The Stolper-Samuelson Theorem when the Labor Market Structure Matters

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1 Introduction

The Stolper-Samuelson theorem is a key result of the classical trade literature. Nevertheless, this theoretical argument does not provide a sufficient explanation for either historical or modern evidence on the dynamics of relative wages following a trade liberalization; see [Lawrence and Lawrence, 2010] and [Haskel et al., 2012]. In particular, the increase in wage inequality for developing countries opening to trade is a robust finding, see Goldberg, Koujianou, and Pavcnik (2007), that can hardly be reconciled with the theoretical predictions of the theorem.

Frictions in the labor market weaken the link between relative prices, relative wages and relative productivity, that is at the basis of the theorem. The reason is that firms yield vacancies and then, conditionally on productivity, they offer a wage that is increasing in the probability of finding a worker in the market who can fill the vacant position. Building on the notion that firm-worker matches are relatively harder to find in some sectors, [Davidson et al., 1999] extend the classical results on gains from trade to a framework in which unemployment arises in equilibrium. They show that a generalized version of the Stolper-Samuelson theorem holds even in that scenario. Our framework is closely related to this seminal
work. The main difference is that we allow for endogenous changes in the tightness of factor markets; following [Mortensen and Pissarides, 1994] and [Mortensen and Pissarides, 1999]. Thanks to this contribution, our framework assesses the link between trade, factor market tightness and relative factor prices.

In this paper, we argue that the theoretical prediction of the Stolper and Samuelson theorem [Stolper and Samelson, 1941] can be reversed when factor specific labor market structures are considered. The motivation for this channel is based on a recent survey by [Hall and Krueger, 2012], in which the authors document how blue collar workers are less likely to bargain on wages compared to skilled workers. The mechanism we describe is based on the assumption that skilled workers have a higher bargaining power than workers with lower skills. We analyze a trade shock that rises the price of no-skill intensive goods relative to skill-intensive goods. Production in both sectors employs both factors, although in different proportions. Then vacancies are distributed in job offers for skilled workers and job offers for unskilled workers. At the same time, more unemployed workers (skilled and unskilled) search in the unskilled intensive sector and fewer unemployed workers search in the skill-intensive sector. If the ratio of vacancies over job applications (labor market tightness) for skilled workers increases then the skill premium will also increase.

The approach we suggest extends the Stolper-Samuelson theorem in a direction that is consistent with the evidence on trade liberalizations by focusing on a channel that is well established in the theory of labor markets and for which there is evidence in the data.

2 Model

There are two countries home $H$ and foreign $F$. Each economy consists of two sectors, producing a skill intensive good $S$ and a no-skill intensive
good $N$. Each country is populated by two types of agents, labor workers and knowledge workers. Workers are endowed each period with one indivisible unit of time that can be rent as labor $L$ or knowledge $K$, according to the worker type. Both factors are mobile across sectors and internationally immobile.

Agents allocate consumption between the two goods according to C.E.S. preferences. The representative consumer maximizes the utility:

\[ X = \left[ S^{\frac{\sigma-1}{\sigma}} + N^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad \sigma \geq 0 \quad (1) \]

where $\sigma$ is the elasticity of substitution across goods. A representative firm in sector $Y = \{S, N\}$ employs both factors to produce output with a C.E.S. technology:

\[ Y = \left[ \lambda_Y L_Y^{\frac{\tau-1}{\tau}} + \kappa_Y K_Y^{\frac{\tau-1}{\tau}} \right]^{\frac{\tau}{\tau-1}} \quad \tau \geq 1 \quad \lambda_Y, \kappa_Y > 0 \quad \lambda_Y + \kappa_Y = 1 \quad (2) \]

where $\tau$ is the elasticity of technical substitution across factors. We assume that $\lambda_N > \lambda_S$ and $\kappa_N < \kappa_S$.

Time is continuous. Agents are infinitely lived and risk neutral. Each period workers are either employed or unemployed. In each period $u_L$ production workers are unemployed and the residual $L - u_L$ are employed. The same is true for $u_K$ and $K - u_K$ knowledge workers respectively. When employed, workers receive a wage $w$ as a remuneration for one unit of labor or a rate of return $r$ for one unit of knowledge. When unemployed, workers search for a job, sending one job application.

