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Intraindustry trade and the skill premium: Theory and evidence

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A B S T R A C T

We explore theoretically and empirically the relationship between intraindustry trade and the skill premium. Our model features a Chamberlinian-type mechanism of income distribution based on quasi-homothetic consumer preferences, non-homothetic production, and factor-biased scale economies at the firm level. The analysis focuses on a two-country, one-sector model of intraindustry trade with two factor inputs consisting of high-skilled and low-skilled labor. We find that a move from autarky to free trade (a) raises the output of the representative firm and its level of total factor productivity, and (b) reduces (raises) the relative wage of high-skilled workers under the hypothesis of output-skill substitutability (output-skill complementarity). Plant-level evidence from Mexico supports the empirical relevance of the proposed income-distribution mechanism.

1. Introduction

An extensive and influential body of literature has documented the evolution of wage-income inequality. Throughout the last three decades the average wage of U.S. college graduates and post graduates increased steadily relative to the average wage of high-school graduates. In contrast, the wage inequality between high-school graduates and workers without a high-school degree increased in the 1980s but remained stable or fell during the 1990s and 2000s.[1] Autor et al. (2008) argue convincingly that these changes in wage inequality are closely related to underlying changes in the demand for the skill premium. In their words, "…[the fact that] employment and wage growth by skill percentile are positively correlated in each of the last two decades leaves us confident that skill demand shifts have played a central role in reshaping the wage structure, both during the monotone rise of inequality during the 1980s and the polarization of wage growth that followed" (p. 320).[2]

Skill-biased technical change (SBTC), changes in the relative supply of college workers, and institutional factors (e.g., changes in the minimum wage and unionization) have all been identified as important factors shaping the trends in wage-income distribution, including the recent polarization of the U.S. labor market. Demand-based theories have addressed the question of whether trade in final and/or intermediate goods, foreign outsourcing, or international technology transfer affect the skill premium. In particular, a number of influential researchers have proposed novel mechanisms that link openness to the skill premium and explored the various channels though which its effects may travel. For example, Feenstra and Hanson (1996, 1999) and

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[1] See Lemieux (2008a), Lemieux (2008b), and Autor et al. (2008) for overviews of the recent developments on the subject.

[2] As pointed out in Katz and Murphy (1992), Johnson (1997), Krusell et al. (2000), Acemoglu (2002), and several others, the evidence on wage inequality in several developed countries reveals that they have experienced an increase in the skill premium (at least in the upper end of the wage distribution). The evidence for developing countries unveils a more complex pattern. For example, Zhu and Trefler (2005) reported that only about half of 20 developing and newly industrialized countries experienced rising inequality in the 1990s. Further, they suggest that the skill premium increased in those developing and newly industrialized countries whose export shares shifted towards more skill-intensive goods. In the case of Mexico, Feenstra and Hanson (1997), among others, documented a rise in the skill premium in the 1980s and the early 1990s. Later, Robertson (2007) showed that globalization has narrowed wage-income inequality in the post-NAFTA period.

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Zhu and Trefler (2005) proposed international outsourcing (i.e., the endogenous relocation of component-production abroad) as a possible mechanism to explain the global rise in the skill premium. Dinopoulos and Segerstrom (1999) and Sener (2001) developed a dynamic Schumpeterian version of the Stolper and Samuelson (1941) mechanism that relates the relative price of innovation to the skill premium. Neary (2002) advanced a mechanism that links trade to wages through strategic interactions among oligopolists. Acemoglu (2002) related an economy's market size to the profitability of new intermediate capital goods that determine the relative efficiency of skilled labor and the skill premium. In the context of a two-sector model of increasing returns and imperfect competition, Epifani and Gancia (2006) clarified the role of the elasticity of substitution in consumption in regulating the manner in which changes in industry-wide output affect the functional distribution of income. And, building on the insights of Acemoglu (2002), Epifani and Gancia (2008) and Unel (2010a) demonstrated how differences in external scale economies across sectors may link changes in the skill premium to changes in an economy's size.

In this paper, we propose and empirically test an alternative and hitherto unexplored demand-based mechanism of income distribution that operates in markets characterized by Chamberlinian monopolistic competition (Chamberlin (1933)). Acemoglu (2002) assumes perfectly competitive product markets. Unlike us, Neary (2002) abstracts from free-entry considerations and highlights the role of “defensive” R&D investments in markets with few competitors. Epifani and Gancia (2006) consider inter-sectoral differences in the degree of scale economies and the elasticity of substitution in consumption; and Epifani and Gancia (2008) and Unel (2010a) focus on differences in external (as opposed to internal) scale economies across sectors. None of these studies considers the possible effects of non-homothetic tastes and non-homothetic firm-level production on the skill premium. Further, our work emphasizes the nexus among internal scale economies, intraindustry trade and the skill premium.[3]

In the spirit of Krugman (1979), our basic model features a monopolistically competitive sector in which firms produce (and trade) horizontally differentiated goods with the help of two factor inputs: high-skilled and low-skilled labor. Two noteworthy features of the model stand out. On the consumption side, the price elasticity of demand for each variety is increasing in per capita consumption and, therefore, in the size of the market (number of consumers). As we will see, this constitutes a key channel through which the effects of trade travel with important consequences for output and total factor productivity.[4]

The second feature lies on the production side. We suppose the efficiency of high-skilled and low-skilled labor is increasing in firm-specific output and, with the help of a CES production function, we link the differential efficiency of each labor type to output changes within a firm or plant. The resulting (non-homothetic) technology exhibits increasing returns to scale and has the novel property that the skill intensity of production (i.e., the relative demand of high-skilled to low-skilled labor) depends, not just on the skill premium, but also on firm output. The responsiveness of skill intensity to firm output changes (captured by the *output* – as opposed to the *wage* – elasticity of substitution) plays a fundamental role in the analysis because it governs the effects of trade-induced firm-size changes on the relative demand for high-skilled labor and the skill premium.[5]

The model generates several insights. A move from autarky to free trade brings about an increase both in firm output and the level of total factor productivity. But, as hinted above, the effect of trade on the skill premium depends on the sign of the output elasticity of substitution. If this elasticity is negative (positive), then a move from autarky to free trade reduces (raises) the skill premium in both countries (Proposition 1). If the output elasticity of substitution is zero (the eminent assumption in the literature) then intraindustry trade does not affect the skill premium in any of the two countries. Importantly, these changes emerge in the absence of inter-sectoral and/or intra-firm resource movements.

On the empirical front, we use Mexican plant-level data over the period 1993–2003 to estimate the wage and output elasticities of substitution. At the aggregate manufacturing level, the wage elasticity of substitution is less than one (0.29) implying that high- and low-skilled workers are gross complements. In addition, we estimate the output elasticity of substitution to be negative (−0.07) and significant. Thus, our empirical analysis predicts that, if the output of a typical Mexican manufacturing firm doubles, its skill intensity falls by about 7%.

We then proceed to investigate the effects of intraindustry trade and trade liberalization on plant output and the skill premium. We find a strong and significant positive correlation between trade liberalization and output of a typical Mexican plant. We also find that if the Chamberlinian mechanism is not active, trade liberalization does not have a significant impact on the Mexican skill premium. However, once we allow for trade to affect the skill premium through changes in plant-level output, intraindustry trade leads to a reduction in the Mexican skill premium. In other words, plant output does in fact appear to be an important channel through which the effects of intraindustry trade on the skill premium travel.

The rest of the paper is organized as follows. Section 2 describes the theoretical model. Section 3 characterizes the closed-economy equilibrium. Section 4 analyzes the effects of a move from autarky to free trade. Section 5 contains the empirical analysis, and Section 6 concludes.

2. The model

In this section, we present the main ingredients of the model. We consider a world that consists of two countries, Home and Foreign, which may differ in factor endowments but are otherwise structurally identical. In each economy there is a single industry producing differentiated goods under increasing returns to scale at the firm level and monopolistic competition.

