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PER CAPITA INCOME AND THE DEMAND FOR SKILLS

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ABSTRACT

Almost all of the literature about the growth of income inequality and the relationship between skilled and unskilled wages approaches the issue from the production side of general equilibrium (skill-biased technical change, international trade). Here, we add a role for income-dependent demand interacted with factor intensities in production. We explore how income growth and trade liberalization influence the demand for skilled labor when preferences are non-homothetic and income-elastic goods are more intensive in skilled labor, an empirical regularity documented in Caron, Fally and Markusen (2014). In one experiment, counterfactual simulations show that sector neutral productivity growth, which generates shifts in consumption towards skill-intensive goods, leads to significant increases in the skill premium: in developing countries, a one percent increase in productivity leads to a 0.1 to 0.25 percent increase in the skill premium. In several countries, including China and India, simulations suggest that the historical growth experienced in the last 25 years may have led to an increase in the skill premium of more than 10%. In a second experiment, we show that trade cost reductions generate quantitatively very different outcomes once we account for non- homothetic preferences. These imply substantially less predicted net factor content of trade and allow for a shift in consumption patterns caused by trade-induced income growth. Overall, the negative effect of trade cost reductions on the skill premium predicted for developing countries under homothetic preferences (Stolper-Samuelson) is strongly mitigated, and sometimes reversed.

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1 Introduction

Over the past three decades, the large increase in income inequality, especially between skilled and unskilled workers, has led to a vast body of research aiming to explain these changes, often focusing on the roles of trade and (or versus) skilled-biased technological change.[1] Other recent work has highlighted the role of several alternative channels in explaining these changes, such as trade and offshoring through Heckscher-Ohlin-type mechanisms,[2] heterogeneous technology adoption across firms,[3] changes in matching patterns between heterogeneous workers and firms,[4] and quality upgrading encouraged by trade liberalization.[5] While this significant body of work concentrates on the production side of general equilibrium, there is a smaller literature that considers shifting patterns of demand across sectors which require different types of skills.[6] The source of these demand shifts are in some cases modeled explicitly and in others simply taken as exogenous as the consequences of the shifts for the skill premium are explored. Our paper fits with some of this demand-driven literature, though we link characteristics of goods in consumption to characteristics of goods in production in a very explicit way. We will first describe our approach, and then explain how it relates to other literature later in the section.

In this paper, we illustrate how income growth and reductions in trade costs affect the skill premium when preferences are non-homothetic. Our results rely on the correlation between income elasticity in consumption and skill intensity in production across goods, shown to be very large in Caron, Fally and Markusen (2014). This correlation implies that homogeneous productivity growth across sectors is no longer neutral for the skill premium in general equilibrium. It implies that as countries get richer, their consumers increase their relative consumption of goods which are more skill-intensive in their production, thereby increasing the returns to skilled labor relative to those of unskilled labor. The effect of trade cost reductions on the skill premium also differ when preferences are non-homothetic and when income-elastic goods are more skill intensive, as they affect the factor content of trade and interact with trade-driven income growth.

To quantify these mechanisms, our analysis proceeds in three steps. In step 1, we describe a model of production, trade and consumption in general equilibrium. In step 2, we estimate the preference, trade cost and technology parameters of the model. We take a cross-sectional approach which allows us to identify the role of income in explaining shifts in consumption. In step 3, we simulate various counterfactual equilibria to quantify and illustrate the impact of productivity growth and trade cost reductions on the skill premium.

Before proceeding, it might be appropriate to emphasize that our methodology does not permit a "horse race" between alternative theories of the skill premium mentioned above, and we make no attempt to evaluate the relative contributions or lack thereof of alternative mechanisms. Our

[1] Katz and Murphy (1992), Goldberg and Pavnick (2007), Autor et al. (2015)
[2] Krugman (2000), Feenstra and Hanson (1997)
[3] Bustos (2011), Burstein and Vogel (2017).
[4] Card et al. (2013), Helpman et al. (2017)
[5] Hallak (2010), Feenstra and Romalis (2014), Fieler, Eslava and Xu (2016)
[6] Buera and Kaboski (2012), Johnson and Keane (2013)

conclusions are limited to the argument that the overlooked correlation between income elasticities and skill intensities is likely an important contributor to understanding the skill premium, especially for developing countries where standard trade theory offers quite different predictions.

The first step of our analysis is to develop a model combining non-homothetic preferences with a standard multi-sector and multi-factor model on the supply side. Consumption patterns are derived from "constant relative income elasticity" (CRIE) preferences as in Caron et al (2014) and Fieler (2011). The supply-side structure is an extension of Costinot et al. (2012) and Eaton and Kortum (2002) with multiple factors of production and an input-output structure as in Caliendo and Parro (2012). The model can be used to derive first-order approximations of the response of the skill premium to small changes in productivity and trade costs, with and without taking the demand for intermediate goods into account. These approximations help develop intuition behind the mechanisms and emphasize the role played by the correlation between income elasticity and skill intensity.

In a second step, we estimate preference, trade cost and technology parameters. Our estimations rely on the Global Trade Analysis Project (GTAP) version 8 dataset (Narayanan et al., 2012) for 2007, which comprises 109 countries with a wide range of income levels, 56 broad sectors including manufacturing and services, and 5 factors of production including the disaggregation of skilled and unskilled labor. This dataset is uniquely suited to our purposes, as it contains a consistent and reconciled cross-section of production, input-output, consumption and trade data. However, the broad categories of goods and services make it unsuitable for the discussion of issues related to product quality and within-industry heterogeneity. We follow the same estimation method as Caron et al (2014). We first estimate gravity equations within each sector, which allows us to identify patterns of comparative advantage and construct price indexes across importers and sectors. We then estimate consumer preferences, adjusting for these price differences. To account for endogeneity, we instrument prices with indices which do not depend on domestic demand. This strategy allows us to estimate and identify price and income elasticity parameters for a large range of sectors. Doing so is usually complicated by the lack of consistent price and expenditure data as well as endogenous prices. We find that per capita income plays a crucial role in determining demand patterns across countries and sectors. Income-elasticity in consumption varies largely across goods and is highly correlated with skill intensity in production, as documented also in Caron et al (2014), with an estimated correlation close to 50 percent across all goods, and even higher if we exclude services.

In a third step, we use our estimates of preference, trade cost and technology parameters to quantitatively illustrate the role of non-homothetic preferences, by comparing results to an homothetic preference benchmark, with two sets of counterfactual simulations in general equilibrium. The first set of counterfactual exercises aims to quantify the potential for growth in income to affect the skill premium through shifts in consumption patterns. We simulate a homogeneous one percent increase in factor productivity across all sectors. If this increase is uniform in all countries, homothetic preferences imply that the counterfactual equilibrium should be identical to the baseline equilibrium in terms of skill premium, consumption shares, trade and production patterns. However, with our non-homothetic preference estimates, homogeneous productivity growth leads to an increase in the skill premium in

all countries in our dataset. Our results are very close to the first-order approximation provided in the first step. They are driven by the strong correlation between skill intensity and income elasticity, which induces a quantitatively large increase in the demand for skill intensive goods as per capita income increases. The main mechanism in this counterfactual does not rely on trade and we obtain no sizable difference between closed and open economy simulations, except for a few small open countries. The results are also only slightly mitigated when we account for input-output linkages, since the industries that are upstream of skill-intensive final demand industries tend to be skill intensive themselves.

We also simulate country-specific productivity growth based on historic rates. The magnitude of the skill premium estimates coming out of the model suggests that this demand-driven mechanism may have played a quantitatively important role in driving observed changes in relative wages[7]. The predicted increase in the skill premium is especially large in the developing world. For example, the growth in income which occurred between 1990 and 2014 would have led to a 10% predicted increase in the skill premium in China. This compares to the 40% increase believed to have occurred in China between 1992 and 2006 (Ge and Tao Yang, 2009). The predicted increase is larger in many of the least developed countries. In rich countries the effect is smaller, but not negligible: the mechanism generates an increase in the skill premium which represents about 20% of the increase in the US over that period (Parro, 2012). These findings are overall consistent with the fact that the observed skill premium increases have generally been more important in developing countries during that period.

Our second set of counterfactuals examines how preferences affect the relationship between trade liberalization and the skill premium. We simulate a one percent trade cost reduction, both uniformly across all countries or to and from a given country. The impact of trade costs reductions depends on export and import patterns across industries. The standard Stolper-Samulelson argument suggests that in skill-abundant rich countries, the direct effect of trade costs reductions is to lead to an increase in the relative demand for skilled workers. The reverse would occur in developing countries. Our results suggest that the introduction of non-homothetic preferences into the model substantially moderates this prediction: the benefits of trade for the unskilled workers of the developing world are smaller. We highlight and quantify four channels through which non-homothetic preferences affect results.

The first channel reflects how non-homothetic preference affect predicted trade patterns and the strength of the Stolper-Samulelson effect. With non-homothetic preferences, consumption and production patterns are more correlated, as rich and skill abundant countries are predicted to consume more of the income-elastic and skill-intensive goods which they have a comparative advantage in producing. As documented in Caron et al (2014), this leads to less trade overall and relatively more trade between countries which have similar levels of income per capita. The net factor content of trade is thus smaller, which leads to a weakening of the Stolper-Samuelson effect and a weaker relationship between trade cost reductions and the relative demand for skilled labor. Our results indicate this to

[7]We emphasize that our discussion of the skill premium is strictly a counterfactual: we do not estimate the effect of actual productivity changes on the skill premium nor do we assert that neutral technical change is a characteristic of recent history. Previous research has emphasized the role of skill-biased technological change (Autor et al., 1998), as well as outsourcing and competition from low-wage countries (Feenstra and Hanson, 1999). Our counterfactual does not dispute the findings of this research, we just use it to help quantify the significance of our results.

be especially important for developing countries which are predicted to export less unskilled-intensive goods and for which trade liberalization has a smaller depressing effect on the skill premium. The opposite occurs to rich countries, but to a lesser extent.

A second channel highlights the income effect of trade. As trade costs decline, gains from trade make countries richer. Similar to the effect productivity growth, consumption thus shifts towards income-elastic and skill intensive goods. Simulations show that the trade-induced income effect is quantitatively large in many developing countries and neutralizes a significant share of the remaining Stolper-Samuelson effect on the skill premium. We also illustrate the role of input-output linkages (which magnify our results) and general-equilibrium feedbacks (which mitigate our results), but we find that these two channels only moderately affect the first two. Combined, these effects suggest that non-homothetic preferences generate a higher skill premium for the same amount of trade liberalization. The difference is most striking for developing countries, many of which see trade's depressing effect on the skill premium disappear altogether.

As noted earlier, there is a great deal of literature on the skill premium. Since we are not attempting to run a horse race among approaches as also noted earlier, we will not review the large literatures focusing on skill-biased technical change and standard Heckscher-Ohlin type trade mechanisms. These models and results are clearly empirically important, but for the sake of exposition we instead focus on work more related to our own.

In the international trade literature, Markusen (2013) theoretically identified the potential consumption - driven impacts on the skill premium which we quantify. In a stylized model, he postulates that non-homothetic preferences and a possible correlation between income elasticity in consumption and skill intensity in production would make neutral productivity growth increase the relative wage of skilled workers. Caron, Fally and Markusen (2014) show that the correlation is empirically strong and illustrate the consequences for trade patterns, trade-to-GDP ratios, and the missing trade puzzle. Here, we examine and quantify the implications of this correlation for the skill premium.[8]

More generally, this paper is part of a renewed interest in non-homothetic preferences in open-economy settings in the trade literature. Fieler (2011), Simonovska (2015), Fajgelbaum and Khandelwal (2016) also incorporate non-homotheticities in consumption, adding to a literature initiated by Markusen (1986), Flam and Helpman (1987), Matsuyama (2000) among others. While related to our work in terms of non-homotheticity, these papers concentrate on issues other than the skill premium, such as explaining trade volumes and patterns, and markups in relation to per-capita incomes. Matsuyama (2017) pushes this literature further by endogenizing the relationship between non-homothetic preferences and differential productivity growth rates across sectors and patterns of specialization in production.

Conversely, work on trade and the skill premium has mostly focused on the supply-side. Few papers have confirmed Stolper-Samuelson effects for developing countries (e.g. Robertson 2004 for

[8] A working paper version, Caron et al. (2012), included some of our results on the skill premium. The working paper had to be split in two and these results are not part of the published version, Caron et al. (2014).

Mexico, Gonzaga et al. 2006 for Brazil) which are often at odds with increasing wage inequality that we observe in most countries (Goldberg and Pavcnik 2007). Most of the recent literature on trade and the skill premium thus aims to explain why trade may lead to a larger increase on the skill premium than suggested by the standard Heckscher-Ohlin model. Bustos (2011) proposes a mechanism whereby access to foreign markets triggers the adoption of skill-biased technologies and provides supportive evidence from Argentinian firm-level data. Burstein and Vogel (2016) also examine how the heterogeneous effect of trade across firms influences the relative demand for skilled labor, and show that this within-sector reallocation channel can be potentially much larger than standard Heckscher-Ohlin channels. Costinot and Vogel (2010) indicate that poor countries facing large demand for skill intensive goods from rich countries might experience a positive effect of trade on the skill premium, but do not examine this claim empirically. Cravino and Sotelo (2016) show that a reduction in trade costs leads to a relative expansion of the service sector relative to the manufacturing sector when those are strong complements. Since service activities are more intensive in skilled labor, this leads to a larger increase in the skill premium.

Non-homotheticity in consumption also plays an important role in the literature on trade and quality (e.g. Hallak, 2010, Feenstra and Romalis, 2014). If the production of higher-quality goods requires relatively more skilled labor, the idea developed here can be applied to link the skill premium to the demand for quality. Opening to trade with richer countries, as well as increasing income per capita should both lead to increasing demand for higher-quality goods and an increase in the skill premium. The link between quality and skill labor is present in the work of Fieler et al. (2016) who examine the effect of trade liberalization in Columbia. They argue that opening to trade led to a quantitatively important increase in the demand for skilled workers due to the increase in the quality of goods being produced.

Since our model and approach rely on shifts in the composition of demand across sectors, at least two papers that provide strong evidence for these shifts should be noted. In the literature examining the source and consequences of structural change, Buera and Kaboski (2012) discuss how productivity growth leads to an increase in the skill premium. They develop and calibrate a two-sector model in which growth leads to a higher share of services that are more skill intensive. They do not however estimate or quantify the role of non-homothetic preferences, nor do they discuss the correlation between skill intensity and income elasticity beyond the two-sector approach. Our estimated income elasticities tend to be larger for services sectors, but the correlation between skill intensity and income elasticity holds even when we exclude services. Since it holds for traded goods, the correlation also has implications for the composition of trade and can help us explain why trade has a smaller effect on the skill premium in developing countries relative to standard models. A second paper is Johnson and Keane (2013) who examine how sectoral shifts in consumption influence the demand for many different types of labor. In particular, they document the importance of demand shifts across occupations, such as the shift toward (heavily female) service occupations.[9] However, Johnson and Keane (2013) do not

[9]Parenthetically, they document a number of other facts that cast doubt on the proposition that skill-biased technical change is the main culprit behind the skill premium.

model or explain these sectoral demand shifts, a primary purpose of our paper.

Finally, a growing literature examine the differential effect of trade on the cost of living across workers and households within a country. This channel has been examined, among others, by Fajgelbaum and Kandelwahl (2016), Nigai (2016) and He and Zhang (2017).[10] For most countries, Fajgelbaum and Kandelwahl (2016) estimate that poor households gain relatively more from trade through cost-of-living effects, while Nigai (2016) tends to find the opposite. He and Zhang (2017) extend Fajgelbaum and Kandelwahl (2015) to allow for worker sorting across multiple sectors, and show that the effect of trade on the cost of living can be quantitatively larger than the effects on nominal income. While we acknowledge that cost-of-living effects matter for welfare, we focus here on the channels through which trade (and growth) affects the skill premium in nominal terms.[11] Our approach is closer to the Heckscher-Ohlin tradition of multiple factors of production, so we can easily analyze skilled versus unskilled wages and distinguish sectors by factor intensities, which is exactly what we have in our data.

The rest of the paper is organized in three sections. We describe our theoretical framework in Section 2, our empirical strategy and estimation results in Section 3, and the quantitative implications for the skill premium in Section 4.

2 Theoretical framework

2.1 Benchmark Model set-up

The model closely follows Caron et al (2014) with the same non-homothetic preferences but a more flexible production function in terms of skilled and unskilled workers.

Demand

The economy is constituted of heterogeneous industries. In turn, each industry k is composed of a continuum of product varieties indexed by $j_k \in [0,1]$. Preferences take the form:

$$U = \sum_k \alpha_{1,k} Q_k^{\frac{\sigma_k - 1}{\sigma_k}}$$

where $\alpha_{1,k}$ is a constant (for each industry k) and Q_k is a CES aggregate:

$$Q_k = \left(\int_{j_k=0}^{1} q(j_k)^{\frac{\xi_k - 1}{\xi_k}} dj_k \right)^{\frac{\xi_k}{\xi_k - 1}}$$

[10] See also Porto (2006) for Argentina, Faber (2014), Cravino and Levchenko (2016) for Mexico, Faber and Fally (2017) for the US.

[11] Our approach allows us to generate predictions of the change in the relative wage of skilled vs. unskilled workers even if there is no available data on initial wages by skill category in most of the developing countries in our sample. Adjusting for cost-of-living effects would instead require data on initial wages differences between types of workers and the distribution within each type.

Preferences are identical across countries, but non-homothetic if σ_k varies across industries. If $\sigma_k = \sigma$, we are back to traditional homothetic CES preferences.[12]

The CES price index of goods from industry k in country n is $P_{nk} = \left(\int_0^1 p_{nk}(j_k)^{1-\xi_k} dj_k\right)^{\frac{1}{1-\xi_k}}$. Given this price index, individual expenditures ($P_{nk}Q_{nk}$) in country n for goods in industry k equal:

$$x_{nk} = \lambda_n^{-\sigma_k} \alpha_{2,k} (P_{nk})^{1-\sigma_k} \tag{1}$$

where λ_n is the Lagrange multiplier associated with the budget constraint of individuals in country n, and $\alpha_{2,k} = (\alpha_{1,k}\frac{\sigma_k - 1}{\sigma_k})^{\sigma_k}$. The income elasticity of demand η_{nk} for goods in industry k and country n equals:

$$\eta_{nk} = \sigma_k \cdot \frac{\sum_{k'} x_{nk'}}{\sum_{k'} \sigma_{k'} x_{nk'}} \tag{2}$$

which implies that the ratio of the income elasticities of any pair of goods k and k' equals the ratio of their σ parameters: $\frac{\eta_{nk}}{\eta_{nk'}} = \frac{\sigma_k}{\sigma_{k'}}$ and is constant across countries.[13]

Production

We assume a constant-returns-to-scale production function that depends on several factors and bundles of intermediate goods from each industry. We assume that factors of production are perfectly mobile across sectors but immobile across countries. We denote by γ_{hk} the share of the input bundles from industry h in total costs of industry k (direct input-output coefficient), and each input bundle is a CES aggregate of all varieties available in this industry (for the sake of exposition we assume that the elasticity of substitution between varieties is the same as for final goods). We denote by w_{fn} the price of factor f in country n. Total factor productivity $Z_{ik}(j_k)$ varies by country, industry and variety. Labor inputs, comprised of unskilled or low-skill labor ($f = L$) and high-skilled labor ($f = H$), are combined into a CES aggregate with elasticity of substitution ρ.

As common in the trade literature, we assume iceberg transport costs $d_{nik} \geq 1$ from country i to country n in sector k. The unit cost of supplying variety j_k to country n from country i equals:

$$p_{nik}(j_k) = \frac{d_{nik}}{Z_{ik}(j_k)} \, (c_{ikLab})^{\gamma_{kLab}} \prod_{f \notin Lab} (w_{if})^{\gamma_{kf}} \prod_h (P_{ih})^{\gamma_{hk}} \tag{3}$$

where P_{ih} is the price index of goods h in country i and $\sum_f \gamma_{kf} + \sum_h \gamma_{hk} = 1$ to ensure constant returns to scale in each industry k. The cost of labor c_{ikLab} is a CES aggregate of the wage of high-skilled and low-skilled workers:

$$c_{ikLab} = \left[\mu_{ikL} \, w_{iL}^{1-\rho} + \mu_{ikH} \, w_{iH}^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{4}$$

[12] These preferences are used in Fieler (2011), with early analyses and applications found in Hanoch (1975) and Chao and Manne (1982). To the best of our knowledge, there is no common name attached to these preferences, so we will refer to them as constant relative income elasticity (CRIE) tastes.

[13] Note that CRIE preferences (and separable preferences in general) preclude any inferior good: the income elasticity of demand is always positive for any good. Another notable feature of income elasticities is that they decrease as income increases (holding prices fixed). This property is actually quite general: average income elasticities decrease with income for any Walrasian demand.

Parameters μ_{ikH} and μ_{ikL} capture the high and low-skilled-labor intensity of sector k in country i, and ρ the elasticity of substitution between types of labor.

There is perfect competition for the supply of each variety j_k. Hence, the price of variety j_k in country n in industry k equals:

$$p_{nk}(j_k) = \min_i \{p_{nik}(j_k)\}$$

We follow Eaton and Kortum (2002) and assume that productivity $Z_{ik}(j_k)$ is a random variable with a Frechet distribution. This setting generates gravity within each sector. Productivity is independently drawn in each country i and industry k, with a cumulative distribution:

$$F_{ik}(z) = \exp\left[-(z/z_{ik})^{-\theta_k}\right]$$

where z_{ik} is a productivity shifter reflecting average TFP of country i in sector k. As in Eaton and Kortum (2002), θ_k is related to the inverse of productivity dispersion across varieties within each sector.[14] As in Costinot, Donaldson and Komunjer (2010), we also allow the shift parameter z_{ik} to vary across exporters and industries, keeping a flexible structure on the supply side and controlling for any pattern of Ricardian comparative advantage forces at the sector level.

