industries decreases by 0.014% and the wage of unskilled labor in all industries increases by 0.051%. The effect of terms of trade on wages seems to be very small, contrary to what Stolper-Samuelson theorem argues. Stolper Samuelson Theorem implies an even higher effect on wages than 1%, when price changes by 1% which is known as the magnification effect.[13] This is due to aggregating all industries to 2 single industries and lumping all the effects together into a single parameter. The methodology used here allows one to evaluate this aggregation problem.

To test the validity of Stolper Samuelson's magnification effect under aggregation, all prices in skill intensive industries are raised by 1% and as a result skilled wage rises by 2.13% and unskilled wage decreases by 0.60%. Similarly, when all prices in unskill intensive industries increase by 1%, skilled wage decreases by 1.13% and unskilled wage increases by 1.6%, which is consistent with the magnification effect.

These results have two important implications. First, to generate a Stolper-Samuelson magnification effect, it is necessary to have a large number of price changes across industries intensive in either skilled or unskilled labor. This may explain most of the debate in the literature on the validity of the Stolper Samuelson theorem. The results show that when price increases in an industry, the return to the specific factor in that industry increases by an increased amount, suggesting a magnification effect within that industry, but specific factors in all other industries change only a fractional amount. It is shown that other than the specific factor in the corresponding industry, factor returns do not show a magnification effect.

The second implication is that the Stolper-Samuelson theorem may be seriously plagued by an aggregation problem (Leontief, 1947; Fisher & Monz, 1992). Suppose a country is abundant in unskilled labor, and begins to liberalize its trade. All of the products that it exports will not necessarily face higher prices; some prices may go down. Moreover, prices of some skill-intensive goods will be rising as well, not because of the liberalizing of trade but because of other factors going on at the same time. Therefore, it may be asking too much to expect that the liberalization of trade will raise the price of the abundant factor relative to the scarce factor in a multi-commodity environment. The studies that show that Stolper-Samuelson theorem fails in many instances therefore are not really critical tests of the theorem simply because the aggregation conditions may not be satisfied.

In this context, it is helpful to analyze the labor endowments. As an important aspect of the model is that it is easy to see the effect of changes in factor endowments on factor returns. Fixed labor endowments can be seen as a sensible assumption since the entire labor force is being analyzed in the model. Yet in case of a migration or changing the composition of labor force from unskilled to skilled, the effect on factor returns can be found. In response to a 1% increase in labor endowment shows that factor returns are changing by a magnified amount. Such an increase is similar in effect to a price change in all industries and therefore it is normal to have a magnification effect in all industries. The effects of such changes are also reported in Table 4.

The results show that substitution elasticities of skilled and unskilled labor with respect to capital are critical in explaining how the returns of other factors are changing when a single price changes. Results show that whether the skilled labor or unskilled labor benefits or loses due to price changes depends on the elasticity of substitutions between capital and skilled and unskilled labor. Both skilled and unskilled labor benefits from a price increase in industries such as farms, construction, and wood products that have positive elasticity of substitution between capital and both skilled and unskilled labor. This shows that if capital and both labor types are substitutes, they both gain from price increases. On the other hand, in industries such as nonmetallic mineral products, furniture and related products, and paper products, where the elasticity of substitution is negative between capital and skilled labor, suggesting complementarity, and positive between capital and unskilled labor, suggesting substitutability, skilled labor loses and unskilled labor gains as a result of a price increase. As a matter of fact, data shows that there are 11 industries that have positive elasticity of substitution capital and both labor types. In all these 11 industries, both labor types gain in response to a price increase. 9 industries have a negative elasticity of substitution between capital and skilled labor while having a positive elasticity of substitution between capital and unskilled labor. Skilled labor loses and unskilled labor gains in response to a price increase in all these 9 industries. These results show the critical role elasticity of substitution between factor inputs play in factor returns. It should be noted that the results do not show an effect of the elasticity of substitution between skilled labor and unskilled labor in factor returns.

[12] Theoretically, if all prices go up by 1% then both wages should rise by 1%. If labor endowments increase, then returns of all specific factors should decrease.

[13] See Thompson (1993) for thirteen magnification effects in a $3 \times 2$ setting.

Moreover, the general equilibrium model stated here allows one to see the ripple effect of a price change on the return of each and every factor input even without assuming trade. For any reason, if a price of good $i$ increases, what happens to the return of specific factor of good $j$ and wages can be obtained by solving the system (13) for that variable. In the standard specific factors model the rate of return in other industries must fall as one industry expands because they have to pay more for the mobile factor. There are, however, many cases in which the rate of return in industries that compete for mobile factors may actually rise presumably because they intensively use the mobile factor whose price goes down. For example, if price in paper products industry increases then the wages of unskilled labor and the return to the specific capital in paper products industry increase while the wages of skilled labor decreases. Consequently, industries that are highly skilled labor intensive such as educational services and healthcare and social assistance benefit from this decrease in skilled wages and the returns to the specific capitals in those industries increase. Similarly, when the price in health care and social assistance industry increases, return to specific capital in almost all industries that are unskilled intensive increase as well. These estimated effects may also be highly useful in evaluating the tax and tariff policy effects on the industry outcomes. Say, if the government imposes a 1% tax on primary metals, the return of the specific capital in machinery industry decreases by 0.037%.

## 7. Conclusion

The skill premium has been studied in many different contexts and researchers have drawn different conclusions in regards to what the underlying reasons are. Theoretically, majority of the studies use the Heckscher–Ohlin Model, which uses two industries only and has additional restrictive assumptions. Alternatively, this paper employs the specific factors model to exploit substitution elasticities in determining the general equilibrium. This paper appears to be the first application of the specific factors model to the study of the relative wages of skilled and unskilled workers by considering a multi-industry model with those two types of labor as the only mobile factors. To make the model operational, substitution elasticities between capital and two types of mobile labor, skilled and unskilled labor, are estimated using a translog cost function for 27 U.S. industries. Then the model is calibrated by those estimates and solved for a general equilibrium.

It is shown that for changes in price of a single industry, the impact on the skill premium is usually quite modest and sometimes the sign is the reverse of expectations. It is necessary to have a large number of price changes across industries to generate a Stolper-Samuelson magnification effect. This indicates how much valuable information is lost when industries are aggregated. In contrast to what the standard H–O Model predicts, in a large number of industries, both skilled and unskilled wages rise in response to an increase in commodity prices. With all substitution elasticities and labor shares playing a role, it is not straightforward, as in the two industry case, to predict changes in factor prices without solving for the general equilibrium. The results suggest that further research with even more disaggregation of labor in terms of skill levels or industry level may provide valuable insights in understanding the skill premium and the role elasticity of substitution between factor inputs play.

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