2.1. Translated additive consumer preferences

Home's economy consists of N individuals (consumers/workers) who are partitioned into two groups: high-skilled workers, H, and low-skilled workers, L. Every individual i has taste for variety, as indicated by the additive utility function $U^i = \sum_{j=1}^{m} u(x_j^i)$ where x_j^i denotes consumption of variety j and m is the number of available varieties. The subutility function $u(x_j^i)$ is assumed to take the form $u(x_j^i) = (x_j^i + \theta)^\rho$ for $x_j^i > 0$ and $u(x_j^i) = 0$ for $x_j^i = 0$, where $\theta > 0$ and $\rho \in (0,1)$. These consumer

[3] While the model does not fully explain, without appropriate adjustments, the observed polarization of the U.S. labor market it, nonetheless, identifies a demand-based mechanism of income distribution that provides a plausible explanation for the steadily increasing inequality in the upper part of the wage distribution. Further, our proposed mechanism is consistent with the endogenous SBTC hypothesis, for which Autor et al. (2008) find support.

[4] Focusing on firm heterogeneity, Melitz and Ottaviano (2008) consider quasi-linear consumer preferences and one factor of production to study the effects of trade liberalization on markups and welfare. In addition to incorporating high-skilled and low-skilled types of labor into the model, we consider *translated CES preferences* (Pollak, 1971) to analyze the impact of intraindustry trade on the skill premium. Thus, our work differs in methodology and scope.

[5] The output elasticity of substitution is captured by the percentage change in the relative demand for high-skilled labor brought about by a small percentage change in firm output. If this elasticity is positive (negative), then an increase in output raises (reduces) the relative demand for high-skilled labor and raises (reduces) the skill premium.

preferences are "quasi-homothetic" which, following Pollak (1971), may be christened "translated additive" (TA) preferences.[6]

In Appendix A, we derive the following expression for the (absolute value of the) price elasticity of market demand for a typical variety j:

$$\eta_j \equiv -\frac{p_j}{x_j}\frac{\partial x_j}{\partial p_j} = \varepsilon\left(1+\frac{\theta N}{x_j}\right) > 1 \qquad j = 1, 2, \ldots, m; \tag{1}$$

p_j and $x_j = \sum_{i=1}^{N} x_j^i$ respectively denote the price and quantity of variety j, and $\varepsilon = 1/(1-\rho) > 1$ is a parameter that would equal the price elasticity of demand if $\theta = 0$. In particular, since in this case $\eta_j = \varepsilon = 1/(1-\rho)$ for all j, the price elasticity of demand is constant, identical across varieties and independent of per capita consumption and market size, TA preferences coincide with the standard CES preferences.

Our parameter restrictions, $\rho \in (0,1)$ and $\theta > 0$, reveal several notable properties of TA preferences. *First*, they ensure the price elasticity of demand, η_j, for every good j exceeds unity; therefore, imperfectly competitive market structures are supportable without any additional parameter restrictions. *Second*, η_j is decreasing in per capita consumption, x_j/N. This is so because every consumer has a finite "reservation price" that is inversely related to θ.[7] Holding income and the prices of all other varieties constant, an increase in θ causes every consumer's reservation price for variety j to fall, thereby forcing the inverse demand function to become flatter, as hypothesized in Krugman (1979). However, unlike Krugman – who *assumed* η_j to be decreasing in per capita consumption – TA preferences generate this property and, therefore, provide utility-based foundations for this feature. *Third*, neither total income nor income distribution appear as arguments in the price elasticity of demand. As we will see later, this property simplifies the analysis and helps establish causal links between intraindustry trade, firm output and the functional distribution of income.

The restriction $\theta > 0$ implies a positive relationship between the intensity of competition and the price elasticity of demand. As can be seen in Eq. (1), for any given number of consumers N, $\theta > 0$ suggests that a reduction in per capita consumption of variety j raises the price elasticity of demand and thereby reduces the equilibrium mark-up. By contrast, if $\theta \le 0$, there is a negative relationship between per capita consumption and the price elasticity of demand.

Empirical evidence supports a positive relationship between the price elasticity of demand and the intensity of market competition in markets characterized by Cournot quantity competition. Employing data from gas stations in Southern California, Barron et al. (2008) estimated price elasticities of demand for regular graded gasoline and found these elasticities to be significantly higher in areas with higher seller density (measured by the number of gas stations within a two-mile area). This evidence supports the assumed negative relationship between the price elasticity of demand and per capita consumption and is therefore consistent with $\theta > 0$. Accordingly, in what follows, we focus on this case.

2.2. The output elasticity of substitution

The technology for each produced variety is non-homothetic, exhibits increasing returns to scale, and does not differ across varieties. The framework proposed here is inspired by literature on the capital-skill complementarity which has focused on the effects of capital accumulation on the efficiency of low and high-skilled labor (Krusell et al. (2000), Acemoglu and Zilibotti (2001), Acemoglu (2002), and Unel (2010b), among others). However, this literature focuses on perfectly competitive product markets and does not address the effects of firm size on the skill premium.

Since firms are symmetric, in equilibrium every active firm will supply the same quantity of a variety. Letting x denote firm output, we capture technology with the following augmented CES production function that has been routinely used in the literature on the skill premium:

$$x = \left[(\Phi_H Z_H)^{\frac{\sigma-1}{\sigma}} + (\Phi_L Z_L)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where Z_J and Φ_J ($J = H,L$) capture the amount and efficiency of the J type of labor, respectively. According to Eq. (2), then, firm output depends both on $\Phi_H Z_H$ and $\Phi_L Z_L$ efficiency units.[8]

Analytical simplicity compels us to model the efficiency of labor as a function of its market size measured by the representative firm's output. The idea that a larger market leads to increased efficiency through specialization goes back to Adam Smith's famous statement that "the division of labor is limited by the extent of the market" and constitutes one of the main sources of scale economies.[9] As in Panagariya's (1981) contribution to variable returns to scale, we suppose that the dependence of each efficiency coefficient on the representative firm's output takes the simple form, $\Phi_J(x) = x^{\gamma_J}$, where parameter $\gamma_J \in (0,1)$ captures the constant output elasticity of the J-type of labor efficiency (i.e., $\gamma_J \equiv (\partial \log \Phi_J)/(\partial \log x)$). Notice that homotheticity in production would arise if $\gamma_H = \gamma_L \in (0,1)$. Therefore, technology is non-homothetic if $\gamma_H \neq \gamma_L \in (0,1)$.

Let us now explore the analytical properties of the proposed technology through the corresponding unit-cost function it gives rise to. Denote with w_H and w_L the wages of high-skilled and low-skilled labor, respectively. The solution to the relevant cost minimization problem yields the cost function $C(w_H, w_L, x) \equiv c(w_H, w_L, x)x$, where

$$c(w_H, w_L, x) = \left[\left(\frac{w_H}{\Phi_H}\right)^{1-\sigma} + \left(\frac{w_L}{\Phi_L}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} = \left[(x^{-\gamma_H} w_H)^{1-\sigma} + (x^{-\gamma_L} w_L)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{3}$$

is the corresponding unit-cost function. It can be inferred from Eq. (3) that, if $\gamma_H > 0$ and $\gamma_L > 0$, the unit-cost function is decreasing in the firm's output ($c_x \equiv \partial c(\cdot)/\partial x < 0$) and the production function exhibits increasing returns to scale. If $\gamma_H = \gamma_L = 0$, the unit-cost function is independent of the firm's output and the production technology exhibits constant returns to scale. Lastly, if $\gamma_H < 0$ and $\gamma_L < 0$, the unit-cost function increases in the firm's output and the production function exhibits decreasing returns to scale.

Differentiating Eq. (3) yields the unit-output requirements for high- and low-skilled labor

$$\alpha_H(\omega, x) \equiv \frac{\partial c(w_H, w_L, x)}{\partial w_H} = \left[(x^{-\gamma_H}\omega)^{1-\sigma} + (x^{-\gamma_L})^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} \omega^{-\sigma} x^{(\sigma-1)\gamma_H} \tag{4}$$

$$\alpha_L(\omega, x) \equiv \frac{\partial c(w_H, w_L, x)}{\partial w_L} = \left[(x^{-\gamma_H}\omega)^{1-\sigma} + (x^{-\gamma_L})^{1-\sigma}\right]^{\frac{\sigma}{1-\sigma}} x^{(\sigma-1)\gamma_L} \tag{5}$$

[6] The term "translated" captures the property that the indifference map implied by the assumed structure of preferences is a translation of the indifference map of homothetic additive preferences.

