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Abstract

In this article, we disentangle the relationship between the skill premium, trade liberalization and productivity changes in accounting for the skill premium patterns of transition economies that joined the European Union (EU) in 2004. To conduct our 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 then assess the role of the multiple factors that affected the patterns of the skill premium: trade liberalization reforms, factor and sector bias of technical change and capital deepening, and find that all the factors can jointly account for approximately 87% of the actual change in skill premium between 1995 and 2005. Individually, capital deepening accounts for the largest share of the rise in the skill premium, whereas trade liberalization accounts for a small portion of that increase. While productivity changes account for only a small fraction of the skill premium increases during 1995 and 2000, they significantly offset the impact of the capital deepening on the skill premium in the period between 2000 and 2005.

JEL classification: D58, E16, F16, O33.

Keywords: Transition Economies, Skill Premium, Trade Liberalization, Skill-biased Technical Change, Capital-skill complementarity.

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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 (1995, 1996) 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 Acemoglu (2002) and Krugman (2000), for example), while another points to the sector bias of technical change as the culprit of the changes in the relative wages of skilled workers (see Haskel and Slaughter (2002) and Kahn and Lim (1998) 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 framework that is also employed by Lindquist (2005) for the Swedish case.

Of course, all of these explanations are not necessarily mutually exclusive. A pertinent example 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 Free Trade Agreement, or CEFTA) and with the "old" EU members (included in the European Union Association Agreement, or EUAA). Thus, these economies significantly liberalized their foreign sectors by allowing freer transactions of goods and services with their major trade partners. Similarly, as these countries transitioned from centrally planned systems to market-oriented economies, they experienced rapid increases in productivity across sectors. Finally, at the onset of their transition, these countries were significantly poorer than their Western counterparts in terms of their levels of capital stock. Over the years, the "new" EU members have accumulated sizable amounts capital, either through domestic investment or borrowing from abroad, although they have not quite yet caught up with the "old" members.

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. With this paper, 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 European Union. 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 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. 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 parametrizations can generate different decomposition results between trade and technological change as sources of an observed change in inequality."

In light of these remarks, we use an applied general equilibrium modeling approach that can clearly specify the impact of a particular shock in the economy under study. Our modeling choice also allows us to assess 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 two main issues. First, for the 1995-2005 period, the skill premium in Hungary registered the largest increase among new EU members for which data is available. 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 where being implemented, and during which 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%. Second, as far as we know, Hungary is the only country among these nations 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. Using a variety of data sources, including Social Accounting Matrices, Household Budget Surveys and the EU KLEMS database, we 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 "trade liberalization" shock, where we model the different trade liberalization reforms implemented by Hungary (initially, the free trade agreements with the European Union and afterwards, as a 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. 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 find that 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. However, different shocks played different roles in accounting for the changes in the skill premium, which can be summarized as follows: first, the trade shock played only a small role at accounting for the observed increases in the skill premium for both periods. Second, the role 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 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.

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 ρ, the parameter that governs the elasticity of substitution between capital and skilled labor in order to understand the role of the capital-skill complementarity assumption. On the one hand, when we run the capital deepening simulation using higher values of ρ, the implied smaller degree of capital-skill complementarity (measured as $\sigma - \rho$) results in a smaller increase in the skill premium compared to our benchmark results. On the other hand, a higher value for ρ also implies that capital and skilled labor become more substitutable. When we run the factor-biased simulation, the fact that it becomes easier to switch to skilled labor combined with the fact that this type of labor becomes more productive, leads to an increased demand for skilled labor which in turn leads to a higher increase in the skill premium. Overall, when we simulate all three types of shocks, the skill premium increases are higher than the benchmark case.

The remainder of the paper is organized as follows: in Section 2 we present a brief overview of the skill premium and relevant macroeconomic variables in Hungary. In Section 3 we describe the model that we use to conduct our quantitative analyses. In Section 4 we describe how we calibrate most of the model's parameters and how we assign values to the parameters that cannot be calibrated. In Section 5 we present the results of our numerical experiments, including the sensitivity simulations. Finally, we conclude in Section 6 summarizing our findings and presenting possible research strategies for the future.

