Structural Change and Skill Premium in a Quantitative Model of Trade*

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Abstract

I develop a multi-country general equilibrium trade model to investigate the effects of international trade and technical change on structural change and the skill premium. In my three-sector framework, trade and technical change affect structural change by altering the household and intermediate expenditure shares for each sector. Sectors differ in their skill intensity, so that reallocation to skill intensive sectors increases the skill premium. I apply the framework to 37 countries, and the model replicates the changes in trade shares, production shares, consumption shares, and skill premium from 1997 to 2007. I find that (1) trade increased the skill premium in all countries; (2) trade and technical change each explains half of the increase in skill premium in countries where both channels contributed positively; (3) the underlying force of trade increasing the skill premium is higher foreign production efficiency rather than reductions in the trade costs. An application to the U.S. and China reveals that, for the U.S., (1) trade with China explains more than half of the decline in manufacturing share; and (2) trade and technical change together reallocate 1.6% of skilled workers out of the shrinking manufacturing sector, but only 0.2% of the unskilled workers.

Keywords: trade, technical change, structural change, skill premium

JEL codes: F16, F62, F63, O14

*I am extremely grateful to Nuno Limão for his continual guidance and support through the various stages of this project. I am indebted to Luca David Opromolla and Felipe Saffie for their many helpful comments and suggestions. I am grateful to Eunhee Lee for many in-depth and insightful discussions at the later stage of the project. I would also like to thank the seminar participants at the trade group meetings and brown bag meetings at University of Maryland as well as the participants at 2016 spring Midwest international trade meetings, for their helpful comments. All remaining errors are my own.

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1 Introduction

Over the past 20 years, both developed and developing countries have experienced a rapid pace of globalization. Many of these countries have also experienced large increases in the skill premium, measured by the wage ratio of college graduates to non-college graduates.[1] Figure 1 illustrates that around two thirds of countries experienced rising skill premium from 1997 to 2007, including both advanced economies, such as the U.S. and Italy, and emerging ones, such as China and Brazil. While there has been considerable research on the role of trade and skill-biased technical change in skill premium, to date there is no conclusive evidence on their relative importance.

Another important feature of the global economy has been the substantial reallocation of economic activity across broad sectors, i.e., structural change. There have been substantial shifts from the agricultural to the manufacturing sector in developing countries, and from the manufacturing to the services sector in developed countries. These structural changes may further increase the skill premium because skill intensity in production is the highest in services and the lowest in agriculture.

As such, I examine the roles of trade and technical change on the skill premium in the presence of structural change. Specifically, I address the following two questions. First, to what extent have recent fundamental shocks, which affect trade and technical change, impacted the skill premium across countries? Second, how are the impacts from these fundamental shocks affected by structural change across developed and developing countries?

I address these questions by first developing a multi-sector, multi-country general equilibrium trade model based on Eaton and Kortum (2002) and Caliendo and Parro (2015), augmented with elements of structural change. I divide the economy into agriculture, manufacturing, and services, where goods from all sectors are tradable. The production factors include skilled and unskilled labor as well as intermediate inputs from each sector, so that the model allows for input-output linkages. Structural change is driven by endogenous changes in expenditure shares. For households, it is due to nonhomothetic preferences, while for firms, it is through changes in expenditures on intermediate goods.

The framework allows me to perform a structural decomposition exercise to quantify the relative importance of alternative explanations, in the spirit of the accounting

[1] See, for example, Goldberg and Pavcnik (2007) for evidence of rising skill premium in developing countries in the 1990s.

approach used in Eaton et al. (2016). Specifically, changes between any two periods can be fully explained by six types of country-specific shocks: (i) changes in the bilateral trade cost between each pair of trading partners in each sector, (ii) changes in each sector's production efficiency, (iii) changes in each sector's skill intensity, (iv) changes in the supply of skilled and unskilled labor, (v) changes in trade deficits, and (vi) changes in the model residuals.[2][3] After retrieving these shocks, I combine them into trade and technology shocks, which affect both within and between sectoral reallocations, so that I can quantify their relative importance on the changes in the skill premium.

I apply the framework to 37 countries from 1997 to 2007, a period when global trade values increased by more than 50%. I retrieve data on production, factor payments, consumption, and bilateral trade from four versions of the Global Trade Analysis Project (GTAP), corresponding to 1997, 2001, 2004, and 2007. In addition, I assemble data on skill premium from various sources for each sample country. Based on my framework, I use these data to estimate model parameters and retrieve the shocks on trade and technology.

The model generates a gravity equation that relates bilateral trade flows to country-sector price indices, which I obtain using an approach similar to that of Parro (2013) and Reyes-Heroles (2016). The gravity structure also allows me to recover sectoral bilateral trade costs and production efficiency. Since the supply of labor is exogenous in the framework, the shocks to the relative supply of skilled labor are adjusted to be consistent with the observed skill premium. I measure skill intensity by the cost share of skilled labor in total labor payments. Shocks to total employment and trade deficits are also obtained directly from the data.

The estimated sectoral prices allow for the calibration of parameters of household expenditure and a firm's intermediate expenditure, by matching the model-implied household expenditure share and firm intermediate expenditure share with the data counterparts. I employ an Almost Ideal Demand System (AIDS), which allows for changes in real income and relative sectoral prices to affect household expenditure shares across sectors.[4] Changing intermediate expenditure shares across sectors is possible by

[2]Trade deficits in my framework are exogenous because there are no capital accumulation and household saving decisions as in Eaton et al. (2016).

[3]The residual shocks include the ones from the estimation of household expenditures and intermediate expenditures as well as changes in the value added share.

[4]Fajgelbaum and Khandelwal (2016) also use AIDS to show that poor consumers gain more from trade as they consume more tradable goods, which are less income elastic.

modeling a translog expenditure function for intermediates.[5]

These calibrated demand parameters and the shocks allow me to replicate the data on production share, household expenditure share, trade flows, and skill premium in 1997 and 2007. Instead of applying each shock individually to the model, I classify them into shocks on the labor supply, trade, technology, and model residuals so that I can attribute the observed changes in the skill premium to trade and technical change.

The trade shocks consist of three components. The first are bilateral trade costs. The second are shocks to country-specific trade deficits. The third is related to changes in the production efficiency of foreign countries, since in this framework foreign productivity growth affects the home country through trade only. On the technology side, I include shocks to skill intensity and home production efficiency, i.e., neutral technical change. By feeding each mutually exclusive group of shocks separately into the model, I quantify the relative importance of trade and technical change on the changes in the skill premium. Several results emerge.

I find that both trade and technical change made significant contributions to the increases in the skill premium from 1997 to 2007. Trade increases the skill premium in all countries, with a median of 8% across countries. The effects of trade are larger in countries that experienced significant reductions in trade costs, such as China, and in those more exposed to the global economy, such as Ireland and Luxembourg. On the other hand, the average effects of technical change are smaller and very heterogenous across countries. The model interprets some countries that experienced decreases in the skill intensity within certain sectors, such as Peru, as negative effects from skill-biased technical change.

I gauge the relative importance of trade and technical change by focusing on two-thirds of countries in my sample, in which technical change increases the skill premium. I find that trade and technical change each explain half of the increases in the skill premium. Lastly, the changes in the relative supply of skilled labor increased during this period, contributing to a decrease in the skill premium.

This approach also allows for identifying trade as a quantitatively important conduit for foreign technical change to affect home skill premium. By feeding each type of trade shocks separately into the framework, I find that changes in foreign production efficiency

[5]Two channels drive endogenous changes in intermediates expenditure share. First, each sector uses its own intermediates intensively, so any structural change is amplified through sectoral linkages, as in Cravino and Sotelo (2016) and Sposi (2015). Second, sectoral relative prices affect intermediates expenditure share through cross sectoral price elasticity terms in the translog specification.

are responsible for the positive effects of trade on the skill premium, while changes in the trade cost and deficits have negligible or negative effects. This implies that, in order to get a complete picture of the effects of trade on the skill premium, we have to consider the effects from foreign technical change.

To investigate the effects of structural change on the skill premium, I impose a Cobb-Douglas expenditure structure on households and firms.[6] The simple model is similar to the standard multi-sector general equilibrium trade model (e.g., Caliendo and Parro (2015)), into which I feed the same set of shocks and compare with the baseline to obtain the effects due to structural change. There are two main findings. First, the trade effects via foreign technical change are halved once structural change is shut down. The reason is that the shocks to sectoral production efficiency are the main driver of structural change in the model.[7] Second, structural change increases the skill premium more in developing countries relative to developed countries, as growth in own sectoral production efficiency has been larger in developing countries.

Finally, I apply the framework to study the effects of trade and technical change on sectoral reallocations in the U.S. and China from 1997 to 2007, by feeding in U.S. and China specific shocks. Specifically, the shocks include changes in the relative supply of skilled labor, skill intensity, production efficiency, and trade deficits in the U.S. and China, as well as changes in the bilateral trade cost between the two countries.

In the case of the U.S., the model predicts that trade with China explains more than half of the decline in the manufacturing production share, while increases in the production efficiency of the U.S. explain one-third of the decline. In terms of labor reallocations, trade and technical change reallocate 1.6% of the skilled workers out of the shrinking manufacturing to services, but only 0.2% of the unskilled workers. Therefore, I contribute to recent studies on the distributional impacts of imports from China on the U.S. local labor markets by providing a general equilibrium assessment.[8]

In the case of China, the model reveals that trade and technical change together explain almost all of the sectoral reallocations from agriculture to manufacturing. Labor reallocations are characterized by the unskilled workers moving from agriculture to

[6]This implies that there are no endogenous changes in household and economy-wide intermediate expenditure shares.

[7]The result that structural change is mainly driven by changes in sectoral production efficiency is consistent with the work on structural change. See, for example, Swiecki (2014). In my framework, structural change is mainly due to the income effect from nonhomothetic preferences and the amplification effect from the intensive usage of own intermediates in each sector.

[8]See, for example, Autor et al. (2013, 2014) on the effects of imports from China on the U.S. labor markets.

manufacturing, leading to a 6.6% increase in the manufacturing employment share of the unskilled workers. These predictions are consistent with the process of structural transformation in China.[9]

2 Related Literature

My work bridges two recent research strands. The first focuses on quantifying the effects of trade and technical change on the skill premium, and the second focuses on structural change.

Most recent studies attempting to explain the impact of trade on the skill premium focus on within sector variation of skill intensity.[10] In this literature, international trade reallocates market share to the more productive and skill-intensive firms so that the demand for the skilled increases. In my framework, this channel is captured in the exogenous changes in the skill intensity within each sector. From the data below, increases in skill intensity are concentrated in the least tradable services sector, which casts doubt on the quantitative importance of this within channel. Nonetheless, incorporating this channel into my framework will strengthen the effects of trade on the skill premium, as some effects from skill-biased technical change are attributable to trade.

Methodologically, my work is related to Caron et al. (2014) and Fieler (2011), who also use nonhomothetic preferences. They explore nonhomotheticity to explain why rich countries trade more with each other, whereas I use it as a natural motive for structural change.

My work contributes to the literature on structural change by connecting it to the changes in the skill premium in an open economy setting. Buera et al. (2015) build a two-sector closed economy model and show that reallocations to the skill intensive services sector due to structural change explain around 30% of the observed increases in the skill premium in advanced economies, while the rest are due to skill-biased technical change. I complement their results by showing that trade also increases the skill premium through structural change, and most positive effects of trade on the skill premium come from productivity growth in foreign countries.

My work also relates to the literature that investigates the determinants of structural

[9] See, for example, Brandt et al. (2008) on structural transformation in China.

[10] See, for example, Burstein and Vogel (2016) for technology skill complementarity, Parro (2013) for capital skill complementarity, Verhoogen (2008) for quality upgrading in Mexico, and Bustos (2011) for skill upgrading in Argentina.

change. For example, Swiecki (2014) attributes the observed structural change to trade, sectoral technical change, nonhomothetic demand, and inter-sectoral wedges, while I find that technical change, sectoral linkages and nonhomothetic demand are relatively more important drivers of structural change.

Finally, Cravino and Sotelo (2016) also quantify the effects of trade-induced structural change on the skill premium. They find that, between 1995 and 2007, trade increased the skill premium by an average of 4% across countries. My work differs in several aspects. First, they only compute the effects of trade, while I separately identify the effects of trade and technical change. Doing so is important both because changes in production efficiency are the major drivers of structural change, and because the impacts of trade are reflected through changes in the foreign production efficiency, as my results highlight. The second key difference is that Cravino and Sotelo (2016) only allow for structural change from the goods to the services sector, whereas I also include the agricultural sector. Therefore, my framework captures the important structural change from agriculture to manufacturing in developing countries, which is an important source of the increases in skill premium.

The rest of the paper is organized as follows. Section 3 presents the data on skill intensity and structural change. Section 4 builds the theoretical framework. Section 5 discusses the strategy to retrieve exogenous shocks and calibrate the model parameters. Section 6 uses the framework to conduct counterfactuals, which investigate the effects of trade and technical change on the changes in the skill premium. Section 7 presents an application of the model to study sectoral reallocations in the U.S. and China. Section 8 concludes the paper.

3 A First Look at the Data

In this section, I present some aspects of the data that concern the evolution of the skill premium, skill intensity, and structural change in my sample countries from 1997 to 2007.

Figure 1 plots the observed changes in the skill premium in each country, measured by the changes in the ratio of wage of the college workers to the non-college workers, against log real GDP per worker. It shows that around two-thirds of the countries experienced increases in the skill premium, including both developed and developing countries. Moreover, the experiences across countries reveal a lot of heterogeneity. Some

countries, such as China and Italy, have an increase in the skill premium of over 10%. Some other countries, like Chile and France, have a decrease in the skill premium of over 10%. In my framework, I will connect the observed changes in the skill premium to different shocks.

The reason that why structural change affects the skill premium is that sectors have different skill intensity. Table 1 presents the data on skill intensity (β^k) in each sector, measured as the share of wage payments to the skilled workers in total labor cost.[11] The left panel reveals that the services sector is most skill intensive while the agriculture sector is least skill intensive. The right panel shows that in OECD countries the services sector has the largest increase in skill intensity, while all three sectors in non-OECD countries experience increases in skill intensity. The changes in skill intensity within each sector are one of the shocks that affect the changes in skill premium.

Now I go to the data on structural change. I measure structural change by changes in the production share of each sector: $y^k = \frac{\text{value of output in sector } k}{\text{total value of output}}$. The first three columns of Table 6 present the changes in production share in each sector from 1997 to 2007. In OECD countries, sectoral reallocation is from agriculture and manufacturing to services, while the pattern of structural change in non-OECD countries is from agriculture to manufacturing and services. Together with the observation that the services sector is most skill intensive and the agriculture sector is least skill intensive, structural change may increase the skill premium in all countries.

Changing household expenditure across sectors influences structural change. Table 2 shows the average household expenditure share on each sector. Looking at the levels in the left panel, OECD countries consume relatively more goods from services and less goods from agriculture than non-OECD countries. The changes in household expenditure share are mainly characterized by switching from agriculture to services. The upper panel of Figure 2 shows that the changes in household expenditure share are positively correlated with structural change. These observations indicate the role of income differences in explaining the consumption patterns across countries, if goods from services are more income elastic than agriculture. In my model, household preferences are nonhomothetic to capture this potential income effect.

Changes in firms' expenditure shares for intermediates across sectors also affect structural change. I define the intermediates expenditure share e^{kl} as the ratio of the cost of intermediates from sector l to sector k's total intermediates cost. Table 3 presents

[11] In the model the skilled and unskilled labor are combined with a Cobb-Douglas technology, so the skill intensity is directly measured by the cost share of the skilled labor.

the average intermediates expenditure share in each sector. From the left panel, we see that each sector uses its own intermediates intensively. This implies that any change in production share is amplified through sectoral linkages. From the right panel, we see that each sector uses more skill-intensive services intermediates overtime.

What matters for structural change is the changes in average intermediate expenditure share for each sector e^k, defined as $e^k = y^A e^{Ak} + y^M e^{Mk} + y^S e^{Sk}$. The lower panel of Figure 2 illustrates that the changes in average intermediate expenditure share are highly positively correlated with structural change in each sector.

To capture the rich input-output linkages that are important for structural change, total intermediates expenditure is translog and sector specific, to incorporate both the intensive usage of own sector intermediates and to allow relative sectoral prices to influence the sectoral intermediates expenditure share.

4 Model

The static trade model is based on Eaton and Kortum (2002) and Caliendo and Parro (2015). The world economy has $n = 1, \ldots, N$ countries, each with three tradable sectors: agriculture (A), manufacturing (M), and services (S). Let $\Omega = \{A, M, S\}$ denotes the set of all sectors. Country n is endowed with U_n units of unskilled labor, and S_n units of skilled labor.

Output in each sector is a CES aggregate (with constant elasticity of substitution σ) of the outputs of a unit continuum of goods (different across each sector) indexed by $j \in [0, 1]$. Country n's efficiency $z_n^k(j)$ at making good j in sector k is the realization of a random variable z_n^k distributed as:

$$F_n^k(z) = \mathbf{Pr}(z_n^k \leq z) = \exp\left(-T_n^k z^{-\theta^k}\right), \tag{1}$$

drawn independently across each good j in country n. Here, T_n^k reflects the overall production efficiency in country n sector k, and the parameter θ^k is an inverse measure of the dispersion of productivities.

Households consume outputs from all sectors with a preference structure of the Almost Ideal Demand System (AIDS). Production of good j in each sector combines the services of each type of labor and intermediates from each of the three sectors. Technology is such that the intermediates from each sector are aggregated into a composite intermediates bundle with translog technology, and the composite bundle is further

combined with two labor inputs following a Cobb-Douglas technology with constant returns to scale.

Trade in the outputs of the three sectors incurs standard iceberg costs, such that delivering one unit of output from country i to country n requires $\kappa_{ni}^k \geq 1$ units, with $\kappa_{nn}^k = 1$. Taking into account the ad valorem tariff rate $\tau_{ni}^k \geq 0$, the trade cost from country i to country n is $d_{ni}^k = \left(1 + \tau_{ni}^k\right) \kappa_{ni}^k$.[12]

4.1 Preferences

The preference of household h in country n is AIDS, as in Fajgelbaum and Khandelwal (2016). The preference is defined by expenditure share on goods from each sector, $s_n^k(h)$:

$$s_n^k(h) = \alpha_k + \delta_{kA} \ln P_n^A + \delta_{kM} \ln P_n^M + \delta_{kS} \ln P_n^S + b_k \ln \left(\frac{I_n(h)}{P_n} \right) \quad k \in \Omega,$$

where $I_n(h)$ is household h's income and P_n^k is sectoral price level. The overall price level P_n is of the translog form:

$$\ln P_n = \sum_{k \in \Omega} \alpha_k \ln P_n^k + \frac{1}{2} \sum_{k \in \Omega} \sum_{l \in \Omega} \delta_{kl} \ln P_n^k \ln P_n^l.$$

I restrict $\sum_{k \in \Omega} \alpha_k = 1$, $\sum_{k \in \Omega} \delta_{kl} = 0$, $\sum_{k \in \Omega} b_k = 0$ so that the expenditure shares add up to 1. In addition, $\sum_{l \in \Omega} \delta_{kl} = 0$ and $\delta_{kl} = \delta_{lk}$ correspond to the homogeneity and symmetry assumptions, so the AIDS is well defined.

