Importing Skill-Biased Technology*

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Abstract

The production of capital equipment is concentrated among a small group of countries, and many countries import a large share of their equipment. Given a large body of research arguing that capital-skill complementarity is an important feature of technology, it is possible that international trade has important effects on the skill premium through its impact on the accumulation of capital equipment. In this paper we propose a tractable framework for evaluating this effect and provide simple analytic expressions linking observable changes in import shares by sector to changes in the real wages of skilled and unskilled workers and, therefore, the skill premium. Quantitatively, we find that while international trade raises the real wages of both skilled and unskilled workers, it benefits skilled workers disproportionately, especially in countries that rely heavily on imports for their capital equipment.

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1 Introduction

The production of capital equipment—such as computers and industrial machinery—is concentrated among a small group of countries, and many countries import a large share of their equipment;[1] see e.g. Eaton and Kortum (2001). Although the evidence is not definitive, a large body of research has argued that capital-skill complementarity is an important feature of technology.[2] Taking this evidence at face value, it is possible that international trade has important effects on the skill premium through its impact on the accumulation of capital equipment. The first goal of this paper is to provide a tractable framework for evaluating this effect. Given the lack of consensus on the extent of capital-skill complementarity, the second goal is to obtain a transparent analytic mapping between the extent of capital-skill complementarity and the strength of this effect. The final goal is to quantify the importance of this effect for a large set of countries.

To do so, we embed a production function that allows for capital-skill complementarity as in Krusell, Ohanian, Rios-Rull, and Violante (2000), henceforth KORV, into the multi-country model of international trade developed in Eaton and Kortum (2002), henceforth EK. With capital-skill complementarity, an increase in the stock of capital equipment raises the demand for skilled relative to unskilled labor. With international trade, the aggregate stock of capital equipment in one country depends on foreign and domestic productivities and labor endowments and on trade costs between every pair of countries. In our model as in EK, changes in all trade costs and foreign variables affect a country's steady-state stock of capital equipment only through changes in its domestic sectoral expenditure shares, i.e., the share of its sectoral absorption that is produced domestically.[3] Using this result, we provide simple analytic expressions relating steady-state changes in (i) the skill premium, (ii) the real wage of skilled workers, and (iii) the real wage of unskilled workers to changes in domestic expenditure shares, domestic productivities, and domestic labor endowments.

Three parameters are key in shaping the elasticities of $(i) - (iii)$ with respect to changes in observable domestic expenditure shares in each sector. The first is the elasticity of trade

[1] For example, 80% of the world's capital equipment production occurred in just eight countries in the year 2000: the U.S., Japan, Germany, China, France, Korea, the U.K., and Italy. The share of domestic absorption imported from abroad in the equipment sector in the year 2000 was 73% in the U.K., 81% in Australia, 84% in Chile, and 96% in Cameroon. Source: our calculation using NBER-UN world trade data described in Feenstra et. al. (2005) and Unido Industrial Statistics.

[2] See e.g. Katz and Autor (1999), who summarize the literature documenting a positive correlation between the use of computer-based technologies and employment of skilled labor within industries, firms, and plants.

[3] This result applies in EK to a country's stock of domestic consumption (average real wage). Arkolakis, Costinot, and Rodriguez-Clare (2012) show that this result holds across a wide range of quantitative trade models. In section 3.3 we discuss the generality of our results.

with respect to variable trade costs, which depends only on the dispersion of productivities within sectors in our Ricardian model. As in standard quantitative trade models, this parameter shapes the extent to which observable changes in domestic sectoral expenditure shares lead to changes in the domestic stock of capital equipment. The other two important parameters are production function elasticities that jointly determine the extent of capital-skill complementarity and the elasticity of substitution between skilled and unskilled labor. In equilibrium these parameters shape the response of the skill premium to a given change in the stock of capital equipment. We pursue several strategies similar to those in KORV to parameterize these elasticities using structural equations delivered by the model and calibrated using US and Chilean data.

We use our parameterized model to quantify the impact of trade, through capital-skill complementarity, on the skill premium and the real wages of skilled and unskilled workers. We conduct two counterfactuals exploiting the simple structure of our solution, which allows us to conduct these exercises country-by-country. In the first counterfactual, we hold all technologies and factor endowments fixed and raise all trade costs to infinity. Through this counterfactual we quantify how much each country's skill premium and both of its real wages would change if it were moved to autarky. In the second counterfactual, we hold a given country's technologies and factor endowments fixed and change its domestic expenditure shares from their observed levels in 2000 to those in 1963. This second counterfactual measures, up to a first-order approximation, the response of real wages in a given country to all changes over this time period in technologies, endowments, and trade costs—both domestic and foreign—relative to what the response to these same changes in primitives would have been had that country been in autarky over this time period.

Given our baseline parameter values, we find that while international trade raises the real wage of both skilled and unskilled workers, it benefits skilled workers disproportionately: in our counterfactuals the log point change in the real wage is more than two times greater for skilled workers than for unskilled workers in the median country. While international trade plays an important role in shaping the skill premium through capital-skill complementarity, we find that its importance varies widely across countries in our sample. For example, moving from the trade levels observed in the year 2000 to 1963, or the first year with available data, would imply a reduction in the skill premium of 0.05 log points (about 5%) for the median country in our sample. The decrease in the skill premium is relatively small in the US (0.04 log points), which has a comparative advantage in capital equipment,[4] and is much larger in countries that rely heavily on imports for their capital equipment, including developed

[4]The contribution of trade predicted by our model is small compared to the observed change in the US skill premium, which is roughly 0.3 log points over this period.

countries such as Canada (0.17 log points) and developing countries such as Latvia (0.26 log points).[5]

We conduct sensitivity analyses taking advantage of our analytic results and our exact quantitative solution. In each exercise we report the elasticity of the skill premium to changes in domestic sectoral expenditure shares resulting from alternative parameter values (using our first-order approximation) as well as the median change in the skill premium for both of our counterfactual exercises (using the exact solution). We emphasize, in particular, alternative values for the parameters that control capital-skill complementarity, since our baseline calibration strategy is subject to the same set of issues that have led to an active debate on the strength of this force; see e.g. Acemoglu (2002) and our discussion in section 4.4.

Our paper builds on a growing literature empirically documenting the impact of international trade on the skill intensity of production—see e.g. Verhoogen (2008), Bloom, Draca, and Van Reenen (2011), Bustos (2011), and Koren and Csillag (2011)—using detailed firm, plant, and sector-level data. These papers provide empirical support for the hypothesis that international trade can generate skill-biased technological change, as posited by, e.g., Acemoglu (2003), Thoenig and Verdier (2003), and Yeaple (2005). Our contribution is to embed a mechanism studied in these papers into a multi-country general equilibrium trade model.[6]

To isolate the impact of importing equipment on real wages and the skill premium in a simple and transparent way, we abstract from many other mechanisms through which trade affects relative wages. Hence, we do not view our paper as providing a full quantitative assessment of the role of international trade in shaping the skill premium.[7]

Our paper is most closely related to Parro (2012), who uses a similar model that incorporates capital-skill complementarity to study the impact of trade on the skill premium.[8] There are two main differences between these papers. First, we provide simple expressions

[5] For most countries we consider there are no consistent measures of changes in the skill premium, and producing such consistent measures for a large set of countries is out of the scope of this paper. Krueger, Perri, Pistaferri, and Violante (2010) document college premium changes in 9 countries over different years. For 4 out of 9 of those countries, the skill premium fell. Hence, comparing the impact of trade to the overall change in the skill premium does not make sense for these 4 countries. According to our results, in the absence of trade the reduction in the skill premium would have been larger in these 4 countries.

[6] The approach has served as a basic building block in a number of other macroeconomic models of inequality; see e.g. Polgreen and Silos (2008) and Jaimovich, Pruitt, and Siu (2010)

[7] In a related paper, Burstein and Vogel (2012) study the impact of international trade on the skill premium arising from two mechanisms from which we abstract: (*i*) the Stolper-Samuelson effect and (*ii*) within-sector factor reallocation in the presence of skill-biased productivity. The presence of firm heterogeneity in skill intensity allows Burstein and Vogel (2012) to discipline their parameters using cross-sectional firm-level evidence at the expense of losing analytic gravity equations and, hence, simple analytic results on changes in the skill premium.

[8] For an earlier theoretical treatment of trade in skill-complementary capital in a neo-classical growth model, see Stokey (1996).

for steady-state changes in a country's skill premium and both of its real wages, up to first-order approximations, which yield analytic mappings from parameters to quantitative results. This is particularly useful given the extent of uncertainty regarding a number of key parameters, especially the degree of capital-skill complementarity. Second, the counterfactuals that we perform are different. Whereas we study the overall impact of given changes in trade patterns on the skill premium (which can be understood in terms of changes in primitives, as summarized above), Parro feeds into his model estimated changes in trade costs and sector-level technologies. Beyond differences in their nature, a benefit of our counterfactuals is that they can be solved country-by-country without solving the full world-wide general equilibrium; hence, our counterfactual results for a given country are not sensitive to most of the parameter values we assign to its trading partners. A benefit of Parro's counterfactuals is that, given his estimates, he can answer a broader range of questions such as the impact on the skill premium in each country of separately changing trade costs and sector-level technologies.

2 The Model

Overview: We consider a world economy featuring I countries, indexed by $i = 1, .., I$. Within each country, a representative household acquires utility from consumption of manufactured goods and services. Each country is endowed with H_i and L_i efficiency units of skilled and unskilled labor, respectively. Heterogeneous producers of intermediate goods use labor in combination with capital equipment, capital structures, and intermediate inputs. To incorporate capital-skill complementarity, we allow for the elasticity of substitution between skilled labor and capital equipment to differ from that between unskilled labor and equipment.

Producers differ in terms of productivity and the sector in which they produce. There are three sectors, indexed by j: (i) a manufacturing sector, $j = M$, in which firms produce tradable goods that are used for consumption and as intermediate inputs; (ii) a service sector, $j = S$, in which firms produce non-tradable goods that are used for consumption, intermediate inputs, and investment in structures; and (iii) a capital equipment sector, $j = E$, in which firms produce tradable goods that are used for investment in capital equipment.[9] Tradable goods are subject to variable iceberg international trade costs. All labor and goods markets are perfectly competitive.

[9] We abstract from government, agriculture, and mining.

Preferences: Utility of the representative household is given by

$$\sum_{t=0}^{\infty} \beta^t u \left(C_{i,t} (M)^{\phi} C_{i,t} (S)^{1-\phi} \right),$$

where $C_{i,t}(M)$ and $C_{i,t}(S)$ denote consumption of manufactured goods and services, respectively, $u(.)$ is a concave sub-utility function defined over aggregate consumption, $\phi \in [0,1]$ is the share of manufactured goods in consumption, and $\beta \in (0,1)$ is the discount rate. The household's budget constraint equates consumption and investment expenditures (investment is discussed below) with labor income, payments to capital, and the value of net exports. Given that our steady-state results do not depend on the value of the trade balance, we do not make assumptions on the availability of international financial assets. Given that we focus our attention on steady-state equilibria, in what follows we mostly abstract from time subscripts.

Sectoral output: Sector j uses a continuum of intermediate goods, each indexed by $\omega \in [0,1]$, according to a CES production function with country- and sector-specific elasticity of substitution $\eta_i(j) > 1$,

$$Y_i(j) = \left\{ \int_0^1 q_i(\omega, j)^{[\eta_i(j)-1]/\eta_i(j)} \, d\omega \right\}^{\eta_i(j)/[\eta_i(j)-1]}, \tag{1}$$

where $q_i(\omega, j)$ is consumption of intermediate good (ω, j) in country i. Each intermediate good (ω, j) is potentially produced in every country.

Output from the manufacturing sector can be used for consumption, $C_i(M)$, and intermediate inputs, $X_i(M)$:

$$Y_i(M) = C_i(M) + X_i(M). \tag{2}$$

Output from the service sector can be used for consumption, $C_i(S)$, intermediate inputs, $X_i(S)$, and structures investment, $I_i(S)$:

$$Y_i(S) = C_i(S) + X_i(S) + I_i(S). \tag{3}$$

Output from the equipment sector is used only for equipment investment, $I_i(E)$:

$$Y_i(E) = I_i(E). \tag{4}$$

The aggregate law of motion of structures and equipment is

$$K_{i,t+1}(j) = [1 - \delta_i(j)] K_{i,t}(j) + I_{i,t}(j), \text{ for } j = S, E,$$

where we have re-introduced time subscripts to indicate the dynamics, and where $\delta_i(j) \in (0,1)$ is the depreciation rate of capital of type $j = S, E$ in country i.

Production of intermediate goods: All producers of intermediate good (ω, j) in country i produce according to the following constant returns to scale production function:

$$y_i(\omega, j) = A_i(j) z_i(\omega, j) \left(x_S^{\varepsilon_i} x_M^{1-\varepsilon_i}\right)^{1-\zeta_i} k_S^{\alpha_i \zeta_i} \times \left\{ \mu_i^{\frac{1}{\sigma}} l^{\frac{\sigma-1}{\sigma}} + (1-\mu_i)^{\frac{1}{\sigma}} \left[\lambda_i^{\frac{1}{\rho}} k_E^{\frac{\rho-1}{\rho}} + (1-\lambda_i)^{\frac{1}{\rho}} h^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho(\sigma-1)}{(\rho-1)\sigma}} \right\}^{\frac{\sigma(1-\alpha_i)\zeta_i}{\sigma-1}} \quad (5)$$

Producers combine intermediate inputs (of services, x_S, and manufactured goods, x_M) with structures, k_S, capital equipment, k_E, unskilled labor, l, and skilled labor h. The share of value added in gross output is given by ζ_i. As discussed in more detail below, the parameters σ and ρ determine the elasticities of substitution between capital equipment, unskilled labor, and skilled labor. A low value of ρ relative to σ implies that capital equipment is less substitutable with skilled labor than with unskilled labor. In particular, when $\sigma > \rho$ the production function exhibits capital-skill complementarity.[10]

Productivity of all country i producers in (ω, j) is given by the product of a country-sector-specific term, $A_i(j)$, shared by all sector j producers in country i, and a country-intermediate-good-specific productivity, $z_i(\omega, j)$, shared by all (ω, j) intermediate good producers in country i. The country-intermediate-good-specific productivity is equal to $z_i(\omega, j) = u^{-\theta(j)}$, where u is an *i.i.d* random variable that is exponentially distributed with mean and variance 1. A higher value of $\theta(j)$ increases the dispersion of productivities across producers within sector j.

