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Accounting for Skill Premium Patterns: Evidence from the EU Accession

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In this article, we decompose the joint and individual contributions of tariff reductions, productivity changes and capital deepening to account for the skill premium patterns of the transition economies that joined the European Union (EU) in 2004. To conduct our accounting analysis, we construct an applied general equilibrium model with skilled and unskilled labor, and combining Social Accounting Matrices, Household Budget Surveys and the EU KLEMS Growth and Productivity Accounts database, we calibrate it to match Hungarian data, a transition economy where the skill premium consistently increased between 1995 and 2005. We find that capital deepening coupled with capital-skill complementarity is the main force behind the rise in the skill premium.

JEL Classification: D58, E24, F16, O11

1. Introduction

What drives the increasing patterns of the skill premium? This is a topic of extensive and at times contentious debate in the economics literature with no definitive consensus. While a variety of explanations have been laid out, two factors have been identified as the major forces leading to rising skill premia: increased trade volumes and technological change that is biased against unskilled workers. The main proponents of the first hypothesis are Feenstra and Hanson (1996, 1999) and Wood (1995, 1998). There is further disagreement within the second strand of the literature since one line of thought argues that the factor bias of technical change can account for the observed changes in the skill premium (see e.g., Krugman 2000; Acemoglu 2002), while another points to the sector bias of technical change as the culprit (see Kahn and Lim 1998; Haskel and Slaughter 2002 for details). Finally, Krusell et al. (2000) provide an explanation for the increasing pattern of the skill premium in the United States due to capital-skill complementarities, a result further validated by Polgreen and Silos (2008).

Of course, all of these explanations are not necessarily mutually exclusive as different forces could potentially affect the skill premium simultaneously. A pertinent example of this is the case of the so-called transition economies of Central and Eastern Europe that joined the European Union (EU) in the 2004 and 2007 enlargement rounds. En route to their accession into the EU, most of these countries initially signed free trade agreements among themselves (the Central European

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Free Trade Agreement or CEFTA) and with the "old" EU members (included in the European Union Association Agreement, or EUAA). Thus, by reducing or eliminating their import tariffs, they allowed for freer transactions of goods and services with their major trade partners. Moreover, as these countries transitioned from centrally planned to market-oriented systems, they experienced rapid increases in productivity across sectors. In addition, while at the onset of their transition these countries were significantly poorer than their Western counterparts in terms of their levels of capital stock, they accumulated sizable amounts of capital over the years, either through domestic investment or borrowing from abroad. Finally, the citizens of the Central and Eastern European nations became eligible to work in Ireland, the United Kingdom, and Sweden starting from the year after the countries' accession to the EU. Thus, migration of workers from the relatively poor "new" EU members to the more affluent "old" members could have also played a role in affecting the skill premium.

To the best of our knowledge, no article in the literature has conducted a decompositional analysis of the main drivers of skill premium patterns for the transition economies. These economies present an interesting case since prior to the transition wages were determined in a rigid centrally planned mechanism, whereas currently they respond to labor market forces.

With this article, we aim to contribute to the literature by disentangling the multiple factors that affected the patterns of the skill premium as the transition countries restructured their economies and ultimately joined the EU. While a number of articles has been written on the subject (see Crinò 2005; Esposito and Stehrer 2009; and Parteka 2012, among others), most of those studies have focused on the role of one single contributing factor at a time and have concentrated on the manufacturing sector, thus neglecting approximately two thirds of economic activity. Moreover, the vast majority of these studies are conducted using reduced-form regressions. But as Abrego and Whalley (2000) point out, "structural models are needed to make a meaningful decomposition of an observed relative wage change into a portion due to trade and a portion due to technological change." They continue to argue that "because the model parameters consistent with given reduced-form data are not unique, different parameterizations can generate different decomposition results between trade and technological change as sources of an observed change in inequality." Cho and Díaz (2013) is an example of an economy-wide study that uses a structural model, but instead of conducting a decompositional analysis their focus is on the role of trade integration on the Slovenian skill premium through the Heckshер–Ohlin (H–O) mechanism.

In light of these remarks, we use an applied general equilibrium modeling approach which allows us to conduct a decompositional analysis that compares the relative importance of the various competing theories of the skill premium. Using a general equilibrium model, we can clearly assess the impact of a particular shock in the economy under study. Our modeling choice also allows us to evaluate the effect of specific shocks on the whole economy, not just the manufacturing sector. To conduct our quantitative analysis, we focus on the evolution of the skill premium patterns for the case of Hungary, one of the leading reformers among the transition economies. Our choice of Hungary is motivated by three main facts. First, for the 1995–2005 period, the skill premium in Hungary registered the largest increase among new EU members for which data are available.[1] Second, during the same period we observe that the skill premium in Hungary exhibits a strong, positive correlation with trade volumes, total factor productivities, and the stock of

[1] The skill premium in Hungary is also higher in absolute terms than in other transition countries for which comparable data are available.

capital. Third, as far as we know, Hungary is the only transition economy for which the necessary data to conduct all of our numerical experiments are readily available.

The applied general equilibrium model that we construct displays a sectoral disaggregation that is relevant to our analysis. It also includes skilled and unskilled consumers/workers, so that we can track the effects of different shocks on their wages, and consequently the skill premium. Finally, our model incorporates complementarity between capital and skilled labor in the production process.

For the quantitative analysis, we use a variety of data sources, including Social Accounting Matrices (SAM), Household Budget Surveys (HBS), and the EU KLEMS database and calibrate the parameters of our model to match the start dates of the two periods identified previously: 1995 and 2000. Once calibrated, we subject the model economy to a variety of shocks: a "tariff reduction" shock, where we model the different tariff reductions implemented by Hungary (initially, the free trade agreements with the EU and afterwards, as an EU member, the customs union arrangement with the rest of the world); a "productivity" shock, where we replicate the changes in sectoral and skill-biased productivities observed in the data; and a "capital deepening" shock, where we let the capital stock in Hungary grow at the rates observed in the data.[2] After implementing each shock, we compute the new corresponding equilibrium and assess the role of each particular hypothesis, as well as the effect of all shocks implemented jointly.

We understand that these shocks are not necessarily disconnected from each other. For instance, trade liberalization can generate biased technical changes through endogenous technological adoption in line with comparative advantages. Similarly, this process can also accelerate capital accumulation through foreign direct investment. However, our objective in this article is not to explain why these events took place, but instead to assess their relative roles given that they occurred in their observed magnitudes. In fact, when we implement all three shocks jointly, our model can account for approximately 87% of the actual changes in the skill premium for both periods.

Looking at the contribution of each particular hypothesis, we find that different shocks played different roles in accounting for the changes in the skill premium. First, the tariff reductions played only a small role at accounting for the observed increases in the skill premium for both periods. Second, the effect of the productivity shocks is mixed as the sector-biased shocks generate a decrease in the skill premium while the factor-biased shocks lead to an increase in the skill premium. While the magnitude of changes in the skill premium generated by both types of productivity shocks are modest in the first period, the sector-biased shocks generate a large decrease in the skill premium in the second period. Third, the capital deepening shock coupled with the presence of capital-skill complementarity accounts for the largest fraction of the increase in the skill premium for both periods. Therefore, the strong increase in the skill premium during the first period was mainly driven by the capital deepening effect, whereas the slowdown of the skill premium in the second period was a result of the combination of the negative effect of the productivity shock (and specifically the sector-biased shock) against the positive effect of capital deepening.

[2] We could similarly conduct a "migration" shock which replicates the emigration flows of workers from Hungary to the rest of the EU, but as Galgóczi, Leschke, and Watt (2009) and Hárs (2009) document, up until 2006 Hungary was one of the few low emigration countries in Central and Eastern Europe, and thus we expect this factor to have only minor implications for the patterns of the skill premium.

In order to assess the validity of the predictions generated by our model, we perform a series of sensitivity experiments on the values of a subset of key parameters. In particular, when we allow for differentiated import elasticities across sectors, both foreign trade and the skill premium exhibit changes that closely resemble those found in our benchmark experiment. Additionally, we allow for different values of the elasticity of substitution between capital and skilled labor in order to understand the role of the capital-skill complementarity assumption. This includes an extreme scenario where we remove the complementarity assumption and use a Cobb–Douglas production function instead. Our results highlight the importance of the capital-skill complementarity mechanism presented by Krusell et al. (2000), which is also backed up empirically by the firm-level findings in Koren and Csillag (2011) for the Hungarian manufacturing sector.

The article is organized as follows. Section 2 presents a brief data overview. Section 3 describes the model we use to conduct our quantitative analyses. Section 4 describes how we calibrate most of the model's parameters and how we assign values to the parameters that cannot be calibrated. Section 5 presents the results of our numerical experiments, including the sensitivity simulations. Section 6 concludes.

2. Relevant Data Trends

In this section, we show the skill premium trends as well as other relevant macroeconomic variables in Hungary for the period between 1995 and 2005. Specifically, we document the trends of international trade, the stock of capital, and total factor productivity (TFP).

Skill Premium Trends

We use the EU KLEMS Growth and Productivity Accounts database, which contains annual data on labor compensation and hours worked by production sector, skills levels and country for the 1995–2005 period, to calculate the skill premium series for Hungary. Following Krusell et al. (2000), we define skilled workers as those with tertiary education, and unskilled workers as those with primary or secondary education. The EU KLEMS database does not contain the wages of skilled and unskilled workers explicitly, but we can calculate the skill premium by dividing the ratios of total labor compensation to total hours worked for skilled and unskilled workers, which can be found in the database, as shown in Appendix A. Thus, we obtain:

$$skill\,premium = \frac{w_s}{w_u} = \frac{\frac{w_s L_s}{L_s}}{\frac{w_u L_u}{L_u}} \tag{1}$$

where w_s and w_u are, respectively, the wages of skilled and unskilled workers. Similarly, L_s and L_u are the total hours worked by skilled and unskilled workers, and consequently $w_s L_s$ and $w_u L_u$ are the total labor compensations of skilled and unskilled workers.