Notice here that the substitution patterns between sectors are translog, so that it is more flexible than the usual CES considered in the structural change literature. If the income elasticity of demand $b_k \neq 0$, preferences are nonhomothetic. In sum, the AIDS specification captures complementarity across sectors and nonhomotheticity, both of which are important in explaining structural change from the side of household demand.

[12] There is no tariff in the services sector, so $\tau_{ni}^S = 0$.

4.1.1 Aggregation

The AIDS is easily aggregated to the economy level household expenditure share s_n^k:

$$s_n^k = \alpha_k + \delta_{kA} \ln P_n^A + \delta_{kM} \ln P_n^M + \delta_{kS} \ln P_n^S + b_k \left[Th_n + \ln \left(\frac{\bar{I}_n}{P_n} \right) \right] \quad k \in \Omega, \tag{2}$$

where $\bar{I}_n$ is the average income of consumers in each country, and Th_n is the Theil index of inequality.[13] Note that the preferences are the same across the countries, but the expenditure shares are different because real income per capita, the Theil index and the relative prices vary. In the quantitative exercises I use those variations in the data to estimate the parameters of the demand system.

4.2 Technology

4.2.1 Composite Intermediates Bundle

In each sector, intermediates from different sectors are combined with a translog technology. The price of the composite intermediates bundle is:

$$r_n^k = \sum_{l \in \Omega} \gamma_n^{kl} \ln P_n^l + \frac{1}{2} \sum_{l \in \Omega} \sum_{m \in \Omega} \eta_{lm}^k \ln P_n^l \ln P_n^m, \tag{3}$$

with the restrictions $\sum_{l \in \Omega} \gamma_n^{kl} = 1$, $\sum_{l \in \Omega} \eta_{lm}^k = 0$, $\sum_{m \in \Omega} \eta_{lm}^k = 0$, and $\eta_{lm}^k = \eta_{ml}^k$ so that the translog cost function is well defined. The share of intermediates from sector l in sector k's total intermediates spending is:

$$e_n^{kl} = \gamma_n^{kl} + \sum_{m \in \Omega} \eta_{lm}^k \ln P_n^m \tag{4}$$

for $k, l \in \Omega$. The intermediates expenditure share differs across sectors, as the constant terms γ_n^{kl}, and the price elasticities η_{lm}^k are sector specific. Notice that if all the price elasticities equal to zero, the intermediates expenditure shares are constant, which corresponds to a Cobb-Douglas technology.

[13] See Deaton and Muellbauer (1980).

4.2.2 Firm's Problem

The firm producing good j in country n sector k solves the following cost minimization problem:

$$\min \; c_n^k(j) = w_n^u l_u + w_n^s l_s + r_n^k M_n^k \quad \text{s.t.} \quad z_n^k(j) \left[l_u^{1-\beta_n^k} l_s^{\beta_n^k} \right]^{v_n^k} \left(M_n^k \right)^{1-v_n^k} \geq 1,$$

where l_u, l_s, and M_n^k are the demand for unskilled labor, skilled labor, and composite intermediates bundle, respectively, v_n^k is the value added share, and w_n^u, w_n^s are the wages paid to the unskilled and skilled labor, respectively.

Perfect competition implies that the price of good j in country n sector k is:

$$p_n^k(j) = \min \left\{ p_{ni}^k(j) : \; i = 1, \ldots, N \right\},$$

where $p_{ni}^k(j) = c_i^k(j) d_{ni}^k$ is the price charged by a firm in country i shipping to country n.

4.3 Equilibrium Relationships

In this section, I list the equilibrium outcomes of the model that I will later take to the data.

4.3.1 Prices and Trade Shares

From the firm's cost minimization problem, the unit cost c_n^k of producing in country n sector k, combining labor and composite intermediates bundle is:

$$c_n^k = \left[\left(\frac{1}{v_n^k} \right)^{v_n^k} \left(\frac{1}{1 - v_n^k} \right)^{1-v_n^k} \right] \left[\left(\frac{w_n^u}{1 - \beta_n^k} \right)^{1-\beta_n^k} \left(\frac{w_n^s}{\beta_n^k} \right)^{\beta_n^k} \right]^{v_n^k} \left(r_n^k \right)^{1-v_n^k}, \tag{5}$$

where r_n^k is given by (3), and the price level in country n sector k, after combining production costs in each country, is:

$$P_n^k = \epsilon_k \left[\sum_{l=1}^{N} T_l^k \left(c_l^k d_{nl}^k \right)^{-\theta^k} \right]^{-\frac{1}{\theta^k}}, \tag{6}$$

where $\epsilon_k = \left[\Gamma \left(\frac{\theta^k + 1 - \sigma}{\theta^k} \right) \right]^{\frac{1}{1-\sigma}}$, and $\Gamma(\cdot)$ is the Gamma function.

The share of spending in country n sector k that goes to goods imported from country i is:

$$\pi_{ni}^k = \frac{X_{ni}^k}{X_n^k} = \frac{T_i^k \left(c_i^k d_{ni}^k\right)^{-\theta^k}}{\Phi_n^k}, \tag{7}$$

where $\Phi_n^k = \sum_{l=1}^N T_l^k \left(c_l^k d_{nl}^k\right)^{-\theta^k}$ is the multilateral resistance term.

4.3.2 Market Clearing

Denote X_n^k as the value of country n's total spending on sector k, and Y_n^k as the value of gross production. World goods market clearing implies that:

$$Y_n^k = \sum_{i=1}^N \frac{\pi_{in}^k}{1+\tau_{in}^k} X_i^k. \tag{8}$$

Using (2) and (4), total spending on goods from sector k is the sum of household spending on sector k plus the use of sector k's output as intermediates in sector l:

$$X_n^k = s_n^k I_n + \sum_{l\in\Omega} (1-v_n^l) e_n^{lk} Y_n^l, \tag{9}$$

where $I_n = w_n^u U_n + w_n^s S_n + D_n + \sum_{l\in\Omega} X_n^l \left(1 - \sum_{i=1}^N \frac{\pi_{ni}^l}{1+\tau_{ni}^l}\right)$ is the total income of households in country n, consisting of wage payments $w_n^u U_n + w_n^s S_n$, trade deficits D_n, and tariff revenue $\sum_{l\in\Omega} X_n^l \left(1 - \sum_{i=1}^N \frac{\pi_{ni}^l}{1+\tau_{ni}^l}\right)$.

Clearing in the competitive market for each type of labor implies that total labor income equals labor demand across sectors:

$$\begin{aligned} w_n^u U_n &= \sum_{k\in\Omega} (1-\beta_n^k) v_n^k Y_n^k, \\ w_n^s S_n &= \sum_{k\in\Omega} \beta_n^k v_n^k Y_n^k. \end{aligned} \tag{10}$$

Finally, gross production plus trade deficits and tariff revenue equals total spending in each country:

$$\sum_{k\in\Omega} \left[Y_n^k + X_n^k \left(1 - \sum_{i=1}^N \frac{\pi_{ni}^k}{1+\tau_{ni}^k}\right)\right] + D_n = \sum_{k\in\Omega} X_n^k. \tag{11}$$

As the model is static, trade deficits are just exogenous transfers between countries.[14]

4.4 The Exogenous Variables

For the purpose of the quantitative exercises, I divide exogenous variables of the model into constant parameters Θ and time-varying shocks Ψ:

$$\Theta = \{\alpha_k, \delta_{kl}, b_k, \gamma_n^{kl}, \eta_{lm}^k, \theta^k\} \quad \text{and} \quad \Psi = \{\kappa_{ni}^k, \tau_{ni}^k, T_n^k, \beta_n^k, v_n^k, U_n, S_n, D_n\},$$

for $k, l, m \in \Omega$, and $n, i = 1 \ldots N$. Equations (2) through (11) determine the endogenous variables, which include wages w_n^u, w_n^s, prices of intermediates bundle r_n^k, prices P_n^k, trade shares π_{ni}^k, household expenditure shares s_n^k, total spending X_n^k, output Y_n^k for sectors $k \in \Omega$, and intermediates expenditure shares e_n^{kl} for $k, l \in \Omega$.

Shocks in the framework affect structural change through their effects on sectoral prices and the real income, which in turn affect household expenditure shares and intermediates expenditure shares according to (2) and (4). In addition, sectoral linkages amplify the structural change due to intensive usage of own sector intermediates.

4.5 Connecting Shocks to the Skill Premium

In my framework, shocks affect the skill premium through four channels.

The first channel relates to the shock to skill intensity β_n^k. A larger β_n^k implies that the sector becomes more skill intensive in production, so that the relative demand for the skilled labor increases. It can be interpreted as skill-biased technical change (SBTC). The changes in β_n^k are *exogenous* to other types of shocks in the model.

The second channel comes from the shock to skill abundance $\frac{S_n}{L_n}$. An increase in the relative supply of the skilled labor $\frac{S_n}{L_n}$ decreases the skill premium.

The third channel is based on the Hechscher-Ohlin theory. Countries that are skill abundant (with high $\frac{S_n}{L_n}$) tend to be net exporters in the skill-intensive services sector, so trade increases the skill premium. On the other hand, countries that are skill scarce are likely to be net exporters in the skill-unintensive agriculture sector, so trade decreases the skill premium in these countries. Changes in trade costs $\{\kappa_{ni}^k, \tau_{ni}^k\}$, trade deficits D_n, sectoral production efficiency T_n^k, and skill abundance $\frac{S_n}{L_n}$ affect the magnitude of the Hechscher-Ohlin force.

[14] When solving the model, I normalize the total world expenditure $\sum_{n=1}^N X_n = 1$. Trade deficits are then regarded as a constant share of total world expenditure that satisfies $\sum_{n=1}^N D_n = 0$.

The final channel relates to the endogenous changes in household and intermediates expenditure shares, which affect structural change directly.[15] Structural change is mainly due to shocks to sectoral production efficiency. Home technical change affects structural change in the domestic economy directly. Foreign technical change affects structural change in foreign countries, which in turn affects the home country through trade.

The effects of all shocks on the skill premium depends on the strength of each of the four channels.

4.6 Structural Change and the Skill Premium

How do trade and technical change affect the skill premium through structural change? In this subsection, I make some simplifying assumptions to study the effects of structural change on the skill premium. I assume that there are two countries, $N = 2$; two sectors, $k = a, b$, and sector b is the skill-intensive ($\beta_n^b > \beta_n^a$) and income-elastic ($b_b > 0 > b_a$) sector; and that the value added share is the same across sectors and countries, $v_n^k = v$. Details are provided in Appendix A3.

With the simplifying assumptions, the equilibrium skill premium can be written as:

$$\frac{w_n^s}{w_n^u} = \frac{U_n - FCT_n(U)}{S_n - FCT_n(S)} \frac{\sum_{k=\{a,b\}} \beta_n^k \left[v s_n^k + (1-v) e_n^k \right]}{\sum_{k=\{a,b\}} (1-\beta_n^k) \left[v s_n^k + (1-v) e_n^k \right]}, \tag{12}$$

where $e_n^k = y_n^a e_n^{ak} + y_n^b e_n^{bk}$ is the average intermediates expenditure share on sector k, y_n^k is the production share of sector k, and $FCT_n(l) = \sum_{k=\{a,b\}} l_n^k \omega_n^k$, $l = U, S$ is the factor content of trade, with $\omega_n^k = \frac{X_{-nn}^k - X_{n-n}^k}{X_{-nn}^k + X_{nn}^k}$. If a country has a comparative advantage in skill-intensive sector b, then the country is a net exporter of the skilled labor ($FCT_n(S) > 0$) and a net importer of the unskilled labor ($FCT_n(U) < 0$). Therefore, international trade raises the skill premium in a country with a comparative advantage in the skill-intensive sector and decreases the skill premium in a country with comparative disadvantage in the skill-intensive sector.

Structural change at foreign country $-n$ also affects the factor content of trade at home. Given the same trade shares, if foreign households and firms have larger expenditure shares on goods from skill-intensive sector b, the home country is more likely to be a net exporter in sector b. Therefore, changes in factor content of trade

[15] Hechscher-Ohlin force relies on sectoral reallocation, and therefore it is also one channel that affects structural change.

of the skilled at home is positive ($\Delta FCT_n(S) > 0$), while the changes in the factor content of trade of the unskilled is negative ($\Delta FCT_n(U) < 0$), leading to an increase in the skill premium at home.

The second part on the right-hand side of (12) captures the effects of structural change at home on the skill premium. It includes the changes in expenditure shares due to both households and firms. As the changes in numerator and denominator are opposite in sign, I only investigate the changes in numerator (Num):

$$Num_n = \underbrace{v \sum_{k=\{a,b\}} \beta_n^k s_n^k}_{\text{consumer}} + \underbrace{(1-v) \sum_{k=\{a,b\}} \beta_n^k e_n^k}_{\text{firm}}.$$

On the side of the households:

$$\sum_{k=\{a,b\}} \beta_n^k s_n^k = \left(\beta_n^b - \beta_n^a\right) \Delta s_n^b, \tag{13}$$

where $\Delta s_n^k = \left(s_n^k\right)' - s_n^k$ is the difference in the household expenditure share between two periods. Over time, households demand relatively more sector b goods due to gains from trade or technology progress if preferences are nonhomothetic. This in turn implies that $\Delta s_n^b > 0$, which increases the skill premium.

I further decompose the expression on the side of firms into three parts:

$$\begin{aligned} &\sum_{k=\{a,b\}} \beta_n^k e_n^k = \left(\beta_n^b - \beta_n^a\right) \Delta e_n^b \\ &= \left(\beta_n^b - \beta_n^a\right) \left[\underbrace{\left(e_n^{aa} + e_n^{bb} - 1\right) \Delta y_n^b}_{\text{between-sector}} + \underbrace{\left(y_n^b \Delta e_n^{bb} - y_n^a \Delta e_n^{aa}\right)}_{\text{within-sector}} + \underbrace{\left(\Delta e_n^{aa} + \Delta e_n^{bb}\right) \Delta y_n^b}_{\text{interaction}} \right]. \end{aligned} \tag{14}$$

The between-sector component is non-zero when the intermediates expenditure share differs across sectors.[16] If each sector uses its own intermediates intensively ($e_n^{aa}, e_n^{bb} > 1$), reallocation to skill-intensive sector b ($\Delta y_n^b > 0$) increases the skill premium. The within-sector component is active when changes in the intermediates expenditure share are non-zero within each sector. If each sector uses more skill-intensive intermediates over time ($\Delta e_n^{aa} < 0$ and $\Delta e_n^{bb} > 0$), the skill premium increases. The sign of the interaction term is in general ambiguous, and depends on which sector has the larger

[16] By definition, $e_n^{ka} + e_n^{kb} = 1$. If different sectors use the same inputs, $e_n^{aa} = e_n^{ba}$ and $e_n^{ab} = e_n^{bb}$, such that $e_n^{aa} + e_n^{bb} = 1$.

changes in the intermediates expenditure share.

5 Taking the Model to the Data

In this section, I estimate the parameters of the model and back out the shocks. I use data mainly from Global Trade Analysis Project (GTAP) versions 5 to 8, corresponding to the years 1997, 2001, 2004, and 2007, to 38 countries including the rest of the world (ROW). I use data on total expenditure $X_n^k(t)$, output $Y_n^k(t)$, and bilateral trade flows $X_{ni}^k(t)$ to compute production shares y_n^k and trade shares π_{ni}^k for $k \in \Omega$.[17] I take total employment $L_n(t)$ from the Penn World Tables 8.1 and the skill premium $\frac{w_n^s}{w_n^u}(t)$ from various sources. Details on how I assemble the data are provided in Appendix A2.

The procedure of quantification involves two major steps. In the first step, I retrieve sectoral prices P_n^k from the model-implied gravity equation on trade flows. Armed with sectoral prices and other observables from the data, I estimate the demand parameters $\Theta_d = \{\alpha_k, \delta_{kl}, b_k, \gamma_n^{kl}, \eta_{lm}^k\}$ and back out the shocks Ψ. In the end, the model replicates the trade share, production share, consumption share, and skill premium in each country in 1997 and 2007.

5.1 Sectoral Prices

In this section I show how to get sectoral prices by estimating a model-implied gravity equation. More precisely, I identify sectoral prices relative to a base country (ROW) from the estimates of country fixed effects in the gravity equation.[18]

Starting from (7), dividing the trade share from country i to country n by country n's own share and taking logs, I get:

$$\ln\left(\frac{\pi_{ni}^k}{\pi_{nn}^k}\right) = \ln\left[T_i^k\left(c_i^k\right)^{-\theta^k}\right] - \ln\left[T_n^k\left(c_n^k\right)^{-\theta^k}\right] - \theta^k \ln d_{ni}^k, \tag{15}$$

where $d_{ni}^k = \left(1+\tau_{ni}^k\right)\kappa_{ni}^k$. As the iceberg cost κ_{ni}^k is unknown, I further parameterize it as $\kappa_{ni}^k = \bar{\kappa}_{ni}^k \zeta_{ni}^k$, where $\bar{\kappa}_{ni}^k = \bar{\kappa}_{in}^k$ is the symmetric part of the iceberg cost. I pin down the symmetric iceberg cost $\bar{\kappa}_{ni}^k$ by adding to (15) the trade flow in the opposite direction $\ln\left(\frac{\pi_{in}^k}{\pi_{ii}^k}\right)$, with the assumption of no asymmetry in iceberg cost ($\zeta_{ni}^k = \zeta_{in}^k = 1$). This

[17] Specifically, $y_n^k = \frac{Y_n^k}{\sum_{l\in\Omega} Y_n^l}$ and $\pi_{ni}^k = \frac{X_{ni}^k}{X_n^k}$.

[18] The procedure I employ is similar to that used by Parro (2013) and Reyes-Heroles (2016).

implies that

$$\bar{\kappa}_{ni}^k = \left(\frac{\pi_{ni}^k}{\pi_{ii}^k}\frac{\pi_{in}^k}{\pi_{nn}^k}\right)^{-\frac{1}{2\theta^k}} \left[(1+\tau_{ni}^k)(1+\tau_{in}^k)\right]^{-\frac{1}{2}}.$$

The only unknown parameter here is the trade elasticity θ^k, which I set as $\theta^k = 4$ for $k \in \Omega$ from the estimates of Simonovska and Waugh (2014a).[19]

Moving the part of the trade costs that is known, which includes tariff $\left(1+\tau_{ni}^k\right)$ and symmetric iceberg cost $\bar{\kappa}_{ni}^k$, to the left-hand side of (15), I obtain the equation to estimate:

$$\ln\left[\left(\frac{\pi_{ni}^k}{\pi_{in}^k}\frac{\pi_{ii}^k}{\pi_{nn}^k}\right)^{-\frac{1}{2\theta^k}}\left(\frac{1+\tau_{ni}^k}{1+\tau_{in}^k}\right)^{-\frac{1}{2}}\right] = \underbrace{\ln\left[\left(T_i^k\right)^{-\frac{1}{\theta^k}} c_i^k\right]}_{\text{exporter fixed effect}} - \underbrace{\ln\left[\left(T_n^k\right)^{-\frac{1}{\theta^k}} c_n^k\right]}_{\text{importer fixed effect}} + \underbrace{\ln \zeta_{ni}^k}_{\text{residual}}. \quad (16)$$

Everything on the left hand side of (16) is either taken from the data or assigned, and I estimate (16) by OLS for each year sector.