The representative firms in the two sectors are infinitely lived and risk neutral. They hire workers by posting wage offers. The factor market is segmented by skill. There is a market for labor and a market for knowledge; such that firms specify the type of factor they search for. In each period the demand side of the two factor markets consists of $v_L$ and $v_K$ vacancies, respectively. The job applications from unemployed labor workers $u_L$ and knowledge workers $u_K$ represent the supply side of the two segments of the factor market.

3
Within each segment of the factor market, workers who search and firms
who hold a vacant job match randomly according to a Cobb-Douglas technol-
ogy; such that the number of matches in a period is $\epsilon u^\alpha f v^{1-\alpha}$ where $f = L, K$
identifies the type of factor, $\alpha \in (0,1)$ and $\epsilon > 0$ parametrize the response
to unemployment and the efficiency of matching. Let $m_f$ be the probability
that a worker of type $f = \{L, K\}$ matches with a firm in a given period and
let $h_f$ be the probability that a firm hires a workers of type $f = \{L, K\}$ in a
given period. They are respectively an increasing and a decreasing function
of the labor market tightness $\theta_f = v_f/u_f$:

$$m_f = \epsilon \theta_f^\alpha, \quad h_f = \epsilon \theta_f^{\alpha-1} \quad (3)$$

There are matching frictions in the labor market, such that $m_f, h_f \in (0,1)$
in every period. Moreover, searching is costly on the firm side: holding a
vacancy has a cost $\gamma > 0$ per period. For notational convenience, in what
follows we discuss one segment of the factor market and we drop the factor
subscript $f = \{L, K\}$ and the sector subscript $Y = \{S, N\}$ when they are
not necessary.

Existing matches separate because of an exogenous destruction shock that
occurs with arrival rate $\delta > 0$. When this shock occurs an employed worker
becomes unemployed and a filled job turns into a vacant job. Let $E(w)$ and
$U$ be the asset values for a worker of being employed at a wage $w$ and being
unemployed, respectively. Workers and firms discount future at a rate $\varrho > 0$.
The flow value of employment $\varrho E(w)$ is given by the wage $w$, (current value),
plus the value of a change in the agent’s status $[U - E(w)]$, (capital gain),
that occurs with probability $\delta$. The current value of unemployment consists
of the benefit workers enjoy from leisure $b$ whereas with probability $m$ an
unemployed worker becomes employed. The flow values that characterize
the supply side of the labor market are:

$$\varrho E(w) = w + \delta [U - E(w)], \quad \varrho U = b + m(\theta) [E(w) - U] \quad (4)$$

Firms value the match with each worker as if she was providing the marginal
unit of labor, or knowledge. Let \( J(\pi) \) be the value of a filled job when the profit on the marginal unit of factor is \( \pi \) and let the value of a vacancy be \( V \). The flow value of a job of the labor type for the representative firm in sector \( \{S, N\} \) consists of the revenue associated to the marginal unit of labor in one of the two sectors \( y_L = \{y_{LS}, y_{LN}\} \) minus the wage \( w \), then \( \pi = y_L - w \). The continuation value accounts for the effect of a destruction of the match, that occurs with probability \( \delta \) and replaces a filled job with a vacant job. The current value of a vacant job is the cost of holding a vacancy for the current period \( -\gamma \). Whereas, the continuation value consists of the net gain of filling a vacant job \( [J(\pi) - V] \) which occurs with probability \( h \). The flow values that characterize the demand side of the labor market are:

\[
\varrho J(\pi) = \pi + \delta [V - J(\pi)] \quad , \quad \varrho V = -\gamma + h(\theta) [J(w) - V]
\]

Equations (4) and (5) characterize the labor market. A similar pair of conditions characterizes the market for knowledge workers, where the wage is replaced by the return on knowledge \( r \) and the value of a match accounts for revenue due to the marginal unit of knowledge: \( y_K = \{y_{KS}, y_{KN}\} \).

