

Trade liberalization and the wage gap: the role of vertical linkages and fixed costs

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Published online: 4 August 2017

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Abstract This paper studies the labor market impacts of trade liberalization, and specifically tariff reductions, with a focus on the wage gap between skilled and unskilled workers in presence of vertical linkages in the fixed costs of production. To that purpose, we develop and empirically test a monopolistic competition model with variable elasticity of substitution and labor differentiated by skill level, where skilled workers are the residual claimants of savings on imported inputs. Consistently with the model predictions, we find that a 10% reduction in tariffs implies on average a 3.8% increase in the wage gap. In addition, the same level of tariff reduction is expected to lower unskilled employment in domestic production by 3.3%, which is partially offset by an expansion of unskilled employment in the export segment of production. These results are obtained matching detailed international trade data with World Input–Output Tables and EU KLEMS data on country-sector wage by skill level on 17 OECD countries from 1996 to 2005.

The original version of this article was revised: In the original publication of the article, the sign “<” has been converted into latex code ‘lt0’ and the sign “>” has been missed in one of the equations. The equation has been corrected in this article.

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Keywords Tariffs · Vertical linkages · Wage gap · Skill premium

JEL Classification F12 · F16 · J31

1 Introduction

This paper aims to complement the vast literature on the effects of trade liberalization on employment and the wage gap by introducing variable elasticity of substitution and vertical linkages on fixed cost of production into the picture. In particular, we identify an additional channel to explain why trade agreements (and in particular North–North agreements) can affect wage inequality by allowing skilled workers, as residual claimants of firm profits, to reap the benefits of reductions in fixed costs of production due to the availability of cheaper intermediate inputs.

After almost two decades of impasse in multilateral trade liberalization, developed countries have turned towards bilateral and regional deals such as Free Trade Agreements (FTAs) and Preferential Trade Agreements (PTAs), whose impact on jobs, wages and inequality is increasingly debated (see Ornelas, 2012 for a detailed discussion). In the past, PTAs have mostly involved developing countries (World Trade Report 2011, chapter II.B) and this feature also indirectly influenced the focus of trade literature, but the recent EU–South Korea FTA (in 2011) and the talks on Japan–EU, Canada–EU, US–EU Transatlantic Trade and Investment Partnership and the Trans-Pacific Partnership deals signal a renewed interest for PTAs among developed economies, calling for some fine-tuning in the analytical framework. Over the period covered by this paper, the average number of PTAs per country grew from 4 in 1996 to 16 in 2005.¹ This implied a consistent improvement in market access for exporting firms (according to CEPII MacMap dataset the average worldwide applied tariff in 2010 is only 4.2%),² involving both developed and developing countries (see Table 1). A similar trend is observed for the subset of rich OECD countries considered in this paper (see Table 2). Such a reduction in tariffs has been associated with a surge in intra-industry trade, whose fastest-growing component over the period 1962–2006 has been trade in intermediates,³ making it an essential component of any new trade theory. Thus, our main contribution to the rich literature on the effects of trade liberalization on the wage gap between skilled and unskilled workers is the inclusion of *vertical linkages* in the theoretical framework to explain trade flows in both consumption and intermediate goods between countries that have *similar levels of development*.

We develop theoretically and test the hypothesis that the availability of cheaper inputs due to trade liberalization frees up resources that can increase the income of skilled workers, who are regarded as the residual claimants of firm profits because of their relative scarcity and the need to use their skills to set up a firm. Specifically, we

¹ See Figure 1 in Freund and Ornelas (2010).

² See Sect. 3.1 for details on the sample of countries used in this paper and on the extent of changes in the market access for the exporting countries in our sample.

³ See Box 3 (p. 20) in World Bank (2009).

Table 1 Tariff and PTAs changes. *Source:* Authors' calculation on TRAINS and WTO data

| | Average tariff (in %) | | Weighted average tariff (in %) | | N. partners with PTA | |
|----------|-----------------------|------|--------------------------------|------|----------------------|------|
| | 1996 | 2005 | 1996 | 2005 | 1996 | 2005 |
| World | 7.94 | 6.65 | 6.92 | 5.66 | 2523 | 4105 |
| OECD | 3.59 | 3.19 | 1.65 | 1.37 | 377 | 590 |
| Non OECD | 8.55 | 7.09 | 7.66 | 6.21 | 2146 | 3515 |

Full sample. Period 1996–2005

Average Tariff: average applied tariff faced by each group of countries; *Weighted Average Tariff:* average applied tariff weighted by export values; *Partners with PTA:* total number of trade partners with PTA. If a trade partner has n PTAs, it is counted n times

Table 2 Tariff and PTAs changes. *Source:* Authors' calculation on TRAINS and WTO data

| Country | Average tariff (in %) | | Weighted average tariff (in %) | | Partners with PTA | |
|----------------|-----------------------|------|--------------------------------|------|-------------------|------|
| | 1996 | 2005 | 1996 | 2005 | 1996 | 2005 |
| Australia | 6.73 | 4.60 | 4.52 | 3.55 | 14 | 16 |
| Austria | 3.13 | 2.39 | 0.11 | 0.19 | 17 | 40 |
| Czech Republic | 2.29 | 2.73 | 0.17 | 0.21 | 24 | 40 |
| Denmark | 2.62 | 2.25 | 0.33 | 0.16 | 30 | 41 |
| Finland | 2.01 | 2.12 | 0.29 | 0.46 | 17 | 40 |
| Germany | 2.61 | 2.01 | 0.24 | 0.28 | 30 | 40 |
| Hungary | 1.64 | 2.69 | 0.09 | 0.26 | 23 | 40 |
| Italy | 2.89 | 2.16 | 0.23 | 0.45 | 30 | 40 |
| Japan | 7.39 | 6.07 | 6.05 | 6.62 | 0 | 2 |
| Korea | 11.47 | 8.69 | 13.57 | 9.04 | 40 | 43 |
| Netherlands | 2.80 | 2.12 | 0.17 | 0.20 | 30 | 40 |
| Poland | 1.75 | 2.36 | 0.12 | 0.16 | 23 | 41 |
| Slovakia | 1.37 | 1.98 | 0.04 | 0.11 | 21 | 40 |
| Slovenia | 0.91 | 2.57 | 0.04 | 0.36 | 22 | 40 |
| Spain | 2.72 | 2.09 | 0.19 | 0.31 | 23 | 40 |
| United Kingdom | 2.66 | 2.16 | 0.37 | 0.37 | 30 | 40 |
| United States | 6.18 | 5.30 | 1.60 | 0.57 | 3 | 7 |

OECD countries. Period 1996–2005

Average Tariff: average applied tariff faced by each country; *Weighted Average Tariff:* avg applied tariff weighted by export values; *Partners with PTA:* total number of trade partners with PTA

develop a monopolistic competition model characterized by vertical linkages and variable elasticity of substitution à la Picard and Tabuchi (2013), in which trade liberalization yields market competition effects reducing markups in the integrating

markets.⁴ As in Krugman and Venables (1995), we assume that firms use the same set of differentiated goods as those purchased by final consumers and that the savings associated with their use as intermediates take the same functional form as consumers' preferences. However, instead of assuming that the elasticity of substitution of varieties is constant and that firms use intermediate inputs in both the variable and the fixed components of the cost functions as done in Krugman and Venables (1995), we follow Picard and Tabuchi (2013) and assume that the elasticity of substitution is variable and that firms use intermediate inputs only in the fixed component of the cost function.⁵ This framework was originally developed by Picard and Tabuchi (2013) in the context of the urban economics literature to account for linkages between firms, but in this paper we adapt it to a trade framework to highlight a new source of gains from trade: savings on fixed costs for capital goods, thanks to the availability of cheaper intermediate imports.⁶ Our model differs from that of Picard and Tabuchi (2013) because they consider goods that are not internationally or interregionally traded, but only locally consumed within a city given that the aim of their work is to establish how consumers are distributed within the city.⁷ Moreover, the mechanism that we highlight in this paper differs from that in Feenstra and Hanson (1996) because we allow firms in *all* countries to use intermediate inputs produced domestically and/or abroad. In this way, firms can benefit from reductions in trade barriers also among North–North countries (thanks to the reduction in the cost of intermediate inputs), while in Feenstra and Hanson (1996) intermediate goods that are more intensive in unskilled labor are outsourced from skill-intensive to skill-scarce countries.

The intuition behind our model is that entrepreneurs can substitute their in-house production of equipment with the purchase of intermediates, obtaining savings on the fixed costs of production. For example, firms can buy computers, software and electronics on the market rather than developing them on their own and, given that these intermediates can be sourced both domestically and from abroad, trade liberalization reduces their costs, allowing skilled workers to extract higher wages out thank to the increase in profits. Therefore, the first implication of our model is that trade liberalization, by lowering the cost of intermediates, increases the wage gap because it benefits inelastic skilled workers more than elastic unskilled workers.

⁴ Our framework differs from purely theoretical New Economic Geography models with vertical linkages à la Krugman and Venables (1995) because, to ensure empirical tractability, we focus on static properties of the model and assume fixed the number and location of firms (i.e., they are not determined endogenously by the interplay of agglomeration and dispersion forces or by the reduction in fixed costs of entry due to cheaper intermediate goods). Starting from the seminal work by Venables (1996), the New Economic Geography literature has shown that intermediates and vertical linkages among firms play a relevant role in determining the space distribution of firms (i.e. Krugman and Venables 1995).

⁵ The same framework, known as the Footloose Entrepreneur Vertical Linkage model, has been proposed by Ottaviano (2002) and its properties are discussed in Ottaviano and Robert-Nicoud (2006).

⁶ Vertical linkages in fixed costs of capital investments can also be interpreted as a “make it or buy it” choice, as it is sometimes referred to in the literature.

⁷ Specifically, Picard and Tabuchi (2013) extend the endogenous mark-ups setup with the linear demand system developed by Ottaviano et al. (2002) to explain the location within a city of firms that produce without variable inputs, making use of three different fixed inputs: labor, physical capital equipment and intermediate goods or services.

Moreover, the model implies the testable prediction that trade liberalization decreases unskilled employment on the domestic segment while increasing it on the export segment, the net effect depending on the relative size of each.

Using a model with a combination of vertical linkages on fixed costs and variable elasticity of substitution also allows us to be consistent with the recent empirical findings concerning markup heterogeneity across firms and markets (see, for example, Foster et al. 2008; Behrens et al. 2014; Di Comite et al. 2014). In our model firms are characterized by a simple production function exhibiting increasing returns to scale through the combination of fixed and variable costs of production. Firms produce goods that can be used for final consumption or as intermediates by other firms to save on their fixed costs. Workers can be skilled or unskilled, the latter being employed in quantities proportional to total output and the former being hired in fixed quantities to run a firm.⁸ We develop a three-country model in order to identify analytically the welfare and labor market effects of tariff reductions on both the integrating and third countries.

Our modeling choice delivers implications on the impact of trade liberalization on the wage gap and unskilled workers' employment similar to those resulting from models based on skill-biased technology mechanisms (see Burstein and Vogel, 2017), but different implications concerning the employment of skilled workers, which is unaffected in our framework. We test these theoretical results using EU KLEMS data on wage and employment level by education attainment, which are available only for a set of OECD countries, including 26 ISIC-2 sectors over the period 1996–2005. Consistently with our model predictions, we find that the wage gap increases with trade liberalization and that lower tariffs imply a net loss of unskilled jobs in the domestic production, while the employment levels of skilled workers remain unaffected. These results hold also in the case of North–North integration, which is another peculiarity of the model presented in this paper.

The main empirical contribution of the paper lies in the adoption of a multi-country perspective in the analysis of labor-market impacts of trade policy at the sectoral level, going beyond a single-country analysis and working on a panel dataset that includes 17 OECD countries over the period 1996–2005. Indeed, to the best of our knowledge, existing literature focuses solely on single country studies in assessing the wage gap effects of trade liberalization.⁹

⁸ We disregard firm heterogeneity and intra-sector reallocations for the sake of tractability, being aware that this important channel of adjustment has been studied extensively in the above-mentioned literature and is not alternative to the industry-wide cost-saving channel identified here.

⁹ See Attanasio et al. (2004), Goldberg and Pavcnik (2005), Gonzaga et al. (2006), Amiti and Davis (2011), Amiti and Cameron (2012). The only partial exception is Behrman et al. (2007), who focus on the effect of trade reform on wage differentials for Latin American countries. Also Autor et al. (2013), Autor et al. (2014), Autor et al. (2015) and (2016) examine the impact of import competition on local labor markets adopting a single country perspective with the effects of Chinese import competition on US local labor markets.