The sectoral relative price P_n^k for each year is identified from either the importer or exporter fixed effects $S_n^k = \left(T_n^k\right)^{-\frac{1}{\theta^k}} c_n^k$:

$$P_n^k = \frac{\epsilon_k S_n^k}{\left(\pi_{nn}^k\right)^{-\frac{1}{\theta^k}}}. \quad (17)$$

5.2 Backing out Shocks

With the equilibrium conditions (2) through (11) and data on endogenous variables $\{y_n^k, \frac{w_n^s}{w_n^u}, \pi_{ni}^k, P_n^k\}$, I can back out the following shocks without knowing the equilibrium wages:

1. Equations (6) and (7), as it applies to $n \neq i$ relative to $n = i$, give me trade costs d_{ni}^k:

$$d_{ni}^k = \left(\frac{\pi_{ni}^k}{\pi_{ii}^k}\right)^{-\frac{1}{\theta^k}} \frac{P_n^k}{P_i^k}. \quad (18)$$

   With data on tariffs τ_{ni}^k, iceberg costs $\kappa_{ni}^k = \frac{d_{ni}^k}{1+\tau_{ni}^k}$.[20]

2. I compute the value added shares v_n^k directly from the data, measured as the ratio of total labor payments to total production costs.

[19] I also use $\theta^k = 3$ and $\theta^k = 5$ to check whether my results are affected.

[20] An alternative way to recover the trade costs is to use the bilateral residuals ζ_{ni}^k from (16) so that $d_{ni}^k = \left(1+\tau_{ni}^k\right)\bar{\kappa}_{ni}^k \zeta_{ni}^k$. These two methods give the same trade costs.

3. I compute the skill intensity β_n^k directly from the data, measured as the ratio of payments to the skill labor to total labor payments.

4. I compute the total labor force L_n directly from the data on total employment in country n.

5. Dividing the two expressions in (10), I retrieve the relative supply of the skilled labor given data on the skill premium $\frac{w_n^s}{w_n^u}$:

$$\frac{S_n}{U_n} = \frac{\sum_{k\in\Omega} \beta_n^k v_n^k y_n^k}{\sum_{k\in\Omega}(1-\beta_n^k) v_n^k y_n^k} \left(\frac{w_n^u}{w_n^s}\right). \tag{19}$$

   Together with the values on L_n, I know the S_n and U_n levels.

6. I compute trade deficits D_n directly from the data.

To back out sectoral production efficiency T_n^k and estimate demand parameters Θ_d require the values of equilibrium wages w_n^u and w_n^s. This can be done by first using (8) and (11) to solve for equilibrium outputs Y_n^k and then solving for the wages using (9) and (19).

To back out sectoral production efficiency, I calculate the equilibrium values of the unit cost c_n^k from (5) and use expression (7) with $n = i$:

$$T_n^k = \left(\frac{P_n^k}{\epsilon_k c_n^k}\right)^{-\theta^k}. \tag{20}$$

5.3 Demand Parameters

I estimate the AIDS parameters $\{\alpha_k, \delta_{kl}, b_k\}$ by minimizing the distance between the model-implied household expenditure shares $\tilde{s}_n^k(t)$ from (2) and the expenditure shares from the data $s_n^k(t)$:

$$\{\alpha_k, \delta_{kl}, b_k\} = \text{argmin} \sum_{k\in\Omega} \sum_{n=1}^{N} \sum_{t} \left[s_n^k(t) - \tilde{s}_n^k(t)\right]^2.$$

Similarly, I estimate the translog intermediates cost parameters $\{\gamma_n^{kl}, \eta_{lm}^k\}$ by minimizing the distance between the model-implied intermediates expenditure shares $\tilde{e}_n^{kl}(t)$ from

(4) and the respective shares from the data $e_n^{kl}(t)$ sector by sector:

$$\{\gamma_n^{kl}, \eta_{lm}^k\} = \text{argmin} \sum_{l\in\Omega} \sum_{n=1}^{N} \sum_t \left[e_n^{kl}(t) - \tilde{e}_n^{kl}(t)\right]^2, \quad k \in \Omega.$$

To match household expenditure shares in the data, I regard the residuals from the estimation of AIDS as another shock, which I call the preference shifters:

$$a_n^k(t) = s_n^k(t) - \tilde{s}_n^k(t), \quad k \in \Omega,\ n = 1, \ldots, N. \tag{21}$$

For the model to match production shares and therefore structural changes in the data, the model-implied intermediates expenditure shares have to be internally consistent with the aggregate intermediates expenditure share $e_n^k(t)$ implied by (9).[21] I match production shares by finding input shifters $g_n^{kl}(t)$, which minimizes the distance to the residuals from the estimation of intermediates cost parameters in each year sector:

$$g_n^{kl}(t) = \text{argmin} \sum_{l\in\Omega} \sum_{n=1}^{N} \left[e_n^{kl}(t) - \tilde{e}_n^{kl}(t) - g_n^{kl}(t)\right]^2, \tag{22}$$

subject to

$$\frac{\sum_{l=\in\Omega} \left[1 - v_n^l(t)\right] \left[\tilde{e}_n^{lk}(t) + g_n^{lk}(t)\right] Y_n^l(t)}{\sum_{l\in\Omega} \left[1 - v_n^l(t)\right] Y_n^l(t)} = e_n^k(t) \quad \text{and} \quad \sum_l g_n^{kl}(t) = 0,$$

where the first restriction ensures that the model matches the production shares in the data.[22]

The procedure delivers the constant parameters Θ and time-varying shocks $\Psi = \{\kappa_{ni}^k, \tau_{ni}^k, T_n^k, \beta_n^k, v_n^k, U_n, S_n, D_n, a_n^k, g_n^{kl}\}$ of the baseline model. By construction, the solution to the baseline model matches the trade shares π_{ni}^k, household expenditure shares s_n^k, production shares y_n^k, and skill premium $\frac{w_n^s}{w_n^u}$ in both the initial (1997) and the end (2007) equilibria.

[21] $e_n^k(t) = \frac{X_n^k(t) - s_n^k(t) I_n(t)}{\sum_{l\in\Omega}[1 - v_n^l(t)] Y_n^l(t)}$.

[22] Simply matching the intermediates expenditure shares in the data does not work, as I do not have factors such as capital and land in the model.

5.4 Values of Exogenous Parameters

Table 4 and Table 5 summarize the baseline demand parameters.

For the AIDS parameters in Table 4, the values of income elasticities b_k indicate that goods from the agriculture sector are necessities, while goods from the services sector are luxuries. The estimates of income elasticities are consistent with the estimates from the structural change literature, which find services to be the luxury sector. The estimates of price elasticities δ_{kl} reveal that goods from the agriculture and services sectors are in general complements to other sectors ($\delta_{AA}, \delta_{SS} > 0$), while goods from the manufacturing sector are substitutes ($\delta_{MM} < 0$). The estimates here are consistent with the final expenditure approach in Herrendorf et al. (2013), who find that substitutability between sectors is close to a Cobb-Douglas utility.

Table 5 presents the estimates on the price elasticities of the translog intermediates cost function. In general, intermediates from all sectors are complements to each other in the agriculture sector and substitutes to each other in the manufacturing and services sector.

Table 7 summarizes the baseline shocks. I report the cumulative changes in the shocks for each country and sector between 1997 and 2007.

The first three columns in Table 7 summarize the average changes in trade costs. I report the trade volume weighted trade costs for each country, as well as the average trade costs in OECD and non-OECD countries. The first observation is that the reductions in trade costs are larger in non-OECD countries, especially in the manufacturing sector. It is also interesting to note that there are significant reductions in the trade costs of the services sector. Given that the services sector often has the largest production share in each country, especially in the OECD countries, the effects of trade may be larger than trade models in which services are regarded as non-tradable.

The next three columns in Table 7 present the relative changes in average sectoral productivities $\left(\hat{T}_n^M\right)^{\frac{1}{\theta}}$. Again, productivity growth is much larger in non-OECD countries, especially in the manufacturing sector. As sectoral productivity growth is found to be the most important driver of structural change in the literature, the impacts of structural change on the skill premium is likely to be larger in non-OECD countries.

For the skill-biased technical change in the next three columns of Table 7, we see that most of the increases in skill intensity happened in the services sector. As OECD countries have larger production shares in the services sector, the impacts of skill-biased technical change on the skill premium is likely to be relatively more important than in

non-OECD countries.

Finally, the last column of Table 7 shows the changes in the relative supply of skilled labor. On average, the share of the skilled labor increases, implying downward pressure on the skill premium.

5.5 External Validation

The model replicates the trade shares, production shares, consumption shares, and skill premium in the data, so I assess the fit of the model by using external data to verify some of the shocks I back out.

5.5.1 Labor Productivity

The first validation exercise tests whether labor productivity in the model reflects the true values in the data. Figure 3 plots labor productivity in the model against TFP in the data.[23] Labor productivity in each country is a production share weighted average of sectoral labor productivity. Sectoral labor productivity takes into account the effect of trade and is calculated as $\mathrm{LP}_n^k = \frac{c_n^k}{P_n^k}$.[24] The plots show that labor productivity in each country correlates well with TFP in both years. Figure 4 also shows that the log changes in labor productivity correlates reasonably well with log changes in TFP.

5.5.2 Share of the Skilled Labor

The second exercise verifies the share of the skilled labor $\frac{S_n}{L_n}$ in each country. Figure 5 plots the model-implied $\frac{S_n}{L_n}$ against the share of populations with incomplete tertiary degree taken from Barro and Lee (2013).[25] The fit is reasonable with R^2 over 0.2 for both years, but the model over-estimates the share of the skilled labor for most countries. Figure 6 presents the model-implied changes in $\frac{S_n}{L_n}$ against the corresponding changes in the Barro and Lee (2013) measure. The slope is positive when I take into account the outliers.[26]

[23] I compute TFP directly from PWT 8.1 as the TFP valued at current PPPs in the corresponding years.

[24] See Finicelli et al. (2013) for detail.

[25] As data from Barro and Lee (2013) is at 5-year intervals, I compare the model-implied share in 2007 to the data in 2005, and the model share in 1997 to the data in 1995.

[26] I drop 7 countries where the deviations from the changes in the data are at least 8 percentage points.

One reason of the coarse fit is that the skilled labor in developed countries may be of higher quality than their counterparts in developing countries. If this is the case, the share of the skilled labor I back out also reflects the quality of the labor force.[27] To check whether this is the case, Figure 7 plots the model-implied share against the TFP-adjusted data share: TFP $\times \frac{S_n}{L_n}$(data). There is a large improvement in the fit, as indicated by an increase in the R^2. The changes in the model-implied share also see a large improvement in the fit from Figure 8.

Finally, I regress the model-implied share of the skilled labor on observables, which help explain cross country differences in educational attainment. Restuccia and Vandenbroucke (2014) find that variations in TFP and life expectancy explain most of the differences in educational attainment across countries and over time. Therefore, I regress the model-implied share on TFP, life expectancy, and the share of government expenditure on education as a percentage of GDP to assess the model fit. Table 8 presents the regression results. The first observation is that for the model-implied share, all three observables are of the correct sign and the R-squares are over 0.5 in both years. Moreover, the data measure from Barro and Lee (2013) does not fit well as the model-implied share, indicating that the model share may reflect the quality difference of the skilled labor.

In sum, the validation exercises above show that the shocks on the share of the skilled labor are reasonable.

5.5.3 Trade Cost

I verify the validity of the bilateral trade cost I back out by regressing it on common determinants of trade cost.[28] The observables include tariffs, log distance, and the dummy variables such as contiguity (=1 if two countries share the border), common language (=1 if two countries speak the same official language), non-reciprocal preferential trade agreements (=1 if two countries have a NRPTA), reciprocal preferential trade agreements (=1 if two countries have a RPTA), and trade agreements (=1 if two countries either are in the same currency or economic union, or in the same free trade agreement).

The left panel of Table 9 presents the regression results on levels of trade cost for

[27] Another interpretation is that the same college graduate is more productive in rich countries, as rich countries have larger capital stock.

[28] As almost all country pairs in my sample have bilateral trade flows, there is no problem of zero trade flows.

each sector in year 1997 and 2007. The first observation is that all the coefficients on tariffs and distance are of the correct sign and statistically significant, except the tariff coefficient on agriculture in 2007. Second, all of the coefficients on contiguity and common language are negative and statistically significant, except the common language coefficient on services in 2007. In sum, the level of trade cost I back out is reasonable as it correlates well with the common determinants of trade cost.[29]

The right panel of Table 9 presents the regression results on changes in trade costs. Log distance is interacted with the changes in world crude oil price so that the coefficient is identified. The first observation is that the distance coefficient is of the correct sign and statistically significant. The fit is particularly good for the changes in trade costs in the services sector, with all coefficients of the correct sign and a large R^2. In sum, the changes in trade costs are also reasonable.

5.6 Classifying Shocks

In this section I classify shocks Ψ into trade shocks, technology shocks, labor supply shocks, and model residuals.

For a home country n, any shocks outside country n affect the home country through trade only. These shocks include the trade cost shocks $\{\hat{\kappa}^k_{mi}, \hat{\tau}^k_{mi}\}$, shocks to trade deficits $\hat{D}_n$, and shocks to foreign sectoral production efficiency $\hat{T}^k_{-n}$, which corresponds to the definition of foreign shocks in Arkolakis et al. (2012).[30] The technology shocks at home include shocks to home production efficiency $\hat{T}^k_n$ as well as skill-biased technical change $\Delta\beta^k_n$. The shocks to home sectoral production efficiency $\hat{T}^k_n$ can be regarded as neutral technical change (NTC). I classify the shocks as follows:

1. Trade shocks consist of
   - trade cost shocks: $\{\hat{\kappa}^k_{mi}, \hat{\tau}^k_{mi}\}$,
   - trade deficits shocks: ΔD_n,
   - foreign technology shocks: $\hat{T}^k_{-n}$;
2. Technology shocks consist of:

[29] The exception is that some of the coefficients on the TA dummy imply higher trade costs. These may reflect an endogeneity bias since TAs are correlated with bilateral unobserved characteristics (e.g., Limão (2016)), which I can't control for in levels.

[30] I focus on shocks that affect trade directly to study the first order effect. Other shocks, such as skill-biased technical change $\Delta\beta^k_{-n}$, affect trade flows indirectly through their effects on the unit cost c^k_n.

- skill-biased technical change: $\Delta\beta_n^k$,
- neutral technical change: $\hat{T}_n^k$;

3. Labor supply shocks: $\{\hat{L}_n, \hat{S}_n, \hat{U}_n\}$;

4. Model residuals consist of the changes in:

   - value added share: Δv_n^k,
   - preference shifters: Δa_n^k,
   - input shifters: Δg_n^{kl}.

6 Counterfactuals

With the shocks that fully account for the changes that occurred from 1997 to 2007, I can provide insight on whether it is trade or technical change that drives the changes in the skill premium in each country. To do so I consider a scenario where only one set of shocks is operative, keeping other types of shocks fixed at their 1997 levels, and apply each set of shocks country by country to see the effects on the skill premium.

Table 10 summarizes my main findings. It shows the effects of shocks from the labor supply, trade, technology, and residuals on changes in the skill premium, with each group of shocks acting in isolation.[31][32] The first three rows present the median values across the respective group of countries. In general, both trade and technical change increase the skill premium, while labor supply shocks decrease it.

The results for each individual country reveal that trade increases the skill premium in all countries, with a median of 8.3%. In particular, small countries, such as Ireland and Luxembourg, or countries experiencing large reductions in trade costs, such as China, have larger effects of trade on the skill premium. In general, trade increases the skill premium more in non-OECD countries than in OECD countries. The effects of technical change on the skill premium are more heterogeneous. For some countries, such as China and India, technical change increases the skill premium by over 20%, while for some other countries, such as Peru, the effects are negative and large. The heterogeneity can be explained by the average changes in skill intensity for each country,

[31] All changes in the skill premium are relative changes: $\Delta\text{SP}\% = \frac{\text{SP}(c)-\text{SP}(97)}{\text{SP}(97)} \times 100\%$, where $\text{SP}(c)$ is the skill premium at the counterfactual.

[32] There is no reason for the effects of each shock to add up to the observed value because there are interactions between different shocks.

as shown in the left panel of Figure 9. This suggests that SBTC plays a major role in explaining the changes in skill premium due to technical change.

To gauge the relative importance of trade and technical change, I focus on the subset of countries where both forces increase the skill premium. Trade increases the skill premium by 7.5%, while technical change increases the skill premium by 5.3% in a typical country in this subset. The last two columns of Table 10 illustrate the contribution of each channel to the rise in the skill premium.[33] In a typical country, trade and technical change are equally important.

It is interesting to note that for Latin American countries and some Asian emerging economies, the residuals are particularly large, indicating that a lot of the observed changes in the skill premium are due to neither trade nor technical change. To investigate whether the large residuals are due to changes in the value added share Δv_n^k for $k \in \Omega$, the right panel of Figure 9 plots the changes in the skill premium due to shocks to value added share against the skill premium predicted by residuals.[34] The shocks to value added share help explain the effects from the residuals, but a significant portion remains unexplained, especially for the Latin American countries. This shows that the channels in the model do not capture the observed changes in household expenditure shares and intermediates expenditure shares in some countries.[35]

6.1 Trade and Technical Change

As I have different types of trade shocks, it is worthwhile to understand which type of trade shocks is more important. The first three columns of Table 11 present the effects of the three types of trade shocks on the changes in skill premium. The main findings are that trade increases the skill premium due to foreign technical change but not changes in the trade cost or deficits. In general, the effects of trade cost and trade deficits are small for most of the countries. The effects of foreign technical change, on the other hand, have a median value of 6.3% on the skill premium for OECD countries and a larger value of 13% for non-OECD countries. This illustrates the importance of considering foreign technical change, in addition to changes in the trade cost and deficits, when evaluating the impact of trade on the skill premium.

The last two columns of Table 11 illustrate the effects of NTC and SBTC on the

[33] The contribution from trade, for example, is computed as $\frac{\Delta \text{SP(trade)}}{\Delta \text{SP(trade)} + \Delta \text{SP(tech)}} \times 100\%$.

[34] I only focus on countries where the effects of the residuals are larger than 5% in absolute values.