The production function (5) extends that in KORV to include (*i*) intermediate inputs; (*ii*) differences in productivities across sectors, as in a standard Ricardian model, so that countries can have sectoral comparative advantages; and (*iii*) exponentially distributed country-intermediate-good-specific productivities within a sector, as in EK, so that our multi-country framework remains tractable. In an extension we allow for skill-biased technical change by incorporating exogenous trend growth in the productivity of the composite of skilled labor and capital equipment relative to unskilled labor. While our analytic results are unchanged, our parameter values depend on this trend growth.

International trade: Delivering a unit of intermediate good (ω, j) from country i to country n requires producing $\tau_{in}(j) \geq 1$ units of that good in country i, where $\tau_{ii}(j) = 1$. We assume that services are not tradable, so that $\tau_{in}(S)$ is infinite for all $i \neq n$.

[10] We use a nested CES so that the elasticities are constant globally. We follow the literature in nesting equipment and skilled labor together.

Equilibrium: Producers hire unskilled and skilled labor at wages w_i and s_i, respectively, and rent structures and capital equipment at rental rates v_i and r_i, respectively. The skill premium in country i is defined as s_i/w_i. To construct prices, it is useful to define the unit cost of producers of intermediate good (ω, j) producing in country i and selling in country n, $c_{in}(\omega, j)$, where

$$c_{in}(\omega, j) = \frac{c_i \tau_{in}(j)}{A_i(j) z_i(\omega, j)}.$$

Here, c_i is the unit cost of production for the domestic market of a producer of any intermediate (ω, j) in country i with productivity $A_i(j) z_i(\omega, j) = 1$, and is given by:

$$\begin{aligned} c_i &= \kappa_i \left[P_i(S)^{\varepsilon_i} P_i(M)^{1-\varepsilon_i}\right]^{1-\zeta_i} v_i^{\alpha_i \zeta_i} \times \\ &\left\{\mu_i w_i^{1-\sigma} + (1-\mu_i)\left[\lambda_i r_i^{1-\rho} + (1-\lambda_i) s_i^{1-\rho}\right]^{\frac{1-\sigma}{1-\rho}}\right\}^{\frac{(1-\alpha_i)\zeta_i}{1-\sigma}} \end{aligned}$$

where κ_i is a constant, and $P_i(j)$ is the aggregate price of output in sector j.[11]

The price of intermediate good (ω, j) in country n is:

$$p_n(\omega, j) = \min_i \{c_{in}(\omega, j)\},$$

where we have used the fact that good (ω, j) is perfectly substitutable across all potential source countries that can supply the good to country n. The aggregate price of sector j output in country n is given by

$$P_n(j) = \left[\int_0^1 p_n(\omega, j)^{1-\eta_i(j)} d\omega\right]^{1/[1-\eta_i(j)]}.$$

The share of country n's expenditure in sector j that is allocated to goods from country i, $\pi_{in}(j)$, is given by

$$\pi_{in}(j) = \int_0^1 p_n(\omega, j)_{in}^{1-\eta_i(j)} \mathbb{I}_{in}(\omega, j) d\omega \Big/ P_n(j)^{1-\eta_i(j)}. \tag{6}$$

where $\mathbb{I}_{in}(\omega, j)$ is an indicator variable that equals one if country n purchases intermediate good (ω, j) from country i, and equals zero otherwise. The domestic expenditure share is given by $\pi_{ii}(j)$. Using the assumption of exponentially distributed productivities, one can

[11] The constant is given by $\kappa_i = \left[(1-\zeta_i)\varepsilon_i^{\varepsilon_i}(1-\varepsilon_i)^{1-\varepsilon_i}\right]^{\zeta_i - 1}\left[\zeta_i \alpha_i^{\alpha_i}(1-\alpha_i)^{1-\alpha_i}\right]^{-\zeta_i}$

show (see e.g. EK 2002) that in equilibrium

$$\pi_{in}(j) = \left[\tau_{in}(j)\frac{c_i}{A_i(j)}\right]^{-1/\theta(j)} \Big/ \sum_{k=1}^{I}\left[\tau_{kn}(j)\frac{c_k}{A_k(j)}\right]^{-1/\theta(j)}. \tag{7}$$

In the following sections, we use Equation (7) to solve analytically for the change in the skill premium between any two steady states.

A competitive equilibrium is a set of prices and quantities such that all markets clear. Each producer must satisfy worldwide demand for its output. Sectoral output must satisfy the resource constraints (2), (3), and (4). The demand for unskilled and skilled labor across producers must equal the endowments L_i and H_i, respectively. The demand for intermediate inputs of services and manufacturing must equal $X_i(S)$ and $X_i(M)$, respectively. The demand for structures and capital equipment across producers must equal their supplies $K_i(S)$ and $K_i(E)$. The supplies of each type of capital must be consistent with the household's optimal investment decisions. The household's budget constraints must be satisfied. A steady-state equilibrium is an equilibrium in which all variables remain constant over time. We characterize the steady-state equilibrium in Appendix A.

3 Analytic Results

In this section, we examine the central forces that shape changes in the skill premium and in real wages for skilled and unskilled workers in our model.

3.1 The Skill Premium

Cost minimization implies that producers set the ratio of the marginal product of skilled labor to unskilled labor equal to the skill premium. Equation (5) and the fact that producers in all sectors use the same factor intensity imply

$$\frac{s_i}{w_i} = \left(\frac{1-\mu_i}{\mu_i}\right)^{\frac{1}{\sigma}}(1-\lambda_i)^{\frac{1}{\rho}}\left(\frac{L_i}{H_i}\right)^{\frac{1}{\sigma}}\left[\lambda_i^{\frac{1}{\rho}}\left(\frac{K_i(E)}{H_i}\right)^{\frac{\rho-1}{\rho}} + (1-\lambda_i)^{\frac{1}{\rho}}\right]^{\frac{\sigma-\rho}{(\rho-1)\sigma}}, \tag{8}$$

exactly as in KORV. From equation (8), changes in country i's skill premium are fully determined by changes in country i's endowments of skilled and unskilled labor and changes in its stock of capital equipment. All else equal, an increase in unskilled labor relative to skilled labor increases the skill premium with an elasticity of $1/\sigma$ while an increase in capital equipment relative to skilled labor increases the skill premium if and only if $\sigma > \rho$ (that is, if skilled labor is more complementary with capital equipment than is unskilled labor). This second component captures the effect on the skill premium of capital-skill complementarity.

Of course, the stock of capital equipment, $K_i(E)$, is endogenous, and changes in $K_i(E)$ potentially depend on changes in bilateral trade costs (between each pair of countries and in each sector), changes in each country-sector-specific productivity, and changes in labor endowments in each country. We can show, however, that there is a small set of sufficient statistics that fully determine the equilibrium change in the stock of capital equipment and the skill premium across steady-states. Appendix A presents a set of six equations from which the steady-state change in the skill premium (and the real wages of skilled and unskilled workers) can be calculated for any country i.

For given values of the elasticities of substitution (σ and ρ), the dispersion of productivities $\theta(j)$, and factor shares in the initial equilibrium, the change in country i's skill premium depends only on: (i) changes in domestic expenditure shares, $\pi_{ii}(j)$ for all j; (ii) changes in domestic technologies, $A_i(j)$ for all j; and (iii) changes in domestic labor endowments, H_i and L_i. Importantly, conditional on $(i)-(iii)$, changes in trade costs, changes in other countries' technologies and endowments, and changes in all other trade shares do not affect country i's skill premium. That is, international trade costs, foreign technologies, and foreign endowments only affect country i's skill premium through $\pi_{ii}(j)$. Moreover, for a given change in domestic expenditure shares $\pi_{ii}(j)$, we do not need to compute the multi-country general equilibrium model to calculate the change in country i's skill premium.

First-Order Approximation for Changes in the Skill Premium: To better understand the role of changes in (i) domestic expenditure shares, (ii) domestic technologies, and (iii) domestic labor endowments in shaping changes in the skill premium, we log-linearize the steady-state equilibrium equations. In Appendix B we show that the change in the skill premium is, to a first-order approximation, given by

$$\widehat{s}_i - \widehat{w}_i = -\frac{\xi_i^L + \xi_i^H}{\rho\xi_i^L + \sigma\xi_i^H}\left(\widehat{H}_i - \widehat{L}_i\right) + \Theta_i \sum_j \varkappa_i(j)\left[\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)\right], \tag{9}$$

where variables with hats denote log differences, ξ_i^H denotes the initial steady-state ratio of skilled labor payments to capital equipment payments, and ξ_i^L denotes the initial steady-state ratio of unskilled labor payments to the sum of all labor payments and payments to capital equipment,

$$\xi_i^H = \frac{s_i H_i}{r_i K_i(E)} \quad \text{and} \quad \xi_i^L = \frac{w_i L_i}{w_i L_i + s_i H_i + r_i K_i(E)}.$$

The elasticity of the skill premium with respect to $\widehat{A}_i(j) - \theta(j)\widehat{\pi}_{ii}(j)$ is given by $\Theta_i \varkappa_i(j)$, where

$$\Theta_i = \frac{\sigma - \rho}{\rho \xi_i^L + \sigma \xi_i^H} \tag{10}$$

is common across sectors, and where

$$\varkappa_i(j) = \begin{cases} \frac{(1-\zeta_i)\varepsilon_i + \zeta_i \alpha_i}{\zeta_i(1-\alpha_i)} & \text{if } j = S \\ \frac{(1-\zeta_i)(1-\varepsilon_i)}{\zeta_i(1-\alpha_i)} & \text{if } j = M \\ 1 & \text{if } j = E \end{cases} \tag{11}$$

depends on production function parameters and varies across sectors.

Decomposing changes in the skill premium: Equation (9) decomposes the change in the skill premium into four components. The first component depends on the growth of skilled labor relative to unskilled labor and captures the relative supply effect already present in equation (8). All else equal, an increase in the relative supply of skilled labor reduces the skill premium with an elasticity of $\left(\xi_i^H + \xi_i^L\right) / \left(\rho \xi_i^L + \sigma \xi_i^H\right)$. Note that if $\sigma = \rho$, so that equipment is equally complementary to skilled and unskilled labor, then this elasticity reduces to $1/\rho$, exactly as in Tinbergen (1974, 1975) and Katz and Murhpy (1992), what Acemoglu and Autor (2010) call the *canonical model.*

The second, third, and fourth components ($j = S$, M, and E) are all contained in the summation term in equation (9). Each component depends on changes in sector j's productivity and domestic expenditure share and captures the capital-skill complementarity effect. All else equal, the elasticity of the skill premium with respect to $\widehat{A}_i(j) - \theta(j)\widehat{\pi}_{ii}(j)$ is $\Theta_i \varkappa_i(j)$, where $\varkappa_i(j) \geq 0$ for all j. If $\sigma > \rho$, so that $\Theta_i > 0$, then an increase in the supply of capital equipment relative to skilled labor increases the skill premium, as shown in equation (8). Here, we describe why $\widehat{A}_i(j) - \theta(j)\widehat{\pi}_{ii}(j) > 0$ for any j tends to raise $K_i(E)$, and hence the skill premium.

Intuitively, country i's stock of equipment rises either through increased domestic production or increased imports of equipment. All else equal, country i produces more equipment as $A_i(E)$ rises and imports more equipment as $\pi_{ii}(E)$ falls.

Country i's supply of equipment also rises if $\widehat{A}_i(j) - \theta(j)\widehat{\pi}_{ii}(j) > 0$ for $j = S, M$. Intuitively, in equilibrium $X_i(S)$ and $X_i(M)$ rise with $\widehat{A}_i(j) - \theta(j)\widehat{\pi}_{ii}(j)$ for $j = S$ and $j = M$, respectively, for the same reason that $K_i(E)$ rises with $\widehat{A}_i(E) - \theta(j)\widehat{\pi}_{ii}(E)$. Because $X_i(S)$ and $X_i(M)$ are used as inputs in the production of equipment, the stock of equipment rises as well.

The elasticity of the skill premium: Equation (9) provides the elasticity of a country's skill premium with respect to each of its sectoral productivities, $\Theta_i \varkappa_i(j)$, and each of its domestic sectoral expenditure shares, $-\Theta_i \varkappa_i(j)\,\theta(j)$. These elasticities have clear economic interpretations that highlight the roles played by different model parameters and they allow us to conduct sensitivity analyses analytically.

A higher value of within-sector technological dispersion, $\theta(j)$, tends to magnify the impact of changes in trade shares on the skill premium. This follows from the fact that for a given domestic expenditure share in the equipment sector (for example), the increase in the stock of equipment generated by trade is greater for higher values of $\theta(j)$. Intuitively, when productivity dispersion rises, the cost differential between imported varieties and the domestic varieties they replace becomes greater, so that the same reduction in the domestic expenditure share leads to a greater reduction in the price of capital equipment and, therefore, a greater increase in its stock.

Similarly, a higher value of the elasticity $\Theta_i \varkappa_i(j)$ tends to magnify the impact of $\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)$ on the skill premium. Stronger capital-skill complementarity implies a higher value of Θ_i. Inspecting equation (11), it is apparent that sectors that are more important in the production of capital equipment have a higher value of $\varkappa_i(j)$, and hence have a higher elasticity of the skill premium with respect to $\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)$.

Note that the equipment stock and the skill premium rise if there is growth in technology and trade in manufacturing, equipment, or services—regardless of the sector in which growth is greatest—whereas the price of equipment relative to the price of manufacturing (for instance) falls if technological and trade growth are relatively larger in the equipment sector:

$$\widehat{P}_i(E) - \widehat{P}_i(M) = \widehat{A}_i(M) - \widehat{A}_i(E) + \theta(E)\,\widehat{\pi}_{ii}(E) - \theta(M)\,\widehat{\pi}_{ii}(M).$$

Hence, an increase in the stock of equipment and the skill premium are not necessarily accompanied by a decline in the relative price of equipment to manufactured consumption goods, contrary to what is typically discussed in the literature. Instead, they are accompanied by a decline in the relative price of equipment to a composite of equipment, skilled labor, and unskilled labor (which we define in Appendix A).

Summary: We summarize the previous results in the following Proposition.