We find that in Hungary the skill premium exhibits a consistent upward trend during the 1995–2005 period, with an overall increase of approximately 13%. Our findings for the skill premium in Hungary are in line with the results presented by Campos and Jolliffe (2007) who use labor earnings survey data between 1986 and 2004. Looking deeper into the data, we identify two distinct episodes within the 1995–2005 period: one, from 1995 to 2000, when most of Hungary's economic reforms and a major stabilization program were being implemented, and during which

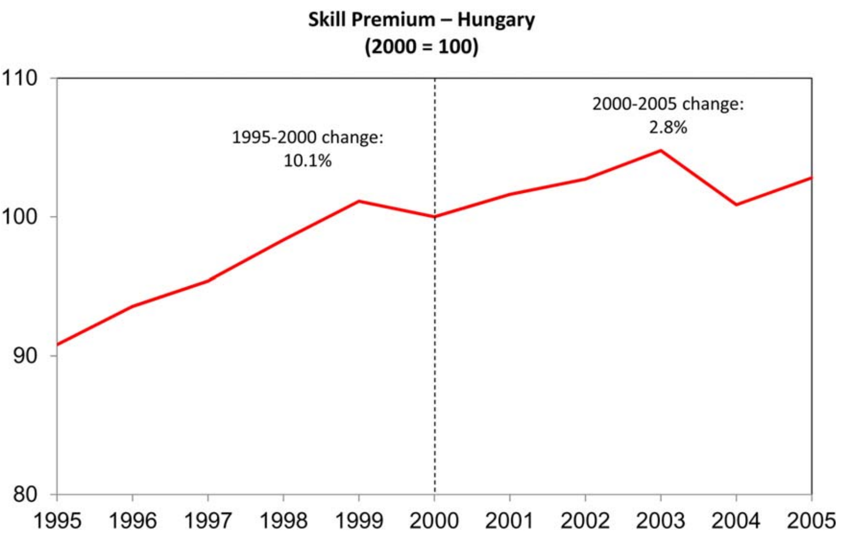

Figure 1. Skill Premium in Hungary

the skill premium rose at a strong 10.1% rate, and the second one, from 2000 to 2005, when Hungary's transition towards a fully fledged market economy culminated with its accession into the EU, and during which the skill premium rose at a more modest rate of 2.8% (see Figure 1).

International Trade Trends

Until the early 1990s, Hungary's main trade partners were the members of the Council for Mutual Economic Assistance (CMEA), an economic organization comprised of most Eastern bloc countries and other socialist states in the world. The collapse of the CMEA in 1991 severely impacted Hungary's foreign sector and resulted in the disappearance of almost half of its previous export markets (for more details, see World Trade Organization [WTO] (1998)).

In spite of this major shock, Hungary took steps to increase its openness to international trade by joining the CEFTA in 1992, signing a free trade agreement with the European Free Trade Association (EFTA) in 1993, and signing an Association Agreement with the EU in 1994, which included a free trade agreement with the EU and laid out Hungary's candidacy to become a full-fledged member of the EU, which ultimately took place in 2004. As a result of these opening initiatives, total trade more than doubled (a 109.43% increase) between 1995 and 2000, and its relative importance in total activity (measured by total trade as a fraction of GDP) grew by 50.94% during the same period (see Figure 2). Between 2000 and 2005, total trade continued growing strongly, although at a somewhat slower rate (a 81.12% increase), whereas the size of trade in total activity kept growing, but at a significantly lower rate (only a 23.08% increase). During this period, most of Hungary's international trade was conducted with EU members.

The Stock of Capital and Total Factor Productivity

Starting in the mid-1990s, Hungary started accumulating capital at much faster rates than in the past (see Figure 3). The data from Feenstra, Inklaar, and Timmer (2013) indicates that whereas

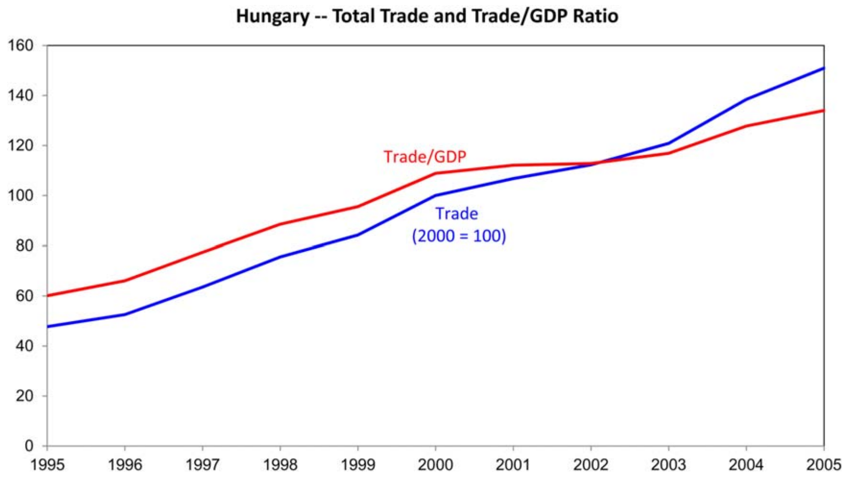

Figure 2. Hungary—Total Trade and Openness

in the 1990–1995 period the capital stock grew by 7%, for the 1995–2000 period capital stock grew by 14.62%, more than doubling the rate of increase of the previous five-year period. During the 2000–2005 period, capital kept growing at an even faster pace, at a rate of 17.07%. Figure 3 also depicts the capital to working-age population ratio, which shows a similar trend of increasing growth rates over time. The corresponding growth rates of capital to working-age population ratio are 15.02% for the 1995–2000 period and 17.51% for the 2000–2005 period, respectively.

Similarly, both gross output (GO) and value added (VA) TFP exhibited consistent growth over the 1995–2000 period as shown in Figure 4. However, just as in the case of the skill premium, the growth in TFP slowed down during the 2000–2005 period: while GO and VA TFP grew by

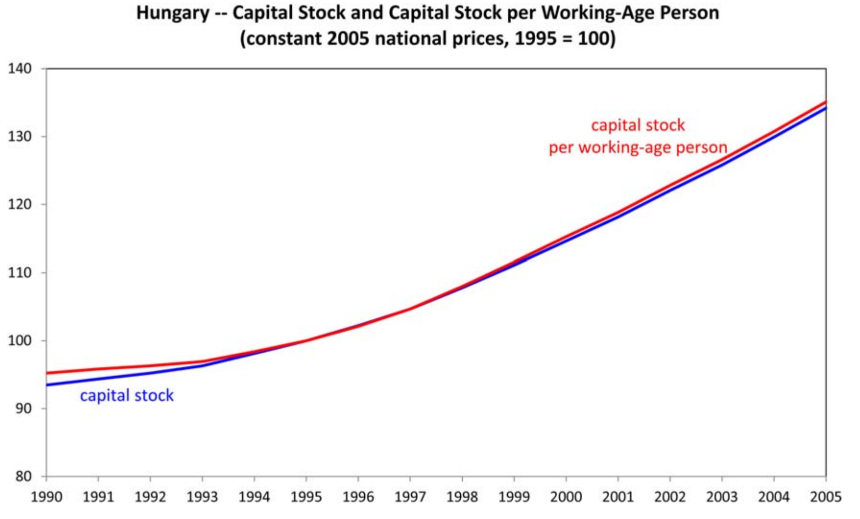

Figure 3. Hungary—Capital Stock

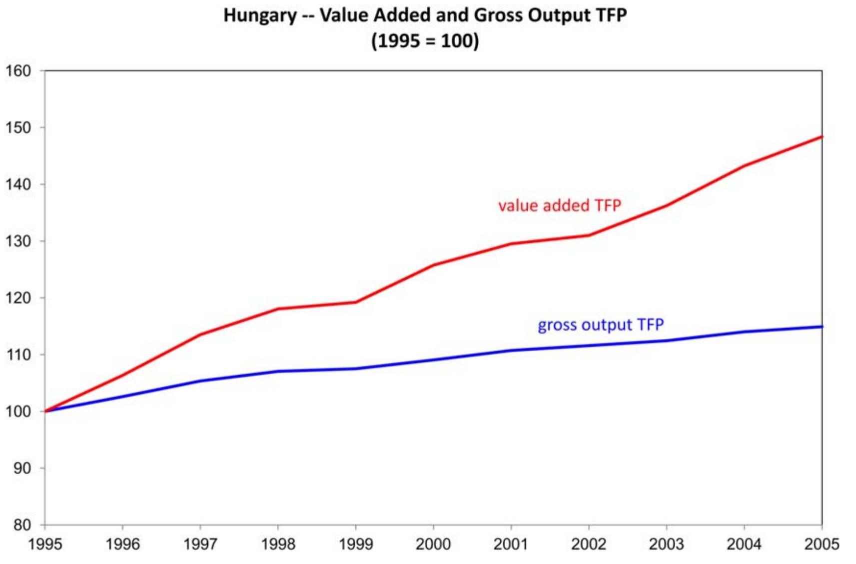

Figure 4. Hungary—Trends in TFP

9.06% and 25.75% between 1995 and 2000, respectively, their growth rates between 2000 and 2005 were 5.36% and 17.99%.[3]

3. The Model

Overview

We construct a static applied general equilibrium model and disaggregate the Hungarian economy into three main sectors: primaries, manufacturing, and services. Each sector is in turn divided into two, depending on its skill intensity: skilled or unskilled. Thus, our model economy is effectively disaggregated into six sectors. Our artificial economy is populated by several agents: two representative consumers (differentiated by their skills levels), producers, a domestic government and foreign trade partners. The richness of our model allows us to accommodate various simulations, and their implications to the aggregate economy as well as across different sectors. We provide a more detailed explanation of their features below.

Domestic Production Firms

We assume that final goods are produced combining a domestically produced component and an imported component. Domestic production firms produce the local component of the final goods. They use intermediate inputs from all sectors in fixed proportions, and also combine capital and skilled and unskilled labor using a constant elasticity of substitution (CES) technology for output.[4] The production function of the domestic firm producing good i is:

[3] Data for GO and VA TFP are taken from the EU KLEMS database.

[4] We thank an anonymous referee for pointing out to us the importance of assuming an aggregate Cobb–Douglas production function for our analysis. As shown in Felipe and Fisher (2008), the relations among aggregate variables may be implied by accounting identities with stable factor shares.

$$y_{i,d}=\min\left\{\frac{x^d_{1,i}}{a^d_{1,i}},\ldots,\frac{x^d_{i,i}}{a^d_{i,i}},\ldots,\frac{x^d_{n,i}}{a^d_{n,i}},\beta_i\left[\lambda_i\left[\mu_i k_i^\rho+(1-\mu_i)(\varphi_s\ell_{s,i})^\rho\right]^{\frac{\sigma}{\rho}}+(1-\lambda_i)(\varphi_u\ell_{u,i})^\sigma\right]^{\frac{1}{\sigma}}\right\} \tag{2}$$

where $y_{i,d}$ is the output of the domestic firm i, $x^d_{m,i}$ is the amount of intermediate input of good m used in the production of good i, $a^d_{m,i}$ is the unit-input requirement of intermediate good m in the production of good i, and k_i, $\ell_{s,i}$ and $\ell_{u,i}$ are, respectively, the capital, skilled labor and unskilled labor inputs used to produce good i. Our modeling choice of fixed-proportion technology for intermediate inputs is standard in the input-output literature and reflects the empirical findings in Sevaldson (1970) and Miller and Blair (2009) that unit-input requirement coefficients are stable over time. In Equation 2, changes in β_i define sector-specific, Hicks neutral technical change in the domestic goods production, whereas changes in φ_s and φ_u reflect factor-biased technical change.