[35] One reason may be that I do not have other factors of production such as land, which may be important for exporters of agricultural goods such as Argentina.

changes in the skill premium. SBTC explains most of the increases in the skill premium, which confirms the findings in the left panel of Figure 9. On the other hand, the effects of NTC are mostly negative except for China, where sectoral productivity growth is exceptional. Moreover, the median effects of SBTC are larger in OECD countries. This is partially explained by the fact that SBTC are larger in the services sector in the OECD countries (from Table 7), and that rich countries have a larger production share in services.

6.2 Role of Structural Change

In this section, I investigate the effects of structural change on the skill premium by shutting down the endogenous changes in household expenditure share (s_n^k) and aggregate intermediates expenditure share (e_n^k).[36] More specifically, both the consumer utility and intermediates expenditure function are Cobb-Douglas. In addition, there are no sectoral linkages, so each sector has the same intermediates expenditure share for all sectors.[37] The no structural change model is similar to the standard multi-sector trade model considered by Caliendo and Parro (2015).

The no structural change model has two additional shocks compared to the baseline: the household expenditure share $s_n^k(t)$ and aggregate intermediates expenditure share $e_n^k(t)$ for $k \in \Omega$. The values of $s_n^k(t)$ are set to the values in the data, while the values of $e_n^k(t)$ are equal to the $e_n^k(t)$ in the baseline, which matches the structural change.[38] I match the no structural change model to the same moments in the baseline so that it yields the same exogenous variables and shocks.[39]

I apply the same groups of shocks one by one to the no structural change model and compare the results with the baseline. Table 12 decomposes the changes in skill premium for the no structural change model. Comparing with the baseline results in Table 10, the main observation is that the effects of trade on the skill premium

[36]To be precise, there is still structural change induced by international trade, which is the "net export channel" as in Uy et al. (2013), due to differences in sectoral production efficiency and skill abundance across countries. Keeping that in mind, I will call the simple framework the "no structural change model."

[37]Mathematically, $e_n^k = e_n^{Ak} = e_n^{Mk} = e_n^{Sk}$ for $k \in \Omega$.

[38]The shocks to consumption expenditure share and intermediates expenditure share play the same roles as preference shifters and input shifters, respectively, in the baseline model. These two shocks are counted as residuals.

[39]Shocks to production efficiency are slightly different as sectoral linkages differ, which implies a different unit cost $c_n^k(t)$. I compare the production efficiency T_n^k implied by the two models and find that they are very similar.

are almost halved (from 8.3% to 4.2%). Moreover, the effects of technical change are negligible in non-OECD countries. In terms of percentage contributions, trade now explains only 35% of the increases in skill premium in a typical country, compared to 50% in the baseline. From Figure 10, where I plot the changes in skill premium in the no structural change model against the baseline, the effect of trade is smaller in almost every country.

To quantify the effects of structural change on the skill premium, I add up the differences implied by the labor supply, trade, and technology shocks between the baseline and no structural change model. The calculation shows that structural change increases the skill premium by 2.3% in OECD countries and 7.7% in non-OECD countries.[40] This shows that structural change has larger effects on the skill premium in non-OECD countries.

The effects of structural change come mainly from the shocks to sectoral production efficiency T_n^k, as shown in Table 13. Comparing to the baseline results in Table 11, the effects of foreign technical change decrease a lot. The reason is that sectoral technical change is the main driver of structural change in the model. Other types of shocks that have little effect on structural change, such as labor supply and SBTC, give similar results as the baseline.[41]

The finding that structural change has a larger effect in non-OECD countries is also shown in Figure 11, where I plot the differences in the skill premium implied by the baseline and no structural change model against income per worker in each country. Both graphs for trade and technology shocks give a negative slope, indicating that the effect of structural change is larger for non-OECD countries. This may be due to the fact that non-OECD countries have larger increases in sectoral production efficiency than do OECD countries, as shown in Table 7. Sectoral technical change drives structural change, leading to larger increases in the skill premium in non-OECD countries.

6.3 Robustness

In this section, I check whether my main results are sensitive to alternative values of trade elasticity and separate estimation of expenditure functions for OECD and non-OECD countries. In all the exercises, I recalibrate the parameters and back out the

[40] An alternative is to calculate the increases in the effects of the residuals. This gives an increase of 1.7% in OECD countries and 7.4% in non-OECD countries.

[41] See Appendix A4 for details on contributions of different shocks to structural change.

shocks so that the model with alternative specifications match the same data as the baseline.

6.3.1 Trade Elasticity

The upper part of Table 14 presents the results under $\theta = 3$ and $\theta = 5$. Comparing with the baseline, we see that the results under alternative values of trade elasticity imply different effects of trade and technical change on the skill premium. Moreover, the results on non-OECD countries are more sensitive to different values of trade elasticity. The reason that why my results are sensitive to the values of trade elasticity is that it affects the values of the shocks I back out. In particular, I back out sectoral prices conditional on the value of trade elasticity from the estimation of (16), and shocks to sectoral production efficiency and trade cost depend on sectoral prices.

To gauge whether the value of trade elasticity of $\theta = 4$ is reasonable, I estimate the elasticities in agriculture and manufacturing, following the triple difference method used by Caliendo and Parro (2015).[42] From (7), I multiply the trade flows from country i to country h, from country h to country n, and finally from country n to country i, and then divide the trade flows in the opposite directions. The procedure gives the flowing estimation equation:

$$\ln\left(\frac{X_{in}^k X_{nh}^k X_{hi}^k}{X_{ih}^k X_{hn}^k X_{ni}^k}\right) = -\theta^k \ln\left(\frac{\tau_{in}^k \tau_{nh}^k \tau_{hi}^k}{\tau_{ih}^k \tau_{hn}^k \tau_{ni}^k}\right) + \varepsilon^k, \tag{23}$$

and I estimate it by OLS. Table 15 presents the estimates for each year of GTAP data for 37 countries in my sample. We see that the trade elasticity in manufacturing ranges from 1.5 to 4.5, while the estimates in the agriculture sector are too small. The reason may be due to the fact that variation in tariffs provide little information on identifying trade elasticity, as pointed out by Simonovska and Waugh (2014b). Therefore, I use $\theta = 4$ from Simonovska and Waugh (2014a), which is the standard value of trade elasticity for models with broad sectors.[43]

[42] The method utilizes variation in tariffs, so it is not applicable to the services sector.

[43] In the future, I plan to use sectoral price data to estimate the trade elasticity consistent with my framework. As pointed out by Simonovska and Waugh (2014b), different trade models imply different sectoral prices conditional on the same trade flows, so different model-consistent trade elasticities can be identified from variation in sectoral prices.

6.3.2 Separate Estimation of Expenditure Functions

The bottom part of Table 14 shows the results when AIDS and translog intermediates expenditure functions are estimated separately for OECD and non-OECD countries. Comparing with the baseline, estimating translog intermediates expenditure function separately does not have much effect on the results. However, a separate estimation of AIDS reduces (increases) the effects of technical change on OECD (non-OECD) countries and reduces the residuals in non-OECD countries.[44] Overall, the effects are similar to the baseline results.

7 Structural Change in the U.S. and China

In this section, I apply the framework to investigate the effects of trade and technical change on structural change in the U.S. and China. The motivation comes from the fact that since 2001, the U.S. has experienced a huge increase in manufacturing imports from China.[45] The influx of cheap Chinese goods has profound influences on the U.S. labor markets, such as a declining manufacturing employment share in trade-exposed regions and larger earning losses for unskilled manufacturing workers.[46] Meanwhile, China is able to transform from an agricultural economy to a world manufacturing factory through its export-oriented growth strategy.[47]

There is a growing body of literature analyzing the effects of imports from China on the U.S. labor markets, both at the levels of industry and local labor markets. Autor et al. (2013) find that there is a larger decline in employment in commuting zones that are more exposed to imports from China. At the industry level, Acemoglu et al. (2016) find that manufacturing industries that face greater import penetration from China face larger employment losses.

Based on my structural model, I can investigate the effects of imports from China on the U.S. labor market at the sector level, using the trade shocks that I back out. Though I do not have industry and local labor market variation, one advantage of my approach is that it does not suffer from the potential endogeneity problem of the instrument used in these papers.[48] In addition, the structural model incorporates the

[44] The residuals for Latin American countries are still very large.
[45] See, for example, Handley and Limão (2013).
[46] See, for example, Autor et al. (2013, 2014) and others.
[47] See, for example, Brandt et al. (2008) on structural transformation in China.
[48] These papers often instrument imports from China in the U.S. by imports from China in other

general equilibrium effects of trade shocks from China, which are in general hard to estimate using a reduced form approach.

My framework can also shed light on whether it is trade or technical change that is driving the changes in the U.S. labor markets. Autor et al. (2015) uses exposure to computerization as technology shock, together with imports from China as trade shock, to investigate the effects of trade and technical change on the employment at the commuting zone level. Given that I have different types of trade and technology shocks that are independent, I can separately identify the effects of each shock on the U.S. economy.

7.1 Shocks

I use the baseline specification to focus on the effects of shocks that involve only the U.S. and China. These shocks include $\hat{T}_n^k$, $\Delta\beta_n^k$, ΔD_n, and $\{\hat{L}_n, \hat{S}_n, \hat{U}_n\}$ in the U.S. and China, as well as trade cost shocks $\{\hat{\kappa}_{ni}^k, \hat{\tau}_{ni}^k\}$ involving only the U.S.–China pair. Shocks for other countries are kept at 1997 values.

Suppose the U.S. is the home country. Shocks on the trade deficits in the U.S. reflect only the effects of trade with China, which is given by:

$$\Delta D_{\text{US}} = \Delta X_{\text{US CHN}} - \Delta X_{\text{CHN US}}.$$

From the perspective of the U.S., foreign technical change refers only to changes in the production efficiency in China, $\hat{T}_{\text{CHN}}^k$. This implies that the trade shocks for the U.S. in the counterfactual are:

1. trade cost shock: $\{\hat{\kappa}_{\text{CHN US}}^k, \hat{\tau}_{\text{CHN US}}^k\}$,
2. trade deficits shock: ΔD_{US},
3. changes in production efficiency in China: $\hat{T}_{\text{CHN}}^k$.

A similar set of trade shocks can be grouped for China. The technology and labor supply shocks are the same as the counterfactuals on the skill premium.

high-income countries in order to correct for factors affecting imports originated in the U.S. The instruments are invalid if shocks in the home country that affect imports from China correlate across high-income countries. To the extent that the patterns of structural change are similar across high-income countries, the identifying assumption of the instrument is likely to fail.

7.2 Counterfactuals

I first compare the effects of trade between the U.S. and China on the skill premium to the effects of trade between all countries (baseline) in Table 16. We see that U.S.–China trade has larger effects on the skill premium in China, contributing to 34% of the rise in skill premium due to trade. For the U.S., the contribution is smaller at 13%. The reason for this finding is that the U.S. is a very important trading partner for China during the period, while the U.S. trades mostly with developed countries.

In the following, I present the effects of trade and technical change on the production share and labor reallocations in the U.S. and China.

7.2.1 Sectoral Reallocation

Figure 12 shows the effects of trade and technical change on the changes in production share in the U.S.. The main findings are that trade with China explains more than half of the decline in the manufacturing share, and NTC explains around one-third of the decline. Moreover, the main effect of NTC is to reallocate economic activity from agriculture to the services sector. These results are consistent with the findings of Autor et al. (2015), who find that trade with China mainly affects the manufacturing sector, while computerization has wider effects on the whole economy.

Comparing the left and right panel gives us the general equilibrium effects from structural change. The negative effects of trade with China are smaller under the standard model. The effects of NTC are mainly due to structural change, which is important in explaining the expansion of the services sector. Moreover, NTC decreases the manufacturing share through structural change, as the effects of NTC are opposite in sign under the standard model.

In the case of China, Figure 13 illustrates that the effect of trade with the U.S. and NTC is to shift resources from the agriculture to the manufacturing sector. From Table 17, Trade and technical change together completely explain the rise in the manufacturing share. This is consistent with the experience in China that a lot of resources are shifting from agriculture-based rural villages to industrialized city coasts. Similar to the case of the U.S., most of the effects of NTC on sectoral reallocation come from structural change.

7.2.2 Labor Reallocation

In the following, I investigate the differential effects of trade and technical change across the skilled and unskilled workers, through the angle of labor reallocation across sectors.

Figure 14 presents the effects of trade and technical change on the sectoral employment share in the U.S. From the left panel, the skilled worker switches out of the manufacturing into the services sector. The contributions from trade with China, NTC, and SBTC are similar in magnitude. For the reallocation of the unskilled worker, the effects of trade and NTC are similar as in the case of the skilled worker, but the effects of SBTC are opposite. The reason for this is that most SBTC occurs in the services sector in the U.S., as can be seen from Table 7. From Table 18, the net effect of trade with China and technical change is to reduce the manufacturing employment share of skilled workers by 1.6%, but only 0.2% for the unskilled workers. This is consistent with the findings of Autor et al. (2014) that workers with low qualifications are more likely to remain in trade-exposed manufacturing sector and subject to further trade shocks. Moreover, NTC has wider impacts than trade in that some unskilled workers from agriculture switch out to services.

The above results suggest that the distributional impacts on workers with different skills come mainly from SBTC but not NTC. As computerization has both the neutral and skill-biased components of technical change, the results from Autor et al. (2015) probably capture a mixture of these two types of technical change. In particular, the authors find that computerization has no significant impact on the net manufacturing employment, which can be reconciled from the above findings that NTC and SBTC has the opposite effect on the manufacturing employment shares of the skilled and unskilled workers.

In the case of China from Figure 15, most of the labor reallocation is characterized by unskilled workers switching out of agriculture to manufacturing, with a net increase in the manufacturing employment share of the unskilled workers at 6.6%. From Table 18, trade with the U.S. increases the manufacturing employment share of the unskilled by 4.9%, while the effect of NTC is smaller at 3.8%. Relative to trade with the U.S., NTC induces more unskilled workers in agriculture to move to services. The skilled workers mainly move out of manufacturing to services, and most of this pattern is due to skill-biased technical change.

8 Conclusion

This paper quantifies the effects of trade and technical change on the changes in skill premium in the presence of structural change. I find that trade and technical change each contributes 50% to the rise in the skill premium from 1997 to 2007. Moreover, the positive effects of trade on the skill premium come from changes in foreign production efficiency but not changes in the trade cost.

The key mechanism behind the positive effects of trade on the skill premium is structural change, driven by endogenous changes in household expenditure and a firm's intermediates expenditure. The household side is due to nonhomothetic preferences, and the firm side is due to intensive usage of own sector intermediates. Once structural change is shut down, the effects of trade on the skill premium are halved. My results therefore highlight a quantitatively important channel by which foreign productivity growth increases the skill premium at home through reallocation to skill-intensive sectors and international trade.

My framework also sheds light on the shrinking of the manufacturing sector in the U.S. The quantitative exercise on the U.S. and China reveals that in the U.S., more than half of the decline in the manufacturing production share is attributable to trade with China. Moreover, 1.6% of the skilled workers have moved out of the shrinking manufacturing sector, but only 0.2% of the unskilled workers are able to do so. On the other hand, trade with the U.S. explains most of the rise in the manufacturing production share in China. Moreover, 6.6% of the unskilled workers move from agriculture to manufacturing.

My results point to the fact that, to the extent that most of the increases in the skill premium are driven by technical changes (whether through skill-biased technical change or foreign productivity growth), inequality is a byproduct of economic development. This underlines the importance of designing policies such that the people with low skill also benefit from technological progress.

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Tables and Figures

Table 1: Average skill intensity (%)

	β^k in 1997			$\Delta\beta^k$		
	A	M	S	A	M	S
OECD	15.89	30.88	43.86	-0.07	0.05	2.35
Non-OECD	5.66	16.56	38.40	1.65	0.70	0.62

Notes: A=Agriculture, M=Manufacturing, S=Services. $\Delta x = x(07) - x(97)$ is simple difference between the two periods. Skill intensity is measured by share of total wage payments to the skilled.

Table 2: Average consumption expenditure share (%)

	s^k in 1997			Δs^k		
	A	M	S	A	M	S
OECD	14.46	18.85	66.68	-3.16	1.06	2.10
Non-OECD	30.19	22.83	46.98	-8.40	-2.34	10.74

Table 3: Average intermediates expenditure share (%)

	e^{kl} in 2007			Δe^{kl}		
	A	M	S	A	M	S
Agriculture	56.29	17.46	26.25	-2.10	0.58	1.52
Manufacturing	2.00	71.63	26.36	-1.17	0.77	0.40
Services	5.91	30.10	63.99	0.95	-1.95	1.01

Table 4: Calibrated AIDS parameters

α_A	α_M	α_M	b_A	b_M	b_S
0.065	0.176	0.759	-0.062	-0.008	0.070
δ_{AA}	δ_{AM}	δ_{AS}	δ_{MM}	δ_{MS}	δ_{SS}
0.034	0.032	-0.067	-0.059	0.027	0.040

Table 5: Calibrated intermediates cost share parameters

	η^k_{AA}	η^k_{AM}	η^k_{AS}	η^k_{MM}	η^k_{MS}	η^k_{SS}
Agriculture	0.059	-0.045	-0.014	0.041	0.004	0.010
Manufacturing	-0.029	0.063	-0.035	-0.126	0.063	-0.028
Services	-0.083	0.096	-0.013	-0.103	0.007	0.006

Table 6: Structural change: 1997 to 2007 (%)

	Production share			Consumption share			Intermediates share		
	A	M	S	A	M	S	A	M	S
OECD	-2.9	-1.6	4.5	-3.2	1.1	2.1	-1.4	0.1	1.2
Non-OECD	-5.8	1.9	3.9	-8.4	-2.3	10.7	-3.7	0.0	3.7
AUS	-2.7	-2.5	5.2	-3.0	0.8	2.1	0.4	-9.0	8.6
AUT	-1.0	5.7	-4.7	-2.1	2.4	-0.3	-0.3	11.7	-11.4
BEL	-2.6	-1.7	4.3	-0.5	4.2	-3.7	-3.5	0.7	2.8
CAN	-2.4	-6.0	8.4	-1.9	-4.2	6.1	-1.4	-3.3	4.7
DEU	-0.9	4.9	-4.1	-1.0	3.5	-2.5	-1.0	1.4	-0.5
DNK	-3.3	1.2	2.1	-1.1	6.4	-5.3	-2.3	5.1	-2.8
ESP	-3.4	-0.3	3.7	-1.2	-3.6	4.8	-3.6	1.5	2.1
FIN	-2.4	3.5	-1.1	-3.3	5.9	-2.5	-1.5	9.8	-8.4
FRA	-1.3	-2.7	4.0	-2.8	1.6	1.2	1.0	1.9	-2.9
GBR	-1.8	-5.0	6.8	-0.2	4.5	-4.3	-1.5	-5.4	6.9
GRC	-7.2	-0.5	7.8	-19.6	-3.4	23.0	2.4	21.1	-23.5
IRL	-6.5	-5.8	12.3	-0.4	0.7	-0.4	-2.0	-15.4	17.4
ITA	-1.2	0.8	0.4	-0.6	4.7	-4.1	-1.0	2.1	-1.1
JPN	-1.5	0.0	1.5	-2.0	-2.8	4.8	-0.4	-1.5	1.9
KOR	-3.9	1.1	2.8	-10.5	-6.0	16.5	-2.2	1.7	0.6
LUX	-7.7	-16.0	23.7	-2.1	0.5	1.6	-9.7	-23.7	33.5
NLD	-1.7	-5.0	6.6	1.7	1.9	-3.6	-0.6	-2.8	3.4
PRT	-2.3	-1.6	3.9	-10.2	-5.9	16.1	1.9	6.4	-8.3
SWE	-2.1	-0.4	2.5	-1.2	10.0	-8.8	-1.2	-1.2	2.4
USA	-1.3	-1.6	2.9	-1.2	-0.1	1.3	-0.2	0.8	-0.6
ARG	-5.6	-14.3	19.9	-12.4	-11.9	24.4	-6.7	-18.6	25.4
BRA	-4.0	-4.4	8.4	-9.0	-9.2	18.1	-3.5	-5.2	8.7
CHL	-9.7	4.2	5.5	-11.4	-3.8	15.2	-6.6	-1.3	7.9
CHN	-6.9	3.6	3.3	-19.1	-5.7	24.8	-2.8	0.2	2.6
CZE	-6.8	6.5	0.3	-8.8	-7.9	16.7	-4.9	5.4	-0.5
HUN	-4.3	11.5	-7.2	4.4	-1.1	-3.3	-3.8	11.0	-7.2
IDN	-5.4	4.9	0.6	-9.1	1.4	7.7	-3.7	5.0	-1.3
IND	-7.3	-1.1	8.4	-10.7	-3.2	13.9	-3.1	0.8	2.3
MEX	-6.9	-6.5	13.4	-7.7	-5.8	13.5	-6.4	-8.1	14.5
PER	-1.8	11.2	-9.4	1.9	4.7	-6.7	-1.9	3.8	-1.9
PHL	-8.3	10.8	-2.5	-15.7	4.0	11.7	-2.0	4.0	-2.0
POL	-6.4	2.0	4.4	-9.5	0.5	9.0	-3.9	1.2	2.7
SVK	-9.4	0.4	9.0	-11.0	-0.2	11.2	-6.9	-1.6	8.5
SVN	-6.9	-1.7	8.6	-11.7	2.6	9.1	-4.1	-2.1	6.1
THA	-1.2	8.1	-6.9	-1.8	-5.3	7.0	-0.8	6.3	-5.5
URY	-5.9	-1.8	7.6	-12.8	0.3	12.6	-4.1	-1.6	5.7
VEN	-1.1	-1.2	2.2	1.4	0.8	-2.3	1.6	1.0	-2.6

Notes: The first two rows present the simple averages for the OECD and non-OECD countries respectively. OECD and non-OECD countries are separated by a horizontal line.

