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Factor-Biased Technical Change and Specialization Patterns

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Factor–Biased Technical Change and Specialization Patterns

Jana Brandt[*], Jürgen Meckl[*] and Ivan Savin[†]

Abstract

We analyze the medium– and long–run effects of international integration of capital markets on specialization patterns of countries. For that purpose, we incorporate induced technical change into a Heckscher–Ohlin model with a continuum of final goods. This provides a comprehensive theory that explains the dynamics of comparative advantages based on differences in effective factor endowments. Our model constitutes an appropriate framework for understanding the changes in industrial structure of foreign trade observed, e.g., in the CEE countries over the last two decades. In addition, our approach provides a theoretical foundation for the empirical prospective comparative advantage index (Savin and Winker 2009) with new insights into the future dynamics of comparative advantages. Eventually, the model may serve as a basis to set development priorities in countries being in the period of transition.

Keywords: Factor-biased technical change, continuum of goods, comparative advantage, factor mobility, innovation, knowledge spillovers.

JEL-Classification: F15, F17, F21, F43, O33.

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1 Introduction

In this study we analyze the dynamics of comparative advantages (CAs) considering an endogenous technical change framework (see, e.g., Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992)) and allowing for technical change to be directed in favor of one of the production factors. Analyzing motivation of companies to invest in technologies, Acemoglu (2002) identifies two main forces affecting the factor–biased technical change (FBTC): a price effect and a market size effect. These two forces work in opposite directions: the former fosters technologies with lacking production factors and, respectively, more expensive goods, while the latter directs technical change towards abundant factors, i.e. with potentially larger economies of scale.

While this framework provides an instrument predicting the direction of technical change during the last century in the developed countries, it fails to explain the capital-biased technical change observed in certain economies in transition. In particular, developing countries lacking capital before integration of factor markets are expected to experience technical bias towards (unskilled) labor intensive goods (Acemoglu 2002, p 801). But this result is not always true.

A good example is presented by the Central and Eastern European (CEE)[1] countries that have recently passed a transition period of their economies and joined the EU. According to Zaghini (2005), most of these countries had excessive natural and labor resources in comparison to other EU countries specializing (at the beginning of 1990s) in sectors that used these resources more intensively, e.g., products of steel and glass, agricultural goods. Nevertheless, during a period of ten years these countries gained CAs in some capital intensive industries, e.g., transport, machinery building and electronics. This is in contrast with Acemoglu (2002) that the new EU members were anticipated to 'concentrate' on their CAs, instead of diversifying them. Further examples controverting the existing literature are newly industrialized countries (e.g., Taiwan, South Korea, China) that experienced a rapid growth in their CAs in capital intensive goods in response to capital inflow and trade liberalization (see, e.g., Rugman and Collinson (2006)).

Consider Figure 1 as an illustration. The Figure plots dynamics of CAs measured by the Lafay index (LFI, Lafay (1992)) for a pooled sample of eight CEE

[1] The CEE countries consist of Poland, the Czech Republic, Hungary, Slovenia, Slovak Republic, Cyprus, Malta, Lithuania, Latvia and Estonia.

countries (excluding Cyprus and Malta) in high tech items according to UNIDO (2003)[2] in the period 1993–2000. In addition, the pooled FDI inflows for the sample of countries over the same period are shown.[3] One sees that the inflow of capital into the CEE countries is accompanied by a rapid growth of CAs in capital intensive goods, which contradicts Acemoglu (2002).