1.1 Literature review

Traditionally, the effects of trade liberalization on the wage gap between skilled and unskilled workers have been analyzed through the lens of a standard Heckscher and Ohlin mechanism: reductions in trade cost shift factors towards the sector in which the country has a comparative advantage, so that the skill premium increases in those countries having a comparative advantage in skill intensive sectors. However, several empirical studies have cast doubt on this approach. For example, using Mexican data, Harrison and Hanson (1999) find that the skill premium increased after the trade reform in 1985, which is puzzling in a Heckscher and Ohlin framework, given Mexico's comparative advantage in low-skill intensive goods. Similarly, Goldberg and Pavcnik (2007) report that the skill premium increased also in unskilled-workers abundant countries after trade liberalization. The departure from the standard Heckscher–Ohlin framework has resulted in different competing approaches to study how tariff reduction affects labor markets.¹⁰

The seminal contribution by Feenstra and Hanson (1996) emphasizes the role of intermediate goods that can be imported from overseas to explain why the wages of low-skilled workers have fallen relative to those of high-skilled workers relying on a model in which activities that are more intensive in unskilled work are outsourced from the North to the South, which is a skill-poor country relatively to the North.¹¹ In this vein, measuring trade by the foreign outsourcing of intermediate input and potential technical change by the shift toward high-technology capital, Feenstra and Hanson (1999) show how much of the observed rise in wage inequality in the U.S. is attributable to each structural variable separately.¹²

A second type of models takes into account North–North trade (even though they do not consider internationally sourced intermediate goods), where countries do not differ in terms of relative endowments and technologies, assuming that scale and skill intensity are correlated at the sector or firm level. Following this observation, Epifani and Gancia (2008) and Dinopoulos et al. (2011) show that, under appropriate assumptions on preferences, the increase in scale inherent to trade liberalization exerts a bias towards skill demand and raises the skill premium in frameworks that consider a representative firm. The bias towards skill demand generated by trade liberalization is also present in Burstein and Vogel (2017) who, instead, use a different framework with Bertrand competition and no free entry that augments the Heckscher–Ohlin model by introducing heterogeneity in productivity across producers within sectors with skill-biased technology at the firm level. Specifically, Burstein and Vogel (2017) show that trade liberalization can reallocate factors towards more skill intensive sectors in all countries raising the relative

¹⁰ A survey of the studies analyzing the effect of trade liberalization on wages and inequality in developing countries is provided by Goldberg and Pavcnik (2007), while Harrison et al. (2011) survey a number of mechanism, including more recent ones, that have been explored to explain the channels through which trade can affect and usually increase income inequality.

¹¹ See also Feenstra and Hanson (2001).

¹² Specifically, using data from 1979 to 1990 for the U.S. manufacturing sector, Feenstra and Hanson (1999) find that offshoring explains 25% of the increase in the relative wage of non-production workers, while technological change explains about 30%.

demand for skill and, consequently, the skill premium in the North and the South. Vannoorenberghe (2011) suggests an alternative mechanism introducing the distinction between skilled and unskilled labor in a North–North model of trade with heterogeneous firms à la Melitz (2003) and assuming that more productive firms are more skill intensive. In Vannoorenberghe (2011), a drop in the variable trade costs raises the wage inequality in the exporting country through two channels. First, it increases the labor demand by exporting skill intensive firms. Second, it drives out of the market the unproductive firms, who release relatively more unskilled labor. Similarly, Harrigan and Reshef (2015) assume a positive relationship between firm-level skill intensity and productivity. However, the model they develop differs from that by Vannoorenberghe (2011) as they assume explicitly free entry of firms and consider two countries that can differ in their relative factor endowments in order to explain why globalization and wage inequality move together in both skill-abundant (North) and skill-scarce (South) countries. In addition, other models that consider firm heterogeneity in productivity levels to describe North–North trade have then been developed to analyze how different types of labor market imperfections shape the way in which trade liberalization affects wage inequality within-industry.¹³ However, differently from the model developed in this paper, all these works do not consider intermediate goods that can be internationally traded.

Finally, a different approach is based on capital accumulation mechanisms and introduces capital-skill complementarities into a Ricardian comparative-advantage framework (Burstein et al. 2013; Eaton and Kortum 2002; Krusell et al. 2000). In these models, imports of capital equipment alter the ratio of skilled-to-unskilled marginal labor productivity and hence the skill-driven wage gap (also referred to as skill premium).¹⁴

The remainder of the paper is organized as follows. Section 2 introduces the theoretical model and derives the predictions on the labor market impact of trade liberalization, which are then tested in Sect. 3, where a series of robustness checks are also performed on both the main empirical results and the model assumptions. Section 4 puts our theoretical and empirical results in the perspective of the existing literature. Section 5 concludes.

¹³ Specifically, this stream of the literature, together with other more recent approach to comparative advantage and inequality, is surveyed in Harrison et al. (2011) and includes the work by Egger and Kreickemeier (2009) who assume that workers care about receiving fair wages, Davis and Harrigan (2011) with efficiency wages, and by Helpman et al. (2010) with search frictions and workers assumed to be heterogeneous in some unobservable ability (we refer the interested reader to the survey by Harrison et al. (2011) for the details on the mechanisms through which trade can increase wage inequalities in these frameworks). In addition, also Montagna and Nocco (2013) study how the interaction between the degree of centralization of wage bargaining and intra-industry competitive selection affects the emergence of within-group wage inequality accounting for the emergence of both inter-firm and intra-firm wage dispersion. Montagna and Nocco (2013) adopt the quasi-linear utility framework developed by Melitz and Ottaviano (2008) and used in the present work.

¹⁴ This literature builds on the extensive empirical literature linking international trade and skill intensity of production, see Verhoogen (2008), Bustos (2011), Koren and Csillag (2011).

2 The model

Consider a world that consists of three countries indexed with $r = i, j, z$, each populated by L_r identical unskilled workers supplying labor services to a competitive industry producing a homogeneous good and to a monopolistically competitive industry in which each firm produces a variety of a horizontally differentiated good. In addition, in each country there are H_r identical skilled workers supplying labor services only to the monopolistically competitive industry. Each differentiated variety s is associated with a constant marginal cost of production equal to the wage of c unskilled workers. To start production, firms are assumed to face three types of fixed costs, which are given by the requirement to employ, respectively, physical capital equipment, intermediate goods and skilled labor. All the producers in the monopolistically competitive sector employ the same technology and are thus homogeneous in their marginal cost of production. Finally, the three countries are assumed to be symmetric both in consumer preferences and in the production technologies of the two sectors, but they may vary in the size of their populations and in the degree of bilateral integration. We turn now to the description of the demand and supply side of the economy which, given the symmetry of the setting, for ease of exposition will be presented without location identifiers. These are reintroduced when trade and market outcomes are presented.

2.1 The demand side

The preferences of each individual ζ are represented by the following quadratic utility function à la Ottaviano et al. (2002) and Melitz and Ottaviano (2008):

$$U(q_0^\zeta; q_s^\zeta, s \in N) = q_0^\zeta + \alpha \int_{s \in N} q_s^\zeta ds - \frac{1}{2} \beta \int_{s \in N} (q_s^\zeta)^2 ds - \frac{1}{2} \gamma \left(\int_{s \in N} q_s^\zeta ds \right)^2 \quad (1)$$

where q_s^ζ is individual ζ 's consumption of variety $s \in N$ of the differentiated good and q_0^ζ is its consumption of the homogeneous good which is chosen as the numéraire of the model; α , β and γ are positive preference parameters. Specifically: α represents the intensity of preferences for the differentiated good relative to the homogeneous good; β represents the degree of consumers' bias towards product differentiation; and γ represents the degree of substitutability between each pair of varieties. The budget constraint of an individual ζ is

$$\int_{s \in N} p_s q_s^\zeta ds + q_0^\zeta = w^\zeta + \bar{q}_0^\zeta \quad (2)$$

where p_s is the price of variety s , w^ζ is the individual's income and \bar{q}_0^ζ is his/her initial endowment of the numéraire, which is assumed to be sufficiently large to ensure that consumers have positive demands for the numéraire in equilibrium.

Maximization of (1) subject to (2) yields the following representative consumer ζ demand function:

$$q_s^\gamma = \frac{\alpha}{(\beta + \gamma N)} - \frac{1}{\beta} p_s + \frac{\gamma}{\beta(\beta + \gamma N)} P \quad (3)$$

where N is the measure of consumed varieties (that are also used by firms as intermediates) with average price $\bar{p} = \frac{1}{N} \int_{s \in S} p_s ds$, and the price index $P = N\bar{p}$. As usual in quadratic utilities, the demand for each variety is influenced by three factors, reflected in the three terms of (3). The first term captures consumers' preference for the differentiated good, which applies to all the varieties; the second is the varieties' own price sensitivity; the third can be interpreted as a cross price elasticity of demand with respect to the general price level, P , which yields the pro-competitive effects of the quadratic utility. Notice that the resulting linear demand displays variable elasticity of substitution ranging from 0 when $p_s = 0$ to ∞ when $q_s = 0$.

2.2 The supply side

In the competitive sector, one unit of the homogeneous good is produced with one unit of unskilled labor. The homogeneous good is assumed to be freely traded and is used as the numéraire. This implies that the unit wage of unskilled workers is equal to one in all countries.¹⁵

In the monopolistic sector, a firm producing variety s employs c units of unskilled labor at the prevailing wage to produce one unit of the good and it incurs a fixed cost of production that consists of three inputs: physical capital equipment, intermediate goods (and services) and skilled labor. Specifically, each firm needs h units of skilled labor (with wage w^H) and capital, built up by the firm consuming K units of the numéraire. Alternatively, as in Picard and Tabuchi (2013), each firm of type s can acquire $q^t(\cdot)$ units of intermediate varieties x at a price $p(\cdot)$ to reduce its need for physical capital. Thus, physical capital and intermediate goods are input substitutes.¹⁶ One interpretation is that a part of the physical capital can be replicated by a set of intermediate inputs at a lower cost. More specifically, the use of a set of all intermediate inputs $q^t(\cdot)$ (available in the country where the firm is producing) reduces the requirement for physical capital to $K - C(\cdot)$ units of numéraire, where for the sake of tractability $C(\cdot)$ is modeled employing the same functional form as the composite good in the consumers' preferences, that is

$$C(q_x^t, x \in N) = \alpha \int_{x \in N} q_x^t dx - \frac{1}{2} \beta \int_{x \in N} (q_x^t)^2 dx - \frac{1}{2} \gamma \left(\int_{x \in N} q_x^t dx \right)^2 \quad (4)$$

where q_x^t is the demand of variety $x \in N$ used as intermediate by a firm and the total cost of intermediates is given by $\int_{x \in S} p_x q_x^t dx$. Notice that this cost of intermediates

¹⁵ The assumptions on the homogeneous good are not only common in many New Economic Geography models, but they also used in trade models such as Melitz and Ottaviano (2008).

¹⁶ Let us notice that in our paper both the parameters m and k , which denote the input–output multipliers in Picard and Tabuchi (2013), are set equal to 1.

and the expression for $C(\cdot)$ in (4) are common to all firms in the monopolistic sector. Finally, since each firm has to employ h units of skilled workers, fixed costs are given by the following expression

$$f = K - C(\cdot) + \int_{x \in N} p_x q'_x dx + hw^H$$

where w^H is the unit wage paid to skilled workers.

As in Picard and Tabuchi (2013), each firm has to set the price p_s for its variety and to determine its demand of intermediate inputs $q'(\cdot)$ produced by other firms. Since the former decision affects operating profits and the latter fixed costs, the two decisions can be disentangled into the maximization of operating profits and the minimization of fixed costs. Given that firm's cost minimization has the same form as the consumer's utility maximization, it entails that the intermediate demand for variety x of each firm has the same form as (3) and is given by

$$q'_x = \frac{\alpha}{(\beta + \gamma N)} - \frac{1}{\beta} p_x + \frac{\gamma}{\beta(\beta + \gamma N)} P. \quad (5)$$

Following Picard and Tabuchi (2013), the minimized fixed cost is then given by

$$F = K - S[p(\cdot)] + hw^H, \quad (6)$$

where $S[p(\cdot)]$ are the cost savings due to the use of intermediates and they are given by

$$\begin{aligned} S[p(\cdot)] = & \frac{\alpha^2}{2(\beta + N\gamma)} N - \frac{\alpha}{\beta + N\gamma} \int_{x \in N} p_x dx + \\ & - \frac{\gamma}{2\beta(\beta + N\gamma)} \left(\int_{x \in N} p_x dx \right)^2 + \frac{1}{2\beta} \int_{x \in S} (p_x)^2 dx. \end{aligned} \quad (7)$$

Given its functional form, the cost savings function features properties similar to the consumer surplus under quadratic preferences, but the interpretation of its parameters is slightly different. The parameter α can here be interpreted as the quality of the intermediates used, whereas better intermediates will be more expensive but allow firms to substitute more capital. Similarly, firms display love for variety in intermediates, which means that a combination of more intermediates can allow firms to save on more capital. However, the benefits of variety are mediated by the parameter γ , capturing the degree of substitutability between intermediate varieties, a higher degree of substitution being associated with lower gains from variety N .