Table 7: Values of shocks 1997 to 2007 (%)

	$\hat{d}_n^A$	$\hat{d}_n^M$	$\hat{d}_n^S$	$\left(\hat{T}_n^A\right)^{\frac{1}{\theta}}$	$\left(\hat{T}_n^M\right)^{\frac{1}{\theta}}$	$\left(\hat{T}_n^S\right)^{\frac{1}{\theta}}$	$\Delta\beta_n^A$	$\Delta\beta_n^M$	$\Delta\beta_n^S$	$\Delta\left(\frac{S_n}{L_n}\right)$
OECD	-6.1	-0.2	-5.4	44.6	16.1	4.9	-0.05	-0.62	2.64	1.58
Non-OECD	-11.7	-10.3	-7.0	37.8	31.6	7.6	0.68	-0.05	1.73	2.54
AUS	-8.9	-7.1	-0.7	46.7	34.3	17.5	0.59	0.36	-1.45	-1.91
AUT	-18.9	-4.6	-3.8	41.5	16.3	-1.4	0.10	-0.10	8.52	5.78
BEL	-3.7	1.7	-2.8	16.8	-3.4	-14.4	-2.35	0.86	3.82	2.72
CAN	-7.4	6.8	-2.4	40.3	23.0	29.1	1.01	0.48	10.66	7.87
DEU	-7.1	-4.8	-9.2	53.8	18.2	0.9	-0.33	0.19	1.96	0.29
DNK	-6.4	0.7	-18.7	39.3	33.1	13.2	-1.51	-0.01	4.54	2.57
ESP	-5.6	0.1	-11.7	52.0	23.9	14.1	-0.49	0.43	-0.59	-0.40
FIN	-6.0	1.8	-10.2	43.1	27.8	13.8	-0.90	0.64	3.80	1.55
FRA	-0.1	0.3	2.8	39.1	7.7	-5.4	-0.40	-0.41	5.54	7.19
GBR	-3.3	3.8	-10.2	60.0	36.3	13.3	0.43	0.01	1.20	4.54
GRC	-5.0	-7.4	-22.6	80.9	40.6	11.6	3.89	-1.18	1.52	4.45
IRL	-5.3	-1.0	-28.5	49.4	33.8	27.6	-0.11	2.18	-2.90	-0.35
ITA	-3.0	-0.5	-0.5	37.1	16.4	-9.9	1.49	0.21	2.10	-2.96
JPN	-0.6	-4.0	5.3	28.8	2.7	-14.2	0.26	0.70	-0.28	0.12
KOR	3.4	-5.7	-6.9	35.2	24.1	21.8	0.83	0.75	1.09	2.22
LUX	-25.4	-10.0	-47.2	13.9	47.9	16.4	-3.99	-0.83	0.14	-4.82
NLD	0.9	13.6	-1.7	39.4	28.0	2.8	1.02	-1.84	5.10	3.05
PRT	-9.1	1.8	-8.9	51.3	30.9	21.4	-2.40	-0.22	-1.71	-2.18
SWE	-12.7	1.1	-12.0	49.8	8.4	-1.1	1.00	-0.96	1.29	2.72
USA	-7.7	-0.2	1.3	44.2	24.8	13.8	0.51	-0.23	2.64	1.08
ARG	-13.1	-19.8	-5.4	27.4	2.1	-16.2	-0.32	0.93	1.93	4.40
BRA	-4.4	-12.3	-5.6	42.9	26.0	4.2	1.66	0.07	-1.26	-0.85
CHL	-13.5	-15.6	-1.8	44.5	39.1	8.3	1.47	-0.10	-0.17	2.86
CHN	-9.9	-11.0	-12.6	90.9	42.4	18.4	0.55	0.15	5.62	2.07
CZE	-20.9	-9.0	-3.6	31.0	28.2	20.3	1.75	1.75	-2.46	-1.53
HUN	-11.0	-4.5	-13.1	51.5	44.5	27.9	2.04	1.53	3.54	-0.57
IDN	-15.0	-1.9	12.9	39.0	33.2	1.7	1.13	0.50	-4.46	-0.48
IND	-17.4	-18.7	-22.7	123.6	39.0	7.6	2.51	-0.06	5.36	5.26
MEX	-14.7	0.2	3.4	61.5	29.3	37.4	4.27	0.68	3.33	2.75
PER	-3.6	-14.5	0.6	38.5	23.5	2.5	3.42	-0.13	-10.23	-5.51
PHL	-3.1	1.3	45.3	36.5	17.2	-8.0	1.30	3.32	-6.08	-1.86
POL	-19.6	-12.8	-9.2	67.7	48.4	24.8	0.85	1.12	4.64	4.27
SVK	-23.7	-6.3	-11.0	37.3	33.0	32.6	1.31	1.08	0.59	3.06
SVN	-16.0	-7.4	-12.8	33.3	31.2	11.5	1.39	1.36	-2.71	0.63
THA	-7.6	-6.1	-3.3	47.9	22.6	-17.3	1.66	0.99	0.09	-0.58
URY	0.3	-8.5	9.0	43.8	25.8	-14.9	1.32	-0.67	10.44	6.82
VEN	7.2	-3.1	19.1	59.5	47.2	21.1	1.77	-0.64	2.30	6.43

Notes: The weights to compute the average changes in trade costs, sectoral technology, skill biased technology and share of the skilled labor are trade volumes, sectoral output, sectoral output and total employment respectively.

Table 8: Validation on the share of the skilled labor

	2007 $\frac{S_n}{L_n}$		1997 $\frac{S_n}{L_n}$	
	model	data	model	data
TFP	15.14*	29.08*	15.60*	16.06
	(2.19)	(2.25)	(2.06)	(1.46)
Life expectancy	0.173	-0.0228	0.194	0.182
	(0.52)	(-0.04)	(0.55)	(0.35)
$\frac{\text{Education expenditure}}{\text{GDP}}$	1.570	-1.472	1.253	0.446
	(1.62)	(-0.81)	(1.81)	(0.44)
N	33	33	35	35
R^2	0.543	0.271	0.507	0.265

Notes: t statistics in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The model column uses the model implied $\frac{S_n}{L_n}$ as the dependend variable, while the data column uses the share of incomplete teriary from Barro and Lee (2013).

Table 9: Validation on the trade cost

	2007			1997			Change		
	$\ln d_{ni}^A$	$\ln d_{ni}^M$	$\ln d_{ni}^S$	$\ln d_{ni}^A$	$\ln d_{ni}^M$	$\ln d_{ni}^S$	$\Delta \ln d_{ni}^A$	$\Delta \ln d_{ni}^M$	$\Delta \ln d_{ni}^S$
$\ln\left(1+\tau_{ni}^k\right)$	0.113	1.743***		0.201**	0.961***		0.036	-0.004	
	(1.00)	(5.43)		(2.69)	(4.61)		(0.57)	(-0.06)	
distance	0.320***	0.286***	0.079***	0.257***	0.230***	0.008*	0.036***	0.013*	0.065***
	(27.90)	(29.39)	(12.86)	(22.40)	(24.55)	(2.29)	(6.18)	(2.46)	(15.86)
contig	-0.128***	-0.028	-0.208***	-0.158***	-0.109***	-0.032**			
	(-3.60)	(-0.92)	(-10.60)	(-4.91)	(-3.93)	(-3.18)			
comlang	-0.113***	-0.108***	0.011	-0.104***	-0.102***	-0.023**			
	(-4.10)	(-4.67)	(0.72)	(-4.12)	(-4.71)	(-2.93)			
NRPTA	-0.024	0.053*	-0.072***	-0.086***	-0.034	-0.004	-0.041	-0.022	-0.021
	(-0.76)	(2.01)	(-4.20)	(-3.48)	(-1.60)	(-0.48)	(-1.53)	(-0.92)	(-1.11)
RPTA	0.071	0.035	-0.036	0.069	0.076	-0.028	-0.027	0.025	-0.175***
	(1.10)	(0.65)	(-1.02)	(1.46)	(1.86)	(-1.87)	(-0.73)	(0.77)	(-6.81)
TA	0.015	0.068**	0.050***	-0.033	-0.190***	-0.010	0.095***	0.022	-0.011
	(0.62)	(3.24)	(3.68)	(-1.09)	(-7.82)	(-1.19)	(4.41)	(1.15)	(-0.74)
N	1322	1332	1332	1324	1330	1330	1317	1330	1330
R^2	0.797	0.799	0.836	0.801	0.839	0.931	0.356	0.310	0.697

Notes: t statistics in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The independent variable, from top to bottom, reads log tariff, log distance, common border, common language, non-reciprocal preferential trade agreement, reciprocal PTA, and trade agreement capturing currency union, economic union, and free trade agreement. All regressions with exporter and importer fixed effects. There are a total of 37 countries, so that the total number of bilateral pairs is 1332. Data on distance and the dummy variables comes from Limão (2016). For the specification on changes in the trade cost, log distance is interacted with changes in the crude oil price.

Table 10: Decomposition of changes in the skill premium (%): baseline

	Actual	Labor supply	All trade shocks	All tech shocks	Residual	Trade	Tech
All	2.30	-10.72	8.31	1.74	0.30		
All(tech>0)	2.30	-16.63	7.45	5.31	1.07	49.9%	50.1%
OECD	2.45	-8.78	7.31	2.29	-0.25		
Non-OECD	-0.64	-14.48	10.57	1.74	3.33		
AUS	6.48	9.01	5.62	-5.11	-1.52		
AUT	-1.45	-24.13	4.91	20.77	0.24	19.1%	80.9%
BEL	2.30	-11.52	8.27	5.31	-0.63	60.9%	39.1%
CAN	0.27	-34.24	2.82	43.52	0.30	6.1%	93.9%
DEU	4.91	-1.57	4.06	3.63	0.13	52.8%	47.2%
DNK	2.60	-10.72	8.45	8.48	-2.41	49.9%	50.1%
ESP	4.08	1.81	10.89	-5.15	-0.73		
FIN	4.52	-6.84	7.45	9.95	-3.65	42.8%	57.2%
FRA	-11.91	-28.79	7.02	11.67	2.23	37.6%	62.4%
GBR	-14.46	-19.38	6.92	1.36	-0.85	83.6%	16.4%
GRC	-4.65	-18.73	23.44	1.39	1.07	94.4%	5.6%
IRL	1.29	2.54	13.10	-11.06	0.35		
ITA	14.91	13.73	7.29	1.20	-5.71	85.9%	14.1%
JPN	-0.30	-0.60	1.16	-1.06	0.98		
KOR	-2.84	-12.12	4.95	5.16	3.00	49.0%	51.0%
LUX	34.20	24.42	17.03	-8.40	-3.66		
NLD	5.01	-13.01	9.27	3.19	2.24	74.4%	25.6%
PRT	5.82	12.28	9.12	-7.43	-2.81		
SWE	-6.08	-11.19	7.32	0.75	0.20	90.7%	9.3%
USA	4.82	-5.14	2.01	9.62	-1.01	17.3%	82.7%
ARG	-0.64	-25.97	4.25	1.74	29.03	71.0%	29.0%
BRA	12.83	6.24	3.13	-4.52	9.87		
CHL	-10.82	-20.45	6.80	-4.67	14.79		
CHN	20.92	-14.48	20.28	24.64	1.15	45.1%	54.9%
CZE	2.72	10.07	7.71	-9.27	-6.98		
HUN	8.73	3.68	13.46	4.10	-14.69	76.7%	23.3%
IDN	-6.22	3.00	11.49	-11.21	-6.14		
IND	10.52	-33.60	8.31	24.65	27.97	25.2%	74.8%
MEX	8.26	-18.22	9.38	16.51	10.24	36.2%	63.8%
PER	-10.24	42.85	10.57	-26.78	-25.17		
PHL	-2.97	8.62	29.11	-30.70	3.33		
POL	-2.31	-20.35	19.39	8.28	4.14	70.1%	29.9%
SVK	-2.47	-16.63	9.01	3.92	1.39	69.7%	30.3%
SVN	-3.93	-4.23	13.63	-10.60	-1.22		
THA	4.58	2.85	18.29	-21.24	8.34		
URY	6.05	-38.22	12.23	15.57	23.55	44.0%	56.0%
VEN	-24.30	-33.34	3.46	5.21	1.93	39.9%	60.1%

Notes: The second row presents the median values for the subset of countries where technical change increases the skill premium. The last two columns compute the contributions from trade and technical change to the increase in skill premium for countries where the effects of both are positive.

Table 11: Effects of trade and technical change on the skill premium (%): baseline

	Trade costs	Deficits	Foreign tech	NTC	SBTC
All	-0.25	0.07	8.03	-3.82	5.85
OECD	-0.10	0.28	6.31	-2.98	5.91
Non-OECD	-1.40	-0.38	13.02	-4.79	4.07
AUS	-1.01	0.13	6.07	-1.07	-4.24
AUT	0.28	-0.55	5.48	-4.24	29.57
BEL	-0.34	1.07	7.40	-4.91	12.22
CAN	-0.34	0.07	2.83	-0.26	43.23
DEU	-0.38	-0.60	4.59	-2.03	5.97
DNK	-0.91	0.66	7.25	-4.10	14.44
ESP	0.20	1.87	8.18	-3.52	-1.63
FIN	-0.52	0.97	5.96	-1.75	12.33
FRA	-0.08	0.87	6.54	-4.13	17.35
GBR	0.14	0.74	5.53	-2.26	3.87
GRC	3.66	0.95	14.41	-4.22	5.85
IRL	-1.74	-7.12	10.86	-6.29	-5.31
ITA	-0.13	0.63	6.79	-5.45	7.31
JPN	0.04	0.07	1.11	-0.68	-0.40
KOR	-0.17	-0.12	5.29	0.37	4.82
LUX	4.95	1.59	10.70	-6.74	-1.99
NLD	0.16	-0.42	8.04	-8.65	15.29
PRT	0.27	-0.15	8.03	-1.95	-5.64
SWE	0.29	0.24	5.38	-2.45	3.19
USA	-0.12	0.33	1.66	0.47	9.02
ARG	-2.32	-1.01	5.24	-3.82	6.31
BRA	-0.25	-1.06	4.05	-1.29	-3.43
CHL	-1.44	-3.98	11.57	-5.30	0.56
CHN	3.18	2.81	10.04	7.10	16.45
CZE	-5.70	0.13	17.06	-6.71	-3.51
HUN	-1.40	-1.59	15.17	-8.30	13.96
IDN	-1.40	0.56	12.09	-0.62	-11.92
IND	-1.82	-1.09	6.80	-0.21	25.72
MEX	0.66	-0.33	9.91	1.14	15.23
PER	-0.73	-2.09	13.02	-4.79	-24.42
PHL	-3.90	8.16	32.18	-23.03	-13.30
POL	1.08	-0.03	16.42	-5.75	15.55
SVK	-4.76	-0.60	17.67	-0.10	4.07
SVN	-2.48	1.15	14.87	-7.07	-4.77
THA	0.56	-1.22	17.02	-24.51	2.55
URY	-2.83	0.32	14.33	-12.35	39.13
VEN	0.63	-0.38	6.28	-1.69	7.86

Table 12: Decomposition of changes in the skill premium (%): no structural change

	Actual	Labor supply	All trade shocks	All tech shocks	Residual	Trade	Tech
All	2.30	-10.71	4.24	3.07	3.04		
All(tech>0)	2.30	-16.79	3.96	6.92	3.30	34.7%	65.3%
OECD	2.45	-8.77	4.00	3.27	1.42		
Non-OECD	-0.64	-14.58	4.52	0.24	10.71		
AUS	6.48	9.09	2.28	-5.84	2.29		
AUT	-1.45	-24.16	3.40	23.24	0.48	12.8%	87.2%
BEL	2.30	-11.52	5.58	6.38	1.02	46.7%	53.3%
CAN	0.27	-34.25	1.39	42.55	2.00	3.2%	96.8%
DEU	4.91	-1.53	2.04	3.89	1.13	34.4%	65.6%
DNK	2.60	-10.71	5.40	10.14	-0.21	34.7%	65.3%
ESP	4.08	1.91	6.61	-4.42	3.04		
FIN	4.52	-6.83	3.96	10.17	-0.87	28.0%	72.0%
FRA	-11.91	-28.84	3.79	13.37	3.30	22.1%	77.9%
GBR	-14.46	-19.39	4.04	1.33	1.70	75.2%	24.8%
GRC	-4.65	-18.69	14.03	0.76	8.19	94.9%	5.1%
IRL	1.29	2.37	7.63	-8.75	4.58		
ITA	14.91	13.84	3.94	3.07	-5.15	56.2%	43.8%
JPN	-0.30	-0.62	0.49	-0.62	0.78		
KOR	-2.84	-12.13	2.21	3.46	5.81	39.0%	61.0%
LUX	34.20	24.85	13.41	-7.35	2.87		
NLD	5.01	-13.05	5.60	7.95	3.31	41.3%	58.7%
PRT	5.82	12.39	5.13	-8.16	0.10		
SWE	-6.08	-11.19	4.24	1.45	1.14	74.4%	25.6%
USA	4.82	-5.13	0.90	8.44	0.81	9.6%	90.4%
ARG	-0.64	-25.93	0.64	3.58	28.22	15.1%	84.9%
BRA	12.83	6.30	1.03	-5.35	12.24		
CHL	-10.82	-20.50	1.01	-4.36	17.49		
CHN	20.92	-14.58	10.04	13.61	19.71	42.4%	57.6%
CZE	2.72	10.59	4.89	-9.36	-1.15		
HUN	8.73	3.91	8.59	5.34	-5.73	61.7%	38.3%
IDN	-6.22	3.10	4.42	-13.99	2.34		
IND	10.52	-33.69	1.30	21.51	35.61	5.7%	94.3%
MEX	8.26	-18.27	3.57	13.22	15.54	21.2%	78.8%
PER	-10.24	43.63	3.33	-27.13	-20.59		
PHL	-2.97	9.58	12.92	-24.68	7.36		
POL	-2.31	-20.62	10.65	6.92	10.71	60.6%	39.4%
SVK	-2.47	-16.79	5.15	0.24	13.06	95.6%	4.4%
SVN	-3.93	-4.20	8.23	-9.77	6.46		
THA	4.58	3.00	9.90	-11.32	7.77		
URY	6.05	-38.28	4.52	23.70	21.73	16.0%	84.0%
VEN	-24.30	-33.39	1.21	4.29	5.86	22.0%	78.0%

Notes: the subset of countries where technical change increases the skill premium are the same as the baseline.