[7] The FOC for consumer i 's maximization problem is given by $p_j = (\rho/\mu^i)(x_j^i + \theta)^{\rho-1}$, where μ^i captures his/her marginal utility of income; therefore, the inverse demand curve yields the reservation price $p_j = (\rho/\mu^i)\theta^{\rho-1}$ which is inversely related to θ.

[8] Empirical studies on capital-skill complementarity (e.g., Krusell et al. 2000; Unel 2010b) use a capital-augmented version of Eq. (2).

[9] There are other sources of internal scale economies: fixed inputs associated with human or physical capital, research and development, and engineering principles such as the "cube-square rule." The question of how different sources of scale economies affect the skill premium is beyond the scope of this paper.

where $\omega \equiv w_H/w_L$ is the relative wage of high-skilled labor and is identified with the skill premium.[10] Dividing Eq. (4) by Eq. (5) yields the following expression for the representative firm's relative demand for high-skilled labor (the skill intensity of production):

$$\frac{\alpha_H(\omega, x)}{\alpha_L(\omega, x)} = \omega^{-\sigma} x^{(\sigma-1)(\gamma_H-\gamma_L)}. \tag{6}$$

Taking logs and differentiating Eq. (6) yields the familiar (constant) *wage* elasticity of substitution $\sigma \equiv -\partial \ln(\alpha_H/\alpha_L)/\partial \ln \omega$. Now, thanks to the assumed non-homotheticity in production, Eq. (6) generates the non-standard (constant) *output* elasticity of substitution $\lambda \equiv \partial \ln(\alpha_H/\alpha_L)/\partial \ln x = (\sigma-1)(\gamma_H-\gamma_L)$. The interpretation of these two elasticities is simple. Since $\sigma \in (0,\infty)$ for any given output level, an increase in the relative wage of high-skilled labor ω induces firms to substitute low-skilled for high-skilled labor, thereby reducing the skill intensity of production. If $\sigma<1$, an increase in ω reduces the skill intensity of production but raises the share of high-skilled labor in the cost of producing the good, so the two types of labor are "gross complements" (Acemoglu, 2002). In contrast, if $\sigma>1$, an increase in ω reduces both the skill intensity of production and the cost share of high-skilled labor, so the two factors are "gross substitutes."

The output elasticity of substitution λ is a new concept. It captures the effects of output changes on the skill intensity of production and thus suggests the following natural definition.

Definition 1. *The output elasticity of substitution is the percentage change in the ratio of high-skilled to low-skilled labor demanded brought about by a marginal percentage change in output; that is,* $\lambda \equiv \partial \ln(\alpha_H/\alpha_L)/\partial \ln x = (\sigma-1)(\gamma_H-\gamma_L)$. *We say that the technology exhibits output-skill complementarity/substitutability/neutrality if and only if the output elasticity of substitution* λ *is positive/negative/zero, respectively.*

The economic intuition behind the output elasticity of substitution can be described by considering the case of output-skill substitutability. The unit-cost function in Eq. (3) reveals that a firm's average cost depends on the "effective" wages of high-skilled and low-skilled labor (i.e., on w_H/x^{γ_H} and w_L/x^{γ_L}), where the term "effective" refers to the wage per efficiency unit of labor. Thus, for any given wage rates w_H and w_L, an increase in output will reduce the effective wage of high-skilled labor relative to the effective wage of low-skilled labor (and thus will reduce the effective skill premium ω) if and only if $\gamma_H>\gamma_L \in (0,1)$. In turn, the fall in the effective skill premium will reduce the relative demand for high-skilled labor α_H/α_L if and only if the two factors of production are gross complements ($\sigma<1$) because firms substitute low-skilled for high-skilled labor. The opposite holds if the two factors of production are gross substitutes ($\sigma>1$). In the case of a Cobb–Douglas production function ($\sigma=1$) the skill-intensity of production is independent of the effective relative wage. If the production function is homothetic ($\gamma_H=\gamma_L$), a change in output does not affect the relative effective wage and thus does not change the relative demand for high-skilled labor. In both of these cases (i.e., $\sigma=1$ and $\gamma_H=\gamma_L$) technology exhibits output-skill neutrality.

Next, consider the second component of the output elasticity of substitution, $\gamma_H-\gamma_L$, which captures the difference between the output elasticities of labor efficiency of high-skilled and low-skilled labor. There are several factors that could generate scale-related differences in efficiency between high-skilled and low-skilled workers. For instance, the relative demand for high-skilled labor would be a function of firm output if the cost function contained a fixed-cost component.[11] It can be shown that, in the case of constant marginal costs, the output-elasticity of substitution would be negative (positive) if fixed costs were high-skilled (low-skilled) labor intensive. The intuition is simple: ceteris paribus, an increase in firm output reduces (increases) the weight placed on the high-skilled labor ratio demanded in the fixed-cost (variable-cost) activity thereby causing the relative demand for high-skilled labor to fall (rise).

The above ideas provide a rationale for allowing firm output to affect high-skilled and low-skilled worker efficiency differentially and let the data determine the sign and magnitude of this difference. Accordingly, in Section 5, we present our own empirical analysis of plant-level Mexican data, which lends support to the empirical relevance of the output-skill substitutability hypothesis ($\lambda<0$). For this reason, in the next section, we highlight the main results of our analysis for this case. But, for completeness, we also examine the implications of output-skill complementarity and output-skill neutrality.

3. Closed-economy equilibrium

The existence of horizontal product differentiation and the presence of internal economies of scale induce every firm to specialize in the production of a unique variety. Thus, by the structural symmetry of the model, we may concentrate on the behavior of the representative firm. Since every active firm has monopoly power over its variety, the typical firm will maximize its profit by choosing the level of output so that its marginal revenue equals its marginal cost; that is,

$$p\left[1-\frac{1}{\eta(x,N)}\right] = c(w_H, w_L, x) + x c_x(w_H, w_L, x), \tag{7}$$

where p denotes the price of the representative variety and $\eta(x,N)$ is the price elasticity of demand that was defined in Eq. (1). The left-hand side (LHS) of Eq. (7) is the firm's marginal revenue whereas the right-hand side (RHS) is its marginal cost. Unrestricted free entry and exit drive economic profits down to (approximately) zero, so that the price of a typical variety equals its average production cost; that is,

$$p = c(w_H, w_L, x). \tag{8}$$

Turning to factor markets, we assume that workers are perfectly mobile across firms and that wages are flexible. Thus, demand for each of the two factors will equal its supply and full employment will prevail. The following full-employment conditions ensure factor market clearing and close the model:

$$\alpha_H(\omega, x) x m = H \tag{9}$$

$$\alpha_L(\omega, x) x m = L. \tag{10}$$

The RHS of Eq. (9) is the economy's endowment (fixed aggregate supply) of high-skilled labor. The LHS is the aggregate demand for high-skilled labor. Since firm output is x units, each firm will employ $\alpha_H x$ high-skilled workers, thus yielding an aggregate demand $\alpha_H x m$. A similar interpretation applies to the full-employment condition of low-skilled labor in Eq. (10).

We may now investigate the properties of Home's autarkic (closed-economy) equilibrium. Substituting the zero-profit condition (Eq. (8)) into the optimality condition (Eq. (7)) and simplifying expressions yields

$$\eta(x,N) = s(x,\omega), \quad (\textit{Pricing Condition}) \tag{11}$$

[10] These conditional input demand functions are derived from Shephard's lemma. In general, if $c(\cdot)$ is linear homogeneous in factor prices, then $c_x(\cdot)$ is also linear homogeneous in factor prices; furthermore $\alpha_H(\cdot)$ and $\alpha_L(\cdot)$ are homogeneous of degree zero in factor prices.