Proposition 1 *In any equilibrium, the skill premium in country i is given by equation* (8)*, and the change in the skill premium in country i across two steady-states is, to a first-order approximation, given by equation* (9)*.*

3.2 Real Wages

Whereas our previous focus has been on the skill premium, most of the quantitative trade literature focuses on gains from trade. Here we show that our framework also yields clear predictions on how changes in (*i*) domestic expenditure shares, (*ii*) domestic technologies, and (*iii*) domestic endowments shape changes in real wages for skilled and unskilled workers. Real wages of skilled and unskilled workers are simply $s_i/P_i(C)$ and $w_i/P_i(C)$ respectively, where

$$P_i(C) = \frac{P_i(S)^{1-\phi}\, P_i(M)^{\phi}}{\phi^{\phi}(1-\phi)^{1-\phi}}.$$

In Appendix B we show that changes in real skilled and unskilled wages are, to a first-order approximation, given by

$$\widehat{s}_i - \widehat{P}_i(C) = -\frac{\xi_i^L\left(1+\xi_i^H\right)}{\rho\xi_i^L + \sigma\xi_i^H}\left(\widehat{H}_i - \widehat{L}_i\right) + \sum_j \nu_i(j)\left[\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)\right] \tag{12}$$

and

$$\widehat{w}_i - \widehat{P}_i(C) = \frac{\left(1-\xi_i^L\right)\xi_i^H}{\rho\xi_i^L + \sigma\xi_i^H}\left(\widehat{H}_i - \widehat{L}_i\right) + \sum_j \left[\nu_i(j) - \Theta_i\varkappa_i(j)\right]\left[\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)\right], \tag{13}$$

where

$$\nu_i(j) = \begin{cases} \frac{\sigma\left(1+\xi_i^H\right)}{\rho\xi_i^L+\sigma\xi_i^H}\frac{\zeta_i+\varepsilon_i-\zeta_i\varepsilon_i}{\zeta_i(1-\alpha_i)} - \frac{\sigma-\rho\xi_i^L}{\rho\xi_i^L+\sigma\xi_i^H} - \phi & \text{if } j = S \\ \frac{\sigma\left(1+\xi_i^H\right)}{\rho\xi_i^L+\sigma\xi_i^H}\frac{(1-\zeta_i)(1-\varepsilon_i)}{\zeta_i(1-\alpha_i)} + \phi & \text{if } j = M \\ \frac{\sigma-\rho\xi_i^L}{\rho\xi_i^L+\sigma\xi_i^H} & \text{if } j = E \end{cases}$$

depends on production function parameters and factor shares and varies across sectors. Note that equations (12) and (13) together imply equation (9).

Decomposing changes in real wages: Equations (12) and (13) decompose changes in real wages into four components. The first component depends on the growth of skilled labor relative to unskilled labor and captures the relative supply effect. All else equal, the real wage of a given factor is decreasing in its relative supply.

The second, third, and fourth components ($j = S$, M, and E) are all contained in the summation terms in equations (12) and (13). Each component depends on changes in sector j's productivity and domestic expenditure share, and captures both the effects of trade and productivity growth on the real wage in standard quantitative trade models as well as the capital-skill complementarity effect. To see the standard effects, consider the case in which capital is equally complementary with skilled and unskilled labor, $\sigma = \rho$. In this case $\Theta_i = 0$, so that $\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)$ has the same effect on the real wage of skilled and unskilled workers. Specifically, in this case $\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j) > 0$ raises the real wage of both factors, as $\nu_i(j) > 0$ for all j. In the presence of capital-skill complementarity, however, $\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)$ has different effects on skilled and unskilled workers as discussed above.

Specifically, $\widehat{A}_i(j) - \theta(j)\widehat{\pi}_{ii}(j) > 0$ raises the real wage of skilled workers relatively more than the real wage of unskilled workers for any j.[12]

As in the section on the skill premium, equations (12) and (13) provide the elasticity of skilled and unskilled real wages in country i with respect to each of i's sectoral productivities and each of its domestic sectoral expenditure shares.

Summary: We summarize the previous results in the following Proposition.

Proposition 2 *The changes in real wages for skilled and unskilled workers in country i across two steady-states are, to a first-order approximation, given by equations* (12) *and* (13)*, respectively.*

3.3 Robustness

Alternative quantitative trade models: In this paper we embed capital-skill complementarity into a version of the quantitative Ricardian model of international trade pioneered in EK. In EK, changes in trade costs and in foreign technologies and labor endowments affect the domestic real wage only through their impact on the domestic expenditure share; moreover, the elasticity of the real wage to the domestic expenditure share is θ. Arkolakis, Costinot, and Rodriguez-Clare (2012), henceforth ACR, show that these two results hold across a range of quantitative trade models. To what extent does this generality apply to our results?

Consider an Armington version of our model (in which the pattern of specialization across intermediate goods is exogenous). In this model, all our results are unchanged except that the dependence of our expressions on the dispersion parameter $\theta(j)$ is substituted by the inverse of the elasticity of substitution across intermediate goods in sector j, $1/(\eta(j) - 1)$.

Next, consider a monopolistic competition version of our model in which each firm produces a differentiated intermediate good and is subject to a fixed cost (expressed in terms of the factor composite) to sell the good in each country. If firm entry is restricted in each sector and the productivity distribution of entering firms is Pareto (as in Chaney 2008), we show the following two results in the Online Addendum. First, as in our EK model, changes in variable and fixed trade costs and in foreign technologies and labor endowments affect prices and quantities in the domestic economy only through their impact on a small set of

[12] In response to increases in trade shares in any sector ($\widehat{\pi}_{ii}(j) < 0$), the real wage of unskilled workers increases for any value of σ and ρ, while the real wage of skilled workers may fall if skilled labor is sufficient substitutable with capital equipment ($\sigma << \rho$). However, this result depends on the specific form of our production function. Reversing the nest in the production function (i.e. nesting equipment and unskilled labor together) we obtain the opposite result: the real wage of skilled workers increases in response to $\widehat{\pi}_{ii}(j) < 0$ for any degree of capital-skill complementarity, while the real wage of unskilled workers may fall if unskilled labor is sufficient substitutable with equipment capital.

sufficient statistics in the domestic economy: domestic sectoral expenditure shares, as in our EK model, and total net exports relative to GDP in the domestic country, unlike in our EK model. Hence, given these statistics, changes in real wages and the skill premium can still be solved country-by-country without computing the multi-country general equilibrium model. Second, the expressions linking changes in the skill premium to changes in domestic sectoral expenditure shares (even when net exports are zero) differ from those in the Ricardian model because they depend on changes in the share of each sector in total absorption in the domestic economy, which in general are not constant.[13] If, instead, firm entry into each sector is endogenous (as in Melitz 2003), then our first result above does not hold and, analogously to the results in Section 5.1 of ACR, changes in factor prices also depend on changes in employment in each sector. Hence, in the case of endogenous entry we cannot apply the simple sufficient statistics approach that we use in this paper to solve, country by country, for changes in factor prices.

Differences in factor intensities across sectors: In the Online Addendum we briefly discuss an extension of our basic environment that relaxes our assumption that factor intensities are common across sectors. In particular, we allow for the parameters of the production function $\{\varepsilon, \zeta, \alpha, \mu, \lambda, \rho, \sigma\}$ to all vary across sectors. We show that changes in a country's skill premium are not only determined by changes in domestic productivities, domestic labor endowments, and domestic expenditure shares—as in our baseline model—but also by changes in the factor-content of trade (i.e., the amount of each factor embodied in a country's net exports).[14] This extended model thus embeds the standard Stolper-Samuelson effect, through which international trade raises the relative return of the factor used intensively in the comparative advantage sector. We show, however, that conditional on observing changes in domestic productivities, domestic labor endowments, domestic expenditure shares, and the factor-content of trade in country i, one can still calculate changes in country i's skill premium without actually computing the multi-country general equilibrium model. Burstein and Vogel (2012) show that the Stolper-Samuelson effect is not quantitatively strong in a multi-country model. Hence, in order to isolate the role of capital-skill complementarity on the skill premium, we assume that factor intensities are common across sectors in our quantitative analysis.

[13] In the Cobb-Douglass multi-sector extension of ACR, the share of each sector in total absorption is constant.

[14] See Burstein and Vogel (2011) for a discussion of the factor content of trade in a general class of trade models.

3.4 Motivating our counterfactuals

In the next section, we use our framework to conduct two counterfactual exercises quantifying the impact of international trade on the skill premium (and real wages) through its impact on the accumulation of capital equipment. Specifically, we solve for changes in real wages and the skill premium resulting from given changes in domestic sectoral expenditure shares ($\pi_{ii}(j)$s) using equations (38) – (43) in Appendix A. In the first counterfactual we move countries to autarky. In the second counterfactual we move countries from their domestic sectoral expenditure shares observed in 2000 to those in 1963 (or the first year with available data).

In what follows we show that our second counterfactual provides a specific way to quantify the impact of international trade on real wages and the skill premium over a given time period. Fix the set of parameters $\{\sigma, \rho, \theta(M), \theta(E), \zeta_i, \varepsilon_i, \alpha_i, \phi_i\}$ and fix country i's year t steady-state factor shares $\{\xi_i^H, \xi_i^L\}$. Suppose that between two steady-state years, t and t', the primitives—worldwide trade costs, technologies, and labor endowments—changed in some unobserved manner. These changes in primitives cause changes in domestic sectoral expenditure shares, the skill premium, real wages of skilled workers, and real wages of unskilled workers in each country i, which we denote by $\widehat{\pi}_{ii}(j)$ for all j, $\widehat{s_i/w_i}$, $\widehat{s_i/P(C)_i}$, and $\widehat{w_i/P(C)_i}$ for all i. Now consider a counterfactual environment in which country i is in autarky between years t and t'.[15] Suppose that the same percentage changes in unobserved primitives occurred, excluding the changes in country i's trade costs, which are set to infinity in both years in this counterfactual environment. These changes in primitives cause changes in country i's skill premium and real wages, which we denote by $\widehat{s'_i/w'_i}$, $\widehat{s'_i/P'_i(C)}$, and $\widehat{w'_i/P'_i(C)}$. The following corollary of Propositions 1 and 2 relates the steady-state implications of this change in primitives between the environment in which country i trades and the counterfactual environment in which it is in autarky.

Corollary 1 *To a first-order approximation,*

$$\begin{aligned}
\widehat{s_i/w_i} - \widehat{s'_i/w'_i} &= -\Theta_i \sum_j \varkappa_i(j)\,\theta(j)\,\widehat{\pi}_{ii}(j) \\
\widehat{s_i/P_i(C)} - \widehat{s'_i/P'_i(C)} &= -\sum_j \nu_i(j)\,\theta(j)\,\widehat{\pi}_{ii}(j) \\
\widehat{w_i/P_i(C)} - \widehat{w'_i/P'_i(C)} &= -\sum_j \left[\nu_i(j) - \Theta_i \varkappa_i(j)\right]\theta\widehat{\pi}_{ii}(j)\,,
\end{aligned}$$

for a fixed set of parameters $\{\sigma, \rho, \theta(M), \theta(E), \zeta_i, \varepsilon_i, \alpha_i, \phi_i\}$ *and fixed year* t *steady-state*

[15] In order to fix country i's year t steady-state factor shares $\left\{\xi_i^H, \xi_i^L\right\}$ in this counterfactual environment (without trade) at their levels in our baseline environment (with trade), we must adjust the levels of some combination of country i's sectoral productivities, its factor endowments, and its parameters λ_i and μ_i.

factor shares $\left\{\xi_i^H, \xi_i^L\right\}$ *in country* i.

Corollary 1 provides an answer to the following question: What are the additional effects of changes in primitives on the skill premium and real wages in an open economy relative to the effects in a closed economy? According to corollary 1, we can answer this question—up to a first-order approximation—using observable changes in domestic sectoral expenditure shares between two time periods without needing to observe the underlying changes in primitives.

Our answer to this question would be exact (instead of a first-order approximation) if factor shares and the share of each sector in total absorption were constant across steady-states, conditions which in general do not hold in our model. However, these conditions do hold trivially in standard quantitative trade models with one factor and one sector. It is straightforward to show that in versions of such models considered in ACR, this question can be answered exactly using a result similar to that in corollary 1.

Note that changes in international trade patterns that affect relative prices—both the skill premium and sectoral price indices—may alter incentives to acquire education and engage in innovative activities that affect sectoral productivities. In our two counterfactuals, we abstract from the indirect effects of trade on the supply of skilled and unskilled labor and on sector-level productivities.

4 Quantitative Results

In this section we conduct the two counterfactuals described above. To conduct these counterfactuals we need information on domestic expenditure shares, $\pi_{ii}(j)$, and we need to assign values to our model's parameters. In what follows, we first describe how we construct domestic expenditure shares and how we parameterize the model. Further details are provided in Appendix C. We next present our baseline quantitative results. Finally, we conduct alternative parameterizations and sensitivity analyses.

4.1 Domestic Expenditure Shares

To construct domestic expenditure shares in equipment and manufacturing, $\pi_{ii}(E)$ and $\pi_{ii}(M)$, we use trade and production data and compute expenditures as the difference between gross output and net exports. Trade data comes from Feenstra et. al. (2005), which contains data by commodity, disaggregated at the 4-digit Standard International Trade Classification (SITC) level, for the 1962-2000 period. For gross output data, we use the UNIDO Industrial Statistics Database, which covers the 1963-2007 period and is arranged at the 2-digit level of the third revision of the International Standard Industrial Classification (ISIC Rev. 3). Recall that we abstract from trade in non-manufacturing industries (which, in our model, means that we abstract from trade in the non-manufacturing, non-equipment sectors).

We follow Eaton and Kortum (2001), who group manufactured commodities into equipment goods and other manufacturing goods using input-output tables and capital flows tables of domestic transactions (OECD, 1996) for the three major capital goods producers (Germany, Japan, and the US). For trade data, we match 4 digit SITC codes to a set of industry codes used by the Bureau of Economic Analysis (BEA). Following Eaton and Kortum, we define equipment trade as the sum of BEA industry codes 20-27 and 33.

For gross output data, Eaton and Kortum identify three ISIC Rev. 2 industries as equipment producers: non-electrical equipment, electrical equipment, and instruments. We define equipment producers as the ISIC Rev. 3 industries that most closely correspond to the ISIC Rev. 2 industries identified by Eaton and Kortum.[16] In particular, we define equipment commodities to be the sum of ISIC Rev. 3 codes 29-33.

After combining these datasets, we are left with 53 countries for which data both on trade and output is available until at least 1995. For each country in our sample, our counterfactuals are based on the first and last year with available data. Importantly, we do not require a balanced panel because we do not need data on changes in any country $n \neq i$ when solving for the change in the skill premium in country i in our counterfactuals.

We report the resulting domestic expenditure shares in Table 2. Two features are striking from the table. First, as noticed by Eaton and Kortum (2001), most countries import a significant fraction of their capital equipment. For the median country in our sample, the import share of equipment in the year 2000 is roughly $1 - 0.25 = 0.75$, more than twice as large as the import share for other manufactured goods. Note that these import shares are large for countries at different stages of the development process, including developed countries such as Canada and the UK. Second, most countries experienced sizable increases in their import shares over our sample period, especially in the equipment sector. Notable exceptions are the poorest countries in the sample, which were already importing almost all of their equipment at the beginning of the sample. The median values across countries for the changes in the domestic expenditure shares in equipment and manufacturing, $\widehat{\pi}_{ii}(E)$ and $\widehat{\pi}_{ii}(M)$, are -0.3 and -0.15, respectively.