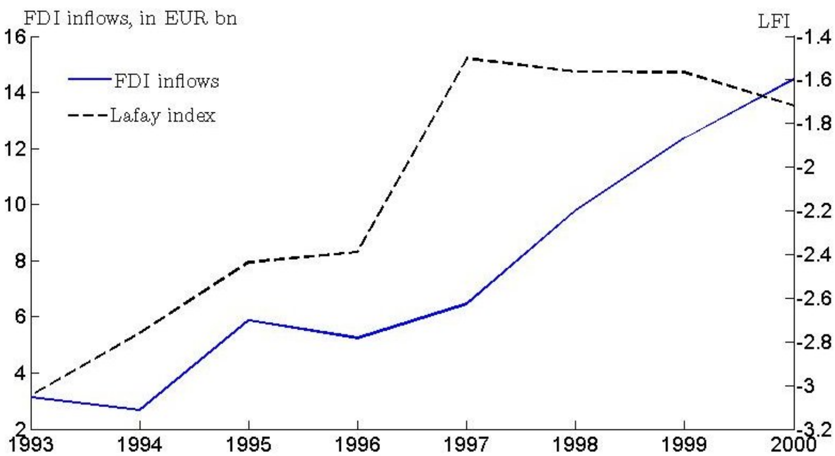

Figure 1: Pooled FDI inflows and LFI in high tech goods in the CEE countries

Further empirical evidence on the positive impact of factor inflow on technical change can be found, among others, in Borbely (2005) and Radosevic and Rozeick (2005). In particular, for the Czech Republic, Poland and Hungary Borbely (2005) identifies a considerable growth in the R&D intensity in capital intensive industries (e.g., chemicals, machinery and equipment) being accompanied by massive inflow of FDI in those countries, while Radosevic and Rozeick (2005) determine a significant effect of FDI on both productivity and export performance for the CEE countries in the automotive industry.

[2]The pooled LFI index is calculated for the following product groups: medicinal and pharmaceutical products (541), steam & other vapor power units, steam eng. (712), rotating electric plant and parts (716), other power generating machinery and parts (718), office machines (751), automatic data processing machines & units (752), parts of and accessories suitable for 751 (759), television receivers (761), telecommunications equipment and parts (764), electric power machinery and parts thereof (771), electric apparatus for medical purposes (774), thermionic,cold & photo-cathode valves, tub (776), electrical machinery and apparatus, n.e.s. (778), aircraft & associated equipment and parts (792), optical instruments and apparatus (871), measuring, checking, analyzing instruments (874) and photographic apparatus and equipment (881). The data on the LFI indices were kindly provided by Andrea Zaghini (CFS, Frankfurt).

[3]The data on the FDI inflows is from the EU Foreign Direct Investment Yearbook 2001.

To resolve this puzzle, we integrate the FBTC concept into a neoclassical Heckscher–Ohlin (HO hereafter) framework with a continuum of final goods (Dornbusch *et al.* 1980). The HO–model explains how CA is related to a country's relative factor supplies for given technologies, while the FBTC concept explains how technical change is induced by changes in relative factor endowments. Trefler (1993, 1995) emphasized that differences in factor supplies have to be analyzed in conjunction with technology differences between countries to be consistent with empirical findings on the factor content of international trade. We take up his suggestion and consider factor endowments in 'effective units' as basis for factor–abundance driven trade. The efficiency of physical factor endowments, however, is determined endogenously by investment into the division of factors.

Other studies also account for technology differences between countries in a HO–type model as developed by Dornbusch *et al.* (1980). Zhu and Trefler (2005) explain factor–price inequalities through exogenous technological convergence between countries, while Zhu (2007) examines welfare implications of this type of convergence. In contrast, to our knowledge the present paper is the first that analyzes factors triggering this technology convergence by endogenizing decisions to invest in new technologies.

Integrating the HO–model with the FBTC concept provides a theory that can explain the dynamics of CAs based on differences in factor endowments. In particular, we argue that an inflow of a factor through the international factor market integration causes, first, the price effect reducing production costs of factor intensive goods and, second, the market size effect inducing companies to innovate in the respective sector and further reducing relative prices. In this way, this paper explains the progression of CAs in the CEE countries over time (see, e.g., Savin and Winker (2009, p 123)). The speed of reaction of CAs in response to capital inflow can vary across countries and sectors. This is mainly due to different time periods and factor stocks required to conduct R&D and produce goods, which are in demand in the home country and abroad.[4]

To this end, consider as an example dynamics of FDI inflows and stocks in Hungary *vis–à–vis* its LFI in optical, photo, technical, medical apparatus (group 90 in the UN Comtrade Harmonized System) on Figure 2.[5] In contrast to the

[4]This can be also caused by different 'catching-up' scenarios observed in productivity levels in emerging and developing countries (see Stehrer and Woerz (2003)).