2.3 Trade and market outcomes

Each firm s located in country $r = i, j, z$ produces for market $v = i, j, z$ the quantity that satisfies both the demand of consumers and of firms located in v , that is

$$q_{s,r\nu} = q_{s,r\nu}^c(H_\nu + L_\nu) + q_{s,r\nu}^f M_\nu \quad (8)$$

where $q_{s,r\nu}^c$ and $q_{s,r\nu}^f$, respectively, denote the demand per consumer and firm located in country ν for the production of firm s located in country r . The number of skilled and unskilled workers is denoted, respectively, by H_ν and L_ν ; the number of firms producing (and thus buying intermediates) in ν is given by M_ν . Moreover, given that h units of skilled workers are employed as a fixed input to produce each variety, assuming full employment, the number of firms in country ν can be expressed as

$$M_\nu = \frac{H_\nu}{h}.$$

This implies that the price index for the differentiated good in country ν is

$$P_\nu = \int_{x \in N_\nu} p_{x,r\nu} dx = \frac{H_i}{h} p_{i\nu} + \frac{H_j}{h} p_{j\nu} + \frac{H_z}{h} p_{z\nu}. \quad (9)$$

Finally, given that all firms are symmetric and they sell in all markets, the overall number of varieties used as intermediates by firms and consumed by workers is equal in all countries and given by $N_\nu = M_i + M_j + M_z = N$ with

$$N = \frac{H_i + H_j + H_z}{h}$$

Operating profits of a representative firm that produces in r are obtained by adding operating profits that derive from sales in all the three countries. Specifically, operating profits obtained by a firm s producing in r from its sales in country ν are given by

$$\pi_{s,r\nu} = (p_{s,r\nu} - \tau_{r\nu}c)q_{s,r\nu} \quad (10)$$

where $\tau_{r\nu} > 1$ denotes iceberg trade costs: each firm producing in r has to ship $\tau_{r\nu}$ units of its production from r in order to have one unit sold in ν . Moreover, $\tau_{r\nu} = 1$ when $r = \nu$, that is there are no domestic trade costs. We also assume symmetric trade costs and symmetric reductions between any pair of countries, i.e. $\tau_{r\nu} = \tau_{\nu r}$. Hence, markets are segmented and each firm can sell its product at different prices in different markets.

Then, making use of (10) and (6), pure profits π_r of firm s which produces in country r are

$$\pi_{s,r} = \pi_{s,ri} + \pi_{s,rj} + \pi_{s,rz} - F_{s,r} \quad (11)$$

where minimized fixed costs in r , $F_{s,r}$, can differ across the three countries for firms having the same technology because of differences in: (i) the wage of skilled workers w_r^H ; and (ii) the price of intermediate goods used in r (which is equal to the price of consumption goods available in r because of the optimization of similar functional forms), that is $P_r = \int_{x \in N_r} p_{x,rv} dx$.

In equilibrium, firms earn zero profits and this implies that using (11), the unit wage paid by each firm s at location r to skilled workers is bid up to

$$w_r^H = \frac{\pi_{ri} + \pi_{rj} + \pi_{rz} - K + S[P_r]}{h}. \tag{12}$$

Since markets are segmented, each firm s producing in r sets its price for market v by

$$\max_{p_{s,r,v}} \pi_{s,r,v} = (p_{s,r,v} - \tau_{rv}c)q_{s,r,v}$$

subject to its demand function in v

$$q_{s,r,v} = (L_v + H_v + M_v) \left[\frac{\alpha}{(\beta + \gamma N)} - \frac{1}{\beta} p_{s,r,v} + \frac{\gamma}{\beta(\beta + \gamma N)} P_v \right]$$

obtained substituting (3) and (5) into (8). This demand function displays standard properties in a quadratic preference setting. The higher the preference for the differentiated good and/or the quality of the intermediates used, α , or the degree of substitution between varieties (captured by higher γ or lower β), the more consumers will be willing to buy. In addition, an increase in the price index P_v , which signals a higher price of competing varieties, is associated with a higher demand for the individual variety s , perceived as relatively cheaper.

A well-known property of quadratic utilities is the presence of different markups across firms, resulting from the variable elasticity of substitution. A way to see how it works out in the framework used in this paper is to consider the choke price for variety s produced in r and sold in market v , i.e. the price such that $q_{s,r,v} = 0$, which is

$$p_{0,s,r,v} = \frac{\alpha\beta + \gamma P_v}{\beta + \gamma N}, \tag{13}$$

which allows us to rewrite the demand function as

$$q_{s,r,v} = \frac{(L_v + H_v + M_v)}{\beta} [p_{0,s,r,v} - p_{s,r,v}],$$

whose price elasticity is simply

$$\epsilon_{s,r,v} = \frac{p_{s,r,v}}{p_{0,s,r,v} - p_{s,r,v}}. \tag{14}$$

This concise price elasticity formulation encapsulates a wealth of information. First of all, it shows that the elasticity of substitution varies between 0 and ∞ as $p_{s,r,v}$ goes from 0 to $p_{0,s,r,v}$. In addition, by looking at (13), we can see that $p_{0,s,r,v}$ grows in α and, more importantly, in the price index in the destination market P_v , which can be directly affected by trade policy. For example, a decrease in P_v due to trade liberalization in v with a third country will lower the choke price of goods s produced in r , $p_{0,s,r,v}$, and hence increase their perceived elasticity and lower equilibrium prices and profits.

In fact, the price set in market v by firm s producing in r is

$$p_{s,rv} = \frac{1}{2} \tau_{rv} c + \frac{\alpha\beta + \gamma P_v}{2(\beta + \gamma N)}. \quad (15)$$

The profit maximizing price $p_{s,rv}$ and output level $q_{s,rv}$ of a firm with cost c satisfy

$$q_{s,rv} = \frac{(L_v + H_v + M_v)}{\beta} (p_{s,rv} - \tau_{rv} c) \quad (16)$$

and maximized operating profits are

$$\pi_{s,rv} = \frac{(L_v + H_v + M_v)}{\beta} (p_{s,rv} - \tau_{rv} c)^2. \quad (17)$$

We can substitute prices from (15) in (9) keeping in mind that N is common to all countries to get

$$P_v = \frac{N \frac{\alpha\beta}{2(\beta+\gamma N)} + \frac{1}{2} \delta_v c}{1 - \frac{\gamma N}{2(\beta+\gamma N)}}, \quad (18)$$

where δ_v can be interpreted as an inverse measure of openness to trade of country v , $\delta_v = M_i \tau_{iv} + M_j \tau_{jv} + M_z \tau_{zv}$. Notice that, if trade is frictionless, then $\tau_{iv} = \tau_{jv} = \tau_{zv} = 1$ and $\delta_v = N$.

Making use of (16), (15) and (18), we get that local sales of a firm producing in i are

$$q_{s,ii} = \frac{L_i + H_i + M_i}{\beta} \left[\alpha \frac{\beta}{2\beta + \gamma N} + \frac{1}{2} \gamma c \frac{H_j \tau_{ji} + H_z \tau_{zi}}{(2\beta + \gamma N)h} - \mu_i \frac{1}{2} c \right], \quad (19)$$

where $0 < \mu_i = 1 - \frac{\gamma M_i}{(2\beta + \gamma N)} < 1$ as $M_i < N$. The export quantity, respectively, to j and z for a firm producing in i are

$$\begin{aligned} q_{s,ij} &= \frac{L_j + H_j + M_j}{\beta} \left[\alpha \frac{\beta}{2\beta + \gamma N} + \frac{1}{2} \gamma c \frac{H_j + H_z \tau_{zj}}{(2\beta + \gamma N)h} - \mu_i \frac{\tau_{ij}}{2} c \right] \\ q_{s,iz} &= \frac{L_z + H_z + M_z}{\beta} \left[\alpha \frac{\beta}{2\beta + \gamma N} + \frac{1}{2} \gamma c \frac{H_z + H_j \tau_{jz}}{(2\beta + \gamma N)h} - \mu_i \frac{\tau_{iz}}{2} c \right]. \end{aligned} \quad (20)$$

Thus, it is readily verifiable from (20) that the quantities exported by firms in i towards j , $q_{s,ij}$, increase if τ_{ij} decreases, as usually found in the literature where two countries are considered (Melitz and Ottaviano 2008). In addition, the introduction of a third country in our analysis allows us to show also that quantities $q_{s,ij}$ decrease when τ_{jz} decreases but are not affected by a reduction in τ_{iz} .

Therefore, bilateral trade liberalization like FTAs and PTAs (here assumed symmetric for analytical tractability, also based on the observation that the majority of bilateral reductions in trade barriers stem from negotiations involving some degree of reciprocity) increases the market access into member countries and stimulates bilateral trade flows. This diverts trade from the excluded country, which

experiences a reduction in its exports towards the two integrating countries. Moreover, the bilateral liberalization between country i and j also implies bilateral trade in cheaper intermediate imports and, therefore, firms producing in countries i and j can use cheaper intermediates to substitute physical capital. Hence, in the vertical linkages framework developed here intermediates reduce firms' fixed costs for capital. This is a crucial difference with respect to existing models linking trade and labor market outcomes.

In addition to the fixed-costs assumption, the lack of increase in exports to third countries stems from the assumption of market segmentation. This former assumption is widely documented in the literature (Engel and Rogers 2001; Görg et al. 2010) and warrants that changes in market aggregates in one country do not spill over directly to other markets (they may do so only over time, due to an overall reallocation of productive resources in the economies).

In terms of predictions, turning to the labor market outcomes, one proposition can be derived from the model. Noting that unskilled workers are employed proportionally to the quantities produced, it can be noted from (19) and (20) that the number of unskilled workers employed in country i decreases on the domestic segment and increases in the export segment if trade barriers decrease. The overall effect is ambiguous and depends on the parameters of the model.

Proposition 1 *Unskilled employment loss on the domestic segment: a decrease in trade barriers for country i is expected to reduce employment of unskilled workers producing in i for the domestic market and increase employment in the export segment.*

In other words, once the level of exports is controlled for, a decrease in trade barriers is expected to decrease the employment level of unskilled workers. Here the intuition is straightforward. For a firm producing in country i merely for the domestic market, the reduction in the bilateral trade cost with countries j and z represents just an increase in the competition against imported goods, which reduces the volumes produced and hence in the employment of unskilled workers. However, the cheaper trade costs will make the export segment more profitable.

Turning to the predictions on the wage gap, making use of (15), (17) and (18), maximized operating profits of a firm producing in i from local sales and exports in country j and z are respectively given by

$$\pi_{s,ii} = \frac{(L_i + H_i + M_i)}{\beta} \left[\alpha \frac{\beta}{2\beta + \gamma N} + \frac{1}{2} \gamma c \frac{H_j \tau_{ji} + H_z \tau_{zi}}{(2\beta + \gamma N)h} - \mu_i \frac{1}{2} c \right]^2; \quad (21)$$

$$\pi_{s,ij} = \frac{(L_j + H_j + M_j)}{\beta} \left[\alpha \frac{\beta}{2\beta + \gamma N} + \frac{1}{2} \gamma c \frac{H_j + H_z \tau_{zj}}{(2\beta + \gamma N)h} - \mu_i \frac{1}{2} \tau_{ij} c \right]^2 \quad (22)$$

and

$$\pi_{s,iz} = \frac{(L_z + H_z + M_z)}{\beta} \left[\alpha \frac{\beta}{2\beta + \gamma N} + \frac{1}{2} \gamma c \frac{H_z + H_j \tau_{jz}}{(2\beta + \gamma N)h} - \mu_i \frac{1}{2} \tau_{iz} c \right]^2. \quad (23)$$

Notice that domestic profits are expected to be negatively affected by a decrease in trade costs vis-à-vis the other two countries, the more so the higher the number of firms producing abroad. The opposite is true for profits obtained from exports, which increase when the bilateral trade barriers with the trade partner are lowered. However, the effect on profits is negative for firms exporting from third countries towards the integrating countries. The latter suffer a decrease in profits similar to the losses on the domestic market of the firms in the integrating markets, but are not compensated by higher sales elsewhere (differently from the firms in the integrating markets, exporting more to each other). Expressions (21)–(23), together with the expression for $S(P_i)$ can be substituted into (12) to get w_i^H .