The fact that $\pi_{ii}(E)$ tends to be lower in developing countries might suggest that the relative price level of equipment is higher in these countries; see e.g. Eaton and Kortum (2001) and Hsieh and Klenow (2007). In our model, this relative price depends on a combination of trade costs and productivities in each country. Since our parameterization does

[16] UNIDO discontinued its Industrial Statistics Database using ISIC Rev. 2.

not separately identify trade costs and productivities in each country, our paper is silent on our model's implications for these relative prices.[17]

4.2 Parameterization

By inspecting the set of equations that determines the change in the skill premium and real wages in our counterfactuals (described in Appendix A) and in the log-linearized equations above, the parameters that we must choose are those that determine the elasticities of substitution between capital equipment, unskilled labor, and skilled labor, σ and ρ; the within-sector dispersion of productivity in manufacturing and equipment, $\theta(M)$ and $\theta(E)$; the constant share of value added in production, ζ_i; the constant share of services in intermediate inputs, ε_i; the constant share of structures in value added, α_i, and the constant share of manufacturing in consumption, ϕ_i. We must also assign values to relative factor shares ξ_i^L and ξ_i^H in the initial equilibrium (the year 2000). Conditional on matching these endogenous values, we do not need to assign values to the two remaining production function parameters (μ_i and λ_i) or to sectoral productivities $A_i(j)$ and labor endowments H_i and L_i. Because of data availability, we assume that all of the above parameters $\{\sigma, \rho, \theta(M), \theta(E), \zeta, \varepsilon, \alpha, \phi\}$ are common across countries. We also assume that relative factor shares in the initial equilibrium $\left\{\xi^L, \xi^H\right\}$ are common across countries.[18] Given data availability it would be straightforward to run our counterfactuals allowing all parameters except $\theta(j)$ to vary across countries. We now provide an overview of our baseline procedure, the results of which are summarized in Table 1.

Baseline parameterization: We pick ϕ, ζ, ε, α, σ, ρ, ξ^L, and ξ^H to match certain features of US data between 1963 and 2000. The share of manufacturing in households' consumption, ϕ, the share of value added in gross output, ζ, and the share of services in intermediate inputs, ε, are set at their average shares in 1995 and 2000 from the OECD Input-Output database.[19] We calibrate the share of structures in value added, α, and relative factor shares in the initial equilibrium (the year 2000), ξ^L and ξ^H, to match observed factor shares in the US. Annual estimates for these shares are obtained as follows. We calculate the labor share

[17] Waugh (2010) shows that quantitative Ricardian models are consistent with observed differences across countries in the level of tradeable goods prices if one allows for asymmetric trade costs (e.g. $\tau_{in}(j) \neq \tau_{ni}(j)$), as we do in this paper.

[18] The assumption that $\left\{\xi^L, \xi^H\right\}$ are equal across countries in the initial equilibrium implies that a combination of sectoral productivities $A_i(j)$, labor endowments H_i and L_i, and parameters λ_i and μ_i vary across countries to match these relative factor shares.

[19] In calculating these statistics, we only consider consumption, valued added, gross output, and intermediates of manufacturing (which includes equipment and non-equipment manufacturing in our model) and service industries in the IO tables. The resulting parameter values are $\phi = 0.2$, $\zeta = 0.54$ and $\varepsilon = 0.62$.

in value added from NIPA as the ratio of compensation for employees to value added less taxes, in the corporate and non-corporate business sector. We disaggregate labor payments into skilled and unskilled labor using data on quantities and prices of skilled and unskilled labor from Polgreen and Silos (2008), who use detailed CPS data. We disaggregate capital payments into structures and equipment using data on the value of capital stocks and, since rental rates are not directly observable, using the steady-state Euler equations of our model for the accumulation of each type of capital, where a time period represents a year. We set α equal to the share of payments to structures capital in total factor payments on average between 1963 and 2000. We set ξ^L and ξ^H in the original equilibrium (year 2000) equal to the respective relative factor shares on average between 1996 and 2000.[20] This procedure implies $\alpha = 0.1$, $\xi^L = 0.44$, and $\xi^H = 1.37$.[21] Further details are provided in Appendix C.

From equation (7), $1/\theta(j)$ is the sector-level elasticity of trade with respect to trade costs (i.e., the trade elasticity). If trade costs and the trade elasticity are the same across sectors, then $1/\theta(j)$ is also the aggregate trade elasticity. Under these assumptions, we could choose $\theta(j)$ using aggregate trade elasticities. To match an aggregate elasticity of 5, for instance, we would pick $\theta(j) = 0.2$. However, we allow for variation in trade costs across sectors. In this case, even if $\theta(j)$ is constant across sectors, $1/\theta(j)$ need not equal the aggregate trade elasticity. Using a technique developed in Caliendo and Parro (2011), Parro (2012) estimates sector-level trade elasticities in the equipment and manufacturing sectors using gravity equations that hold in our model. We use his estimates, implying $\theta(E) = 0.22$ and $\theta(M) = 0.19$.

The two final and key parameters whose values we need to pick are σ and ρ. We pursue several strategies to parameterize these. We calibrate σ and ρ so that our model reproduces the observed cumulative changes in factor shares and the skill premium in the US between 1963 and 2000, given the observed changes in the supplies of capital equipment and of skilled

[20] Consistent with our model, factor shares ξ^H and ξ^L in the U.S. changed considerably in our time period (e.g. the payments to capital equipment rise over time relative to the payments to skilled labor). While our baseline year (the initial equilibrium) is 2000, we use the average estimated shares in the period 1996-2000 to reduce measurement error. Using instead the average estimates of factor shares between 1963 and 2000, the elasticity of the skill premium to trade flows is significantly larger than in our baseline parameterization.

[21] We assume that factor shares are identical across countries because of data limitations only. If, contrary to our assumption, developing countries have lower equipment shares (or lower skill shares), then Θ_i would be lower (higher) in developing countries. Our assumption that the labor share is not systematically correlated with a country's level of development is consistent with evidence in Gollin (2002). In our model the labor share changes in response to the changes in trade shares we feed in from the data, but for our counterfactuals these changes are very small.

and unskilled labor. In particular, we use the two following equations

$$\rho^{-1} = 1 + \frac{\widehat{\xi^H}}{\widehat{K(E)/H}} \tag{14}$$

$$\sigma = \frac{(\rho - 1)\,\widehat{(H/L)} + \rho\widehat{\left(1 + 1/\xi^H\right)}}{(1 - \rho)\,\widehat{(s/w)} + \widehat{\left(1 + 1/\xi^H\right)}}, \tag{15}$$

where variables with hats denote log differences between 1963 and 2000. Equation (14) is obtained by log-differentiating the producers' first-order condition for capital equipment relative to skilled labor. Equation (15) is obtained by log-differentiating equation (8). In solving for ρ and σ, we use data on changes in the skill premium and on the stocks of (quality adjusted) capital equipment, skilled labor and unskilled labor from Polgreen and Silos (2008). This procedure implies $\rho = 0.63$ and $\sigma = 1.56$.

With these parameters, the elasticity of the skill premium with respect to $\widehat{A}_i(j) - \theta(j)\,\widehat{\pi}_{ii}(j)$ in all countries is $\Theta = 0.39$ for equipment goods and $\Theta\varkappa_i(M) = 0.39 \times 0.36 = 0.14$ for manufacturing goods, from equation (9).[22] Together with our values of $\theta(j)$, this implies an elasticity of the skill premium with respect to domestic expenditure shares, $\Theta\varkappa(j)\,\theta(j)$, in equipment and manufacturing of 0.085 and 0.026, respectively.

In addition to determining the extent of capital-skill complementarity, Θ, the parameters ρ and σ also determine the elasticity of substitution between skilled and unskilled labor. Following Sato (1967), the direct partial elasticity of substitution between skilled and unskilled labor—defined as $d\log(H/L)/d\log(w/s)$ holding output and all inputs except H and L constant—is given by $\sigma\rho\left(\xi^L + 1\right) / \left(\xi^L\sigma + \rho\right)$, which equals 1.08. We also calculate an alternative measure of the elasticity of substitution between skilled and unskilled labor: $d\log(H/L)/d\log(w/s)$ holding $H/K(E)$ constant, which equals $\sigma = 1.56$. In the context of our production function, this elasticity is equivalent to the Allen partial elasticity of substitution between skilled and unskilled labor, as defined in Sato (1967).

4.3 Baseline Results

We now quantify the impact of international trade, through capital-skill complementarity, on real wages and the skill premium.[23] We perform the two counterfactual exercises described

[22] Using measures of changes in labor supplies and the skill premium from Acemoglu and Autor (2010) we obtain $\Theta = 0.40$. If we parameterize our model using data from 1963 to 1992 as in KORV (as opposed to 1963-2000), we obtain $\Theta = 0.35$. Using the values of the elasticities σ and ρ estimated in KORV we obtain $\Theta = 0.39$.

[23] In our model, real wages do not equal welfare because net exports are not zero.

above using our baseline parameterization.

Counterfactual 1—Autarky: In our first counterfactual, we hold all technologies and factor endowments fixed at the baseline levels and raise all trade costs to infinity. Through this counterfactual we quantify how much each country's skill premium and both of its real wages would change if it were moved to autarky. The counterfactual implications for real wages and the skill premium are reported in Table 3. The results of our first counterfactual exercise are summarized in Figures 1 and 2. Figure 1 plots the logarithmic change in real wages of skilled and unskilled workers in each country (y-axis). Given our emphasis on international trade in capital goods, we plot on the x-axis the log change of the domestic expenditure share in the equipment sector moving from the year 2000 to autarky.

Figure 1 establishes two results. First, moving to autarky, real wages fall for both skilled and unskilled workers in all countries, and, as in most standard models, fall relatively more in countries that experience a larger increase in domestic expenditure shares, both in equipment and in manufacturing, as implied by equations (12) and (13). Second, the losses from moving to autarky are unevenly distributed within countries. While both factors lose, skilled workers lose disproportionately. The ratio of the change in a skilled worker's real wage relative to the change in an unskilled worker's real wage, $\Delta \log \left(s_n/P_n\right) / \Delta \log \left(w_n/P_n\right)$, is 2.36 in the median country.

This ratio can be expressed as a function of the log change in the skill premium

$$\frac{\Delta \log \left(s_n/P_n\right)}{\Delta \log \left(w_n/P_n\right)} = 1 + \frac{\Delta \log \left(s_n/w_n\right)}{\Delta \log \left(w_n/P_n\right)}.$$

Figure 2 plots the logarithmic change in the skill premium (y-axis)—i.e. the vertical distance between changes in log real wages of skilled and unskilled workers plotted in Figure 1—and the log change in the domestic expenditure share in the equipment sector moving from the year 2000 to autarky (x-axis). Absent international trade in both capital equipment and manufactures the skill premium falls in all countries. The log of the skill premium falls by roughly 0.14 in the median country. While the skill premium falls everywhere, the decrease is much larger for countries that are very dependent on imports of capital equipment, such as Cameroon and the Czech Republic. On the other extreme, the decline in the log of the skill premium is only 0.01 for Japan and 0.05 for the US.

Expression (9) provides a decomposition of changes in the skill premium induced by changes in trade shares in equipment and changes in trade shares in manufacturing (recall that we refer to non-equipment manufacturing simply as manufacturing). The line in Figure 2 shows the log change in the skill premium resulting from shutting down trade in equipment goods only, while keeping trade shares in the manufacturing sector constant. The skill premium falls by less when only equipment trade is shut down because manufacturing imports raise the stock of equipment and, therefore, the skill premium. The role of (non-equipment) manufacturing trade in shaping the skill premium is large for some countries such as Bulgaria, Slovakia, and Greece, which import a substantial share of their manufacturing absorption. However, for most countries, trade in equipment is significantly more important than trade in manufacturing in driving the change in the skill premium, because both the 2000 import share and the elasticity of the skill premium with respect to a change in the import share are larger for equipment than for manufacturing.

The first-order approximation of the change in the skill premium from going to autarky implied by equation (9) is quite accurate. Across our set of countries, the median and maximum differences between the exact and approximated changes in the skill premium are 0.01 and 0.09 log points, respectively (which represent 8% and 21%, respectively, of the exact changes in the skill premium). Of course, the approximation error is larger for countries with lower domestic expenditures shares. The first-order approximations of the changes in the real wages of skilled and unskilled workers are similarly accurate.

Counterfactual 2—Observed changes in trade shares: In our second counterfactual, we hold a given country's technologies and factor endowments fixed and change its domestic expenditure shares from their observed levels in 2000 to 1963, or the first year with available data. Through this counterfactual we gauge the response of real wages in a given country to all changes in technologies, endowments, and trade costs (over this time period) relative to the what the responses would have been had that country been in autarky over this time period, as stated in corollary 1.

This counterfactual change in trade disproportionately impacts skilled workers: the ratio of the change in a skilled worker's real wage relative to the change in an unskilled worker's real wage, $\Delta \log (s_n/P_n) / \Delta \log (w_n/P_n)$, is 2.38 in the median country. The results on the skill premium are summarized in Figure 3, which plots the logarithmic change in the skill premium (y-axis) and the logarithmic change in the domestic expenditure share in the equipment sector (x-axis). International trade plays an important role in shaping the skill premium through capital-skill complementarity, but its importance varies widely across countries in our sample depending on the magnitude of the changes in the domestic expenditure shares in equipment and other manufactured goods. While the counterfactual change in the skill premium is -0.05 log points for the median country of our sample and -0.04 log points for the US, the decline in the skill premium is quite large in various developing countries such as Argentina, Chile, Colombia, Greece, and Uruguay, and in some developed countries such as Canada and the UK. Note that for countries in the northwest corner of Figure 3, domestic expenditure shares in the equipment sector rose during our sample period, so that moving from the domestic expenditure shares in equipment observed in 2000 to those in the base year contributes to increasing the skill premium. Once again, trade in equipment plays a more significant role than trade in other manufactured goods in shaping the change in skill premium.

As in the previous counterfactual exercise, the first-order approximation of the change in the skill premium from equation (9) is quite accurate. The median and maximum differences between the exact and approximated changes in the skill premium are only 0.003 and 0.04 log points, respectively (which represent 4% and 14% of the exact changes in the respective skill premia). The first-order approximations of the changes in the real wages of skilled and unskilled workers are similarly accurate.