2. Relevant Data Trends

2.1. Skill Premium Trends

We follow Cho and Díaz (2013) and 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. We calculate the skill premium by dividing the ratios of labor compensation to hours worked for skilled and unskilled workers:

$$\textit{skill premium} = \frac{\text{skilled workers' wage}}{\text{unskilled workers' wage}} = \frac{\frac{w_s L_s}{L_s}}{\frac{w_u L_u}{L_u}} = \frac{w_s}{w_u} \tag{1}$$

where w_s and w_u are, respectively, the wages of skilled and unskilled workers, and similarly, L_s and L_u are the total hours worked by 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%. The increase in Hungarian skill premium, however, slows down over time: while during the 1995-2000 period the skill premium rose at a strong 10.1% rate, during the 2000-2005 period it only grew at a more modest 2.8% rate (see Figure 1).

2.2. 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 (1998)).

In spite of this major shock, Hungary took steps to increase its openness to international trade by joining the Central European Free Trade Agreement (CEFTA) in 1992, signing a free trade agreement with the European Free Trade Association (EFTA) in 1993, and signing an Association Agreement with the European Union 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 European Union, 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.

2.3. 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 et al. (2013) indicates that whereas in the 1990-1995 period the capital stock grew at a rate of almost 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.

Similarly, both gross output and value added total factor productivity (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 gross output and value added TFP grew by 9.06% and 25.75% between 1995 and 2000, respectively, their growth rates between 2000 and 2005 were 5.36% and 17.99%.

3. The Model

3.1. Overview

We construct a standard static applied general equilibrium model that follows the tradition of Shoven and Whalley (1984). We choose to disaggregate the Hungarian economy in three main sectors: primaries, manufacturing, and services, with each sector in turn divided into two sub-sectors depending on its skill intensity. Thus, the 6 sectors are labeled as unskilled labor intensive primary goods, skilled labor intensive primary goods, unskilled labor intensive manufacturing, skilled labor intensive manufacturing, unskilled labor intensive services, and skilled labor intensive services.[1] Our artificial economy is populated by

[1] We follow the classification used in Abrego and Whalley (2001) to assign skilled and unskilled labor intensive sectors. A detailed description of the industries included in each sector is presented in Appendix 1-2.

several agents: two representative consumers (differentiated by their skills levels), producers, a domestic government and foreign trade partners. We provide a more detailed explanation of their features below.

3.2. 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. The production function of the domestic firm producing good i is:

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

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 j, $a^d_{m,i}$ 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. In (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.

3.3. Final Production Goods Firms

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

$$y_i = \gamma_i\left[\delta_i y_{i,d}^{\rho_{m,i}} + (1-\delta_i) y_{i,f}^{\rho_{m,i}}\right]^{\frac{1}{\rho_{m,i}}} \quad (3)$$

where $\sigma_{m,i} = 1/(1-\rho_{m,i})$ 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 the final good i, $y_{i,d}$ is the domestic component in final good i, and $y_{i,f}$ is the imported component. Note that when $\rho_{m,i} \to 0$, the production function takes the usual Cobb-Douglas form, i.e., $y_i = \gamma_i y_{i,d}^{\delta_i} y_{i,f}^{(1-\delta_i)}$. As in (2), changes in γ_i capture sector-specific, Hicks-neutral technical change in the final goods production. Finally, imports of good i are subject to an ad-valorem tariff rate τ_i.

3.4. 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 goods using a fixed proportion technology, together with capital, and skilled and unskilled labor:

$$y_{i,c} = \min\left\{\frac{x^c_{1,i}}{a^c_{1,i}}, \ldots, \frac{x^c_{i,i}}{a^c_{i,i}}, \ldots, \frac{x^c_{1,n}}{a^c_{1,n}},\ \beta^c_i \left[\lambda^c_i \left[\mu^c_i (k^c_i)^{\rho_c} + (1-\mu^c_i)(\varphi^c_s \ell^c_{s,i})^{\rho_c}\right]^{\frac{\sigma_c}{\rho_c}} + (1-\lambda^c_i)(\varphi^c_u \ell^c_{u,i})^{\sigma_c}\right]^{\frac{1}{\sigma_c}}\right\} \quad (4)$$

where $\{1, 2, ..., n\}$ are the goods in $\mathsf{G_c}$, the set of consumption goods. We make an additional assumption: $x^c_{j,i} = 0$ for $j \neq i$, services. This implies that for consumption good i, the firm only uses as inputs final goods of its own sector and services as well as labor and capital. 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^c_i, and φ^s_u and φ^c_u, respectively.