Final Production Goods Firms

The firm that produces the final production good i combines the domestic component with an imported component using an Armington aggregator of the form:

$$y_i=\gamma_i\left[\delta_i y_{i,d}^{\rho_{m,i}}+\sum_{f\in T}\delta_{i,f}y_{i,f}^{\rho_{m,i}}\right]^{\frac{1}{\rho_{m,i}}} \tag{3}$$

where $i\in\{1,2,\ldots,n\}$ are the goods in G_p, the set of final production goods, $\sigma_{m,i}=1/(1-\rho_{m,i})$ is the elasticity of substitution between domestic and imported goods (note that we allow for possibly different elasticities of substitution for different production goods), y_i is the output of final good i, $y_{i,d}$ is the domestic component in final good i and $y_{i,f}$ is the imported component from trade partner $f\in T$, the set of trade partners. As in Equation 2, changes in γ_i capture sector-specific, Hicks-neutral technical change in the final goods production. Finally, imports of good i from country f are subject to an ad valorem tariff rate $\tau_{i,f}$.

Consumption Goods Firms

We assume that the goods purchased by households are different from those purchased by production firms for their intra-industries transactions. In particular, the goods that consumers purchase have a very high service component embedded in them. Therefore, we assume that consumers purchase goods that we label as "consumption goods." The consumption goods firms combine the final production good of its own sector and unskilled and skilled services (indexed as *us* and *ss*, respectively) in fixed proportions, together with capital, and skilled and unskilled labor:

$$y_{i,c}=\min\left\{\frac{x^c_{i,i}}{a^c_{i,i}},\frac{x^c_{us,i}}{a^c_{us,i}},\frac{x^c_{ss,i}}{a^c_{ss,i}},\beta_i^c\left[\lambda_i^c\left[\mu_i^c(k_i^c)^{\rho_c}+(1-\mu_i^c)(\varphi_s\ell^c_{s,i})^{\rho_c}\right]^{\frac{\sigma_c}{\rho_c}}+(1-\lambda_i^c)(\varphi_u\ell^c_{u,i})^{\sigma_c}\right]^{\frac{1}{\sigma_c}}\right\} \tag{4}$$

As previously denoted for the domestic goods production, sector-specific technical change, and factor-biased technical change in the consumption goods production are captured by changes in β_i^c, and φ_s and φ_u, respectively. The set of consumption goods is denoted by G_c.

Investment Good Firm

The model includes an investment good in order to account for the savings observed in the data. In a dynamic model, agents save in order to enjoy future consumption. In a static model like the one we use, agents derive utility from consuming the investment good, just as they derive utility from the consumption goods. The investment good y_{inv} is produced by a firm that combines the final goods as intermediate inputs using a fixed proportions technology, as shown:

$$y_{inv} = \min\left\{\frac{x_{1,inv}}{a_{1,inv}}, \ldots, \frac{x_{i,inv}}{a_{i,inv}}, \ldots, \frac{x_{n,inv}}{a_{n,inv}}\right\} \tag{5}$$

Consumers

As we previously described, we disaggregate the Hungarian households into two different representative consumer groups, characterized by their skills levels. We denote the set of households by H. The motivation of this disaggregation is to explicitly trace the effects of the different shocks on the wages of skilled versus unskilled workers. Household preferences are represented by a Cobb–Douglas utility function defined over the consumption goods and savings. The problem of a representative household j is:

$$\max \sum_{i \in G_C} \theta_i^j \log c_i^j + \theta_{inv}^j \log c_{inv}^j + \sum_{f \in T} \theta_{inv,f}^j \log c_{inv,f}^j \tag{6}$$

$$\text{s.t.} \sum_{i \in G_C} p_{c,i} c_i^j + p_{inv} c_{inv}^j + \sum_{f \in T} e_f \bar{p}_{inv,f} c_{inv,f}^j = (1 - \tau_d^j)(w_j \bar{\ell}_j + r \bar{k}_j)$$

where c_i^j is the consumption of good i by household j; $p_{c,i}$ is the price of consumption good i; τ_d^j is the direct tax rate imposed on household j; w_j is the wage rate for either skilled and unskilled labor; r is the rental rate of capital; and $\bar{\ell}_j$ and $\bar{k}_j$ are the endowments of labor and capital of household j. Since this is a static setup, we model household savings as purchases of the investment good. As such, c_{inv}^j represents the purchase of the investment good by household j, and p_{inv} is the price of the investment good. Additionally, if Hungary runs a trade surplus with a trade partner, we model this as household purchases of a foreign investment good (i.e., Hungarian households are saving abroad). Thus, $c_{inv,f}^j$ represents the purchases of the investment good from the trade partner by household j, $\bar{p}_{inv,f}$, its price (which is assumed to be exogenous) and e_f is the bilateral real exchange rate.

The Government

The data show that the Hungarian government makes purchases of goods and services. At the same time, the government collects revenues from direct and indirect taxes, as well as tariffs imposed on imports. In general, tax revenues and government purchases do not match, with the difference being the government balance. In our setup, the government balance is modeled as purchases of the investment good by the government, which we denote as c_{inv}^g. We assume that the government is an agent that enjoys utility from consuming the final production goods and the investment good. Thus, the problem of the government is:

$$\max \sum_{i \in G_p} \theta_i^g \log c_i^g + \theta_{inv}^g \log c_{inv}^g \tag{7}$$

$$\text{s.t.} \sum_{i \in G_p} p_i c_i^g + p_{inv} c_{inv} = \sum_{j \in H} \tau_d^j (w_j \bar{\ell}_j + r\bar{k}_j) + \sum_{i \in G_p} t_{p,i} p_{d,i} y_{i,d}$$
$$+ \sum_{i \in G_c} t_{c,i} p_{c,i} y_{i,c} + \sum_{f \in T} \sum_{i \in G_p} \tau_i e_f \bar{p}_{i,f} y_{i,f}$$

The left-hand side of the budget constraint for the government includes purchases of goods and the investment good. The right-hand side of the equation includes tax and tariff revenues: the first term is the direct taxes collected from the income of the two different households; the second and third terms are the revenues collected from taxing the domestic and consumption goods firms, respectively; the last term represents the tariff revenues collected.

Foreign Trade Partners

In our model, Hungary trades with two trade partners: the EU and the Rest of the World (ROW). In each trade partner country $f \in T$ there is a representative consumer that purchases imported goods $x_{j,f}$ from Hungary and consumes its local good $x_{f,f}$. In this setup, foreign trade does not need to balance. Thus, if Hungary runs a trade deficit with a foreign trade partner, we model this trade deficit as foreign purchases of the Hungarian investment good $x_{inv,f}$ (i.e., foreigners are saving in Hungary).

The problem of the representative household in the foreign country *f* is

$$\max \left[\sum_{j \in G_P} \theta_{j,f} x_{j,f}^{\rho_x} + \theta_{inv,f} x_{inv,f}^{\rho_x} + \theta_{f,f} x_{f,f}^{\rho_x} - 1 \right] / \rho_x \tag{8}$$
$$\text{s.t.} \sum_{j \in G_P} (1+\tau_j^f) p_j x_{j,f} + p_{inv} x_{inv,f} + e_f x_{f,f} = e_f I_f$$

where τ_j^f is the ad valorem tariff rate that country *f* imposes on the imports of good *j*, ρ_x is the parameter that determines the exports elasticity of substitution σ_x (i.e., $\sigma_x = 1/(1-\rho_x)$), e_f is the bilateral real exchange rate between Hungary and trade partner *f*, and I_f is the (exogenous) income of the household in country *f*.

Definition of Equilibrium

An equilibrium for this economy is defined by a set of prices for the domestic goods $\{p_{i,d}\}_{i \in G_p}$; prices for the final goods $\{p_i\}_{i \in G_p}$; a price for the investment good p_{inv}; prices for the consumption goods $\{p_{c,i}\}_{i \in G_c}$; factor prices w_s, w_u, r; bilateral exchange rates $\{e_f\}_{f \in T}$; foreign prices $\{\bar{p}_{i,f}\}_{i \in G_p, f \in T}$; a consumption plan for each type of household $\{c_i^j, c_{inv}^j, c_{inv,f}^j\}_{i \in G_c, j \in H}$; a consumption plan for the government $\{c_i^g, c_{inv}^g\}_{i \in G_p}$; a consumption plan for the foreign household in country *f* $\{x_{i,f}, x_{inv,f}, x_{f,f}\}_{i \in G_p, f \in T}$; a production plan for the domestic good *i* firm $(y_{i,d}, x_{1,i}^d, \ldots x_{n,i}^d, k_i, \ell_{u,i}, \ell_{s,i})$; a production plan for the final good *i* firm $(y_i, y_{i,d}, y_{i,f})$; a production plan for the investment good firm $(y_{inv}, x_{1,inv}, \ldots, x_{n,inv})$; a production plan for the consumption good *i* firm $(y_{i,c}, x_{i,i}^c, x_{us,i}^c, x_{ss,i}^c, k_i^c, \ell_{u,i}^c, \ell_{s,i}^c)$; such that, given the tax rates and the tariff rates:

i. The consumption plan $\{c_i^j, c_{\text{inv}}^j, c_{\text{inv},f}^j\}_{i \in G_c}$ solves the problem of household *j*.

ii. The consumption plan $\{c_i^g, c_{inv}^g\}_{i\in G_p}$ solves the problem of the government.

iii. The consumption plan $\{x_{i,f}, c_{inv,f}\}_{i\in G_c}, x_{f,f}$ solves the problem of the representative foreign household.