4.4 Alternative Parameterizations and Sensitivity

In this section we provide a set of alternative parameterization strategies and conduct sensitivity analyses using the results. We consider alternative strategies for determining the strength of capital-skill complementarity (σ and ρ) and we pick alternative values for the dispersion of productivities ($\theta(j)$) and the share of structures (α). For each alternative parameterization Table 4 reports the elasticity of the skill premium with respect to changes in domestic expenditure shares in equipment and in manufacturing (using the first-order approximation), $\Theta\varkappa(j)\,\theta(j)$, as well as the median log points change in the skill premium for both of our counterfactuals (using the exact solution).

The strength of capital-skill complementarity: Because no consensus exists in the literature on the strength of capital-skill complementarity, we provide a number of alternative strategies for choosing σ and ρ.

One concern in the literature is that if there is exogenous skill-biased technical change, then estimates of σ and ρ that ignore this trend will overstate the extent of capital-skill complementarity; see e.g. Acemoglu (2002). While addressing this concern fully is beyond the scope of the present paper, we follow a suggestion in Acemoglu (2002) and re-calibrate σ and ρ while allowing for trend growth in the productivity of the composite of skilled labor and capital equipment relative to unskilled labor. Specifically we generalize equation (5) by replacing the term $(1-\mu_i)^{1/\sigma}$ with $T(t)(1-\mu_i)^{1/\sigma}$, where $T(t) = \exp(\vartheta t)$ and ϑ denotes the annual trend.

In this extended version of the model, we obtain a version of Proposition 1 generalized as follows. In any equilibrium in period t, the skill premium in country i is given by a generalized version of equation (8) in which $T(t)$ multiplies the right-hand side. The change in the skill premium in country i across two steady-states in years t and $t' > t$

is, to a first-order approximation, given by a generalized version of equation (9) in which $\left(1+\Theta_i-\frac{\xi_i^L+\xi_i^H}{\rho\xi_i^L+\sigma\xi_i^H}\right)\frac{\sigma}{\sigma-1}\vartheta\left(t'-t\right)$ is added to the right-hand side. Note that in the special case in which $\sigma=\rho$, this final term simplifies to $\vartheta\left(t'-t\right)$.

Given this extension, we re-calibrate ρ and σ under two alternative values for the annual trend growth, $\vartheta=0.01$ and $\vartheta=0.02$, using equation (14) and an adjusted version of equation (15). The strength of capital-skill complementarity, as represented by Θ, falls from 0.39 to 0.30 and 0.22 if $\vartheta=0.01$ and $\vartheta=0.02$, respectively. Our approximation implies that this reduces the elasticity of the skill premium with respect to $\pi_{ii}\left(j\right)$ to slightly more than 3/4 and 1/2 of its baseline level, respectively; this is confirmed when we re-run our counterfactual exercises using these parameters. We continue to infer capital-skill complementarity, $\sigma>\rho$, as long as annual trend growth is less than 0.052.

Another concern in the literature is that although there is cross-country evidence supportive of capital-skill complementarity, the evidence is not strong; see e.g. Duffy, Papageorgiou and Perez-Sebastian (2004). Again, whereas we do not aim to fully address this concern, we do assess the degree of capital-skill complementarity in a developing country that is a net importer of capital equipment, Chile, over the years 1983-2000; we provide details in the Appendix C.[24] Together with the factor shares, the resulting elasticities imply stronger capital-skill complementarity, as represented by Θ, in Chile than in the US: $\Theta=0.63$. Table 4 reports correspondingly larger effects in the median country of both of our counterfactual exercises.

Alternative values for productivity dispersion: There is a similar debate regarding the correct value of the aggregate trade elasticity; see e.g. Anderson and Van Wincoop (2004), Donaldson (2010), Simonovska and Waugh (2011), Eaton, Kortum and Kramarz (2011), and Costinot, Donaldson, and Komunjer (2012). To understand the sensitivity of our results to our choice of sector-level trade elasticities, determined by $\theta\left(j\right)$, we choose two alternative values of $\theta\left(j\right)$: $\theta\left(j\right)=0.15$ and $\theta\left(j\right)=0.25$ for $j=E,M$. A higher value of $\theta\left(j\right)$ raises the elasticity of the skill premium (and of the real wage of skilled and unskilled workers) to changes in domestic sectoral expenditure shares, as shown in equation (9) (and in equations (12) and (13), respectively) and as described in section 3. Table 4 reports correspondingly smaller (larger) effects in the median country of both of our counterfactual exercises under the assumption that $\theta\left(j\right)=0.15$ ($\theta\left(j\right)=0.25$, respectively) for all j.

Alternative values for the share of structures: Because we do not directly observe separately the share of payments to structures and equipment capital in total factor payments, we disaggregate total capital payments using data on the value of capital stocks and

[24] We choose 1983 as an initial year to focus on the period in the aftermath of the Chilean debt crisis. We obtain a similar value for Θ if we choose 1974 as a starting year.

the steady-state Euler equations of our model, as discussed above in section 4.2 and in more depth in Appendix C. The implied split of payments to capital is 2/3 to equipment and 1/3 to structures (implying $\alpha = 0.10$) in our baseline parameterization. Given the complication of measuring this share, here we perform sensitivity by considering a lower share of 1/2 (corresponding to $\alpha = 0.15$) and a higher share of 3/4 (corresponding to $\alpha = 0.076$) of capital payments accruing to equipment.

A higher share of capital payments accruing to equipment (a lower α) mechanically lowers $\xi_i^H = s_i H_i / \left(r_i K_i \left(E\right)\right)$ and $\xi_i^L = w_i L_i / \left(w_i L_i + s_i H_i + r_i K_i \left(E\right)\right)$. Lower values of ξ_i^H and ξ_i^L are associated with a higher value of $\Theta_i = \left(\sigma - \rho\right) / \left(\rho \xi_i^L + \sigma \xi_i^H\right)$. Hence, a higher share of capital payments accruing to equipment is associated with stronger capital-skill complementarity and, therefore, a larger impact of changes in domestic sectoral expenditure shares on the skill premium (and real wages). This intuition is confirmed in Table 4.

5 Conclusions

Given the difficulty of empirically measuring the impact of international trade on the aggregate stock of capital equipment and, through capital-skill complementarity, the skill premium, we use a model to do so in this paper. Our framework combines a standard quantitative trade model with a basic component of macroeconomic models of inequality, an aggregate production function that exhibits capital-skill complementarity. We provide simple analytic expressions relating steady-state changes in the skill premium and the real wages of skilled and unskilled workers to changes in domestic expenditure shares, domestic productivities, and domestic labor endowments. Changes in domestic expenditure shares by sector fully summarize the effects of international trade, whether generated by changes in foreign or domestic technologies, foreign or domestic labor endowments, or trade costs. Using these results, we perform a range of simple counterfactual exercises to assess the importance of international trade on real wages and, through capital-skill complementarity, on the skill premium. We find that international trade can have a substantial impact on the skill premium, especially in countries that import a large fraction of their equipment. While our quantitative analysis is only suggestive—as there is an active debate on the role of capital-skill complementarity in accounting for changes in the skill premium—we view our main contribution as providing a simple set of analytic equations linking observable changes in domestic sectoral expenditure shares to changes in the real wages of skilled and unskilled workers for any given parameter values.

In our quantitative analysis, we make three choices in the pursuit of tractability that deserve further discussion. First, we focus on steady-state equilibria, abstracting from transition dynamics as countries open up to trade and gradually accumulate capital; see e.g. Stokey (1996). Second, we parameterize the degree of capital-skill complementarity to match observed changes in aggregate factor shares and the skill premium in the US and in Chile. An alternative approach would be to make use of micro-level evidence on the relationship between skill intensity and capital intensity at the producer level. This would require extending the model to allow for heterogeneity in factor intensities across producers within a country and sector.[25] Third, we assume that the degree of capital-skill complementarity is common across each type of capital equipment. If, however, different types of equipment exhibit different degrees of capital-skill complementarity, then countries might choose to invest in and import different mixes of equipment depending on their relative endowment of skilled to unskilled labor; see e.g. Caselli and Wilson (2004).[26]

While we focus on the implications of changes in trade patterns for real wages and the skill premium, our framework can be applied to study the importance of skill-biased technical change as well. In particular, by incorporating factor-specific technical change into our production function, as we do in the sensitivity analysis in Section 4.4, we obtain an equation that extends Tinbergen's (1974, 1975) pioneering work—what Acemoglu and Autor (2010) call the *canonical model*—to include the effects on the skill premium not only of labor endowment and skill-biased technical changes, but also of changes in the pattern of international trade.

Finally, in this paper we model the international transfer of skill-biased technology through trade in capital goods. We abstract from other potentially important channels by which technologies diffuse across countries, such as multinational production, see, e.g., Burstein and Monge-Naranjo (2009) and Ramondo and Rodriguez-Clare (2010); migration, see, e.g., Gandal, Hanson, and Slaughter (2004); or spillovers, see, e.g., Coe and Helpman (1995) and Gancia, Müller, and Zilibotti (2010). We also abstract from endogenous skill-biased technical change through innovation, see, e.g., Acemoglu (2003). Understanding the quantitative link between globalization and inequality through these alternative channels remains an important area for future research.

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[25] Burstein and Vogel (2012) provide a related model in which producer productivity is positively correlated with skill intensity. With this heterogeneity, one loses the tractable gravity structure of the model, even at the sectoral level, and the model must be solved numerically.

[26] Such an extension would have to be consistent with our finding that the extent of capital-skill complementarity is similar in the US and Chile. Moreover, if imported capital exhibits a greater degree of capital-skill complementarity than domestically produced capital, then trade would produce a larger rise in the skill premium.

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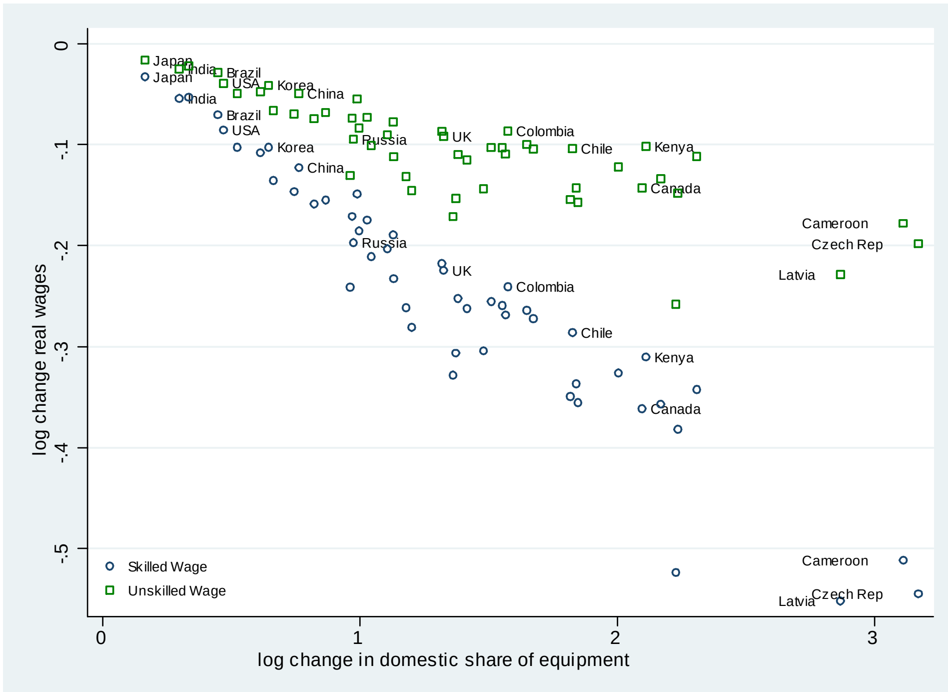
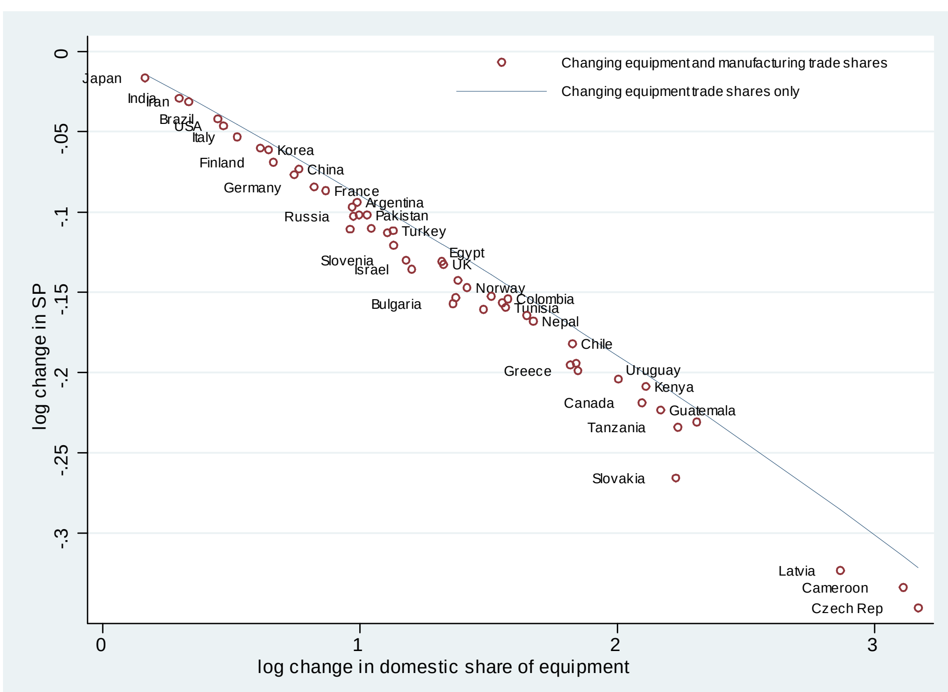
Figure 1: Move to autarky, change in real wages



Note: Malawi (log changes in the skilled and unskilled real wages are -0.6 and -0.2, respectively) is excluded from the figure.

Figure 2: Move to autarky, change in the skill premium



Note: Malawi (log change in skill premium of -0.4) is excluded from the figure.