Endowments

Each country i is populated by a number L_i of individuals. The total supply of factor f is fixed in each country and denoted by V_{if}. Each person is endowed by V_{if}/L_i units of factor V_{fi} implying no within-country income inequality.[15]

2.2 Equilibrium

Equilibrium is defined by the following equations. On the demand side, total expenditures D_{nk} of country n in final goods k simply equals population L_n times individual expenditures as shown in (1). This gives:

$$D_{nk} = L_n(\lambda_n)^{-\sigma_k}\alpha_{2,k}(P_{nk})^{1-\sigma_k} \tag{5}$$

where λ_n is the Lagrange multiplier associated with the budget constraint:

$$L_n e_n = \sum_k D_{nk} \tag{6}$$

where e_n denotes per-capita income. Total demand X_{nk} for goods k in country n is the sum of the demand for final consumption D_{nk} and intermediate use:

$$X_{nk} = D_{nk} + \sum_h \gamma_{kh} Y_{nh} \tag{7}$$

[14] Note that we also assume $\theta_k > \xi_k - 1$ for all k to insure a well-defined CES price index for each industry.

[15] We show in Caron et al (2014) that we obtain very similar preference estimates when account for the distribution of income across quintiles for a subset of countries.

where Y_{nh} refers to total production in sector h.

On the supply side, each industry mimics an Eaton and Kortum (2002) economy. In particular, given the Frechet distribution, we obtain a gravity equation for each industry. We follow Eaton and Kortum (2002) notation with the addition of industry subscripts. By denoting π^M_{nik} as import shares and X_{nik} as the value of trade *from* country i *to* country n, we obtain:

$$\pi^M_{nik} \equiv \frac{X_{nik}}{X_{nk}} = \frac{S_{ik}(d_{nik})^{-\theta_k}}{\Phi_{nk}} \tag{8}$$

where S_{ik} and Φ_{nk} are defined as follows. The "supplier effect", S_{ik}, is inversely related to the cost of production in country i and industry k. It depends on the factor productivity parameter z_{ik}, intermediate goods and factor prices:

$$S_{ik} = z_{ik}^{\theta_k} \left(c_{ikLab}\right)^{-\theta_k \gamma_{kLab}} \prod_{f \notin Lab} \left(w_{if}\right)^{-\theta_k \gamma_{kf}} \prod_h (P_{ih})^{-\theta_k \gamma_{hk}} \tag{9}$$

with the cost of labor $c_{ikLab} = \left[\mu_{ikL}\, w_{iL}^{1-\rho} + \mu_{ikH}\, w_{iH}^{1-\rho}\right]^{\frac{1}{1-\rho}}$ as in equation (4).

In turn, we define Φ_{nk} as the sum of exporter fixed effects deflated by trade costs. Φ_{nk} plays the same role as the "inward multilateral trade resistance index" as in Anderson and van Wincoop (2003):

$$\Phi_{nk} = \sum_i S_{ik}(d_{nik})^{-\theta_k} \tag{10}$$

This Φ_{nk} is actually closely related to the price index, as in Eaton and Kortum (2002):

$$P_{nk} = \alpha_{3,k}(\Phi_{nk})^{-\frac{1}{\theta_k}} \tag{11}$$

with $\alpha_{3,k} = \left[\Gamma\left(\frac{\theta_k+1-\xi_k}{\theta_k}\right)\right]^{\frac{1}{\xi_k-1}}$ where Γ denotes the gamma function.[16]

Finally, two other market clearing conditions are required to determine factor prices and income in general equilibrium. Income for each factor equals the sum of total production weighted respectively by factor intensity. With factor supply V_{fi} and factor price w_{fi} for factor f in country i, market clearing for factors other than labor implies:

$$V_{fi} w_{fi} = \sum_k \gamma_{kf} Y_{ik} = \sum_{n,k} \gamma_{kf} X_{nik} \tag{12}$$

For each type of labor $l \in \{L, H\}$, factor intensity is given by:

$$\beta_{ikl} \;=\; \frac{\mu_{ikl}\, w_{il}^{1-\rho}}{\mu_{ikL}\, w_{iL}^{1-\rho} + \mu_{ikH}\, w_{iH}^{1-\rho}} \;=\; \mu_{kl}\, w_{il}^{1-\rho}\, c_{ikLab}^{\rho-1} \tag{13}$$

[16] Alternatively, we can generalize this model and assume that the elasticity of substitution for intermediate use differs from the elasticity of substitution for final use, and depends on the parent industry. This does not affect the elasticity of the price index w.r.t. Φ_k. Differences in elasticities of substitution would be captured by the industry fixed effect that we include in our estimation strategy and would not affect our estimates.

and labor market clearing imposes:

$$V_{il} w_{il} = \sum_k \beta_{ikl} \gamma_{kLab} Y_{ik} = \sum_{n,k} \beta_{ikl} \gamma_{kLab} X_{nik}. \tag{14}$$

In turn, per-capita income is determined by average income across all factors:

$$e_i = \frac{1}{L_i} \sum_f V_{fi} w_{fi} \tag{15}$$

By Walras' Law, trade is balanced at equilibrium.

2.3 Counterfactual equilibria

Following Dekle et al. (2007) and Caliendo and Parro (2014), the model lends itself naturally to counterfactual simulations in general equilibrium. By reformulating the above equilibrium conditions in terms of changes relative to the baseline observed equilibrium, counterfactuals can be obtained using a set of observed variables and only a few parameters to estimate. We do so with the help of hat notation, where $\widehat{Z} = Z'/Z$ denotes the relative change for variable Z (Z' referring to the value in the new equilibrium).

We consider two sets of counterfactual simulations. In a first set, we examine the impact of an increase in productivity $\widehat{z_{ik}} = \frac{z'_{ik}}{z_{ik}}$. We will simulate both a homogeneous 1% productivity increase across all countries and sectors and growth in productivity corresponding to recent changes in real GDP per capita for each country, as well as the impact of factor-specific changes in productivity.

In a second set of counterfactual equilibria, we examine the impact of a uniform 1% decrease in trade costs $\widehat{d_{nik}} = \frac{d'_{nik}}{d_{nik}}$ across all country pairs as well as the impact of country-by-country decrease in trade costs.

The model yields the following set of equilibrium conditions:

$$\widehat{D_{nk}} = \widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k} \tag{16}$$

$$\widehat{e_n} = \frac{\sum_k \widehat{D_{nk}} D_{nk}}{\sum_k D_{nk}} \tag{17}$$

$$\widehat{X_{nk}} = \frac{1}{X_{nk}} \left[D_{nk} \widehat{D_{nk}} + \sum_h \gamma_{kh} Y_{nh} \widehat{Y_{nh}} \right] \tag{18}$$

$$\widehat{X_{nik}} = \widehat{S_{ik}} \, \widehat{d_{nik}}^{-\theta_k} \, \widehat{P_{nk}}^{\theta_k} \, \widehat{X_{nk}} \tag{19}$$

$$\widehat{Y_{ik}} = \frac{\sum_n X_{nik} \widehat{X_{nik}}}{\sum_n X_{nik}} \tag{20}$$

$$\widehat{S_{ik}} = \widehat{z_{ik}}^{\theta_k} \left(\widehat{c_{ikLab}} \right)^{-\theta_k \gamma_{kL}} \prod_{f \neq L} \left(\widehat{w_{if}} \right)^{-\theta_k \gamma_{kf}} \prod_h \left(\widehat{P_{ih}} \right)^{-\theta_k \gamma_{hk}} \tag{21}$$

$$\widehat{P_{nk}} = \left[\frac{1}{X_{nk}} \sum_i X_{nik} \widehat{S_{ik}} \, \widehat{d_{nik}}^{-\theta_k} \right]^{-\frac{1}{\theta_k}} \tag{22}$$

$$\widehat{c_{ikLab}} = \left[\beta_{ikL}\,\widehat{w_{iL}}^{1-\rho} + \beta_{ikH}\,\widehat{w_{iH}}^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{23}$$

$$\widehat{w_{if}} = \left[\sum_k sh_{ikf}\,\widehat{c_{ikLab}}^{\rho-1}\widehat{Y_{ik}}\right]^{\frac{1}{\rho}} \qquad \text{for } f \in \{L,H\} \tag{24}$$

$$\widehat{w_{if}} = \sum_k sh_{ikf}\,\widehat{Y_{ik}} \qquad \text{for } f \notin \{L,H\} \tag{25}$$

$$\widehat{e_i} = \frac{\sum_f V_{fi}w_{fi}\widehat{w_{fi}}}{\sum_f V_{fi}w_{fi}} \tag{26}$$

where, in equations (24) and (25), $sh_{ifk} = \frac{\beta_{ifk}Y_{ik}}{\sum_{k'}\beta_{ifk'}Y_{ik'}}$ is the share of sector k in total revenues for factor f, and β_{ifk} is factor intensity described in equation (13) and also equals γ_{kf} for factors other than labor.

Knowing the values of variables D_{nk}, e_n, X_{nk}, X_{nik} and $V_{fi}w_{fi}$ in the baseline equilibrium as well as parameters σ_k, θ_k, γ_{hk} and β_{fk}, we can solve for all changes $\widehat{D_{nk}}$, $\widehat{\lambda_n}$, $\widehat{e_n}$, $\widehat{P_{nk}}$, $\widehat{S_{nk}}$ and $\widehat{w_{fn}}$ driven by a given change in productivity $\widehat{z_{ik}}$ or trade costs $\widehat{d_{nik}}$.

We solve this system in three iterative steps. In a first step, taking income and factor prices as given, we use equations (21), (22) and (23) to solve for prices. Then, in a second step, given the change in prices from step 1, we use equations (16) to (20) to solve for demand, trade and production. In a third step, we adjust for changes in factor prices and income using (24) to (26). We iterate these three steps until convergence is achieved.

2.4 Implications for the skill premium

In this section, we illustrate how productivity growth and trade can have an impact on the returns of some factors production if demand is non-homothetic and there is a systematic relationship between preference parameters and factor intensities. Such a relationship is supported by the results presented in Caron et al (2014) which finds, in particular, a positive correlation across sectors between skilled-labor intensity and income elasticity.

2.4.1 Productivity growth and the skill premium

When skill intensity and income elasticity are correlated across industries, productivity (TFP) growth has a positive effect on the skill premium through the composition of consumption. The intuition is simple. As productivity increases, people become richer and consume more goods from income-elastic industries which are, as we show, more intensive in skilled labor.[17] This increases the demand for skilled labor relative to less skilled labor and thus increases the relative wage of skilled workers. On the contrary, with homothetic preferences, uniform productivity growth across countries is neutral in terms of skill premium. To develop intuition, we now derive first order approximations of the response of the skill premium to productivity growth. We show later on how these approximations compare

[17] Assuming that the evolution of income is not driven by an accumulation of skills, which can of course mitigate the increase in the skill premium.

with estimates of changes in the skill premium from general equilibrium simulations. The complete derivation of these approximations can be found in Appendix B.

Autarky without intermediate goods If countries are in autarky and intermediate goods are ignored, all changes in production can be traced back to changes in domestic consumer demand. Holding nominal GDP constant (normalization), homogeneous productivity increase $\widehat{z}$ leads, as a first approximation, to a homogeneous change in prices $\widehat{P_{nk}} \approx \widehat{z}^{-1}$. Using equations (16) and (26), we obtain that the changes in demand, and therefore production, in country n and sector k are simply given by the income elasticity η_{nk}: $\log \widehat{D_{nk}} \approx (\eta_{nk} - 1) \log \widehat{z}$. We can then obtain a simple expression for the elasticity of the skill premium, $\frac{w_{nH}}{w_{nL}}$, to a TFP increase $\widehat{z}$:

$$\log\left(\widehat{\frac{w_{nH}}{w_{nL}}}\right) = \frac{1}{\tilde{\rho}_n} \log \widehat{z} \sum_k (sh^H_{nk} - sh^L_{nk})\, \eta_{nk} \tag{27}$$

where $sh^H_{nk} \equiv \frac{\beta_{Hk} Y_{nk}}{\sum_{k'} \beta_{Hk'} Y_{nk'}}$ is the share of sector k in the total skill labor employment in country n (and sh^L_{nk} refers to to the share of unskilled workers in sector k), and η_{nk} is the income elasticity in sector k, country n. In this expression, the effect on the skill premium is deflated by an adjusted elasticity of substitution $\tilde{\rho}_i = \rho - (\rho - 1) \sum_k (sh^H_{ik} - sh^L_{ik}) \beta_{ikH}$, which is very close to ρ for most countries (and always smaller than ρ given the positive correlation between skill intensity and income elasticity).

We can see that this term is positive if income elasticity η_{nk} is correlated with the demand for high vs. low-skilled labor (the term in $sh^H_{nk} - sh^L_{nk}$) across sectors. In that case, growth in TFP generates an increase in the skill premium.

This first-order approximation neglects the feedback effect of the changes in the skill premium on relative prices across products. When the skill premium increases, the relative price of skill-intensive goods increases, decreasing the relative demand for these goods and thus the relative demand for skilled workers. Our general equilibrium simulations indicate that that this feedback effect is small and can be neglected in a first-order approximation. Note also that this equation provides a good approximation of the skill premium increase even if labor is not the only factors of production – we also consider capital, land and other natural resources in our simulations to confirm this. Finally, let us also point out that this relationship would hold with income elasticities derived from any other type of preferences as a first-order approximation: the structure imposed on the model only matters for large changes and for the estimation of income elasticities.

Input-output linkages and trade can also affect the relationship between income elasticity and the demand for skills, and can be approximated as described just below.

With trade in final and intermediate goods: Under the assumption that the productivity increase $\widehat{z}$ augments all factors of production in all countries, the change in price $\widehat{P_{nk}}$ still corresponds to $\widehat{z}^{-1}$ when we neglect the feedback effect of wages on prices.[18] Similarly, we obtain that $\widehat{S_{ik}} \approx \widehat{z}^{\theta_k}$ for each exporter i in industry k, which implies that trade shares $\pi^M_{nik} = \frac{X_{nik}}{X_{nk}}$ remain constant. Combining

[18] Holding world nominal GDP constant as our normalization.

equations (18), (19) and (20), we can now account for trade and international production chains. The changes in production and demand satisfy:

$$Y_{ik}\widehat{Y_{ik}} \;=\; \sum_{n} \pi^{M}_{nik} D_{nk} \widehat{D_{nk}} + \sum_{h}\sum_{n} \pi^{M}_{nik}\; \gamma_{kh} Y_{nh}\; \widehat{Y_{nh}} \tag{28}$$

Coefficients $\pi^{M}_{nik}\gamma_{kh}$ (direct requirement coefficients) reflect the value of inputs from industry k and country i required for the production of one unit of output in sector h and country n. The matrix contraining these coefficients is a standard modeling tool to account for input-output linkages (Miller and Blair, 2009; Johnson, 2014). If we denote this matrix by Γ, the coefficients of the matrix $(I-\Gamma)^{-1}$, also called Leontief total requirement coefficients, can be then used to link changes in output to changes in final demand (see appendix for additional details):

$$\widehat{Y_{ik}} \;=\; \frac{1}{Y_{ik}} \sum_{n,h} \gamma^{tot}_{nikh} D_{nh} \widehat{D_{nh}} \tag{29}$$

where γ^{tot}_{nikh} is the value of inputs from i in sector k needed for each dollar of final good h consumed in country n. Using this result and $Y_{ik} = \sum_{n,h} \gamma^{tot}_{nikh} D_{nh}$, we can then express the difference in the changes in wages between skilled and unskilled workers as function of the changes in final demand, and therefore as a function of income elasticities in downstream sectors, following the same first-order approximation as above:

$$\begin{aligned}
\log\left(\frac{\widehat{w_{iH}}}{w_{iL}}\right) \;&=\; \frac{1}{\tilde{\rho}_i} \underbrace{\sum_{k,h,n} (sh^{H}_{ik} - sh^{L}_{ik})\, \varphi^{dir}_{nikh}\, \log \widehat{D_{nh}}}_{\text{Income effects in final demand}} + \frac{1}{\tilde{\rho}_i} \underbrace{\sum_{k,h,n} (sh^{H}_{ik} - sh^{L}_{ik})\, \varphi^{indir}_{nikh}\, \log \widehat{Y_{nh}}}_{\text{IO linkage effects}} \\
&=\; \frac{1}{\tilde{\rho}_i} \log \widehat{z} \sum_{k,h,n} (sh^{H}_{ik} - sh^{L}_{ik})\, \varphi^{tot}_{nikh}\, \eta_{nh}
\end{aligned} \tag{30}$$

where $\varphi^{tot}_{nikh} = \gamma^{tot}_{nikh} D_{nh}/Y_{ik}$ denotes the share of production in country i sector k that is eventually consumed as final good from sector h in country n. This generalizes equation (27) to account for international trade and intermediate goods: a country's skill premium will increase if a sector's demand for high vs. low-skilled labor (the term in $sh^{H}_{nk} - sh^{L}_{nk}$) is correlated with the average income elasticity of all its downstream sectors, in all countries.

2.4.2 Trade cost reductions and the skill premium with non-homothetic preferences

How does a reduction in trade costs affect the skill premium? Standard models of trade such as Heckscher-Ohlin model have focused on the supply side and ignored any role for the demand side in explaining the changes in the skill premium. Here we discuss how the structure of preferences may affect these results relative to a similar structure where we impose homothetic preferences.

In a similar fashion as above for the productivity and the skill premium, we can provide a first-order approximation of the effect of trade cost reductions $\hat{d}$ on the skill premium (additional details are provided in Appendix) by neglecting second-order terms in $(\log \hat{d})^2$. The decomposition isolates the direct effect of changes in trade costs and the direct effect of changing consumption patterns from remaining general equilibrium effects.

Combining equations (25) for factor prices, (20) for production and (19) for bilateral trade, we obtain:

$$\log\left(\widehat{\frac{w_{iH}}{w_{iL}}}\right) \approx -\frac{1}{\tilde{\rho}_i}\sum_k (sh^H_{ik} - sh^L_{ik}) \underbrace{\theta_k \left[(1-\pi^X_{iik}) - \sum_n \pi^X_{nik}(1-\pi^M_{nnk})\right] \log \hat{d}}_{\text{Direct trade patterns effects}} \tag{31}$$

$$+\frac{1}{\tilde{\rho}_i}\sum_k (sh^H_{ik} - sh^L_{ik}) \underbrace{\sum_n \pi^X_{nik}\,\varphi_{nFk}\,\log\left(\widehat{\lambda_n}^{-\sigma_k}\widehat{P_{nk}}^{1-\sigma_k}\right)}_{\text{Income effects in final demand}} \tag{32}$$

$$+\frac{1}{\tilde{\rho}_i}\sum_k (sh^H_{ik} - sh^L_{ik}) \underbrace{\sum_{n,h} \pi^X_{nik}\,\varphi_{nhk}\,\log\,\widehat{Y_{nh}}}_{\text{IO linkage effects}} \tag{33}$$

$$+\frac{1}{\tilde{\rho}_i}\sum_k (sh^H_{ik} - sh^L_{ik}) \underbrace{\sum_n \pi^X_{nik} \sum_j \pi^M_{njk}(\log\widehat{S_{ik}} - \log\widehat{S_{jk}})}_{\text{Cost feedback effects}} \tag{34}$$

where π^X_{nik} denotes the share of production from country i in sector k that is exported to country n and $\varphi_{nhk} = \frac{\gamma_{hk}Y_{nh}}{X_{nk}}$ is the share of production in country n that is purchased as inputs by sector h. π^X_{nik} and π^M_{nik} are fitted export and import shares which are constructed based on consumption patterns derived from either homothetic or non-homothetic preferences.

This decomposition, (31) through (34), can be used to illustrate several mechanisms through which consumption patterns and trade costs affect the demand for skills. The first term captures the direct incidence of trade costs on production, ignoring changes in consumption patterns and other general-equilibrium effects, while the remaining terms capture indirect effects. The second term captures the effect of changes in the composition of final demand caused by changes in income and prices. The third term captures the effect of changes in intermediate demand through input-output linkages. The fourth term captures changes in factor costs. As we will show, the quantification of all of these terms depends on preferences being homothetic or non-homothetic.

The first term, which reflects the most direct effect of trade costs on production, depends crucially on export shares π^X across countries and sectors. In particular, it reveals that trade cost reductions will lead to a larger increase in the skill premium in countries in which the sectors which employ the largest shares of skilled workers (high $sh^H_{ik} - sh^L_{ik}$) have the highest export shares $(1 - \pi^X_{iik})$. $\sum_n \pi^X_{nik}(1 - \pi^M_{nnk})$ is a term capturing import competition, indicating that the skill premium will be negatively affected by the decrease in trade costs in a country that imports a large share of their

consumption of skill-intensive products.

As we will illustrate, fitted export shares depend not only on the supply side (comparative advantage) but also differ largely across specifications on the demand side. With non-homothetic preferences, poor countries consume relatively less skill-intensive and income-elastic goods than other countries, and thus have higher export shares for these goods. Conversely, they have relatively lower export shares in income-inelastic and less skill-intensive goods. A consequence is that a reduction in trade leads to proportionally larger increases in the production of skill-intensive goods relative to the homothetic case in poor countries. In rich countries, the opposite should hold.

Another direct impact of trade cost reductions on the skill premium can potentially stem from differences in tradability and trade elasticities across sectors. If skill-intensive sectors have higher elasticity of trade to trade costs θ_k or higher export shares, they would expand relatively more with a reduction in trade costs, and the demand for skills would increase with trade openness. Hence we will later examine whether trade shares $1 - \pi_{iik}$ or θ_k are correlated with skill intensity and income elasticities (section 3.4).

The remaining channels in the decomposition relate to different ways in which the model's endogenous variables react to the reduction in trade costs. The second channel identifies the role of trade-induced income effects in final demand described in (32), leading to changes in consumption patterns across industries. As a country and its neighbors open to trade, their income increases, λ_n decreases, and consumption shifts towards income-elastic and skill-intensive goods. This mechanism is the same as was highlighted in the first set of counterfactuals in which we increase productivity. Obviously, this income effect is not present if we assume homothetic preferences. The term (32) also captures a price effect, as trade affects the relative price of final goods.