The determination of wage and rate of return on knowledge is the equilibrium outcome of a bargaining process. Firms bargain with each worker on the total surplus of the match as she was the marginal worker. The value of a match for the firm is \( J \), for the worker is \( E \). The outside option is the value of a vacancy \( V \), for a firm and the value of being unemployed \( U \) for the worker. Both parties do not commit to match in future periods. Under this scenario, [Stole and Zwiebel, 1996] show that the equilibrium wage and rate of returns are the unique solutions to the following bargaining rules:

\[
\mu_L [J(\pi_L) - V_L] = (1 - \mu_L) [E(w) - U_L] \quad , \quad \mu_L \in (0, 1) \tag{6}
\]

\[
\mu_K [J(\pi_K) - V_K] = (1 - \mu_K) [E(r) - U_K] \quad , \quad \mu_K \in (0, 1)
\]

where \( \pi_L = y_L - w, \pi_K = y_K - r \) and we are assuming that knowledge workers have a higher bargaining power than labor workers: \( 0 < \mu_L < \mu_K < 1 \).
2.1 Equilibrium in autarky

The equilibrium of the output market consists of quantities of consumption \( \{S, N\} \) and prices \( \{p_S, p_N\} \) such that the representative consumer maximizes utility subject to the budget constraint and the representative firms maximize profit subject to the technological constraint.

In the derivation of the equilibrium, we assume that each sector is populated by an arbitrary large number of firms, employing one worker each. A representative firm in each sector produces the aggregate supply of output, with demand elasticity to price that is equal to the elasticity of substitution and without monopsony power in the factor market. Therefore, the model does not address firm heterogeneity within sector and it is silent on the number of firms. This framework is consistent with the relevant literature, see Davidson et al. (1999).

The representative consumer maximizes utility (1) over consumption of goods \( S \) and \( N \) subject to the budget constraint \( p_S S + p_N N = I \); given the price of the two goods \( p_S, p_N \) and given the income \( I \). Let the price be \( P = \left( p_S^{1-\sigma} + p_N^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \), then the residual demand functions are:

\[
S = X \left( \frac{p_S}{P} \right)^{-\sigma}, \quad N = X \left( \frac{p_N}{P} \right)^{-\sigma}
\]  

(7)

where the demand shifter is \( X = I/P \) and it coincides with the indirect utility. Therefore, we consider \( X \) as the measure of welfare in the economy.

In each sector the representative firm minimizes the cost \( wL_Y + rK_Y \) for a target level of output \( Y \). Representative firms do not have monopsony power on factor prices. As a consequence, firms demand labor and knowledge such that the ratio in factor prices is equal to the marginal rate of technical substitution: \( w/r = \lambda_Y/k_Y (K_Y/L_Y)^\tau \), in both sectors \( Y = \{S, N\} \). Deriving the cost function yields the average cost, equal to the marginal cost of production:

\[
c_Y (w, r) = \left[ \lambda_Y w^{1-\tau} + \kappa_Y r^{1-\tau} \right]^{\frac{1}{1-\tau}}
\]  

(8)
The optimal factor demand functions are $L_Y = [\lambda_Y c_Y (w, r)/w]^{\tau} Y$ and $K_Y = [\kappa_Y c_Y (w, r)/r]^{\tau} Y$. The marginal productivities of labor and knowledge are respectively $\lambda_Y (Y/L_Y)^{1/\tau} = w/c_Y (w, r)$ and $\kappa_Y (Y/K_Y)^{1/\tau} = r/c_Y (w, r)$. In both sectors, profit maximizing firms set the price such that the marginal revenue $(\sigma - 1)/\sigma p_Y$ is equal to the marginal cost $c_Y (w, r)$. This equilibrium condition gives the pricing rule:

$$p_Y = \frac{\sigma c_Y (w, r)}{\sigma - 1}$$  (9)

The income of the representative consumer is given by the sum of factor rewards of employed workers plus total profit in the two sectors $\Pi$:

$$I = w (L_S + L_N) + r (K_S + K_N) + \Pi = c_S (w, r) S + c_N (w, r) N + \Pi$$  (10)

where $L_Y$ and $K_Y$ for $Y = \{S, N\}$ are the factor demand functions. Equations (7)-(10) characterize the unique equilibrium of the output market in autarky, for a given level of total profit $\Pi$.

The equilibrium of the factor market consists of factor prices $\{w, r\}$, labor market tightness $\{\theta_L, \theta_K\}$ and unemployment rates $\{u_L, u_K\}$ in the two segments of the factor market.