[11] We are grateful to a referee for suggesting this possibility.

where

$$s(x,\omega)\equiv-\frac{c(w_H,w_L,x)}{xc_x(w_H,w_L,x)}=\frac{1+x^{\lambda}\omega^{1-\sigma}}{\gamma_L+\gamma_H x^{\lambda}\omega^{1-\sigma}}>1 \qquad (12)$$

is the (absolute value of the) inverse of the output elasticity of the unit cost function, and $\gamma_J\in(0,1)$ for $J=H,L$. We refer to Eq. (11) as the "Pricing Condition" for obvious reasons. The restriction that γ_H and γ_L lie in the unit interval ensures firms operate on the elastic segment of their respective demand curve.

Differentiating Eq. (11) appropriately and separating terms yields the slope of the *Pricing Condition* $dx/d\omega=s_\omega/(\eta_x-s_x)$ in the skill-premium and output space. From Eq. (1) we know that $\eta_x<0$. In Appendix A, we show that the second-order condition for profit maximization requires the firm's perceived inverse demand curve to be steeper than its unit-cost curve at the equilibrium (or, equivalently, the firm's marginal revenue curve to be steeper than its marginal cost curve) which implies $\eta_x-s_x<0$. We also show that, under output skill substitutability, $s(x,\omega)$ is decreasing in the skill premium ω (i.e., $s_\omega<0$). Thus, for given N, the *Pricing Condition* defines a direct relationship between ω and x, as indicated by the upward sloping dotted-line curve *PP* in Fig. 1. (Ignore the other curves for now.)

To close the model, we need one more equation. Dividing Eq. (9) by Eq. (10) and utilizing Eq. (6) yields

$$\frac{\alpha_H(\omega,x)}{\alpha_L(\omega,x)}=\omega^{-\sigma}x^{\lambda}=\frac{H}{L}. \quad (\textit{Market}-\textit{Clearing Condition}) \qquad (13)$$

The LHS of Eq. (13) captures the economy's (and, by symmetry, the firm's) relative demand for high-skilled labor; the RHS is the economy's relative supply of high-skilled labor (skill abundance). Thus, in this one-sector economy, the *Market-Clearing Condition* requires every active firm's skill intensity to be equal to the economy's skill abundance.[12] Under the hypothesis of output-skill substitutability (λ<0), Eq. (13) defines a negatively-sloped locus captured by the dotted-line curve *FF* in Fig. 1. For some intuition, first note that, ceteris paribus, an increase in output *x* reduces the relative demand for high-skilled labor. To restore equilibrium the relative demand for high-skilled labor must increase, thus requiring the skill premium to fall.

The unique intersection of *FF* and *PP* curves at point *A* in Fig. 1 determines the closed-economy equilibrium values of firm output and the skill premium. Once these variables are determined, the equilibrium values of the remaining variables can be readily obtained.[13]

Focusing on the case of output-skill substitutability ($\lambda<0$), consider now an increase in the economy's size, measured by the number of consumers *N*. At the initial skill premium, the increase in *N* renders the demand for each variety more sensitive to a price change (η_N>0) and, as the typical firm moves down its average cost curve, induces it to expand output. This causes the *PP* curve in Fig. 1 to shift upward (not shown). Since $\lambda<0$, by Eq. (13), the increase in output creates an excess supply of high-skilled labor thereby forcing the equilibrium skill premium ω to fall. The impact of a change in the country's skilled-labor ratio, *H*/*L*, is also easy to see. Holding ω fixed, *x* raised to the λ varies proportionally with *H*/*L* (see Eq. (13)). Hence if λ is positive (negative) an increase in *H*/*L* will shift *FF* up (down).

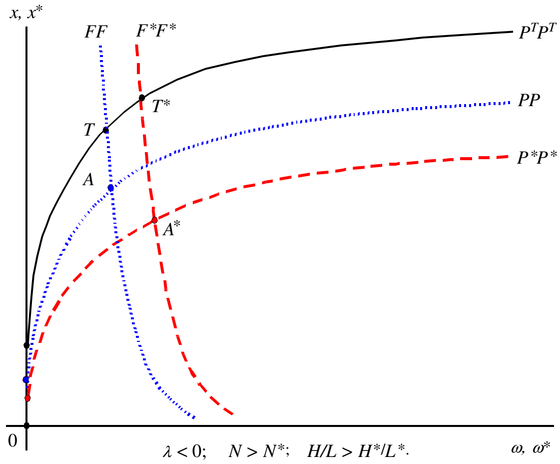

Fig. 1. Effects of intraindustry trade under output-skill substitutability (λ<0).

4. Effects of intraindustry trade

We now explore the effects of intraindustry trade on two economies that may differ in their relative endowments of high-skilled labor and possibly in their relative size. We consider the extreme scenario whereby these economies move from autarky to free trade. This approach encompasses a variety of factors that may promote intraindustry trade, including reductions in trade barriers through the establishment of trade agreements, improvements in transportation and communication technologies, etc.

Denote with a star "*" Foreign's variables and, for clarity but no loss of generality, assume that Home is skill abundant ($H/L>H^*/L^*$) and the largest country ($N>N^*$). In the absence of trade obstacles, the two countries will engage in free intraindustry trade. From the perspective of each individual country, the effect of trade in this context is analytically equivalent to the effect of an expansion in its market-size that was analyzed in the previous section.

Let us first consider the case of output-skill substitutability ($\lambda<0$). Fig. 1 illustrates the impact of trade on the skill premium and the size of the representative firm in each country. The *PP* curve lies to the left of the P^*P^* curve because Home is assumed to be larger than Foreign. The *FF* schedule is to the left of F^*F^* because Home is skill-abundant. The coordinates of points *A* and A^* determine the closed-economy equilibrium values of the skill premium and firm size at Home and Foreign, respectively. Note that, although in the autarky equilibrium the skill premium is relatively lower in Home, the ranking of the size of firms is generally ambiguous. For specificity, Fig. 1 depicts the case where home is populated by smaller firms.

The move from autarky to free trade does not affect the location of schedules *FF* and *FF* because the *Market-Clearing Condition* (Eq. (13)) does not depend on trade-related parameters. However, with the opening of trade, Home and Foreign firms now serve $N+N^*$ consumers, so the new *Pricing Condition* in Eq. (11) is evaluated at $N+N^*$.[14] Since these firms have identical technologies and serve the same number of consumers, the P^TP^T curve in Fig. 1 describes the common *Pricing Condition*. It can now be seen that, a move from autarky to free trade expands the size of the market for the representative firm in each country, thereby raising the price elasticity

[12] The analysis could be extended to render the economy's skill abundance $H(\omega)/L(\omega)$ an increasing function of the skill premium ω. In that case, an increase in the equilibrium skill premium would generate both firm-specific and economy-wide skill upgrading. We abstract from incorporating this supply-based skill upgrading mechanism in the model to keep the analysis simple and direct.

[13] The hypothesis of output-skill complementarity, which arises when the output elasticity of substitution is positive (λ>0), reverses the slopes of the *PP* and *FF* schedules in Fig. 1 and is illustrated in Fig. 2. (Section 4 and Appendix A provide additional details for this case.) It can also be verified that the hypothesis of output-skill neutrality, which corresponds to the case of $\lambda=0$, causes the *PP* and *FF* curves to become horizontal and vertical, respectively. As a consequence, in this case, the *Pricing Condition* does not depend on the skill premium and it alone determines the firm's output *x*. Similarly, the *Market-Clearing Condition* is independent of output and it alone determines the skill premium ω.

[14] More precisely, there exists a corresponding *Pricing Condition* for Foreign that is functionally identical to (11) but with variables ω^* and x^* appearing in the two sides of the equation.

of demand η for each variety and shifting the PP and P^*P^* schedules to P^TP^T.