3.5. 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:

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

3.6. 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 trade integration 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:

$$\max \quad \sum_{i\in \mathsf{G_C}} \theta^j_i \log c^j_i + \theta^j_{inv} \log c^j_{inv} + \theta^j_{inv,f} \log c^j_{inv,f} \quad (6)$$

$$\text{s.t.} \quad \sum_{i\in \mathsf{G_C}} p_{c,i} c^j_i + p_{inv} c^j_{inv} + e\bar{p}_{inv,f} c^j_{inv,f} = (1-\tau^j_d)(w_s \bar{\ell}^j_s + w_u \bar{\ell}^j_u + r\bar{k}^j)$$

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_s and w_u are, respectively, the wage rate for skilled and unskilled labor, and r is the rental rate of capital; $\bar{\ell}_s^j$, $\bar{\ell}_u^j$, $\bar{k}^j$ are, respectively, the endowments of skilled, unskilled and capital.

Note that given our disaggregation of households, we must have either $\bar{\ell}_s^j > 0$ and $\bar{\ell}_u^j = 0$, or $\bar{\ell}_s^j = 0$ and $\bar{\ell}_u^j > 0$, but any household cannot have a positive endowment of both skilled and unskilled labor.

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 is running a trade surplus with the rest of the world, we model this as household purchase 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 rest of the world by household j, $\bar{p}_{inv,f}$, its price (which is assumed to be exogenous) and e is the real exchange rate.

3.7. The Government

A look at the SAM shows that the Hungarian government makes purchases of goods and also that it runs a fiscal surplus. To account for these observations, we assume that, in the model, the government is an agent that enjoys utility from consuming the production goods and the investment good. Purchases of these goods must be financed by the revenues collected from direct and indirect taxes and tariffs imposed on imports.

The problem of the government is then:

$$\begin{aligned} \max \quad & \sum_{i \in \mathsf{G_p}} \theta_i^g \log c_i^g + \theta_{inv}^g \log c_{inv}^g \qquad (7) \\ \text{s.t.} \quad & \sum_{i \in \mathsf{G_p}} p_i c_i^g + p_{inv} c_{inv} = \sum_{j \in \mathsf{H}} \tau_d^j (w_s \bar{\ell}_s^j + w_u \bar{\ell}_u^j + r \bar{k}^j) + \sum_{i \in \mathsf{G_p}} t_{p,i} p_{d,i} y_{i,d} \\ & \qquad + \sum_{i \in \mathsf{G_c}} t_{c,i} p_{c,i} y_{i,c} + \sum_{f \in \mathsf{T}} \sum_{i \in \mathsf{G_p}} \tau_i e \bar{p}_{i,f} y_{i,f} \end{aligned}$$

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 (T is set of trade partners, see below).

3.8. Foreign Trade Partners

In our model, Hungary trades with two trade partners: the European Union (EU) and the Rest of the World (ROW). We denote the set of trade partners by $\mathsf{T} = \{\text{EU, ROW}\}$. In each trade partner country $f \in \mathsf{T}$ there is a representative consumer that purchases imported goods $x_{j,f}$ from Hungary, and consumes its local good $x_{f,f}$. If a particular trade partner is running a trade surplus with Hungary, we model these savings as foreign purchases of the Hungarian investment good $x_{inv,f}$. The problem of the representative household in the foreign country f is

$$\max \quad \left[\sum_{j \in \mathsf{G_P}} \theta_{j,f} x_{j,f}^{\rho_x} + \theta_{inv,f} x_{inv,f}^{\rho_x} + \theta_{f,f} x_{f,f}^{\rho_x} - 1\right] / \rho_x \tag{8}$$

$$\text{s.t.} \quad \sum_{j \in \mathsf{G_P}} (1 + \tau_j^f) p_j x_{j,f} + p_{inv} x_{inv,f} + e_f x_{f,f} = e_f I_f$$

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 between Hungary and trade partner f, and I_f is the (exogenous) income of the household in country f.