The third term in (33) captures the relationship between the skill premium and changes in the demand for intermediate goods. Skill-intensive sectors tend to require skill-intensive inputs, so differences in demand patterns caused by non-homothetic preferences can potentially magnify both the direct effect and the final demand effect through input-output linkages.[19]

Finally, the fourth "Cost feedback" term (34) reflects changes in the supplier terms S_{jk} and captures general-equilibrium feedback on wages and other factor prices. This feedback mitigates the effect of trade on the skill premium. For instance, a higher skill premium leads to relative higher costs in skill-intensive industries, lower exports in these industries, and mitigation of the skill premium increase.

3 Estimation

We now discuss the data and the estimation of the key parameters in the model. The estimation here closely follows Caron, Fally and Markusen (2014), although with a newer dataset and a number of additional robustness checks.

[19] One should note that we assume Cobb-Douglas production functions, which implies constant input-output requirement coefficients. Additional effects on the skill premium can be obtained by assuming strong complementarity between manufacturing goods and services, as described in Cravino and Sotelo (2016).

3.1 Data

Our empirical analysis is mostly based on the Global Trade Analysis Project (GTAP) version 8 dataset (Narayanan et al., 2012). This dataset contains consistent and harmonized production, consumption, endowment, trade data and input-output tables for 57 sectors[20] of the economy, 5 production factors, and 109 countries in 2007. The set of sectors covers both manufacturing and services and the set of countries covers a wide range of per-capita income levels. Demand systems are estimated over all available countries using final demand values based on the aggregation of private and public expenditures in each sector.

Factor usage data by sector are directly available in GTAP and cover capital, high-skilled and low-skilled labor, land and other natural resources. In our counterfactual simulations, we use country-specific labor shares to characterize our benchmark equilibrium, but our results remain essentially identical when we use averages of labor shares instead, either across all countries or across relevant subset of countries. These robustness checks are discussed in Section 4.3.[21]

Finally, bilateral variables describing physical distance, common language, access to sea, colonial link and contiguity, required to estimate gravity equations, are obtained from CEPII (www.cepii.fr).[22] Dummies for regional trade agreement and common currency are from de Sousa (2012).

Among other model parameters, all but one will be estimated. We do not estimate the elasticity of substitution between skilled and unskilled labor, ρ, and instead calibrate ρ to 1.4 as estimated by Katz and Murphy (1994). We examine alternative calibrations in Section 4.3 and show that the effect of productivity growth and trade costs reductions are approximately proportional to $\frac{1}{\rho}$. Since most estimates in the literature lie between 1 and 2, our results are robust to alternative calibrations.

3.2 Estimation strategy

The value of final demand in an industry is determined as in Equation (5) or equivalently Equation (1) for individual expenditures $x_{nk} = \frac{D_{nk}}{L_n}$. In log, the model provides:

$$\log x_{nk} = -\sigma_k . \log \lambda_n + \log \alpha_{2,k} + (1 - \sigma_k) . \log P_{nk} \tag{35}$$

where $\alpha_{2,k}$ is a preference parameter which varies across industries only. In addition, final demand should satisfy the budget constraint which determines λ_n: a higher income per capita is associated with a smaller Lagrange multiplier λ_n.

[20] Some sectors in GTAP are used primarily as intermediates and correspond to extremely low consumption shares of final demand. 6 sectors for which less than 10% of output goes to final demand (coal, oil, gas, ferous metals, metals n.e.c. and minerals n.e.c.) are assumed to be used exclusively as intermediates and are dropped from the final demand estimations. We also drop "dwellings" from our analysis, as it is associated with no trade and large measurement errors in consumption and factor intensities.

[21] The results are also not sensitive to using either country-specific or average direct requirement coefficients to calibrate the cost parameters γ_{khi} (equation 9).

[22] Distance between two countries is measured as the average distance between the 25 largest cities in each country weighted by population. Similarly, internal distance within a country is measured as the weighted average of distance across each combination of city pairs. See Mayer and Zignago (2011).

If there were no trade costs, the price index P_{nk} would be the same across countries and could not be distinguished from an industry fixed effect. If, in richer countries, consumption were larger in a particular sector relative to other sectors, the estimated $\hat{\sigma}_k$ would be larger for this sector. Since trade is not costless, estimated income elasticities would be biased if we did not control for the price index P_{nk} (to capture supply-side characteristics). As richer countries have a comparative advantage in skill-intensive industries, the price index is relatively lower in these industries. Conversely, poor countries have a comparative advantage in unskilled-labor-intensive industries and thus have a lower price index in these industries relative to other industries. When the elasticity of substitution between industries is larger than one, these differences in price indexes in turn affect the patterns of consumption. If we were not controlling for P_{nk}, we would overestimate the income elasticity in skill-intensive sectors.

We thus proceed in two steps. The main goal of the first step is to obtain a proxy for the price index $\log P_{nk}$. According to equilibrium condition (11), $\log P_{nk}$ depends linearly on $\log \Phi_{nk}$ which itself can be identified using gravity equations. Gravity equations by sector are derived from equation (8). Specifying trade costs $\log d_{nik}$ as a linear combination of trade proxies, we obtain our first-step estimation equation:

$$X_{nik} \;=\; \exp\left[FX_{ik} \;+\; FM_{nk} \;-\; \sum_{var} \beta_{var,k} TC_{var,ni} \;+\; \varepsilon^{G}_{nik}\right] \tag{36}$$

where the set of variables $TC_{var,ni}$ refers to trade costs proxies: log physical distance between countries n and i, a border effect (dummy equal to one if $n = i$), dummies for common language, colonial links, contiguity (equal to one if countries i and n share a common border), free-trade-agreements, common currency and common legal origin (additional details are provided in Appendix). Following the model structure and using our estimates, we can then construct :

$$\widehat{\Phi}_{nk} \;=\; \sum_{i} \exp\left(\widehat{FX}_{ik} - \sum_{var} \widehat{\beta}_{var,k} TC_{var,ni}\right) \tag{37}$$

Notice that, if country n is close to an exporter that has a comparative advantage in industry k, i.e. an exporter associated with a large exporter fixed effect FX_{ik} (large S_{ik}), our constructed $\widehat{\Phi}_{nk}$ will be relatively larger for this country reflecting a lower price index of goods from industry k in country n.

In a second step, we estimate the final demand equation (35) using $\widehat{\Phi}_{nk}$, which can be rewritten as:

$$\log x_{nk} = -\sigma_k . \log \lambda_n + \alpha_{3,k} + \frac{(\sigma_k - 1)}{\theta_k} \log \widehat{\Phi}_{nk} + \varepsilon^{D}_{nk} \tag{38}$$

where $\alpha_{3,k}$ is an industry fixed effect and λ_n is the Lagrange multiplier associated with the budget constraint which must be endogenously satisfied, such that $\sum_k x_{nk} = e_n$ (using observed per capita income e_n). While the coefficient for $\log \widehat{\Phi}_{nk}$ helps identify the ratio $\frac{(\sigma_k - 1)}{\theta_k}$, the level of each term is not identified. We therefore allow θ_k to vary across sectors but we impose its average to equal 4, a standard calibration value in the trade literature (Simonovska and Waugh, 2014).[23] We estimate

[23] In our estimation, the coefficients for $\log \widehat{\Phi}_{nk}$ equal 0.4 on average. This implies that σ_k lies around 2 for most sectors.

equation (38) by constrained non-linear least squares.

Using our estimates of σ_k, income elasticities can then be retrieved as:

$$\widehat{\eta}_{nk} = \hat{\sigma}_k \cdot \frac{\sum_{k'} \hat{x}_{nk'}}{\sum_{k'} \hat{\sigma}_{k'} \hat{x}_{nk'}} \tag{39}$$

given that the weighted average of income elasticities must equal one (Engel aggregation).

We describe our procedure in the appendix in more details, along with alternative specifications to examine the robustness of our estimates. Firstly, an alternative specification disregards the budget constraint in our estimation, i.e. estimates equation (38) without imposing the sum of fitted expenditures to equal the sum of actual expenditures. Secondly, we instrument $\log \widehat{\Phi}_{nk}$ by an alternative measure based only on foreign markets, i.e.: $\widehat{\Phi}^{IV}_{nk} = \sum_{i \neq n} \exp\left(\widehat{FX}_{ik} - \sum_{var} \widehat{\beta}_{var,k} TC_{var,ni}\right)$ summing across $i \neq n$. This leaves out each country's own exporter fixed effect $\widehat{FX}_{nk}$ which may be endogenously related to final expenditures x_{nk}. Thirdly, we examine an alternative specification approximating the log of the Lagrange multiplier by a linear function of the log of income per capita: $\log \lambda_n \approx -\nu \log e_n$. This approach allows us to identify $\widehat{\sigma_k \nu}$ up to a constant term ν, but one can see that this constant term drops out of equation (39): the implied income elasticities estimates are scale invariant. Finally, we have also re-estimated (38) by calibrating $\theta_k = 4$ across all sectors thereby imposing an additional constraint on the coefficient of $\log \widehat{\Phi}_{nk}$ in equation (38).

3.3 Parameter estimates

Gravity Table 1 presents the results of the gravity equation estimations (Equation 36). The first column shows the average estimated coefficient across industries while the second column shows the standard deviation of the coefficient estimate across industries. These standard deviations reflect the variations of the coefficients across industries but do not reflect measurement errors: all coefficient estimates are significantly different from zero for most industries. There is significant variation in the distance and border effect coefficients across industries. As usually found in the gravity equation literature, the coefficient for distance is on average close to minus one and the border effect coefficients are large. Coefficients for political variables such as free trade agreements and currency unions are also significant. These estimates imply an important role for geography in explaining relative prices. Proximity to countries with a comparative advantage in certain industries leads to significantly lower relative prices in these industries. These effects are captured in the $\widehat{\Phi}_{nk}$ terms, which vary greatly across countries and sectors (the standard deviation of demeaned $\log \widehat{\Phi}_{nk}$ is 1.22, taking the residual of a regression of $\log \widehat{\Phi}_{nk}$ on country and sector fixed effects).

Preferences: Table 2 describes our income elasticities estimates for the average-income country, as well as differences in skill intensity across sectors. Estimates range from nearly zero for rice to 1.311

Note that the level of sigmas does not affect the computation of income elasticities, as described in equation (39). Note that while CRIE preferences imply an explicit link between price and income elasticities, In Section 4.3 we examine the robustness of our results by using Comin et al. (2015) preferences, which results in an estimated elasticity of substitution of 0.76 across sectors.

for financial services, with a clear dominance of agricultural sectors at the low end and service sectors at the high end. Half of the estimates are significantly different than unity at 95 %, with standard errors between 0.05 and 0.2 for most sectors.[24]

Comparing our estimation results with the same regression imposing homotheticity (i.e. imposing $\sigma_k = \sigma$), we confirm the results from Caron, Fally and Markusen (2014): allowing for non-homotheticity improves the R-squared (non-homotheticity reduces by 25.6% the variance left unexplained with a homothetic preference specification). The contribution of non-homotheticity to the fit of demand patterns is statistically significant: the F-stats associated with imposing common σ_k's across industries show that homotheticity is clearly rejected (F-stat equal to 12.15, all P-values < 0.001).[25]

We also examine several alternative specifications as robustness checks. First, removing the budget constraint as a constraint in our estimation leads to very similar results, with the new estimates of Lagrange multipliers correlated at 99% with our baseline estimates. In other words, given the large variations in per capita income, introducing error terms in the budget constraint constraint does not affect our results. In all these regressions, Lagrange multipliers and per capita income are highly correlated, hence once can obtain very similar results by approximating $\log \lambda_n$ by a linear function of the log of per capita income. In an alternative specification, we instrument $\log \widehat{\Phi}_{nk}$ by an alternative measure based only on foreign markets, taking the sum of exporter fixed effects across all other countries but excluding its own market, but the estimated income elasticity estimates remain very close, as shown in Figure A.1 in Appendix. Finally, imposing $\theta_k = 4$ leads to estimates of income elasticities that are highly correlated with our baseline estimates, as illustrated again in Figure A.1 in Appendix.

Aside from alternative estimations of preferences featuring Constant Relative Income Elasticities (CRIE), we have also estimated preferences as in Comin, Lashkari and Mestieri (2016). These preferences impose a common price elasticity σ across sectors while allowing for different income elasticities of demand. Again, this specification leads to very similar results. We also refer to Caron et al (2014) for a comparison between CRIE, LES (Stone Geary) and AIDS (Deaton and Muellbauer, 1980). While LES yields to much smaller differences in income elasticities across sectors, estimates based on AIDS are fairly similar to CRIE (the rank correlation is higher than 85% between any two of these specifications).

3.4 Empirical regularities

Correlation between income elasticity and skill intensity We now investigate the relationship between income elasticities and factor intensities across sectors, as in Caron, Fally and Markusen (2014). As we illustrated in the theory section, the correlation between skill intensity and income elasticity plays a crucial role in determining the impact of productivity growth and trade on the relative demand for skilled labor. Table 3 reports correlation coefficients between skill intensity and

[24] Two sectors have standard deviations between 0.2 and 0.3: gas and wheat.

[25] As in Caron et al (2014), the Akiake (AIC) and Bayesian (BIC) information criterions favor the specification allowing for non-homotheticity.

income elasticity, or, in columns 2 and 4, the beta coefficients associated with each intensity parameter in regressions of income elasticity on several factor intensities, as well as robust standard errors.[26] Our measures of factor intensity correspond to the ratio of skilled labor, capital or natural resource (including land) to total labor input. These factor intensities are computed including the factor usage embedded in the intermediate sectors used in each sector's production. The correlation is also illustrated in Figure 1.

We find that skill intensity is positively and significantly correlated with income elasticity. This correlation is particularly large and higher than 50%, while income elasticity is only weakly correlated with natural resources intensity and capital intensity once we control for skill intensity. Part of this large correlation is explained by the composition of consumption into services vs. manufacturing industries, with services being generally associated with a larger income elasticity. However, the correlation remains above 50% even after excluding service industries.

As described in appendix, we examine the robustness of our income elasticities estimates using alternative specifications: imposing $\theta_k = 4$, instrumenting $\log \Phi_{nk}$, using a reduced-form approximation, etc. In all these specifications, the correlation between the estimated income elasticity and skill intensity remains very high, above 50%. Moreover, we find similar correlations if we estimate alternative (non-homothetic) preferences such as AIDS, LES or implicitly additive preferences as in Comin et al (2016).

Correlation between income elasticity and other factor intensities It is interesting to note that capital intensity is positively correlated with income elasticity, as found by Reimer and Hertel (2010), but this correlation is not as large as for skill intensity (less than 10% in most specifications) and not robust to controlling for skill intensity as shown in columns (2) and (4) of Table 3. In our framework, this implies for instance that growth should not greatly affect the returns from capital relative to wages. Income elasticity also tends to be negatively correlated with intensity in natural resources, which supports Prebisch-Singer hypothesis and implies that a growth in income per capita would lower the relative price of natural resources. However the correlation is small and not robust to controlling for skill intensity (Table 3).

Correlation with trade shares Another potential determinant of the incidence of trade costs on the skill premium is the correlation between trade shares and skill intensity across sectors. A decrease in trade costs leads to a increase in the relative price of traded products, and therefore a change in the relative employment share of sectors, depending on the elasticity of substitution among sectors. Here we examine the cross-sectoral correlations between skill intensity and average export shares $(1 - \pi^X_{iik})$ (averaged across countries).

Burstein and Vogel (2016) document that skill intensive sectors tend to be more traded, but do not consider service sectors. In our data, we find that the correlation depends crucially on the

[26] In Caron et al (2014), we find that robust standard errors are very close to bootstrap standard errors constructed by resampling importers and sectors in all steps of the estimation in order to account for generated variable biases (income elasticities are estimated rather than observed).

inclusion of service sectors. If service sectors are ignored, the correlation is positive at +30%. Once we include services, however, the correlation is considerably reduced, weakly negative (-6%) and no longer significantly different from zero. These patterns are illustrated in Figure 2.

Similar patterns are observed for the correlation between export shares and income elasticities. Looking across all sectors, income-elastic goods tend to be less traded (-27% correlation). Once we exclude services, this correlation becomes significantly positive (+38%).

4 Quantitative implications for the skill premium

4.1 Productivity growth and the skill premium

As argued in Section 2.4, non-homothetic preferences may help explain why the skill premium has been increasing for a large number of countries (see Goldberg and Pavcnik 2007 for empirical evidence on the skill premium increase).

When preferences are homothetic, an homogeneous increase in productivity in all countries should neither affect the patterns of trade nor the relative demand for skilled labor. However, when preferences are non-homothetic and when the income elasticity of demand is positively correlated with the skill intensity of production, an increase in productivity makes consumers richer which in turn induces a relative increase in consumption in skill-intensive industries (high-income elastic industries) and thus raises the relative demand for skilled labor. This demand-driven explanation contrasts with previous studies that have focused on the supply side.

In this section, we use our general equilibrium model[27] to quantitatively estimate the elasticity of the skill premium to total factor productivity (TFP). We first simulate a 1% increase in TFP in all countries and examine how it affects the skill premium in an open economy setting. This counterfactual pinpoints the role of non-homothetic preferences since the same counterfactual would keep the skill premium unchanged if preferences were homothetic. We also simulate productivity increases corresponding to growth rates of per capita income in each country between 1990 and 2014. Finally, we use the approximations provided in Section 2.4.1 to decompose the role of preferences, intermediate goods and trade.

Figure 3 displays the elasticity of the skill premium to TFP resulting from an exogenous 1% TFP increase in all countries[28]. Very similar elasticities are obtained by simulating a 10% increase. Our simulations show that this elasticity is positive for all countries and often large, particularly for developing countries. For instance, the elasticity of the skill premium to productivity is about 0.07 for China. The predicted elasticity is higher than 0.2 in a number of the least developed countries, particularly those of South Asia and Africa. The elasticity for South American countries and other middle income countries is generally in the 0.05 to 0.10 range, while the elasticity for most rich countries is around or below 0.05.

[27]The model is formulated in GAMS and solved by the non-linear PATH solver.

[28]The elasticity is simply the result of dividing the simulated change in the skill premium by the exogenous change in TFP, 0.01.

Role of trade and input-output linkages We now use the approximations derived in the theory section to identify the relative roles of trade and intermediates in explaining the results above. As discussed in section 2.4.1, the main argument for the role of non-homothetic preferences does not involve trade. It also applies to closed economies. To identify the role of trade, we compute closed-economy approximations of the elasticity of the skill premium to productivity. We use our estimates for income elasticities (η_{nk}) as well as labor shares (sh^H_{nk} and sh^L_{nk}) and input-output coefficients, in the approximation described by equation (30), which accounts for input-output linkages.

These closed-economy elasticity approximations are plotted on Figure 4 against the simulated open-economy elasticity estimates. As can be seen, there is a very high correlation between the approximated skill-premium elasticity in closed economy and the simulated elasticities in open economy. The coefficient of the fitted line yields a coefficient equal to 1.03 (s.e. 0.03) with an R-squared of 99%. Besides production being mostly destined to local consumption, the difference between the closed-economy and open-economy counterfactuals is small because countries tend to trade with countries of similar per capita income, so that the change in the composition of consumption of their trading partners is fairly similar to their own. We conclude that ignoring trade linkages when investigating the role of income-driven shifts in consumption would not lead to substantial biases.

We next investigate the importance of input-output linkages in determining the skill premium estimates. Figure 4 shows that the skill premium elasticity approximations implied by the formula in equation (27), which only takes the final demand for goods into account, also provides a good approximation of the open-economy simulated elasticity. In this case, though, approximated elasticities are consistently above the simulated elasticities, suggesting that ignoring input-output linkages would lead to over-estimating the increase in skill premium somewhat.

Decomposition Why is this effect on the skill premium larger for poor countries? As we have shown in section 4, it depends on the income elasticity of demand and employment shares across skills and sectors. CRIE preferences generate income elasticities of consumption which decrease with income, which could explain why the effect on the skill premium may be smaller for richer countries: income growth leads to less re-allocation of consumption across sectors.

A simple decomposition shows that while this mechanism is at play, differences in employment shares across skills and countries play a more important role. In developing countries, a larger share of the low-skilled labor force produces income-inelastic goods while skilled workers produce income-elastic goods. In rich countries, there are smaller differences in income elasticity between the goods that skilled and less-skilled workers produce. This is illustrated in Figure 5: the predicted elasticity of the skill premium to productivity also decreases with income if we replace employment shares by their average across countries within each sector, but the difference across countries is slightly more pronounced if instead we replace income elasticity by its average across countries within each sector (i.e. such that all the variations across countries comes from differences in employment shares).

With actual growth in per capita GDP Finally, we examine the change in the skill premium predicted by our mechanism if each country grew at historical rates. Figure 6 shows our estimates of the change in the skill premium resulting from the simulation of growth rates from the Penn World Table (version 9 "cgdpe") between 1990 and 2014. Per capita GDP and simulated skill premium increases are also reported in Table 4) in Appendix. The objective of the exercise is not to provide predictions of future changes in the skill premium, nor quantify the share of observed changes which the mechanism might have explained. Observed estimates of skill premium are likely caused by a number of confounding and possibly interacting mechanisms. Rather, it aims to provide an estimate of the potential magnitude of the effect which can simply be contrasted with observed values.

Results vary considerably between countries. The predicted increase can be very large (above 10% for 18 countries) or negative (for only 3 countries). For China, our simulation leads to a 10.1% increase in the skill premium. To contrast, Ge and Yang (2009) find that the skill premium increase was 40% in China between 1992 and 2006. [29] Our simulation yield a 15.6% increase for India, to be contrasted to an observed 11.9% increase over the 1987-2004 period (Azam, 2009). For Thailand, our simulations lead to a 5% increase, to be contrasted to the 17.2% observed skill premium increase from 1990 to 2004 (DiGropello and Sakellariou, 2010). Overall, the effect is largest in fast-growing developing economies.

