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Globalization and Wage Premia: Reconciling Facts and Theory

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Abstract

This paper analyzes the effect of globalization on wage premia by studying the interaction between trade costs, firms' location decision, and relative demand for labor. It suggests that globalization, through vertical specialization and/or agglomeration, increases inequality in countries with a relative abundance of skilled workers in a way that is observationally equivalent to skilled-biased technological progress (i.e., joint increases in the wage premium and the within-industry skilled–unskilled employment ratio). This confirms the potential role of international trade in explaining the observed increase in wage inequality between skilled and unskilled workers that has occurred in most industrialized countries since the mid-1970s. Calibration of the model supports this result. It shows that NAFTA has contributed significantly to the observed increase in the U.S. wage premium.

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Keywords: Agglomeration, Intermediate Inputs, Skilled/Unskilled Wages, Trade Liberalization, Vertical Specialization.

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1. Introduction

In the last twenty years, most OECD countries have seen a large increase in the ratio of skilled to unskilled wages (i.e., the wage premium) and/or in the share of skilled workers in employment (see Figure 1). In Europe and North America, where economic integration is far along, the increased inequality between skilled and unskilled has further fueled the debate as to the benefits of integration (e.g., the North American Free Trade Agreement (NAFTA) was one of the most controversial issues of the 1992 U.S. presidential campaign and has also become one of the most important arguments against the 1992 Maastrich treaty). Whereas a popular belief is that increased international trade is to a large extent responsible for the growth in inequality, economists are divided over the source of the labor demand shift. Two explanations have dominated the debate. One is that the rapid diffusion of information technologies, computers, and new forms of work organization have biased production techniques toward skilled workers.[1] The other is that increased import competition from low-wage countries has shifted resources toward industries that are relatively more skilled-intensive. The reluctance to assign trade a major role stands on two main arguments. First, most authors argue that trade volumes with low-wage countries are too small to generate the observed increase in wage inequality. Second, standard theory predicts that an increase in the relative price of skilled labor should increase the within-industry relative employment of unskilled workers.[2] But, as shown by various authors, the growth in inequality has been accompanied primarily by a within-industry shift in relative demand *away* from unskilled workers.[3] Therefore, economists have generally concluded that trade must play a small role in generating the recent increase in inequality.

Most studies to date, however, have focused on trade in final goods. Considering trade in intermediate goods and looking at trade from a different angle than import competition may help us reconcile fact and theory. A fall in the cost of trade (e.g., lower tariffs, transportation costs, or information/communication costs) may indeed encourage the delinking of stages of production and so lead to the development of trade in intermediate goods, components, parts, or work in progress between production units in different countries. International trade may hence become increasingly vertically specialized.[4] Because vertical specialization splits the production chain across countries, the unskilled-intensive stages within manufacturing industries shift to low-(unskilled) wage countries and consequently the wage premium and the within-industry ratio of skilled to unskilled workers rises in skilled-abundant countries. When firms are linked through an input–output structure, globalization may also generate agglomeration– that is, the clustering of economic activity in one location. This would occur as a result of different stages of production within a given industry locating close to each other in order to take advantage of increased competitiveness and greater demand.[5] If these stages differ in their mix of labor factors, then agglomeration shifts the relative within-industry demand for skilled versus unskilled workers. Under certain conditions, it also results in both an increased wage premium and an increased within-industry ratio of skilled to unskilled workers.

The aim of this paper is to analyze the effect of globalization on inequality and, more specifically, to present a trade explanation of the observed joint increase in the wage premium and the within-industry share of skilled workers. In order to do so, I look at the interaction between trade costs, firms' location decision, and the relative demand for labor. This paper develops a general equilibrium model that endogenously determines the equilibrium structure of production (vertical specialization or agglomeration) and wage premia. It addresses the following questions: When does vertical specialization occur? In which countries and under what conditions does agglomeration take place? How does globalization affect the wage premium, in different locations? By considering trade in intermediate inputs and firms' location decisions can we reconcile facts and theory? In the last part of the paper I evaluate, through calibration of the model, the potential impact of NAFTA in explaining the observed increased in the U.S. wage premium.

Two bodies of literature are related to this work. The first one, gathered under the name of "new economic geography" studies firms' location decision. It analyzes whether and why industrial activity tends to cluster in specific locations and hence provides insight concerning the effects that a decrease in trade costs may have on structures of production. It also helps us understand how cross-national income gaps form and decline as trade costs vary.[6] Although recent empirical evidence (e.g., Davis and Weinstein 1998, Torstensson 1997) seem to support the relevance both of agglomeration effects and of comparative advantage in affecting trade and production patterns, the economic geography literature considers two symmetrical countries and hence neglects the comparative advantage channel. It also fails to provide a trade explanation of within-country increases in inequality between skilled and unskilled workers.

The second body is the profuse literature on the potential role of trade in explaining the increased inequality within industrialized countries. Closely related to the present work is Feenstra and Hanson (1996), which use an Hecksher–Ohlin type of model and study how reallocation of production across countries (caused by exogenous reallocation of capital) affects the wage premium. They point out that increased outsourcing (vertical specialization) generates within-industry skill upgrading. In subsequent papers (e.g., Feenstra and Hanson 1996, 1997), the authors estimate the impact of outsourcing on wages. This paper significantly extends their results by studying the case of trade in differentiated products and allowing for agglomeration.

The paper proceeds as follows. Section 2 sets out the formal model ; Section 3, the equilibrium. Sections 4–6 analyze firms' location decision for different levels of trade costs, as well as the induced effects on wage premia. Section 7 presents simulations of the model and discussions. Section 8 calibrates the model using U.S. and Mexican data, and Section 9 concludes. (Section 10 comprises Appendices.)

2. The Model

I use a new economic geography model (à la Krugman and Venables 1995) in which I introduce two factors of production. This enables me to examine the location decisions of vertically linked firms when the upstream and downstream sectors differ in factor intensity and countries differ in endowments of labor factor. Thus I analyze the effect of globalization on asymmetric countries and derive conclusions regarding the wage premium. Note that, in an independent work, Amiti (2001) uses a similar framework. However, she focuses on the firm's location pattern whereas I analyze the implication of globalization on skilled–unskilled wage inequality.

Consider two countries (home and foreign), two imperfectly competitive industries (or stages of production) that are linked through an input–output structure and an agricultural sector.[7] Firms in the upstream industry produce intermediate goods with production function

$$x_{ui} = F_i(L),$$

where x_{ui} is the production of intermediate good i (the subscript u stands for upstream) and L represents unskilled labor. Firms in the downstream industry produce final goods with production function

$$x_{di} = G_i(H, C_u),$$

where x_{di} is the production of final good i (the subscript d stands for downstream), H represents skilled labor, and C_u represents a composite good made up of varieties of upstream (intermediate) goods, as will be seen later in the model.[8]

As is standard in trade models labor is assumed to be immobile across countries, the home and foreign countries face the same technology, and consumers in home and foreign have identical homothetic preferences over a composite good made up of varieties of downstream (final) goods and an agricultural good. The assumption of homotheticity permits separation of the consumption decision into two stages: (i) the allocation of expenditure between the agricultural good and manufactured goods, and (ii) suballocation of manufaturing expenditure among varieties. The agricultural good is assumed to be freely tradeable and its price is used as numeraire. There is trade in both intermediate and final goods. I also make the assumptions

$$\bar{H} > \bar{H}^* \text{ and } \bar{L} < \bar{L}^*,$$

where $\bar{H}$ is the endowment in skilled labor, $\bar{L}$ is the endowment in unskilled labor, and variables with a * superscript correspond to foreign variables. These assumptions are specific to this model.

Within this framework, three forces influence a firm's production location choice: vertical (cost and demand) linkages, factor prices, and access to market. Vertical linkages increase the profitability of firms producing in the same location. Firms that use intermediate inputs find it profitable to locate close to firms that produce these inputs, since the price of intermediate inputs is lower in such a location. This is the cost linkage. Firms that produce intermediate inputs find it profitable to locate where there is high demand for their goods. This is the demand linkage. Vertical linkage forces are standard in the economic geography literature, and if strong enough they give rise to agglomeration of the industrial production in one location. On the other hand, two considerations play against agglomeration: immobility of final demand; and differences in indowments (and hence prices) of labor factors. Whether agglomeration or vertical specialization takes place depends on the relative magnitudes of these forces, which in turn depend on the level of trade costs.

Next I specify the equations of the model for the home country. Symmetric equations hold for the foreign country.