Trade liberalization is expected to increase firms' savings on the fixed costs by allowing them to source cheaper intermediates. Indeed, $S(P_i)$ increases when τ_{zi} decreases as it can be shown that

$$\frac{\partial S(P_i)}{\partial \tau_{zi}} = -M_z \frac{1}{2} c \left[\frac{\alpha}{\beta + \gamma N} - \frac{1}{\beta} p_{s,zi} + \frac{\gamma}{\beta(\beta + N\gamma)} P_i \right] < 0,$$

where $\left[\frac{\alpha}{\beta + \gamma N} - \frac{1}{\beta} p_{s,zi} + \frac{\gamma}{\beta(\beta + N\gamma)} P_i \right] > 0$ as long as $q_{s,zi} > 0$.¹⁷

Turning our attention to the wage of skilled workers in i , from Eq. (12) we can see that skilled workers' wages depend on the savings function $S(P_i)$ and firms' profits in i . Hence, the overall effect of changes of τ_{zi} on the salary is given by

$$\frac{\partial w_i^H}{\partial \tau_{zi}} = \frac{\partial \pi_{s,ii}}{\partial \tau_{zi}} + \frac{\partial \pi_{s,iz}}{\partial \tau_{zi}} + \frac{\partial S(P_i)}{\partial \tau_{zi}}.$$

The algebraic sum of the first two addends of $\frac{\partial w_i^H}{\partial \tau_{zi}}$, that is $\frac{\partial \pi_{s,ii}}{\partial \tau_{zi}} + \frac{\partial \pi_{s,iz}}{\partial \tau_{zi}}$, is negative with $\alpha > \tau_{iz}$ and $\alpha > c\tau_{iz}$ if and only if the size of the domestic country ($H_i + L_i$) is relatively not too large compared with that of the other integrating economy (notice that M_i depends on H_i). That is, if

$$\frac{(H_i + L_i + M_i)}{(H_z + L_z + M_z)} < \frac{(2\beta + N\gamma) 2\beta(\alpha - c\tau_{iz}) + c\gamma(M_z + M_j\tau_{jz} + M_i\tau_{zi} - N\tau_{iz})}{\gamma M_z 2\beta(\alpha - c) + c\gamma(M_i + M_j\tau_{ji} + M_z\tau_{zi} - N)}.$$

¹⁷ Specifically, using (18) and the following expression

$$\int_{x \in N} p_x^2 dx = \left[\frac{\alpha\beta + \gamma P_i}{2(\beta + \gamma N)} \right]^2 N + \frac{1}{4} c^2 \frac{H_i + H_j\tau_{ij}^2 + H_z\tau_{iz}^2}{h} + c \frac{\alpha\beta + \gamma P_i}{2(\beta + \gamma N)} \delta_i$$

we can rewrite $S(P_i)$ in (7) as follows

$$S(P_i) = \frac{1}{2} \alpha^2 N \frac{\beta + \gamma N}{(2\beta + \gamma N)^2} + \frac{1}{4} c \frac{2\alpha\beta + c\gamma\delta_i}{\beta(2\beta + \gamma N)} - \frac{1}{8} c\delta_i(4\beta + 3\gamma N) \frac{4\alpha\beta + c\gamma\delta_i}{\beta(2\beta + \gamma N)^2} + \frac{1}{8\beta} c^2 \frac{H_i + H_j\tau_{ij}^2 + H_z\tau_{iz}^2}{h}$$

which depends on τ_{ij} and on τ_{iz} , while it is not directly affected by τ_{jz} . Notice that while $S(P_i)$ is affected by the endowments of skilled workers in the three countries, it is not affected by the endowments of unskilled workers.

Thus, given that $\frac{\partial S(P_i)}{\partial \tau_{zj}} < 0$, a sufficient condition to have $\frac{\partial w_i^H}{\partial \tau_{zj}} < 0$ is that the size of the domestic country i ($H_i + L_i$) is relatively not too large compared with that of the other integrating economy z . Finally, as the numerator (denominator) decreases (increases) with τ_{iz} , the condition above is more likely to hold the smaller the value of τ_{iz} is. In other words, when two economies are sufficiently integrated, the wage of skilled workers is more likely to increase when there is a reduction in their bilateral trade costs.

Also numerical analysis shows that w_i^H increases if τ_{ji} decreases for sufficiently integrated small, open country pairs.¹⁸ For instance, Fig. 1 shows that w_i^H increases when τ_{ji} decreases for all relevant values of trade costs. The positive relation between market access (lower τ_{ji}) and w_i^H becomes less obvious when the size of the economies grows (i.e. increases in the endowment of unskilled workers). In Fig. 1 panels b and c show that such positive relation holds true for country pairs with sufficiently high initial market access. Specifically, all the cases plotted in Fig. 1 show that the wage of skilled workers in the integrating economy increases with the level of market access granted by its partner country, this is always true for country pairs with not too low level of initial integration.¹⁹ We believe that this is the relevant case to be considered here. Indeed, our labor market estimations are based on OECD countries that show high levels of integration in the starting year (as shown in Table 2, for the average tariff level faced by each OECD country in 1996).

The increase in the wage of skilled workers in the integrating countries is due to total firms' profits increase as a consequence of lower cost of intermediates $S[N_r, P_r]$ in (7). At first sight, this finding may appear in contradiction with Eq. (22), in which reduction in τ_{zi} are shown to have no impact on π_{ij} , a positive impact on $\pi_{s,iz}$ in equation (23) and a negative impact on the more important domestic market $\pi_{s,ii}$ in Eq. (21). It is not so because it should be remembered that the expressions (21)–(23) refer to operating profits, whereas skilled worker wages are paid from total profits, which benefit from the reduction in fixed costs engendered by cheaper intermediates even if such reduction in fixed costs is not passed through to selling prices. Considering that the unskilled workers are remunerated at the wage they could obtain by producing and selling the numéraire, the following proposition holds:

Proposition 2 *Trade-liberalization-driven wage gap: a decrease in the trade barriers faced by country i is expected to increase the wage gap between skilled and unskilled workers in i for sufficiently high levels of trade openness.*

Bilateral liberalization between country i and j makes imported intermediate inputs cheaper and thus reduce the fixed costs of the firm. Cheaper intermediate inputs translate into a reduction in the total fixed cost of the firm and thus into increased total profits. Since skilled workers are assumed to be the factor remunerated from total

¹⁸ All the curves in the figure are obtained for $\tau_{zj} = 4$, $\alpha = 10$, $h = 1$, $\beta = 2$, $c = 0.1$, $\gamma = 2$, $\tau_{zi} = 3$ and $K = 15$. Notice that all the black, red and green lines are, respectively, drawn for $\tau_{ij} < 6.5383$, $\tau_{ij} < 7.1429$, $\tau_{ij} < 8.1250$ so that $q_{ij}(s) > 0$.

¹⁹ The wage of skilled workers in Fig. 1 tends to rise in i for a given level of economic integration τ_{ij} , when they become relatively less abundant in unskilled workers (this can be seen for a given value of τ_{ij} comparing the wage curves of the same color in the three different panels of Fig. 1).

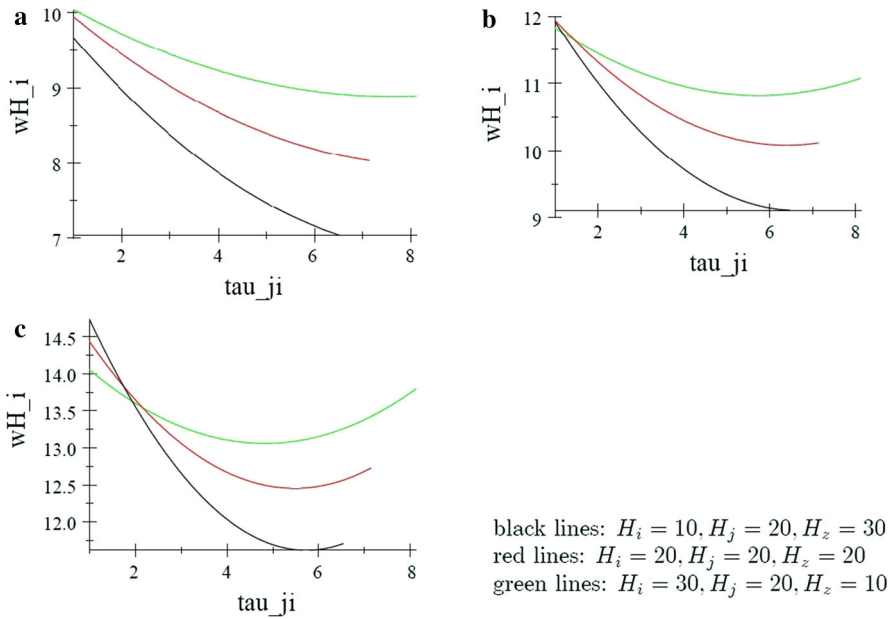


Fig. 1 Simulation of impact of tariff reductions on skilled workers' wages in i

profits (zero profit condition), the wage of skilled workers increases while the wage of unskilled remains unchanged. That's how bilateral trade liberalization affects the skill premium in this model. Notice that our results hold for the case of trade liberalization between countries that have similar level of development and are sufficiently integrated, which differ from those obtained by Feenstra and Hanson (1996) who, instead, analyze how trade liberalization contributes to explain increases in wage inequality due to foreign outsourcing of intermediate inputs that are more intensive in unskilled work from the North to the South, which is the relatively skill poor country. In so doing we are identifying a new channel through which trade in intermediates can affect wage inequality when there is a process of trade integration, that is a channel that can act also among similar countries (that is North–North trade) that reciprocally trade intermediate goods. This is a peculiar feature of our model that we explicitly consider in our empirical estimations.

Proposition 3 *Skilled employment unaffected by trade liberalization: a decrease in trade barriers for country i is not expected to affect domestic skilled employment levels in the short run.*

This theoretical property of the model is the result of the combination of the assumptions of a production technology assuming a fixed amount of skilled workers per firm and inelastic skilled labor supply, implying that all skilled workers would accept to work at the prevailing wage in the labor market. These two assumptions are common in New Economic Geography models and imply that skilled workers are needed in fixed quantities to set up a firm and thus absorb all the operating profits of the existing firms, so that in the short run only their remuneration changes

after a shock, but not their supply of labor (Forslid and Ottaviano 2003). In the long run, if the number of skilled workers adjust to changes in the salary to allow for net entry or exit of firms, then also skilled employment levels would be affected, but for the empirical validation of the model, we focus on the short run. It should be noted that the combination of differentiated impact of trade liberalization on unskilled workers on the domestic and export segment of production, combined with an increase in the wage gap and the lack of effects of skilled employment is a unique feature of the model presented in this paper, which cannot be replicated by existing models linking trade shocks and labor market outcomes.

Finally, before turning to the empirical validation of the theory, it is worth noting that the model can also be used to contribute to the debate on the welfare effect of trade liberalization. Indeed, in what follows we show that, since prices in the integrating countries fall and real wages increase for skilled and unskilled workers, tariff reductions are locally welfare improving for the participants of the agreement and are likely to be globally beneficial, as inferred theoretically from the observation that the only loss in the third countries stems from the profit shifting to the integrating countries. In addition, while no changes in market prices are expected in the excluded country, consumers in the integrating countries have access to cheaper final goods and a lower price index.

Specifically, the system of preferences expressed in (1) can be used to draw the indirect utility functions capturing the welfare of consumers in the three countries considered:

$$W^\zeta = \frac{\alpha^2 N}{2(\beta + \gamma N)} - \frac{\alpha}{\beta + \gamma N} \int_{s \in N} p_s ds + \frac{\int_{s \in N} (p_s)^2 ds}{2\beta} - \frac{\gamma}{2\beta(\beta + \gamma N)} \left(\int_{s \in N} p_s ds \right)^2 + w + \bar{q}_0, \quad (24)$$

from which it can be noted that²⁰

$$\frac{\partial W^\zeta}{\partial p_s^\zeta} < 0; \quad \frac{\partial W^\zeta}{\partial w^\zeta} > 0.$$

Combining this result with the impact on prices, from Eqs. (15) and (18), and the impact on profits and skilled workers' wages, from Eqs. (21)–(23), we can affirm that the decreases in tariffs can have a positive impact on the welfare of the consumers of the countries involved at least for economies that are sufficiently integrated. Thus, our results support Wonnacott's (1996) intuition that the benefits of trade creation can be expected to more than offset the losses of welfare caused by trade diversion when PTAs or bilateral tariff reductions result in lower prices. In our model this outcome is driven by the fact that the price index will reflect the higher importance in the bundle of consumption of cheaper varieties imported from the integrating partners.