In Latin America, the mechanism explains smaller but still significant shares of observed increases: our simulations lead to a 6.2 % increase in Peru, contrasted to an observed increase of 23.9% from 1994 to 2000 (Mazumdar and Quispe-Agnoli, 2004); a 1.8% increase in Mexico, contrasted to an observed 12.5% increase (Verhoogen, 2008) from 1990 to 2001; and a 3.5% increase in Columbia to be contrasted to an observed 26.4% skill premium increase between 1990 and 2000 (Gutierrez, 2009).

Among developed countries, the predicted increase in skill premium driven by demand-side reallocation is rather small but non-negligible: slightly less than 1% for instance for the US, contrasted to an observed 3.1% skill premium increase (Parro, 2013); 1% in Great Britain, contrasted to an observed 2% increase for 1990-2005 (Parro, 2013). The low estimates resulting from the simulations generally match the lower observed increases in the skill premium for the richest countries.

Another observation which we can make is that despite large differences in skill premium estimates, we find that the implied elasticities of the skill premium to productivity using actual income growth are similar to what we obtain in the neutral productivity growth simulations. Indeed, most of the variation in estimates stems from the high variation in the growth rates which countries experienced during this time period, especially among developing countries. This suggests again that trade linkages between countries are not major drivers of this demand-driven mechanism.

4.2 Trade liberalization and the skill premium

Our next set of counterfactual simulations examines the effect of a 1% reduction in trade costs, first across all country pairs, then, in Section 4.3, country-by-country (to and from each country in turn).

[29] The Gini coefficient in China has also sharply increased from less than 30 in the early 1990s to 42 in 2005 (World Bank data).

In each case, we compare two specifications, one imposing homothetic preferences and one allowing for non-homotheticity, using our baseline estimates.

Figure 7 displays the percentage change in the skill premium caused by the 1% reduction in trade costs. With homothetic preferences, the effect of trade on the skill premium tends to be negative for developing countries and positive among the richest countries. This is in line with standard Stolper-Samuelson predictions: trade leads to a decrease in the relative demand for skilled labor in countries that are abundant in unskilled labor, and an increase in the skill premium in more skilled-labor abundant countries.

This effect is mitigated, and sometimes reversed, when we allow for non-homothetic preferences. As can be seen in Figure 7, the significant correlation between the effect of trade on the skill premium and a country's per capita GDP largely disappears. To make things clearer, Figure 8 plots the difference in the effect of trade on the skill premium between non-homothetic and homothetic preferences. While the difference is largest for countries with low per capita income, it is positive for almost all countries: trade cost reductions lead to a larger increase in the skill premium with non-homothetic preferences.

Decomposition: We use equations (31) through (34) to examine the channels that explain these systematic differences between homothetic and non-homothetic preferences.

Figure 9(a) plots the "direct trade patterns effects" term of the decomposition, (31). This term approximates the direct effect of a trade cost reduction on the skill premium, holding trade and demand patterns constant (for each specification of preferences) and neglecting general-equilibrium feedback effects caused by changes in factor costs. Figure 11(a) plots the difference between non-homothetic and homothetic preferences. These differences are driven only by variations in trade shares caused differences in demand patterns, as the supply-side parameters are held constant across both preference specifications. With non-homothetic preferences, low income countries have a relatively smaller demand for skill-intensive goods, and thus tend to export a larger share of these goods relative to the homothetic preferences benchmark. As a result, a decrease in trade costs leads to a larger expansion of skill-intensive sectors and therefore a larger increase in the relative demand for skilled labor and the skill premium. The converse holds for rich countries, who end up facing a relatively smaller demand for skill-intensive goods when they open up to trade. The difference between non-homothetic and homothetic preferences is quite large and explains (on average) about half of the overall simultated difference in skill premium changes for the poorest countries. While the effect on high-income countries is much weaker, it does reveal that a homothetic model would slightly over-estimate the impact of the skill premium on very open rich countries. We conclude that models imposing homothetic preferences when describing trade shares would substantially over-estimate the net factor content of trade, and therefore the effect of trade on the skill premium.

As equation (31) suggests, the direct effect of trade costs may also be affected by a systematic correlation between income elasticity, skill intensity and average tradability across sectors. In Section 3.4, however, we find that such a correlation is slightly negative but very weak once services are

included.[30] In order to further test for the potential relevance of this correlation, we have re-evaluated the direct effect using average export shares at the sector level. The difference between non-homothetic and homothetic preferences in this case is very small. Most of the direct effect, thus, relies on variations in country-specific export shares driven by differences in comparative advantage.

Figure 9(b) plots the second "income effects in final demand" term of the decomposition and Figure 11(b) plots the difference between the two preference specifications. This term captures changes in consumption patterns driven by changes in prices and income. With homothetic preferences, trade only generates small changes in consumption patterns.[31] However with non-homothetic preferences, trade liberalization generates an increase in real income which, similar to productivity growth, leads to a reallocation of consumption towards income-elastic goods which are also more skill intensive, and leads to an increase in the skill premium. Contrasted to the direct impact of trade on the skill premium, this channel is quantitatively strong. The effect of trade on income changes consumption patterns in a way that explains a large part of the differences in the effect of trade across preference specifications. As in the first set of counterfactual simulations, it is strongest for developing countries. Note that this term only reflects the direct impact of changes in final demand, the effect of intermediate demand being captured in the following term.

Figure 10(a) illustrates the role of input-output linkages for each specification, while Figure 11(c) plots the difference between the two specifications. Since trade-driven income growth leads to a larger expansion in skill-intensive sectors with non-homothetic preferences, it also leads to a relatively larger demand for skill-intensive intermediate goods. One can see in Figure 11(c) that the difference in the specifications is not as large as what is explained by the first two decomposition terms (and about half of the differential effect on final demand).

Finally, as illustrated in the fourth term of our decomposition, general equilibrium effects captured by the differences in S_{ik} mitigate the direct effect of trade costs. As shown in Figure 10(b) this feedback effect can be large for some countries, especially those for which the direct effect was large. However, the difference between homothetic and non-homothetic preferences is small (as also illustrated in Figure 11(d) – notice the scale on the Y axis): while general equilibrium feedbacks mitigate the differences described with the previous decomposition terms, they are far from offsetting them.

To summarize, a combination of the income-driven consumption composition effect (which drives the second and third terms) and the substantially reduced Stolper-Samuelson effect (identified through the first term) explains why, in our general equilibrium simulations, non-homothetic preferences imply only a small depressing effect of trade on the skill premium in poor countries. For rich countries, non-homothetic preferences play a smaller role, in part because the two effects coming from non-homotheticities (direct and income effects) go in opposite directions. In their case, though, the income effect generally dominates and the skill premium is slightly higher than with homothetic preferences.

[30] Note that to be able to simulate general equilibrium effects on the skill premium, we must include all sectors in the economy.

[31] With lower price elasticities, as in Cravino and Sotelo (2016), we find higher effects on the skill premium, but the effects remain larger with non-homothetic preferences, as documented in our robustness checks in Section 4.3.

4.3 Robustness

Elasticity of substitution between skilled and unskilled workers As made evident in the analytical approximations provided in Section 2.4, the effects of productivity and trade are sensitive to the elasticity of substitution ρ between skilled and unskilled labor. A higher ρ leads to smaller effects. While this elasticity is difficult to estimate in practice, most estimates lie between 1.4 and 1.7 (Acemoglu 2007).

Using our analytical approximations, it is fairly straightforward to predict the role of alternative elasticities on the effect of productivity and trade. Relative to the Cobb-Douglas specification ($\rho = 1$), the change in the skill premium is scaled by a ratio of 1 over $\tilde{\rho}_i = \rho - (\rho - 1)\sum_k (sh_{ik}^H - sh_{ik}^L)\beta_{ikH}$. We find that this adjustment provides a very good approximation of actual simulations results with higher elasticities as long as the changes are not too large. It can therefore be used to quickly identify the sensitivity of results to ρ.

For instance, for the trade counterfactual (reducing trade costs by 1%), we compare results with $\rho = 1.4$ (as in our benchmark calibration) and $\rho = 1.7$, after multiplying the skill premium increase by $\tilde{\rho}_i = \rho - (\rho - 1)\sum_k (sh_{ik}^H - sh_{ik}^L)\beta_{ikH}$. Elasticities of substitutions between 1.4 and 1.7 imply values of $\tilde{\rho}_i$ between 1.3 and 1.6. As shown in Figure 12, there is virtually no difference between simulations once we account for the $\tilde{\rho}_i$ adjustment. Also, the effect of growth and trade remains sizeable across this range of elasticities.

Homogeneous trade elasticity $\theta_k = 4$ Another parameter which may potentially affect our simulation results is θ_k. This parameter drives the response of trade flows to changes in trade costs. It affects our price index estimates and thus the estimation of income elasticities, and may also affect the results of the trade cost counterfactual. Our baseline simulations rely on sector-specific estimates of θ_k which we recover from the estimation of preferences of equation (38). As documented in Caron et al 2014, the income elasticity estimates are sensitive to this choice. Moreover, our estimated θ_k are slightly correlated with income elasticity (11% correlation) but this correlation is not crucial for our results. To check the robustness of results, a simple alternative is to assume that $\theta_k = 4$ in all sectors as in Simonovska and Waugh (2011), a calibrated value often borrowed by the international trade literature, also in line with estimates by Costinot et al (2012), Donaldson (2012) among others. In appendix, we show that this assumption leads to alternative estimates of income elasticities that are highly correlated (at 86%) with our baseline estimates. As these are also highly correlated with skill intensity, using these estimates in our simulations leads to similar results for the skill premium. Figure A.3 in appendix replicates the productivity counterfactual and Figure A.4 replicates the trade cost counterfactual with these alternative preference estimates.

Price elasticity and Comin et al (2016) implicitly-additive preferences The preferences assumed in our benchmark specification are separable. Separability is a natural and common assumption but an important disadvantage is that it imposes a strong link between price elasticities and income elasticities in consumption. Comin et al (2016) and Matsuyama (2017) explore "implicitly-additive"

preferences that have the advantage of breaking the link between price and income elasticities. As a robustness check, we estimate Comin et al (2016) preferences using our data and similar tools.

This specification is described in equation (A.11) in Appendix. We impose a value $\theta_k = 4$ for this specification, and estimate the elasticity of substitution between sectors. Our estimated elasticity of substitution is equal to 0.76, which is within the range of Comin et al (2016)'s own estimates (0.8 and 0.6 with cross-section and panel data respectively). Using mean expenditure shares, implied income elasticities are highly correlated with our benchmark income elasticities (CRIE) as described in Figure A.5 (89.9% correlation) and are again highly correlated with skill intensity in production (71.2% correlation).

As argued by Cravino and Sotelo (2016), lower elasticity of substitution between sectors leads to larger skill premium increases with both types of preferences, yet the difference between non-homothetic and homothetic preferences remains large, if not larger with Comin et al (2016) implicitly-additive specification. The results of our two main counterfactuals (1% productivity increase and 1% trade costs decrease) are plotted in Figure A.6(a) and (b) and are qualitatively and quantitatively similar to our benchmark specification.

Alternative measures of skill and unskilled labor intensity While the GTAP dataset provides skilled and unskilled labor usage for all countries, part of this information is extrapolated from a subset of European countries and 6 non-European countries (US, Canada, Australia, Japan, Taiwan and South Korea).[32] Also, skilled labor is defined on an occupational basis for a few of these countries (e.g. the US). In our baseline analysis, we use country-specific shares of skilled labor (provided by GTAP) β_{ikL} and β_{ikH} in equation 23 in order to solve for the counterfactual change in wages. Our results are however not very sensitive to this choice. An alternative would be to use a cross-country average of skilled labor and unskilled labor intensity ($\bar{\beta}_{kL}$ and $\bar{\beta}_{kH}$) in equation 23. As shown in Figure A.3 for the productivity counterfactual and Figure A.4 for the trade cost counterfactual, this specification leads to similar results. The robustness of results is due to income elasticities being strongly correlated with the country-specific measures of skill intensity of most countries, as documented in Caron et al (2014).

Reducing trade costs one country at a time An alternative set of counterfactual simulations is to reduce trade costs for each country, one at a time (to and from a given country). The effect of trade costs reductions on the skill premium slightly differs from the main counterfactuals, but the main point remains: non-homothetic and homothetic preferences yield very different changes in the skill premium for the country for which we consider a trade cost reduction. With this set of counterfactuals, we can derive a similar decomposition as in Equation (31-34), highlighting a direct effect of trade costs on production patterns (taking demand and factor prices as given) as well as an income effect and general-equilibrium feedback effects. We provide the details in Appendix and results are provided in Figure A.7. In this graph, each point is a different counterfactual (one counterfactual

[32] See: https://www.gtap.agecon.purdue.edu/resources/download/4183.pdf

separately for each country liberalizing trade) and we plot the effect on the skill premium for the corresponding country. Simulated changes in the skill premium are similar to the baseline counterfactual for the country from and to which trade costs are reduced. Importantly, the results strongly differ between homothetic and non-homothetic specifications, especially for developing countries where the skill premium does not decrease as much as in the homothetic case.

5 Summary and conclusions

Growing income inequality is a defining feature of our time, and many reasons for the increasing premium awarded to skilled workers have been identified and studied by the literature. We provide a quantitative assessment of a simple yet overlooked mechanism: growth in income increasingly shifts consumption patterns towards goods and services that require relatively more skilled labor in their production. We assess the potential scope for this mechanism through a general-equilibrium framework which relates consumption choices to the demand for skills. Our approach relies on cross-country variations in income and consumption to identify the income elasticity of demand.

Simulations suggest that factor-neutral productivity growth can indeed lead to substantial increases in the skill premium, especially for developing countries which are rapidly transitioning out of unskilled-labor intensive sectors such as agriculture and basic manufacturing. The predicted changes in the skill premium caused by the changing composition of consumption represents a sizable share of observed increases in many countries and is comparable in magnitude to other well-studied mechanisms such as skill-biased technological change in explaining why, despite accumulation of skills, inequality has been increasing.

We then show that income-driven changes in the composition of consumption can also be quantitatively important during an episode of trade liberalization – another commonly studied cause of changes in the skill premium. Like productivity, trade raises incomes and increases the return to skill labor, with, once again, a strong effect in the developing world. The relationship between income and consumption patterns has further implications: relative to a homothetic preference benchmark in which consumption shares across sectors are independent of income, accounting for non-homothetic preferences reduce trade's impact on the skill premium. The sector-level correlation between income elasticity and skill intensity implies a country-level correlation between relative specialization in consumption and relative specialization in production. This leads to a lower predicted net factor content of trade and therefore a weaker link between trade and relative wages. In many developing countries, this weakening of Stolper-Samuelson forces, combined with the effect of shifting consumption patterns, completely cancel the decrease on the skill premium predicted by a standard homothetic-preference model. In rich countries, both of these effects are weaker. Overall, our simulations suggest much smaller differences in the impact of trade liberalization on the skill premium between rich and poor countries.

We do not claim this to be the main mechanism behind increasing wage disparities. It is likely working alongside other forces, such as skill-biased technical change (Burstein and Vogel 2015) and

structural transformation (Cravino and Sotelo 2016), with which it is not incompatible. Future research may want to integrate and contrast alternative mechanisms in a unified framework.

Our results are contingent on the cross-country approach which we have taken. While the broad cross-section of countries allows us to predict the range of per capita incomes in which the effect is likely to be strong, we cannot directly test whether preferences are indeed identical across countries nor constant in time. Our approach also does not allow us to make out-of-sample predictions regarding the continuing evolution of income-driven consumption shifts in the richest countries. Instead, we rely on a robust empirical fact (the correlation between income elasticity and skill intensity) and a structural approach to illustrate the impact of trade and growth on the skill premium.

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Tables and Figures

Table 1: Coefficients from the gravity equation estimations

Trade cost variable:	Mean across sectors	Standard Deviation across sectors
Distance (log)	-0.879	0.636
Contiguity	0.328	0.460
Common language	0.407	0.370
Colonial link	0.320	0.534
Both access to sea	0.574	0.610
RTA	0.567	0.589
Common currency	0.586	1.034
Common legal origin	0.024	0.264
Border effect	3.767	2.128
Exporter FE	Yes	
Importer FE	Yes	
Nb. of industries	55	
Pseudo-R2 (incl. domestic)	0.999	
Pseudo-R2 (excl. domestic)	0.833	

Notes: Poisson regressions; dependent variable: trade flows. The coefficients above are estimated separately for each industry. Pseudo-R2 equal the square of the correlation coefficient between fitted and observed trade flows, including or excluding domestic flows.

Table 2: Estimated income elasticity by sectors

GTAP code	Sector name	Skill intens.	Income elast.	Theta θ_k	Export share
pdr	Paddy rice	0.060	0.001	0.962	0.133
wol	Wool, silk-worm cocoons	0.088	1.042	1.354	0.423
c_b	Sugar cane, sugar beet	0.090	0.633	2.226	0.020
v_f	Vegetables, fruit, nuts	0.094	0.538	14.04	0.231
ocr	Crops nec	0.114	0.783	1.998	0.376
wht	Wheat	0.116	0.863	3.360	0.217
frs	Forestry	0.117	0.323	0.962	0.185
osd	Oil seeds	0.118	0.183	0.962	0.276
fsh	Fishing	0.123	0.270	0.962	0.145
pcr	Processed rice	0.129	0.137	0.962	0.151
oap	Animal products nec	0.131	0.310	4.397	0.114
gro	Cereal grains nec	0.134	0.212	1.555	0.146
rmk	Raw milk	0.151	0.466	0.962	0.004
ctl	Bovine cattle, sheep and goats, horses	0.163	0.186	1.988	0.085
pfb	Plant-based fibers	0.166	1.277	4.390	0.289
lea	Leather products	0.211	0.997	3.609	0.351
vol	Vegetable oils and fats	0.216	0.424	2.239	0.359
sgr	Sugar	0.220	0.587	3.709	0.250
tex	Textiles	0.230	0.769	3.517	0.384
omt	Meat products nec	0.232	1.075	3.837	0.116
cmt	Bovine meat products	0.237	0.970	4.587	0.107
wap	Wearing apparel	0.246	1.031	5.923	0.323
mil	Dairy products	0.247	0.884	3.356	0.106
lum	Wood products	0.247	0.626	4.299	0.318
ofd	Food products nec	0.267	0.706	2.077	0.225
omf	Manufactures nec	0.278	1.074	2.941	0.246
nmm	Mineral products nec	0.280	0.921	9.078	0.157
cns	Construction	0.293	0.972	3.820	0.012
otp	Transport nec	0.295	0.865	2.258	0.164
b_t	Beverages and tobacco products	0.296	0.667	2.015	0.124
fmp	Metal products	0.296	0.908	4.787	0.203
wtp	Water transport	0.298	0.676	0.962	0.409
trd	Trade	0.307	1.052	2.347	0.063
p_c	Petroleum, coal products	0.312	0.831	9.748	0.169
atp	Air transport	0.312	0.901	1.652	0.455
ppp	Paper products, publishing	0.339	0.879	1.913	0.159
mvh	Motor vehicles and parts	0.340	1.167	6.150	0.323
otn	Transport equipment nec	0.342	1.084	2.552	0.347
crp	Chemical, rubber, plastic products	0.355	0.992	11.82	0.393
ele	Electronic equipment	0.357	1.083	2.264	0.352
ely	Electricity	0.371	0.773	2.164	0.054
ome	Machinery and equipment nec	0.371	0.973	2.126	0.428
wtr	Water	0.377	0.829	0.962	0.029
ros	Recreational and other services	0.474	0.819	1.180	0.124
cmn	Communication	0.484	1.032	3.079	0.128
osg	Public Administration and services	0.502	1.060	2.905	0.037
obs	Business services nec	0.503	1.192	2.149	0.176
isr	Insurance	0.532	1.073	1.631	0.208
ofi	Financial services nec	0.545	1.311	3.159	0.094

Notes: Estimates of income elasticities and theta θ_k based on the benchmark specification; income elasticities evaluated using average country expenditure shares; skill intensity based on total requirements; export share is the sector average of the export share $(1 - \pi^X_{iik})$ across countries.

Table 3: Correlation between income elasticity and skill intensity

Dependent variable:	Income elasticity			
	(1)	(2)	(3)	(4)
	All sectors	All sectors	Excl. services	Excl. services
Skill intensity	0.583	0.546	0.613	0.660
	[0.108]**	[0.114]**	[0.126]**	[0.154]**
Capital intensity		0.177		-0.033
		[0.200]		[0.274]
Natural resource Intensity		-0.045*		0.138
		[0.021]		[0.255]
Observations (sectors)	55	55	43	43

Notes: Dependent variable: income elasticity by sector evaluated using average expenditures; beta coefficients; robust standard errors in brackets; * significant at 5%; ** significant at 1%.