iv. The production plan $(y_{i,d}, x_{1,i}^d, \ldots, x_{n,i}^d, k_i, \ell_{u,i}, \ell_{s,i})$ satisfies:

$$y_{i,d}=\min\left\{\frac{x_{1,i}^d}{a_{1,i}^d},\ldots,\frac{x_{n,i}^d}{a_{n,i}^d},\beta_i\left[\lambda_i\left[\mu_i k_i^\rho+(1-\mu_i)(\varphi_s\ell_{s,i})^\rho\right]^{\frac{\sigma}{\rho}}+(1-\lambda_i)(\varphi_u\ell_{u,i})^\sigma\right]^{\frac{1}{\sigma}}\right\}$$

$$\text{and } (1-t_{p,i})p_{i,d}y_{i,d}-\sum_{j\in G_p}p_j x_{j,i}^d-w_u\ell_{u,i}-w_s\ell_{s,i}-rk_i\leq 0, =0 \text{ if } y_{i,d}>0$$

v. The production plan $(y_i, y_{i,d}, y_{i,f})$ satisfies:

$$p_i y_i-p_{i,d}y_{i,d}-\sum_{f\in T}(1+\tau_{i,f})e_f\bar{p}_{i,f}y_{i,f}\leq 0, =0 \text{ if } y_i>0$$

where $y_{i,d}$ and $y_{i,f}$ solve:

$$\min\ p_{i,d}y_{i,d}+\sum_{f\in T}(1+\tau_{i,f})e_f\bar{p}_{i,f}y_{i,f}$$

$$\text{s.t. } \gamma_i\left[\delta_i y_{i,d}^{\rho_{m,i}}+\sum_{f\in T}\delta_{i,f}y_{i,f}^{\rho_{m,i}}\right]^{\frac{1}{\rho_{m,i}}}=y_i$$

vi. The production plan $(y_{inv}, x_{1,inv}, \ldots, x_{n,inv})$ satisfies:

$$y_{inv}=\min\left\{\frac{x_{1,inv}}{a_{1,inv}},\ldots,\frac{x_{i,inv}}{a_{i,inv}},\ldots,\frac{x_{n,inv}}{a_{n,inv}}\right\}$$

$$\text{and } p_{inv}y_{\text{inv}}-\sum_{j\in G_p}p_j x_{j,inv}\leq 0, =0 \text{ if } y_{inv}>0$$

vii. The production plan $(y_{i,c}, x_{i,i}^c, x_{\text{us},i}^c, x_{\text{ss},i}^c, k_i^c, \ell_{u,i}^c, \ell_{s,i}^c)$ satisfies:

$$y_{i,c}=\min\left\{\frac{x_{i,i}^c}{a_{i,i}^c},\frac{x_{\text{us},i}^c}{a_{\text{us},i}^c},\frac{x_{\text{ss},i}^c}{a_{\text{ss},i}^c},\beta_i^c\left[\lambda_i^c\left[\mu_i^c(k_i^c)^{\rho_c}+(1-\mu_i^c)(\varphi_s\ell_{s,i}^c)^{\rho_c}\right]^{\frac{\sigma_c}{\rho_c}}+(1-\lambda_i^c)(\varphi_u\ell_{u,i}^c)^{\sigma_c}\right]^{\frac{1}{\sigma_c}}\right\}$$

$$\text{and } (1-t_{c,i})p_{i,c}y_{i,c}-p_i x_{i,i}^c-p_{\text{us}}x_{\text{us},i}^c-p_{\text{ss}}x_{\text{ss},i}^c-w_u\ell_{u,i}^c-w_s\ell_{s,i}^c-rk_i^c\leq 0, =0 \text{ if } y_{i,c}>0$$

viii. The factor markets clear:

$$\sum_{i\in G_p}\ell_{u,i}+\sum_{i\in G_c}\ell_{u,i}^c=\bar{\ell}_u$$

$$\sum_{i\in G_p}\ell_{s,i}+\sum_{i\in G_c}\ell_{s,i}^c=\bar{\ell}_s$$

$$\sum_{i\in G_p}k_i+\sum_{i\in G_c}k_i^c=\sum_{j\in H}\bar{k}_j=\bar{K}$$

where $\bar{\ell}_u$, $\bar{\ell}_s$, and $\bar{K}$ denote the aggregate stocks of unskilled labor, skilled labor and capital, respectively.

ix. The goods markets clear:

$$y_i = \sum_{j \in G_p} x^d_{j,i} + \sum_{j \in G_c} x^c_{j,i} + x_{i,inv} + c^g_i + \sum_{f \in T} x_{i,f} \quad \forall i \in G_p$$

$$y_{i,c} = \sum_{j \in H} c^j_i \quad \forall i \in G_c$$

$$y_{inv} = \sum_{j \in H} c^j_{inv} + c^g_{inv} + \sum_{f \in T} x_{inv,f}$$

x. The balance of payments condition is satisfied:

$$\sum_{i \in G_p} e_f \bar{p}_{f,i} y_{i,f} + \sum_{j \in H} e_f \bar{p}_{inv,f} c^j_{inv,f} = \sum_{i \in G_p} p_i x_{i,f} + p_{inv} x_{inv,f} \quad \forall f \in T$$

4. Calibration and Data

The construction of an applied general equilibrium model requires that all the parameters that govern the preferences of the agents and the technologies of the firms, as well as the different tax rates, tariff rates, and elasticities, must be numerically specified.

We assign values to these parameters by calibrating them. This implies that the values of the parameters are chosen so that, in equilibrium, the agents of the model replicate the transactions that their counterparts in the real world make. Since we aim to account for the skill premium changes that took place between the 1995–2000 and 2000–2005 periods, we conduct separate calibrations so that our model matches the reference years 1995 and 2000. In order to conduct our calibration exercise, we first document the various data sources we employ and construct the linkages among the different sectors.[5]

Social Accounting Matrices (SAM)

Most of the parameters (such as the input shares and TFP scale parameters in the production functions, as well as the parameters in the agents' utility functions) can be directly calibrated from a SAM using the optimality and market clearing conditions and choosing physical units such that prices (including factor prices) are equal to one in the base case.[6,7]

A SAM is a record of all the transactions that take place in an economy, usually during a one-year period. It provides a snapshot of the structure of production, where the rows record the receipts of a particular agent and the columns represent the payments made by the agents. Depending on the data availability, it can provide a much disaggregated level of institutional detail, with different types of firms, levels of government, households that differ in basic demographic characteristics, and several trade partners. Given the richness of information contained in

[5] Tables F1–F4 in Appendix F present the values of the calibrated parameters. In particular, Tables F2 and F3 allow us to determine the factor intensities in each of the disaggregated sectors.

[6] For a brief sketch of the calibration procedure, see Appendix E.

[7] For those parameters that cannot be calibrated from the data, we explain how we chose those values in section 4.

them, SAMs have been frequently and extensively used in applied general equilibrium models designed to analyze policy reforms (see e.g., Kehoe 1996).

To the best of our knowledge, there is no readily available SAM for Hungary, at least at the level of disaggregation that our analysis requires. Thus, using a variety of data sources (including input-output tables for Hungary provided by the Hungarian Central Statistical Office), we build SAMs for the years 1995 and 2000. In Appendix B, we present our choice of sectoral disaggregation. Our classification of skilled and unskilled labor intensities sectors follows Abrego and Whalley (2001). The resulting SAMs are presented in Appendices C and D.

Hungary Household Budget Survey (HBS)

A SAM gives information about the aggregate economy, but it does not provide us with detailed household-level data. In order to decompose the "household column" in the SAM, we use the HBS, compiled by the Hungarian Central Statistical Office. The Hungary HBS for the year 2003 contains data on household-level income and consumption expenditures for 8314 households.[8]

Using the data contained in the survey we divide the Hungarian households into two groups according to their skill levels: "high skill" workers (or simply, "skilled" workers) and "low skill" workers (or "unskilled" workers). Following Krusell et al. (2000), skilled workers are defined as requiring college completion or better. Once we have divided the households according to their skill levels, we are able to determine their consumption patterns. In particular, we can determine what percentage of household income is devoted to the consumption of a specific good. Having pinned down those ratios, we are able to break down the "household column" in the SAM in the same proportions as in the HBS.

EU KLEMS Growth and Productivity Accounts

The SAMs for Hungary give us information on the composition of sectoral capital and labor income compensation, but they do not provide a disaggregation of labor compensation between skilled and unskilled labor. In order to decompose the "labor compensation row" in the SAM, we use the EU KLEMS Growth and Productivity Accounts database.

EU KLEMS is a project financed by the European Commission which maintains an industry-level research database with information on output, productivity, capital formation and labor structure, among many other variables, for the EU member countries between 1995 and 2005. Relevant to our work, it provides detailed data on labor compensation and the number of hours worked by industry and by skill level for Hungary. The EU KLEMS categorization of labor by skill is relatively similar to ours, but instead of two types of skills, it provides data on three types (low, medium, and high skills). We group the low and medium levels into a single category that corresponds to our definition of unskilled labor, and the remaining data coincides with our definition of skilled labor.

Once we have determined the shares of skilled and unskilled labor in labor compensation in each sector, we are able to decompose the "labor compensation row" in the SAM using the same proportions that we observe in the EU KLEMS database.

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[8] Due to data availability, we use the 2003 survey to determine the consumption patterns of skilled and unskilled households for both the 1995 and 2000 SAMs.

Remaining Parameters

Tariff Rates

The tariff rates that Hungary imposes on its imports (τ_i) can be calibrated directly from the SAM. To determine the tariff rates that the foreign trade partners impose on imports from Hungary, we use the Tariff Download Facility database compiled by the World Trade Organization. We calculate the ROW tariffs as a weighted average of the tariffs imposed by the Czech Republic, Poland, Russia and the United States. These countries are Hungary's main export partners after the EU and accounted for 13.9% and 15.0% of Hungarian exports in 1995 and 2000, respectively. Note that trade in the service sectors are not subject to tariffs.

Import and Export Elasticities of Substitution

In our model, the elasticities of substitution for exports and imports cannot be calibrated directly from the SAM. Instead, we use different sets of values for these parameters. For our "benchmark" case, we set $\rho_{m,j}=0.9\,\forall j \in G_p$ in Equation 3, and $\rho_x=0.9$ in Equation 9, implying elasticities of import and export substitution of 10, respectively.[9] Later, in the sensitivity analysis, we take a set of values from Rolleigh (2003) that reports the import elasticity of substitution for disaggregated primary and manufacturing sectors.

Capital-skill Complementarity Elasticities

The production functions for domestic goods and consumption goods are assumed to use intermediate inputs in fixed proportions and an aggregate of capital and the two types of labor nested in a general two-level CES form. In the domestic goods production functions, the parameters ρ and σ govern the elasticities of substitution between capital and skilled labor and capital and unskilled labor, respectively. Their counterparts in the consumption goods production functions are ρ_c and σ_c. As specific estimates for the Hungarian economy are not available in the literature, we take the average of the values reported in Polgreen and Silos (2008) for the United States and set $\rho=\rho_c=-0.357$ and $\sigma=\sigma_c=0.659$, which imply elasticities of substitution of 0.737 between capital and skilled labor and 2.933 between capital and unskilled labor, respectively.[10] As $\sigma > \rho$, our production function exhibits complementarity between capital and skilled labor. Later, in the sensitivity analysis, we assess the role of the capital-skill complementarity by changing the values of ρ and σ.

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[9] Several studies have tried to estimate the value of the Armington elasticity. For example, Ruhl (2008) finds a value of 6.4 for the trade elasticity. Similarly, Simonovska and Waugh (2014) find values for this parameter that range from 2.79 to 4.46, with a preferred value of 4.14. Eaton and Kortum (2002) find values in the 3.60–12.86 range, with a preferred value of 8.28. Hillberry et al. (2005) estimate values of Armington elasticities as high as 40, with an average of approximately 16. Romalis (2007) puts this value in a range between 4 and 13. Finally, Yi (2003) finds that elasticities in excess of 12 are necessary to replicate the trade flows observed in the data. We chose a value of 10 as good compromise with the existing literature, given the large range of possible values found in previous studies.