2.1. Preferences

Consumers have Cobb–Douglas preferences over the agricultural good and the manufactured good. Their utility is

$$U = C_A^{1-\gamma} C_d^{\gamma}, \tag{2.1}$$

where C_A is the demand for agricultural good (with price used as numeraire; i.e., $p_A = 1$). Here C_d is the demand for a variety of final goods ; it represents a composite good made up of variety of final downstream goods. Consumers have identical preferences among varieties of the final (downstream) good, which take the form of a "constant elasticity of substitution" subutility function of the Dixit–Stiglitz–Spence type. Hence

$$C_d = \left[\sum_i^{n_d} c_{di}^{\frac{\sigma-1}{\sigma}} + \sum_j^{n_d^*} (m_{dj})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}},$$

where c_{di} is the demand in the home country for downstream good i produced domestically and m_{dj} is the home demand for downstream good j produced abroad ; n_d (resp., n_d^*) is the number of downstream firms located in the home (resp., foreign) country. We refer to C_d as the aggregate downstream good.

Shipment of the manufactured goods incurs "iceberg" trade costs. That is, in order to deliver one unit of any good from one country to another, $\tau > 1$ units must be shipped because only a fraction $1/\tau$ arrives; 1-$1/\tau$ melts in transit. The manufacturing price index of the aggregate downstream good, P_d, is hence defined by

$$P_d = \left[\sum_i^{n_d} p_{di}^{1-\sigma} + \sum_j^{n_d^*} (p_{dj}^* \tau_d)^{1-\sigma} \right]^{\frac{1}{1-\sigma}},$$

where p_{di} is the producer price of downstream good i.

2.2. Agriculture

The agricultural sector is perfectly competitive and produces an homogenous good, x_A, that is assumed to be costlessly tradeable. Since the agricultural good's price is the same in both countries, I choose it as numeraire. Note that x_A is produced using unskilled labor and arable land, R, with constant returns to scale. Here R is a specific factor used only in the x_A industry ; it acts partly to "convexify" the model. As the manufactured sector expands, it draws unskilled labor from the agricultural sector. This raises the R/L_A ratio and thereby the cost of unskilled labor measured in terms of x_A. Since the purpose of this paper is to study firms' location decisions when countries differ in labor endowments and the resulting skilled–unskilled inequality, I assume that countries are otherwise similar and hence that $R = R^*$. The production function is assumed to take a Cobb-Douglas form so that

$$x_A = (L_A)^{\delta} R^{1-\delta}, \tag{2.2}$$

where L_A denotes agricultural employment.

2.3. Firms

The manufacturing sector is monopolistically competitive (à la Dixit and Stiglitz 1977) and is composed of two industries or stages that are vertically linked through an input–output structure. At each stage, differentiated goods are produced under increasing returns to scale. Following Dixit and Stiglitz, we assume that production of a quantity x_{hi} of any variety i in any stage h requires the same fixed (α) and variable (βx_{hi}) quantities of inputs.

The upstream industry uses only unskilled labor, L, as input. Therefore,

$$L_i = \alpha + \beta x_{ui}. \tag{2.3}$$

Then an upstream firm, producing quantity x_{ui} of variety i, has a total cost function of

$$TC_{ui} = w_L(\alpha + \beta x_{ui}),$$

where w_L denotes the price of unskilled labor.

Downstream firms feature a production function defined over skilled labor, H, and a composite good C_u made up of varieties of upstream goods. Following Ethier (1982), upstream goods contribute in a symmetric fashion to the production of a downstream good with a constant elasticity of substitution $\sigma > 1$ across varieties. C_u is defined by

$$C_u = \left[\sum_i^{n_u} c_{ui}^{\frac{\sigma-1}{\sigma}} + \sum_j^{n_u^*} (m_{uj})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}},$$

where c_{ui} is the demand (summed over all domestic downstream firms) for upstream good i produced domestically and m_{uj} is the total home demand for upstream good j produced abroad; n_u (resp., n_u^*) is the number of upstream firms located in the home (resp., foreign) country. We will refer to C_u as the aggregate upstream good. The input used by the downstream industry is a Cobb–Douglas composite of (a) skilled labor H with share $1 - \mu$ and (b) the aggregate upstream good C_u with share μ. We thus have

$$H_i^{1-\mu} C_{ui}^{\mu} = \alpha + \beta x_{di}. \tag{2.4}$$

The share μ of the intermediate input in production is a key parameter because it represents the vertical linkages between the two sectors. The higher is μ, the more upstream goods are used in production of a downstream good and hence the stronger are forces that influence downstream and upstream firms to locate close to each other.[9] The manufacturing price index of the aggregate upstream good, P_u, is defined by:

$$P_u = \left[\sum_i^{n_u} p_{ui}^{1-\sigma} + \sum_j^{n_u^*} (p_{uj}^* \tau_u)^{1-\sigma} \right]^{\frac{1}{1-\sigma}},$$

where p_{ui} is the producer price of upstream good i. Therefore, a downstream firm producing quantity x_{di} of variety i has a total cost function of

$$TC_{di} = w_H^{1-\mu} P_u^{\mu} (\alpha + \beta x_{di}),$$

where w_H denotes the price of skilled labor.

I assume that there is free entry and exit at both stages. With a large number of symmetric firms in each stage, in equilibrium each firm's profit is driven to zero.

3. Solving for the Equilibrium

I solve for the equilibrium by considering the optimization problems of the consumers, downstream firms, and upstream firms in turn and then clearing the product and labor markets. First, I compute consumers' demand for final goods. Second, solving for the upstream and downstream firms, profit maximization, I obtain producers' prices as well as their demand for labor and for intermediate inputs. Then, using the condition of free entry and exit, I derive the output required for each firm to break even. Finally, after clearing markets, I derive the equilibrium conditions that simultaneously yield, for each country, the number of firms in each stage and the associated equilibrium of skilled and unskilled wages.

3.1. Consumer Demand for Final Goods

Consumers maximize utility subject to their budget constraints. Given homothetic preferences, this problem is equivalent to maximizing a representative consumer's utility where the consumer's income, I, is the sum of labor income and landowner income within a country.

Using Roy's identity on the indirect utility function $V = P_d^{-\gamma} I$ and recalling that the price of the agricultural good equals unity, we obtain c_{di}, the consumer demand for final good i produced at home, as well as m_{dj}, the consumer demand for final good j produced abroad:

$$c_{di} = \gamma I P_d^{\sigma-1} p_{di}^{-\sigma}, \tag{3.1}$$

$$m_{dj} = \gamma I P_d^{\sigma-1} (p_{dj}^{*})^{-\sigma} \tau_d^{1-\sigma}. \tag{3.2}$$

3.2. Agricultural Sector Demand for Factors

In the agricultural sector, producers choose L_A and R that maximize profit. Since the sector is perfectly competitive, the profit is zero. Landowners receive positive returns defined by rR, where r is the price of land. Using (2.2), and normalizing R to 1, the first-order conditions are:

$$L_A = \left(\frac{\delta}{w_L}\right)^{\frac{1}{1-\delta}} \tag{3.3}$$

$$r = (1-\delta)\left(\frac{\delta}{w_L}\right)^{\frac{\delta}{1-\delta}}. \tag{3.4}$$

3.3. Downstream Price, Quantity, and Factor Demand

A downstream firm i chooses a quantity x_{di} to maximize its profit, taking other firms, quantities as given. Each firm produces a distinct variety, since a firm always does better by introducing a new product variety than by sharing in the production of an existing one. The first-order condition equating marginal revenue to marginal cost yields

$$p_{di} = P_u^{\mu} w_H^{1-\mu} \beta \left(\frac{\sigma}{\sigma - 1} \right), \tag{3.5}$$

so that the price is a constant mark-up over marginal cost. (To derive this result, note that the price elasticity of demand is equal to the consumer elasticity of substitution between varieties).

Because each firm has the same technology, all downstream firms within a country set the same price and so the i subscript can be dropped. Substituting the profit-maximizing price back into the profit equation yields

$$\pi_{di} = P_u^{\mu} w_H^{1-\mu} \beta \left(\frac{1}{\sigma - 1} \right) \left(x_{di} - \frac{\alpha(\sigma - 1)}{\beta} \right).$$

The demand for each variety depends negatively on the number of varieties produced (the more varieties, the lower the index price and therefore the smaller the demand for each variety). Hence, in equilibrium the number of varieties produced is such that each firm breaks even. Using the condition of free entry and exit and setting profit equal to zero determines the quantity of output at which a firm breaks even:

$$x_{di} = \frac{\alpha(\sigma - 1)}{\beta}. \tag{3.6}$$

The equilibrium quantity produced is constant and is independent of its price, factor prices, and the number of firms. It is the same across firms, so the i subscript can be dropped. This is a well-known consequence of Dixit–Stiglitz preferences and constant elasticity of substitution.