3.9. Definition of Equilibrium

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

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

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

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

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

$$\begin{aligned} y_{i,d} &= \min\left\{\frac{x^d_{1,i}}{a^d_{1,i}}, \ldots, \frac{x^d_{n,i}}{a^d_{n,i}}, \beta_i\left[\lambda_i\left[\mu_i k_i^\rho + (1-\mu_i)(\varphi_s \ell_{s,i})^\rho\right]^{\frac{\sigma}{\rho}} + (1-\lambda_i)(\varphi_u \ell_{u,i})^\sigma\right]^{\frac{1}{\sigma}}\right\} \\ \text{and} &\quad (1+t_{p,i})p_{i,d}y_{i,d} - \sum_{j\in \mathsf{G_p}} p_j x^d_{j,i} - w_u \ell_{u,i} - w_s \ell_{s,i} - rk_i \leq 0, \ = 0 \ \text{ if } \ y_{i,d} > 0 \end{aligned}$$

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

$$p_i y_i - p_{i,d} y_{i,d} - (1+\tau_i)e\bar{p}_{i,f} y_{i,f} \leq 0, \ = 0 \ \text{ if } \ y_i > 0$$

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

$$\begin{aligned} \min &\quad (1+t_{p,i})p_{i,d}y_{i,d} + (1+\tau_{i,f})e\bar{p}_{i,f}y_{i,f} \\ \text{s.t.} &\quad \gamma_i\left[\delta_i y_{i,d}^{\rho_{m,i}} + (1-\delta_i)y_{i,f}^{\rho_{m,i}}\right]^{\frac{1}{\rho_{m,i}}} = y_i \end{aligned}$$

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

$$\begin{aligned} y_{inv} &= \min\left\{\frac{x_{1,inv}}{a_{1,inv}}, \ \ldots, \frac{x_{i,inv}}{a_{i,inv}}, \ \ldots, \frac{x_{n,inv}}{a_{n,inv}}\right\} \\ \text{and} &\quad p_{inv}y_{inv} - \sum_{j\in \mathsf{G_p}} p_j x_{j,inv} \leq 0, = 0 \ \text{ if } \ y_{inv} > 0 \end{aligned}$$

(vii) The production plan $(y_{i,c}, x^c_{1,i}, ..., x^c_{n,i}, k^c_i, \ell^c_{u,i}, \ell^c_{s,i})$ satisfies:

$$\begin{aligned} y_{i,c} &= \min\left\{\frac{x^c_{1,i}}{a^c_{1,i}}, ..., \frac{x^c_{i,i}}{a^c_{i,i}}, ..., \frac{x^c_{1,n}}{a^c_{1,n}}, \ \beta^c_i\left[\lambda^c_i\left[\mu^c_i(k^c_i)^{\rho_c} + (1-\mu^c_i)(\varphi^c_s \ell^c_{s,i})^{\rho_c}\right]^{\frac{\sigma_c}{\rho_c}} + (1-\lambda^c_i)(\varphi^c_u \ell^c_{u,i})^{\sigma_c}\right]^{\frac{1}{\sigma_c}}\right\} \\ \text{and} &\quad (1+t_{c,i})p_{i,c}y_{i,c} - \sum_{j\in \mathsf{G_p}} p_j x^c_{j,i} - w_u \ell^c_{u,i} - w_s \ell^c_{s,i} - rk^c_i \leq 0, \ = 0 \ \text{ if } \ y_{i,c} > 0 \end{aligned}$$

(viii) The factor markets clear:

$$\begin{aligned} \sum_{i\in \mathsf{G_p}} \ell_{u,i} + \sum_{i\in \mathsf{G_c}} \ell^c_{u,i} &= \sum_{j\in \mathsf{H}} \bar{\ell}^j_u \\ \sum_{i\in \mathsf{G_p}} \ell_{s,i} + \sum_{i\in \mathsf{G_c}} \ell^c_{s,i} &= \sum_{j\in \mathsf{H}} \bar{\ell}^j_s \\ \sum_{i\in \mathsf{G_p}} k_i + \sum_{i\in \mathsf{G_c}} k^c_i &= \sum_{j\in \mathsf{H}} \bar{k}^j \end{aligned}$$