The free trade equilibrium for Home (Foreign) is depicted at point T (T^*) in Fig. 1 where P^TP^T intersects FF (F^*F^*). It should now be clear that, under skill-output substitutability ($\lambda<0$), the introduction of intraindustry trade will cause the skill premium to fall and firm output to rise in both countries. Interestingly, the output of every active firm under free trade is larger (as compared to autarky) in both trading partners. In addition, owing to the presence of increasing returns and free entry and exit, the increase in output per variety forces producers to rationalize production as they move down along their negatively-sloped average cost curves. As a consequence, the efficiency of both types of labor rises, causing the level of total factor productivity everywhere to rise as well.

Lastly, comparison of the coordinates at points T and T^* in Fig. 1 reveals that both the skill premium and firm size are lower in Home (the high-skilled labor abundant country) than in Foreign (the low-skilled labor abundant country). Furthermore, free intraindustry trade fails to equalize relative factor prices internationally and may also cause these prices to diverge.

For completeness, let us now consider the effects of trade under the hypothesis of output-skill complementarity ($\lambda>0$), a case illustrated in Fig. 2. Now the negatively-sloped PP schedule is located to the right of P^*P^* because $N>N^*$, and the positively-sloped FF schedule is located to the left of F^*F^* (except the origin) because $H/L>H^*/L^*$. Once again, points A and A^* capture the closed-economy equilibria for Home and Foreign, respectively. In addition, the move from autarky to free intraindustry trade does not affect the location of the FF and F^*F^* schedules. Since each firm serves more consumers under free trade, curve P^TP^T is located to the right of both PP and P^*P^* curves. The free trade equilibrium for Home (Foreign) is depicted at point $T(T^*)$, the intersection of curves P^TP^T and FF (F^*F^*). The effect of trade on the skill premia is now reversed: under output-skill complementarity intraindustry trade causes the skill premium in both countries to rise. The effects on firm size and productivity remain similar to the case of output-skill substitutability: they both rise. It is also obvious from Fig. 2 that under free trade the skill premium is relatively lower and firm size is relatively larger in the high-skilled abundant country. For clarity, we summarize these findings below:

Proposition 1. *Suppose consumers in both countries consume positive quantities of all available varieties under free trade. Then, in both countries, a move from autarky to free trade will*

(a) *reduce (increase) the skill premium if the output elasticity of substitution is negative (positive);*
(b) *raise firm output;*
(c) *bring about an improvement in total factor productivity.*

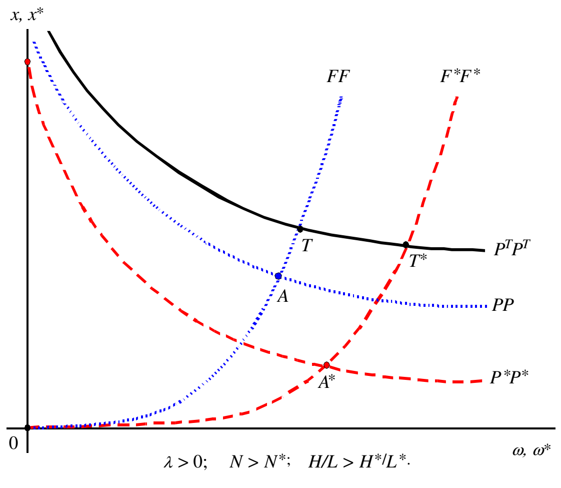

Fig. 2. Effects of intraindustry trade under output-skill complementarity ($\lambda>0$).

Proposition 2. *Consider a free-trade equilibrium in which consumers throughout the world consume positive quantities of all available varieties. Then, in the presence of output-skill*

(a) *substitutability ($\lambda<0$), both the skill premium and firm output will be smaller (larger) in the high-skilled- (low-skilled-) labor-abundant country;*
(b) *complementarity ($\lambda>0$), the skill premium will be lower (higher) and firm output relatively larger (smaller) in the high-skilled- (low-skilled-) labor-abundant country.*

Let us briefly consider the special case of two equally sized countries ($N=N^*$) that differ only in skill abundance (e.g., $H/L>H^*/L^*$). In this case, both countries share the same *Pricing Condition* (captured by, say, the PP curve) but have distinct *Market Clearing Conditions* (captured by the FF and F^*F^* curves), so both Propositions 1 and 2 apply. Consequently, as long as countries differ in skill abundance, free trade will not lead to factor price equalization.

According to Proposition 1, intraindustry trade increases the size of each firm and raises industry-wide total factor productivity, independently of its effect on the skill premium. There is a perfect correlation between changes in representative firm size and changes in labor productivity. This correlation is based on internal scale economies that link firm output to lower unit costs. This prediction is consistent with the exporting-and-productivity literature which has documented substantial industry-wide productivity gains associated with access to larger markets. See, for instance, Bernard and Jensen (1999) and Lileeva and Trefler (2010).[15]

5. Evidence from Mexico

In this section, we investigate the effects of intraindustry trade on the skill premium in the Mexican manufacturing sector during the period 1993–2003. There are several reasons for focusing on Mexico. First, the effects of trade liberalization on the Mexican economy have been studied extensively. This facilitates the comparison of our results to those obtained in other studies and offers additional insights on the determinants of the Mexican skill premium. Second, during the period of investigation, Mexico was heavily involved in trade liberalization, thus rendering it especially attractive for the present study.[16] Third, the National Institute of Statistics and Geography (INEGI) in Mexico maintains the Monthly Industrial Survey (EIM), a database that fits our objectives well.[17]

5.1. Elasticity Estimates

Eq. (6) translates into the following econometric specification

$$\ln \alpha_{it} = \beta_0 + \beta_1 \ln \omega_{it} + \beta_2 \ln x_{it} + \varepsilon_{it} \qquad 14$$

[15] Although the focus of these studies is whether or not intraindustry trade affects the productivity of firms in the Melitz (2003) model of trade with heterogeneous firms, the presence of fixed (exporting) costs delivers the same mechanism as in the present paper: higher firm output results in lower average production costs and higher total factor productivity.

[16] In 1993, Mexico participated in the formation of the Latin American Free Trade Agreement (LAFTA). In 1994, the country participated in the establishment of North American Free Trade Agreement (NAFTA), along with Canada and the United States. During the 90s, Mexico also became member of numerous bilateral free-trade agreements.

[17] The EIM includes data on establishment employment and remuneration by worker type (i.e., production versus non-production workers) as well as data on plant-level production. It does not include data on capital and materials. However, since we aggregate the original data to yearly observations, we can add these variables from the Annual Industrial Survey (EIA). Verhoogen (2008) offers detailed descriptions of the EIM and EIA data sets. Summary statistics of the data employed in our study are available upon request. The EIM does not cover maquiladora plants. Therefore, our findings are complementary to studies investigating the effects of trade on maquiladoras (e.g., Feenstra and Hanson, 1997).

where, for each plant i and period t, $\alpha_{it} \equiv \alpha_{H,it}/\alpha_{L,it}$ is the skill intensity of production, measured as the ratio between non-production and production workers.[18] $\omega_{it} \equiv w_{H,it}/w_{L,it}$ is the relative wage of high-skilled workers, where $w_{H,it}$ and $w_{L,it}$ are the wages of the two occupational categories (non-production and production workers, respectively) in each plant i at time t. Finally, x_{it} is the output in each plant i at time t, which we measure as real value of production.

Both of the covariates in Eq. (14) are potentially endogenous. To address this issue, we employ the panel data econometric techniques advocated by Wooldridge (2002) and we estimate the empirical model in first-differences:

$$\Delta \ln \alpha_{it} = \beta_0 + \beta_1 \Delta \ln\omega_{it} + \beta_2 \Delta \ln x_{it} + \varphi_j + \psi_t + \varepsilon_{ijt}, \quad (15)$$

where we introduce a set of sector-specific fixed effects φ_j and a set of year dummies ψ_t to capture any sector- and time-specific economy-wide shocks and also to account for systematic measurement differences across sectors and over time.

Comparison of Eqs. (6) and (15) reveals that the wage and output elasticities of substitution are given by $\sigma = -\beta_1$ and $\lambda = \beta_2$. Utilizing the definition of the output elasticity of substitution $\lambda = (\sigma - 1)(\gamma_H - \gamma_L)$ enables us to express the difference between (but not the individual values of) the output elasticities of labor efficiency of high- and low-skilled labor as a function of the estimated coefficients, namely $\gamma_H - \gamma_L = -\beta_2/(\beta_1 + 1)$.