Figure 3: Observed changes in trade shares between 1963 and 2000

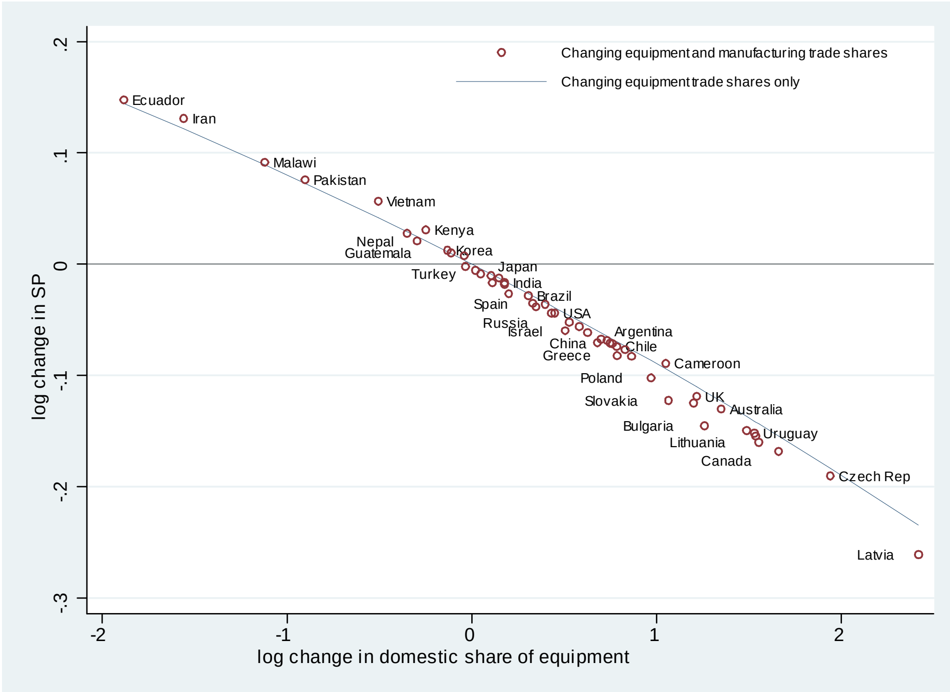


Table 1: Baseline parameter values

	US	Chile
σ	1.56	1.54
ρ	0.63	0.38
ζ	0.54	0.49
ε	0.62	0.6
ξ_i^H	1.37	1.12
ξ_i^L	0.44	0.31
ϕ	0.2	Not used for skill premium
α	0.1	0.1
$\theta(E)$	0.22	0.22
$\theta(M)$	0.19	0.19

We impose that α and $\theta(j)$ are equal in Chile and the US

Table 2: Domestic Expenditure Shares

Country	Initial eqm yr	Counterf. eqm yr	$\pi_{ii}(E)$	$\pi'_{ii}(E)$	$\pi_{ii}(M)$	$\pi'_{ii}(M)$	Country	Initial eqm yr	Counterf. eqm yr	$\pi_{ii}(E)$	$\pi'_{ii}(E)$	$\pi_{ii}(M)$	$\pi'_{ii}(M)$
Argentina	2000	1984	0.37	0.77	0.83	0.95	Kyrgyzstan	2000	1992	0.21	0.98	0.66	0.98
Australia	2000	1963	0.19	0.74	0.70	0.87	Latvia	2000	1992	0.06	0.64	0.36	0.76
Austria	2000	1963	0.16	0.54	0.47	0.79	Lithuania	2000	1992	0.16	0.75	0.52	0.87
Bangladesh	1998	1972	0.37	0.43	0.65	0.65	Malawi	2000	1965	0.02	0.01	0.59	0.54
Brazil	2000	1990	0.64	0.87	0.89	0.95	Nepal	1996	1986	0.19	0.14	0.68	0.79
Bulgaria	2000	1980	0.26	0.90	0.35	0.95	Norway	2000	1963	0.24	0.43	0.57	0.68
Cameroon	2000	1970	0.04	0.13	0.60	0.50	Pakistan	2000	1963	0.36	0.15	0.72	0.63
Canada	2000	1963	0.12	0.65	0.56	0.87	Poland	2000	1982	0.35	0.93	0.57	0.97
Chile	2000	1963	0.16	0.35	0.71	0.84	Portugal	2000	1963	0.25	0.28	0.59	0.77
China	2000	1977	0.47	0.99	0.81	0.97	Romania	2000	1985	0.22	0.98	0.65	0.97
Colombia	2000	1963	0.21	0.44	0.76	0.88	Russia	2000	1996	0.38	0.58	0.59	0.75
Czech Rep	2000	1995	0.04	0.29	0.51	0.64	Slovakia	2000	1993	0.11	0.31	0.22	0.54
Denmark	2000	1963	0.23	0.54	0.46	0.56	Slovenia	2000	1992	0.31	0.44	0.46	0.62
Ecuador	2000	1963	0.10	0.02	0.78	0.68	Spain	2000	1963	0.38	0.53	0.70	0.90
Egypt	1998	1964	0.27	0.27	0.70	0.81	Sweden	2000	1963	0.33	0.67	0.64	0.78
Finland	2000	1963	0.52	0.50	0.68	0.83	Switzerland	2000	1986	0.25	0.58	0.41	0.45
France	2000	1963	0.42	0.79	0.72	0.90	Macedna	2000	1993	0.38	0.47	0.43	0.61
Germany	2000	1991	0.44	0.65	0.67	0.71	Tanzania	1999	1965	0.11	0.08	0.56	0.59
Greece	1998	1963	0.16	0.35	0.46	0.71	Tunisia	2000	1963	0.21	0.20	0.63	0.54
Guatemala	1998	1968	0.11	0.10	0.62	0.61	Turkey	2000	1963	0.32	0.34	0.72	0.85
India	1999	1963	0.74	0.89	0.88	0.92	UK	2000	1963	0.27	0.90	0.67	0.89
Iran	2000	1963	0.72	0.15	0.91	0.60	USA	2000	1963	0.63	0.98	0.82	0.97
Israel	2000	1963	0.30	0.50	0.41	0.72	Ukraine	2000	1992	0.48	0.94	0.68	0.99
Italy	2000	1967	0.59	0.71	0.76	0.84	Uruguay	2000	1968	0.13	0.62	0.65	0.91
Japan	2000	1963	0.85	0.94	0.91	0.96	VietNam	2000	1998	0.32	0.19	0.53	0.29
Kenya	2000	1963	0.12	0.09	0.80	0.54	Zimbabwe	1996	1964	0.54	0.92	0.79	0.99
Korea	2000	1963	0.53	0.46	0.84	0.80							

Note: "Initial eqm yr." — the year used to obtain trade shares for the initial steady state of our counterfactuals. "Counterf. eqm. yr." — the year used to obtain trade shares in the new steady state of counterfactual 2.

Table 3: Counterfactual (Cf) logarithm changes in real wages and the skill premium

	Cf 1: Autarky			Cf 2: Observed trade				Cf 1: Autarky			Cf 2: Observed trade		
	S/P	W/P	S/W	S/P	W/P	S/W		S/P	W/P	S/W	S/P	W/P	S/W
Argentina	-0.15	-0.05	-0.09	-0.11	-0.04	-0.07	Kyrgyzstan	-0.26	-0.10	-0.16	-0.25	-0.10	-0.15
Australia	-0.26	-0.10	-0.16	-0.20	-0.07	-0.13	Latvia	-0.55	-0.23	-0.32	-0.44	-0.18	-0.26
Austria	-0.35	-0.15	-0.20	-0.23	-0.10	-0.12	Lithuania	-0.34	-0.14	-0.19	-0.28	-0.12	-0.16
Bangladesh	-0.19	-0.08	-0.10	-0.02	0.00	-0.01	Malawi	-0.66	-0.22	-0.44	0.14	0.05	0.09
Brazil	-0.07	-0.03	-0.04	-0.05	-0.02	-0.03	Nepal	-0.27	-0.10	-0.17	0.01	-0.01	0.02
Bulgaria	-0.33	-0.17	-0.16	-0.31	-0.16	-0.15	Norway	-0.26	-0.12	-0.15	-0.10	-0.04	-0.06
Cameroon	-0.51	-0.18	-0.33	-0.10	-0.02	-0.09	Pakistan	-0.17	-0.07	-0.10	0.12	0.04	0.08
Canada	-0.36	-0.14	-0.22	-0.28	-0.11	-0.17	Poland	-0.21	-0.10	-0.11	-0.20	-0.09	-0.10
Chile	-0.29	-0.10	-0.18	-0.12	-0.05	-0.07	Portugal	-0.25	-0.11	-0.14	-0.05	-0.03	-0.02
China	-0.12	-0.05	-0.07	-0.12	-0.05	-0.07	Romania	-0.26	-0.10	-0.15	-0.25	-0.10	-0.15
Colombia	-0.24	-0.09	-0.15	-0.11	-0.04	-0.07	Russia	-0.20	-0.09	-0.10	-0.09	-0.04	-0.04
Czech Rep	-0.54	-0.20	-0.35	-0.28	-0.09	-0.19	Slovakia	-0.52	-0.26	-0.27	-0.26	-0.14	-0.12
Denmark	-0.30	-0.14	-0.16	-0.14	-0.05	-0.08	Slovenia	-0.26	-0.13	-0.13	-0.08	-0.05	-0.04
Ecuador	-0.34	-0.11	-0.23	0.22	0.07	0.15	Spain	-0.17	-0.07	-0.10	-0.07	-0.04	-0.04
Egypt	-0.22	-0.09	-0.13	-0.02	-0.02	-0.01	Sweden	-0.20	-0.09	-0.11	-0.11	-0.05	-0.07
Finland	-0.14	-0.07	-0.07	-0.02	-0.02	0.00	Switzerland	-0.31	-0.15	-0.15	-0.12	-0.04	-0.08
France	-0.15	-0.07	-0.09	-0.11	-0.05	-0.06	Macedonia	-0.24	-0.13	-0.11	-0.07	-0.05	-0.03
Germany	-0.16	-0.07	-0.08	-0.06	-0.02	-0.04	Tanzania	-0.38	-0.15	-0.23	0.03	0.00	0.03
Greece	-0.36	-0.16	-0.20	-0.16	-0.08	-0.08	Tunisia	-0.27	-0.11	-0.16	0.03	0.02	0.01
Guatemala	-0.36	-0.13	-0.22	0.02	0.01	0.01	Turkey	-0.19	-0.08	-0.11	-0.03	-0.02	-0.01
India	-0.05	-0.03	-0.03	-0.03	-0.01	-0.02	UK	-0.22	-0.09	-0.13	-0.19	-0.07	-0.12
Iran	-0.05	-0.02	-0.03	0.23	0.09	0.13	USA	-0.09	-0.04	-0.05	-0.08	-0.04	-0.04
Israel	-0.28	-0.15	-0.14	-0.14	-0.08	-0.06	Ukraine	-0.15	-0.07	-0.08	-0.14	-0.07	-0.07
Italy	-0.10	-0.05	-0.05	-0.04	-0.02	-0.02	Uruguay	-0.33	-0.12	-0.20	-0.25	-0.09	-0.15
Japan	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	Viet Nam	-0.23	-0.11	-0.12	0.14	0.09	0.06
Kenya	-0.31	-0.10	-0.21	0.08	0.05	0.03	Zimbabwe	-0.11	-0.05	-0.06	-0.10	-0.04	-0.05
Korea	-0.10	-0.04	-0.06	0.02	0.01	0.01	Median	-0.25	-0.10	-0.14	-0.10	-0.04	-0.05

"Cf 1: Autarky" — counterfactual moving from 2000 trade to autarky. "Cf 2: Observed trade" — counterfactual moving from 2000 to start of sample trade.

S/P: real wage of skilled workers, W/P: real wage of unskilled workers, S/W: skill premium. S/W may not equal $S/P - W/P$ in the table due to rounding error.

Table 4: Alternative Parameterizations

	Implied elasticity of the skill premium to sectoral import shares:		Counterfactual change in the skill premium: median country	
Parameterization	Equipment: $\Theta\theta(E)$	Manufacturing: $\Theta\varkappa_i(M)\theta(M)$	Cf1: Autarky	Cf 2: Observed trade
Baseline with US data	0.085	0.026	-0.14	-0.05
Calibration with Chilean data	0.138	0.055	-0.26	-0.09
Skill-biased trend $\vartheta = 0.01$	0.066	0.020	-0.11	-0.04
Skill-biased trend $\vartheta = 0.02$	0.048	0.015	-0.08	-0.03
$\theta(E) = \theta(M) = 0.15$	0.058	0.021	-0.09	-0.04
$\theta(E) = \theta(M) = 0.25$	0.096	0.035	-0.16	-0.06
$r_i K_i(E) / v_i K_i(S) = 1$; i.e. $\alpha = 0.15$	0.071	0.023	-0.11	-0.04
$r_i K_i(E) / v_i K_i(S) = 3$; i.e. $\alpha = 0.076$	0.091	0.028	-0.15	-0.06

Note: Elasticities are derived to a first-order approximation. Counterfactuals are computed using the exact solution. "Cf 1: Autarky" refers to the counterfactual moving from 2000 trade levels to autarky. "Cf 2: Observed trade" refers to the counterfactual moving from 2000 to start of sample trade levels.

A Equilibrium

In this section, we characterize a steady-state equilibrium. We show how to solve the key steady-state variables of interest as a function of domestic expenditure shares, $\pi_{ii}(j)$s. In addition, we provide a system of six equations with which we can solve for changes in country i's skill premium and both of its real wages as functions of changes in its domestic expenditure shares, $\pi_{ii}(j)$s; its domestic technologies, $A_i(j)$s; and its domestic labor endowments, H_i and L_i.

A.1 Steady-State Equilibrium

We now define and characterize the steady state equilibrium for the world economy. In doing so, we show how aggregate quantities and prices can be determined before solving for product level variables. A steady-state equilibrium for the aggregate variables in the world economy consists of a set of prices $\{v_i, w_i, r_i, s_i\}_{i\in I}$, $\{p_{b_{1,i}}, p_{b_{2,i}}, p_{b_{3,i}}, p_{b_{4,i}}, c_i\}_{i\in I}$, $\{P_i(S), P_i(M), P_i(E)\}_{i\in I}$, aggregate quantities $\{K_i(S), K_i(E), X_i(M), X_i(S)\}_{i\in I}$, $\{C_i(M), C_i(S)\}_{i\in I}$, $\{Y_i(M), Y_i(S), Y_i(E)\}_{i\in I}$, and trade shares $\{\pi_{in}(j)\}_{i,n\in I, j\in \mathcal{J}}$, such that, given factor supplies, $\{H_i, L_i\}_{i\in I}$, technologies, $\{A_i(S), A_i(M),$ $A_i(E)\}_{i\in I}$, and net exports, $\{nx_i\}_{i\in I}$, in each country, the following are satisfied:

1. Household's maximize utility subject to their budget constraints: The household's optimality conditions in steady state are given by the Euler equations,

$$\begin{aligned} 1/\beta &= r_i/P_i(E) + 1 - \delta_i(E), & (16)\\ 1/\beta &= v_i/P_i(S) + 1 - \delta_i(S), & (17) \end{aligned}$$

the intra-temporal consumption equation,

$$P_i(M)\,C_i(M) = \frac{\phi}{1-\phi} P_i(S)\,C_i(S), \tag{18}$$

and the budget constraint,

$$\begin{aligned} (w_iL_i + s_iH_i + v_iK_i(S) + r_iK_i(E))(1+nx_i) &= P_i(E)\,\delta_i(E)\,K_i(E) & (19)\\ &\quad + P_i(M)\,C_i(M) + P_i(S)\left[C_i(S) + \delta_i(S)\,K_i(S)\right] \end{aligned}$$

where nx_i denotes net exports as a share of GDP, which we take as a parameter.