[5]The data on the FDI is obtained from the Hungarian National Bank, while the LFI index

pooled sample of high tech goods, no CA was formed in this sector in Hungary till the end of 1990s. However, within the next five years the situation has changed dramatically. This illustrates that the inflow of capital with the resulting price effect alone might not be enough to form a CA. One needs a certain time period to advance technologies in this sector and produce goods, which are in a requisition.

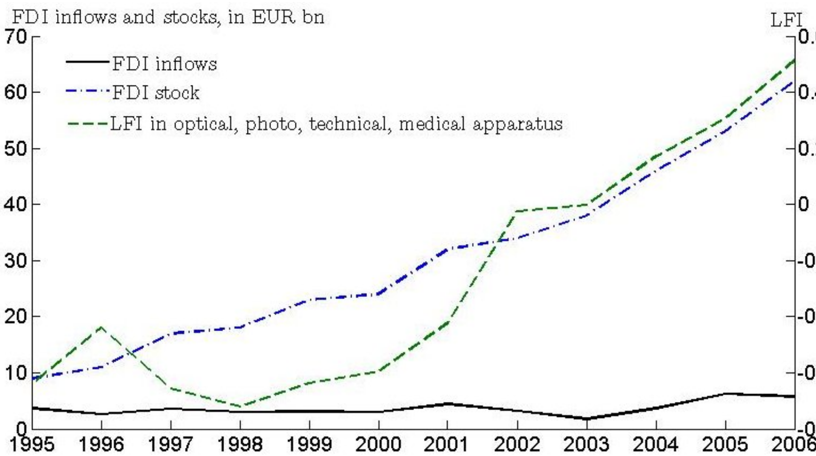

Figure 2: FDI inflows and stocks *vis–à–vis* LFI in Hungary

This study is useful not only for understanding dynamics of CAs in the past, but also for analyzing their future dynamics. In particular, there is a parallel between this model and the idea of the prospective comparative advantage (PCA) instrument that can be used in forecasting CAs (Savin and Winker 2009).

In addition, we summarize our ideas on implications of this model for industrial policies in transition economies. In particular, we argue that countries can stimulate technical change by enhancing an inflow of the respective factor and by mitigating potential inefficiencies on the market of so–called technology producers.

This paper is organized as follows. Section 2 presents the basic model assumptions. In Sections 3 and 4 the static and the dynamic equilibrium of the model are given. In Section 5 we introduce international capital–market integration and analyze dynamics of CAs conditional upon changes in factor endowments. In Section 6 the the model is compared with the concept of PCAs and its implications for industrial policy are discussed. Section 7 concludes.

is calculated based on data from the UN COMTRADE Database.

2 The Model

2.1 Consumer Problem

Consumers in all countries are assumed to have identical preferences of the constant relative risk aversion (CRRA) type

$$U(C(t)) = \int_0^\infty \frac{C(t)^{1-\theta} - 1}{1-\theta} e^{-\rho t} dt \,, \tag{1}$$

where ρ is the rate of time preference and θ is the intertemporal elasticity of substitution. C is a Cobb–Douglas type consumption aggregator defined over a continuum of final goods indexed by z:

$$\ln C(t) = \int_{z \in Z} \alpha \ln d(z,t) \, dz \,, \tag{2}$$

with $d(z,t)$ denoting the consumption of product z at time t, Z being a measure of the set of available final products and α indicating the share of product z in the consumption of Z (identical $\forall\ z$). We drop the time argument t in the following as long as this causes no confusion.

2.2 Production Sector

Suppose that final goods are produced from intermediates Y_K and Y_L. Furthermore, suppose that the technology for final good z can be described by the unit cost function

$$c(p_K, p_L, z) = A p_K^z p_L^{1-z}, \tag{3}$$

where p_j represents the prices of intermediate goods Y_j ($j = K, L$), and A is a parameter of the technology. The market for final goods is assumed to be competitive. Final goods are assumed to be freely traded internationally.