The downstream firm's demand for labor and intermediate goods is obtained by cost minimization. Using Shephard's lemma, we obtain a downstream firm's demand for upstream goods produced at home and abroad and for skilled labor. Then, imposing the zero-profit condition yields the total demand by downstream firms for upstream good i produced at home for upstream good j produced abroad, and for skilled labor H, as follows:

$$c_{ui} = \mu n_d p_d x_d P_u^{\sigma-1} p_{ui}^{-\sigma}, \tag{3.7}$$

$$m_{uj} = \mu n_d p_d x_d P_u^{\sigma-1} (p_{uj}^*)^{-\sigma} \tau_u^{1-\sigma}, \tag{3.8}$$

$$H = (1-\mu)\frac{n_d p_d x_d}{w_H}. \tag{3.9}$$

3.4. Upstream Price, Quantity, and Factor Demand

Upstream firms face the same optimization problem as downstream firms. The upstream firm i chooses x_{ui} to maximize its profit, implying that

$$p_{ui} = w_L \beta \left(\frac{\sigma}{\sigma-1}\right) \tag{3.10}$$

In equilibrium, free entry and exit yield

$$x_{ui} = \frac{\alpha(\sigma-1)}{\beta}. \tag{3.11}$$

The maximizing price and the equilibrium quantity produced are constant and the same across firms, so the i subscript can be dropped.

Upstream firms choose unskilled labor to minimize cost. Total home demand for unskilled labor, L, is

$$L = \frac{n_u p_u x_u}{w_L}. \tag{3.12}$$

3.5. Market-Clearing Conditions

Product market equilibrium requires demand to equal supply for each good in each manufacturing industry and for the agricultural good. For simplicity, as traditional in the literature, units of measurement are chosen such that $\beta = \alpha(\sigma - 1)$. This implies $x_u = x_d = 1$. Moreover,

$$\begin{aligned} x_h &= c_h + m_h^* \text{ for } h = u \\ \text{and } x_A + x_A^* &= c_A + c_A^*. \end{aligned}$$

Labor market equilibrium requires that demand equal supply for each type of labor:

$$\bar{H} = H \quad \text{and} \quad \bar{L} = L + L_A.$$

3.6. The General Equilibrium

Using the products and factors market conditions and the free-entry and market-clearing conditions for home and foreign, we can solve for the equilibrium number of firms, wages, and prices.

For each value of trade costs τ, there is an equilibrium level of n_u, n_u^*, n_d, n_d^*, w_L, w_L^*, w_H, and w_H^*. In the following sections, I study how these equilibrium values change as trade costs decrease. I analyze the autarkic situation ($\tau = \infty$) the free-trade situation (low τ), and the "intermediate trade cost" situation for any τ in between.

4. The Autarkic Equilibrium

If trade costs are infinite then countries do not trade; this is the autarkic equilibrium. At high but finite trade costs, there is some trade but it is highly expensive to ship intermediate and final goods from one country to the other and hence there is a positive number of both upstream and downstream firms in each country. This is the quasi-autarkic situation. I first show that the autarkic equilibrium exists. Since autarky will be used as benchmark in the rest of the paper, I then compute the relative number of firms and wage premia for autarkic equilibrium.

Proposition 4.1. *As τ tends to infinity, autarky is the unique equlibrium.*

Proof. Note that, for $\tau \to \infty$, the price of a foreign good τp_h $(h = d, u.)$ becomes infinite. Thus, countries no longer trade and we have $P_d = n_d^{\frac{1}{1-\sigma}} p_d$ and $P_u = n_u^{\frac{1}{1-\sigma}} p_u$. ■

In equilibrium, the quantity produced is constant and similar across varieties. Given the production functions, this implies that each firm of the same type (upstream or downstream) uses a constant and similar quantity of input. As a result, the quantity of unskilled labor employed in the upstream sector in equilibrium is $L = n_u L_i = n_u \alpha\sigma$. Similarly, the equilibrium quantity of skilled labor employed in the downstream sector is $H = n_d H_i = n_d \left(\alpha\sigma C_{ui}^{\mu}\right)^{1/(1-\mu)}$.[10] Also, in autarky, $C_{ui} = n_u^{\sigma/(\sigma-1)}(1/n_d)$.[11] Using these expressions and their foreign equivalents yields the relative number (home to foreign) of upstream and downstream firms in autarkic equilibrium:

$$\frac{n_u}{n_u^*} = \frac{L}{L^*} \quad \text{and} \quad \frac{n_d}{n_d^*} = \left(\frac{H}{H^*}\right)^{1-\mu} \left(\frac{L}{L^*}\right)^{\frac{\sigma\mu}{\sigma-1}}.$$

Now, applying the equilibrium condition that wage equals marginal productivity of labor in both the agricultural and the downstream goods sectors, using the autarkic expressions for relative downstream price, and then substituting, I obtain the equilibrium relative wages:

$$\frac{w}{w^*} = \left(\frac{L_A^*}{L_A}\right)^{1-\delta} \quad \text{and} \quad \frac{v}{v^*} = \frac{H^*}{H}\frac{L}{L^*}\left(\frac{L_A^*}{L_A}\right)^{1-\delta}.$$

Proposition 4.2. *The share of unskilled labor endowment used in agriculture is the same in both the home country and the foreign country. That is,* $L_A^*/L = L_A^*/L^*$.

Proof. . *See Appendix 1.* ■

Using Proposition 4.2 and the skilled labor market-clearing condition (i.e., $\bar{H} = H = n_d H_i$) yields the autarkic equilibrium relative wages and numbers of firms in term of relative labor endowments:

$$\frac{w}{w^*} = \left(\frac{\bar{L}^*}{\bar{L}}\right)^{1-\delta}, \quad \frac{v}{v^*} = \left(\frac{\bar{H}^*}{\bar{H}}\right)\left(\frac{\bar{L}}{\bar{L}^*}\right)^{\delta}, \quad \frac{n_u}{n_u^*} = \frac{\bar{L}}{\bar{L}^*}, \quad \frac{n_d}{n_d^*} = \left(\frac{\bar{H}}{\bar{H}^*}\right)^{1-\mu}\left(\frac{\bar{L}}{\bar{L}^*}\right)^{\frac{\sigma\mu}{\sigma-1}}.$$

In autarkic equilibrium, relative-factors prices mirror relative-factors endowments. The unskilled wage is higher in the home country whereas the skilled wage is higher in the foreign country and hence the foreign country is more unequal (i.e., has a higher wage premium, recall that: $\bar{L} < \bar{L}^*$ and $\bar{H} > \bar{H}^*$). The relative number of upstream firms corresponds to the relative unskilled labor endowment. More upstream firms locate where unskilled labor is more abundant– that is, where it is cheaper. The autarkic relative number of downstream firms depends on (a) the relative skilled labor endowment (up to the share at which skilled labor enters final goods' production) and on (b) the relative unskilled labor endowment (up to the share at which unskilled labor– through the relative price of intermediate goods– enters final goods' production). Note that the ratio of home to foreign downstream firms is increasing in relative skilled labor endowment (or in relative skilled wage) and decreasing in relative unskilled labor endowment (or in relative intermediate goods price).

5. The Vertical Specialization Equilibrium: Low Trade Costs

At low trade costs, access to market (i.e., being close to the demand for final goods) and vertical linkages influence only partially the firm's location decision. The price of the immobile factors is the force that matters. Because downstream and upstream firms differ with respect to intensify of labor factors, stages of production tend to locate in different countries; that is vertical specialization occurs. Variations in the number of firms shift labor demand and hence modify wages. In equilibrium, wages are such that a marginal firm does not find it profitable to relocate. It is interesting, that, in the home country, the wage premium and the within-industry skilled–unskilled employment ratio move in tandem– in line with empirical evidence. This corroborates the potential role of international trade in explaining the within-industry increase in inequality observed in most industrialized countries.

I first show how free-trade equilibrium numbers of firms differ from their autarkic counterparts and analyze the induced consequences on the labor market. I then discuss similar issues for low levels of trade costs. For clarity, it is useful to define the following ratios (in what follows, the superscript a denotes autarkic variables):

$$\begin{aligned} \Psi_L &= \frac{w_L}{w_L^*}, \quad \Psi_H = \frac{w_H}{w_H^*}, \quad N_u = \frac{n_u}{n_u^*}, \quad N_d = \frac{n_d}{n_d^*}, \\ \Pi &= \left(\frac{P_u}{P_u^*}\right) = \left(\frac{N_u \Psi_L^{1-\sigma} + \tau^{1-\sigma}}{N_u \Psi_L^{1-\sigma} \tau^{1-\sigma} + 1}\right)^{\frac{1}{1-\sigma}}. \end{aligned}$$

If trade incurs no costs, then demand-side considerations do not influence firms' location decisions. Firms find it profitable to locate where their production costs are lowest. Since the foreign country has abundant unskilled labor, its autarkic unskilled wage is relatively lower. Thus, with free trade, upstream firms have an incentive to locate in the foreign country.

Proposition 5.1. *In an interior equilibrium, the relative number of upstream firms (home to foreign) is lower under free trade than under autarky, i.e.;* $N_u < N_u^a$.