Firms have an incentive to employ factors as long as the value of the marginal job is positive and it is strictly higher than the value of holding a vacancy. If there is an unbounded mass of workers searching for a job then the value of holding the marginal vacancy has to be zero. The free entry condition $J(\pi) > V = 0$ applies to both factor markets. Combining the free entry condition with the value of a job (5) yields the job creation condition:

$$\frac{\gamma}{h(\theta_L)} = \frac{y_L - w}{\delta + \varrho}, \quad \frac{\gamma}{h(\theta_K)} = \frac{y_K - r}{\delta + \varrho}$$  (11)

Combining the free entry condition with the bargaining rule (6) yields the wage equation:

$$w = \mu_L (y_L + \gamma \theta_L) + (1 - \mu_L) b$$

$$r = \mu_K (y_K + \gamma \theta_K) + (1 - \mu_K) b$$  (12)
Hereafter let the value of leisure be zero \( b = 0 \), without loss of generality for our research question.

The system of (11) and (12) yields the pairs of factor prices and labor market tightness. Factor market clearing determines the number of unemployed workers of both types:

\[
\begin{align*}
    u_L &= L - L_S - L_N, \\
    u_K &= K - K_S - K_N
\end{align*}
\]  

(13)

where as before, \( L_Y \) and \( K_Y \) for \( Y = \{S, N\} \) are the factor demand functions. Equations (11)-(13) characterize the equilibrium of the labor market, for a given pair of revenues associated to the marginal worker \( \{y_L, y_K\} \).

The channels that link the output market and factor market goes through aggregate profit \( \Pi \) and the pair of marginal revenues \( \{y_L, y_K\} \). As a consequence of the pricing rule (9), the values of the marginal productivity of labor \( y_L \) and knowledge \( y_K \) are proportional to factor rewards:

\[
\begin{align*}
    y_L &= \frac{\sigma w}{\sigma - 1}, \\
    y_K &= \frac{\sigma r}{\sigma - 1}
\end{align*}
\]

(14)

therefore, they do not depend on the sector in which the factor is employed. Total profit is given by revenue minus total cost due to production, minus the cost of vacancy posting:

\[
\Pi = \frac{c_S(w, r)}{\sigma - 1} S + \frac{c_N(w, r)}{\sigma - 1} N - \gamma (v_L + v_K)
\]

(15)

where the total number of vacancies is obtained inverting the definition of labor market tightness \( (v_L + v_K) = \theta_L u_L + \theta_K u_K \).

### 2.2 Factor price premium

In autarky, the system of job creation (11) and wage equation (12), when the marginal values (14) are understood, yields the ratio in labor market tightness and the premium for knowledge:

\[
\begin{align*}
    \frac{\theta_K}{\theta_L} &= \left( \frac{(\sigma - 1) - \sigma \mu_K}{(\sigma - 1) - \sigma \mu_L} \right)^{\frac{1}{2}}, \\
    \frac{r}{w} &= \frac{\mu_K}{\mu_L} \left( \frac{\theta_K}{\theta_L} \right)^{1 - \alpha}
\end{align*}
\]

(16)
3 Equilibrium with international trade

Opening to trade, we assume that the domestic economy is small in the international market and it specializes in the production and export of no-skill intensive goods. Skill intensive goods are exported by the foreign country, which has the same technology and preferences than the domestic country, but it differs in terms of relative factor endowments \( \frac{K}{L} \neq \frac{K^*_f}{L^*_f} \); hereafter variables with a star refers to the foreign economy.

The unit cost of the skill intensive goods in the foreign country is \( \varphi \in (0, 1] \times \) lower than in the domestic economy \( c_S (w^*_S, r^*_S) = \varphi c_S (w_S, r_S) \), relative to the unit cost of no-skill intensive goods \( c_N (w^*_N, r^*_N) = c_N (w_N, r_N) \); where \( w_Y \) and \( r_Y \) are wage and return on knowledge when the two factors are employed in sector \( Y = \{S, N\} \). In an integrated equilibrium, goods are traded in the international market at the terms of trade of the foreign (large) economy \( \frac{p^*_S}{p^*_N} < \varphi \frac{p_S}{p_N} \). The value \( \varphi \) parametrizes the change in the relative price from autarky \( \varphi = 1 \) to an integrated equilibrium \( 0 < \varphi < 1 \).