Table 13: Effects of trade and technical change on the skill premium (%): no structural change

	Trade costs	Deficits	Foreign tech	NTC	SBTC
All	-0.16	0.02	4.44	-3.10	5.98
OECD	-0.06	0.14	3.46	-2.78	6.00
Non-OECD	-0.70	-0.29	5.32	-3.92	4.06
AUS	-0.77	0.07	2.90	-1.79	-4.27
AUT	0.32	-0.22	3.37	-3.07	30.15
BEL	-0.21	0.76	4.92	-4.40	12.43
CAN	-0.15	0.01	1.40	-0.68	43.80
DEU	-0.31	-0.37	2.41	-1.81	6.01
DNK	-0.76	0.42	4.27	-3.16	14.72
ESP	0.14	1.08	4.44	-2.85	-1.64
FIN	-0.38	0.55	3.11	-1.77	12.49
FRA	-0.05	0.47	3.55	-2.91	17.56
GBR	0.06	0.46	3.06	-2.34	3.91
GRC	2.84	0.12	7.78	-4.88	5.98
IRL	-2.20	-5.24	6.38	-3.47	-5.41
ITA	-0.08	0.35	3.65	-3.76	7.32
JPN	0.01	0.02	0.50	-0.27	-0.39
KOR	-0.19	-0.04	2.49	-1.29	4.84
LUX	2.54	1.01	7.21	-5.55	-1.70
NLD	0.17	-0.27	5.11	-5.47	15.64
PRT	0.09	-0.13	4.56	-2.71	-5.69
SWE	0.09	0.15	2.94	-1.71	3.25
USA	-0.08	0.17	0.75	-0.42	9.01
ARG	-1.66	-0.65	2.51	-2.41	6.36
BRA	-0.16	-0.65	1.90	-2.16	-3.41
CHL	-1.07	-2.63	5.32	-4.89	0.47
CHN	1.26	1.76	4.48	-2.36	16.63
CZE	-2.68	0.26	9.36	-6.32	-3.99
HUN	-0.60	-0.97	8.41	-7.50	14.22
IDN	-0.70	0.50	5.07	-3.02	-12.28
IND	-1.94	-1.29	2.96	-3.19	25.91
MEX	0.01	-0.29	4.16	-1.70	15.03
PER	-0.56	-1.04	5.31	-3.92	-24.96
PHL	-0.76	5.01	14.24	-13.87	-14.36
POL	0.88	-0.02	7.87	-7.22	15.88
SVK	-2.67	-0.27	9.49	-3.76	4.06
SVN	-1.39	0.77	8.28	-5.68	-5.05
THA	0.30	-0.68	8.66	-14.09	2.38
URY	-2.42	0.40	7.36	-8.54	40.24
VEN	0.56	-0.30	2.68	-3.10	7.92

Table 14: Decomposition of changes in the skill premium (%): robustness

	Actual	Labor supply	All trade shocks	All tech shocks	Residual
			Baseline		
All	2.30	-10.72	8.31	1.74	0.30
OECD	2.45	-8.78	7.31	2.29	-0.25
Non-OECD	-0.64	-14.48	10.57	1.74	3.33
			$\theta = 3$		
All	2.30	-10.73	6.07	3.87	0.10
OECD	2.45	-8.78	5.62	4.19	-0.70
Non-OECD	-0.64	-14.52	7.24	3.87	2.93
			$\theta = 5$		
All	2.30	-10.72	10.87	-0.71	0.24
OECD	2.45	-8.78	8.95	-0.60	-0.30
Non-OECD	-0.64	-14.45	14.61	-0.71	3.96
			Different intermediates expenditure		
All	2.30	-10.72	8.73	2.36	0.42
OECD	2.45	-8.78	7.32	1.70	0.06
Non-OECD	-0.64	-14.49	11.00	2.69	3.51
			Different AIDS		
All	2.30	-10.70	7.92	1.84	1.28
OECD	2.45	-8.76	6.67	0.75	1.25
Non-OECD	-0.64	-14.56	10.64	4.38	1.28

Table 15: Estimates of trade elasticity: triple difference

	pool	2007	2004	2001	1997
Agriculture	0.09	0.03	-0.27	-0.34	0.99
s.e.	(0.02)	(0.06)	(-0.05)	(-0.04)	(0.05)
Manufacturing	2.81	2.93	4.48	3.59	1.48
s.e.	(0.07)	(0.17)	(0.16)	(0.14)	(0.10)

Notes: The table presents the estimates of trade elasticity (negative value of the coefficients in front of $-\theta^k$) in agriculture and manufacturing, using the triple difference method as in Caliendo and Parro (2015). The first column presents the estimates when pooling four years of data together.

Table 16: Changes in the skill premium (%): U.S. and China

	Trade	NTC	SBTC	Labor supply	Trade (baseline)	
CHN	6.83	7.10	16.45	-14.61	20.28	33.7%
USA	0.27	0.47	9.02	-5.15	2.01	13.4%

Notes: The last column computes the contribution from the trade between the U.S. and China to the total increase in the skill premium due to trade in these two countries.

Table 17: Changes in production share (%): U.S. and China

	Actual	Trade +tech	Trade	NTC	SBTC	Labor supply
			U.S.			
A	-1.30	-0.98	-0.20	-0.83	-0.07	0.04
M	-1.59	-1.06	-0.98	-0.57	0.21	0.04
S	2.90	2.04	1.18	1.40	-0.14	-0.08
			China			
A	-6.91	-5.18	-4.49	-4.05	0.06	0.01
M	3.60	4.62	4.42	3.28	0.13	-0.08
S	3.32	0.56	0.07	0.77	-0.19	0.07

Table 18: Changes in manufacturing employment share (%): U.S. and China

	Trade +tech	Trade	NTC	SBTC	Labor supply
			U.S.		
Skilled	-1.63	-0.70	-0.51	-0.68	0.03
Unskilled	-0.22	-0.79	-0.53	0.90	0.03
			China		
Skilled	-1.29	1.82	0.96	-2.67	-0.07
Unskilled	6.57	4.93	3.81	1.12	-0.07

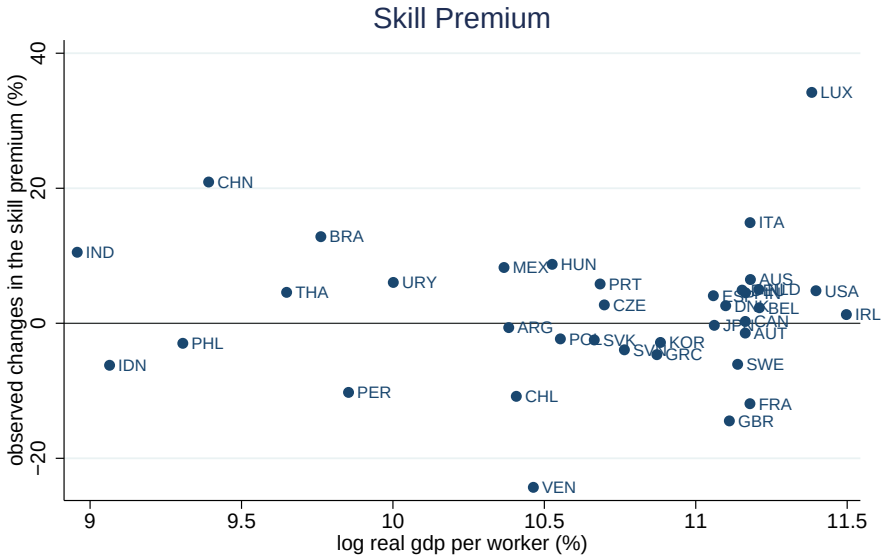

Figure 1: Observed changes in the skill premium: 1997–2007

Notes: The skill premium is defined as the ratio of wage payments to a college educated worker relative to a non-college educated worker. Source: EU KLEMS, SEDLAC (CEDLAS and The World Bank), see Appendix A2 for details on how I compute the skill premium.

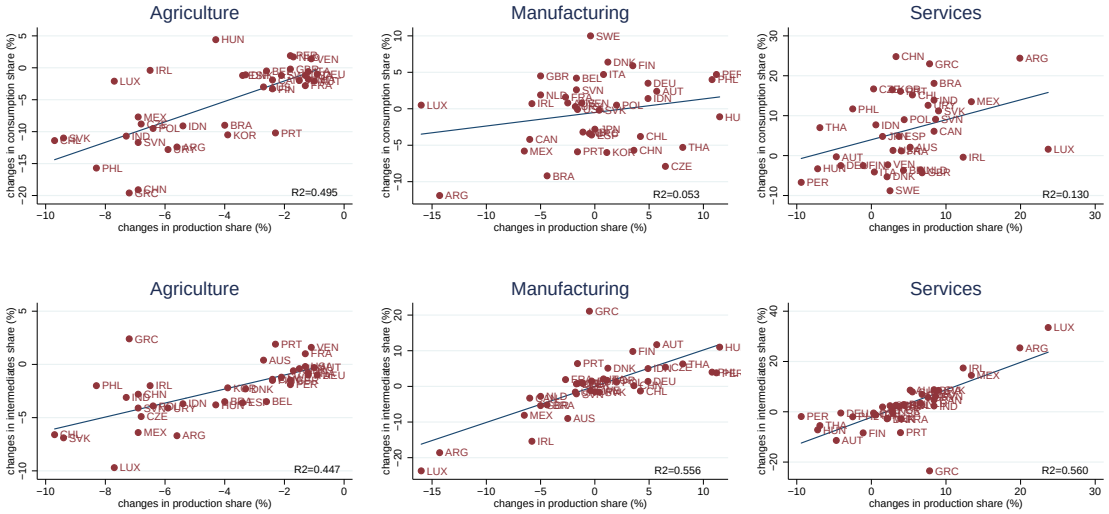

Figure 2: Observed structural change: 1997–2007

Notes: The upper panels plot the changes in the consumption expenditure share against the changes in production share in each sector. The bottom panels plot the changes in the average intermediates expenditure share against the changes in production share in each sector.