Proof. In an interior equilibrium (in which there is production of upstream and downstream goods in both countries), at $\tau = 1$, it must be true that $w_L = w_L^*$, for if not then at least one upstream firm would find it profitable to relocate. By assumption, $R = R^*$ and thus the marginal productivity of labor is the same in the home country as in the foreign country. This implies that the same number of unskilled workers is employed in the agricultural sector in both countries : $L_A = L_A^*$. In autarky, $n_u^a/n_u^{*a} = \bar{L}/\bar{L}^*$; in free trade, $n_u/n_u^* = L/L^* = (\overline{L} - L^A)/(\overline{L}^* - L^{*A})$ Recalling that $\bar{L}^* > \bar{L}$, the proposition follows. ■

Similarly, since the home country has abundant skilled labor, its autarkic skilled wage is relatively lower. Since upstream goods are shipped at no cost, under free trade the downstream firms have an incentive to locate in the home country.

Proposition 5.2. *In an interior equilibrium, the relative number of downstream firms (home to foreign) is higher under free trade, than under autarky ; i.e.,* $N_d > N_d^a$.

Proof. In an interior equilibrium, it must be true that downstream firms' production costs at $\tau = 1$, are equal across countries; if this were not the case then at least one downstream firm would find it profitable to relocate. Downstream firms use skilled labor and intermediate goods as factors of production. Free trade guarantees that the price of the upstream good is the same in both locations, which implies that $w_H = w_H^*$. The skilled labor demand equation (3.9) implies that $n_d p_d / \bar{H} = n_d^* p_d^* / \bar{H}^*$. Free trade likewise guarantees that the price of the downstream good is the same in both locations and so, under free trade, $n_d/n_d^* = \bar{H}/\bar{H}^*$. In autarky, $n_d^a/n_d^{*a} = (\bar{L}/\bar{L}^*)^{\sigma\mu/(\sigma-1)}(\bar{H}/\bar{H}^*)^{1-\mu}$. Since $\bar{H} > \bar{H}^*$and $\bar{L}^* > \bar{L}$, the proposition follows. ■

Thus, relatively more upstream (downstream) firms locate in the foreign (home) country under free trade than under autarky. The foreign country specializes in the production of upstream goods whereas the home country specializes in the production of downstream goods. Different stages of the production process locate in different countries, so there is vertical specialization.

Owing to specialization and gain from trade, the number of downstream firms in the home country is higher under free trade than under autarky. Simulations of the model confirm that the contrary is true of the number of upstream firms.[12] Changes in the number of firms translate to wages and, as a result, the home wage premium is higher under vertical specialization than under autarky. Proposition 5.3 shows that, in the home country, the within-industry skilled–unskilled employment ratio is also higher under free trade than under autarky.

Proposition 5.3. *If the free-trade number of home upstream firms is lower than the autarkic one, then the home-country ratio of skilled to unskilled workers is higher under free trade than under autarky. That is,* $> H/L > H^a/L^a$.

Proof. There is full employment of skilled labor in the downstream sector. Hence, $H = H^a = \bar{H}$. If $n_u < n_u^a$, then $L < L^a$ (recall that there is a one-to-one relationship between number of upstream firms and level of unskilled workers employed in the upstream sector). The proposition follows.[13] ■

Whereas empirical evidence supports this co-movement, it is at odds with a Stolper–Samuelson type of explanation of the increase in skilled–unskilled worker inequality (as mentioned earlier, traditional trade theory posits that the ratio of skilled to unskilled workers decreases within industry). Most studies to date have therefore concluded that international trade plays a limited role in explaining the increased inequality and have argued for skilled-biased technological progress as the most likely culprit. However, under vertical specialization, labor demand shifts along the production chain in a way that is observationally equivalent to a labor shift induced by skilled-biased technological changes. The "vertical specialization" story thus provides an alternative explanation for the joint occurrence of the wage premium increase and the within-industry share of skilled workers increase. Hence international trade, through vertical specialization, may be an important cause of the increased inequality observed in most industrialized countries.

In the foreign country, the wage premium is lower under free trade than under autarky. This result, although in line with standard Hecksher–Ohlin theory, is counterfactual in that most developing countries undergo an increase in wage inequality.[14] Note, however, that the present paper does not aim to provide an explanation for all wage premium variations in all countries but rather to explain part of the increase in wage premium in countries with abundant skilled labor. Skilled-biased technological progress, which undoubtedly plays a role in explaining increased wage premia, may have a dominant effect in developing countries or in those with an abundance of unskilled labor. In fact, in developing countries, skilled-biased technological progress may result from trade with, foreign direct investment in, and transnational firms relocating from industrialized countries. Discussing such arguments is, however, beyond the scope of this paper.

Next, we analyze an equilibrium characterized by low trade costs. Let Ψ_L^a denote the autarkic equilibrium relative unskilled wage.

Proposition 5.4. *For any trade-cost levels such that* $\Psi_L^a > \tau$, *upstream firms have an incentive to locate in the foreign country.*

Proof. Upstream firms decide to locate in the foreign country if the potential profit of a single firm is higher in the foreign country than in the home country– that is, if $\pi_u^* > \pi_u$. A single upstream firm located in the home country produces a quantity $x_u = x_u^{ho} + x_u^{fo}$. It sells a quantity x_u^{ho} in the home country at price p_u and a quantity x_u^{fo}/τ in the foreign country at price τp_u. Its cost of production is $(x_u^{ho} + x_u^{fo})w_L$. If the upstream firm were to locate in the foreign country, it could always chose to sell the same quantities at the same price and thus generate the same revenue. In order to sell x_u^{ho} units of the good in the home country, an upstream firm located in the foreign country must produce a quantity τx_u^{ho}. Its cost of production is therefore $(\tau x_u^{ho} + x_u^{fo}/\tau)w_L^*$. Since $x_u^{fo} w_L > (x_u^{fo}/\tau)w_L^*$ always holds, a sufficient condition for the cost to be higher in the home country than in the foreign country (and hence for $\pi_u^* > \pi_u$) is $x_u^{ho} w_L > \tau x_u^{ho} w_L^*$, which is equivalent to

$$\Psi_L = \frac{w_L}{w_L^*} > \tau.$$

The proposition follows. ■

Similarly, suppose that Ψ_H^a and Π^a characterize, respectively, the autarkic equilibrium relative skilled wage and the relative intermediate goods price.

Proposition 5.5. *For any trade-cost levels such that $(\Psi_H^a)^{\mu-1}(\Pi^a)^{-\mu} > \tau$, downstream firms have an incentive to locate in the home country.*

Proof. Using an argument similar to the previous one, it follows that $\pi_d > \pi_d^*$ if $(x_d^{ho} + x_d^{fo})w_H^{*(1-\mu)}P_u^{*\mu} > (x_d^{ho}/\tau + \tau x_d^{fo})w_H^{1-\mu}P_u^{\mu}$. A sufficient condition for the cost to be higher in the foreign than in the home country is that

$$\Psi_H^{\mu-1}\Pi^{-\mu} = \left(\frac{w_H}{w_H^*}\right)^{\mu-1}\left(\frac{P_u}{P_u^*}\right)^{-\mu} > \tau.$$

The proposition follows. ■

In fact, simulations of the model (see Section 7) show that (a) if $\Psi_L^a > \tau$ then the relative number of upstream firms decreases compared to its autarkic level (i.e., $N_u < N_u^a$) and (b) if $(\Psi_H^a)^{\mu-1}(\Pi^a)^{-\mu} > \tau$ then the relative number of downstream firms increases compared to its autarkic level (i.e., $N_d > N_d^a$). This is true for a full range of parameters.[15] Thus, at low trade costs, vertical specialization occurs. Consequences on wages are similar to the free-trade case. That is, wages converge across countries, and both the wage premium and the within-industry share of skilled workers rise in the home country compared to their autarkic levels.

6. The Agglomeration Equilibrium: Intermediate Trade Costs

At some intermediate level of trade costs, an agglomeration process may occur. It is importantly to note that, when the relative labor endowments (skilled vs. unskilled) differ across countries– that is, when countries are asymmetric– one may determine in which country the agglomeration takes place. The rationale runs as follows. Agglomeration is caused by the vertical link between upstream and downstream firms. If the use of intermediate goods by downstream firms is important (i.e., if μ is high enough), then the vertical linkages overcome the forces of factor prices and hence upstream and downstream firms find it profitable to locate in the same location. If countries differ in their relative (home to foreign) endowment of unskilled labor, the agglomeration takes place in the foreign country. A decrease in trade costs encourages upstream firms to locate in the foreign country, where the autarkic unskilled wage is relatively cheaper. If the cost linkage overcomes the relatively high wages of skilled labor in the foreign country, then downstream firms find it profitable to locate in the foreign country as well. Demand and cost linkages reinforce each other and their combination leads to a circular causality that entails the clustering of production activity in that country. The process is similar (but reversed) when the agglomeration takes place in the home country.

In this section, I aim to examine the agglomeration process and identify some elements that may help us understand its mechanism. Although the dimensionality of the model limits the extent of analytical results, I identify conditions under which agglomeration takes place. In the next section, simulations of the model corroborate the existence of agglomeration. I also address broader issues concerning its impact on wages, prices and trade volume.