As long as both goods are produced in both economies there will be four values of marginal revenue in the domestic country:

\[
\begin{align*}
\eta_{SL} &= \frac{\varphi \sigma w_S}{\sigma - 1}, \quad \eta_{SK} = \frac{\varphi \sigma r_S}{\sigma - 1} \\
\eta_{NL} &= \frac{\sigma w_N}{\sigma - 1}, \quad \eta_{NK} = \frac{\sigma r_N}{\sigma - 1}
\end{align*}
\]

Substituting the hiring rates from (3) and the marginal values (17) in (11) yield the job creation conditions in open economy become:

\[
\begin{align*}
w_S &= \frac{(\sigma - 1)(\delta + \varphi \sigma - (\sigma - 1))}{\varphi \sigma - (\sigma - 1)} \frac{\gamma}{\epsilon} \hat{\theta}_L^{1-\alpha}, \quad r_S = \frac{(\sigma - 1)(\delta + \varphi \sigma - (\sigma - 1))}{\varphi \sigma - (\sigma - 1)} \frac{\gamma}{\epsilon} \hat{\theta}_K^{1-\alpha} \\
w_N &= \frac{(\sigma - 1)(\delta + \varphi \sigma - (\sigma - 1))}{\varphi \sigma - (\sigma - 1)} \frac{\gamma}{\epsilon} \hat{\theta}_L^{1-\alpha}, \quad r_N = \frac{(\sigma - 1)(\delta + \varphi \sigma - (\sigma - 1))}{\varphi \sigma - (\sigma - 1)} \frac{\gamma}{\epsilon} \hat{\theta}_K^{1-\alpha}
\end{align*}
\]

where \( \hat{\theta}_f \) identifies the (endogenous) labor market tightness for the factor \( f = \{L, K\} \). Substituting the marginal values (17) in (12) yields the wage equations in open economy:

\[
\begin{align*}
w_S &= \frac{(\sigma - 1)\mu_L}{\sigma - 1 - \varphi \sigma \mu_L} \hat{\theta}_L, \quad r_S = \frac{(\sigma - 1)\mu_K}{\sigma - 1 - \varphi \sigma \mu_K} \hat{\theta}_K
\end{align*}
\]
\[ w_N = \frac{(\sigma - 1) \mu_L \hat{\theta}_L}{(\sigma - 1) - \sigma \mu_L}, \quad r_N = \frac{(\sigma - 1) \mu_K \hat{\theta}_K}{(\sigma - 1) - \sigma \mu_K} \]

The four systems (18) and (19) characterize the open economy equilibrium. Figure (1) shows the change in the market tightness for labor and wage in the import sector, from autarky (point A, \( \varphi = 1 \)) to a trade equilibrium (point T, \( \varphi < 1 \)).

\[ \text{Figure 1: Opening to trade.} \]

The job creation condition defines a wage as an increasing concave function of labor market tightness, whereas the wage equation (19) is a straight line. There exists one non trivial equilibrium. When the economy opens to trade (a decrease in the terms of trade \( \varphi \)) the two curves identifies a new equilibrium with higher wage in the import sector and a tighter labor market.

Before approaching the discussion of the premium in factor prices, the set of factor prices (19) is sufficient to derive two implications of the open economy equilibrium.

**Proposition 1.** *Opening the economy, the same type of worker will be better
off in the export sector: \( \frac{w_S}{w_N} < 1 \) and \( \frac{r_S}{r_N} < 1 \).

Proof. From equations (19), wage \( w_S \) and return on knowledge \( r_S \) are increasing in the price gap \( \varphi \). In autarky, \( \varphi = 1 \) then \( w_S = w_N \) and \( r_S = r_N \). When the economy opens to trade \( \varphi \in (0, 1) \) then \( w_S < w = w_N \) and \( r_S < r = r_N \).

**Proposition 2.** If the import sector uses intensively the factor with higher bargaining power (\( \varphi \in (0, 1) \) and \( \mu_K > \mu_L \)) then, opening the economy, the relative price of the factor with higher bargaining power is higher in the export sector than in the import sector: \( \frac{r_S}{w_S} < \frac{r_N}{w_N} \).