Table 1 presents results from estimating Eq. (15). The first row of the table reports estimates for the whole manufacturing sector and the next nine rows present the two-digit, industry-level estimates.[19] The first panel of Table 1 (columns 2–5) reports OLS estimates. The second panel (columns 6–10) presents IV estimates obtained after we control for potential endogeneity between skill intensity and the skill premium.[20] As the OLS and IV estimates are similar, we only discuss the former. Column (2) reports estimates of the wage elasticity of substitution between high- and low-skilled workers. They are, without exception, significant, positive, and less than unity. At the aggregate manufacturing level, the wage elasticity of substitution is $\sigma = 0.29$: a ten percent increase in the skill premium reduces skill intensity by about three percentage points. The sector-specific estimates are relatively stable, varying between 0.22 and 0.35. These findings support the hypothesis that high- and low-skilled workers are gross complements in Mexican manufacturing.

Column (3) of Table 1 presents estimates of the output elasticity of substitution λ. Two features stand out. First, the estimates of λ are always highly statistically significant, which is consistent with the assumption of non-homothetic technology. Second, all estimates of λ are negative, varying between -0.05 and -0.13, with aggregate output elasticity of substitution $-.07$; thus, a doubling of output generates a reduction in the skill intensity of about 7%. These results offer strong empirical support to the hypothesis of output-skill substitutability: as plant-level output expands, firms substitute low-skilled labor for high-skilled labor.[21]

Column (4) of Table 1 reports estimates of the difference between the output elasticities of labor efficiency between high- and low-skilled labor $\gamma_H - \gamma_L = -\beta_2/(\beta_1 + 1)$. As expected, the estimated output elasticity of labor efficiency of high-skilled labor is significantly larger than the output elasticity of low-skilled labor. On average, we find this difference to be about 10 percentage points for the aggregate manufacturing sector. At the sectoral level, $\gamma_H - \gamma_L$ varies between 8 percentage points for Food and 18 percentage points for Other Manufacturing, which includes high-tech industries, such as scientific equipment, where high-skilled labor is an important component of production.

5.2. Trade and the skill premium

Based on the estimates in this section, Proposition 1 implies that intraindustry trade must increase output x and reduce the skill premium ω of the typical Mexican manufacturing plant.[22] We test these predictions by estimating

$$\Delta \ln\omega_{it} = \beta_0 + \beta_1 \Delta T_{jt} + \beta_2 \Delta \ln \alpha_{it} + \beta_3 \Delta \ln x_{it} + \varphi_j + \psi_t + \varepsilon_{ijt}. \quad (16)$$

Here, following our theory's guidelines, we control for plant-level skill intensity $\alpha_{it} \equiv \alpha_{H,it}/\alpha_{L,it}$ and plant output x_{it}, and we introduce a new variable, T_{jt}, which captures sector-specific effects of trade. Our most preferred measure of T_{jt} is the standard Grubel and Lloyd (1975) index of intraindustry trade (IIT), which is defined as $IIT_{jt} = 1 - |M_{jt} - X_{jt}|/(M_{jt} + X_{jt})$, where M_{jt} and X_{jt} denote real imports and exports, respectively, in industry j at time t.[23] Finally, we control for unobserved industry and time characteristics by including sector-specific dummies, φ_j, and time fixed effects, ψ_t.

We start by estimating Eq. (16) without controlling for plant output and skill intensity. OLS estimates, reported in column (1) of Table 2, do not reveal any significant relationship between intraindustry trade and the skill premium in the Mexican manufacturing.[24] In our next experiment, we control for skill intensity (but not for output). Results from column (2) confirm a significant negative relationship between skill intensity and the skill premium; however, the estimate of the coefficient on the trade variable is still not statistically significant. Next, we control for output as well. OLS estimates of Eq. (16) with skill intensity and output controls are reported in column (3) of Table 2. Once again, the estimate on the coefficient on trade is not significant. Even if one controls for skill

[18] While our theoretical predictions are about the typical *firm*, data availability requires *plant-level* empirical analysis. The reason is that the observational unit in the EIM survey is the plant rather than the firm, and, by construction, it is possible that (a) the database does not include all plants or units of the same firm and (b) some establishments may be missing unique firm identifiers. The use of production versus non-production workers to measure skill intensity is common in the trade and wages literature. Although this practice has been criticized when applied to U.S. data, it is accepted as valid in the case of Mexico. Robertson (2004) provides convincing evidence that Mexican non-production workers are significantly more educated than production workers in every two-digit manufacturing sector, which is the level of aggregation used in our analysis.

[19] The nine 2-digit sectors of the Mexican Classification of Activities and Products (CMAP) are listed in column (1) of Table 1.

[20] Our instruments include the log of skill premium at the beginning of the period and its square. In the sensitivity analysis (see footnote 22) we also instrument for the output variable and find that the estimates are unaltered.

[21] In Appendix B we discuss papers that provide empirical support for the output-skill complementarity hypothesis.

[22] In Appendix B we provide a series of sensitivity checks that confirm the robustness of the elasticity estimates presented here. Our findings are comparable to those from related studies. For example, Dunne et al. (1997) estimate output elasticity of substitution for U.S. in the range of -0.015 and -0.105. Our estimates of the wage elasticity of substitution are remarkably similar to the numbers reported in Krusell et al. (2000), who analyze U.S. data, and provide an estimate of 0.29, varying between 0.21 and 0.40 depending on the model's specification. Furthermore, Krusell et al. (2000) estimate the difference between the output elasticities of labor efficiency between high- and low-skilled labor between 9.4 and 11 percentage points. Similar estimates are reported in Unel (2010b).

[23] In addition, we experiment with changes in real imports and exports at the sectoral level and with economy-wide trade growth. Data on sectoral imports and exports are from COMTRADE. Deflation data, needed to convert nominal exports and imports to real values, are from the WDI database. Data on economy-wide trade growth is from the World Bank's World Development Indicators (WDI) as well. As before, data on the skill premium, skill intensity and plant production are from the EIM.

[24] Even though it is unlikely for industry-wide trade and firm-level skill premium to be endogenous, we instrument for the trade variable with lagged levels from the beginning of the period and their squares. IV estimation results reveal that although our instruments are good (with Sargan p-value = 0.47), the effects of trade on the skill premium are very small and statistically insignificant (point estimate of 0.005, std.err. 0.139).

Table 1
Wage, output and efficiency elasticities.

Sector (1)	OLS				IV				
	(2) σ	(3) λ	(4) $\gamma_H-\gamma_L$	(5) N	(6) σ	(7) λ	(8) $\gamma_H-\gamma_L$	(9) N	(10) OVRID
Manufacturing	.288**	−.073**	.102**	51581	.265**	−.074**	.101**	49532	0.371
	(.011)	(.006)	(.008)		(.032)	(.003)	(.006)		
Food	.310**	−.052**	.076**	9608	.310**	−.053**	.078**	9332	0.823
	(.025)	(.017)	(.024)		(.074)	(.008)	(.014)		
Textiles	.308**	−.069**	.100**	8209	.222**	−.068**	.087**	7897	0.332
	(.022)	(.012)	(.018)		(.067)	(.008)	(.013)		
Wood	.35**	−.094**	.144**	1933	.169	−.101**	.121**	1821	0.577
	(.038)	(.023)	(.037)		(.161)	(.017)	(.028)		
Paper	.331**	−.047**	.070**	3890	.533**	−.031**	.066**	3768	0.376
	(.053)	(.019)	(.029)		(.122)	(.015)	(.032)		
Chemicals	.238**	−.067**	.087**	10545	.191**	−.075**	.093**	10133	0.068
	(.020)	(.014)	(.018)		(.068)	(.008)	(.012)		
Minerals	.239**	−.105**	.138**	3766	.252*	−.099**	.133**	3608	0.89
	(.038)	(.022)	(.029)		(.107)	(.013)	(.025)		
Metals	.222**	−.085**	.109**	1279	.840**	−.066**	.413	1177	0.504
	(.076)	(.025)	(.036)		(.321)	(.025)	(.763)		
Machinery	.298**	−.070**	.100**	11774	.228**	−.072**	.093**	11225	0.162
	(.024)	(.010)	(.015)		(.076)	(.006)	(.010)		
Other	.240**	−.133**	.176**	577	.296	−.131**	.186**	568	0.863
	(.081)	(.045)	(.062)		(.278)	(.030)	(.067)		

Standard errors in parentheses. + p<0.10, *p<.05, **p<.01. All estimates are of Eq. (15). Columns (2)–(5) report OLS results. Columns (6)–(9) report IV estimates. Column (10) reports p-values from Sargan tests of overidentification. Standard errors in columns (4) and (8) are obtained with the Delta method.

intensity and plant-level output, failing to allow for intraindustry trade to affect the skill premium through changes in the plant-level output; that is, shutting down the Chamberlinian mechanism, may render the trade effects on the skill premium statistically insignificant!