Turning to the countries excluded from trade liberalization, it should be noticed that their domestic price indexes will not be affected; but firms' profits and skilled workers'

²⁰ The sign of the first derivative is negative as this is consistent with a positive value of quantities in (3).

salaries will be affected negatively from the fact that their exports will face a tougher competition in the integrating markets, whose price index will instead decrease. However, from (22) it follows that the increase in export profits and high skilled workers' salaries in the integrating countries could be higher than the loss of export income in the excluded country. Therefore our model suggests that even a bilateral tariff reduction can be associated with static global welfare gains. Indeed, consumers in the integrating regions could experience improvements in their welfare that exceed the welfare losses incurred by the countries excluded, whose only sources of loss are the profits shifted towards the integrating countries due to trade diversion.

This result has to be taken *cum grano salis* because the framework developed here leaves income effects aside for the sake of tractability. Nevertheless, our results contribute to the long-standing debate on the welfare impacts of regionalism as opposed to multilateralism (see Krishna and Panagariya (2002), and Bhagwati (1993) for recent studies or Viner (1950), for an earlier one), confirming that under certain conditions bilateral trade liberalization is both locally and globally welfare improving.

3 Testing the model predictions

This section is devoted to the empirical test of the three propositions on the impact of trade liberalization on: unskilled employment (Proposition 1); the wage gap between skilled and unskilled workers (Proposition 2); skilled employment (Proposition 3). We use a wage-premium estimation strategy based on Revenga (1997) using both OLS and 2SLS estimations to solve the endogeneity problem of export tariffs.

3.1 Data and facts on trade policy environment

The labor market data used in our empirical tests come from the EU KLEMS dataset²¹ reporting information on wage and employment level by skill group (primary, secondary and tertiary education). In particular, we have information on the number of hours worked (rather than the number of employees) and labor compensation by country, sector (ISIC 2-digit rev.3) and skill group for a sample of 17 OECD countries and 28 manufacturing sectors in the period 1970–2005.²²

Tariff data are obtained from the TRAINS dataset and refer to the effectively applied tariff for each country pair on a specific HS-4 heading.²³ For the sake of

²¹ EU KLEMS Growth and Productivity Accounts: March 2008 Release. See Timmer et al. (2007) for further details.

²² In what follows we classify tertiary and secondary educated workers as "Skilled" and primary educated workers as "Unskilled" workers. In addition, EU KLEMS does not provide information on employment but on the number of hours worked in a given sector-skill group. Although EU KLEMS provides also labor market data on service sectors, we focus on manufacturing sectors for two reasons. First, our theoretical model would not fit properly service sectors. Second, we do not have trade and tariff data for service sectors.

²³ TRAINS provides effectively applied ad-valorem tariff (minimum between preferential and MFN) and ad-valorem equivalent for non-ad valorem measures.

coherence with the labor market data, we converted these tariff data into the ISIC 2-digit (rev.3) classification using the correspondence Tables from Eurostat RAMON (Reference And Management Of Nomenclatures).²⁴

Trade data come from BACI (CEPII), which provides information on values and quantities of export flows (in USD and tons, respectively) for a complete set of exporting and importing countries in the period 1989–2014. However, our final sample shrinks to the 1996–2005 period because tariff data are available only from 1996 and EU KLEMS data only up to 2005. BACI provides trade data at the product level (classification HS 6-digit), which we convert into ISIC 2-digit industry level to be consistent with labor market data from EU KLEMS. We also use trade data to compute the export specialization of each country in each sector (share of country-sector exports over total country's exports).

The trade policy environment changed substantially in the last 20 years and worldwide tariff protection decreased consistently thanks to the proliferation of Preferential Trade Agreements, which increased from 70 in 1990 to 300 in 2010 (see Figure B1 of the World Trade Report 2011). For example, Table 1 shows average applied tariffs faced by different groups of exporting countries (World, OECD and non-OECD) in our sample in the years 1996 and 2005.²⁵ It can be noted that both OECD and non-OECD countries experienced a decrease in the applied export tariff levels. Since our estimations focus on OECD countries (EU KLEMS data cover OECD countries only), in Table 2 we report the same kind of descriptive evidence but for all the OECD countries in our sample.²⁶ It emerges that the majority of OECD countries experienced a reduction in average applied tariff over the period considered.²⁷

Before moving to the econometric exercise, in Fig. 2 we show preliminary evidence on the negative correlation between wage gap and tariff protection. In the vertical axis we report the conditioned wage gap in a given country-sector,²⁸ while in the horizontal axis we report the corresponding average export tariffs. We

²⁴ We first converted HS classification into SITC classification and then from SITC to ISIC rev.3 (to our knowledge there is not a direct correspondence table from HS to ISIC). We use correspondence tables publicly available from Eurostat RAMON web site. These correspondences can be safely done since the sector in which the firm exports is presumably the same as the one in which produces.

²⁵ The average tariff level faced by the group of exporting countries (World, OECD and non-OECD) in our sample has been computed as follows:

$$Tariff_{world,t} = \frac{1}{R} \sum_r Tariff_{r,t}$$

where R is the sample of exporting countries r , and $Tariff_{r,t}$ is the export tariff faced by country r at time t . We replicated this calculation using a sub-sample of OECD and then non-OECD exporting countries.

²⁶ Notice that differences in export tariffs across EU countries are due to different sets of destination country-sectors.

²⁷ For some Eastern European countries the average tariff faced in exporting has increased over the period 1996–2005 because of changes in the set of destinations countries and the application of EU-wide tariffs after accession in 2004.

²⁸ Conditioned on sector and country fixed effect to control for any sector and country specific factor affecting the wage gap.

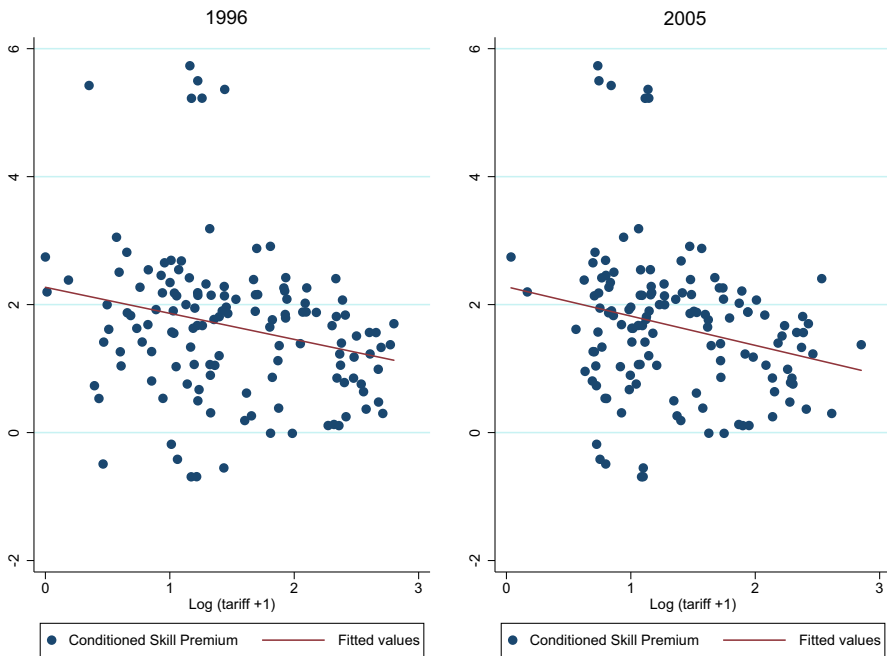


Fig. 2 Wage gap and tariff. Wage gap conditioned on country and sector fixed effects. *Note* Conditioned wage gap is the residual of a OLS regression having wage gap as dependent and sector and country fixed effects as regressors. *Source*: Authors on WITS and EU KLEMS data

observe a negative correlation in both the starting (1996) and final year (2005) of our empirical sample, coherently with the theoretical implication described above.

3.2 From theory to empirics

Moving from the theoretical predictions to the empirical tests, we have to address two main data-driven limitations. First, while the theoretical model has a clear prediction on the effect of tariff liberalization on the employment of unskilled workers used in the *domestic* segment of production, EU KLEMS data provide employment by skill-sector for the overall production of a country (domestic and export segment together).²⁹ To overcome this data limitation we approximate the *domestic* segment of a country-sector employment using Input–Output tables, multiplying the number of hours worked in each country-sector by its domestic share of production (from WIOD input/output tables).³⁰

The second data limitation concerns the different structure of trade and employment data. While tariffs are bilateral in nature, because each country-sector faces a different tariffs in the different destination countries), employment data can

²⁹ To the best of our knowledge, there are not other sources providing employment data by skill-sector differentiating between domestic and export-devoted production.

³⁰ From WIOD input/output tables, for each country-sector-year, we calculated the share of the total production dedicated to the domestic demand.

be only country or country-sector specific. Thus we have to define market access at the country-sector level and we do it using a the simple (and weighted) average of export tariffs faced by each country-sector across all its export destinations. We compute such average tariffs using two sets of destinations. First, we use all the destination countries. Then, to test the robustness of the theoretical predictions on North–North trade discussed in Sect. 2.3, we compute the average tariff across destinations having the same income level as the exporters (income level defined by the World Bank classification).

3.3 Empirical specification

According to our theoretical model (Propositions 1 and 2), trade liberalization (or a reduction in export tariffs) implies a decrease in the level of unskilled workers employed in the domestic segment of production, and an increase in the wage gap between skilled and unskilled workers. A peculiar feature of our theoretical model is the absence (in the short run) of any effect on skilled workers, i.e. skilled workers' services are supplied inelastically—Proposition 3. In order to test these propositions, we estimate the following reduced-form equation (based on Revenga 1997) using country-sector-year level data:

$$\ln(y)_{r,p,t} = \phi_{r,t} + \phi_{p,t} + \beta_1 \text{Log}(\text{Tariff} + 1)_{r,p,t} + \beta_2 X_{r,p,t} + \varepsilon_{r,p,t} \quad (25)$$

where r , p and t denote respectively the exporter country, ISIC sector and year. The dependent variable $y_{r,p,t}$ is in turn: (i) the number of hours worked by unskilled workers in the domestic segment of production (unskilled employment, to test Proposition 1); (ii) the ratio between skilled and unskilled workers' compensation (wage gap, to test Proposition 2); (iii) the number of hours worked by skilled workers (skilled employment, to test Proposition 3).

Our main explanatory variable is the log of the *simple* average export tariff faced by each country-sector across its export markets (i.e. sector-specific average across all partner countries). Then we also use *weighted* average export tariff as a robustness check (weighted by the level of exports to the corresponding partner). In all specifications we include country-year ($\phi_{r,t}$) and sector-year ($\phi_{p,t}$) fixed effects to control for the exporter-year- and sector-year-specific characteristics. Country-year fixed effects capture differences in labor market characteristics (legislation) among countries (i.e. rigidities in labor market) and any macroeconomic dynamics in exporting countries. Sector-year fixed effects capture sector specific shocks common to all countries (i.e. technology or productivity).³¹ In particular, sector-year fixed effects control for technology shocks affecting the wage gap. Indeed, sector specific technological shocks might move the production process towards

³¹ We were prevented to include also country-sector fixed effects because there is not enough time variation in the tariffs for a given country-sector. Indeed, much of the variation in tariff levels shown in Table 2 is due to sector composition of exports by OECD countries. However, in a robustness check we run an alternative specification including country-sector fixed effects (with cluster standard errors) aimed at capturing any unobserved country-sector specific heterogeneity (i.e. within estimation). As expected, this drastically reduces the explanatory power of tariffs (because of the limited variation over time), but the sign of coefficients is in line with our baseline results. See Appendix Table 11

more human capital intensive technology, and so, to an increase in the wage gap. This channel is captured by sector-year fixed effects.

The vector of control variables $X_{r,p,t}$ includes the export specialization of a country in a given sector, defined as the sector export share over total country's exports.³² It is meant to capture the combined effect of all unobservable trade-related channels—other than trade liberalization (tariffs)—on relative wages and specific-factor endowments, as suggested by Carrere et al. (2014). The set of control variables includes also the growth rate of TFP in each country-sector³³ to capture country-sector specific productivity trends that might affect the wage of skilled workers. Tariff liberalization may increase the wage gap also through the complementarity between intermediate inputs and different types of workers.³⁴ If intermediate inputs and skilled workers are complement, then the reduction of the price of imported intermediate inputs would imply an upward pressure on the wage of skilled workers. In order to control for this effects, we augment the baseline specification (25) by including the contribution of intermediate inputs to total output growth in a given country-sector (in percentage points as from EU KLEMS), and its interaction with the average export tariff.³⁵

3.3.1 Endogeneity

While the sets of fixed effects and control variables included in the estimation crucially reduce the omitted variable problem, some concerns on the simultaneity of tariff level need to be addressed. Indeed, as highlighted by Goldberg and Pavcnik (2005) the causation can go either way. If trade liberalization pushes more productive (or able) workers from liberalized to protected sectors, the coefficient on

³² Formally, $ExportIntensity_{r,p,t} = \frac{\sum_{v \in V} export_{r,v,p,t}}{\sum_{p \in P} \sum_{v \in V} export_{r,v,p,t}}$, where r , p and t have the same meaning as above, and v stands for the trade partner.