Proof. The relative price for knowledge workers in the two sectors of the domestic economy, exporting no-skill intensive goods, are:

\[
\frac{r_S}{w_S} = \frac{(\sigma - 1) - \varphi \sigma \mu_L \mu_K \dot{\theta}_K}{(\sigma - 1) - \varphi \sigma \mu_K \mu_L \dot{\theta}_L} \\
\frac{r_N}{w_N} = \frac{(\sigma - 1) - \sigma \mu_L \mu_K \dot{\theta}_K}{(\sigma - 1) - \sigma \mu_K \mu_L \dot{\theta}_L}
\]

The knowledge premium in the import sector \( \frac{r_S}{w_S} \) is equal to the one in the export sector \( \frac{r_N}{w_N} \) but for the price premium \( \varphi \). The premium \( \frac{r_S}{w_S} \) is increasing in \( \varphi \) if and only if \( \mu_K > \mu_L \); which is true by assumption. Opening to trade \( \varphi \) falls below one, then \( \frac{r_S}{w_S} < \frac{r_N}{w_N} \).

4 When the Stolper-Samuelson theorem fails

In order to prove the existence of an equilibrium in which the traditional Stolper-Samuelson result can be reversed one has to show that the premium for knowledge in the skill intensive sector in open economy is higher than in autarky: \( \frac{r}{w} < \frac{r_S}{w_S} < \frac{r_N}{w_N} \).

The system of job creation and wage equation in open economy (18)-(19), when the marginal values (17) are understood, yields the ratio in labor
market tightness and the premium for knowledge (in the import sector):

\[
\frac{\hat{\theta}_K}{\hat{\theta}_L} = \left(\frac{(\sigma - 1) - \varphi \mu_K}{(\sigma - 1) - \varphi \mu_L}\right)^{\frac{1}{\alpha}}, \quad \frac{r_S}{w_S} = \frac{\mu_K}{\mu_L} \left(\frac{\hat{\theta}_K}{\hat{\theta}_L}\right)^{1-\alpha}
\]  

(20)

Notice that the premium in factor prices depends on the ratio of labor market tightness; provided that the matching of unemployed workers is not perfect \(\alpha \in (0, 1)\). Under imperfect labor markets, then the direction of change in the factor price premium depends on the interaction between patterns of specialization and relative bargaining power.

**Proposition 3.** If the import sector uses intensively the factor with higher bargaining power (\(\varphi \in (0, 1)\) and \(\mu_K > \mu_L\)), then opening the economy leads to an increase of the relative price of the factor that is more intensively used in the import sector: \(\frac{r}{w} < \frac{r_S}{w_S} < \frac{r_N}{w_N}\).

**Proof.** From equation (20) it is clear that the ratio in labor market tightness \(\frac{\hat{\theta}_K}{\hat{\theta}_L}\) is a decreasing function of \(\varphi\) if and only if \(\mu_K > \mu_L\). The comparison of the premium under the trade equilibrium (20), with autarky (16) and the result of Proposition 2 complete the proof.

## 5 Conclusion

In this paper we investigate the effect of a trade induced change in relative output prices on relative factor prices. This is a research question to which the classical trade theory answers by the mean of the Stolper and Samuelson theorem. When factor markets are competitive, the change in relative marginal productivities is the only driver of the change in relative factor prices. Nevertheless, we show that when factor markets are not perfect and factors have different bargaining power then the change in market tightness between factors determines the change in relative factor prices.
In a two country, two good, two factor model with search and matching frictions of the [Mortensen and Pissarides, 1999] type, our framework predicts that factors employed in the export sector are better off; which is consistent with the extended version of the Stolper-Samuelson theorem in [Davidson et al., 1999]. But the predictions of the model are richer and novel. We show that (i) trade induced changes in relative prices modify the relative market tightness between factors and (ii) differences in the factor bargaining power are responsible for the direction of change in relative factor price.

We show that the relative price of the factor with higher bargaining power is higher in the export sector than in the import sector. The effect of this channel is strong enough to dominate the effect of relative productivity and reverse the prediction of the Stolper-Samuelson theorem: if the import sector uses intensively the factor with higher bargaining power then the relative price of the factor that is more intensively used in the import sector will increase as a consequence of international trade.
References