Next, we estimate Eq. (16) with plant-level skill intensity and output and we employ an IV estimator that enables us to simultaneously allow for and investigate the link between trade, plant output, and the skill premium, which lies at the heart of the Chamberlinian mechanism of trade and wages. To obtain the results from column (4) of Table 2 we instrument for both skill intensity and plant-level output.[25] For brevity, we suppress most of the first-stage results. However, we report the estimates of the trade coefficient from the first-stage output regressions (see panel "First Stage" in Table 2), as these are of particular interest to us.

Three important relationships stand out. First, once we allow for the Chamberlinian mechanism, intraindustry trade decreases the skill premium in accordance with part (a) of Proposition 1. This is captured by the negative and significant estimate of the ITT coefficient. Second, intraindustry trade increases output of the typical plant in accordance with part (b) of Proposition 1. This is evident from the positive and significant first-stage estimate of the trade coefficient from the first stage regressions. Finally, as predicted by theory, our estimates imply a negative relationship between plant-level output and the skill premium. To emphasize that idea, we interpret the estimates from column (4) in the context of Fig. 1. Under output-skill substitutability ($\lambda<0$), the effects of trade are captured by a north-west movement of the PP curve which can be decomposed into two channels. The movement to the north captures the effect of trade on output. First-stage results suggest that one percent increase in the IIT index is associated with a 0.63% increase in output. The movement to the west captures the negative trade effect on skill premium. According to our results, one percent increase in the IIT index translates into 0.12% fall in the skill premium. Taken together these numbers suggest a negative relationship between plant output and the skill premium. More specifically, we estimate that doubling of output is associated with a 19% reduction in the skill premium.[26]

We test the robustness of our results by performing several experiments. First, we replicate column (4) but for longer (two-year) first-differences. This specification addresses the possibility that the dependent and independent variables may exhibit autocorrelation and might not fully adjust in a single year.[27] Results, reported in column (5), are very similar to our previous findings. Next, we employ alternative measures of trade. In column (6), ALLTRADE, we use growth in economy-wide trade, and we replace the time fixed effects with a time trend. Once again, we find that trade causes plant-level output to rise and the skill premium to fall. In column (7), L2.IMP/EXP, we use changes in real imports and exports at the sectoral level. We find that, while imports have a marginally significant positive effect on the skill premium, an increase in exports leads to a fall in the skill premium that is more economically (and statistically) significant than the effect of imports. As expected, first-stage results establish that increased import competition causes output of the typical plant to fall, whereas an increase in exports causes it to rise. The net trade effect is positive, in accordance with Proposition 1. Finally, the last column of Table 2 presents estimates of Eq. (16) for 1994–2000 to focus on the post-NAFTA period, which also support the predictions of our theory.[28]

The empirical findings regarding the effects of trade on output and the skill premium of the typical manufacturing plant follow closely the theoretical predictions. Intraindustry trade operates through changes in the output of a typical plant. These changes translate into changes in the skill premium via the Chamberlinian mechanism of income distribution. The production technology of a typical

[25] The instruments include the logarithms of the two variables from the beginning of the period, their squares and cross products. It should also be noted that the results do not change if skill intensity is treated as exogenous.

[26] To see this, note that the wage premium ω is a function of firm output x which in turn is a function of trade τ. In other words, the skill premium depends on trade through output, $\omega=\omega(x(\tau))$. Letting $\eta_{\omega\tau}$ and $\eta_{\omega x}$ denote the elasticities of the skill premium with respect to trade and output, respectively, and $\eta_{x\tau}$ the elasticity of output with respect to trade, it can be shown that $\eta_{\omega\tau}=\eta_{\omega x}\eta_{x\tau}$. Thus, the elasticity of the skill premium with respect to output is $\eta_{\omega x}=\eta_{\omega\tau}/\eta_{x\tau}=-0.12/0.63=-0.19$.

[27] This is especially relevant for fixed effects estimations. See Trefler (2004) for more on this issue.

[28] It is worth noting that the magnitude of the effect of intraindustry trade on both plant output and the skill premium increases, as expected.

Table 2
Intraindustry trade and the skill premium.

Covariate	No output		Skill intensity and output					
	(1) IIT	(2) SKILL	(3) OLS-IIT	(4) IV-IIT	(5) L2.IIT	(6) ALLTRADE	(7) L2.IMP/EXP	(8) NAFTA
Trade	0.036	0.006	0.006	−0.130**	−0.132**	−0.136***		−0.191***
	(0.023)	(0.023)	(0.023)	(0.051)	(0.056)	(0.025)		(0.079)
Skill intensity		−0.254***	−0.259***	−0.279***	−0.243***	−0.251***	−0.243***	−0.178**
		(0.008)	(0.008)	(0.039)	(0.037)	(0.037)	(0.037)	(0.064)
Output			−0.005	0.273***	0.303***	0.262***	0.302***	0.286***
			(0.003)	(0.069)	(0.077)	(0.068)	(0.077)	(0.091)
ΔIMP							0.157*	
							(0.043)	
ΔEXP							−0.320**	
							(0.078)	
First-stage:								
Trade				0.491***	0.531***	0.291***		0.642***
				(0.032)	(0.043)	(0.016)		(0.037)
ΔIMP							−0.321***	
							(0.044)	
ΔEXP							0.853***	
							(0.055)	
OVRID				0.33	0.03	0.04	0.04	0.59
R^2	0.001	0.08	0.07	0.07	0.07	0.07	0.07	0.07
N	51956	51956	51581	49537	49537	49537	24210	30656

Robust, clustered standard errors in parentheses. *p<0.10, **p<.05, ***p<.01. The estimating equation is Eq. (16). The dependent variable is always the log of skill premium. All results are obtained with time and industry fixed effects (omitted for brevity). Columns (1)–(3) report OLS estimates. Columns (4)–(8) report IV estimates with skill intensity and plant-level output treated as endogenous. Row "Overld" reports p-values from Sargan tests of overidentification. In each case, the instruments include the logarithms of the two variables from the beginning of the period, their squares and cross products. Most first-stage estimates from the IV regressions are omitted for brevity, however, the bottom panel of the table reports the first-stage estimates of the effects of trade on plant-level output. Change in IIT is the trade variable employed in most estimations. The two exceptions are columns (6) and (7), where we use economy-wide trade growth and changes in real sectoral imports and exports to measure trade, respectively. Column (8) reports estimates for the period 1994–2000, to focus on the post-NAFTA period.

Mexican manufacturing plant exhibits output-skill substitutability captured by a negative output elasticity of substitution. In this case, an increase in output reduces the skill premium and ameliorates wage-income inequality. In summary, our model of monopolistic competition and intraindustry trade strengthens the role of trade as an explanation of changes in the global demand for high-skilled labor independently of differences in skill abundance. As such, it contributes to the literature that studies the link between international trade and the wage premium both in North (advanced countries) and South (developing countries).[29]

6. Conclusions

We modified the one-sector model of intraindustry trade based on monopolistic competition by introducing quasi-homothetic preferences and non-homothetic technology in the production of each variety. These two modifications delivered the Chamberlinian mechanism of income distribution which operates in markets with internal economies of scale, product differentiation, and free entry and exit.