[10] These elasticity values refer to the elasticities between capital equipment and skilled workers and capital equipment and unskilled workers, respectively. This is because, from a theoretical point of view, what really is complementary to skilled workers is capital equipment, and not necessarily the aggregate stock of capital which also includes capital structures. However, to the best of our knowledge, there are no readily available time series that break down capital stock into equipment and structure for the Hungarian economy, and therefore we take these values to represent the elasticities between capital and different types of labor, as in Parro (2013).

Table 1. Tariff Rates for 1995–2000 Simulation (Percent)

	Pre-EU FTA				Post-EU FTA			
	Hungarian Tariffs		Foreign Tariffs		Hungarian Tariffs		Foreign Tariffs	
Sector	EU	ROW	EU	ROW	EU	ROW	EU	ROW
Unskilled Primaries	38.1	38.1	8.1	10.9	0.0	38.1	0.0	10.9
Skilled Primaries	3.7	3.7	0.4	2.6	0.0	3.7	0.0	2.6
Unskilled Manufacturing	15.0	15.0	6.8	11.3	0.0	15.0	0.0	11.3
Skilled Manufacturing	14.6	14.6	4.0	6.8	0.0	14.6	0.0	6.8
All Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5. Numerical Experiments and Results

We conduct a series of numerical experiments to assess the individual as well as the joint contribution of a variety of shocks on the Hungarian skill premium. Our experiments are implemented for two separate time periods: 1995–2000, when Hungary's economy became more integrated with the EU, and 2000–2005, a period that culminated with Hungary's accession into the EU. Before presenting and discussing the results of our simulations, we first describe the experiments we run.

"Tariff Reductions" Experiments

In these simulations, we replicate the changes in the tariff schedules observed in Hungary during the 1995–2000 and 2000–2005 periods. These two periods are characterized by two different tariff reductions: during the first one, Hungary and the EU engaged in an Association Agreement. An important component of this treaty, which entered into effect by the end of 1993, was a free trade agreement between the two parties that mandated the progressive and eventual removal of tariffs and quantitative restrictions on most trade between Hungary and the EU by the end of 2000. Thus, we simulate this arrangement as Hungary and the EU eliminating the tariffs on their respective imports, while at the same time allowing Hungary to keep its own tariff schedule with the ROW unchanged.

The second period corresponds to Hungary's accession into the EU, a process that culminated in 2004. As a full-fledged member, Hungary joined the EU customs union. We model this arrangement as a scenario where Hungary and the EU remove the tariffs on their respective imports (a setup similar to the one in the previous period), and where additionally Hungary replaces the tariff schedule on its imports from the ROW with the EU's tariff schedule.

Table 2. Tariff Rates for 2000–2005 Simulation (Percent)

	Pre-EU Accession				Post-EU Accession			
	Hungarian Tariffs		Foreign Tariffs		Hungarian Tariffs		Foreign Tariffs	
Sector	EU	ROW	EU	ROW	EU	ROW	EU	ROW
Unskilled Primaries	0.0	12.7	0.0	10.2	0.0	6.2	0.0	10.2
Skilled Primaries	0.0	1.2	0.0	2.6	0.0	0.4	0.0	2.6
Unskilled Manufacturing	0.0	4.6	0.0	10.7	0.0	5.0	0.0	10.7
Skilled Manufacturing	0.0	5.3	0.0	6.4	0.0	2.8	0.0	6.4
All Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3. Sectoral TFP Changes for Benchmark Experiment

Sectors	Percent change (1995–2000)		Percent change (2000–2005)	
	VA TFP (β_i, β_i^c)	GO TFP (γ_i)	VA TFP (β_i, β_i^c)	GO TFP (γ_i)
Unskilled primaries	22.24	8.77	83.95	30.88
Skilled primaries	−42.39	−17.34	1.54	−0.24
Unskilled manufacturing	15.29	3.61	6.05	1.04
Skilled manufacturing	97.34	16.37	37.28	5.47
Unskilled services	14.87	6.95	9.30	4.72
Skilled services	18.31	10.12	8.76	4.21

Tables 1 and 2 present the tariff schedules for Hungary, the EU, and the ROW for each period.

"Productivity" Experiments

In these experiments, we reproduce the productivity changes observed in Hungary for the 1995–2000 and 2000–2005 periods. We incorporate two types of productivity changes: one, that we label "sector-biased TFP changes," where we replicate the TFP changes that took place in the Hungarian economy, for both sectoral VA and sectoral GO, corresponding to the β_i, β_i^c, and γ_i parameters described above. The values for these growth rates are taken from the EU KLEMS database and are presented in Table 3.

In the second type of productivity changes, that we refer to as "factor-biased productivity changes," we replicate the changes in the relative productivities of skilled and unskilled Hungarian workers. We proceed as follows: we first normalize φ_s and φ_u in Equations 2 and 4 equal to one in the initial year of each subperiod, since it is only changes in the technology parameters over time that are relevant in the model. Thus, we set $\varphi_s = \varphi_u = 1$ for 1995 and 2000. We then increase φ_s so that it matches the increase in relative productivity of skilled workers during each subperiod as reported in Lovasz and Rigo (2009). They find a 20.1% increase in the relative productivity of skilled workers between 1995 and 2000, and a 26.3% increase between 2000 and 2005. Therefore, our "factor-biased productivity changes" experiments consist in increasing φ_s to 1.201 for the 1995–2000 subperiod and to 1.263 in the 2000–2005 subperiod.

Finally, we report the change in skill premium when both types of productivity changes take place simultaneously, a simulation that we label as "combined productivity changes."

"Capital Deepening" Experiments

As Hungary transitioned from a centrally planned system to a market-oriented economy, its stock of capital grew significantly as documented in section 2. We simulate this capital stock growth by increasing the aggregate capital stock $\bar{K}$ by the observed rates in Hungary. The growth rates of 14.6% for the 1995–2000 period and 17.1% for the 2000–2005 period are taken from Feenstra, Inklaar, and Timmer (2013), which contains the most recent update of the Penn World Table.[11]

[11] As shown in section 2, the growth rates of capital stock per worker and aggregate capital stock are quite similar. Moreover, since in our model working-age population is constant, the increases in capital stock imply capital deepening.

Benchmark Results: 1995–2000

Table 4 presents the results of our simulations for the 1995–2000 period. We first report the results from our joint experiment, where we simultaneously incorporate the trade costs, productivity and capital deepening shocks. Our model generates an increase in the skill premium of 8.80% (compared to 10.12% in the data). This implies that when we take into account all shocks, our model can account for approximately 87% of the increase in the skill premium in Hungary.

When assessing the individual roles of each shock, we find that most of the increase in the skill premium can be accounted for by the increase in the capital stock and the capital-skill complementarity mechanism embedded in our framework. Of the two productivity shocks, the factor-biased productivity changes turn out to be more important, although its role is small when compared to that of capital deepening. Finally, the tariff reductions can only account for a small fraction of the observed increase in the skill premium.

Benchmark Results: 2000–2005

Table 5 presents the results for the 2000–2005 period. The joint experiment yields an increase in the skill premium of 2.45% (compared to 2.81% in the data). This implies that when we take into account all shocks, our model can account for approximately 87.2% of the increase in the skill premium in Hungary.

In terms of our decomposition results, we find that the role of tariff reductions in accounting for the changes in the skill premium is positive but small. This result is similar to the one we found for the 1995–2000 period. Focusing on the importance of productivity shocks, we find that the sector-biased productivity shock actually yields a decline in the skill premium of approximately 8.4%, whereas the factor-biased productivity changes generates a positive but moderate increase in the relative wages. When both types of productivity changes are taken into account, the skill premium decreases by around 7%, which implies that productivity changes played a bigger role during the 2000–2005 period when compared to the 1995–2000 period. Finally, the capital deepening shock suggests an increase in the skill premium by more than 10%, which overstates the actual increase in the skill premium. Thus, our results indicate that the overall change on the skill premium between 2000 and 2005 is due to the combined effects of capital deepening (which would predict a large increase in relative wages) and sector-biased productivity changes (which would predict a decline in the skill premium), with the former effect dominating the latter.

Table 4. Benchmark Results — Skill Premium Changes (1995–2000)

	Skill premium change (percent)	Percentage of change in skill premium due to:
Joint simulation	8.80	87.0
Individual simulations:		
Tariff reductions	0.17	1.7
Sector-biased productivity changes	−0.42	−4.2
Factor-biased productivity changes	0.59	5.8
Combined productivity changes	0.29	2.9
Capital deepening	8.79	86.9
Data	10.12	

Table 5. Benchmark Results — Skill Premium Changes (2000–2005)

	Skill premium change (percent)	Percentage of change in skill premium due to:
Joint simulation	2.45	87.2
Individual simulations:		
Tariff reductions	0.12	4.3
Sector-biased productivity changes	−8.39	−298.6
Factor-biased productivity changes	0.89	31.7
Combined productivity changes	−7.33	−260.9
Capital deepening	10.03	356.9
Data	2.81	

Discussion of Benchmark Results

In the tariff reductions experiments, the skill premium increases in both periods but the magnitude of these increments is small. In fact, the tariffs reductions lead to an increase in the real wage for both skilled and unskilled workers, but the relative increase in the wages of skilled workers is greater than for unskilled workers. Two effects are at play: on the one hand, since Hungary is mainly an exporter of unskilled-intensive goods and services and an importer of skilled-intensive goods and services, the traditional H–O mechanism would imply a decline in the skill premium as a result of opening to trade. However, this mechanism abstracts from the role of the capital-skill complementarity. Our framework incorporates it, thus leading to an increase in the demand for capital, which in turn favors skilled labor more than unskilled labor. Consequently, this second channel would lead to an increase in the skill premium. Taking into account both the traditional H–O mechanism (which lowers skill premium) and the capital-skill complementarity mechanism (which increases skill premium), the overall effect is a priori ambiguous. In our simulations, the small positive increase in skill premium implies that the capital-skill complementarity effect dominated the H–O effect.[12]

Regarding the sector-biased technical change experiments, we obtain a modest decrease in skill premium in the 1995–2000 period and a larger decrease in the 2000–2005 period. While the deep mechanics are difficult to disentangle in a general equilibrium setup, we believe that the results are driven by both the magnitudes in the TFP changes across the different sectors combined with the size of the sectors subject to the shocks in each period. For example, for all the periods we examine, the sector that records the largest increase in TFP is the skilled manufacturing sector, which in fact has a lower skill intensity than both service sectors. This might help explain why the skill premium decreases under the sector-biased productivity change experiments. Moreover, for the 1995–2000 period, it is only the primaries sector where the unskilled sector shows a higher productivity gain than the skilled sectors, thus leading to the minor decline in the skill premium. Instead, during the 2000–2005 period not only the unskilled primaries but also the unskilled services sectors show higher productivity gains than the skilled sectors. This might account for why during the 2000–2005 period the decrease in the skill premium is much more pronounced than in the preceding one.