Table 4: Skill premium increase – Based on actual per capita GDP growth

	1990 pcgdp	2014 pcgdp	skill prem	elasticity		90 pcgdp	14 pcgdp	skill prem	elasticity
ALB	3796	10581	0.0902	0.0880	KWT	20055	63486	0.0439	0.0381
ARG	5931	20144	0.0514	0.0420	LAO	1297	5491	0.4368	0.3026
ARM	5669	8576	0.0425	0.1025	LKA	2825	10262	0.1424	0.1104
AUS	26759	42663	0.0109	0.0233	LTU	12066	28048	0.0319	0.0378
AUT	25245	47285	0.0161	0.0257	LUX	44423	94224	0.0214	0.0285
AZE	6967	15844	0.0490	0.0596	LVA	15274	23487	0.0169	0.0392
BEL	25817	43203	0.0137	0.0267	MAR	4008	7063	0.0471	0.0831
BGD	1379	2862	0.1519	0.2079	MDG	990	1227	0.0546	0.2544
BGR	11068	17359	0.0188	0.0418	MEX	10208	15745	0.0147	0.0338
BHR	15485	41325	0.0347	0.0354	MLT	13611	31432	0.0198	0.0236
BLR	12591	20177	0.0446	0.0946	MNG	3141	11321	0.0927	0.0723
BOL	2115	5988	0.0980	0.0942	MOZ	509	1118	0.1033	0.1315
BRA	5678	14742	0.0390	0.0408	MUS	9140	17777	0.0451	0.0678
BWA	6214	15891	0.0315	0.0335	MWI	947	949	0.0003	0.1350
CAN	30293	41936	0.0079	0.0243	MYS	8266	22949	0.0274	0.0268
CHE	38881	57855	0.0082	0.0206	NAM	4919	10783	0.0427	0.0545
CHL	7638	21404	0.0403	0.0391	NGA	844	5485	0.5824	0.3112
CHN	2363	12240	0.1013	0.0616	NLD	25657	46847	0.0165	0.0274
CIV	2263	3336	0.0614	0.1581	NOR	26405	63479	0.0221	0.0252
CMR	2348	2673	0.0185	0.1430	NPL	1000	2155	0.1639	0.2134
COL	6860	12516	0.0351	0.0583	NZL	20642	34499	0.0163	0.0317
CRI	7221	14099	0.0352	0.0525	OMN	10605	38075	0.0316	0.0247
CYP	21036	28437	0.0096	0.0318	PAK	2443	4641	0.1006	0.1568
CZE	21267	31567	0.0101	0.0255	PAN	6052	19437	0.0786	0.0674
DEU	25465	45652	0.0145	0.0248	PER	3395	10915	0.0624	0.0535
DNK	25970	44522	0.0151	0.0280	PHL	3452	6624	0.0562	0.0863
ECU	4993	10871	0.0670	0.0861	POL	7771	25028	0.0379	0.0324
EGY	2031	9893	0.1488	0.0939	PRT	14426	28306	0.0223	0.0332
ESP	17693	33568	0.0170	0.0265	PRY	3686	8258	0.0706	0.0875
EST	10860	28247	0.0347	0.0363	QAT	26221	142044	0.0405	0.0240
ETH	848	1308	0.0984	0.2266	ROU	6479	20636	0.0684	0.0590
FIN	24976	40027	0.0124	0.0262	RUS	18323	23918	0.0120	0.0450
FRA	24742	39029	0.0139	0.0305	SAU	18588	47441	0.0325	0.0347
GBR	24327	39960	0.0108	0.0218	SEN	1992	2228	0.0135	0.1203
GEO	10201	9332	-0.0147	0.1657	SGP	20767	71568	0.0197	0.0159
GHA	1886	3531	0.1532	0.2444	SLV	1022	7834	0.2010	0.0987
GRC	16336	25888	0.0184	0.0399	SVK	16171	28421	0.0146	0.0260
GTM	3610	6835	0.0551	0.0862	SVN	18940	30250	0.0108	0.0232
HKG	24870	51400	0.0111	0.0152	SWE	27115	44175	0.0136	0.0278
HND	2859	4397	0.0325	0.0754	THA	5015	13843	0.0500	0.0492
HRV	13836	21519	0.0337	0.0764	TUN	5208	10286	0.0567	0.0833
HUN	12149	25586	0.0202	0.0272	TUR	9887	19099	0.0418	0.0635
IDN	3217	9576	0.0977	0.0896	TWN	18852	43999	0.0228	0.0269
IND	1310	5168	0.1559	0.1135	TZA	1116	2189	0.1224	0.1815
IRL	18087	48283	0.0262	0.0267	UGA	801	1824	0.1097	0.1333
IRN	2976	15409	0.1219	0.0742	UKR	10218	10324	0.0006	0.0614
ISR	20942	33024	0.0126	0.0278	URY	8936	20244	0.0325	0.0397
ITA	25384	35531	0.0086	0.0256	USA	36620	51983	0.0078	0.0223
JPN	26714	35107	0.0058	0.0214	VEN	8438	14007	0.0180	0.0355
KAZ	10812	23340	0.0487	0.0633	VNM	1272	5310	0.1531	0.1071
KEN	2032	2757	0.0632	0.2071	ZAF	8211	12044	0.0133	0.0346
KGZ	6978	3350	-0.0922	0.1257	ZMB	1354	3672	0.1080	0.1082
KHM	1051	2983	0.1391	0.1334	ZWE	4148	1867	-0.0551	0.0690
KOR	12347	34701	0.0280	0.0271					

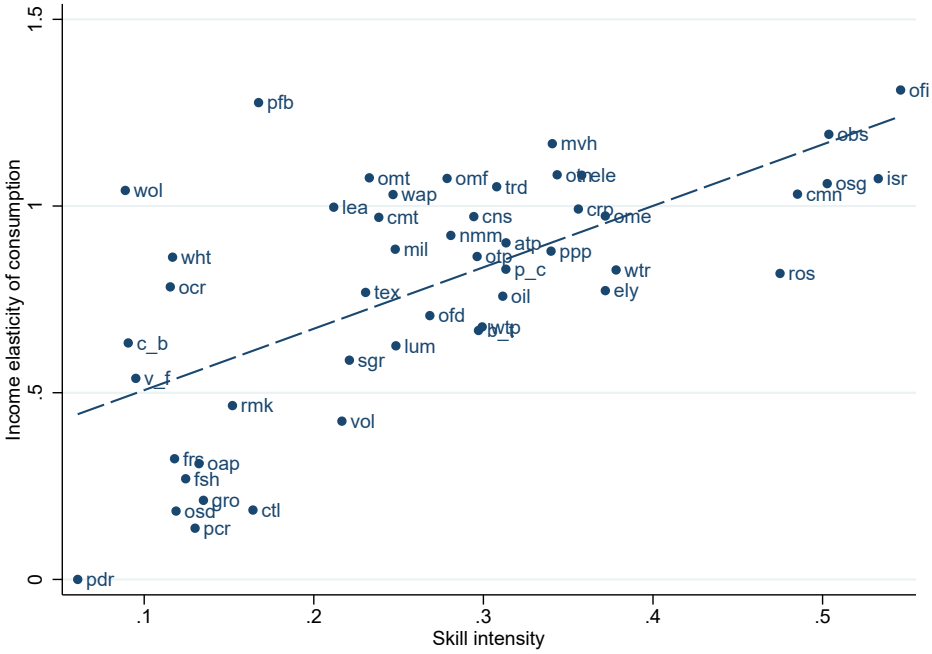


Figure 1: Income elasticity and skill intensity correlation.

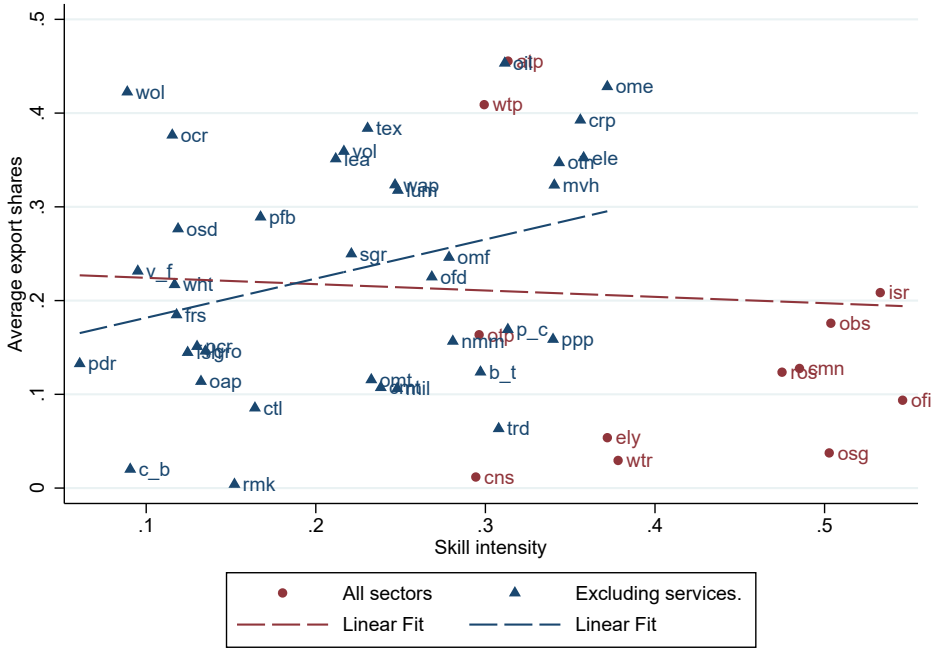


Figure 2: Correlation between average export shares and skill intensity across sectors.

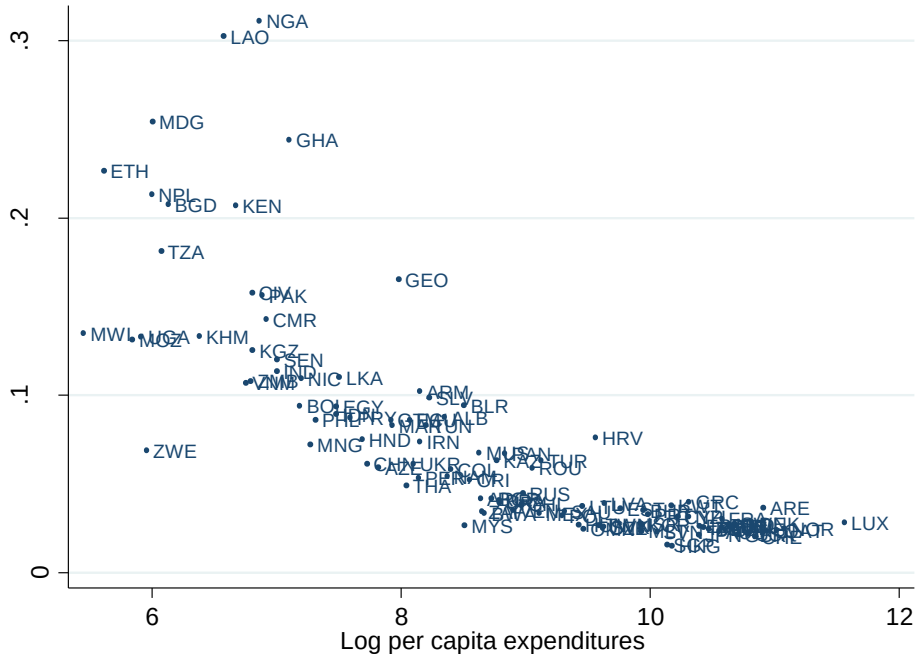


Figure 3: Simulated elasticity of the skill premium to TFP

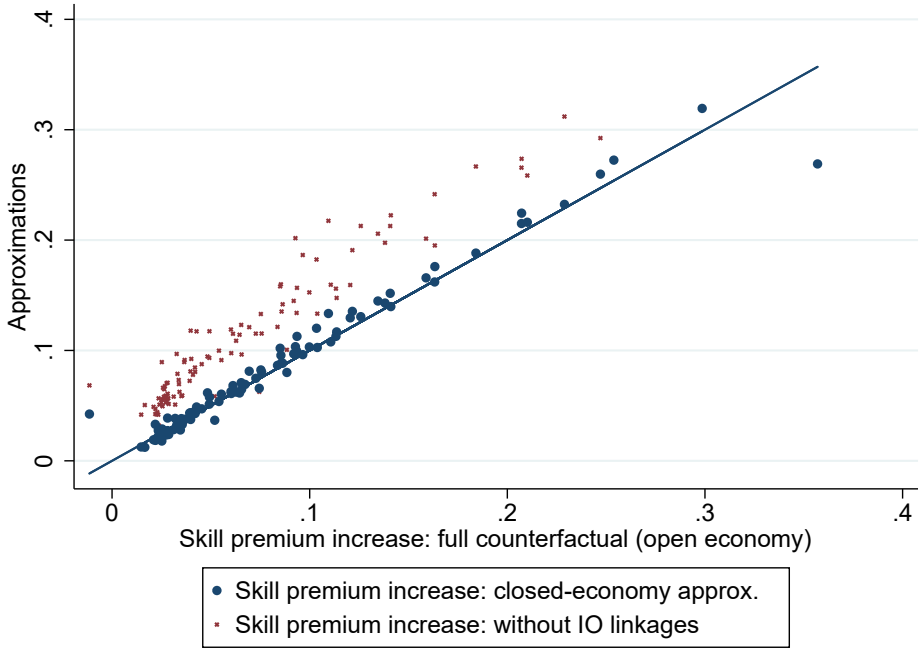


Figure 4: Elasticity of the skill premium to TFP - Closed-economy approximations

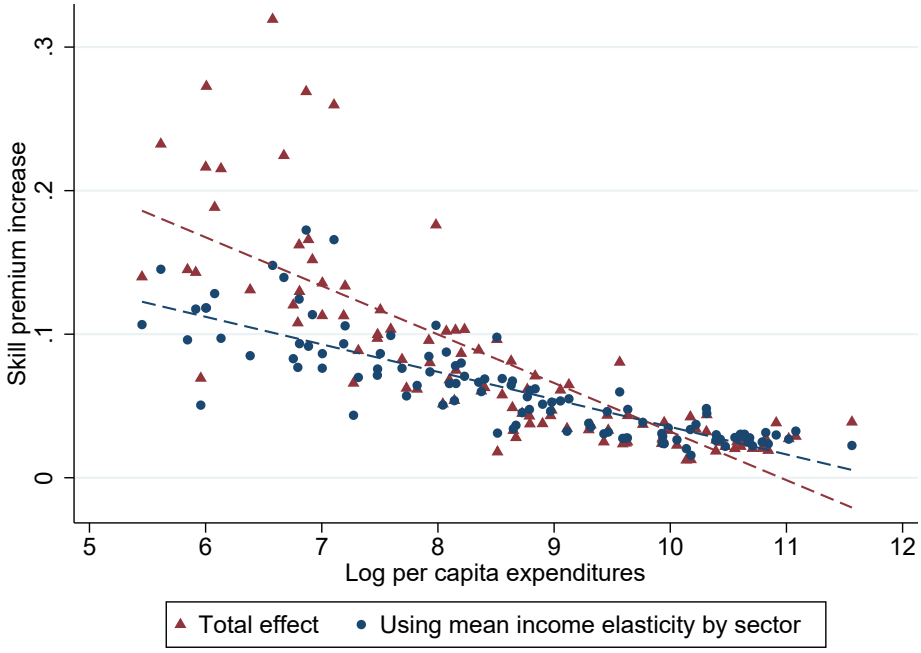


Figure 5: Elasticity of the skill premium to TFP - Decomposition of the closed-economy approximation, using average income elasticity

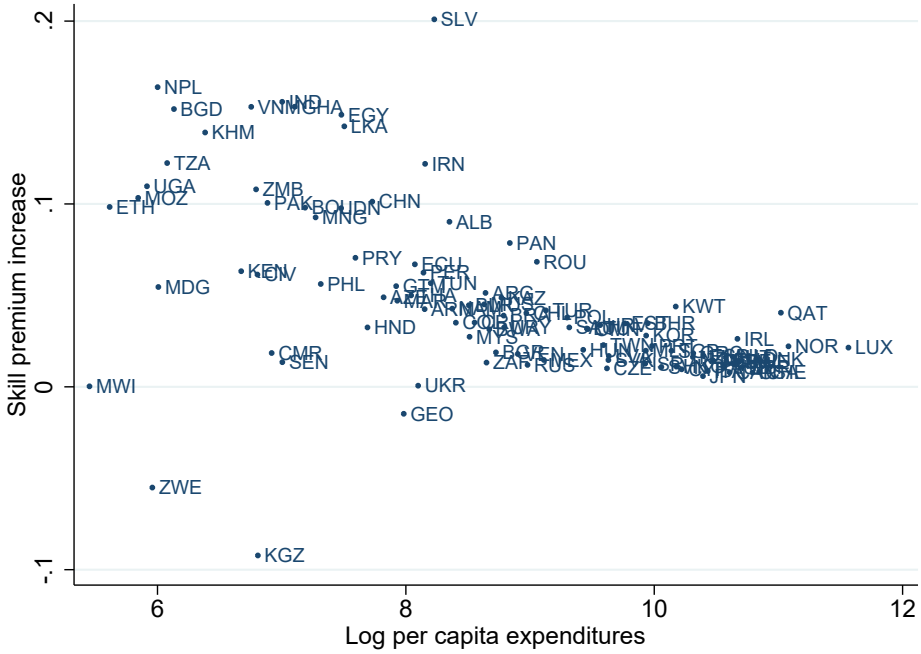


Figure 6: Predicted increase in the skill premium caused by historical per capita GDP growth (1990 to 2014)

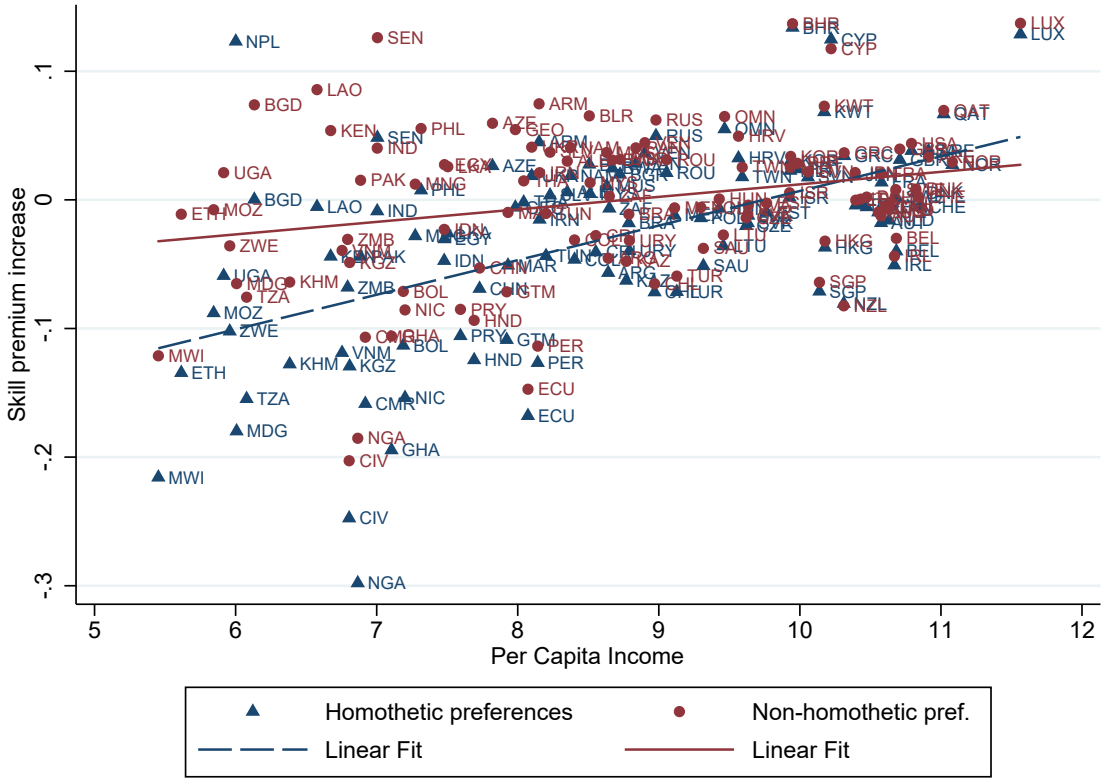


Figure 7: Percent change in the skill premium caused by a 1% trade cost reduction

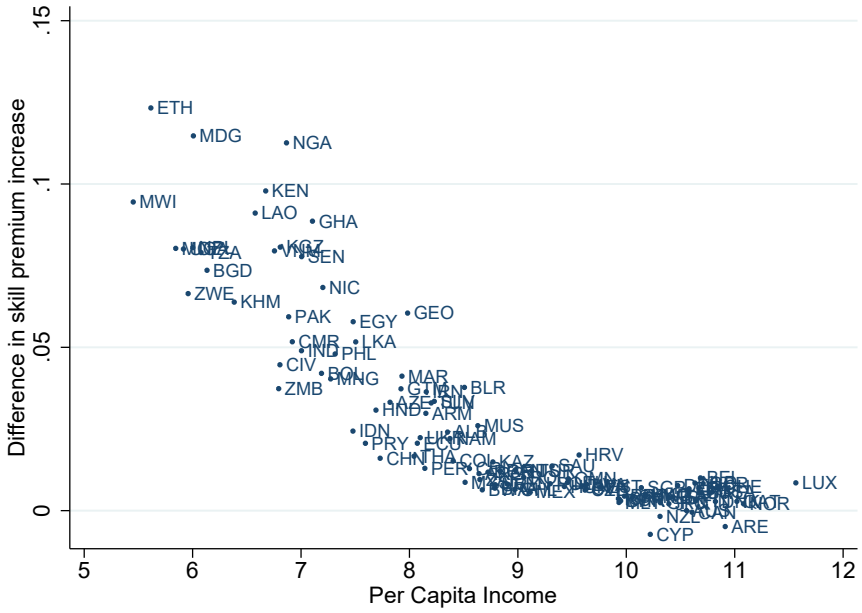
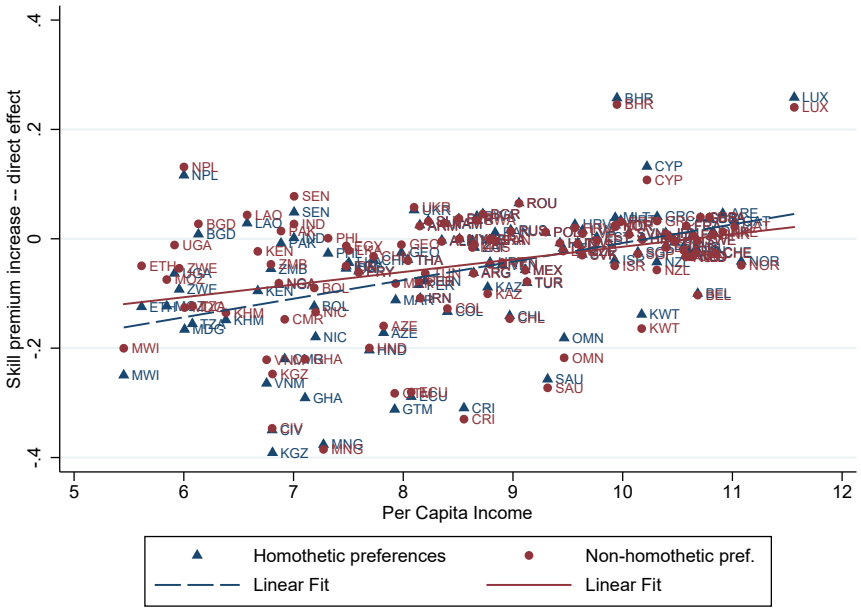
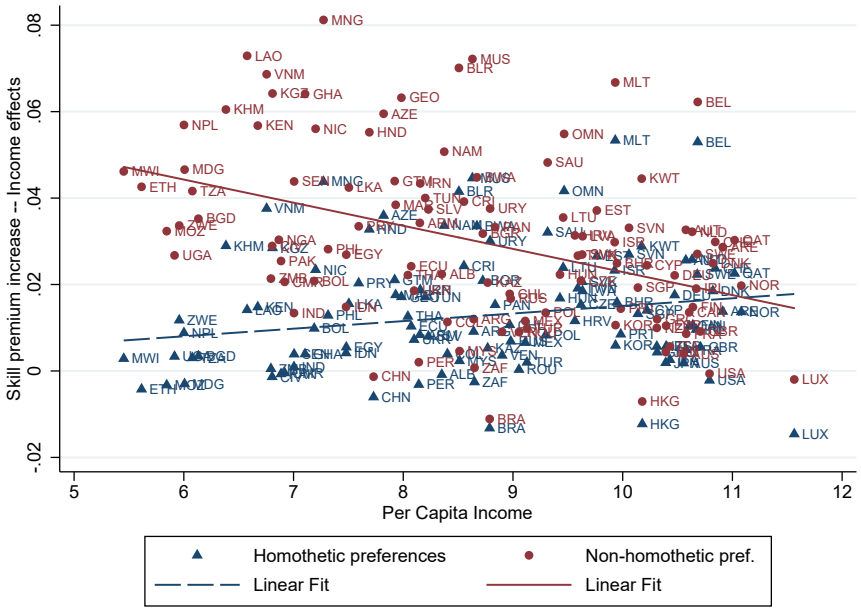