Suppose there exists a range of trade costs at which the relative number of upstream firms decreases compared to its autarkic level, so that $N_u < N_u^a$. Within this range of τ, if the relative number of downstream firms also decreases compared to autarky then there is agglomeration in the foreign country. In fact, as shown by Proposition 6.1, the more upstream firms in the foreign country, the stronger the forces attracting downstream firms to that country. The more downstream firms in the foreign country, the stronger the demand linkage attracting even more upstream firms there. When demand and cost linkages reinforce each other, agglomeration may occur.

Proposition 6.1. *The lower the relative number of upstream firms, the stronger the cost linkage (i.e., the greater the incentive to agglomerate in the foreign country).*

Proof. The relative price of intermediate goods is increasing in the relative number of upstream firms, that is, $\partial \Pi / \partial N_u < 0$. See Appendix 2. ■

Downstream firms decide to locate in the foreign country if the potential profit of a single firm is higher in the foreign country than in the home country. Using an argument similar to that used in the preceding case, $\pi_d^* > \pi_d$ if $(x_d^{ho} + x_d^{fo}) w_H^{1-\mu} P_u^{\mu} > (\tau x_d^{ho} + x_d^{fo}/\tau) w_H^{*(1-\mu)} P_u^{*\mu}$. At $N_u = 0$, i.e., at the highest relative upstream goods price; see Proposition 6.1, the inequality

$\Psi_H^{1-\mu}\Pi^\mu x_d^{ho} > \tau x_d^{ho}$ does not hold. Therefore, a necessary condition for $\pi_d^* > \pi_d$ is

$$\Psi_H^{\mu-1}\Pi^{-\mu} = \left(\frac{w_H}{w_H^*}\right)^{\mu-1}\left(\frac{P_u}{P_u^*}\right)^{-\mu} < \tau.$$

Thus $(\Psi_H^a)^{\mu-1}(\Pi^a)^{-\mu} < \tau$ is a necessary condition for any one downstream firm to wish to locate in the foreign country. Because $(\Psi_H^a)^{\mu-1}(\Pi^a)^{-\mu}$ is decreasing in μ, it follows that, the higher the share of intermediate goods used in final goods production (i.e., the stronger the linkages between firms), the less restrictive the necessary condition. Note that, if a downstream firm finds an incentive to locate in the foreign country, then it must be true that the cost linkage is stronger than the factor price force.

Proposition 6.2. *If the necessary condition for a single downstream firm to locate in the foreign country holds, then the cost linkage is stronger than the factor price force.*

Proof. The necessary condition for $\pi_d^* > \pi_d$ is $\Psi_H^{1-\mu}\Pi^\mu > 1/\tau$. Then, when $\Psi_H^{1-\mu}\Pi^\mu > 1$, the necessary condition holds. It is equivalent to

$$\left(\frac{P_u}{P_u^*}\right)^{\mu} > \left(\frac{w_H^*}{w_H}\right)^{1-\mu}. \tag{6.1}$$

The relative price of the intermediate goods (up to the share at which intermediate goods enter final goods production) is greater than the relative skilled wage (up to the share at which skilled labor enters final goods production). ■

Three conditions make inequality (6.1) more likely to hold: strong vertical linkages (i.e., high μ); high relative unskilled endowment, because it reinforce the cost linkage; and low relative skilled endowment, because it lessens the forces of factor prices.

In fact, if $\Psi_L^a > \tau > (\Psi_H^a)^{\mu-1} (\Pi^a)^{-\mu}$, then (a) the relative number of upstream firms decreases compared to its autarkic level and (b) the necessary condition for the relative number of downstream firms to decrease compared to its autarkic level holds.[16] Agglomeration in the foreign country is a most likely outcome. Agglomeration in the home country may be an equilibrium if the cost linkage is weaker than the relative factor price force (i.e., if $\Psi_H^{\mu-1} > \Pi^{\mu}$). At high relative skilled endowment, this is likely to happen. In fact, as seen in the previous section, if $(\Psi_H^a)^{\mu-1} (\Pi^a)^{-\mu} > \tau$, then a single downstream firm finds it profitable to locate in the home country and the relative number of downstream firms increases compared to its autarkic level.[17] A necessary condition for an upstream firm to wish to relocate in the home country is that $\tau > \Psi_L^a$. Thus, if $(\Psi_H^a)^{\mu-1} (\Pi^a)^{-\mu} > \tau > \Psi_L^a$, agglomeration in the home country is likely to occur.

7. Simulations and Discussion

Simulations of the model are plotted in Figures 1 and Figure 2. The figures sketch the relationship between the share of firms in home (i.e., the ratio of the number of type-h firms locating in the home country to the total number of type-h firms, where h = upstream or downstream) and the level of trade costs. They provide an overview of the equilibrium structures of production and wages as trade costs vary. In Figure 2, countries differ in their unskilled labor endowment whereas in Figure 3, they differ in their skilled labor endowment.[18] Note that in the presented simulations, small differences in labor endowments are considered. Larger differences would obviously enhance agglomeration and vertical specialization.

Simulations confirm the results discussed in previous sections. At high levels of trade costs, both countries produce both goods and the share of firms in each country does not vary much. This is the quasi-autarkic situation. For a range of intermediate trade costs, the share of both types of firms increases in one country compared to their autarkic levels: an agglomeration process takes place. If countries differ in unskilled labor endowments, the industrial activity clusters in the foreign country Figure 2 (a); if countries differ in skilled labor endowments, it clusters in the home country Figure 3 (a). At low levels of trade costs, location decisions depend on comparative advantage. The share of downstream firms in the home country increases compared to its autarkic level, whereas the share of upstream firms decreases. Vertical specialization occurs.

In order to look more closely at the impact of globalization on inequality, we refer to Figures 2 (b) and Figure 3 (b), which sketch the relationship between the wage premium and the level of trade costs. Wages converge from their autarkic level to their level with low trade costs. In the (home) country with abundant skilled labor, the wage premium is higher under vertical specialization than under any other situation (i.e., autarky or agglomeration). Furthermore, the number of home-country upstream firms is lower under vertical specialization than under autarky. Vertical specialization induces a within-industry shift away from unskilled workers, which occurs whereas the wage premium increases. Hence, in empirical studies, this potential cause of within-industry increase in inequality should be carefully disentangled from the observationally equivalent counterpart, skilled-biased technological progress.

Consequences of agglomeration on wage premia are more complex. Because the skilled labor endowment is fully used in the downstream sector, factor market competition is fiercer in this sector than in the upstream one. Hence, the impact of a change in the number of downstream firms on skilled wages tends to be greater than the impact of a change in the number of upstream firms on unskilled wage. Also, firms that relocate against their comparative advantage do so in smaller numbers. If the agglomeration takes place in the home country, then relocation of downstream firms is driven by the cost linkage and by differences in relative factor prices (caused by the difference between countries in relative endowments); however relocation of upstream firms is driven by the demand linkage but contraindicated by differences in relative factor prices. In equilibrium, proportionally more downstream firms than upstream firms relocate their production from the foreign country to the home country. Undoubtedly, then, changes in skilled wages dominate changes in unskilled wages. Home relative wages are more unequal under agglomeration than under autarky whereas foreign relative wages are more equal. This situation is depicted in Figure 3 (b). If the agglomeration takes place in the foreign country the– even though upstream firms relocate in greater proportion than downstream firms– skilled wages seem to be more affected than unskilled wages by the change in relative demand for labor. The wage premium increases in the foreign country and decreases in the home country compared to autarkic levels (see Figure 2 (b)).[19] This last point opens up the discussion to an interesting question that is beyond the scope of this paper but would deserve to be addressed in further research: Could agglomeration of the economic activity in unskilled-abundant countries have caused at least part of the observed increase in their wage premium?

Finally, trade in intermediate goods and agglomeration may help us understand some other empirical facts that standard trade theory fails to explain. Actually, along with the argument that trade could not explain the joint occurrence of an increased wage premium and an increased within–industry skilled-unskilled employment ratio, at least two other observations reinforce our skepticism concerning the role of trade in explaining the rise of wage premia in industrialized countries. First, most authors have argued that the volume of trade with low-wage countries is too small to generate the observed increase in wage inequality. Second, though we should observe a rise in the price of skilled-labor–intensive products relative to those of unskilled-labor–intensive ones (as predicted by the factor proportions model), empirical studies of international price data have failed to find any clear evidence of such a change in relative prices.