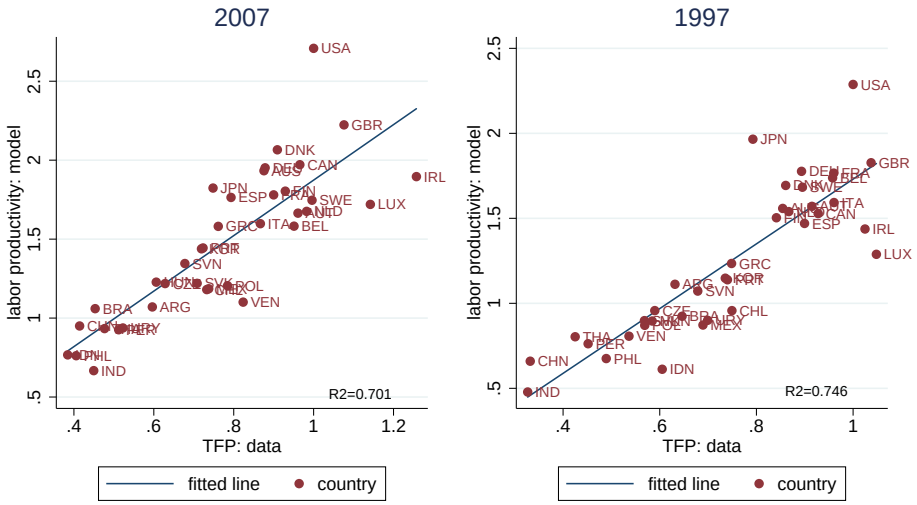

Figure 3: Labor productivity: model VS data

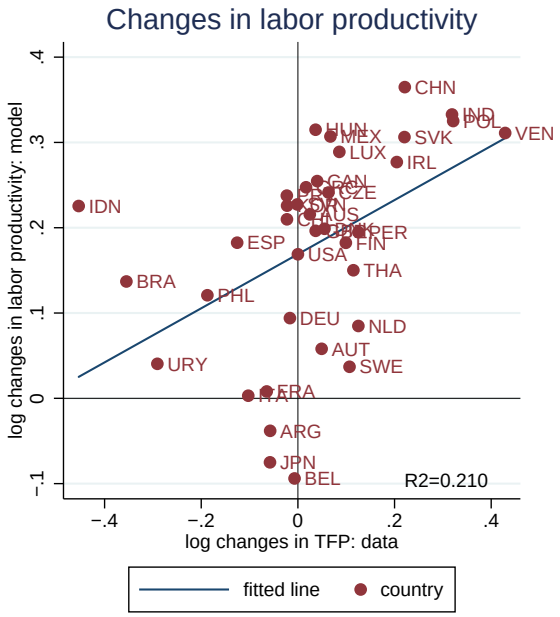

Figure 4: Log change in labor productivity: model VS data

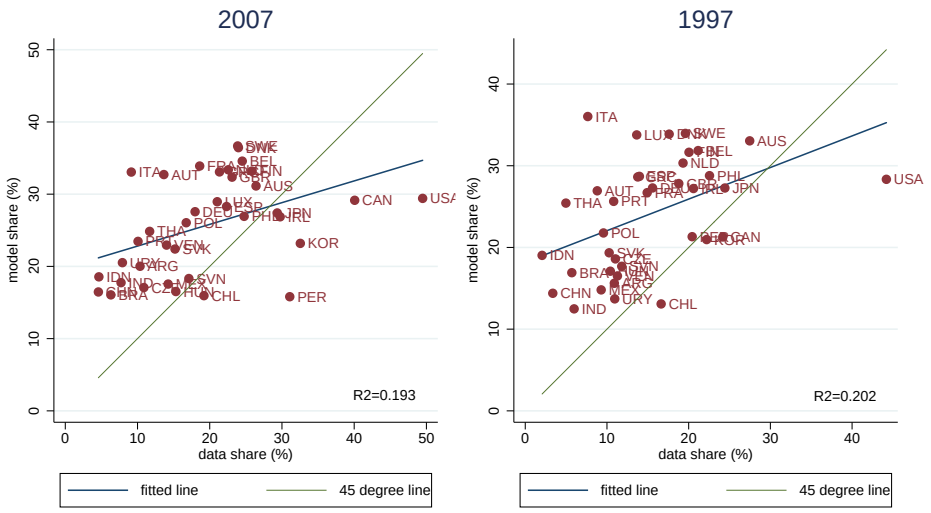

Figure 5: Share of skill abundance: model VS data

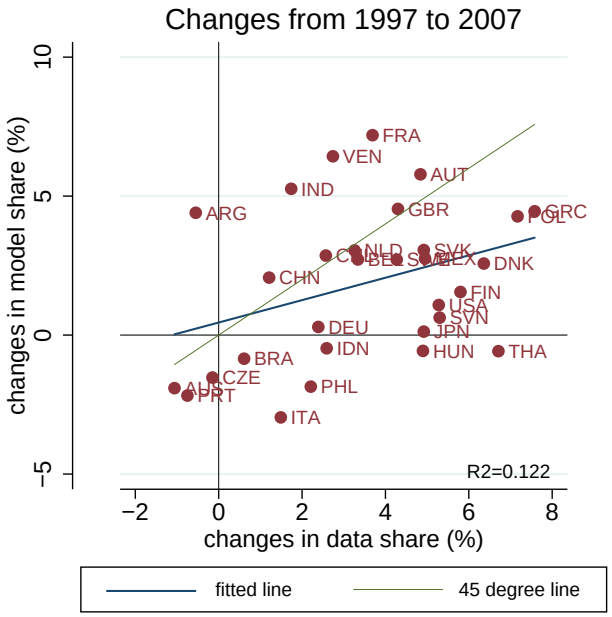

Figure 6: Change in share of skill abundance: model VS data

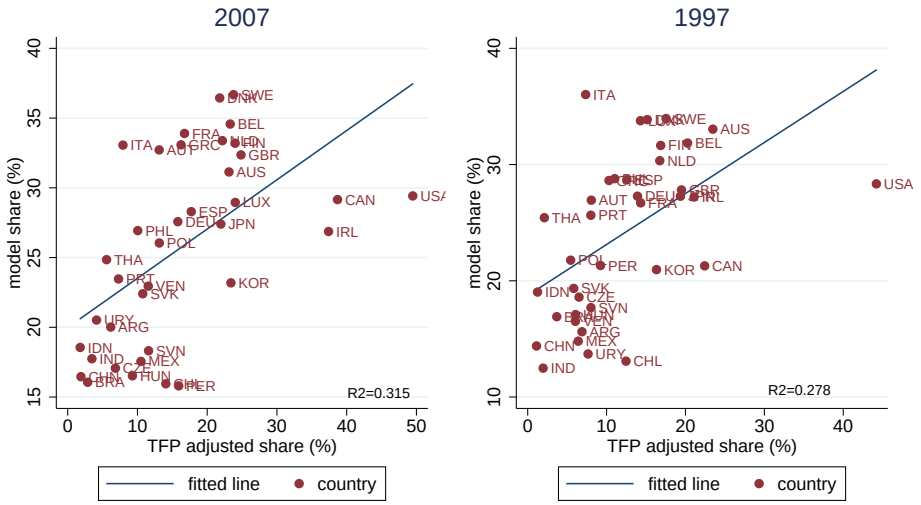

Figure 7: Share of skill abundance: model VS TFP-adjusted data

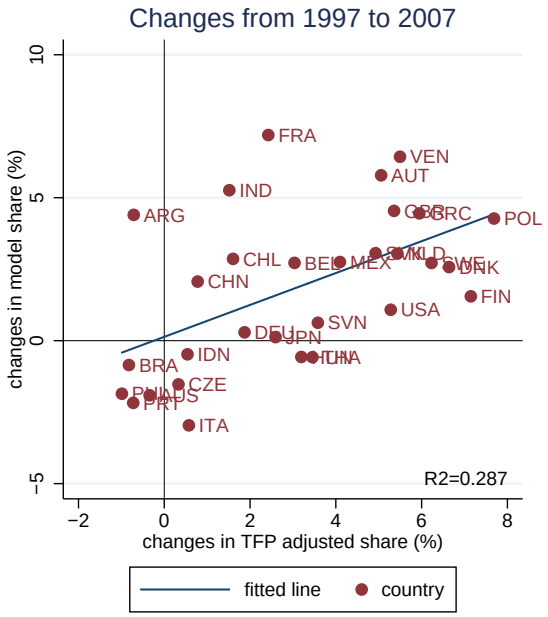

Figure 8: Change in share of skill abundance: model VS TFP-adjusted data

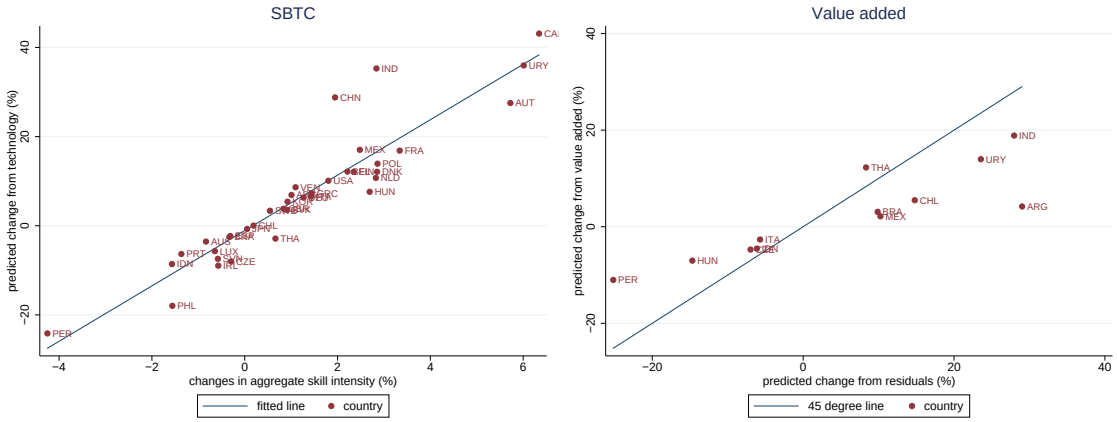

Figure 9: Changes in the skill premium: baseline

Notes: The left panel plots the skill premium due to technical change against the average changes in the skill intensity, which is weighted by the production shares in 1997. The right panel plots the skill premium due to changes in value added share against that of the model residuals.

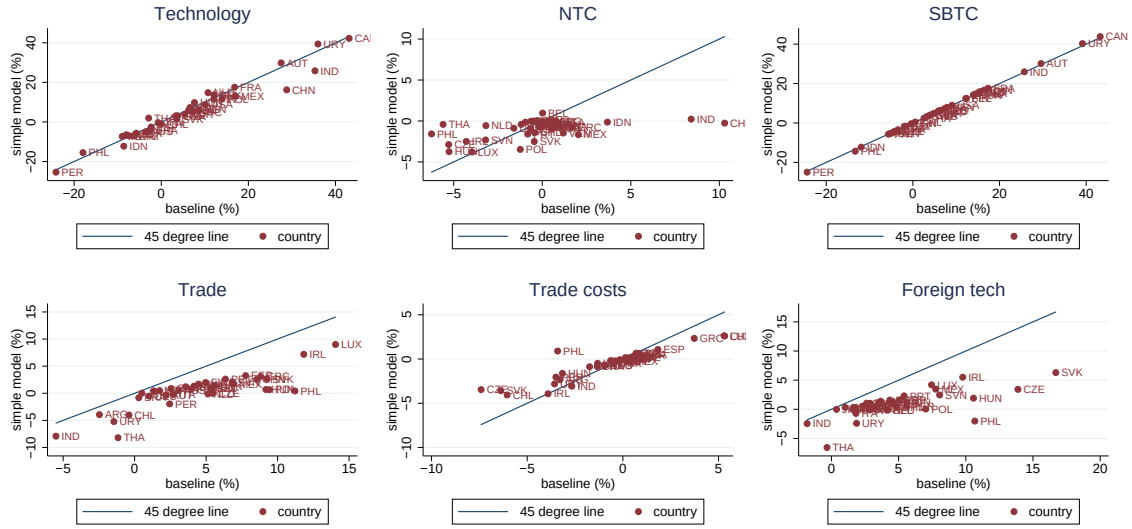

Figure 10: Changes in the skill premium: baseline VS standard model

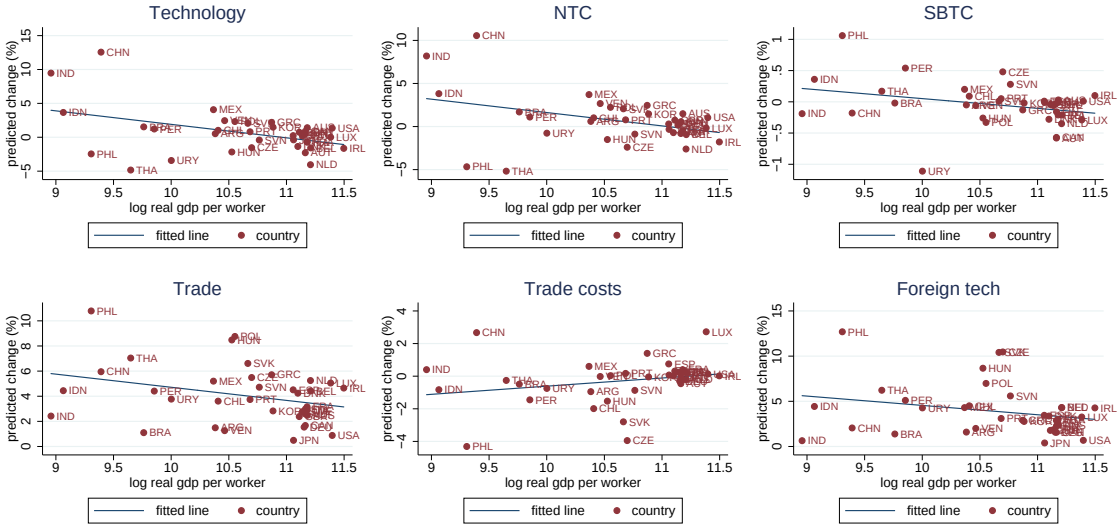

Figure 11: Effects of structural change on the skill premium

Notes: The upper panels plot the differences in the skill premium between the baseline and standard model implied by technology shocks, against the log real income per worker in 2007. The lower panels plot the differences implied by trade shocks.

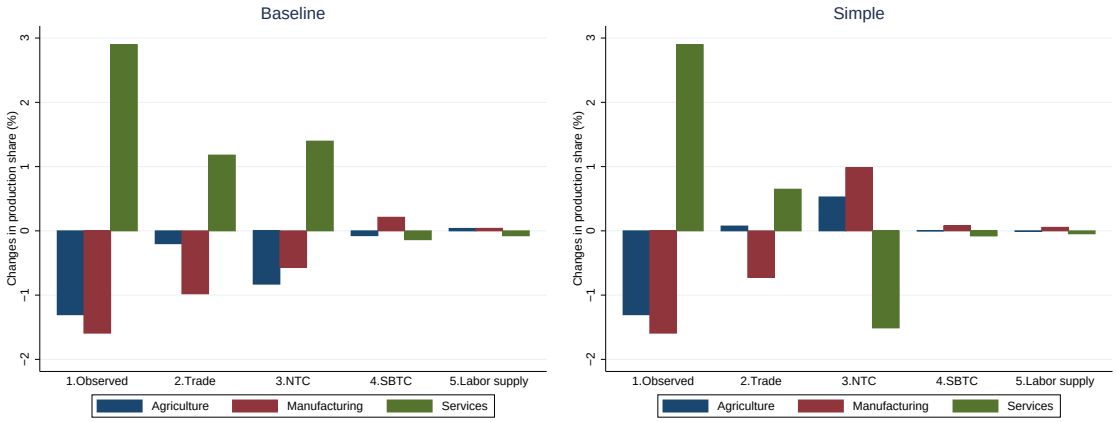

Figure 12: Changes in production share: US

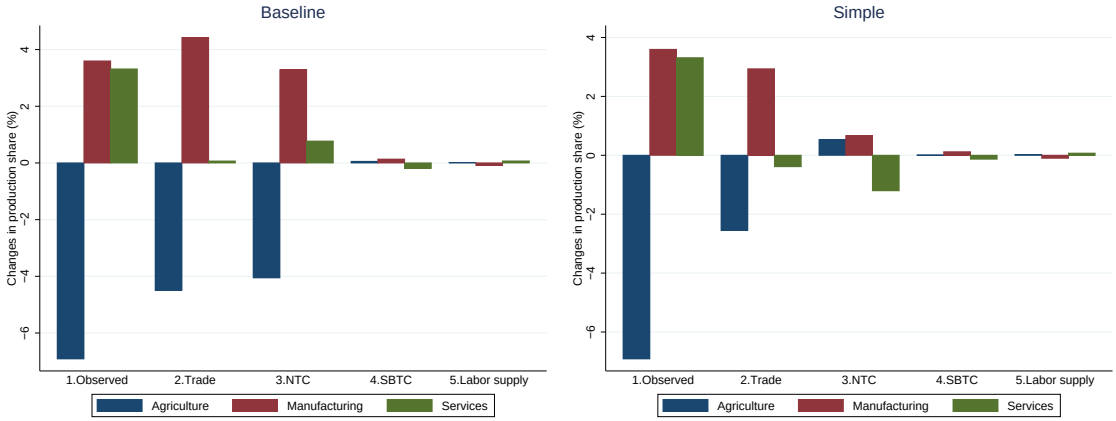

Figure 13: Changes in production share: China

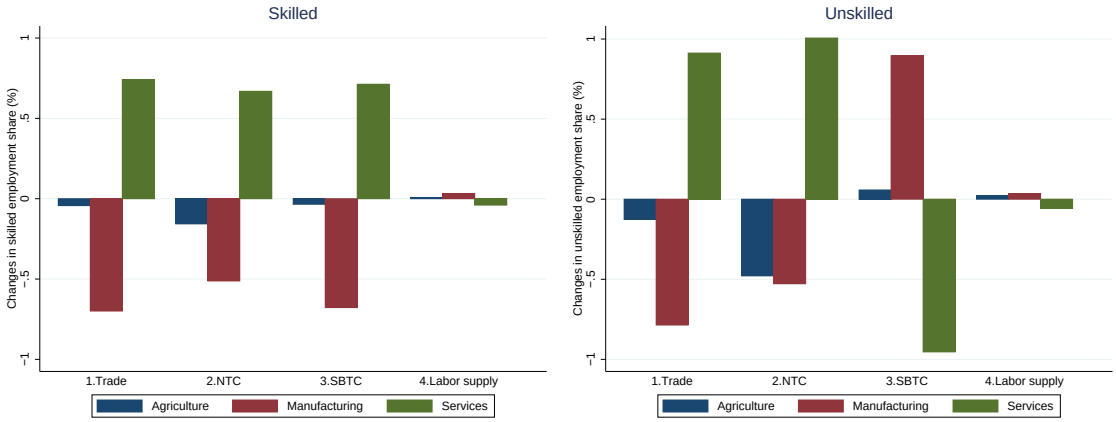

Figure 14: Labor reallocation: baseline US

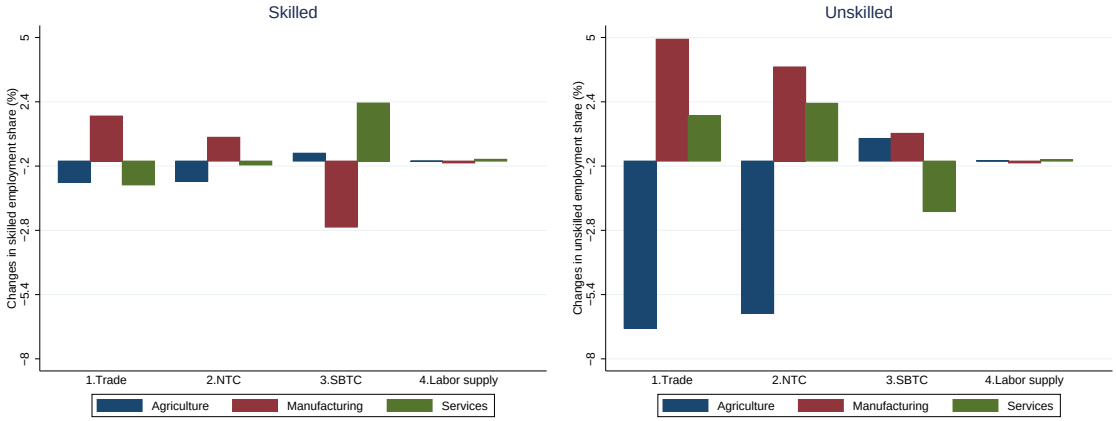

Figure 15: Labor reallocation: baseline China

Appendix

A1 Calibration Details

This section gives more detail on how I calibrate sectoral production efficiency T_n^k.

1. I have to make one normalization in each sector to identify T_n^k. I choose to normalize $P_{\text{ROW}}^k(2007) = 1$ for $k \in \Omega$. Using (20), $T_n^k(2007)$ is identified.

2. Given $T_n^k(2007)$, I back out T_{US}^k in other periods by matching the average sectoral productivity growth in the data.

   - Average sectoral productivity in the model has to be corrected for international trade. Following Finicelli et al. (2013),

   $$\bar{T}_n^k = \Gamma\left(\frac{\theta^k + 1 - \sigma}{\theta^k}\right)\left(T_n^k\right)^{\frac{1}{\theta^k}}\left(\pi_{nn}^k\right)^{-\frac{1}{\theta^k}}$$

     so that everything else equal, a more open country (smaller π_{nn}^k) has higher average productivity because it produces less goods with low productivity.

   - The average yearly productivity growth in agriculture, manufacturing and services in the U.S. are 3.8%, 2.4% and 1.3% respectively from Herrendorf et al. (2013).

   - T_{US}^k in other periods are found from $\bar{T}_{\text{US}}^A(t) = \bar{T}_{\text{US}}^A(2007) \times 1.038^{-(2007-t)}$, $\bar{T}_{\text{US}}^M(t) = \bar{T}_{\text{US}}^M(2007) \times 1.024^{-(2007-t)}$, $\bar{T}_{\text{US}}^S(t) = \bar{T}_{\text{US}}^S(2007) \times 1.013^{-(2007-t)}$ by assuming same growth rate in sectoral productivity.

3. Back out $P_{\text{US}}^k(t)$ in other periods from (17), and then retrieve $T_n^k(t)$ in other periods for $n \neq$ U.S. from (20).

A2 Data

All classifications of industries and countries follow the GTAP codes.

Classification of industries:

- Agriculture: Paddy rice; Wheat; Cereal grains nec; Vegetables, fruit, nuts; Oil seeds; Sugar cane, sugar beet; Plant-based fibers; Crops nec; Cattle, sheep, goats,

horses; Animal products nec; Raw milk; Wool, silk-worm cocoons; Forestry; Fishing; Meat: cattle,sheep,goats,horse; Meat products nec; Vegetable oils and fats; Dairy products; Processed rice; Sugar; Food products nec; Beverages and tobacco products

- Manufacturing: Coal; Oil; Gas; Minerals nec; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Petroleum, coal products; Chemical,rubber,plastic prods; Mineral products nec; Ferrous metals; Metals nec; Metal products; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec

- Services: Electricity; Gas manufacture, distribution; Water; Construction; Trade; Transport nec; Sea transport; Air transport; Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Education; Dwellings

Classification of regions:

- OECD: Australia (AUS) Austria (AUT) Belgium (BEL) Canada (CAN) Germany (DEU) Denmark (DNK) Spain (ESP) Finland (FIN) France (FRA) UK (GBR) Greece (GRC) Ireland (IRL) Italy (ITA) Japan (JPN) Korea (KOR) Luxembourg (LUX) Netherlands (NLD) Portugal (PRT) Sweden (SWE) U.S. (USA)

- Non-OECD: China (CHN) Indonesia (IDN) India (IND) Philippines (PHL) Thailand (THA) Argentina (ARG) Brazil (BRA) Chile (CHL) Mexico (MEX) Peru (PER) Uruguay (URY) Venezuela (VEN) Czech Republic (CZE) Hungary (HUN) Poland (POL) Slovakia (SVK) Slovenia (SVN)

Skill premium:

The skill premium in each country is computed from the following sources:

- OECD and Eastern European countries: from EU KLEMS. Following Parro (2013), I use data on the share of total hours worked by high skilled and medium skilled workers over 15 years old and the share in total labor compensation to high skilled and medium skilled workers over 15 years old.

- Latin American countries: from SEDLAC (CEDLAS and The World Bank). Skill premium is computed as the wage ratio of the high skilled to the medium skilled.

- East Asian countries: Azam (2010) for India, Ge and Yang (2014) for China, Di Gropello and Sakellariou (2010) for Indonesia, Philippines and Thailand. Skill premium is computed as the wage ratio of college graduates to high school graduates.

As EU KLEMS only contain relevant data to compute the skill premium in as late as year 2005, the skill premium of the OECD and Eastern European countries in the end year corresponds to year 2005.

A3 Simple Model

In this section I derive the equations to illustrate the channels that affect the skill premium. I assume that there are two countries, $N = 2$; that there are two sectors, $k = a, b$, and sector b is the skill intensive ($\beta_n^b > \beta_n^a$) and income elastic ($b_b > 0 > b_a$) sector; that value added share is the same across sectors and countries, $v_n^k = v$.

Following Burstein and Vogel (2016), define factor content of trade of factor l in country n, $FCT_n(l)$ as :

$$FCT_n(l) = \sum_{k=\{a,b\}} l_n^k \omega_n^k, \quad l = U, S$$

where l_n^k is the amount of factor l used in the production of sector k goods. The weight ω_n^k is the sectoral net exports share in production, $\omega_n^k = \frac{X_{-nn}^k - X_{n-n}^k}{X_{-nn}^k + X_{nn}^k}$. $FCT_n(l) > 0$ if country n is a net exporter of factor l; and vice versa if country n is a net importer of factor l.