Figure 8: Differential effect of a 1% trade cost reduction: Non-homothetic vs. homothetic preferences

Figure 9: Decomposition of the effect of trade cost reductions on the skill premium

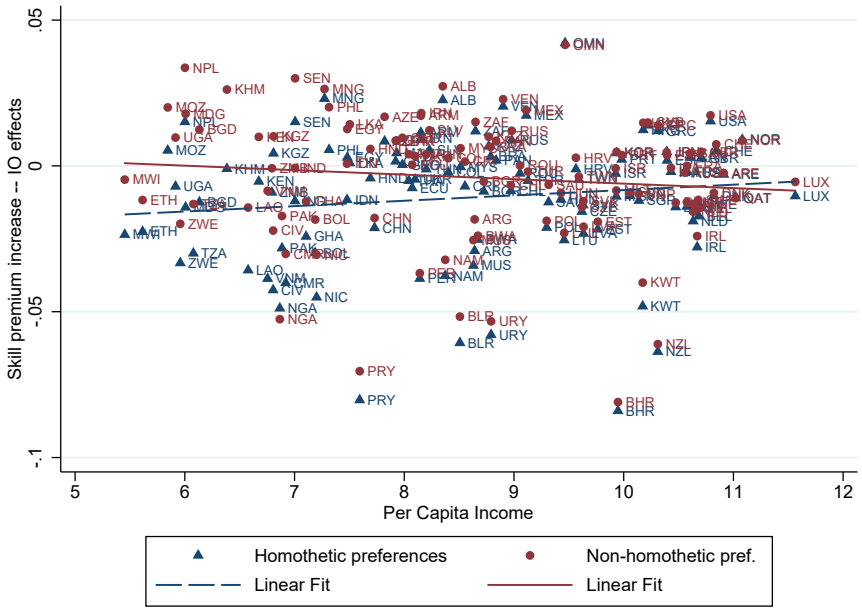


(a) First term: Direct trade patterns effect

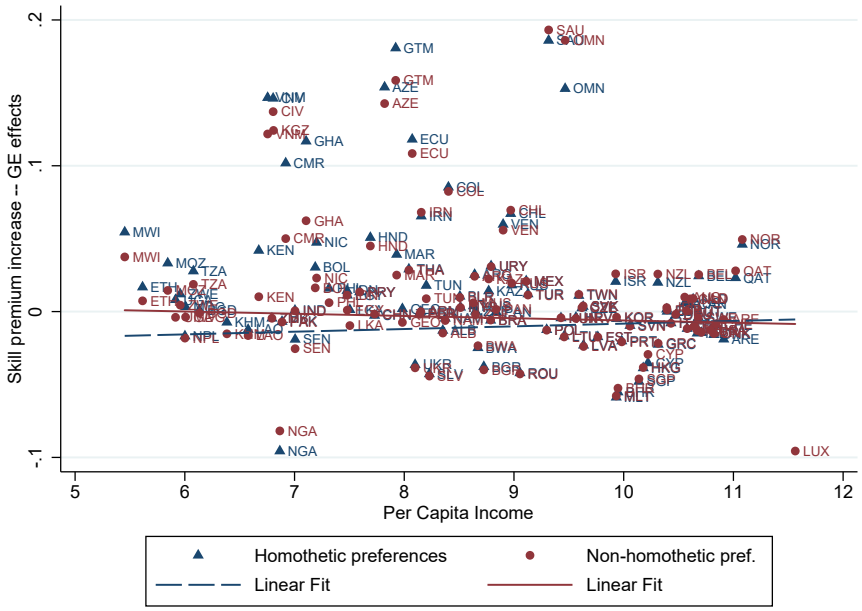


(b) Second term: Income effects in final demand

Figure 10: Decomposition of the effect of trade costs on the skill premium

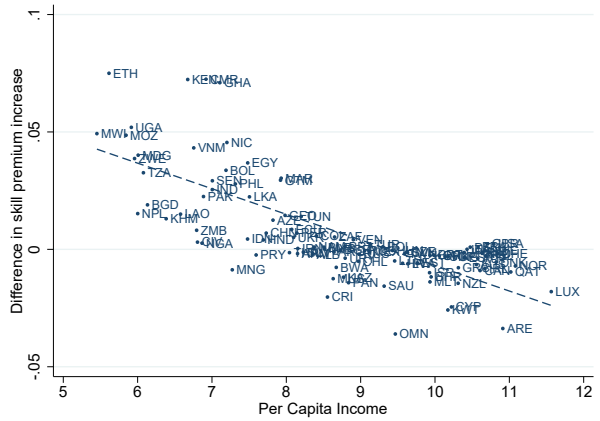


(a) Third term: input-output linkage effects

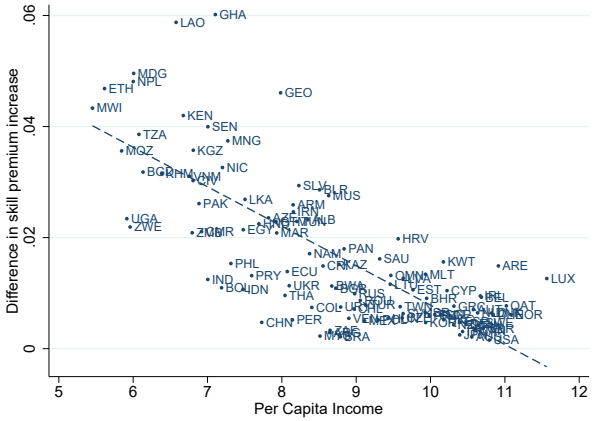


(b) Fourth term: cost feedback effects

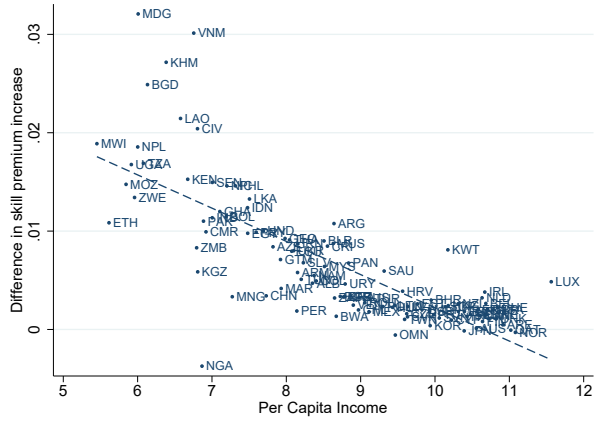
Figure 11: Difference in effects of trade cost reductions on the skill premium - Non-homothetic vs. homothetic preferences



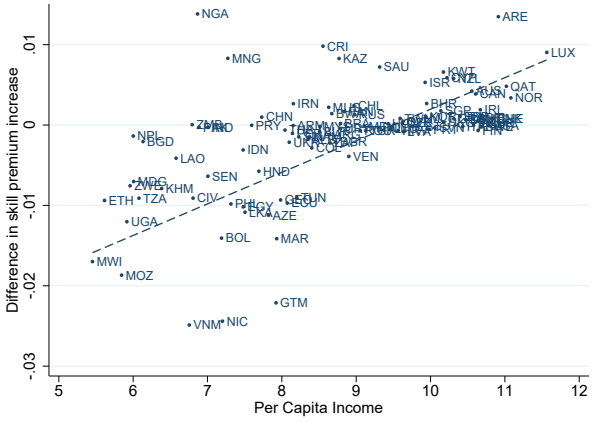
(a) First term: Difference in direct effect



(b) Second term: Difference in income effect



(c) Third term: Difference in input-output linkages effects



(d) Fourth term: Difference in cost feedback effects

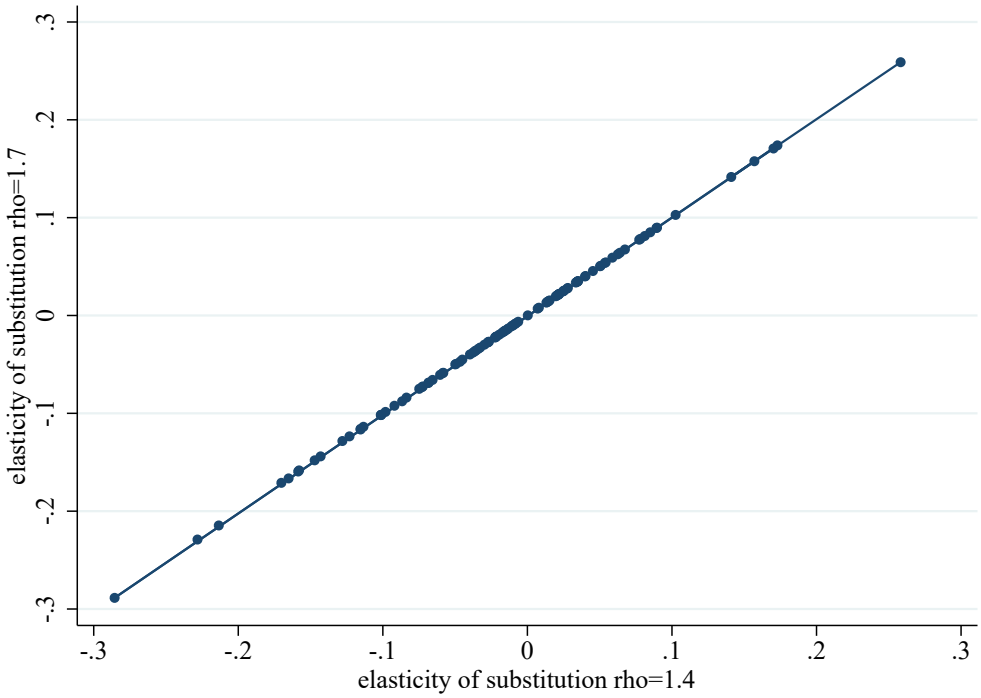


Figure 12: Comparing skill premium increases times $\tilde{\rho}_i$, for $\rho = 1.4$ and 1.7

Appendix – For online publication

A) Baseline and counterfactual equilibria

From the demand equation (5):

$$D_{nk} = L_n(\lambda_n)^{-\sigma_k}\alpha_{2,k}(P_{nk})^{1-\sigma_k}$$

It is easy to obtain the counterfactual change in demand as a function of the change in prices and Lagrange multiplier, which yields equation (16) in the main text:

$$\widehat{D_{nk}} = \widehat{\lambda_n}^{-\sigma_k}\,\widehat{P_{nk}}^{1-\sigma_k}$$

The change in the Lagrange multiplier is such that total expenditures equal income (equation 6). This yields equation (26); the change in total expenditures also equals the change in income:

$$\widehat{e_n} = \frac{\sum_k \widehat{D_{nk}}\,D_{nk}}{\sum_k D_{nk}}$$

Total demand X_{nk} for goods k in country n is the sum of the demand for final consumption D_{nk} and intermediate use (equation 7). This also holds in the counterfactual equilibrium, which yields:

$$X_{nk}\widehat{X_{nk}} = D_{nk}\widehat{D_{nk}} + \sum_h \gamma_{kh}Y_{nh}\widehat{Y_{nh}}$$

which can then be rewritten as in equation (18).

Next, using gravity equation (8) and (9), we directly obtain equation (19):

$$\widehat{X_{nik}} = \widehat{S_{ik}}\,\widehat{d_{nik}}^{-\theta_k}\,\widehat{P_{nk}}^{\theta_k}\,\widehat{X_{nk}}$$

and equation (21):

$$\widehat{S_{ik}} = \widehat{z_{ik}}^{\theta_k}\,(\widehat{c_{ikLab}})^{-\theta_k\gamma_{kL}}\prod_{f\neq L}(\widehat{w_{if}})^{-\theta_k\gamma_{kf}}\prod_h(\widehat{P_{ih}})^{-\theta_k\gamma_{hk}}$$

For the change in labor costs, we have:

$$c_{ikLab}^{1-\rho}\widehat{c_{ikLab}}^{1-\rho} = \mu_{ikL}\,\widehat{w_{iL}}^{1-\rho}w_{iL}^{1-\rho} + \mu_{ikH}\,\widehat{w_{iH}}^{1-\rho}w_{iH}^{1-\rho}$$

Hence:

$$\widehat{c_{ikLab}}^{1-\rho} = \beta_{ikL}\,\widehat{w_{iL}}^{1-\rho} + \beta_{ikH}\,\widehat{w_{iH}}^{1-\rho}$$

which gives equation (23).

In turn, for price indexes, we obtain from equation (10):

$$\widehat{\Phi_{nk}}\Phi_{nk} = \sum_i \widehat{S_{ik}} S_{ik} (\widehat{d_{nik}})^{-\theta_k} (d_{nik})^{-\theta_k}$$

Hence:

$$\widehat{P_{nk}}^{-\theta_k} = \widehat{\Phi_{nk}} = \frac{\sum_i \widehat{S_{ik}} S_{ik} (\widehat{d_{nik}})^{-\theta_k} (d_{nik})^{-\theta_k}}{\Phi_{nk}} = \sum_i \pi^M_{nik} \widehat{S_{ik}}\, \widehat{d_{nik}}^{-\theta_k} \tag{A.1}$$

which yields equation (22) in the text (π^M are import shares).

Given the change in trade flows, equation (20) then follows from the equality between production and total outward trade for country i sector k:

$$\widehat{Y_{ik}} = \frac{\sum_n X_{nik} \widehat{X_{nik}}}{\sum_n X_{nik}} = \sum_n \pi^X_{nik} \widehat{X_{nik}}$$

where π^X_{nik} refers to export shares.

We can now examine the changes in income and factor prices. From

$$V_{fi} w_{fi} = \sum_k \gamma_{kf} Y_{ik}$$

and:

$$V_{fi} w_{fi} \widehat{w_{fi}} = \sum_k \gamma_{kf} Y_{ik} \widehat{Y_{ik}}$$

we obtain for factors other than labor:

$$\widehat{w_{fi}} = \sum_k sh_{ifk} \widehat{Y_{ik}}$$

where $sh_{ifk} = \frac{\gamma_{kf} Y_{ik}}{\sum_k \gamma_{kf} Y_{ik}}$ is the share of factor f used in sector k.

Finally, for labor, we have (equation 13):

$$\beta_{ikl} \;=\; \mu_{kl}\, w_{il}^{1-\rho}\, c_{ikLab}^{\rho-1}$$

and thus:

$$\widehat{\beta_{ikl}} \;=\; \widehat{w_{il}}^{1-\rho}\, \widehat{c_{ikLab}}^{\rho-1}$$

For each type of labor $f \in \{L, H\}$, labor market clearing imposes:

$$V_{if} w_{if} = \sum_k \beta_{ikf} \gamma_{kL} Y_{ik}$$

and thus:

$$\widehat{w_{if}} = \sum_k sh_{ikf} \widehat{\beta_{ikl}} \widehat{Y_{ik}} = \sum_k sh_{ikf} \widehat{w_{if}}^{1-\rho}\, \widehat{c_{ikLab}}^{\rho-1} \widehat{Y_{ik}}$$

where $sh_{ikf} = \frac{\beta_{ikf}\gamma_{kL}Y_{ik}}{V_{if}w_{if}}$ is the share of labor type f employed in sector k. Solving for $\widehat{w_{ikf}}$ as a function of $\widehat{c_{ikLab}}$ and $\widehat{Y_{ik}}$, we obtain equation (24):

$$\widehat{w_{fi}} = \left[\sum_k sh_{ikf}\, \widehat{c_{ikLab}}^{\rho-1} \widehat{Y_{ik}}\right]^{\frac{1}{\rho}}$$

This equation can also be combined with the change in labor costs $\widehat{c_{ikLab}}$, to yield:

$$\widehat{w_{fi}}^{\rho} = \sum_k sh_{ikf}\, \widehat{Y_{ik}} \left[\beta_{ikL}\, \widehat{w_{iL}}^{1-\rho} + \beta_{ikH}\, \widehat{w_{iH}}^{1-\rho}\right]^{-1}$$

B) Implications for the skill premium

First, we examine how the skill premium depends on changes in production patterns. A first-order approximation in log, for each $f \in \{L, H\}$, yields:

$$\begin{aligned}
\log \widehat{c_{ikLab}} &= \beta_{ikL}\, \log \widehat{w_{iL}} + \beta_{ikH}\, \log \widehat{w_{iH}} \\
\rho \log \widehat{w_{if}} &= (\rho-1) \sum_k sh_{ikf}\, \log \widehat{c_{ikLab}} + \sum_k sh_{ikf}\, \log \widehat{Y_{ik}} \\
&= (\rho-1) \sum_k sh_{ikf} \left[\beta_{ikL}\, \log \widehat{w_{iL}} + \beta_{ikH}\, \log \widehat{w_{iH}}\right] + \sum_k sh_{ikf}\, \log \widehat{Y_{ik}}
\end{aligned}$$

Taking the difference between high- and low-skilled workers, we get the change in the skill premium:

$$\begin{aligned}
\rho \log \frac{\widehat{w_{iH}}}{\widehat{w_{iL}}} &= (\rho-1) \sum_k (sh_{ik}^H - sh_{ik}^L) \left[\beta_{ikL} \log \widehat{w_{iL}} + \beta_{ikH} \log \widehat{w_{iH}}\right] + \sum_k (sh_{ik}^H - sh_{ik}^L)\, \log \widehat{Y_{ik}} \\
&= (\rho-1) \sum_k (sh_{ik}^H - sh_{ik}^L) \left[\log \widehat{w_{iL}} + \beta_{ikH}\, \log \frac{\widehat{w_{iH}}}{\widehat{w_{iL}}}\right] + \sum_k (sh_{ik}^H - sh_{ik}^L)\, \log \widehat{Y_{ik}} \\
&= (\rho-1) \sum_k (sh_{ik}^H - sh_{ik}^L) \beta_{ikH}\, \log \frac{\widehat{w_{iH}}}{\widehat{w_{iL}}} + \sum_k (sh_{ikH} - sh_{ikL})\, \log \widehat{Y_{ik}}
\end{aligned}$$

Hence:

$$\log \frac{\widehat{w_{iH}}}{\widehat{w_{iL}}} = \frac{1}{\tilde{\rho}_i} \sum_k (sh_{ik}^H - sh_{ik}^L)\, \log \widehat{Y_{ik}} \tag{A.2}$$

where $\tilde{\rho}_i = \rho - (\rho-1) \sum_k (sh_{ik}^H - sh_{ik}^L) \beta_{ikH}$. This relationship between the skill premium and production can then be used in each counterfactual to link the changes in production patterns to changes in the skill premium.

First counterfactuals: productivity growth First, without intermediate goods and trade, $\widehat{P_{nk}} \approx \widehat{z}^{-1}$ as a first approximation. Holding nominal income constant and using equation (16), we get:

$$\log \widehat{D_{nk}} = -\sigma_k \log \widehat{\lambda_n} + (\sigma_k - 1) \log \widehat{z}$$

Given the constraint on total expenditures provided by (26), we need:

$$0 = \log \widehat{e_n} \approx \frac{\sum_k D_{nk} \log \widehat{D_{nk}}}{\sum_k D_{nk}} = \frac{\sum_k D_{nk} \left(-\sigma_k \log \widehat{\lambda_n} + (\sigma_k - 1) \log \widehat{z}\right)}{\sum_k D_{nk}}$$

Solving for $\log \widehat{\lambda_n}$ yields:

$$\log \widehat{\lambda_n} = \frac{\sum_k (\sigma_k - 1) D_{nk}}{\sum_k \sigma_k D_{nk}} \log \widehat{z}$$

Re-incorporating the solution for $\log \widehat{\lambda_n}$ into the change in demand, we obtain the first-order approximation provided in the text:

$$\log \widehat{D_{nk}} = (\eta_{nk} - 1) \log \widehat{z}$$

$\eta_{nk} = \frac{\sigma_k \sum_{k'} D_{nk'}}{\sum_{k'} \sigma_{k'} D_{nk'}}$ is the income elasticity of demand in sector k, country n.