Concerning the volume of trade, note that this paper mostly captures intraindustry trade, which features "north–north" trade. This can be seen through the similation, which exibit relative abundance of factors close to one. As we have seen, although countries may exhibit close labor profiles, agglomeration and vertical specialization occur at some levels of trade costs and with demonstrated effects on wage premia. Hence, whereas volumes of trade with emerging countries might be low, trade with other industrialized countries that are not much different in labor endowments (nor hence in labor prices) may explain increased wage premium.[20] Thus, small differences in relative labor endowments may help shed some light on within-Europe intraindustry trade and patterns of inequality (e.g., relocation of firms across Europe could at least partially explain why France and the U.K. have seen a greater increase in employment/wage inequality than Ireland or Spain, which are relatively more unskilled-abundant).[21] Concerning relative prices, if there is demand for both domestic and foreign made products, then decreased trade costs tend to reduce the index price of both skilled-intensive and unskilled-intensive goods (more varieties produced, lower cost of imports). Moreover, prices of skilled-intensive goods (downstream goods prices) tend to capture the decrease in input prices and hence to decrease further. Thus, the effect of trade liberalization on the relative prices of skilled- to unskilled-intensive goods is ambiguous. The ratio may remain unchanged or even decrease with trade costs, as assessed by some empirical studies.[22]

8. Calibrations of the Model

Using U.S. and Mexican data, I calibrate the model in order to evaluate the potential impact of the North American Free Trade Agreement (NAFTA) on the U.S. wage premium. This paper posits that a decrease in trade costs should lead to relocation of unskilled-intensive stages of production from the United States to Mexico, which should in turn contribute to the observed increase in the U.S. wage premium. Although NAFTA was enacted in 1994, U.S.– Mexico trade started to be liberalized a few years earlier. I will therefore estimate parameters for the year 1990 and analyze the effect of a decrease in trade costs on the 1990–2000 increase in the U.S. wage premium.

Calibration of the model requires the following parameters: the share δ of labor in agricultural production, the share γ of manufactured goods in consumption, the share μ of manufacturing intermediate goods used as inputs in manufacturing goods production, and the elasticity σ of substitution between varieties in consumer preferences. Using data from the Bureau of Economic Analysis on value added and wage bill per industry, I find that the share of labor in agricultural production is 0.3. Since preferences are presumed to be Cobb–Douglas, the share of manufactured goods in consumption is equivalent to the share of income spent on manufactured goods. Since my model includes agricultural and manufacturing sectors only, workers are employed in either sector and consume both goods. Hence, total income must equate total consumption and γ is defined as the share of manufactured goods' consumption in total (i.e., manufacturing and agricultural) consumption. Using sectoral data on consumption from the Bureau of Economic Analysis, I find that $\gamma = 0.7$. Similarly, input–output data from the Bureau of Economic Analysis shows that manufactures and value added enter final goods' production with similar shares, $\mu = 0.55$. There is a range of estimates for σ, but recent trade studies find values in the neighbourhood of 5 to 6 for the elasticity of import demand with respect to price. Obstfeld and Rogoff (2000) provide a survey of these studies and use such an estimate. I follow their choice and employ $\sigma = 5$ in the calibration.

Data on labor relative endowments of skilled versus unskilled labor are needed for both countries. Population data for the United States and Mexico come from the U.S. Census Bureau. Data on skill composition of the labor force are from Barro and Lee (2000). Skilled labor corresponds to the fraction of the labor force over 25 years of age that has completed some tertiary education. Tariffs between Mexico and the United States have decreased by about 10% over the 1990–2000 period. Although there are no data (to my knowledge) available on non-tariff barriers (NTBs) and transportation costs for U.S.–Mexico trade, I value the former at 13% and the latter at 20% prior to NAFTA. These estimates correspond to the average NTBs and freight costs found by Harrigan (1993) for U.S. bilateral trade.

Assuming that NAFTA eliminates tariffs and NTBs and that freight costs decrease by half, trade costs fall from 43% to 10% over the period.[23] I therefore investigate the impact of a 33% decrease in trade cost on the wage premium. For the sake of robustness, I also consider a smaller decrease in trade costs: assuming that freight costs do not fall and that there are still some tariffs and NTBs, trade costs decrease by about 20%. Calibration of the model shows that such decreases in trade costs induce an increase in the skilled-abundant country's wage premium of 5% and 3.2%, respectively. As mentioned previously, the U.S. wage premium– calculated as the ratio of average annual wage of college to high-school graduates– rose by about 15% in the 1980s (see Bound and Johnson 1992). Harrigan (1998), using a similar measure of relative wage, shows that the increasing trend in the U.S. relative wage persisted over the 1990–1995 period. He finds that the U.S. wage premium rose by about 8% between 1990 and 1995. Since there is some evidence that the increase in wage inequality between skilled and unskilled workers lessens at the end of the considered decade, I assume that the wage premium increases by 10%–15% in the 1990s.

Thus, a 33% (20%) decrease in trade costs would explain 35% (22%) of a 15% increase in the U.S. wage premium; it would explain 52% (33%) of a 10% increase in the U.S. wage premium.[24] The high level of these contributions is partly explained by the extreme structure of the model (i.e., the fact that sectors are labor-specific). However, these results confirm the positive and significant impact of trade, through vertical specialization, in explaining the increase in the wage premium of relatively skilled-abundant countries. Because it increased vertical specialization across countries, NAFTA has indeed contributed to the observed increase in skilled–unskilled worker inequality in the United States.

9. Conclusion

This paper provides a theoretical contribution to the analysis of the firm's location and its impact on labor prices. The main result establishes that if firms are vertically linked and if stages of production differ in labor factor intensity, then a decrease in trade cost implies the joint occurrence of increased wage premium and within-industry skilled-unskilled ratio in skilled-abundant countries. There is strong empirical evidence of this co-movement, yet traditional trade theory offers no explanation. By considering trade in intermediate goods as well as relocation of firms, this paper helps to reconcile facts and theory.

The vertical structure of production presented here corresponds more appropriately to some sectors of the economy than others. It would therefore be interesting to identify these other sectors, to investigate whether reallocation of stages of production across countries has occurred in them and to estimate the effects of relocation on within-industry relative employment levels and wages. Empirical work is in progress that aims to answer these questions by analyzing the case of France. [25]

10. Appendices

10.1. Appendix 1

Proof of Proposition 4.2. Because preferences are Cobb–Douglas in the agricultural good and in the aggregate of downstream goods, a share $1-\gamma$ of income is spent on the former; this implies that $C_A = (1-\gamma)(w_L\bar{L} + w_H\overline{H} + r)$. Similarly, in the foreign country we have $C_A^* = (1-\gamma)(w_L^*\bar{L}^* + w_H^*\overline{H}^* + r^*)$. Supply of the agricultural good is such that $x_A = L_A^\delta$ at home and $x_A^* = L_A^{*\delta}$ (recall that, by assumption, $R = R^*$ and R is normalized to 1). The market-clearing condition implies that

$$\left(\frac{w_L\bar{L} + w_H\overline{H} + r}{w_L^*\bar{L}^* + w_H^*\overline{H}^* + r^*}\right) = \left(\frac{L_A}{L_A^*}\right)^\delta. \tag{10.1}$$

In equilibrium, the price and marginal productivity of factors are equal, so

$$\frac{w}{w^*} = \left(\frac{L_A^*}{L_A}\right)^{1-\delta}, \quad \frac{v}{v^*} = \frac{H^*}{H}\frac{L}{L^*}\left(\frac{L_A^*}{L_A}\right)^{1-\delta}, \quad \text{and} \quad \frac{r}{r^*} = \left(\frac{L_A}{L_A^*}\right)^\delta.$$

Substituting in (10.1) and then rearranging yields

$$w_L^*\left[\left(\frac{L_A^*}{L_A}\right)\bar{L} - \bar{L}^*\right] + v^*\overline{H}^*\left[\left(\frac{L}{L^*}\right)^\delta\left(\frac{L_A}{L_A^*}\right)^{-\delta} - 1\right] = 0.$$

This equality holds if and only if at least one of the following three conditions is true.

(i) $(L_A^*/L_A)\,\bar{L} - \bar{L}^* = 0$ and $(L/L^*)^\delta\,(L_A/L_A^*)^{-\delta} - 1 = 0$, which implies that $L_A/\bar{L}_A^* = \bar{L}/\bar{L}^*$ and $L_A/L_A^* = L/L^*$.

(ii) $(L_A^*/L_A)\,\bar{L} - \bar{L}^* < 0$ and $(L/L^*)^\delta\,(L_A/L_A^*)^{-\delta} - 1 > 0$, which implies that (a) $L_A/L_A^* > \bar{L}/L^*$ and (b) $L_A/\bar{L}_A^* < L/L^*$. Inequality (b) is equivalent to $L_A/L_A^* < (\bar{L} - L_A)/(\bar{L}^* - L_A^*)$.

Solving yields $L_A/L_A^* < \bar{L}/\bar{L}^*$ which contradicts inequality (a).

(iii) $(L_A^*/L_A)\bar{L} - \bar{L}^* > 0$ and $(L/L^*)^{\delta}\,(L_A/L_A^*)^{-\delta} - 1 < 0$, which implies that (c), $L_A/L_A^* < \bar{L}/\bar{L}^*$ >and (d) $L_A/L_A^* > L/L^*$. Inequality (d) is equivalent to $L^*/L_A^* > (\bar{L} - L_A)/(\bar{L}^* - L_A^*)$. Solving yields $L_A/L_A^* > \bar{L}/\bar{L}^*$which contradicts the first inequality (c).