(ix) The goods markets clear:

$$
\begin{aligned}
y_i &= \sum_{j \in \mathsf{G_p}} x^d_{j,i} + \sum_{j \in \mathsf{G_c}} x^c_{j,i} + x_{i,inv} + c^g_i + x_{i,f} \quad \forall i \in \mathsf{G_p} \\
y_{i,c} &= \sum_{j \in \mathsf{H}} c^j_i \quad \forall i \in \mathsf{G_c} \\
y_{inv} &= \sum_{j \in \mathsf{H}} c^j_{inv} + c^g_{inv} + x_{inv,f}
\end{aligned}
$$

(x) The balance of payments condition is satisfied:

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

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 years 1995 and 2000. Below we describe how we conducted our calibration exercise.[2]

4.1. Social Accounting Matrices (SAM)

Most of the parameters (such as the input shares and total factor productivity scale parameters in the production functions and the parameters in the agents' utility functions) can be directly calibrated from a SAM by using the optimality and market clearing conditions.[3]

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.

[2] Tables B1 to B4 in Appendix 1-5 present the values of the calibrated parameters. In particular, Tables B2 and B3 allow us to determine the factor intensities in each of the disaggregated sectors.

[3] For those parameters that cannot be calibrated from the data, we explain how we chose those values in Section 4.4.

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 them, SAMs have been frequently and extensively used in applied general equilibrium models designed to analyze policy reforms (see for example, 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 that match the disaggregation choice in our model (see Appendices 1-3 and 1-4).

4.2. 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 Household Budget Surveys (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.[4]

Using the data contained in the survey we divide the Hungarian households into 2 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.

4.3. 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 European Union member countries

[4] 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.

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.

4.4. Remaining Parameters

Tariff rates. The tariff rates that Hungary imposes on its imports (τ_i) can be calibrated directly from the Social Accounting Matrix. 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 Rest of the World (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 European Union and accounted for 13.9% and 15.0% of Hungarian exports in 1995 and 2000, respectively. Note that the service sectors are not subject to tariffs.

Import and export elasticities of substitution. Given the static nature of our model, the elasticities of substitution for exports and imports cannot be calibrated directly from the Social Accounting Matrix. Instead, we use different sets of values for these parameters. For our "benchmark" case, we set $\rho_{m,j} = 0.9 \ \forall j \in \mathsf{G_p}$ in equation (3) , and $\rho_x = 0.9$ in equation (9), implying elasticities of import and export substitution of 10, respectively. These values are usually found and used in trade liberalization studies in the literature. 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 (or skilled labor) and unskilled labor and capital and skilled labor, respectively. Their counterparts in the consumption goods production functions are ρ_c and σ_c. We take the average of the values reported in Silos and Polgreen (2008) and set

$\rho = \rho_c = -0.357$ and $\sigma = \sigma_c = 0.659$. Later, in the sensitivity analysis, we assess the role of the capital-skill complementarity by changing the values of ρ and ρ_c.

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 to 2000, when Hungary's economy became more integrated with the European Union, and 2000 to 2005, a period that culminated with Hungary's accession into the European Union. Before presenting and discussing the results of our simulations, we first describe the experiments we run.

Trade liberalization experiments. In the trade liberalization 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 trade liberalization arrangements: during the first one, Hungary and the European Union 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 rest of the world unchanged.

The second period corresponds to Hungary's accession into the EU, a process that culminated in 2004. As an 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 rest of the world with the European Union's tariff schedule.

Tables 5-1 and 5-2 below present the tariff schedules for Hungary, the EU, and the rest of the world for each period.

Table 5-1: Tariff Rates for 1995-2000 Simulation (percent)

	Pre-EU liberalization				Post-EU liberalization			
	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

Table 5-2: 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

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 total factor productivity changes that took place in the Hungarian economy, for both sectoral value added (VA) and sectoral gross output (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.

Table 5-3: Sectoral TFP Changes for Benchmark Experiment

	Percent change (1995-2000)		Percent change (2000-2005)	
Sectors	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

In the second type of productivity changes, that we refer to as "factor-biased productivity changes," we replicate the changes in the relative productivity levels of skilled and unskilled

Hungarian workers. These data are taken from Lovasz and Rigo (2009), who conduct an empirical analysis of the relative productivities and wages of various Hungarian worker groups. They report a 20.1% increase in the relative productivity of skilled workers between 1995 and 2000, and a 26.3% increase between 2000 and 2005.