Using equation (A.2) above, we can then obtain a simple expression for the response of the skill premium $\frac{w_{nH}}{w_{nL}}$ to a TFP increase $\widehat{z}$:

$$\log \frac{\widehat{w_{nH}}}{\widehat{w_{nL}}} = \frac{1}{\widehat{\rho_i}} \log \widehat{z} \sum_k (sh_{nk}^H - sh_{nk}^L) \eta_{nk} \tag{A.3}$$

Next, with trade in final and intermediate goods. Under the assumption that the productivity increase $\widehat{z}$ augments factors of production, the change in price $\widehat{P_{nk}}$ still corresponds to $\widehat{z}^{-1}$ when we neglect the feedback effect of wages on prices. One can check that $\widehat{P_{ik}} = \widehat{z}^{-1}$ and $\widehat{S_{ik}} = \widehat{z}^{\theta_k}$ are the solutions to the following system of equations:

$$\begin{aligned}
\widehat{S_{ik}} &= (\widehat{c_{ikLab}}/\widehat{z})^{-\theta_k \gamma_{kL}} \prod_{f \neq L} (\widehat{w_{if}}/\widehat{z})^{-\theta_k \gamma_{kf}} \prod_h (\widehat{P_{ih}})^{-\theta_k \gamma_{hk}} \\
\widehat{P_{nk}} &= \left[\frac{1}{X_{nk}} \sum_i X_{nik} \widehat{S_{ik}} \, \widehat{d_{nik}}^{-\theta_k} \right]^{-\frac{1}{\theta_k}}
\end{aligned}$$

Hence relative prices and import shares remain constant (as a first-order approximation).

Equation 19 yields:

$$\widehat{X_{nik}} = \widehat{S_{ik}} \, \widehat{P_{nk}}^{\theta_k} \, \widehat{X_{nk}} = \widehat{X_{nk}}$$

Combining with 20, we get:

$$\widehat{Y_{ik}} = \sum_n \pi_{nik}^X \widehat{X_{nik}} = \sum_n \pi_{nik}^X \widehat{X_{nk}}$$

Finally, using equation 18 we obtain that the changes in production and demand satisfy:

$$Y_{ik} \widehat{Y_{ik}} = \sum_n \pi_{nik} D_{nk} \widehat{D_{nk}} + \sum_h \sum_n \pi_{nik} \, \gamma_{kh} Y_{nh} \, \widehat{Y_{nh}}$$

If we denote by Γ the matrix with coefficients $\pi_{nik}\gamma_{kh}$, by Π the matrix with coefficients $\pi_{nik} 1_{k,h}$ (and where $1_{k,h}$ is a dummy equal to one if $h = k$), by $Y\widehat{Y}$ the vector of production and $D\widehat{D}$ the vector

demand, we can write this equality as:

$$Y\widehat{Y} \;=\; \Pi\,.\,D\widehat{D} + \Gamma\,.\,Y\widehat{Y}$$

which yields:

$$Y\widehat{Y} \;=\; (\mathrm{I}-\Gamma)^{-1}\,.\,\Pi\,.\,D\widehat{D}$$

Denoting by γ^{tot}_{inkh} the coefficients of the matrix $(\mathrm{I}-\Gamma)^{-1}\Pi$, we can link changes in output to changes in final demand:

$$\widehat{Y_{ik}} \;=\; \frac{1}{Y_{ik}} \sum_{n,h} \gamma^{tot}_{nikh} D_{nh} \widehat{D_{nh}}$$

Given that we also have $Y_{ik} = \sum_{n,h} \gamma^{tot}_{nikh} D_{nh}$, we also have:

$$\widehat{Y_{ik}} - 1 \;=\; \frac{1}{Y_{ik}} \sum_{n,h} \gamma^{tot}_{nikh} D_{nh} (\widehat{D_{nh}} - 1)$$

then, in log, a first-order approximation yields the two expressions in the text:

$$\begin{aligned}
\log \widehat{w_{iH}} - \log \widehat{w_{iL}} &= \frac{1}{\tilde{\rho}_i} \sum_{k,h,n} (sh^H_{ik} - sh^L_{ik})\, \varphi^{tot}_{nikh}\, \log \widehat{D_{nh}} \\
&= \frac{1}{\tilde{\rho}_i} \log \widehat{z} \sum_{k,h,n} (sh^H_{ik} - sh^L_{ik}) \varphi^{tot}_{nikh} \eta_{nh}
\end{aligned}$$

Second counterfactuals: reduction in trade costs. Given equation (A.2), we need to examine how a reduction in trade costs leads to a change in production patterns. Combining equations (20) for production and (19) for bilateral trade, we have:

$$\begin{aligned}
\log \widehat{Y_{ik}} &= \sum_n \pi^X_{nik}\, \log \widehat{X_{nik}} \\
&= \sum_n \pi^X_{nik}\, \log[\widehat{S_{ik}}\, \widehat{d_{nik}}^{\,-\theta_k}\, \widehat{P_{nk}}^{\,\theta_k}\, \widehat{X_{nk}}] \\
&= \sum_n \pi^X_{nik}\, \log[\widehat{S_{ik}}\, \widehat{d_{nik}}^{\,-\theta_k}\, \widehat{P_{nk}}^{\,\theta_k}] + \sum_n \pi^X_{nik} \varphi_{nkF}\, \log \widehat{D_{nk}} + \sum_{n,h} \pi^X_{nik}\, \varphi_{nkh} \log \widehat{Y_{nh}}
\end{aligned}$$

where π^X_{nik} denotes the share of production from country i in sector k that is exported to country n and $\varphi_{nhk} = \frac{\gamma_{nhk} Y_{nh}}{X_{nk}}$ is the share of production in country n that is purchased as inputs by sector h.

Then, using $\widehat{P_{nk}}^{\,-\theta_k} = \sum_i \pi^M_{nik} \widehat{S_{ik}}\, \widehat{d_{nik}}^{\,-\theta_k}$, we get:

$$\begin{aligned}
\log \widehat{P_{nk}}^{\,-\theta_k} &\approx \sum_j \pi^M_{njk} \log(\widehat{S_{jk}}\, \widehat{d_{njk}}^{\,-\theta_k}) \\
&= \sum_j \pi^M_{njk} \log \widehat{S_{jk}} \;-\; \theta_k \sum_j \pi^M_{njk} \log \widehat{d_{njk}}
\end{aligned}$$

$$= \sum_j \pi^M_{njk} \log \widehat{S_{jk}} \; - \; \theta_k(1-\pi^M_{nnk}) \; \log \widehat{d}$$

for a change in trade costs $\log \hat{d}$ between country i and all its foreign trading partners.

Using $\widehat{D_{nk}} = \widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k}$, plugging the change in prices back into the previous equation, we get:

$$\begin{aligned}
\log \widehat{Y_{ik}} &= \sum_n \pi^X_{nik} \log[\widehat{S_{ik}} \widehat{d_{nik}}^{-\theta_k} \widehat{P_{nk}}^{\theta_k}] + \sum_n \varphi_{nkF} \log(\widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k}) + \sum_{n,h} \varphi_{nkh} \log \widehat{Y_{nh}} \\
&= \sum_n \pi^X_{nik} \log[\widehat{S_{ik}} \widehat{d_{nik}}^{-\theta_k}] - \sum_{n,j} \pi^X_{nik} \pi^M_{njk} \log[\widehat{S_{jk}} \widehat{d_{njk}}^{-\theta_k}] \\
&\quad + \sum_n \pi^X_{nik} \varphi_{nkF} \log(\widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k}) + \sum_{n,h} \pi^X_{nik} \varphi_{nkh} \log \widehat{Y_{nh}} \\
&= \sum_n \pi^X_{nik} \left[\log \widehat{d_{nik}}^{-\theta_k} - \sum_j \pi^M_{njk} \log \widehat{d_{njk}}^{-\theta_k} \right] - \sum_n \pi^X_{nik} \sum_j \pi^M_{njk} \left(\log \widehat{S_{jk}} - \log \widehat{S_{ik}} \right) \\
&\quad + \sum_n \pi^X_{nik} \varphi_{nkF} \log \widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k} + \sum_{n,h} \pi^X_{nik} \varphi_{nkh} \log \widehat{Y_{nh}} \qquad \text{(A.4)}
\end{aligned}$$

These four terms reflect the decomposition provided in the text. The first term, capturing the direct effect of the change in trade costs d_{nik}, is also equal to:

$$\begin{aligned}
\text{Direct effect} &= \sum_n \pi^X_{nik} \left[\log \widehat{d_{nik}}^{-\theta_k} - \sum_j \pi^M_{njk} \log \widehat{d_{njk}}^{-\theta_k} \right] \\
&= -\theta_k \sum_n \pi^X_{nik} \log \widehat{d_{nik}} + \theta_k \sum_n \pi^X_{nik} \sum_j \pi^M_{njk} \log \widehat{d_{njk}} \\
&= -\theta_k (1-\pi^X_{iik}) \log \widehat{d} + \theta_k \sum_n \pi^X_{nik} (1-\pi^M_{nnk}) \log \widehat{d} \\
&= -\theta_k \log \widehat{d} \left[(1-\pi^X_{iik}) - \sum_n \pi^X_{nik} (1-\pi^M_{nnk}) \right]
\end{aligned}$$

Combining this direct effect with the previous equality, we obtain:

$$\begin{aligned}
\log \widehat{Y_{ik}} \approx & -\theta_k \log \hat{d} \left[(1-\pi^X_{iik}) - \sum_n \pi^X_{nik} (1-\pi^M_{nnk}) \right] \\
& - \sum_n \pi^X_{nik} \sum_j \pi^M_{njk} (\log \widehat{S_{jk}} - \log \widehat{S_{ik}}) \\
& + \sum_n \pi^X_{nik} \varphi_{nFk} \log \left(\widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k} \right) \\
& + \sum_{n,h} \pi^X_{nik} \varphi_{nhk} \log \widehat{Y_{nh}}
\end{aligned}$$

Combining these changes in production patterns with equation (A.2), we obtain a four-term decom-

position of the effect of a trade cost reduction on the skill premium:

$$\begin{aligned}\log \frac{\widehat{w_{iH}}}{\widehat{w_{iL}}} \;\approx\; & -\frac{1}{\tilde{\rho}_i}\,\log \hat{d}\,\sum_k (sh^H_{ik}-sh^L_{ik})\,\theta_k\left[(1-\pi^X_{iik})\;-\;\sum_n \pi^X_{nik}\,(1-\pi^M_{nnk})\right]\\ & -\frac{1}{\tilde{\rho}_i}\,\sum_k (sh^H_{ik}-sh^L_{ik})\,\sum_n \pi^X_{nik}\,\sum_j \pi^M_{njk}(\log \widehat{S_{jk}}-\log \widehat{S_{ik}})\\ & +\frac{1}{\tilde{\rho}_i}\,\sum_k (sh^H_{ik}-sh^L_{ik})\,\sum_n \pi^X_{nik}\,\varphi_{nFk}\,\log\left(\widehat{\lambda_n}^{-\sigma_k}\,\widehat{P_{nk}}^{1-\sigma_k}\right)\\ & +\frac{1}{\tilde{\rho}_i}\,\sum_k (sh^H_{ik}-sh^L_{ik})\,\sum_{n,h} \pi^X_{nik}\,\varphi_{nhk}\,\log\;\widehat{Y_{nh}}\end{aligned}$$

C) Estimation strategy

Step 1: Gravity equation estimation and identification of Φ_{nk}

As described in the text, the model yields equation (36):

$$X_{nik} = \exp\left[FX_{ik}\;+\;FM_{nk}\;-\;\sum_{var}\beta_{var,k}TC_{var,ni}\;+\;\varepsilon^G_{nik}\right] \tag{A.5}$$

In this equation, importer fixed effects correspond to $\log \frac{X_{nk}}{\Phi_{nk}}$ and exporter fixed effects correspond to $\log S_{ik}$. These terms are identified up to an industry constant (e.g. α_k in preferences). We normalize the exporter fixed effect $S_{US,k}$ to unity in each sector k.

$TC_{var,ni}$ refers to the variables (indexed by var) included in the gravity equation to capture trade costs between n and i. Following the literature on gravity, we include the log of physical distance (including internal distance when $i = n$), a common language dummy, a colonial link dummy, a border effect dummy (equal to one if $i \neq n$), a contiguity dummy (equal to one if countries i and n share a common border), a free-trade-agreement dummy (equal to one if there is an agreement between countries i and n), a common currency dummy and a common-legal-origin dummy (equal to one if i and n have the same legal origin: British, French, German, Scandinavian or socialist). Parameters $\delta_{var,k}$ capture the elasticity of trade costs to each trade cost variable var, which may differ across industries. Since all coefficients to be estimated are sector specific, we estimate this gravity equation separately for each sector. Following Silva and Tenreyro (2006) and Fally (2015), we estimate gravity using the Poisson pseudo-maximum likelihood estimator (Poisson PML).

We then use equation (10), $\Phi_{nk} = \sum_i S_{ik}(d_{nik})^{-\theta_k}$, to construct Φ_{nk}. The exporter fixed effects $\widehat{FX}_{ik}$) provide estimates for $\log S_{ik}$ while $\sum_{var}\widehat{\beta}_{var,k}TC_{var,ni}$ yields an estimate of trade cost d_{nik} multiplied its elasticity for each sector and each country pair: $\theta_k \log d_{nik}$.

$$\widehat{\Phi}_{nk} \;=\; \sum_i \exp\left(\widehat{FX}_{ik}-\sum_{var}\widehat{\beta}_{var,k}TC_{var,ni}-\beta_{ATC,ik}B_{i\neq n}\right) \tag{A.6}$$

This constructed $\widehat{\Phi}_{nk}$ varies across industries and countries in an intuitive way. It is the sum of all potential exporters' fixed effect (reflecting unit costs of production) deflated by distance and other trade cost variables. If country n is close to an exporter that has a comparative advantage in industry k, i.e. an exporter associated with a large exporter fixed effect FX_{ik} (large S_{ik}), our constructed $\widehat{\Phi}_{nk}$ will be relatively larger for this country reflecting a lower price index of goods from industry k in country n. Note that $\widehat{\Phi}_{nk}$ also accounts for domestic supply in each industry k (when $i = n$).

Step 2: Demand system estimation and identification of σ_k

The first step estimation gives us an estimate of Φ_{nk}. From Equation (11), we know that the price index P_{nk} is a log-linear function of Φ_{nk} which we can use as a proxy for P_{nk} on the right-hand side of Equation (35) describing final demand.[33]

As described in the text, we estimate equation (38) for final demand:

$$\log x_{nk} = -\sigma_k . \log \lambda_n + \log \alpha_{3,k} + \frac{(\sigma_k - 1)}{\theta_k} \log \widehat{\Phi}_{nk} + \varepsilon^D_{nk} \tag{A.7}$$

where ε^D_{nk} denotes the error term. In each country n, we further impose the sum of fitted expenditures across sectors to equal observed total per capita expenditures e_n, which leads to the following constraint:

$$\sum_k \exp\left[-\sigma_k . \log \lambda_n + \log \alpha_{3,k} + \frac{(\sigma_k - 1)}{\theta_k} \log \widehat{\Phi}_{nk}\right] = e_n \tag{A.8}$$

We jointly estimate these equations using constrained non-linear least squares (we minimize the sum of squared errors $(\varepsilon^D_{nk})^2$ while imposing both Equations 38 and A.8 to hold). Observed variables are: the price proxies $\widehat{\Phi}_{nk}$, individual expenditures x_{nk} per industry (net of intermediate goods) and total expenditures e_n.Free parameters to be estimated are the σ_k, θ_k, λ_n and $\alpha_{3,k}$. This estimation procedure can be seen as a non-linear least squares estimation of equation (38) in which λ_n is the implicit solution of the budget constraint, equation (A.8), and thus a function of fitted coefficients and observed per capita expenditures e_n.

At least one normalization is required. Given the inclusion of industry fixed effects, λ_n can be identified only up to a constant.[34] We normalize $\lambda_{USA} = 1$ for the US.

Alternative specifications

We explore several alternative specifications to illustrate the robustness of our income elasticity estimates:

- **Specification without budget constraint**

[33] In Caron et al (2014), we show that this approach yields better and more conservative outcomes than using actual prices from the International Comparison Program. Using actual prices leads to a lower R-squared and a stronger correlation between income elasticity and skill intensity across sectors.

[34] To see this, we can multiply λ_n by a common multiplier λ' and multiply the industry fixed effect α_k by $(\lambda')^{\sigma_k}$. Using $\lambda_n \lambda'$ instead of λ_n and $\alpha_k (\lambda')^{\sigma_k}$ instead of α_k in the demand system generates the same expenditures by industry.

In our baseline estimation, we constraint our fitted per capita expenditures to sum up to observed per capita total expenditures e_n for each country. In other words, we assume that e_n is observed without measurement errors. However, we obtain similar estimates without this constraint, as illustrated in Figure A.1.

Given our good fit for final demand at the country-by-sector level, the fit of total expenditures for each country is then also very good. The difference is negligible if we compare it to the very large variations in per capita income across countries. Hence, imposing a perfect fit for e_n does not generate substantial differences in our estimates.

- **Reduced-form estimation**

  While our estimation procedure is consistent with general equilibrium conditions and our specification of preferences, we show that similar estimates are found when estimating Equation (38) with a reduced-form approximation in which $\log \lambda_n$ is replaced by a linear function of $\log e_n$. Assuming that $\log \lambda_n \approx \nu \log e_n$, we obtain:

$$\log x_{nk} = -\sigma_k \nu \log e_n + \log \alpha_{4,k} + \frac{1-\sigma_k}{\theta_k}. \log \Phi_{nk} + \epsilon_{nk} \tag{A.9}$$

  where $\log \alpha_{4,k}$ and ν are constant terms. Even if ν is not separately identified from σ_k, we can obtain an estimate of income elasticities in each sector:

$$\eta_{nk} = \frac{\widehat{\sigma_k \nu} \sum_{k'} x_{nk'}}{\sum_{k'} \widehat{\sigma'_k \nu} x_{nk'}} \tag{A.10}$$

  We report our estimates in Figure A.1.

- **Specification with $\theta_k = 4$**

  The benchmark specification described above identifies σ_k and income elasticities solely based on the coefficient associated with the Lagrange multiplier λ_n. The σ_k parameter also appears in the coefficient for Φ_{nk} in Equation (38) but the benchmark specification does not impose any constraint on the coefficient for Φ_{nk} since θ_k is a free parameter. In an alternative estimation, we jointly identify σ_k from the coefficients on λ_n and Φ_{nk} by constraining θ_k to equal 4 in all sectors. This choice of θ is close to the Simonovska and Waugh (2014) estimates of 4.12 and 4.03. Donaldson (2012), Eaton et al. (2011), Costinot et al. (2012) provide alternative estimates that range between 3.6 and 5.2. Alternative values for θ (e.g. $\theta_k = 8$) yield very similar results for income elasticities.

- **Instrumenting or dropping $\log \widehat{\Phi}_{nk}$**

  Figure A.2 illustrates an alternative estimation of income elasticities where $\log \widehat{\Phi}_{nk}$ is instrumented by an alternative measure constructed using foreign exporter fixed effects only. Instead of taking the sum of fixed effects across all countries as in the text (including own market), we

construct as instrument $\widehat{\Phi}_{nk}^{IV}$ by taking the sum across foreign countries only:

$$\widehat{\Phi}_{nk}^{IV} = \sum_{i \neq n} \exp\left(\widehat{FX}_{ik} - \sum_{var} \widehat{\beta}_{var,k} TC_{var,ni} - \beta_{ATC,ik} B_{i \neq n}\right)$$

Figure A.2 indicates that the two approaches yield very similar estimates with the exception of a few small sectors ("wtr": water, "c_b" cane and beet sugar, "ros": recreational services).

To illustrate how controlling for trade costs matters, we also estimate final demand by dropping $\log \widehat{\Phi}_{nk} = 0$ in the regression. This is equivalent to assuming that there is no trade costs and that all countries face the same prices. In this specification, we find even larger differences in estimated income elasticity, as illustrated in Figure A.1. These estimates are correlated at 93% with our baseline estimates.

- **Comin, Lashkari and Mestieri (2016)**

  Following Comin, Lashkari and Mestieri (2016), we examine a specification where utility U_n for consumers in country n is implicitly defined by:

$$\sum_k \alpha_k^{\frac{1}{\sigma}} U_n^{\frac{\epsilon_k - \sigma}{\sigma}} Q_{nk}^{\frac{\sigma-1}{\sigma}} = 1$$

  This leads to final demand:[35]

$$x_{nk} = \alpha_k e_n^{\sigma} U_n^{\epsilon_k - \sigma} P_{nk}^{1-\sigma} \tag{A.11}$$

  This implicit utility function does not impose any link between income elasticities (parameterized by ϵ_k) and price elasticities (σ), unlike separable utility functions where income elasticities are proportional to price elasticities across sectors for any country.

  We estimate equation (A.11) by letting U_n be a free parameter. An alternative (as in Comin et al 2016) would be to construct a proxy for U_n, which would be roughly equivalent to the reduced-form approach discussed above (estimation equation A.9).[36]

  Using these estimates, the income elasticity can be retrieved as:

$$\eta_{nk} = 1 + (1 - \sigma)\frac{\epsilon_k - \bar{\epsilon}_n}{\bar{\epsilon}_n - \sigma}$$

  where $\bar{\epsilon}_n$ is an average of ϵ_k weighted by consumption shares to ensure that the weighted average of income elasticities equals one for each country n (Engel aggregation).

  Figure A.5 compares these estimates to our baseline specification, using average expenditures to compute $\bar{\epsilon}_n$. The two sets of estimates are very close and correlated at 89.9%. Moreover, the

[35] In this sum, each term is equal to the share of good k in expenditures: $\frac{x_{nk}}{e_n} = \alpha_k^{\frac{1}{\sigma}} U_n^{\frac{\epsilon_k - \sigma}{\sigma}} Q_i^{\frac{\sigma-1}{\sigma}}$.