Thus, condition (i) must be true. Hence $L_A/L_A^* = \bar{L}/\bar{L}^* = L/L^*$. ■

10.2. Appendix 2

Proof of proposition 6.1 (continued).

$$\partial g = (\partial g/\partial N_u)\partial N_u + (\partial g/\partial W)(\partial W/\partial N_u)\partial N_u;$$

$$\partial g/\partial N_u = g^{\sigma} / \left[(1-\sigma)(N_u W^{1-\sigma}\tau^{1-\sigma} + 1)^2\right] W^{1-\sigma}(1 - \tau^{2(1-\sigma)}) < 0;$$

$$\partial g/\partial W = g^{\sigma} / \left[(1-\sigma)(N_u W^{1-\sigma}\tau^{1-\sigma} + 1)^2\right] \left[N_u W^{-\sigma}(1-\sigma)(1 - \tau^{2(1-\sigma)}\right) > 0;$$

$$|\ \partial g/\partial N_u\ | > |\ (\partial g/\partial W)(\partial W/\partial N_u)\ | \quad \text{if} \quad W > N_u(1-\sigma)\ \partial W/\partial N_u \quad \text{which is always satisfied.}$$

$$\text{Hence } \partial g/\partial N_u < 0,\ \ \partial g/\partial W > 0,\ \ \partial W/\partial N_u > 0 \quad \text{and} \quad |\ \partial g/\partial N_u\ | > |\ (\partial g/\partial W)(\partial W/\partial N_u)|\ ■$$

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Notes

[1]See Acemoglu (2000) for a survey.

[2]Hecksher–Ohlin theory (and more specifically the Stolper–Samuelson theorem) predicts that trade with low-wage countries raises the relative price of the skilled-intensive good. It implies an increase in the relative price of skilled labor and consequently an increase in the ratio of unskilled to skilled workers within industries.

[3]Berman et al. (1994) and Lawrence and Slaughter (1993) for the U.S.; Machin et al. (1996) for the U.K., Sweden, and Denmark; and Strauss-Kahn (2001) for France.

[4]Feenstra (1998), Campa and Goldberg (1997), Hummels et al. (1998, 1999), and Strauss-Kahn (2001) document that vertical specialization has increased.

[5]These stages refer either to different links of the production chain (e.g., the production of tires, engines, and electronic components in the automobile industry) or to different varieties at a similar stage of production (e.g., the production of different kinds of tires in the automobile industry).

[6]See Krugman and Venables (1995).

[7]For simplicity, we assume that upstream firms do not sell to consumers. Allowing such sales would weaken the agglomeration forces but would not change the qualitative results.

[8]The notion of "intermediate good" must be understood in its most general conception. A good produced in the upstream sector– which acquires most of its value added in the downstream sector (where the managing, marketing, designing, and wholesaleing activities are processed)– is assumed to be an intermediate good for the downstream firm. This situation justifies a framework in which the upstream sector is unskilled-labor–intensive and the downstream sector is skilled-labor–intensive. I chose to present a simple model where sectors are labor-specific because it allows me to obtain some analytical results. Considering relative labor intensity with the upstream sector being relatively unskilled-labor–intensive and the downstream sector being relatively skilled-labor–intensive would not modify the qualitative results. Agglomeration and vertical specialization would occur but with less magnitude (i.e., the number of firms that relocate would be smaller).

[9]For simplicity, we assume that α and β are the same in both industries. Allowing them to differ changes the scale of production but does not affect the results qualitatively.

[10]See equations (2.3) and (2.4) and recall that $\beta = \alpha(\sigma - 1)$.

[11]C_{ui} is the aggregate of differentiated upstream goods demanded by downstream firm i. In equilibrium, p_u is constant over varieties. A representative downstream firm therefore demands the same quantity of each variety k. Hence in autarky $C_{ui} = n_u^{\sigma/(\sigma-1)} c_{uk}^i$, where c_{uk}^i, is the demand of downstream firm i for a variety k of the domestic upstream good. Also $c_{uk} = n_d c_{uk}^i$, where c_{uk} is the total demand for variety k. In equilibrium, $c_{uk} = x_{uk} = 1$ and thus, $C_{ui} = n_u^{\sigma/(\sigma-1)}(1/n_d)$.

[12]A scenario in which the number of upstream firms increases in both the home and the foreign country (though it rises in greater proportion in the latter) is a potential free-trade equilibrium. This would occur if total demand for upstream goods increases dramatically from its autarkic to its free-trade level. However, simulations of the model rule out such possibilities, and this is true for a full range of parameters and endowment levels.

[13]Although the proof is tied up to the sector-specific structure of the model, the proposition holds in a more general framework. Suppose that both downstream and upstream firms use both types of labor, with downstream firms being skilled-labor–intensive and upstream firms being unskilled-labor–intensive. If the number of home upstream firms is lower under free trade than under autarky, then the within-industry skilled–unskilled employment ratio is higher under vertical specializatin than under autarky .

[14]The Hecksher–Ohlin factor price equalization theorem posits that relative factor prices should converge across countries (i.e., the wage premium should increase in the skilled-abundant country and decrease in the unskilled-abundant country).

[15]Attempts have been made to prove these results, but the dimensionality of the model renders the usual analytical techniques of limited value. The equilibrium equations contain a large number of simultaneously determined endogenous variables, and simulations of the model (with careful sensibility analysis) are often required to support results.

[16]Recall that simulations imply that if $\Psi_L^a > \tau$ then $N_u < N_u^a$.

[17]Recall that simulations imply that if $(\Psi_H^a)^{\mu-1}(\Pi^a)^{-\mu} > \tau$ then $N_d > N_d^a$.

[18]Parameter values for the simulation represented are as follows: $\mu = 0.7$, $\sigma = 4$, $\delta = 0.6$, and $\gamma = 0.55$. In Figure 2 $\overline{L}/\overline{L}^* = 0.9$ and $\bar{H}/\bar{H}^* = 1$; in Figure 3 $\overline{L}/\overline{L}^* = 1$ and $\bar{H}/\bar{H}^* = 1.1$. These parameters are consistent

with those used by Amiti (2001) and by Krugman and Venables (1995).

[19]This is true for a large range of parameters and endowments.

[20]In a recent paper, Davis and Weinstein (2001) confirm the role of relative factor endowments in explaining north–north trade.

[21]For more evidence on inequality and education attainment see OECD (1998).

[22]See for example, Lawrence and Slaughter (1993).

[23]Freight costs decrease because of simplified transaction and communication costs and because of increased trade and hence competition in shipping.

[24]Note that higher values of μ and σ lead to higher contributions.

[25]See Strauss-Kahn (2001).

References

Acemoglu, D., *2000*. "Technical Change, Inequality and Labor Market," NBER working paper 7800.

Amiti, M. 2001. "Location of Vertically Linked Industries: Agglomeration versus Comparative Advantage," CEPR discussion paper 2800.

Barro, R., Lee, J.-W., 2000. "International Data on Educational Attainment Updates and Implications," NBER working paper 7911.

Berman, E., J. Bound and Z. Griliches, 1994, "Change in the Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufactures," *Quarterly Journal of Economics* 109 (May): 367–98

Bound J., Johnson, G., 1992. "Changes in the Structure of Wages in the 1980s: An Evaluation of Alternative Explanations," *American Economic Review* 82, 371–92.

Campa, J., Goldberg, L., 1997. "The Evolving External Orientation of Manufacturing: Evidence from Four Countries," NBER working paper 5919.

Davis, D. R., Weinstein, D. E., 1998. "Economic Geography and Regional Production Structure: An Empirical Investigation," NBER working paper 6093.

Davis, D.R., Weinstein, D.E., 2001. "Do Factor Endowments Matter for North–North Trade?" NBER working paper *8516.*

Dixit, A., Stiglitz, J., 1977. "Monopolistic Competition and Optimum Product Diversity," *American Economic Review* 67, 297–308.

Ethier, W., 1982. "National and International Return to Scale in the Modern Theory of International Trade," *American Economic Review* 72, 389–405.

Feenstra, R., 1998. "Integration of Trade and Disintegration of Production in the Global Economy," *Journal of Economic Perspectives* 12, 31–51.

Feenstra, R., Hanson, G., 1996a. "Foreign Investment, Outsourcing and Relative Wages," In Feenstra, R.,Grossman, G., Irwin, D. (Eds.), *Political Economy of Trade Policy: Essays in Honor of Jagdish Bhagwati.* Cambridge, MA: MIT Press, pp.89–127.

Feenstra, R., Hanson, G., 1996b. "Foreign Investment and Relative Wages: Evidence from Mexico's Maquiladoras," *Journal of International Economics* 42, 371–94.

Harrigan, J., 1993. "OECD Imports and Trade Barriers in 1983," J*ournal of International Economics* 35, 91–111.