³³ The TFP growth is computed on value added based TFP, and it is directly provided by EU KLEMS data. A full description of the methodology used by EU KLEMS in computing the TFP growth is available here: http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_I_Methodology.pdf. We used the TFP growth at the beginning of the period to reduce concerns of endogeneity.

³⁴ Preferential Trade Agreements, PTAs, are often symmetric. So any reduction in the export tariff comes with a reduction in the import tariff also.

³⁵ The contribution of intermediate inputs to total production growth aims at approximating the importance of intermediate inputs for a given country-sector. In computing this variable, EU KLEMS considers both domestic and foreign produced intermediate inputs. A full description of the methodology used by EU KLEMS to compute this share is available here: http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_I_Methodology.pdf. We use intermediate inputs intensity in the initial year in order to reduce any endogeneity concerns. Indeed, variations in wage gap might affect also the share of intermediate input used in the sector, we address such (remote) reverse causality concern by using intermediate inputs intensity in the initial year. This is not problematic in our setting as the share of intermediate is simply used to characterize a sector-country in a static way. However, constant unobserved heterogeneity correlated with the intermediate input share may introduce an omitted variable bias in the estimation. So, as a robustness check, in Table 11 in Appendix we estimate our baseline model on wage inequality including country-sector fixed effects. Although the little variation of tariff over time, the sign and the statistical significance of our coefficient of interest hold, but it reduces in magnitude as we now explain the pure within variation in the wage inequality.

tariff level would be upward biased. But it may also happen that firms respond to trade liberalization by firing less productive (or able) workers, which would imply that the remaining workers represent a sample of more productive and better paid workers, which bias the tariff coefficient. In other words, the tariff variable could capture the proper tariff-liberalization effect and the indirect effect through the sample of workers (composition effect). To solve this problem, we follow a 2SLS approach. Our instrument, *Regional Avg Tariff*, is based on the domino effect in trade liberalization (Baldwin and Jaimovich 2012). The idea is that countries in the same region face similar export tariff because tend to mimic liberalization policies of neighbor countries to avoid diversion effect. So, our instrument is computed as:

$$RegionalAvgTariff_{r,p,t} = \frac{1}{V} \sum_{v \in V} Tariff_{v,p,t} \quad (26)$$

with v being an exporting country in the same region as country r (we use the World Bank region classification of countries). Here the exclusion restriction is that the tariffs faced by neighbor country v across its destinations is not correlated with the labor market characteristics in country r . In the case of two endogenous variables, when we include both tariffs and its interaction with the contribution of intermediate inputs on sector's growth, we use two instruments: the region average tariff and its interaction with the contribution of intermediate inputs to the total production of the sector.

3.4 Employment impacts of trade liberalization

Table 3 shows the baseline results for the OLS estimations on the level of unskilled employment in the *domestic* segment of production in columns (1) to (5) and in the *export* segment in columns (6) and (7). We find strong evidence supporting *Proposition 1*. The coefficient on tariff is positive and significant in all specifications in columns (1) to (5), implying that a reduction in the export tariff faced by a country-sector is associated with a decrease in the employment of unskilled workers in the domestic segment of production. Interestingly, this result holds also when we restrict the sample of destinations to countries in the same income group to compute the average export tariff in columns (4) and (5). This is an important robustness check, as our theoretical model delivers predictions also for "similar" trade partners, in terms of income level, which is a standard proxy for factor endowments. The employment effect of trade liberalization is magnified in sectors where the contribution of intermediate inputs is relevant for production growth (positive coefficient on the interaction between tariff and the contribution of intermediate inputs to the growth of total production of the sector).

As a robustness check, in columns (6) and (7) we use the number of hours worked by unskilled workers in the *export* segment of the production.³⁶ Coherently with our theoretical model, we find that the export tariff liberalization boosts the employment level of unskilled workers in the export segment of production.

³⁶ As explained in Sect. 3.2, the number of hours worked in the *export* segment of production has been approximated by the product between the country-sector hours worked and the share of total production of the country-sector dedicated to the export market (from input/output tables).

Table 3 Trade liberalization and the employment (hours worked) of unskilled workers in domestic production and exports

| | Log of unskilled employment in <i>domestic</i> production | | | | Log of unskilled employment in <i>export</i> production | |
|---|---|----------------------|----------------------|----------------------|---|----------------------|
| | (1) | (2) | (3) | (4) | (5) | (7) |
| $\ln(\text{tariff}+1)$ | 0.208** (0.100) | 0.199* (0.103) | 0.285*** (0.102) | 0.144* (0.088) | 0.144* (0.084) | -0.492*** (0.125) |
| $\ln(\text{tariff}+1) * \text{Sh Intern. 96}$ | | 0.026*** (0.005) | 0.029*** (0.006) | 0.071*** (0.011) | 0.080*** (0.012) | 0.015** (0.006) |
| TFP growth in 1996 | | | -0.003*** (0.001) | | -0.003*** (0.001) | -0.007*** (0.001) |
| Sh Intern. 96 | | -0.007*** (0.002) | -0.028*** (0.005) | -0.014*** (0.002) | -0.013*** (0.002) | -0.001 (0.005) |
| Export specialization | | -0.354 (0.255) | -0.525** (0.257) | -0.366 (0.295) | -0.283 (0.290) | 3.922*** (0.399) |
| <i>Fixed effects</i> | | | | | | |
| Sector-year | Yes | Yes | Yes | Yes | Yes | Yes |
| Country-year | Yes | Yes | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | All countries | Same income group | Same income group | All countries |
| Model | OLS | OLS | OLS | OLS | OLS | OLS |
| Observations | 899 | 899 | 899 | 891 | 891 | 899 |
| R ² | 0.908 | 0.910 | 0.912 | 0.911 | 0.912 | 0.925 |

OLS estimations

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; *Sh Intern. 96* is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; *TFP growth in 1996* is growth rate of value added TFP in 1996; *Export specialization* is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

However, we are aware that our proxy for employment in *domestic* versus *export* segments is not perfect, as our coefficient on tariff may simply capture the effect of export tariff on the share of domestic (over total) production abstracting from any employment effect. Thus, as a further robustness check, in Table 9 in Appendix we replicate our baseline estimation (25) on the total number of hours worked by unskilled worker (independently of their allocation between domestic and export production). We find that, conditional on the export intensity of the sector, on average trade liberalization reduces the number of unskilled employment.

In Table 4 we show results of the 2SLS estimations as described in Sect. 3.3.1. Coherently with OLS estimates, a tariff reduction implies a decrease in the level of employment in the domestic segment of production. The first stage results, reported in the bottom part of Table 4, show that our instrumental variable (regional average tariff at the sectoral level) is highly relevant and that the instrument is a strong predictor of the main variable (country-sector tariff), while the interacted instrument is a strong predictor of the interaction term (country-sector tariff and the contribution of intermediate inputs to output growth).³⁷ The joint F-stat values reported in the last row of Table 4 (Keinberger–Paap F-statistics) are always well above 10, implying that the instrument is not weak. In columns (1) and (2) we use the full sample of destinations to compute the average export tariff (simple and weighted average respectively), while in columns (3) and (4) we use only similar partner countries in computing averages. All the estimations show positive and significant coefficients on tariffs and tariff interactions with shares of intermediates, confirming the OLS result that the number of hours worked by unskilled workers in the domestic segment of the production is negatively affected by trade liberalization. According to our preferred specification, 2SLS using simple average tariff across similar destinations (Table 4, column 3), a 10% reduction in the export tariff implies a 3.3% decrease in the hours worked by unskilled workers in domestic production for sectors with a median contribution of intermediate inputs to growth in 1996 (i.e. 1.4 pp).

Turning to skilled workers, in Table 5, we show that trade liberalization has no statistically significant impact on the employment of skilled workers (conditioned on the characteristics of the country-sectors included in the vector $X_{r,p,t}$ and the number of hours worked by unskilled workers in the initial year).³⁸ This result is in line with *Proposition 3* on the lack of effect of trade liberalization on skilled employment, thus ruling out technological substitution with unskilled labor and justifying the choice of a production function where skilled labor enters inelastically and is not adjusted to firm output. In other words, the absence of any impact of trade liberalization on the number of hours worked by skilled workers does not reject the

³⁷ To save space, we report only relevant first stage regression coefficients. Namely, we report the coefficient on the non-interacted instrument for the first stage regression concerning the non-interacted tariff; and the interacted instrument coefficient for the first stage regression concerning the interacted tariff.

³⁸ The number of hours worked by unskilled workers is meant to control for the unskilled intensity of the country-sector. In the last column of Table 5 we show results for a specification having the skilled/unskilled ratio of employment as a dependent variable. In this case tariff has a (weak) negative effect on the skill/unskilled ratio only in sector with positive contribution of intermediate inputs to production growth.

Table 4 Trade liberalization and the employment of unskilled workers

| | Log of unskilled employment (hours worked) in domestic production | | | |
|---|---|----------------------|----------------------|---------------------|
| | (1) | (2) | (3) | (4) |
| $\ln(\text{tariff}+1)$ | 0.274** (0.125) | -0.024 (0.078) | 0.244** (0.115) | 0.574* (0.321) |
| $\ln(\text{tariff}+1) * \text{Sh Interm. 96}$ | 0.028*** (0.006) | 0.029*** (0.005) | 0.060*** (0.015) | 0.069 (0.071) |
| TFP growth in 1996 | -0.003*** (0.001) | -0.002** (0.001) | -0.002*** (0.001) | -0.002** (0.001) |
| Sh Interm. 96 | -0.028*** (0.006) | -0.008*** (0.002) | -0.011*** (0.003) | -0.004* (0.002) |
| Export specialization | -0.518** (0.260) | -0.646** (0.264) | -0.209 (0.299) | -0.140 (0.315) |
| <i>Fixed effects</i> | | | | |
| Sector-year | Yes | Yes | Yes | Yes |
| Country-year | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | Same income group | Same income group |
| Definition tariff | Simple | Weighted | Simple | Weighted |
| First stage IV results | | | | |
| IV: Regional Avg Tariff | 0.801*** (0.031) | 0.639*** (0.027) | 1.005*** (0.055) | 0.570*** (0.103) |
| IV: Regional Avg Tariff * Sh Interm. 96 | 0.997*** (0.026) | 0.965*** (0.029) | 0.873*** (0.040) | 0.268*** (0.038) |
| Joint F-stat | 302 | 189 | 158 | 22 |
| Observations | 899 | 899 | 813 | 812 |
| R ² | 0.912 | 0.910 | 0.907 | 0.901 |

2SLS estimations

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; *Sh Interm. 96* is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; *TFP growth in 1996* is growth rate of value added TFP in 1996; *Export specialization* is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

inclusion of skilled workers as part of the fixed costs of firms, whose remuneration in the short run is more elastic than employment levels to sales' performance.