[36] One can see from the definition of U above that we can rescale with any exponent $U' = U^a$, hence $(\epsilon_i - \sigma)$ is defined only up to a constant term. However, the income elasticity in CLM can still be identified as it is invariant to re-scaling utility by an exponent a.

income elasticities estimated with Comin et al (2016) preferences remain highly correlated with skill intensity in production (71.2% correlation).

D) Robustness of counterfactual simulation results

D1) Using Comin Lashkari Mestieri preferences

Here we describe the counterfactual equilibrium conditions for final demand when we use the preferences as in Comin et al (2016). Taking change ratios of final demand (equation A.11), we obtain:

$$\widehat{D}_{nk} = \widehat{e_n}^{\sigma} \widehat{U_n}^{\epsilon_k - \sigma} \widehat{P}_{nk}^{1-\sigma}$$

Like the Lagrange multiplier with CREI preferences, the change $\widehat{U_n}$ is constrained by consumers' budget, which yields:

$$\widehat{e}_n = \frac{1}{L_n e_n} \sum_k D_{nk} \widehat{D}_{nk} = \frac{1}{L_n e_n} \sum_k D_{nk} \widehat{e}_n^{\sigma} \widehat{U_n}^{\epsilon_k - \sigma} \widehat{P}_{nk}^{1-\sigma}$$

These two equations allow us to determine $\widehat{D}_{nk}$ and $\widehat{U}_n$ depending on other outcome variables (changes in income $\widehat{e}_n$ and prices $\widehat{P}_{nk}$) and estimated parameters.

D2) Reducing trade costs, one country at a time

We now examine the effect of a trade cost reduction $\log \widehat{d_{nik}}$ for all countries pairs that include a given country i.

The decomposition is the same as before up to equation A.4. The only term that differs from the previous decomposition is the first "direct effect" term:

$$\text{Direct effect} \quad = \quad -\sum_n \theta_k \, \pi^X_{nik} \, \log \widehat{d_{nik}} \; + \; \sum_n \theta_k \, \pi^X_{nik} \, \sum_j \pi^M_{njk} \log \widehat{d_{njk}}$$

With $\widehat{d_{njk}} = \widehat{d}$ if $n = i$ or $j = i$ but $n \neq j$, and $\widehat{d_{njk}} = 1$ otherwise, we get:

$$\begin{aligned}
\text{Direct effect} \quad &= \quad -\theta_k \, \log \widehat{d} \, \sum_{n \neq i} \pi^X_{nik} \; + \; \theta_k \, \log \widehat{d} \; \pi^X_{iik} \, \sum_{j \neq i} \pi^M_{ijk} \; + \; \theta_k \, \log \widehat{d} \, \sum_{n \neq i} \pi^X_{nik} \, \pi^M_{nik} \\
&= \quad -\theta_k \, \log \widehat{d} \, \sum_{n \neq i} \pi^X_{nik} \, (1 - \pi^M_{nik}) \; + \; \theta_k \, \log \widehat{d} \, \pi^X_{iik} \, (1 - \pi^M_{iik}) \\
&= \quad \theta_k \, \log \widehat{d} \; \left[\pi^X_{iik} \, (1 - \pi^M_{iik}) \; - \; \sum_{n \neq i} \pi^X_{nik} \, (1 - \pi^M_{nik}) \right]
\end{aligned}$$

Combining this direct effect with the previous equality we obtain:

$$\log \widehat{Y_{ik}} \quad \approx \quad \theta_k \, \log \hat{d} \; \left[\pi^X_{iik} (1 - \pi^M_{iik}) - \sum_{n \neq i} \pi^X_{nik} (1 - \pi^M_{nik}) \right]$$

$$
\begin{aligned}
&- \sum_n \pi^X_{nik} \sum_j \pi^M_{njk} (\log \widehat{S_{jk}} - \log \widehat{S_{ik}}) \\
&+ \sum_n \pi^X_{nik} \, \varphi_{nFk} \, \log \left(\widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k} \right) \\
&+ \sum_{n,h} \pi^X_{nik} \, \varphi_{nhk} \, \log \, \widehat{Y_{nh}}
\end{aligned}
$$

Combining these changes in production patterns with equation (A.2), we obtain a four-term decomposition of the effect of a trade cost reduction on the skill premium:

$$
\begin{aligned}
\log \frac{\widehat{w_{iH}}}{\widehat{w_{iL}}} \approx \; & \frac{1}{\tilde{\rho}_i} \log \hat{d} \sum_k (sh^H_{ik} - sh^L_{ik}) \, \theta_k \left[\pi^X_{iik} (1 - \pi^M_{iik}) - \sum_{n \neq i} \pi^X_{nik} (1 - \pi^M_{nik}) \right] \\
& - \frac{1}{\tilde{\rho}_i} \sum_k (sh^H_{ik} - sh^L_{ik}) \sum_n \pi^X_{nik} \sum_j \pi^M_{njk} (\log \widehat{S_{jk}} - \log \widehat{S_{ik}}) \\
& + \frac{1}{\tilde{\rho}_i} \sum_k (sh^H_{ik} - sh^L_{ik}) \sum_n \pi^X_{nik} \, \varphi_{nFk} \, \log \left(\widehat{\lambda_n}^{-\sigma_k} \widehat{P_{nk}}^{1-\sigma_k} \right) \\
& + \frac{1}{\tilde{\rho}_i} \sum_k (sh^H_{ik} - sh^L_{ik}) \sum_{n,h} \pi^X_{nik} \, \varphi_{nhk} \, \log \, \widehat{Y_{nh}}
\end{aligned}
$$

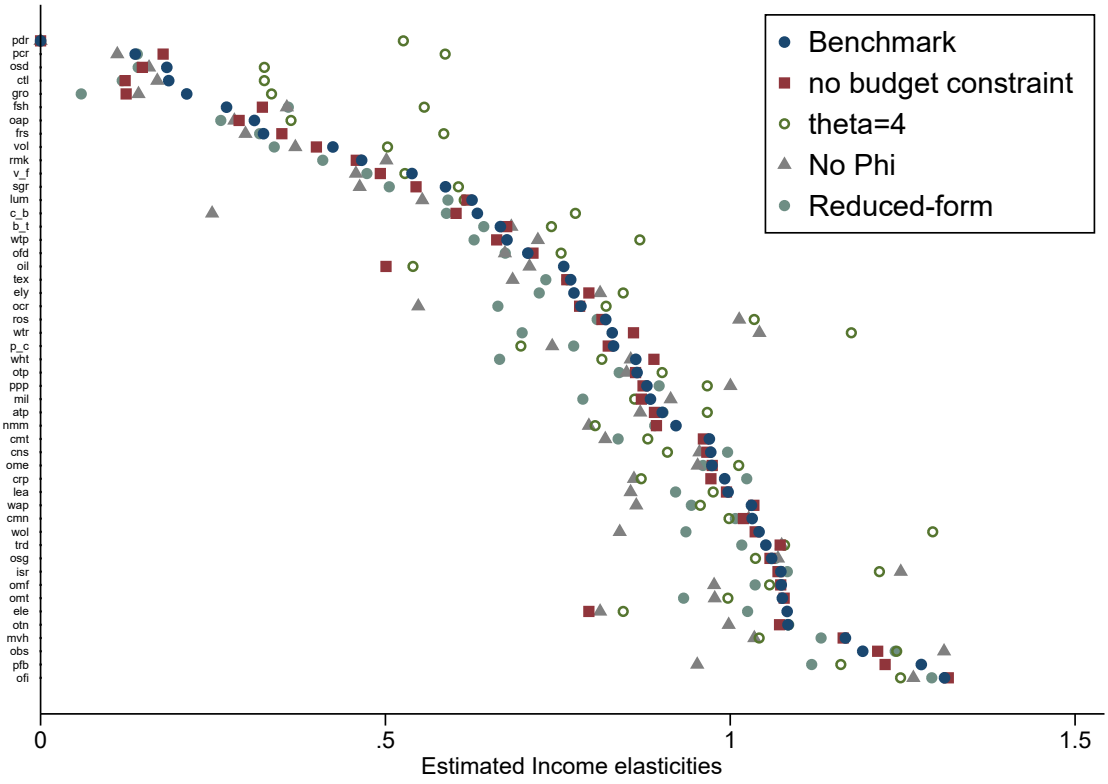


Figure A.1: Estimated income elasticities across alternative specifications

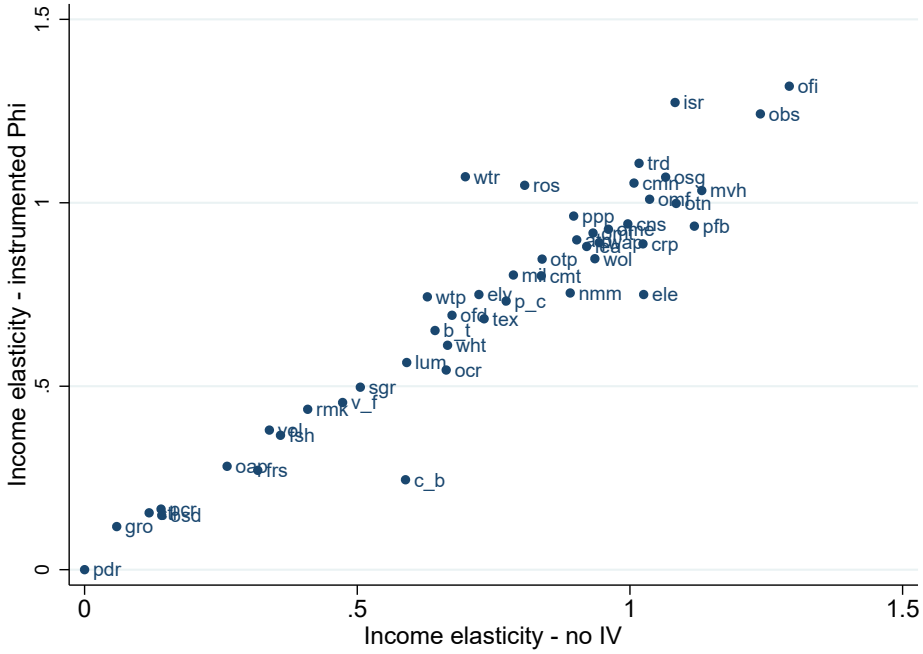


Figure A.2: Estimated income elasticities – Instrumenting Φ

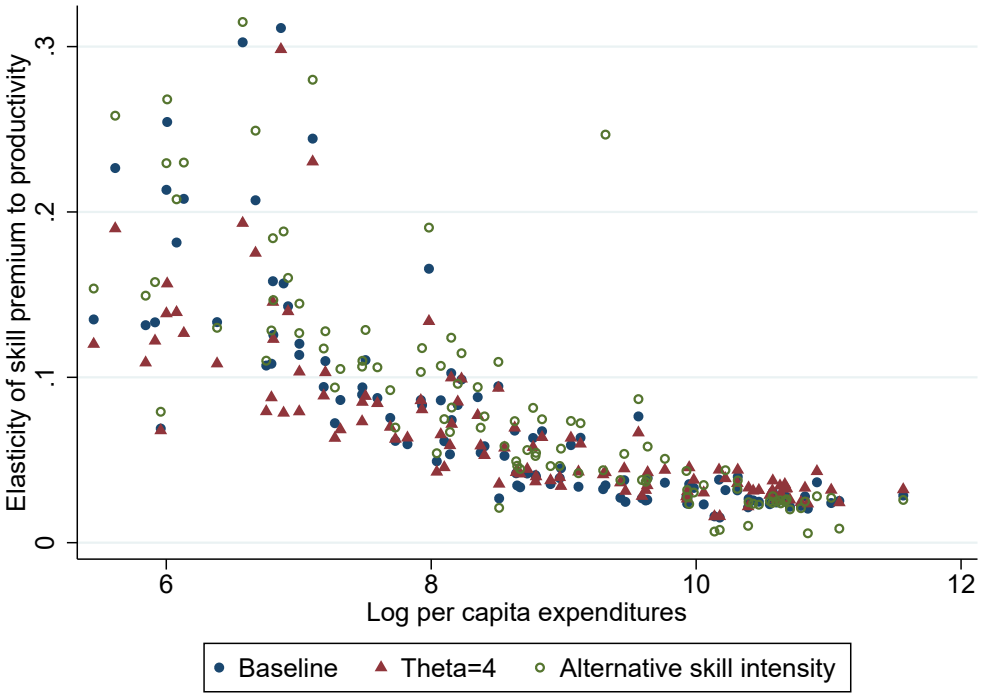


Figure A.3: Simulated elasticity of the skill premium increase to TFP across alternative specifications

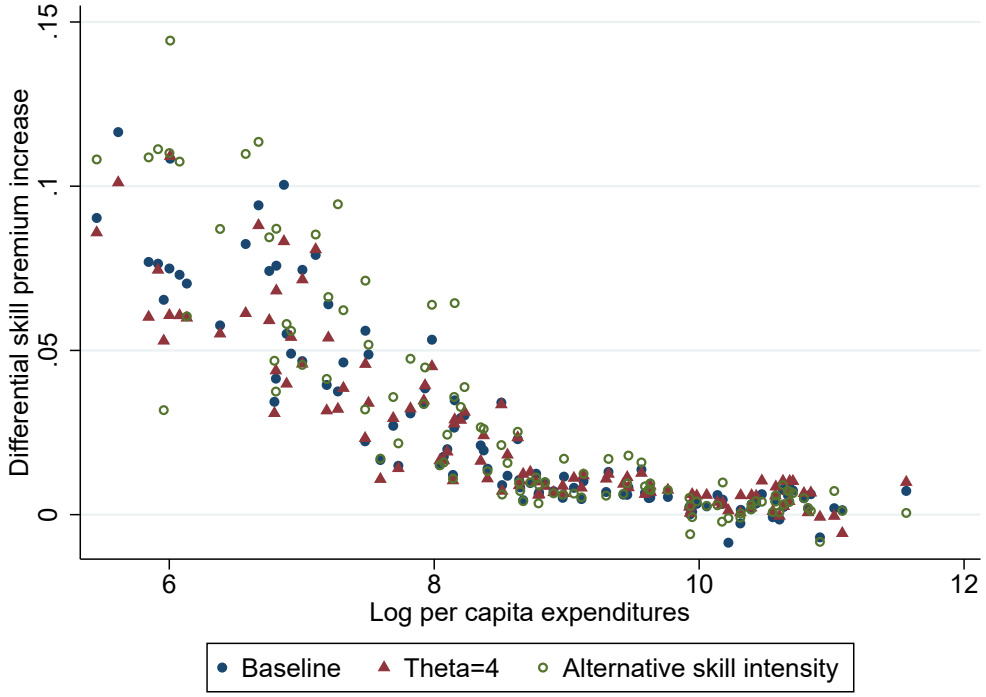


Figure A.4: Trade counterfactual: Differential skill premium increase across alternative specifications (non-homothetic preferences minus homothetic preferences)

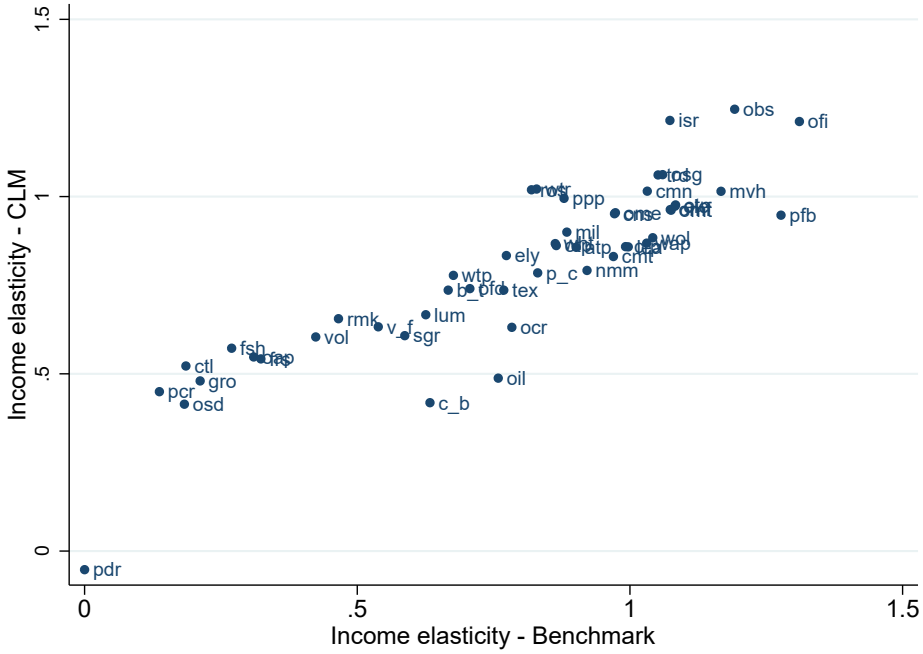
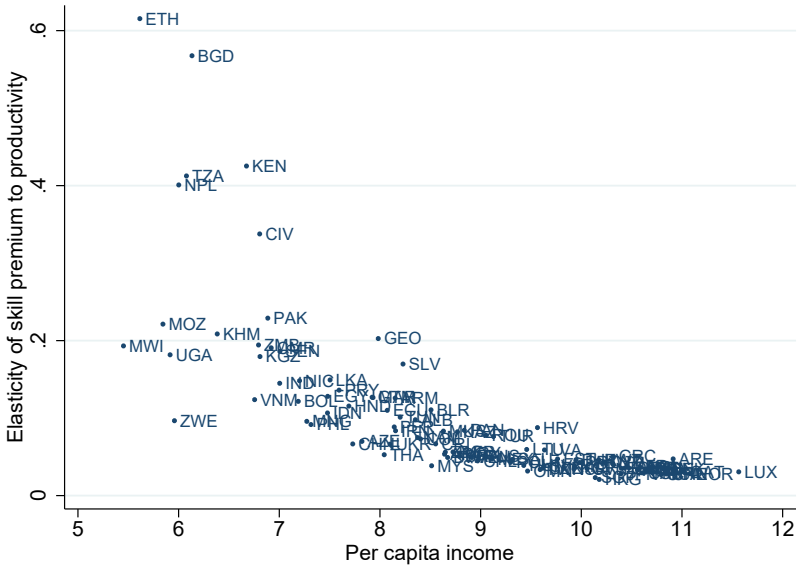
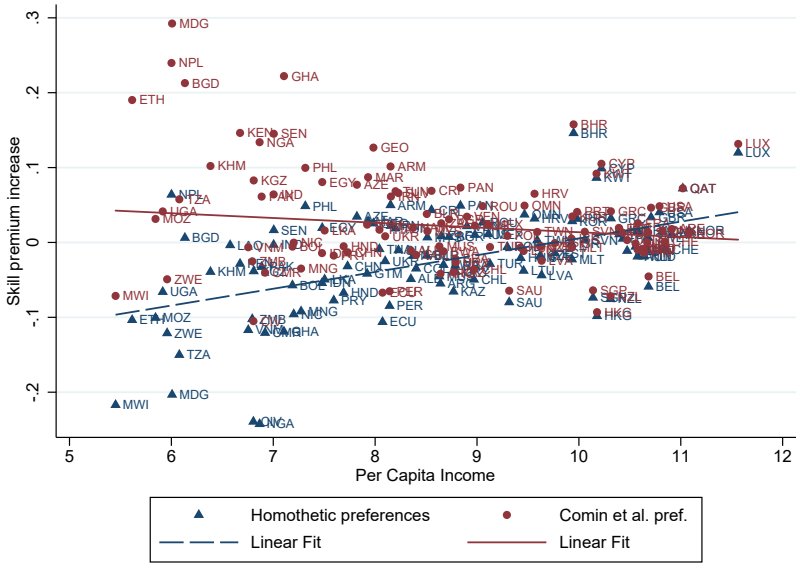


Figure A.5: Estimated income elasticities – based on Comin et al (2016) preferences

Figure A.6: Robustness: counterfactuals based on Comin et al (2016) preferences



(a) First counterfactual: homogeneous productivity increase



(b) Second counterfactual: trade cost reduction

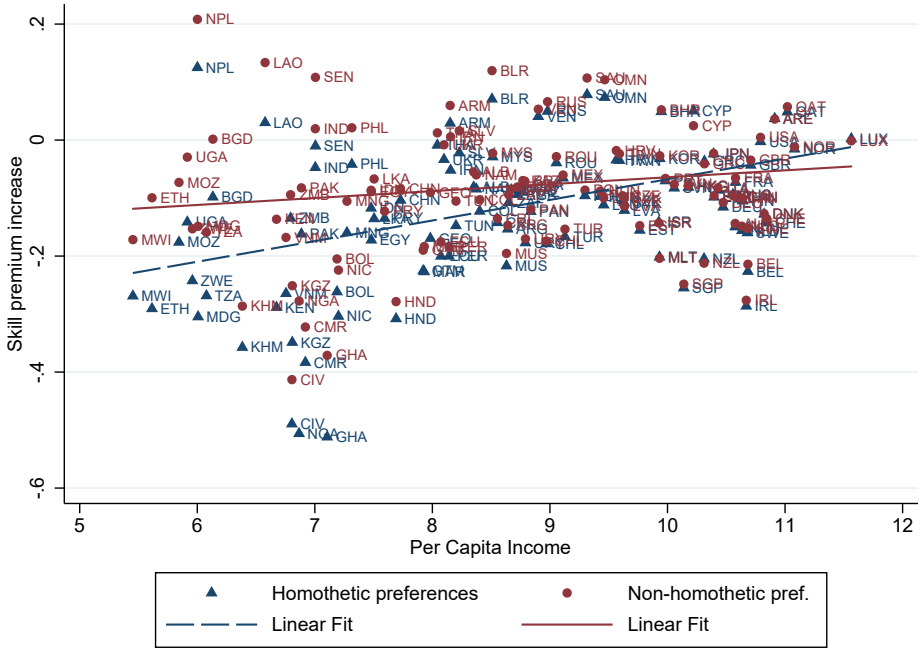


Figure A.7: Change in the skill premium caused by a 1% trade cost reduction, one country at a time (each dot corresponds to a distinct counterfactual)