2. Cost minimization by producers of intermediate goods: We first define the following input bundles to simplify notation,

$$\begin{aligned} b_{4,i} &= x_S^{\varepsilon_i} x_M^{1-\varepsilon_i}, \quad b_{2,i} = \left[\mu_i^{1/\sigma} l^{(\sigma-1)/\sigma} + (1-\mu_i)^{1/\sigma} b_1^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)},\\ b_{3,i} &= k_S^{\alpha_i} b_2^{1-\alpha_i}, \quad \text{and } b_{1,i} = \left[\lambda_i^{1/\rho} k_E^{(\rho-1)/\rho} + (1-\lambda_i)^{1/\rho} h^{(\rho-1)/\rho}\right]^{\rho/(\rho-1)}, \end{aligned}$$

so that the production function of (ω, j) intermediate good producers can be written as:

$$y_i(\omega, j) = A_i(j)\, z_i(\omega, j)\, b_{3,i}^{\zeta_i} b_{4,i}^{1-\zeta_i}.$$

Cost minimization implies that the unit cost of production for the domestic market of a producer with productivity $A_i(j)\,z_i(\omega,j)=1$, c_i, is given by

$$c_i = p_{b_{3,i}}^{\zeta_i} p_{b_{4,i}}^{1-\zeta_i} \Big/ \left[\zeta_i^{\zeta_i}\left(1-\zeta_i\right)^{1-\zeta_i}\right], \tag{20}$$

where

$$p_{b_{1,i}} = \left[\lambda_i r_i^{1-\rho} + \left(1-\lambda_i\right) s_i^{1-\rho}\right]^{1/(1-\rho)} \tag{21}$$

$$p_{b_{2,i}} = \left[\mu_i w_i^{1-\sigma} + \left(1-\mu_i\right) p_{b_{1,i}}^{1-\sigma}\right]^{1/(1-\sigma)} \tag{22}$$

$$p_{b_{3,i}} = v_i^{\alpha_i} p_{b_{2,i}}^{1-\alpha_i} \alpha_i^{-\alpha_i}\left(1-\alpha_i\right)^{\alpha_i-1} \tag{23}$$

$$p_{b_{4,i}} = P_i(S)^{\varepsilon_i} P_i(M)^{1-\varepsilon_i} \varepsilon_i^{-\varepsilon_i}\left(1-\varepsilon_i\right)^{\varepsilon_i-1}. \tag{24}$$

Here, $p_{b_{1,i}}$, $p_{b_{2,i}}$, $p_{b_{3,i}}$, and $p_{b_{4,i}}$ denote the unit costs of the input bundles $b_{1,i}$, $b_{2,i}$, $b_{3,i}$, and $b_{4,i}$ in country i. Given these prices, factors demanded in the production of intermediate good (ω,j) in country i for goods sold in country n are given by:

$$\begin{aligned}
l_{in}(\omega,j) &= \mu_i\left[\tfrac{p_{b_{2,i}}}{w_i}\right]^{\sigma} b_{2,in}(\omega,j), &\quad h_{in}(\omega,j) &= \left(1-\lambda_i\right)\left[\tfrac{p_{b_{1,i}}}{s_i}\right]^{\rho} b_{1,in}(\omega,j),\\
k_{S,in}(\omega,j) &= \alpha_i \tfrac{p_{b_{3,i}} b_{3,in}(\omega,j)}{v_i}, & k_{E,in}(\omega,j) &= \lambda_i\left[\tfrac{p_{b_{1,i}}}{r_i}\right]^{\rho} b_{1,in}(\omega,j),\\
x_{S,in}(\omega,j) &= \varepsilon_i \tfrac{p_{b_{4,i}} b_{4,in}(\omega,j)}{P_i(S)}, & \text{and } x_{M,in}(\omega,j) &= \left(1-\varepsilon_i\right)\tfrac{p_{b_{4,i}} b_{4,in}(\omega,j)}{P_i(M)},
\end{aligned}$$

where

$$\begin{aligned}
b_{4,in}(\omega,j) &= \left(1-\zeta_i\right)\tfrac{p_n(\omega,j)q_n(\omega,j)}{p_{b_{4,i}}}\mathbb{I}_{in}(\omega,j), &\quad b_{2,in}(\omega,j) &= \left(1-\alpha_i\right)\tfrac{p_{b_{3,i}} b_{3,in}(\omega,j)}{p_{b_{2,i}}},\\
b_{3,in}(\omega,j) &= \zeta_i \tfrac{p_n(\omega,j)q_n(\omega,j)}{p_{b_{3,i}}}\mathbb{I}_{in}(\omega,j), & b_{1,in}(\omega,j) &= \left(1-\mu_i\right)\left[\tfrac{p_{b_{2,i}}}{p_{b_{1,i}}}\right]^{\sigma} b_{2,in}(\omega,j).
\end{aligned}$$

Here, $\mathbb{I}_{in}(\omega,j)$ is an indicator function that takes the value of one when country i supplies country n with intermediate good (ω,j) and is zero otherwise.

3. Cost minimization by producers of final goods: Cost minimization by final good producers implies that demand for variety (ω,j) in country i is given by

$$q_i(\omega,j) = \left(\frac{p_i(\omega,j)}{P_i(j)}\right)^{-\eta_i(j)} Y_i(j).$$

As shown in EK under our same distribution assumptions, price indices for final goods in any time period (even out of steady-state) are given by

$$P_i(j) = \gamma_i(j)\left\{\sum_{k=1}^{I}\left[\tau_{kn}(j)\,\frac{c_k}{A_k(j)}\right]^{-1/\theta(j)}\right\}^{-\theta(j)} \tag{25}$$

where $\gamma_i(j) = \left\{\Gamma\left(1+\theta(j)\left[1-\eta_i(j)\right]\right)\right\}^{1/[1-\eta_i(j)]}$ and Γ is the Gamma function. in country i. Trade shares between any pair of countries are given by equation (7).

4. Aggregate factor market clearing: Integrating factor demands across producers, adding across all destination countries n and sectors j, substituting for the demand each for variety $q_i(\omega, j)$ and using equation (6), we can write the aggregate factor market clearing conditions as,

$$
\begin{aligned}
v_i K_i(S) &= \zeta_i \alpha_i \Phi_i, && (26)\\
w_i L_i &= \zeta_i \mu_i (1-\alpha_i) \left(p_{b_{2,i}} / w_i\right)^{\sigma-1} \Phi_i, && (27)\\
r_i K_i(E) &= \zeta_i \lambda_i (1-\alpha_i)(1-\mu_i) \left(\frac{p_{b_{1,i}}}{r_i}\right)^{\rho-1} \left(\frac{p_{b_{2,i}}}{p_{b_{1,i}}}\right)^{\sigma-1} \Phi_i, && (28)\\
s_i H_i &= \zeta_i (1-\alpha_i)(1-\mu_i)(1-\lambda_i) \left(\frac{p_{b_{1,i}}}{s_i}\right)^{\rho-1} \left(\frac{p_{b_{2,i}}}{p_{b_{1,i}}}\right)^{\sigma-1} \Phi_i, && (29)
\end{aligned}
$$

and,

$$
\begin{aligned}
P_i(S) X_i(S) &= \varepsilon_i (1-\zeta_i) \Phi_i, && (30)\\
P_i(M) X_i(M) &= (1-\varepsilon_i)(1-\zeta_i) \Phi_i. && (31)
\end{aligned}
$$

where:

$$
\Phi_i \equiv \sum_n \sum_j \pi_{in}(j) P_n(j) Y_n(j) \qquad (32)
$$

denotes total revenue accruing to all country i producers across all sectors.

5. Aggregate goods markets clear in each country:

$$
\begin{aligned}
Y_i(M) &= C_i(M) + X_i(M), && (33)\\
Y_i(S) &= C_i(S) + X_i(S) + \delta_i(S) K_i(S), && (34)\\
Y_i(E) &= \delta_i(E) K_i(E), && (35)
\end{aligned}
$$

Note that, after choosing a numeraire, $(21 \times I + I \times I - 1)$ aggregate variables must be determined in equilibrium. Equations (7) and $(16) - (35)$ give a system of $(21 \times I + I \times I - 1)$ independent equations, since the market clearing conditions together with the budget constraints and the definition of revenues make one budget constraint redundant.

A.2 Solving Steady-State in Terms of Domestic Expenditure Shares

In this section we show how to solve for all domestic variables as functions of domestic expenditure shares, $\pi_{ii}(j)$. The problem can be split into two parts. First, we use a subset of equations to solve for all domestic prices. Second, we use these prices and the remaining equations to solve for quantities.

From equations (7) and (25), we can write aggregate price indices as functions of domestic expenditure shares

$$
P_i(j) = \gamma_i(j) c_i \pi_{ii}(j)^{\theta(j)} \Big/ A_i(j), \qquad (36)
$$

and from equations (27) and (29) we obtain

$$\frac{s_i^{\rho}}{w_i^{\sigma}}\frac{H_i}{L_i} = (1-\lambda_i)\,\frac{1-\mu_i}{\mu_i}p_{b,i}^{\rho-\sigma}. \tag{37}$$

The 3 price index equations (36), together with equation (37) the Euler equations (16) – (17) and the cost minimization equations (20)-(24) make a system of 11 equations. Together with a choice of numeraire these equations can be used to solve for the 12 domestic prices.

Given prices, we can solve for quantities as follows. First, solve for $K_i(E)$ and $K_i(S)$ using (26), (28), and (29). Second, adding equations (26) – (29), we solve for Φ_i as

$$\zeta_i \Phi_i = v_i K_i(S) + w_i L_i + r_i K_i(E) + s_i H_i.$$

Third, using equations (30) and (31), we obtain intermediate inputs $X_i(M)$ and $X_i(S)$. Fourth, from equations (18) and (19) we can solve for the consumption levels $C_i(S)$ and $C_i(M)$. Finally, from the market clearing equations (33) – (35) we obtain total production in each sector.

A.3 Solving for Price Changes Across Steady States

In this section we derive steady-state changes in the skill premium and real wages in country i using the following system of six equations:

$$\begin{aligned}
\widetilde{r}_i &= \left[\widetilde{A}_i(S)\Big/\widetilde{A}_i(E)\right]\widetilde{\pi}_{ii}(E)^{\theta(E)} && (38)\\
\widetilde{s}_i^{\rho}\Big/\widetilde{w}_i^{\sigma} &= \widetilde{p}_{b_{1,i}}^{\rho-\sigma}\left(\widetilde{L}_i\Big/\widetilde{H}_i\right) && (39)\\
\widetilde{p}_{b_{1,i}} &= \left[\frac{1}{1+\xi_i^H}\widetilde{r}_i^{1-\rho} + \frac{\xi_i^H}{1+\xi_i^H}\widetilde{s}_i^{1-\rho}\right]^{1/(1-\rho)} && (40)\\
\widetilde{p}_{b_{3,i}}^{1/1-\alpha_i} &= \left[\xi_i^L\widetilde{w}_i^{1-\sigma} + \left(1-\xi_i^L\right)\widetilde{p}_{b_{1,i}}^{1-\sigma}\right]^{1/(1-\sigma)} && (41)\\
\widetilde{p}_{b_{3,i}} &= \widetilde{A}_i(S)^{(\varepsilon_i+\zeta_i-\varepsilon_i\zeta_i)/\zeta_i}\left[\widetilde{A}_i(M)\Big/\widetilde{\pi}_{ii}(M)^{\theta(M)}\right]^{(1-\varepsilon_i)(1-\zeta_i)/\zeta_i} && (42)\\
\widetilde{P}_i(C) &= \left(\widetilde{\pi}_{ii}(M)^{\theta(M)}\widetilde{A}_i(M)\Big/\widetilde{A}_i(S)\right)^{\phi} && (43)
\end{aligned}$$

where, $\widetilde{x} \equiv x'/x$ denotes the ratio of a variable between the new and initial equilibrium, and where $\xi_i^H = \frac{s_i H_i}{r_i K_i(E)}$ and $\xi_i^L = \frac{w_i L_i}{w_i L_i + s_i H_i + r_i K_i(E)}$ denote relative factor shares in the initial equilibrium.

We proceed in order. Taking changes between the new and initial equilibrium using equation (36) gives

$$\widetilde{P}_i(j) = \widetilde{c}_i\widetilde{\pi}_{ii}(j)^{\theta(j)}\Big/\widetilde{A}_i(j). \tag{44}$$

Similarly, by equation (18), we have

$$\widetilde{r}_i = \widetilde{P}_i(E). \tag{45}$$

Equations (44) and (45) imply equation (38). Equations (39) and (40) follow directly from expressing equations (37) and the definition of $p_{b_{1,i}}$ in changes, respectively.

To obtain equations, (41) and (42), we express the remaining marginal cost equations in changes,

$$\begin{aligned}
\widetilde{c}_i &= \widetilde{p}_{b_{3,i}}^{\zeta_i}\widetilde{p}_{b_{4,i}}^{1-\zeta_i} && (46)\\
\widetilde{p}_{b_{4,i}} &= \widetilde{P}_i(S)^{\varepsilon_i}\,\widetilde{P}_i(M)^{1-\varepsilon_i} && (47)\\
\widetilde{p}_{b_{3,i}} &= \widetilde{v}_i^{\alpha_i}\widetilde{p}_{b_{2,i}}^{1-\alpha_i} && (48)\\
\widetilde{p}_{b_{2,i}} &= \left[\xi_i^L\widetilde{w}_i^{1-\sigma} + \left(1-\xi_i^L\right)\widetilde{p}_{b_{1,i}}^{1-\sigma}\right]^{1/1-\sigma}. && (49)
\end{aligned}$$

Letting $P_i(S) = 1$ be the numeraire, equation (17) implies $\widetilde{v}_i = \widetilde{P}_i(S) = 1$. Hence, equations (48) and (49) imply equation (41). By equation (44) and $\pi_{ii}(S) = 1$, we have

$$\widetilde{c}_i = \widetilde{A}_i(S). \tag{50}$$

By equations (46), (47), and (50), we have

$$\widetilde{A}_i(S) = \widetilde{p}_{b_{3,i}}^{\zeta_i}\widetilde{p}_{b_{4,i}}^{1-\zeta_i}$$

and

$$\widetilde{p}_{b_{4,i}} = \widetilde{P}_i(M)^{1-\varepsilon_i} = \left\{\widetilde{A}_i(S)\,\widetilde{\pi}_{ii}(M)^{\theta(M)}\Big/\,\widetilde{A}_i(M)\right\}^{1-\varepsilon_i}.$$

The two previous equations imply equation (42).