"Capital deepening" experiments. As Hungary transitioned from a centrally-planned system to a market-oriented economy, its stock of capital significantly grew as detailed in Section 2.3. We incorporate these capital increases by letting the aggregate capital stock grow at 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 et al. (2013), which contains the most recent update of the Penn World Table.

5.1. Benchmark Results: 1995-2000

Table 5-4: 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:		
Trade liberalization	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 5-4 presents the results of our simulations for the 1995-2000 period. Our joint experiment, where we simultaneously incorporate the trade, productivity and capital deepening shocks yields 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 channel embedded in our framework. Of the two productivity shocks, the factor-biased productivity changes appear to be more important, although its role is small when compared to that of capital deepening. Finally, the trade liberalization experiment can only account for a small fraction of the observed increase in the skill premium.

5.2. Benchmark Results: 2000-2005

Table 5-5: 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:		
Trade liberalization	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	

Table 5-5 presents the results for the 2000-2005 period. The joint experiment, where we simultaneously incorporate the trade, productivity and capital deepening shocks 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 trade liberalization 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 would actually yield a decline in the skill premium of approximately 8.4%, whereas the factor-biased productivity changes would generate 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.

5.3. 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, since these parameters cannot be calibrated given the static nature of our model. 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.[5] The results of this sensitivity analysis are presented in Table 5-6 below. 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 trade in accounting for the changes in the skill premium is consistently positive but small across scenarios.

Table 5-6: Sensitivity Analysis - Import Elasticities of Substitution and Skill Premium Changes

	Percent change (1995-2000)		Percent change (2000-2005)	
	Benchmark elasticities	Rolleigh elasticities	Benchmark elasticities	Rolleigh elasticities
Joint simulation	8.80	9.08	2.45	2.38
Individual simulations:				
Trade liberalization	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

5.4. The Role of Capital-Skill Complementarity

In our benchmark experiments we used the average of the values reported in Silos and Polgreen (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 5-7 for the 1995-2000 period and Table 5-8 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

[5] The implied values of ρ_m are 0.952 for both primaries sectors, 0.873 for unskilled manufactures, 0.819 for skilled manufactures, 0.9 for unskilled services and 0.9 for skilled services.

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.

The last column in Tables 5-7 and 5-8 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 trade and factor-biased simulations. On the other hand, the sector-biased 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.

Table 5-7: 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:					
Trade liberalization	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

Table 5-8: 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:					
Trade liberalization	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 sensitivity simulations underscored our choice of production functions that exhibit capital-skill complementarity. Our choice is in line with the empirical findings in Koren and Csillag (2011), who show that capital imports in Hungary increased the demand for skilled workers.

6. Conclusions

What drives the patterns of the skill premium? The economics literature has devised a variety of explanations, ranging from the expansion of international trade to the role of productivity and the complementarity between capital and skilled labor, without reaching a definitive consensus. The case of economies of Central and Eastern Europe presents an interesting example since these explanations were all in place as those countries transitioned from centrally-planned systems to full-fledged members of the European Union. In this article, we conduct a decompositional analysis to disentangle the multiple factors that affected the increasing patterns of the skill premium observed in Hungary between 1995 to 2005.

We build a static applied general equilibrium model, and using a variety of data sources 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. In order to understand how specific factors contributed to the changes in relative wages, we conduct numerical experiments to assess how the skill premium responds to individual shocks. 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) which in turn raises the demand for skilled workers through the capital-skill complementarity channel. On the other hand, we find that productivity changes 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 trade liberalization, at least in the form of tariff reductions, played a small role in accounting for the changes in the skill premium. This, however, should not be interpreted as opening being unimportant. In particular, our results highlight the role of capital deepening as the major driver in the pattern of the skill premium, and for many transition countries a large fraction of that capital accumulation originated from external sources in the form of foreign direct investment, for example. Finally, we perform a series of sensitivity experiments to gauge the robustness of our results to changes in the values of the parameters in the model. We find that in general our results are indeed robust, a fact that enhances the validity of our findings.

Our analysis abstracts from some of the institutional features that have been used to explain the increase of the skill premium in transition economies. For example, Brown et al. (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, Magda et al. (2012) find that collective barganing at the company level increases medium- and high-skilled wages in a subset of transition economies, including Hungary. Incorporating such institutional 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.