[12] In addition, it is also worthwhile to note that tariff removals only affected primary and manufacturing sectors, while most of the value added in labor comes from the service sectors, which were not subject to tariff changes. This channel also serves to mitigate the magnitude of skill premium changes in Hungary.

Table 6. Sensitivity Analysis — Elasticities of Factor Substitution (ρ, ρ_c) (1995–2000)

	Percent change in skill premium				
	(1)	(2)	(3)	(4)	(5)
	$\rho=\rho_c=$				$\rho, \rho_c \to 0$
	−0.393	−0.357	−0.321	−0.237	$\sigma, \sigma_c \to 0$
Joint simulation	8.86	8.80	8.99	9.02	−4.71
Individual simulations:					
Tariff reductions	0.18	0.17	0.15	0.12	−0.65
Sector-biased productivity changes	−0.38	−0.42	−0.46	−0.55	−4.37
Factor-biased productivity changes	0.20	0.59	0.98	1.92	0.00
Capital deepening	9.08	8.79	8.49	7.79	0.17

Finally, in the capital deepening experiments we find that the increase in the stock of capital leads to an increased demand for labor, but this demand is disproportionately biased in favor of skilled workers over unskilled workers. This is due to the capital-skill complementarity assumption included in our framework. In the next section, we discuss the role of capital-skill complementarity in detail.

The Role of Capital-Skill Complementarity

In our benchmark experiments we used the average of the values reported in Polgreen and Silos (2008) and set $\rho=\rho_c=-0.357$ and $\sigma=\sigma_c=0.659$ as the elasticities of substitution between factors in the domestic and consumption goods production functions. In this sensitivity experiment, we assess the importance of capital-skill complementarity in our results by first varying the value of the parameters ρ and ρ_c. Specifically, we use the values of -0.393 and -0.321, which represent 10% deviations from the benchmark value and we also use -0.237 which represents the degree of capital-skill complementarity found in Krusell et al. (2000). For all simulations, we keep the values of σ and σ_c unchanged. Finally, we also test the limiting case where the CES production parameters ρ and σ (as well as ρ_c and σ_c) are jointly set to zero, which corresponds to a Cobb–Douglas production function with no complementarity between capital and skilled labor.

The results are presented in Table 6 for the 1995–2000 period and Table 7 for 2000–2005. In the tables, the first four columns show the results we obtain when we vary the parameter values of ρ and ρ_c. For both periods, changes in the elasticity of substitution between capital and skilled labor have quantitative implications on the skill premium through two different channels. The first channel reflects the fact that an increase in the value of ρ implies a smaller degree of capital-skill complementarity, which is measured by $(\sigma-\rho)$. As shown in the capital deepening simulation, the increase in the stock of capital leads to an increase in the skill premium that is of a smaller magnitude than the one we obtained in the benchmark simulation precisely because capital and skilled labor are less complementary. The second channel reflects the fact that a higher value of ρ implies a higher degree of substitution between capital and skilled labor. The factor-biased simulation replicated the increased productivity of skilled labor observed in the data. A higher value of ρ means that it is easier to switch to the more productive skilled labor, which in turn drives up the demand for this factor and consequently the relative wage of skilled workers. Overall, the second channel dominates the first and thus a higher the value of ρ corresponds to a higher rise in the skill premium, as reflected in the joint simulation.

Table 7. Sensitivity Analysis — Elasticities of Factor Substitution (ρ, ρ_c) (2000–2005)

	Percent change in skill premium				
	(1)	(2)	(3)	(4)	(5)
	$\rho=\rho_c=$				$\rho, \rho_c \to 0$
	−0.393	−0.357	−0.321	−0.237	$\sigma, \sigma_c \to 0$
Joint simulation	2.30	2.45	2.59	2.95	−18.40
Individual simulations:					
Tariff reductions	0.12	0.12	0.12	0.11	0.15
Sector-biased productivity changes	−8.38	−8.39	−8.39	−8.39	−20.47
Factor-biased productivity changes	0.39	0.89	1.38	2.57	0.11
Capital deepening	10.36	10.03	9.69	8.90	0.27

The last column in Tables 6 and 7 show the results of dropping the capital-skill complementarity assumption. In both periods, the increases in the skill premium generated by the capital deepening simulation are close to zero, with similar results for the tariff reductions and factor-biased productivity simulations. On the other hand, the sector-biased productivity simulation generates a significant decrease in the skill premium, which in turn plays a dominant role in the decline of the skill premium obtained in the joint simulation.

The sensitivity simulations underscore our choice of production functions that exhibit capital-skill complementarity. Our choice is backed up empirically by the findings in Koren and Csillag (2011), who show that capital imports in Hungary increased the demand for skilled workers.[13]

Our findings place capital deepening and the capital-skill complementarity channel as the main drivers of the increase in the skill premium observed in Hungary. In that sense, our results are in line with a vast portion of the literature, both theoretical and empirical, and starting at least since Griliches (1969) seminal work, who posited the idea that skilled labor is relatively more complementary to capital than unskilled labor and consequently increases in the stock of capital could account skill premium movements. Additional studies have reaffirmed this hypothesis, most salient among them being Krusell et al. (2000) for the case of the United States. Lindquist (2005) finds similar results for the case of Sweden, as do Flug and Hercowitz (2000) for a panel that includes both developed and developing economies. More recently, both Burstein, Cravino, and Vogel (2002) and Parro (2013) stress the importance of capital-skill complementarity in generating an increase in skill premium using a quantitative general equilibrium model of trade.

Elasticities of Import Substitution Differentiated by Sector

In our benchmark simulations we assign values for the elasticities of substitution for imports that are constant across sectors. A relevant question is whether our results depend on our choice of those elasticity values. To assess the robustness of our results, we re-run our simulations using an alternative set of values for the import elasticities, which we take from Rolleigh (2003), where the values of the elasticities vary depending on the sector. While the simple average of elasticities across

[13] Koren and Csillag (2011) study the effect of imported machines on the wages of machine operators using a linked employer-employee microdata from 1994 to 2004 in Hungary. They find that the wages of workers operating imported machines are about 8% higher than other machine operators at the same firm, suggesting complementarity between imported capital and workers' skill levels in the manufacturing sector.

Table 8. Sensitivity Analysis — Import Elasticities of Substitution (ρ_{m})

	Percent change in skill premium			
	(1995–2000)		(2000–2005)	
	Benchmark elasticities	Rolleigh elasticities	Benchmark elasticities	Rolleigh elasticities
Joint simulation	8.80	9.08	2.45	2.38
Individual simulations:				
Tariff reductions	0.17	0.89	0.12	0.11
Sector-biased productivity changes	−0.42	0.18	−8.39	−8.43
Factor-biased productivity changes	0.59	0.64	0.89	0.89
Combined productivity changes	0.29	0.90	−7.33	−7.39
Capital deepening	8.79	8.71	10.03	10.07

all sectors in Rolleigh (2003) is around 11.3 (which is similar to our benchmark value of 10), the sectoral elasticities take values as low as 2.9 for the electronics sector and as high as 21 for the foods sector. For our specific sectoral disaggregation, the values of ρ_m we use are 0.952 for both primaries sectors, 0.873 for unskilled manufactures, 0.819 for skilled manufactures, 0.9 for unskilled and skilled services.[14] The results of this sensitivity analysis are presented in Table 8. We find that our results are quite robust to the choice of the elasticity values, both in terms of the joint simulation and the individual experiments. Furthermore, we find that the role of tariff reductions in accounting for the changes in the skill premium is consistently positive but small across scenarios.

6. Conclusions

What drives the patterns of the skill premium? The economics literature has provided a variety of explanations on this issue, ranging from the expansion of international trade to the role of productivity and the complementarity between capital and skilled labor, yet a definitive consensus has not been reached. Interestingly, all these forces played a role when the economies of Central and Eastern Europe transitioned from centrally planned systems to full-fledged members of the EU. Thus, such countries present an interesting opportunity for studying the determinants of the skill premium. In this article, we exploit this fact and conduct a decompositional analysis to disentangle the multiple factors that affected the increasing patterns of the skill premium observed in Hungary between 1995 and 2005.

Specifically, we build an applied general equilibrium model, and using a variety of data sources including from input-output matrices to HBS, we calibrate it to match the Hungarian economy. We then perform a series of numerical experiments to assess the roles of the different explanations to the patterns of the skill premium. We find that when all shocks are jointly implemented, our model is able to account for up to 87% of the increase in the skill premium observed in the data. We also conduct numerical experiments to determine how specific factors contributed to the changes in relative wages. We find that throughout our period of analysis the main driver of the increase in the skill premium in Hungary is the increase in the capital stock (capital deepening)

[14] Thus, the implied elasticities range from as low as 5.5 in the skilled manufactures to as high as 21 in the primaries sectors.

which in turn raises the demand for skilled workers through the capital-skill complementarity channel.

Productivity changes, instead, did not have a large impact on the skill premium during the 1995–2000 period. However, productivity changes (and more specifically sector-biased productivity changes) generate a significant decline in the skill premium for the 2000–2005 period. Thus, the interaction between the positive effect of capital deepening and the negative effect of the sector-biased shock accounts for the fact that the skill premium increase was more modest during the 2000–2005 period than during the previous one.

Our findings show that tariff reductions played a small role in accounting for the changes in the skill premium. This, however, should not be interpreted as trade being unimportant. In particular, while our results highlight the role of capital deepening as the major driver in the pattern of the skill premium, for many transition countries a large fraction of that capital accumulation originated from external sources in the form of foreign direct investment, as part of a broader set of trade liberalization reforms. In addition, falling trade costs in capital goods enabled these economies to direct more investment into capital-intensive sectors, which lead to faster capital accumulation.[15] Finally, we perform a series of sensitivity experiments and find that our results are robust to changes in the values of the parameters of the model.

Our analysis abstracts from some of the institutional features that past studies have used to account for the increase of the skill premium in transition economies. These features include, but are not limited to, fiscal reforms, privatization of state-owned enterprises, deregulation of higher education fees, deunionization, and nontariff barriers to trade. For example, Brown, Earle, and Telegdy (2010) find evidence that the transfer of ownership of state firms to domestic or foreign owners through privatization raised productivity and the relative wages of skilled workers in Hungary. On the other hand, Madga, Mardsen, and Moriconi (2012) find that collective bargaining at the company level increases medium- and high-skilled wages in a subset of transition economies, including Hungary.