Harrigan, J., 1998. "International Trade and American Wages in General Equilibrium, 1967–1995," NBER working paper 6609.

Hummels, D., Ishii, J., Yi, K., 2001. "The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* 54, 75–96.

Katz, L., Loveman, G., Blanchflower, D., 1993. "A Comparison of Changes in the Structure of Wages in Four OECD Countries," NBER working paper 4297.

Krugman, P., 1995. "Growing World Trade: Causes and Consequences," Brooking Papers on Economic Activity 1, 327–77.

Krugman, P., Venables, A., 1995. "Globalization and the Inequality of Nations," *Quarterly Journal of Economics* 110, 857–80.

Lawrence, R., Slaughter, M., 1993. "International Trade and American Wages in the 1980s: Giant Sucking Sound or Small Hiccup?" *Brookings Papers on Economic Activity (Micro-economics)* 2, 161–226.

Machin, S., Ryan, A., Van Reenan, J., 1996. "Technology and Changes in Skill Structure: Evidence from an International Panel of Industries," CEPR discussion paper 297.

Obstfeld, M., Rogoff, K., 2000. "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?" NBER working paper 7777.

OECD [Organization for Economic Cooperation and Development], 1998. Employment Outlook..

Strauss-Kahn, V., 2001. "Does Globalization Participate in the French Within-Industry Shift Away from Unskilled Workers?" INSEAD working paper.

Torstensson, J., 1997. "Country Size and Comparative Advantage: An Empirical Study," CEPR discussion paper 297 discussion paper 1554.

Venables, A., 1996. "Equilibrium Locations of Vertically Linked Industries," *International Economic Review* 37, 341–359.

Wood, A., 1994. "North-South Trade, Employment and Inequality" Oxford, U.K.: Oxford University Press.

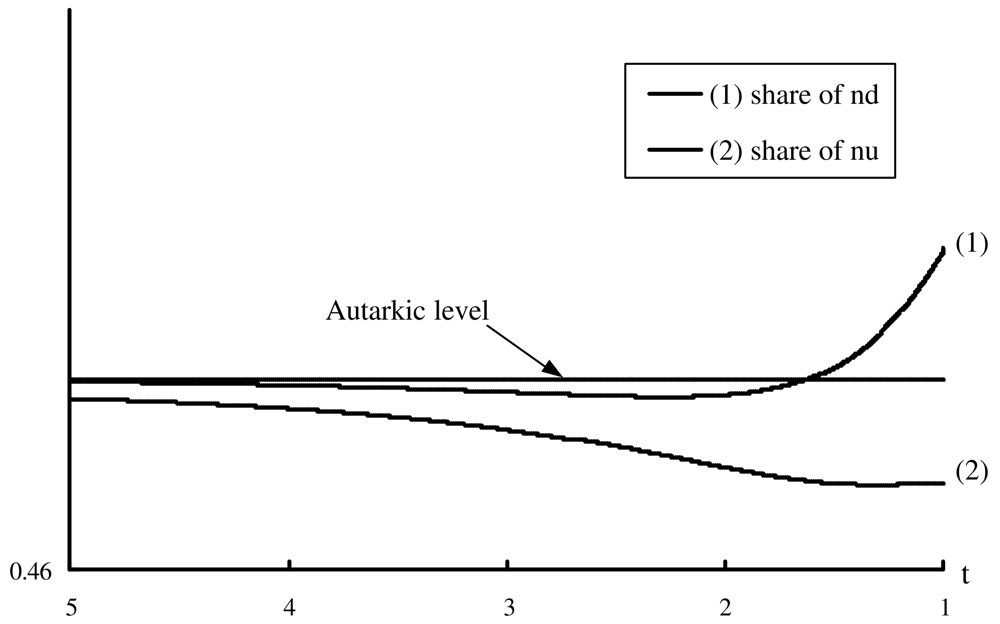
Figure 1: Trend in employment and wages of skilled versus unskilled workers.

Authors	Variable Studied	Country	Period	Result *
OECD (1998)	Skilled--unskilled employment/population ratio differential, based on education levels.	Spain	1981--1994	**6.2**
		Denmark		**8.1**
		France		**11.7**
		U.S.		**6.2**
		U.K.		**9.4**
Katz, Loverman, and Blanchflower (1993)	Ratio of average annual wage of nonmanual to average workers	U.K.	1977--1993	**15** %
Bound and Johnson (1992)	Ratio of average annual wage of college to high-school graduates	U.S.	1979--1988	**15** %
Lawrence and Slaughter (1993)	Ratio of average annual wage of nonproduction to production workers	U.S.	1979--1989	**10** %

* Percentage points unless otherwise indicated.

Figure 2: Equilibrium share of home-country firms and relative wages when $L / L^{*} = 0.9$ and $H / H^{*} = 1$.

(a)



(b)

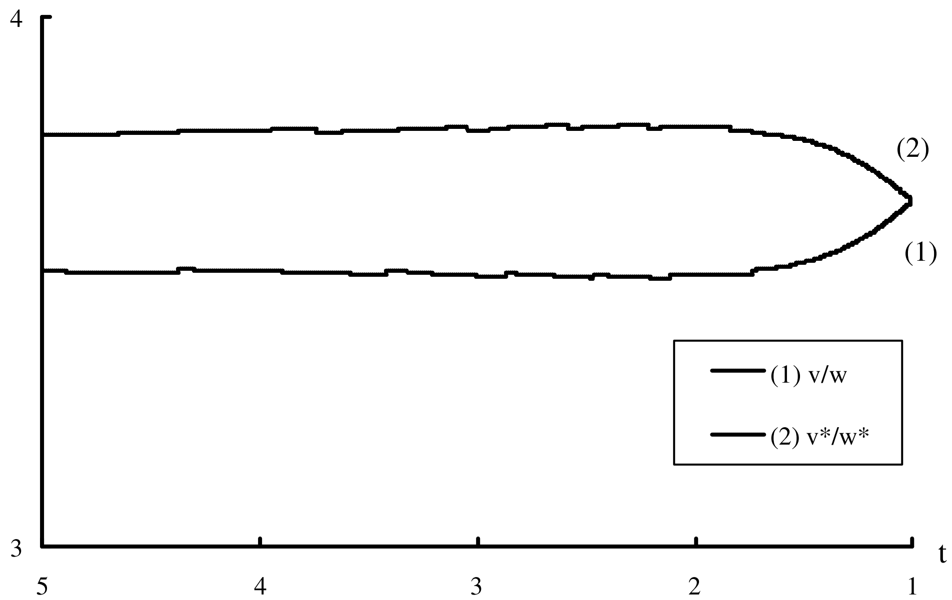
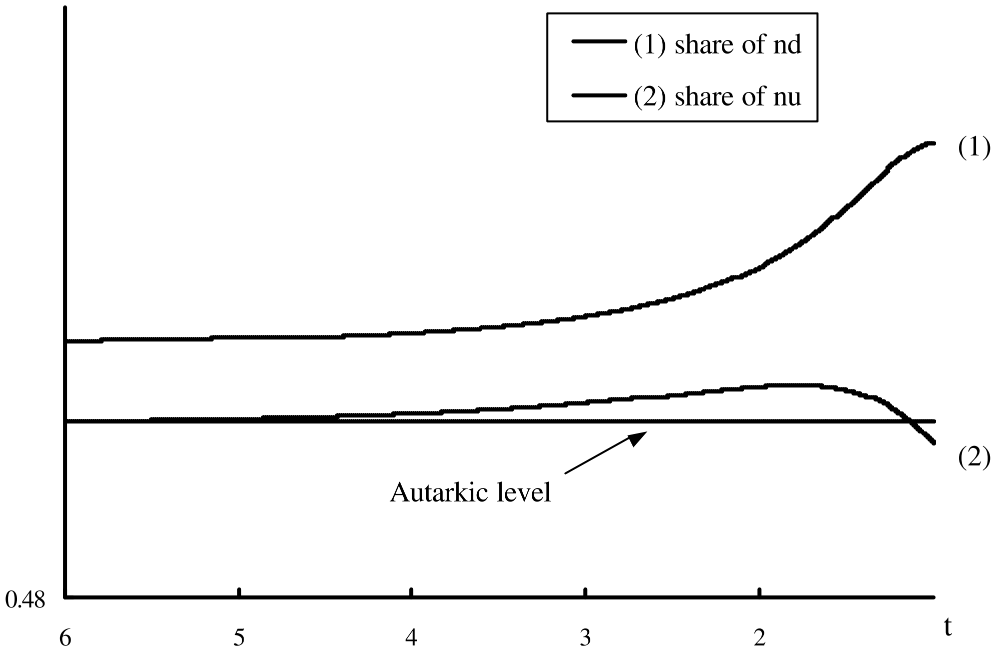


Figure 3: Equilibrium share of home-country firms and relative wages when $L/L^{*}=1$ and $H/H^{*}=1.1$.

(a)



(b)