From the labor market clearing conditions (10), equilibrium skill premium in this simple model can be expressed as:

$$\frac{w_n^s}{w_n^u} = \frac{U_n - FCT_n(U)}{S_n - FCT_n(S)} \frac{\sum_{k=\{a,b\}} \beta_n^k \left[v s_n^k + (1-v) e_n^k \right]}{\sum_{k=\{a,b\}} (1-\beta_n^k) \left[v s_n^k + (1-v) e_n^k \right]},$$

where $e_n^k = \sum_{l=a,b} e_n^{lk} y_n^l$ is the average intermediates expenditure share on sector k. $\frac{U_n - FCT_n(U)}{S_n - FCT_n(S)}$ captures the effect of factor contents of trade on the skill premium, while $\frac{\sum_{k=\{a,b\}} \beta_n^k \left[v s_n^k + (1-v) e_n^k \right]}{\sum_{k=\{a,b\}} \left(1-\beta_n^k\right) \left[v s_n^k + (1-v) e_n^k \right]}$ captures the effect of domestic expenditure shares. If expen-

diture shares are constant, such as in a standard HO model, only changes in the factor contents of trade affect the skill premium.

Expenditure shares are not constant due to changing household and intermediates expenditure shares. Utilizing the identity $s_n^a + s_n^b = 1$ and $e_n^a + e_n^b = 1$, the expenditure share part can be written as:

$$\frac{\sum_{k=\{a,b\}} \beta_n^k \left[v s_n^k + (1-v) e_n^k \right]}{\sum_{k=\{a,b\}} (1-\beta_n^k) \left[v s_n^k + (1-v) e_n^k \right]} = \frac{\beta_n^a + \left(\beta_n^b - \beta_n^a\right) \left[v s_n^b + (1-v) e_n^b \right]}{1 - \beta_n^a + (\beta_n^a - \beta_n^b) \left[v s_n^b + (1-v) e_n^b \right]}.$$

It implies that the changes in the numerator and the denominator due to structural changes (Δs_n^b and Δe_n^b) are opposite in sign. Therefore, I only investigate the changes in the numerator in the following.

I decompose the changes in numerator into changes in household and intermediates expenditure shares:

$$\Delta Num_n = v Num_n \left(\Delta s_n^b\right) + (1-v) Num_n \left(\Delta e_n^b\right).$$

On the household side:

$$Num_n \left(\Delta s_n^b\right) = \left(\beta_n^b - \beta_n^a\right) \Delta s_n^b,$$

as consumers demand relatively more skill intensive goods ($\Delta s_n^b > 0$), $Num_n \left(\Delta s_n^b\right) > 0$ so that the skill premium tends to increase.

For the intermediates expenditure share, substitute in $e_n^b = e_n^{ab} y_n^a + e_n^{bb} y_n^b$ and utilizing the identities $e_n^{aa} + e_n^{ab} = 1$, $e_n^{ba} + e_n^{bb} = 1$ and $y_n^a + y_n^b = 1$, we have

$$\begin{aligned} & Num_n(\Delta e_n^k) = \left(\beta_n^b - \beta_n^a\right) \Delta e_n^b \\ &= \left(\beta_n^b - \beta_n^a\right) \left[\underbrace{\left(e_n^{aa} + e_n^{bb} - 1\right) \Delta y_n^b}_{\text{between-sector}} + \underbrace{\left(y_n^b \Delta e_n^{bb} - y_n^a \Delta e_n^{aa}\right)}_{\text{within-sector}} + \underbrace{\left(\Delta e_n^{aa} + \Delta e_n^{bb}\right) \Delta y_n^b}_{\text{interaction}} \right]. \end{aligned}$$

If production in each sector uses its own inputs intensively ($e_n^{aa}, e_n^{bb} > \frac{1}{2}$), the between-sector component is positive, so that reallocation to skill intensive sectors ($\Delta y_n^b > 0$) further raises the skill premium. If firms uses more skill intensive intermediates overtime within each sector ($\Delta e_n^{aa} < 0$ and $\Delta e_n^{bb} > 0$), the within-sector component is positive. The sign of the interaction term is ambiguous, but the magnitude is likely to be small.

A4 Structural Change

I measure the effects of different shocks on structural change by production reallocation index (PRI), which is defined as

$$PRI_i = 1 - \frac{|\Delta\tilde{y}_i^A - \Delta y_i^A| + |\Delta\tilde{y}_i^M - \Delta y_i^M| + |\Delta\tilde{y}_i^S - \Delta y_i^S|}{|\Delta y_i^A| + |\Delta y_i^M| + |\Delta y_i^S|},$$

where $\Delta y_i^k = y_i^k(07) - y_i^k(97)$ is the observed change in production share, and $\Delta\tilde{y}_i^k = y_i^k(c) - y_i^k(97)$ is the counterfactual change. PRI has the following properties:

1. $PRI \leq 1$; $PRI = 1$ if the counterfactual predicts the exact changes in production shares.

2. $PRI = 0$ if the counterfactual predicts no changes in production shares.

3. It is possible to have $PRI < 0$, if the counterfactual predicts much larger changes in production shares or changes in the opposite direction.

When PRI takes positive value it can be interpreted as the fraction of observed changes in production shares that is explained by the forces operative in the counterfactual scenario.

Table 19 presents the implied PRI when each type of shocks is applied individually to the initial equilibrium. The main observation is that the change in sectoral production efficiency is the major driver of structural change, while shocks to endowment and SBTC play virtually no roles. Looking at each country, reductions in trade costs are more important in OECD countries, while sectoral productivity progress is more important in non-OECD countries.

Table 19: Decomposition of PRI across countries

	Endowment	Trade costs	Sectoral tech	SBTC	Residuals
All	0.00	0.05	0.31	0.00	0.14
AUS	-0.03	-0.22	0.19	0.06	0.26
AUT	-0.01	0.56	-0.54	0.21	0.56
BEL	0.02	0.32	0.03	-0.05	-0.47
CAN	0.04	0.01	0.88	-0.19	0.16
DEU	0.06	0.45	-0.71	-0.01	0.87
DNK	0.00	-0.35	0.41	-0.07	-0.09
ESP	-0.06	0.27	-0.01	0.09	-0.79
FIN	-0.01	-0.44	-0.05	-0.02	-0.14
FRA	0.07	0.44	0.48	-0.12	-0.65
GBR	0.02	0.24	0.31	0.02	0.39
GRC	0.01	0.18	0.39	-0.01	0.26
IRL	0.12	-0.48	0.53	0.11	0.46
ITA	-0.11	-0.59	0.97	0.10	0.81
JPN	-0.22	0.08	-0.53	0.00	-1.28
KOR	0.03	-0.04	0.71	0.00	-0.09
LUX	-0.01	0.40	-0.28	0.01	0.31
NLD	0.02	0.29	-0.29	-0.08	0.49
PRT	-0.06	0.05	0.84	0.10	0.18
SWE	0.03	0.28	-1.06	0.04	-1.53
USA	-0.03	0.49	0.12	-0.01	-1.04
ARG	0.00	-0.08	0.14	0.00	0.69
BRA	-0.02	-0.16	0.27	0.01	0.68
CHL	0.02	-0.21	0.54	0.05	-0.17
CHN	0.02	0.39	0.73	-0.01	-0.69
CZE	0.00	0.04	0.42	-0.12	-0.09
HUN	0.04	0.44	0.34	0.02	-0.10
IDN	-0.01	-0.11	0.58	0.09	-0.44
IND	0.00	-0.16	0.24	-0.03	0.75
MEX	0.01	-0.07	0.40	-0.01	0.66
PER	0.00	0.36	0.01	0.04	0.49
PHL	-0.05	0.33	0.65	-0.04	0.32
POL	0.01	0.28	0.55	-0.01	0.14
SVK	0.00	-0.50	0.47	0.00	-0.17
SVN	-0.01	-0.19	0.22	0.13	0.15
THA	0.01	0.22	0.83	-0.01	-0.23
URY	0.04	-0.32	-0.38	-0.22	-0.28
VEN	0.18	-0.01	-0.82	-0.05	-0.57

A5 Comparing the Results to Cravino and Sotelo (2016)

As mentioned in the literature review, Cravino and Sotelo (2016) also calculate the effects of trade on the skill premium in the presence of structural change. I compare my results to them by conducting the same counterfactual exercise in their work. The counterfactual exercise compares the baseline model to a scenario where all countries are in autarky. By assuming that the same set of fundamental shocks are operative in both the baseline and autarky model, including shocks to endowment, skill intensity, sectoral production efficiency, and residuals, the exercise computes the effects of trade on the skill premium by obtaining the differential effects of skill premium implied by the two models under the same set of fundamental shocks.[49] The advantage of this approach is that the effects of trade on the skill premium can be computed with only information on the changes in sectoral trade shares and revenue shares. The disadvantage of the approach is that we do know whether it is technical change or reductions in the trade costs that are driving the changes in trade and revenue shares.

Column two of Table 20 presents the effects of trade on the skill premium under the autarky experiment in my framework. The main observation is that trade has no effect on the skill premium under the autarky experiment. The reason is that the same fundamental shocks under the closed and open economy will operate quite differently. In addition, trade induces structural change due to complementarity across sectors in Cravino and Sotelo (2016). In my framework, it is mainly due to nonhomothetic preferences, while the force of complementarity between sectors is small due to the small magnitudes of price elasticities in Table 4.

[49]Shocks to trade costs and deficits are set to infinity and zero respectively in the autarky model.

Table 20: Effects of trade on the skill premium: comparison

	Baseline	CS exercise	CS results
All	8.31	0.29	
All (CS)	8.27	0.37	2.50
AUS	5.62	0.37	0.80
AUT	4.91	-0.09	5.40
BEL	8.27	3.00	2.30
CAN	2.82	-0.36	2.30
DEU	4.06	-1.20	
DNK	8.45	1.75	5.30
ESP	10.89	1.36	5.50
FIN	7.45	1.94	1.60
FRA	7.02	1.32	2.50
GBR	6.92	0.96	5.30
GRC	23.44	9.97	14.90
IRL	13.10	5.53	2.20
ITA	7.29	0.68	2.30
JPN	1.16	0.30	-0.10
KOR	4.95	-0.65	-1.00
LUX	17.03	-3.76	
NLD	9.27	-2.17	2.40
PRT	9.12	4.69	12.60
SWE	7.32	2.70	
USA	2.01	0.89	3.70
ARG	4.25	-3.53	
BRA	3.13	-2.12	-1.90
CHL	6.80	-5.11	
CHN	20.28	0.15	-2.70
CZE	7.71	-3.48	-1.20
HUN	13.46	-5.91	10.00
IDN	11.49	0.52	
IND	8.31	2.34	8.70
MEX	9.38	-1.76	4.40
PER	10.57	-2.33	
PHL	29.11	-6.58	
POL	19.39	-4.27	14.40
SVK	9.01	0.29	4.00
SVN	13.63	0.76	
THA	18.29	-5.80	
URY	12.23	-3.03	
VEN	3.46	0.36	

Notes: The first column presents the effects of trade in the baseline counterfactual. The second column presents the results of the autarky experiment using my framework. The last row presents the results from Cravino and Sotelo (2016). The second row computes the median value for a set of countries in Cravino and Sotelo (2016).

A6 Controling the Effects of Home Technical Change on Trade

One potential drawback of the baseline analysis is that the trade shocks do not incorporate the effects of home technical change on trade flows. It tends to *over-estimate* the effects of trade on the skill premium, as the actual changes in comparative advantage due to changes in relative sectoral production efficiency across countries are exaggerated. As sectoral productivity growth is highest in agriculture and lowest in services from Table 7, only considering foreign technical change as trade shocks tends to make home country relatively more productive in manufacturing and services, so that the home country is more likely to be a net exporter in skill intensive sectors.

However, home technical change affects the domestic economy regardless of trade. To overcome this difficulty, I transform the first order effects of shocks on home production efficiency into an equivalent shock on the bilateral trade cost, such that these two shocks have the same first order effects on the trade flows at home. The trade cost equivalent home technology shock has two components, an equivalent shock on the export cost $\tilde{d}^k_{-nn}$, and an equivalent shock on the import cost $\tilde{d}^k_{n-n}$ in home country n. The idea here is to capture the effects of home technical change on exports with an equivalent decrease in the costs of exporting, and the effects on imports with an equivalent increase in the costs of importing.[50]

To find the export cost equivalent $\tilde{d}^k_{-nn}$, I start from (7) with country $i = n$. The first order effect of changes in home sectoral production efficiency $\hat{T}^k_n$ on its own exports is:

$$d \ln \pi^k_{-nn} = d \ln T^k_n - d \ln \Phi^k_{-n},$$

where the second term is the direct effect of home technical change on foreign sectoral prices. Use the fact that $\Phi^k_{-n} = T^k_n \left(c^k_n d^k_{-nn}\right)^{-\theta^k} + \sum_{l \neq n} T^k_l \left(c^k_l d^k_{-nl}\right)^{-\theta^k}$, the first order effect of $\hat{T}^k_n$ on its exports is:

$$d \ln \pi^k_{-nn} = \left(1 - \pi^k_{-nn}\right) d \ln T^k_n. \tag{24}$$

Similarly, the first order effect of export cost shock $\hat{d}^k_{-nn}$ on home's exports is:

$$d \ln \pi^k_{-nn} = -\theta^k \left(1 - \pi^k_{-nn}\right) d \ln d^k_{-nn}, \tag{25}$$

which again includes the direct effect on foreign sectoral prices. Compare (24) and (25),

[50] For example, a rise in home production efficiency makes it more difficult for foreign firms to export to the home country, as if there is an increase in the import cost at home.

the export cost equivalent home technology shock is:

$$\tilde{d}^k_{-nn} = \left(\hat{T}^k_n\right)^{-\frac{1}{\theta^k}}, \quad -n \neq n. \tag{26}$$

Similar procedure applies to the import cost equivalent $\tilde{d}^k_{n-n}$. From (7) with country n as the importer, the first order effect of changes in home sectoral production efficiency $\hat{T}^k_n$ on its own imports is:

$$d \ln \pi^k_{n-n}(\hat{T}^k_n) = -\pi^k_{nn} d \ln T^k_n. \tag{27}$$

The only difference from the export case is that home technical change affects imports only through home prices.

For the first order effect of import cost shocks, I have to consider all home country's trading partners together, as all import costs affect home price. From (7), the first order effect of import cost shocks of all trading partners of home $\{\hat{d}^k_{n-n}\}_{-n}$ is:

$$d \ln \pi^k_{n-n} = \underbrace{-\theta^k \left(1 - \pi^k_{n-n}\right) d \ln d^k_{n-n}}_{\text{direct effect of } \hat{d}^k_{n-n}} + \underbrace{\theta^k \sum_{l \neq n,-n} \pi^k_{nl} d \ln d^k_{nl}}_{\text{other import costs}}, \quad -n \neq n. \tag{28}$$

The effects of $\{\hat{d}^k_{n-n}\}_{-n}$ on imports from country $-n$ consist of two components. The first component is the direct effect from changes in import costs from country $-n$. The second component captures the effect of changes in import costs with other foreign countries on home price. Compare (27) and (28), the import cost equivalent home technology shock is:

$$\tilde{d}^k_{n-n} = \left(\hat{T}^k_n\right)^{\frac{1}{\theta^k}}, \quad -n \neq n. \tag{29}$$

Expressions (26) and (29) imply that the trade cost equivalent home technology shock is:

$$\{\tilde{d}^k_{-nn}, \tilde{d}^k_{n-n}\} \equiv \hat{T}^k_n, \quad -n \neq n. \tag{30}$$

Armed with the trade cost equivalent home technology shocks, I regroup the shocks into trade and technology:

1. Trade shocks:
   - trade cost shocks: $\{\hat{\kappa}^k_{mi}, \hat{\tau}^k_{mi}, \Delta D_n\}$,
   - technology-related trade shocks: $\{\hat{T}^k_{-n}, \tilde{d}^k_{-nn}, \tilde{d}^k_{n-n}\}$;

2. Technology shocks:

   - skill biased technical change: $\Delta\beta_n^k$,
   - neutral technical change: $\left\{\hat{T}_n^k, \left(\tilde{d}_{-nn}^k\right)^{-1}, \left(\tilde{d}_{n-n}^k\right)^{-1}\right\}$.

The only difference from the baseline grouping is that part of the changes in home production efficiency is now attributed to trade.[51] The labor supply and model residual shocks remain the same.

I apply the above shocks to the same baseline model, and the results are presented in Table 21. Compared with the baseline groups of shocks, now the effects of trade decline from 8.4% to 4.3%, while the effects of technical change increase from 1.6% to 5.9%. The difference is due to the smaller effects of technology-related trade shocks. The exercise shows the importance of controling for the effects of home technical change on trade flows.

	All trade shocks	All tech shocks	Trade costs	Foreign tech tech-related	NTC	SBTC
			Baseline			
All	8.38	1.56	-0.45	8.03	-3.67	5.34
OECD	7.31	2.29	0.20	6.31	-2.98	5.91
Non-OECD	10.57	1.74	-2.67	13.02	-4.79	4.07
			Home tech adjusted			
All	4.31	5.86	-0.45	3.92	-0.22	5.34
OECD	4.31	6.46	0.20	3.44	-0.22	5.91
Non-OECD	5.40	3.57	-2.67	5.61	-0.43	4.07

Table 21: Changes in the skill premium under alternative shocks (%): baseline

I also do the same exercise on the no structural change model. Table 22 illustrates the results. Though the changes in the skill premium induced by trade and technical change are quite different under these two grouping schemes, the contribution from structural change is similar. In particular, structural change increases the skill premium by 4.2% in OECD countries, and 6.7% in non-OECD countries, compared to 2.3% in OECD 7.7% in non-OECD when the effects of home technical change on trade flows are not taken into account.

[51] One caveat of the new grouping is that now trade and technology shocks are not orthogonal to each other, as $\tilde{d}_{-nn}^k$ and $\left(\tilde{d}_{-nn}^k\right)^{-1}$ are correlated. Therefore I may double count the general equilibrium effects coming from the trade cost equivalent shocks.

	All trade shocks	All tech shocks	Trade costs	Foreign tech tech-related	NTC	SBTC
			Baseline			
All	4.33	2.26	-0.22	4.46	-3.11	5.41
OECD	4.00	3.27	0.06	3.46	-2.78	6.00
Non-OECD	4.52	0.24	-0.87	5.32	-3.92	4.06
			Home tech adjusted			
All	0.68	4.49	-0.22	0.53	-0.74	5.41
OECD	1.06	5.49	0.06	0.78	-0.64	6.00
Non-OECD	0.42	1.96	-0.87	0.38	-1.44	4.06

Table 22: Changes in the skill premium under alternative shocks (%): no structural change model

In sum, controling the effects of home technical change on trade flows implies smaller effects of trade on the skill premium, but the effects remain positive and economically significant.