Finally, we obtain equation (43) using equation (44), recalling that $P_i(S)$ is the numeraire.

B Proofs: Approximating Changes Across Steady States

In this section, we prove Propositions 1 and 2.

Derivation of Equation (8). By equations (27) and (29), we have

$$\left(\frac{r_i}{s_i}\right)^{1-\rho} = \left[\frac{1-\lambda_i}{\lambda_i}\frac{K_i(E)}{H_i}\right]^{\frac{\rho-1}{\rho}}. \tag{51}$$

From the definition of $p_{b_{1,i}}$ and equation (51), we have

$$\frac{p_{b_{1,i}}}{s_i} = (1-\lambda_i)^{-\frac{1}{\rho}}\left\{\lambda_i^{\frac{1}{\rho}}\left[\frac{K_i(E)}{H_i}\right]^{\frac{\rho-1}{\rho}} + (1-\lambda_i)^{\frac{1}{\rho}}\right\}^{\frac{1}{1-\rho}}. \tag{52}$$

In addition, equations (27) and (29) imply

$$\frac{s_i}{w_i} = (1-\lambda_i)^{\frac{1}{\sigma}}\left(\frac{1-\mu_i}{\mu_i}\right)^{\frac{1}{\sigma}}\left(\frac{p_{b,i}}{s_i}\right)^{\frac{\rho-\sigma}{\sigma}}\left(\frac{L_i}{H_i}\right)^{\frac{1}{\sigma}}. \tag{53}$$

From equations (52) and (53), we obtain equation (8).

Derivation of Equation (9). Let $\widehat{x} \equiv \log(\widetilde{x})$. Using this notation, we express equations (38), (39), and (42) as

$$\begin{aligned}
\widehat{r}_i &= \widehat{A}_i(S) - \widehat{A}_i(E) + \theta(E)\widehat{\pi}_{ii}(E) && (54)\\
\rho\widehat{s}_i - \sigma\widehat{w}_i &= (\rho-\sigma)\widehat{p}_{b_{1,i}} - \left(\widehat{H}_i - \widehat{L}_i\right) && (55)\\
\widehat{p}_{b_{3,i}} &= \frac{\zeta_i + \varepsilon_i - \zeta_i\varepsilon_i}{\zeta_i}\widehat{A}_i(S) + \frac{(1-\zeta_i)(1-\varepsilon_i)}{\zeta_i}\left[\widehat{A}_i(M) - \theta(M)\widehat{\pi}_{ii}(M)\right]. && (56)
\end{aligned}$$

Using the first-order approximation, $exp(\widehat{x}) \approx 1 + \widehat{x}$, we express equations (41) and (40) as

$$\begin{aligned}
\widehat{p}_{b_{1,i}} &= \frac{1}{\left(1-\xi_i^L\right)}\frac{\widehat{p}_{b_{3,i}}}{(1-\alpha_i)} - \frac{\xi_i^L}{1-\xi_i^L}\widehat{w}_i && (57)\\
\widehat{p}_{b_{1,i}} &= \frac{1}{1+\xi_i^H}\widehat{r}_i + \frac{\xi_i^H}{1+\xi_i^H}\widehat{s}_i && (58)
\end{aligned}$$

We now solve equations (54) – (58) for $\widehat{s}_i - \widehat{w}_i$. By equations (57) and (55), we have

$$\widehat{s}_i - \widehat{w}_i = \frac{\sigma-\rho}{\rho}\frac{1}{1-\xi_i^L}\left[\widehat{w}_i - \frac{\widehat{p}_{b_{3,i}}}{(1-\alpha_i)}\right] - \frac{1}{\rho}\left(\widehat{H}_i - \widehat{L}_i\right), \qquad (59)$$

whereas by equations (57) and (58), we have

$$\widehat{s}_i = \frac{1+\xi_i^H}{\xi_i^H\left(1-\xi_i^L\right)}\frac{\widehat{p}_{b_{3,i}}}{(1-\alpha_i)} - \frac{\xi_i^L\left(1+\xi_i^H\right)}{\left(1-\xi_i^L\right)\xi_i^H}\widehat{w}_i - \frac{1}{\xi_i^H}\widehat{r}_i.$$

Using the two previous expressions to solve for $\widehat{w}_i - \frac{\widehat{p}_{b_{3,i}}}{1-\alpha_i}$ we obtain

$$\widehat{w}_i - \frac{\widehat{p}_{b_{3,i}}}{1-\alpha_i} = \frac{\rho\left(1-\xi_i^L\right)}{\rho\xi_i^L + \sigma\xi_i^H}\left[\frac{\widehat{p}_{b_{3,i}}}{(1-\alpha_i)} - \widehat{r}_i + \xi_i^H\frac{1}{\rho}\left(\widehat{H}_i - \widehat{L}_i\right)\right]. \qquad (60)$$

By equations (48), (59), and (60) we have

$$\widehat{s}_i - \widehat{w}_i = -\frac{\xi_i^H + \xi_i^L}{\sigma\xi_i^H + \rho\xi_i^L}\left(\widehat{H}_i - \widehat{L}_i\right) + \Theta_i\left(\widehat{p}_{b_{2,i}} - \widehat{r}_i\right). \qquad (61)$$

Then, given factor supplies in the domestic country, changes in the skill premium are determined by changes in the price of the composite bundle of equipment and both types of labor, $\widehat{p}_{b_{2,i}}$, relative to changes in the price of equipment, $\widehat{r}_i$. Note that Θ_i is the elasticity of the skill premium with respect to this relative price.

Finally, by equations (54), (56), (48) and (61), we have equation (9).

Derivation of Equations (12) **and** (13). We can write the log change in the consumption price index as

$$\widehat{P}_i(C) = \phi\widehat{A_i}(S) - \phi\left[\widehat{A_i}(M) - \theta(M)\widehat{\pi}_i(M)\right] \qquad (62)$$

Using equation (60) to substitute for $\widehat{w}_i$ in (59) and solving for $\widehat{s}_i$ we obtain

$$\widehat{s}_i = \frac{\sigma\left(1+\xi_i^H\right)}{\rho\xi_i^L+\sigma\xi_i^H}\frac{\widehat{p}_{b_{3,i}}}{(1-\alpha_i)} - \frac{\sigma-\rho\xi_i^L}{\rho\xi_i^L+\sigma\xi_i^H}\widehat{r}_i - \xi_i^L\frac{1+\xi_i^H}{\rho\xi_i^L+\sigma\xi_i^H}\left(\widehat{H}_i-\widehat{L}_i\right),$$

Together with equations (54), (56) and (62), the previous expression gives

$$\begin{aligned}\widehat{s}_i - \widehat{P}_i(C) \;=\; & -\xi_i^L\frac{1+\xi_i^H}{\rho\xi_i^L+\sigma\xi_i^H}\left(\widehat{H}_i-\widehat{L}_i\right) + \left[\frac{\sigma\left(1+\xi_i^H\right)}{\rho\xi_i^L+\sigma\xi_i^H}\frac{\zeta_i+\varepsilon_i-\zeta_i\varepsilon_i}{\zeta_i(1-\alpha_i)} - \frac{\sigma-\rho\xi_i^L}{\rho\xi_i^L+\sigma\xi_i^H} - \phi\right]\widehat{A}_i(S) \\ & + \left[\frac{\sigma\left(1+\xi_i^H\right)}{\rho\xi_i^L+\sigma\xi_i^H}\frac{(1-\zeta_i)(1-\varepsilon_i)}{\zeta_i(1-\alpha_i)} + \phi\right]\left[\widehat{A}_i(M) - \theta(M)\widehat{\pi}_{ii}(M)\right] \\ & + \frac{\sigma-\rho\xi_i^L}{\rho\xi_i^L+\sigma\xi_i^H}\left[\widehat{A}_i(E) - \theta(E)\widehat{\pi}_{ii}(E)\right].\end{aligned}$$

The previous expression and the definitions of $\nu_i(j)$, Θ_i, and $\varkappa_i(j)$ yield equation (12).

Solving for $\widehat{w}_i$ in equation (60), subtracting (62), and substituting $\widehat{p}_{b_{3,i}}$ and $\widehat{r}_i$ using (56) and (54) gives

$$\begin{aligned}\widehat{w}_i - \widehat{P}_i(C) \;=\; & \frac{\left(1-\xi_i^L\right)\xi_i^H}{\rho\xi_i^L+\sigma\xi_i^H}\left(\widehat{H}_i-\widehat{L}_i\right) + \left[\frac{\rho+\sigma\xi_i^H}{\rho\xi_i^L+\sigma\xi_i^H}\frac{\zeta_i+\varepsilon_i-\zeta_i\varepsilon_i}{\zeta_i(1-\alpha_i)} - \frac{\rho\left(1-\xi_i^L\right)}{\rho\xi_i^L+\sigma\xi_i^H} - \phi\right]\widehat{A}_i(S) \\ & + \left[\frac{\rho+\sigma\xi_i^H}{\rho\xi_i^L+\sigma\xi_i^H}\frac{(1-\zeta_i)(1-\varepsilon_i)}{\zeta_i(1-\alpha_i)} + \phi\right]\left[\widehat{A}_i(M) - \theta(M)\widehat{\pi}_{ii}(M)\right] \\ & + \frac{\rho\left(1-\xi_i^L\right)}{\rho\xi_i^L+\sigma\xi_i^H}\left[\widehat{A}_i(E) - \theta(E)\widehat{\pi}_{ii}(E)\right].\end{aligned}$$

The previous expression and the definitions of $\nu_i(j)$, Θ_i, and $\varkappa_i(j)$ yield equation (13).

C Data and Parameterization

Domestic Expenditure Shares: For trade data, we define equipment trade as the sum of BEA industry codes 20-27 and 33. These codes are: Farm and Garden Machinery; Construction, Mining, etc.; Computer and Office Equipment; Other Nonelectric Machinery; Household Appliances; Household Audio and Video, etc.; Electronic Components; Other Electrical Machinery; and Instruments and Apparatus.

For gross output data, we define capital equipment goods as the sum of ISIC Rev. 3 codes 29-33. These codes are: Manufacture of machinery and equipment n.e.c.; Manufacture of office, accounting and computing machinery; Manufacture of electrical machinery and apparatus n.e.c.; Manufacture of radio, television and communication equipment and apparatus; and Manufacture of medical, precision and optical instruments, watches and clocks.

Disaggregating capital payments into structures and equipment: For a given share of payments to capital in value added, i.e.

$$\frac{v_i K_i(S) + r_i K_i(E)}{s_i H_i + w_i L_i + v_i K_i(S) + r_i K_i(E)},$$

the parameter α_i determines the ratio of payments to capital structures relative to the payments to equipment capital, i.e. $v_i K_i(S) / [r_i K_i(E)]$. Given the difficulty of measuring capital rental rates, we construct them using the steady-state Euler equations for the accumulation of each type of capital,

$$\begin{aligned} 1 + R_i &= \frac{P_{i,t+1}(S) / P_{i,t+1}(C)}{P_{i,t}(S) / P_{i,t}(C)} \left\{ 1 - \delta_i(S) + \frac{v_{i,t+1}}{P_{i,t+1}(S)} \right\} \\ &= \frac{P_{i,t+1}(E) / P_{i,t+1}(C)}{P_{i,t}(E) / P_{i,t}(C)} \left\{ 1 - \delta_i(E) + \frac{r_{i,t+1}}{P_{i,t+1}(E)} \right\} \end{aligned}$$

where R_i denotes the consumption-based real-interest rate and $P_{i,t}(C)$ denotes the price of the final consumption good in year t. Note that, in this calculation we allow for trends in relative prices (as above, introducing growth into our model does not change our results on the impact of trade on the skill premium).

To solve for the rental rates, we use data from NIPA for the 1963-2000 period. We define non-residential equipment and software as the equipment sector E, and non-residential structures as the structure sector, S. We take $P_{i,t+1}(E) / P_{i,t}(E)$ and $P_{i,t+1}(S) / P_{i,t}(S)$ from NIPA's price indices for private investment (NIPA table 5.3.4). We use the GDP deflator from NIPA for $P_{i,t+1}(C) / P_{i,t}(C)$. We construct the annual depreciation rates of equipment and structures, $\delta_i(E)$ and $\delta_i(S)$, as the ratio of the current-cost depreciation (NIPA fixed assets table 4.4) to the current cost capital stock (NIPA fixed assets table 4.1) in these two sectors. We set the real interest rate R_i to 4%.

We use the 1963-2000 average of these variables and the Euler equations to obtain the relative return for equipment and structures $v_i / P_i(S) / [r_i / P_i(E)]$. We multiply this by the relative value of the capital stocks $[P_i(S) K_i(S) / P_i(E) K_i(E)]$ to obtain $v_i K_i(S) / [r_i K_i(E)]$. We use the 1963-2000 average current cost capital stock of non-residential equipment and non-residential structures (NIPA fixed assets table 4.1) for $P_i(E) K_i(E)$ and $P_i(S) K_i(S)$. Finally, to compute the share of payments to structures capital in value added, α, we use the relative payments to structures and equipment and the share of payments to capital in value added (equal to one minus the average labor share, as defined in the body of the paper). We obtain a very similar value for α if we first calculate, year by year, the relative payments to equipment and structures and the share of capital, and then average these over time.

Chilean data and calibration: We use data on changes in the skill premium and on the stocks of capital equipment (not adjusted for quality), skilled labor and unskilled labor for the time period 1983-2000 from Gallego (2012). We adjust the stock of capital equipment using the same adjustment factor as in the US, obtained from Polgreen and Silos (2008). We calculate the labor share in value added as the ratio of the sum of compensation for employees and the surplus of enterprises owned by households to the sum of compensation for employees and all operating surplus.[27] Due to a lack

[27] We only have data on surplus of enterprises owned by households (Mixed Income) between 1996-2002. We assume that in the years 1983-2000, the ratio of Mixed Income to Operating Surplus equals 0.196, which is the average for the 1996-2002 period. The source of this data is the National Accounts Official Country Data from the United Nations Statistics Division.

of data on prices and on depreciation rates of capital equipment and structures, we assume that the share of structures in value added is the same in Chile as in the US, $\alpha = 0.1$. Finally, the share of value added in gross output ζ, and the share of services in intermediate inputs, ε, used to compute $\varkappa_i(M)$ for Chile are set at their average shares in 1996 and 2003 from the OECD Input-Output database.