3.5 Wage impacts of trade liberalization

As for the impact on skilled workers' wages analyzed in *Proposition 2* (trade-liberalization-driven wage gap), our model yields starker results. In a framework characterized by vertical linkages, the increase in total profits due to cheaper

Table 5 Trade liberalization and the employment (hours worked) of skilled workers

| | Log of skilled employment | | | | | Skilled/unskilled | |
|---|---------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Ln(tariff+1) | -0.004 (0.011) | 0.001 (0.013) | 0.005 (0.014) | 0.010 (0.011) | 0.005 (0.012) | -3.850 (2.354) | -2.682 (2.053) |
| Ln(tariff+1) * Sh Intern. 96 | | | 0.001 (0.001) | | 0.004** (0.001) | | -0.844* (0.480) |
| TFP growth in 1996 | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) | 0.068** (0.032) | 0.078** (0.035) |
| Hours worked by unskilled 96 | -0.138*** (0.010) | -0.139*** (0.010) | -0.139*** (0.010) | -0.136*** (0.011) | -0.137*** (0.011) | | |
| Sh Intern. 96 | 0.000** (0.000) | 0.000** (0.000) | -0.000 (0.000) | 0.000** (0.000) | 0.000 (0.000) | -0.065 (0.057) | 0.030 (0.065) |
| Export orientation | -0.043* (0.022) | -0.042* (0.022) | -0.049** (0.024) | -0.049** (0.025) | -0.052** (0.026) | -25.261* (13.694) | -24.530* (13.619) |
| <i>Fixed effects</i> | | | | | | | |
| Sector-year | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country-year | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | All countries | Same income group | Same income group | Same income group | Same income group |
| Model | OLS | 2SLS | 2SLS | 2SLS | 2SLS | 2SLS | 2SLS |
| First stage IV results | | | | | | | |
| IV: Regional Avg Tariff | | 0.779*** | 0.780*** | 0.977*** | 1.000*** | 0.977*** | 1.000*** |
| IV: Regional Avg Tariff * Sh Intern. 96 | | | 0.994*** | | 0.868*** | | 0.868*** |
| F-stat | | 588 | 265 | 304 | 152 | 304 | 152 |
| Joint F-stat | | | | | | | |

Table 5 continued

| | Log of skilled employment | | | | Skilled/unskilled | |
|----------------|---------------------------|-------|-------|-------|-------------------|-------|
| | (1) | (2) | (3) | (4) | (5) | (7) |
| Observations | 889 | 889 | 889 | 803 | 803 | 803 |
| R ² | 0.971 | 0.971 | 0.971 | 0.964 | 0.964 | 0.784 |

2SLS estimations

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; $Sh\ Inter_{96}$ is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; $TFP\ growth\ in\ 1996$ is growth rate of value added TFP in 1996; $Export\ specialization$ is the sector over total country exports. *Hours worked by unskilled 96* is the number of hours worked in a given country-sector in 1996. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 6 Trade liberalization and the wage premium of skilled workers

| | Log of (skilled/unskilled wage) | | | | |
|---------------------------------|---------------------------------|----------------------|----------------------|----------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) |
| Ln(tariff+1) | -0.327*** (0.088) | -0.337*** (0.087) | -0.367*** (0.086) | -0.229*** (0.081) | -0.208*** (0.079) |
| Ln(tariff+1) * Sh Interm. 96 | | -0.013*** (0.004) | -0.016*** (0.004) | -0.032*** (0.012) | -0.042*** (0.013) |
| TFP growth in 1996 | | | 0.004*** (0.001) | | 0.004*** (0.001) |
| Sh Interm. 96 | 0.002 (0.002) | 0.013*** (0.003) | 0.010*** (0.003) | 0.004** (0.002) | 0.000 (0.002) |
| Export specialization | -0.183 (0.180) | -0.089 (0.178) | 0.014 (0.175) | -0.324* (0.194) | -0.215 (0.190) |
| <i>Fixed effects</i> | | | | | |
| Sector-year | Yes | Yes | Yes | Yes | Yes |
| Country-year | Yes | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | All countries | Same income group | Same income group |
| Model | OLS | OLS | OLS | OLS | OLS |
| Observations | 829 | 829 | 829 | 821 | 821 |
| R ² | 0.966 | 0.966 | 0.967 | 0.967 | 0.968 |

OLS estimations

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; $Sh\ Interm. 96$ is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; $TFP\ growth\ in\ 1996$ is growth rate of value added TFP in 1996; $Export\ specialization$ is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

intermediate imports implies that skilled workers can bid up their salary and increase the ratio between their earnings and the unskilled workers' earnings. In testing this proposition, we rely on the fact that Preferential Trade Agreements (PTAs) and multilateral tariff reductions tend to be symmetric, so that any reduction in the export tariff mirrors a reduction in the import tariff (cheaper intermediate imports).³⁹ Tables 6 and 7 (respectively for OLS and 2SLS estimations) strongly confirm this prediction, with a negative and significant coefficient on export tariff across all specifications. The structure of the two tables are similar to those for unskilled employment discussed in the previous section. The two sets of regressions yield qualitatively identical results and confirm the prediction of *Proposition 2*: as the trade barriers faced by country i in sector s decrease, the skill premium rises.

³⁹ The symmetry between export and import tariff liberalization prevented us to put both import and export tariff in the same regression (multicollinearity). This can be done in firm-level based evidence, when there is high variation across firms in the set of import origins and export destinations, giving different variation in the import vs export tariff.

Table 7 Trade liberalization and the wage premium of skilled workers

| | Log of (skilled/unskilled wage) | | | |
|---|---------------------------------|----------------------|---------------------|---------------------|
| | (1) | (2) | (3) | (4) |
| $\ln(\text{tariff}+1)$ | -0.298** (0.121) | -0.244*** (0.061) | -0.338** (0.141) | -0.821** (0.378) |
| $\ln(\text{tariff}+1) * \text{Sh Interm. 96}$ | -0.018*** (0.004) | -0.021*** (0.005) | -0.030* (0.017) | -0.213** (0.101) |
| TFP growth in 1996 | 0.004*** (0.001) | 0.004*** (0.001) | 0.003*** (0.001) | 0.003*** (0.001) |
| Sh Interm. 96 | 0.012*** (0.003) | -0.004** (0.002) | -0.000 (0.002) | -0.003 (0.002) |
| Export specialization | 0.039 (0.177) | 0.227 (0.158) | -0.290 (0.196) | -0.362* (0.213) |
| <i>Fixed effects</i> | | | | |
| Sector-year | Yes | Yes | Yes | Yes |
| Country-year | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | Same income group | Same income group |
| Definition tariff | Simple | Weighted | Simple | Weighted |
| First stage IV results | | | | |
| IV: Regional Avg tariff | 0.780*** (0.036) | 0.658*** (0.027) | 1.011*** (0.056) | 0.567*** (0.104) |
| IV: Regional Avg Tariff * Sh Interm. 96 | 0.990*** (0.028) | 0.984*** (0.028) | 0.855*** (0.041) | 0.265*** (0.037) |
| Joint F-stat | 213 | 242 | 157 | 23 |
| Observations | 829 | 829 | 743 | 742 |
| R ² | 0.967 | 0.966 | 0.967 | 0.963 |

2SLS estimations

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; *Sh Interm. 96* is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; *TFP growth in 1996* is growth rate of value added TFP in 1996; *Export specialization* is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Both OLS and 2SLS estimations in Tables 6 and 7 show negative and significant coefficients for tariff around -0.3 . According to our preferred specification, 2SLS using simple average tariff across similar destinations (Table 7, column 3), a 10% reduction in the tariff faced by country i implies a 3.8% increase in the wage gap (in sectors with median contribution of intermediate inputs to output growth in 1996). For the 2SLS estimations, first stage results reported at the bottom of Table 7 show the relevance of our instruments (always significantly correlated with tariffs and with a joint F-stat well above 10).

It is important to notice that the results showed in Tables 6 and 7 are robust to the inclusion of an interaction term between tariff and the contribution of intermediate

inputs for the sector's output growth. Tariff liberalization may increase the wage gap also through the complementarity between intermediate inputs and skilled workers: the wage gap can raise because of the upward pressure on the wage of high skilled workers (which are more intensively used as complement for cheaper intermediate inputs). Coherently with this argument, we find that tariff liberalization increases the wage gap particularly in sectors with high usage of intermediate inputs (confirming the complementarity between intermediate inputs and skilled workers highlighted in the literature). Nevertheless, the positive effect of tariff liberalization on the wage gap holds also for sectors with zero intermediate input intensity. This means that tariff liberalization keeps affecting the wage gap even after the complementarity between skilled workers and intermediate inputs is accounted for. As a further robustness check, in Table 10 in Appendix we extend the baseline empirical model (25) by including the share of skilled over total number of hours worked in the country-sector. The estimated coefficients on export tariff remain qualitatively the same (slightly smaller) supporting the robustness of our main results.

Finally, in Table 8 we provide a more direct test of the mechanism described in the model. As discussed in the introduction, the fixed cost-saving channel, which is at the core of our theoretical model, applies in particular for capital goods. Since EU KLEMS data provides information on the computing-equipment intensity of each country-sector, we interact such variable (rescaled by its median value) with the average export tariff to test whether the wage gap effect of tariff liberalization is magnified for computing-equipment-intensive sectors (as expected according to our intuition).⁴⁰ While the average export tariff holds its negative coefficient (first row in Table 8), the interaction with computing-equipment intensity is always negative and significant, suggesting an even stronger effect of tariff liberalization on computing-equipment intensive sectors. Interestingly, in our preferred specification—2SLS using simple average tariff across similar destinations (Table 7, column 4)—the wage gap effect of tariff liberalization is channeled only by sectors with computing-equipment intensity above the mean. These results are coherent with the cost-saving channel which is the core insight of our theoretical model.

4 Discussion on possible alternative explanations

Summing up the results of the previous section, our empirical tests show that trade liberalization has negative effects on the employment of the unskilled in the *domestic* segment of production along with positive effects on the *export* segment; it increases the wage gap between skilled and unskilled workers, even after controlling for the intermediates-skill complementarity; it does not significantly affect skilled employment, supporting our Proposition 3 on the inelastic use of skilled workers as fixed costs and the working assumption of lack of technological substitutability for

⁴⁰ We use computing-equipment intensity in the initial year, in order to reduce endogeneity concerns. We rescale by its median to the sake of easy interpretation. The computing-equipment intensity is directly provided by EU KLEMS and it is the share of computing-equipment cost over the total production cost in a given country-sector. See http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_I_Methodology.pdf for a detailed description of this variable.

Table 8 Trade liberalization and the wage premium of skilled workers: the role of computing equipments

| | Log of (skilled/unskilled wage) | | | |
|--|---------------------------------|----------------------|---------------------|----------------------|
| | (1) | (2) | (3) | (4) |
| Ln(tariff+1) | -0.235** (0.100) | -0.272*** (0.102) | -0.317** (0.152) | 0.858 (0.668) |
| Ln(tariff+1) * Sh Comp. equip. 96 | -0.146** (0.058) | -0.144** (0.058) | -0.151** (0.060) | -0.777*** (0.240) |
| TFP growth in 1996 | | 0.003*** (0.001) | 0.003*** (0.001) | 0.002** (0.001) |
| Sh Comp. equip. 96 | 0.249*** (0.071) | 0.232*** (0.070) | 0.238*** (0.071) | 0.187*** (0.052) |
| Sh Intern. 96 | 0.003 (0.002) | -0.000 (0.002) | 0.000 (0.002) | -0.000 (0.003) |
| Export specialization | -0.580** (0.246) | -0.517** (0.240) | -0.514** (0.240) | -0.564** (0.236) |
| <i>Fixed effects</i> | | | | |
| Sector-year | Yes | | Yes | Yes |
| Country-year | Yes | | Yes | Yes |
| Sample | All countries | All countries | All countries | Same Income Group |
| Model | OLS | OLS | 2SLS | 2SLS |
| First stage IV results | | | | |
| IV: Regional Avg tariff | | | 0.869*** | 0.761*** |
| IV: Regional Avg Tariff * Sh Comp. equip. 96 | | | 0.959*** | 0.850*** |
| Joint F-stat | | | 192 | 298 |
| Observations | 589 | 589 | 589 | 523 |
| R ² | 0.972 | 0.972 | 0.972 | 0.971 |

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; Sh Intern. 96 is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; $\text{TFP growth in 1996}$ is growth rate of value added TFP in 1996; Sh Comp equip. is the share of computing equipment cost over total production cost in 1996. $\text{Export specialization}$ is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

unskilled workers in the short run. In addition, the results hold also for North–North liberalization. Interestingly, when we include both North–North and North–South tariff liberalization in the same regression, we observe that North–North tariff liberalization has a larger effect than North–South tariff reduction on unskilled employment and skill premium. See Appendix Table 12.

To the best of our knowledge, no alternative model would be consistent with this set of empirical results. For example, the fact that our results hold also for trade liberalization within the same income group would be at odds with models based on

comparative advantages à la Heckscher and Ohlin mechanism. In addition, our results depart from the implications of the standard Stolper–Samuelson theorem also because the changes in relative wages caused by trade liberalization do not imply a substitution of skilled workers for relatively cheaper unskilled workers in the short run. We show instead that the employment level of skilled workers is unaffected by trade liberalization and we find a differentiated effect for unskilled workers in the domestic and export segments, the net effect depending on the relative size of each.

While it can be claimed that Stolper–Samuelson effects would kick in only in the case of an increase in relative wages of skilled workers not associated with a corresponding increase in labor productivity, we can also rule out a skill-specific productivity shift such as the ones implied by models suggesting a complementarity between imports (especially technological ones) and skills, or a reallocation towards more productive and more skill intensive firms within a sector. If that were the case, we would not observe a decrease in the skilled-to-unskilled employment ratios in the export segments due to an increase in the number of unskilled workers, but we would observe the same patterns in the domestic and export segments of each sector. In general, the different impacts for domestic and export segments within sectors would rule out any sector- or country-wide explanations based on technological substitutability between skill levels.