Another feature we abstract from is the introduction of dynamics into the model and, more specifically, endogenizing investment decisions and capital accumulation over time. The importance of these issues is emphasized in articles such as Harris and Robertson (2013), who focus on the dynamic aspects of trade and labor market interactions and find that trade liberalization is associated with not only physical capital investment but also human capital accumulation. Incorporating such features in a setup similar to the one developed in this article would undoubtedly complement the analysis presented here. We leave those topics as interesting extensions for future research.

Appendix A: Construction of Skill Premium Series (Hungary, EU KLEMS)

Table A1. Labor Compensation (Share in Total Labor Compensation)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
High-skilled	30.0	30.2	30.3	31.3	34.4	33.5	33.8	34.7	37.2	39.1	40.5
Medium-skilled	57.1	57.2	57.2	56.5	56.0	55.3	55.1	54.9	53.5	52.3	50.9
Low-skilled	12.9	12.6	12.5	12.2	9.6	11.1	11.0	10.5	9.3	8.6	8.7

[15] We thank an anonymous referee for suggesting the potential linkage between tariff reductions and capital investment.

Table A2. Hours Worked (Share in Total Hours)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
High-skilled	15.6	15.3	15.2	15.4	16.9	16.5	16.5	16.9	18.2	20.0	20.6
Medium-skilled	65.4	65.7	66.0	65.8	67.6	65.8	66.1	66.5	66.6	65.6	64.9
Low-skilled	18.9	19.0	18.9	18.8	15.5	17.6	17.4	16.6	15.3	14.4	14.5

Table A3. Skill Premium — Hungary

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Skill Premium	2.31	2.38	2.43	2.50	2.57	2.55	2.59	2.61	2.67	2.57	2.62
(2000 = 100)	90.8	93.6	95.4	98.3	101.1	100	101.6	102.7	104.8	100.9	102.8

Appendix B: Sectoral Matching of Consumption and Production Sectors

6-Sector SAM	Input-Output Table Classifications
Unskilled Primaries (PU)	Products of agriculture, hunting and forestry
Skilled Primaries (PS)	Mining and quarrying
	Coke, refined petroleum and nuclear fuel
Unskilled Manufacturing (MU)	Food, beverages and tobacco
	Textiles, textile, leather and footwear
	Wood and of wood and cork
	Rubber and plastics
	Other nonmetallic mineral
	Basic metals and fabricated metal
	Manufacturing nec; recycling
Skilled Manufacturing (MS)	Pulp, paper, printing, and publishing
	Coke, refined petroleum, and nuclear fuel
	Chemicals and chemical
	Machinery, nec
	Electrical and optical equipment
	Transport equipment
Unskilled Services (SU)	Construction
	Wholesale trade and commission trade, except of motor vehicles and motorcycles
	Retail trade, except of motor vehicles and motorcycles; repair of household goods
	Hotels and restaurants
	Education
	Health and social work
	Other community, social, and personal services
Skilled Services (SS)	Electricity, gas, and water supply
	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
	Transport and storage
	Post and telecommunications
	Financial intermediation
	Real estate activities
	Renting and other business activities
	Public admin and defense; compulsory social security

Appendix C: Social Accounting Matrix (1995)

	Production Goods Sector						Consumption Goods Sector									Consumption					Export		
	PU	PS	MU	MS	SU	SS	PU	PS	MU	MS	SU	SS	L	K	C	Unskilled	Skilled	I	G	X	EU	ROW	Total
PU	242,941	0	361,942	1,949	44,507	8,427	47,277	0	0	0	0	0	0	0	0	0	0	20,067	8,077	144,387	84,394	59,993	879,574
PS	36,565	101,239	100,254	55,443	70,994	266,474	0	107,499	0	0	0	0	0	0	0	0	0	7,405	290	55,336	45,337	9,999	801,499
MU	109,520	8,304	815,117	151,935	282,815	98,994	0	0	773,401	0	0	0	0	0	0	0	0	75,238	0	690,356	528,329	162,026	3,005,680
MS	79,399	14,246	129,068	872,598	160,590	228,245	0	0	0	296,189	0	0	0	0	0	0	0	540,313	98,937	622,139	407,252	214,887	3,041,723
SU	74,540	42,929	365,781	392,955	1,207,781	0	14,850	18,008	147,178	49,913	145,171	0	0	0	0	0	0	536,446	588,554	211,109	129,495	81,615	3,795,214
SS	35,853	6,378	163,714	121,810	411,701	451,731	2,277	2,761	22,563	7,652	0	216,608	0	0	0	0	0	86,928	643,543	455,509	253,718	201,790	2,629,029
PU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	204,992	163,815	41,177	0	0	0	0	0	204,992
PS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	173,144	138,456	34,688	0	0	0	0	0	173,144
MU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,215,791	875,737	340,054	0	0	0	0	0	1,215,791
MS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	468,801	324,225	144,577	0	0	0	0	0	468,801
SU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	522,530	308,627	213,903	0	0	0	0	0	522,530
SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	771,663	535,875	235,788	0	0	0	0	0	771,663
Labor	243,333	45,660	250,890	233,481	893,609	765,534	59,932	11,392	136,645	39,867	180,965	260,165	0	0	0	0	0	0	0	0	0	0	3,121,470
Labor(U)	202,843	36,813	204,662	189,287	593,282	513,726	49,960	9,184	111,467	32,321	120,146	174,588	0	0	0	0	0	0	0	0	0	0	2,238,279
Labor (S)	40,490	8,847	46,228	44,194	300,326	251,808	9,972	2,207	25,178	7,546	60,819	85,576	0	0	0	0	0	0	0	0	0	0	883,191
Capital	68,824	53,167	90,958	110,527	357,767	656,079	16,951	13,264	49,540	18,872	72,452	222,967	0	0	0	0	0	0	0	0	0	0	1,731,368
Capital (U)	35,508	27,430	46,928	57,024	184,581	338,489	8,746	6,843	25,559	9,737	37,380	115,034	0	0	0	0	0	0	0	0	0	0	893,259
Capital (S)	33,316	25,737	44,030	53,503	173,185	317,590	8,206	6,421	23,981	9,136	35,072	107,932	0	0	0	0	0	0	0	0	0	0	838,109
Households	0	0	0	0	0	0	0	0	0	0	0	0	3,121,470	1,731,368	0	0	0	0	0	0	0	0	4,852,838
Government	−54,891	182,546	208,897	114,771	−13,592	33,114	63,705	20,220	86,465	56,308	123,943	71,924	0	0	0	0	0	0	0	0	0	0	893,410
Direct tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	485,284	194,114	291,170	0	0	0	0	0	485,284
Indirect tax	−71,479	169,819	131,143	−28,948	−13,592	33,114	63,705	20,220	86,465	56,308	123,943	71,924	0	0	0	0	0	0	0	0	0	0	642,622
Tariff (Total)	16,588	12,727	77,753	143,719	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250,788
Tariff (EU)	8,626	2,781	58,649	106,108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176,164
Tariff (ROW)	7,962	9,946	19,104	37,611	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74,624
Capital (Saving)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,010,632	590,689	419,943	0	39,294	216,471	73,284	143,187	1,266,397
Import (Total)	43,489	347,030	519,058	986,256	379,042	120,431	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,395,307
Import (EU)	22,614	75,826	391,526	728,153	231,443	72,247	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,521,809
Import (ROW)	20,875	271,204	127,533	258,103	147,599	48,184	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	873,498
Total	879,574	801,499	3,005,680	3,041,723	3,795,214	2,629,029	204,992	173,144	1,215,791	468,801	522,530	771,663	3,121,470	1,731,368	4,852,838	3,131,538	1,721,300	1,266,397	1,378,694	2,395,307	1,521,809	873,498	

Appendix D: Social Accounting Matrix (2000)

	Production Goods Sector						Consumption Goods Sector									Consumption						Export		
	PU	PS	MU	MS	SU	SS	PU	PS	MU	MS	SU	SS	L	K	C	Unskilled	Skilled	S	I	G	X	EU	ROW	Total
PU	337,388	0	672,880	4,300	42,432	12,622	90,012	0	0	0	0	0	0	0	0	0	0	0	44,433	15,026	196,365	124,888	71,477	1,415,457
PS	71,230	375,780	126,704	104,182	108,924	568,906	0	281,638	0	0	0	0	0	0	0	0	0	0	31,888	0	135,905	110,626	25,278	1,805,156
MU	209,530	13,231	1,945,698	567,703	751,782	280,591	0	0	1,666,301	0	0	0	0	0	0	0	0	0	404,745	0	1,846,785	1,414,453	432,332	7,686,367
MS	146,310	19,171	327,409	4,279,327	440,424	549,578	0	0	0	753,575	0	0	0	0	0	0	0	0	1,739,536	198,332	5,101,102	4,233,404	867,697	13,554,763
SU	107,507	61,293	813,161	1,130,714	2,786,487	0	24,366	27,998	263,428	66,607	341,065	0	0	0	0	0	0	0	1,411,856	1,209,276	718,194	440,540	277,654	8,961,953
SS	86,123	28,896	467,221	414,379	1,335,066	1,131,762	4,416	5,075	47,746	12,072	0	558,494	0	0	0	0	0	0	296,193	1,388,242	872,684	486,085	386,599	6,648,370
PU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	373,294	298,310	74,984	0	0	0	0	0	0	373,294
PS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	386,315	308,920	77,395	0	0	0	0	0	0	386,315
MU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,522,030	1,816,624	705,406	0	0	0	0	0	0	2,522,030
MS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,180,141	816,190	363,951	0	0	0	0	0	0	1,180,141
SU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,226,241	724,266	501,975	0	0	0	0	0	0	1,226,241
SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,038,857	1,415,868	622,989	0	0	0	0	0	0	2,038,857
Labor	403,638	66,813	552,845	703,763	1,976,019	1,923,924	113,679	16,942	231,607	64,880	394,341	683,386	0	0	0	0	0	0	0	0	0	0	0	7,131,838
Labor (U)	355,997	52,810	445,279	583,636	1,275,032	1,158,768	100,262	13,391	186,544	53,805	254,450	411,600	0	0	0	0	0	0	0	0	0	0	0	4,891,573
Labor (S)	47,641	14,004	107,566	120,127	700,987	765,155	13,418	3,551	45,063	11,075	139,891	271,786	0	0	0	0	0	0	0	0	0	0	0	2,240,264
Capital	77,465	77,694	233,185	532,580	765,812	1,655,719	21,817	19,701	97,690	49,098	152,828	588,118	0	0	0	0	0	0	0	0	0	0	0	4,271,707
Capital (U)	43,520	43,649	131,003	299,204	430,234	930,184	12,257	11,068	54,882	27,584	85,859	330,405	0	0	0	0	0	0	0	0	0	0	0	2,399,848
Capital (S)	33,945	34,046	102,181	233,376	335,578	725,535	9,560	8,633	42,808	21,515	66,969	257,713	0	0	0	0	0	0	0	0	0	0	0	1,871,859
Households	0	0	0	0	0	0	0	0	0	0	0	0	7,131,838	4,271,707	0	0	0	0	0	0	0	0	0	11,403,545
Government	−113,055	412,647	410,186	145,988	−74,706	34,301	119,004	34,962	215,258	233,908	338,007	208,858	0	0	0	0	0	0	0	0	0	0	0	1,965,358
Direct tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,254,390	495,484	758,906	0	0	0	0	0	0	1,254,390
Indirect tax	−118,102	406,428	376,034	47,146	−74,706	34,301	119,004	34,962	215,258	233,908	338,007	208,858	0	0	0	0	0	0	0	0	0	0	0	1,821,096
Tariff (Total)	5,047	6,220	34,152	98,843	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144,262
Tariff (EU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tariff (ROW)	5,047	6,220	34,152	98,843	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144,262
Capital (Saving)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,906,660	1,114,394	792,265	0	0	408,872	1,097,499	0	1,613,117	3,928,649
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	515,618	301,366	214,253	0	0	0	0	0	0	515,618
Import (Total)	89,320	749,630	2,137,078	5,671,827	829,713	490,967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,968,534
Import (EU)	49,519	223,090	1,400,641	3,819,975	506,623	294,531	0	0	0	0	0	0	0	0	0	0	0	515,618	0	0	0	0	0	6,294,379
Import (ROW)	39,801	526,540	736,437	1,851,851	323,090	196,436	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,674,155
Total	1,415,457	1,805,156	7,686,367	13,554,763	8,961,953	6,648,370	373,294	386,315	2,522,030	1,180,141	1,226,241	2,038,857	7,131,838	4,271,707	11,403,545	7,291,422	4,112,123	515,618	3,928,649	3,219,748	9,968,534	6,809,997	3,674,155	0