In the model, intraindustry trade flattens the inverse demand curve for each variety and intensifies competition pressures. Trade induces each active firm to expand its output and generates total factor productivity improvements. Furthermore, the just-noted output increase alters the relative demand for skilled labor and causes the skill premium to adjust. More specifically, an increase in firm output reduces the relative demand for high-skilled labor and lowers the skill premium if non-homotheticity in production takes the form of output-skill substitutability. In contrast, if technology exhibits output-skill complementarity, the increase in output boosts the relative demand for high-skilled labor, thereby raising the skill premium. Since the Chamberlinian mechanism operates through changes in each firm's output, the above-mentioned changes occur in both trading countries.

To test the principal predictions of the model, we used Mexican plant-level data for the period 1993–2003. At the aggregate manufacturing sector, the estimates of the wage elasticity of substitution (0.29), the output elasticity of substitution (−0. 073), and the difference in the output elasticity of labor efficiency between high- and low-skilled workers (about 10%) were all highly significant, thus providing empirical support for the hypothesis of output-skill substitutability. The effects of intraindustry trade on the skill premium are also consistent with our theoretical predictions: there is a strong and significant positive correlation between intraindustry trade and output of the typical Mexican plant; once the simultaneity between plant-level output and skill intensity is controlled for, intraindustry trade leads to a decrease in the skill premium; without controlling for output, intraindustry trade does not have any significant effect on the skill premium of the typical Mexican plant.

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Appendix A

Due to increasing returns, each firm j produces a unique variety j. From Eq. (1), η_j is the (absolute) value of the price elasticity of firm j's perceived demand. The FOC of consumer i's optimization problem is

[29] See, for instance, Zhu (2005) and Zhu and Trefler (2005).

$p_j\mu^i = \partial u(x_j^i)/\partial x_j^i = \rho(x_j^i+\theta)^{\rho-1}$ $(j=1,2,\ldots,m)$, where μ^i is his marginal utility of income. As in Krugman (1979), each firm j believes that changes in its output x_j do not affect μ^i. Differentiating consumer i's FOC appropriately yields $\eta_j^i = -(p_j/x_j^i)(\partial x_j^i/\partial p_j) = \varepsilon(x_j^i+\theta)/x_j^i$, where $\varepsilon = 1/(1-\rho) > 1$. The price elasticity of total demand η_j can now be calculated to be

$$\eta_j \equiv -\frac{p_j}{x_j}\frac{\partial x_j}{\partial p_j} = -\frac{1}{x_j}\sum_{i=1}^{N} p_j \frac{\partial x_j^i}{\partial p_j} = \frac{1}{x_j}\sum_{i=1}^{N} x_j^i \eta_j^i$$
$$= \frac{1}{x_j}\sum_{i=1}^{N} \varepsilon\left(x_j^i+\theta\right) = \frac{\varepsilon}{x_j}\left(x_j+\theta N\right) = \varepsilon\left(1+\frac{\theta N}{x_j}\right).$$

Focusing on the *Pricing Condition* (Eq. (11)), direct differentiation of Eq. (12) yields

$$s_\omega \equiv \frac{\partial s(x,\omega)}{\partial \omega} = \frac{(\gamma_H-\gamma_L)(\sigma-1)x^\lambda\omega^{-\sigma}}{(\gamma_L+\gamma_H x^\lambda \omega^{1-\sigma})^2} = \frac{\lambda x^\lambda \omega^{-\sigma}}{(\gamma_L+\gamma_H x^\lambda\omega^{1-\sigma})^2}, \quad (A1)$$

$$s_x \equiv \frac{\partial s(x,\omega)}{\partial x} = -\frac{(\sigma-1)(\gamma_H-\gamma_L)^2 x^{\lambda-1}\omega^{1-\sigma}}{(\gamma_L+\gamma_H x^\lambda \omega^{1-\sigma})^2}. \quad (A2)$$

(A1) reveals that $s_\omega > 0$ if and only if the output elasticity of substitution is positive ($\lambda > 0$). In addition, (A2) implies that $s_x < 0$ if the high-skilled and low-skilled labor are gross substitutes ($\sigma > 1$) and the production function is non-homothetic (i.e., $\gamma_H \neq \gamma_L$).

Dropping industry subscripts, partial differentiation of $\eta(x,N)$ yields

$$\eta_x \equiv \frac{\partial \eta}{\partial x} = -\frac{\varepsilon\theta N}{x^2} < 0, \quad (A3)$$

$$\eta_N \equiv \frac{\partial \eta}{\partial N} = \frac{\varepsilon\theta}{x} > 0. \quad (A4)$$

The slope of curve *PP* in Figs. 1 and 2 depends on the sign of $\eta_x - s_x$. But, as can be inferred from (A2), the sign of s_x depends on the sign of $\sigma-1$. However, the second-order condition for profit maximization requires $\eta_x - s_x < 0$ in the neighborhood of equilibrium where $\eta(x) = s(x,\omega)$ and $p(x) = c(x,\omega)$. These equations imply that the inverse demand curve is tangent to the average cost curve, so $p_x(x) = c_x(x,\omega)$ as well. To see these points, write the firm's profit function as $\pi(x) = R(x) - C(x)$, where $R(x)$ is total revenue, and notice that local concavity of $\pi(x)$ requires $\pi_{xx} = R_{xx} - C_{xx} < 0$. This is tantamount to requiring the marginal revenue curve, $R_x = p(1-\eta^{-1})$, to be steeper than the marginal cost curve $C_x = c + xc_x$. Now observe that $R_{xx} = p_x[1-\eta^{-1}] + p\eta_x/\eta^2$ and, utilizing the definition of $s(x,\omega)$, write the marginal cost as $C_x = c[1-s^{-1}]$ and note that $C_{xx} = c_x[1-s^{-1}] + cs_x/s^2$. Evaluating R_{xx} at the equilibrium x gives $R_{xx} = c_x[1-s^{-1}] + c\eta_x/s^2$; therefore, $\pi_{xx} = R_{xx} - C_{xx} = (\eta_x - s_x)c/s^2 < 0$, which holds iff $\eta_x - s_x < 0$. This condition – which essentially requires the inverse demand curve to be less convex than the average cost curve – is satisfied if σ and N are sufficiently small and large, respectively. The slope of the *PP curve* is

$$\frac{dx}{d\omega} = \frac{s_\omega}{\eta_x - s_x}. \quad (A5)$$

Since the denominator of (A5) is negative, by (A1), the expression will be positive (negative) if and only if $\lambda < 0$ ($\lambda > 0$). In other words, output-skill substitutability (complementarity) implies *PP* is positively (negatively) sloped. It can be shown that, if $\gamma_L < \gamma_H < 1/\varepsilon$ then *PP* is defined only for values of x in (x_L, x_H) where $x_J = \gamma_J\varepsilon\theta N/(1-\varepsilon\gamma_J)$ for $J \in \{H,L\}$. Further, if $\lambda < 0$ ($\lambda > 0$) then *PP* starts at x_L (x_H) for $\omega = 0$ and approaches x_H (x_L) asymptotically as $\omega \to \infty$. Figs. 1 and 2 depict these cases. The analysis can also be extended to consider the possibility of $\gamma_H > 1/\varepsilon$.

The *Market-Clearing Condition* (Eq. (13)), can be rewritten as $x = (H/L)^{1/\lambda}\omega^{\sigma/\lambda}$. Appropriate differentiation of this expression reveals that $\lambda < 0$ implies *FF* is downward-sloping. Further, an increase in H/L, shifts *FF* towards the origin. In contrast, if $\lambda > 0$, *FF* starts at the origin and is upward-sloping. In this case, an increase in H/L rotates *FF* clockwise. Lastly, it can be shown that the intersection of *PP* and *FF* is unique.

Appendix B. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.jinteco.2011.01.003.

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