5 Conclusions

This paper sheds light on a new channel explaining the heterogeneous impacts of trade liberalization on different types of workers. We show that, when trade barriers between any two countries decrease, the availability of cheaper imported intermediates allows skilled workers to extract higher wages. To this end, we employ a three-country variable-elasticity-of-substitution monopolistic competition model with vertical linkages on fixed costs and skill heterogeneity in the labor market, which allows us to generalize our predictions also to trade liberalization between countries with similar size and factor endowments because of pro-competitive effects.

Our theoretical model yields three empirically tested predictions. First, among the country-sectors involved in the integration process, unskilled workers' employment decreases on the lines of production serving the domestic market and increase in the lines of production serving the export segment. Second, reductions in trade barriers increase the skill-driven wage gap in the integrating countries by benefiting skilled workers more than the unskilled, because of the difference in their capacity to claim the additional profits made by firms savings on fixed costs of production. Third, trade liberalization does not affect the employment of skilled workers in the short run.

Empirically, we find confirmation for the first and third predictions on employment levels by observing a 3.3% decline in unskilled workers' employment in domestic production following a 10% reduction in tariffs (in sectors with median contribution of intermediate inputs to output growth in 1996), but no statistically significant impact on skilled workers. As for the second prediction, on the wage gap, we find that the difference in remuneration between skilled and unskilled workers in

the OECD economies widens by 3.8% when trade barriers fall by 10% due to a larger real wage increase for skilled workers.

The short-run consequences of an increase in the skill premium in our model are different from those implied by the Stolper–Samuelson theorem in the neoclassical model or a sector-wide technology shift due to complementarities between skills and intermediates. Indeed, we find that the skill premium effect from tariff liberalization is not associated with a decrease in the ratio of skilled-to-unskilled workers (as it should be if the two types of labor were substitutable). We rather find that the employment of skilled workers is unaffected by trade liberalization while the employment of unskilled workers decreases (increases) in the domestic (export) segment of production. In addition, it should be noted that the combination of differentiated impact of trade liberalization on unskilled workers on the domestic and export segment of production, combined with an increase in the wage gap and the lack of effects of skilled employment is a unique prediction of the model presented in this paper, which to the best of our knowledge cannot be replicated by the existing trade models. These effects are observed controlling for the existing explanations in the trade literature relating the wage gap to technological factors and complementarity between capital or intermediates and skilled workers, so we can claim that we identify an additional and not an alternative channel.

A final caveat is due. The results of our model and empirical analysis focus on the short run, i.e. holding the number and location of firms and workers fixed, leaving aside general equilibrium feedback effects on input prices for the sake of analytical tractability and direct empirical testing. A promising future avenue of research would be to investigate the dynamic and general equilibrium properties of the model and test whether its results are robust to the introduction of endogenous entry and exit of firms and/or relocation patterns. For example, the additional entry due to the cost savings associated with trade liberalization may result in dynamic gains increasing exports to third countries. Still, in the current analysis the focus on static properties allowed us to obtain clear predictions to test empirically and keep a tight connection between the theory and the empirics.

Acknowledgements Parts of this paper previously circulated under the title “Tariff reductions, trade patterns and the wage gap in a monopolistic competition model with vertical linkages”. We thank two anonymous referees and participants of the “Economics of Global Interactions” conference in Bari (Italy), HSE Conference in St Petersburg (Russia), SNF Sinergia-CEPR Conference (Ascona, Switzerland), Royal Economic Society (Manchester), ITSG workshop (EUI, Florence), LEO Seminar (University of Orleans), CEPII seminar and the workshop “General Equilibrium Dynamics, Market Structure and Trade” jointly organized by the University of Salento, the University of Southern Denmark and DEGIT (Lecce 10–11 October 2013). We are also grateful to Stefano Bolatto, Matthieu Crozet, Mauro Lanati, Andrea Lamorgese, Anna Maria Mayda, Daniel Mirza, Thierry Mayer, Peter Neary and Mathieu Parenti for useful comments and suggestions. The opinions expressed are those of the author(s) only and should not be considered as representative of the European Commission’s or CEPII’s official position.

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Appendix

See Tables 9, 10, 11 and 12.

Table 9 Trade liberalization and the employment (hours worked) of unskilled workers

| | Log of unskilled employment in total production | | | | |
|---------------------------------|---|----------------------|----------------------|----------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) |
| Ln(tariff+1) | 0.262*** (0.071) | 0.260*** (0.072) | 0.368*** (0.067) | 0.203*** (0.067) | 0.203*** (0.063) |
| Ln(tariff+1) * Sh Interm. 96 | | 0.006** (0.003) | 0.010*** (0.003) | 0.026*** (0.008) | 0.037*** (0.010) |
| TFP growth in 1996 | | | -0.004*** (0.001) | | -0.004*** (0.001) |
| Sh Interm. 96 | -0.005*** (0.001) | -0.011*** (0.003) | -0.011*** (0.003) | -0.007*** (0.002) | -0.006*** (0.002) |
| Export specialization | 0.301** (0.142) | 0.244* (0.145) | 0.319** (0.145) | 0.392** (0.161) | 0.492*** (0.161) |
| <i>Fixed effects</i> | | | | | |
| Sector-year | Yes | Yes | Yes | Yes | Yes |
| Country-year | Yes | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | All countries | Same income group | Same income group |
| Model | OLS | OLS | OLS | OLS | OLS |
| Observations | 899 | 899 | 899 | 891 | 891 |
| R ² | 0.949 | 0.949 | 0.953 | 0.951 | 0.954 |

OLS estimations

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; *Sh Interm. 96* is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; *TFP growth in 1996* is growth rate of value added TFP in 1996; *Export specialization* is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 10 Trade liberalization and the wage premium of skilled workers

| | Log of (skilled/unskilled wage) | | | | | |
|---|---------------------------------|----------------------|-------------------------|-------------------------|----------------------|-------------------------|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Ln(tariff+1) | -0.133** (0.055) | -0.148*** (0.056) | -0.110*** (0.042) | -0.103** (0.041) | -0.088 (0.073) | -0.183*** (0.068) |
| Ln(tariff+1) * Sh Intern. 96 | -0.011*** (0.002) | -0.011*** (0.002) | -0.021*** (0.007) | -0.025*** (0.008) | -0.012*** (0.003) | -0.023** (0.010) |
| TFP growth in 1996 | | 0.002*** (0.001) | | 0.002*** (0.001) | 0.002*** (0.001) | 0.002** (0.001) |
| Sh Intern. 96 | 0.007*** (0.002) | 0.006*** (0.002) | -0.000 (0.001) | -0.002 (0.001) | 0.006*** (0.002) | -0.001 (0.001) |
| Export specialization | 0.231** (0.114) | 0.267** (0.114) | 0.111 (0.129) | 0.150 (0.128) | 0.284** (0.115) | 0.120 (0.133) |
| Skill share | 5.395*** (0.264) | 5.317*** (0.270) | 5.354*** (0.265) | 5.278*** (0.271) | 5.339*** (0.273) | 5.079*** (0.281) |
| <i>Fixed effects</i> | | | | | | |
| Sector-year | Yes | Yes | Yes | Yes | Yes | Yes |
| Country-year | Yes | Yes | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | Same income group | Same income group | All countries | Same income group |
| Model | OLS | OLS | OLS | OLS | 2SLS | 2SLS |
| First stage IV results | | | | | | |
| IV: Regional Avg Tariff | | | | | 0.773*** | 1.011*** |
| IV: Regional Avg Tariff * Sh Intern. 96 | | | | | 0.990*** | 0.854*** |
| Joint F-stat | | | | | 207 | 153 |
| Observations | 829 | 829 | 821 | 821 | 829 | 743 |
| R ² | 0.983 | 0.983 | 0.983 | 0.984 | 0.983 | 0.982 |

Controlling for the skill share in the sector. OLS and 2SLS estimations

$Ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; $Sh\ Intern. 96$ is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; $TFP\ growth\ in\ 1996$ is growth rate of value added TFP in 1996; $Export\ specialization$ is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 11 Trade liberalization and the wage premium of skilled workers

| | Log of (skilled/unskilled wage) | | | | |
|-------------------------------|---------------------------------|---------------|---------------|-------------------|-------------------|
| Ln(tariff+1) | -0.101* | -0.099* | -0.099* | -0.138** | -0.138** |
| | (0.052) | (0.052) | (0.052) | (0.064) | (0.064) |
| Ln(tariff+1) * Sh Interme. 96 | | -0.007 | -0.007 | -0.009 | -0.009 |
| | | (0.005) | (0.005) | (0.023) | (0.023) |
| Export specialization | -0.537* | -0.522* | -0.522* | -0.736* | -0.736* |
| | (0.290) | (0.286) | (0.286) | (0.403) | (0.403) |
| <i>Fixed effects</i> | | | | | |
| Sector-year | Yes | Yes | Yes | Yes | Yes |
| Sector-country | Yes | Yes | Yes | Yes | Yes |
| Sample | All countries | All countries | All countries | Same income group | Same income group |
| Model | OLS | OLS | OLS | OLS | OLS |
| Observations | 829 | 829 | 829 | 821 | 821 |
| R ² | 0.991 | 0.991 | 0.991 | 0.991 | 0.991 |

OLS with country-sector fixed effects and clustered standard errors

Ln(tariff + 1) is the average export tariff faced by each country-sector; *Sh Interme. 96* is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; *TFP growth in 1996* is growth rate of value added TFP in 1996; *Export specialization* is the sector over total country exports. Differences in the number of observations across columns is entirely due to missing in the tariff level for similar destination countries. Standard errors are clustered by country-sector

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 12 Trade liberalization, unskilled employment (hours worked) and wage premium

| | Log of unskilled employment in domestic production | | | Log of (skilled/unskilled wage) | | |
|----------------------------------|--|-----------|-----------|---------------------------------|-----------|-----------|
| Ln(tariff+1) North-North | 0.230** | 0.157* | 0.168* | -0.266*** | -0.246*** | -0.226*** |
| | (0.092) | (0.090) | (0.086) | (0.084) | (0.085) | (0.081) |
| Ln(tariff+1) North-South | 0.087 | 0.064 | 0.140* | -0.149** | -0.158** | -0.155** |
| | (0.070) | (0.072) | (0.071) | (0.067) | (0.068) | (0.066) |
| Ln(tariff+1) NN * Sh Interme. 96 | | 0.065*** | 0.071*** | | -0.025* | -0.034** |
| | | (0.013) | (0.013) | | (0.014) | (0.015) |
| Ln(tariff+1) NS * Sh Interme. 96 | | 0.004 | 0.008 | | -0.005 | -0.006 |
| | | (0.005) | (0.005) | | (0.004) | (0.004) |
| TFP growth in 1996 | | | -0.003*** | | | 0.004*** |
| | | | (0.001) | | | (0.001) |
| Sh Interme. 96 | -0.006*** | -0.021*** | -0.025*** | 0.001 | 0.013** | 0.010* |
| | (0.002) | (0.007) | (0.008) | (0.002) | (0.005) | (0.005) |
| Export specialization | -0.290 | -0.393 | -0.323 | -0.358* | -0.332* | -0.223 |
| | (0.299) | (0.298) | (0.291) | (0.188) | (0.192) | (0.189) |
| <i>Fixed effects</i> | | | | | | |
| Sector-year | Yes | Yes | Yes | Yes | Yes | Yes |

Table 12 continued

| Country-year Sample | Log of unskilled employment in domestic production | | | Log of (skilled/unskilled wage) | | |
|------------------------|---|-------------------------|-------------------------|---------------------------------|-------------------------|-------------------------|
| | Yes All countries | Yes All countries | Yes All countries | Yes All countries | Yes All countries | Yes All countries |
| Model | OLS | OLS | OLS | OLS | OLS | OLS |
| Observations | 891 | 891 | 891 | 821 | 821 | 821 |
| R ² | 0.908 | 0.911 | 0.913 | 0.967 | 0.967 | 0.968 |

OLS estimations with north–north and north–south tariff

$\ln(\text{tariff} + 1)$ is the average export tariff faced by each country-sector; $Sh\ Inter.$ 96 is the contribution of intermediate inputs to total production growth in 1996 for a given country-sector; $TFP\ growth\ in\ 1996$ is growth rate of value added TFP in 1996; $Export\ specialization$ is the sector over total country exports. Differences in the number of entirely due to missing in the tariff observations across columns is level for similar destination countries. Standard errors are clustered by country-sector

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

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