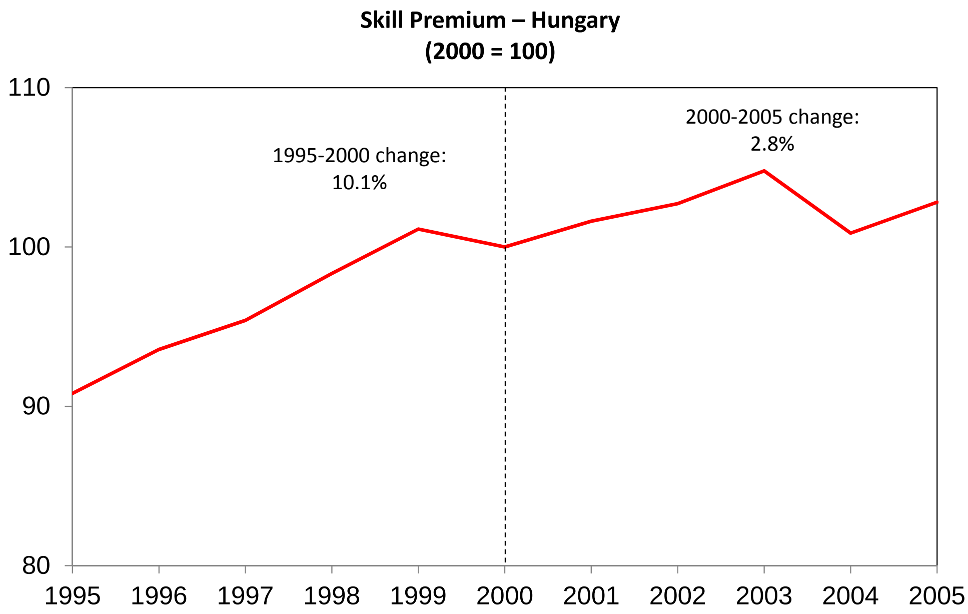

Figure 1: Skill Premium in Hungary

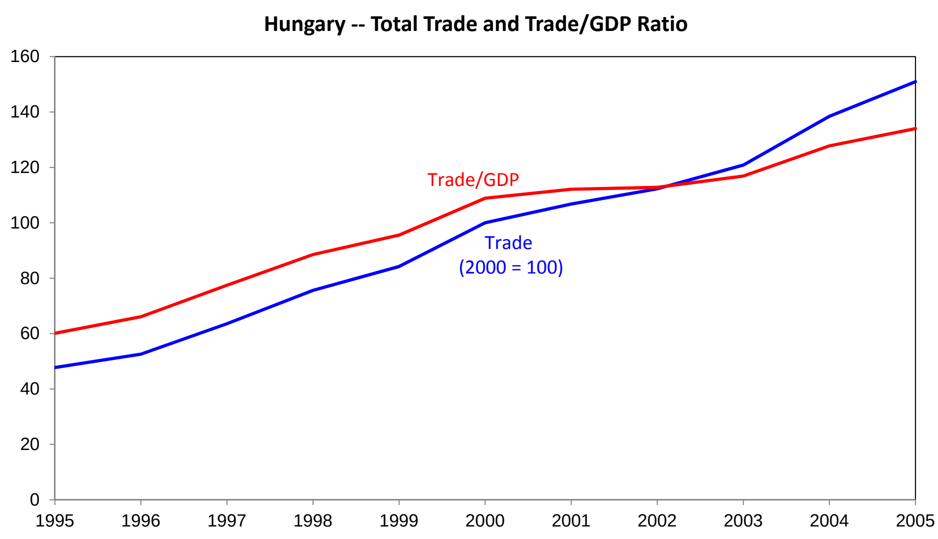

Figure 2: Hungary – Total Trade and Openness

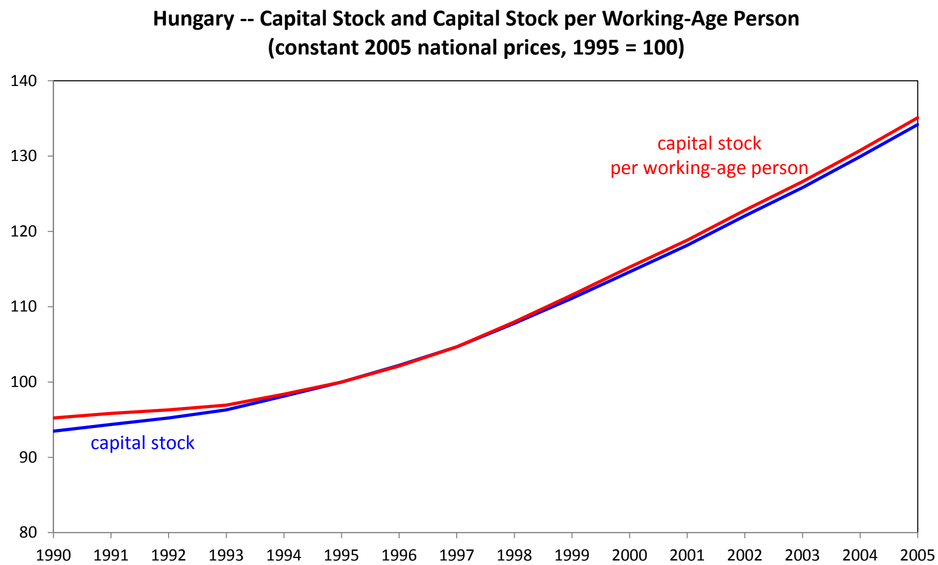

Figure 3: Hungary – Capital Stock

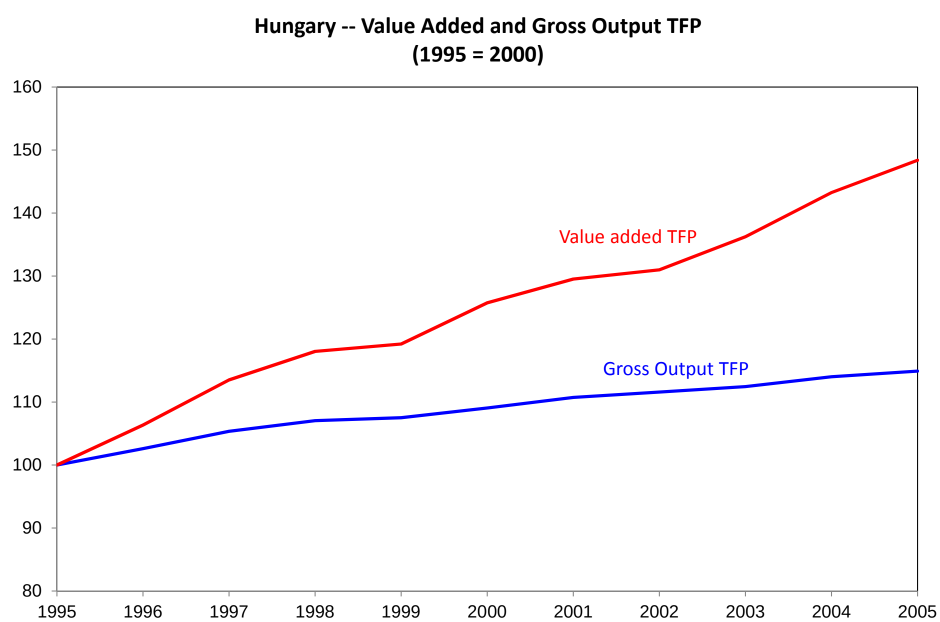

Figure 4: Hungary – Trends in TFP

Appendix 1-1 Construction of Skill Premium (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

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 1-2 Sectoral Matching of Consumption and Production Sectors

6-Sector SAM	Input-Output Table
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 non-metallic 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 Service (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 Service (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 1-3 Social Accounting Matrix - 1995

	Production Goods Sector						Consumption Goods Sector						L	K	C	Consumption		I	G	X	Export		Total
	PU	PS	MU	MS	SU	SS	PU	PS	MU	MS	SU	SS				Unskilled	Skilled				EU	ROW	
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 1-4 Social Accounting Matrix - 2000

	Production Goods Sector						Consumption Goods Sector						L	K	C	Consumption		S	I	G	X	Export		Total
	PU	PS	MU	MS	SU	SS	PU	PS	MU	MS	SU	SS				Unskilled	Skilled					EU	ROW	
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 1-5 Calibrated Parameters

Table B1. 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 B2. 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 B3. 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 B4. 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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