Appendix E: Brief Sketch of the Calibration Procedure

The calibration of the production function parameters follows directly from the firms' optimality conditions. For example, to calibrate the parameters of the domestic production firm, we divide the first order condition for capital (k) by the one for skilled labor (ℓ_s), we obtain:

$$\frac{r}{w_s}=\frac{\mu k^{\rho-1}}{(1-\mu)\varphi_s^{\rho}\ell_s^{\rho-1}} \tag{A1}$$

Note we have dropped the sector index i to simplify the notation. Equation A1 can be rewritten as:

$$\frac{rk}{w_s\ell_s}=\frac{\mu}{(1-\mu)\varphi_s^{\rho}}\left(\frac{k}{\ell_s}\right)^{\rho} \tag{A2}$$

Using again the first order conditions for capital and skilled labor, the right-hand side of the previous expression can be written as:

$$\frac{rk}{w_s\ell_s}=\frac{\mu}{(1-\mu)\varphi_s^{\rho}}\left[\frac{r^{\frac{1}{\rho-1}}(1-\mu)^{\frac{1}{\rho-1}}\varphi_s^{\frac{\rho}{\rho-1}}}{w_s^{\frac{1}{\rho-1}}\mu^{\frac{1}{\rho-1}}}\right]^{\rho} \tag{A3}$$

In the process of calibration the standard practice is to choose units of measurement in such a way that, in the original equilibrium, one unit of good is worth one unit of value. In other words, we choose units such that prices (including factor prices) are equal to one in the original equilibrium. This yields $r=1$, $w_s=1$ and $w_u=1$. Similarly, we normalize labor-specific productivities (φ_s and φ_u) so that they are equal to one in the original equilibrium, because it is only changes in the values of those parameters over time that are relevant in the model. As a result, the previous equation simplifies further to:

$$\frac{rk}{w_s\ell_s}=\left(\frac{\mu}{1-\mu}\right)^{\frac{1}{1-\rho}} \tag{A4}$$

The left-hand side divides sectoral capital compensation by skilled labor compensation, which can be found in the SAM. Since the value of the elasticity of substitution ρ is taken from the literature and the left-hand side is a known value, we can find a value for μ.

A similar process is followed to calibrate the share parameter λ. Using the first order conditions for the nested capital-skilled labor bundle (which for compactness we will denote by $y_{ks}=[\mu k^{\rho}+(1-\mu)(\varphi_s\ell_s)^{\rho}]^{\frac{1}{\rho}}$, with price p_{ks}) and unskilled labor, we obtain:

$$\frac{p_{ks}}{w_u}=\frac{\lambda}{(1-\lambda)\varphi_u^{\sigma}}\left(\frac{y_{ks}}{\ell_u}\right)^{\sigma-1} \tag{A5}$$

which can be rewritten as:

$$\frac{p_{ks}y_{ks}}{w_u\ell_u}=\frac{\lambda}{(1-\lambda)\varphi_u^{\sigma}}\left(\frac{y_{ks}}{\ell_u}\right)^{\sigma} \tag{A6}$$

Using again the first order conditions, and after a bit of algebra, we obtain:

$$\frac{p_{ks}y_{ks}}{w_u\ell_u}=\frac{\lambda}{(1-\lambda)\varphi_u^{\sigma}}\left[\left(\frac{p_{ks}}{w_u}\right)^{\frac{1}{\sigma-1}}\left(\frac{\lambda}{1-\lambda}\right)^{\frac{1}{1-\sigma}}\varphi_u^{\frac{\sigma}{\sigma-1}}\right]^{\sigma} \tag{A7}$$

Imposing the normalizations $w_u=1$ and $\varphi_u=1$, the previous equation simplifies to:

$$\frac{p_{ks}y_{ks}}{w_u\ell_u}=\left(\frac{\lambda}{1-\lambda}\right)^{\frac{1}{1-\sigma}}p_{ks}^{\frac{\sigma}{\sigma-1}}=\left(\frac{\lambda}{1-\lambda}\right)^{\frac{1}{1-\sigma}}\left[r^{\frac{\rho}{\rho-1}}\mu^{\frac{1}{1-\rho}}+w_s^{\frac{\rho}{\rho-1}}(1-\mu)^{\frac{1}{1-\rho}}\varphi_s^{\frac{\rho}{1-\rho}}\right]^{\frac{\rho-1}{\rho}\frac{\sigma}{\sigma-1}} \tag{A8}$$

where the last equality follows from the first-order conditions for the y_{ks} bundle. Using once again the normalizations $r=w_s=1$, and $\varphi_s=1$, the last equation simplifies to:

$$\frac{p_{ks}y_{ks}}{w_u\ell_u}=\left(\frac{\lambda}{1-\lambda}\right)^{\frac{1}{1-\sigma}}\left[\mu^{\frac{1}{1-\rho}}+(1-\mu)^{\frac{1}{1-\rho}}\right]^{\frac{\rho-1}{\rho}\frac{\sigma}{\sigma-1}} \tag{A9}$$

The left-hand side divides the value of the capital-skilled labor bundle by unskilled labor compensation, which can be obtained from the SAM. The right-hand side includes the parameter μ (which was calibrated previously) and the elasticities ρ and σ (which are taken from the literature). The only unknown is the share parameter λ, whose value can thus be found.

Once μ and λ have been calibrated, the TFP parameter β can be backed out as a residual:

$$\beta = \frac{y_d}{\left[\lambda[\mu k^\rho + (1-\mu)(\varphi_s \ell_s)^\rho]^{\frac{\sigma}{\rho}} + (1-\lambda)(\varphi_u \ell_u)^\sigma\right]^{\frac{1}{\sigma}}} \tag{A10}$$

where the numerator is the value of domestic production good and the denominator is VA in that sector. The calibration of the other parameters follows the same logic.

Appendix F: Calibrated Parameters

Table F1. Preferences Parameters (θ, θ^g) — Skilled and Unskilled Consumers and Government

	1995			2000		
	Skilled	Unskilled	Government	Skilled	Unskilled	Government
Unskilled primaries	0.0288	0.0558	0.0059	0.0224	0.0439	0.0047
Skilled primaries	0.0243	0.0471	0.0002	0.0231	0.0455	0.0002
Unskilled manufacturing	0.2378	0.2981	0.0000	0.2104	0.2673	0.0000
Skilled manufacturing	0.1011	0.1104	0.0718	0.1085	0.1201	0.0616
Unskilled services	0.1496	0.1051	0.4269	0.1497	0.1066	0.3756
Skilled services	0.1649	0.1824	0.4668	0.1858	0.2083	0.4312
Investment good	0.2936	0.2011	0.0285	0.2363	0.1640	0.1270
Foreign investment				0.0639	0.0443	

Table F2. Domestic Goods Firm Parameters

	1995			2000		
	β	μ	λ	β	μ	λ
Unskilled primaries	7.1467	0.6726	0.5538	7.1273	0.6592	0.5187
Skilled primaries	10.7970	0.9194	0.6007	17.7351	0.9109	0.6061
Unskilled manufacturing	19.3004	0.7147	0.5678	19.2021	0.7408	0.5757
Skilled manufacturing	14.9976	0.7762	0.5760	15.8566	0.8830	0.5788
Unskilled services	8.0493	0.5591	0.6198	8.7813	0.5300	0.6233
Skilled services	4.8518	0.7857	0.6371	4.8563	0.7403	0.6565

Table F3. Consumption Goods Firm Parameters $(\beta^c, \mu^c, \lambda^c)$

	1995			2000		
	β^c	μ^c	λ^c	β^c	μ^c	λ^c
Unskilled primaries	7.2584	0.6726	0.5538	7.1508	0.6592	0.5187
Skilled primaries	16.9626	0.9194	0.6007	25.7501	0.9109	0.6061
Unskilled manufacturing	17.8856	0.7147	0.5678	20.9601	0.7408	0.5757
Skilled manufacturing	21.5386	0.7762	0.5760	26.0767	0.8830	0.5788
Unskilled services	6.0797	0.5591	0.6198	6.6350	0.5300	0.6233
Skilled services	4.3916	0.7857	0.6371	4.5271	0.7403	0.6565

Table F4. Armington Aggregators Parameters

	1995			2000		
	γ	δ_{dom}	δ_{EU}	γ	δ_{dom}	δ_{EU}
Unskilled primaries	3.4338	0.3139	0.3439	2.8865	0.3693	0.2987
Skilled primaries	3.0473	0.3345	0.3249	2.9912	0.3412	0.3222
Unskilled manufacturing	3.1463	0.3390	0.3434	2.9709	0.3548	0.3225
Skilled manufacturing	3.2407	0.3199	0.3490	3.0276	0.3397	0.3276
Unskilled services	2.8091	0.3796	0.3150	2.7999	0.3810	0.3143
Skilled services	2.6952	0.3982	0.3055	2.7563	0.3891	0.3101

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