Intermediate goods are produced by using specialized machines according to the CES–type production functions

$$Y_K = \left[\int_0^{N_K} x_K(n)^{1-\beta} dn \right]^{\frac{1}{1-\beta}} \quad \text{and} \quad Y_L = \left[\int_0^{N_L} x_L(n)^{1-\beta} dn \right]^{\frac{1}{1-\beta}} \,, \tag{4}$$

where $\beta \in (0,1)$, and $x_j(n)$ denotes the input of variety $n \in [0, N_j]$ of type j

machine in production of intermediate good Y_j ($j = K, L$). N_j measures the range of available machines of type j, i.e.: type–j machines that have been invented in the past. The markets for intermediates are supposed to be fully competitive; however, intermediate goods are assumed to be non-tradable.

Machines of each type j are supplied by technology monopolists. For Section 3, we take the N_K and N_L as given; in Section 4 we analyze the innovation decisions that determine N_K and N_L. We assume that machines cannot be traded internationally. For simplicity, we assume that all machines are fully used up in production. The technology for producing machines is supposed to be as follows:

$$x_K(n) = K(n) \quad \text{and} \quad x_L(n) = L(n)\,. \tag{5}$$

Our model is completed by factor markets. To keep things simple, factor endowments of capital K and labor L are assumed to be given exogenously.

3 Static Equilibrium

A static equilibrium for given (N_K, N_L) consists of a set of prices for machines $(q_K(n), q_L(n))$ that maximize profits of technology monopolists, machine demands from the intermediate producers $(x_K(n), x_L(n))$ that maximize intermediate producers' profits, prices of intermediates (p_K, p_L) that clear the market for intermediates, the range of final goods (z) that is produced by a country, and factor prices (w_K, w_L) that clear factor markets.

Profit maximization of the producers of intermediates (taking as given the price of their product p_j, the prices of machines $q_j(n)$ and the range of available machines N_j) reads

$$\max_{x_j(n)} \left\{ p_j Y_j - \int_0^{N_j} q_j(n) x_j(n) dn \,:\, Y_j = \left[\int_0^{N_j} x_j(n)^{1-\beta} dn \right]^{\frac{1}{1-\beta}} \right\}, \quad j = K, L\,. \tag{6}$$

The following first–order condition in regard to x_j is obtained from this problem:

$$x_j(n) = \left[\frac{p_j}{q_j(n)} \right]^{\frac{1}{\beta}} Y_j\,, \qquad j = K, L\,. \tag{7}$$

Demand for each variety of type–j machine is increasing in the price of the respective intermediate good j and in the demand for intermediate good j, but is decreasing in the price of the respective machine.

Technology monopolists take the demand for their machines in (7) and the factor price w_j as given. Profit maximization of technology monopolists then reads

$$\max_{q_j(n)} \left\{ [q_j(n) - w_j] x_j(n) \, : \, x_j(n) = \left[\frac{p_j}{q_j(n)} \right]^{\frac{1}{\beta}} Y_j \right\} , \quad j = K, L \, . \tag{8}$$

The first–order condition of the problem in regard to $q_j(n)$ yields the well–known markup–pricing condition:

$$q_j(n) = \frac{w_j}{1-\beta} \, , \qquad j = K, L \, . \tag{9}$$

Since (9) holds for all technology monopolists producing j–type machines, we obtain equilibrium machine prices as

$$q_j(n) = \frac{w_j}{1-\beta} \equiv q_j \, , \qquad j = K, L \, , \tag{10}$$

and hence

$$x_j(n) = \left[\frac{p_j}{q_j} \right]^{\frac{1}{\beta}} Y_j \equiv x_j \, , \qquad j = K, L \, . \tag{11}$$

As a result of these symmetries, the production functions for intermediate goods (4) can be written as

$$Y_j = N_j^{\frac{1}{1-\beta}} x_j \, , \qquad j = K, L \, . \tag{12}$$

Given the technologies for producing machines, factor–market equilibrium conditions read

$$K = \int_0^{N_K} x_K(n) \, dn, \quad L = \int_0^{N_L} x_L(n) \, dn \, . \tag{13}$$

Due to the symmetry of machine producers, these conditions reduce to

$$K = N_K x_K \, , \quad L = N_L x_L \, .$$

Finally, by substituting for x_j from (12), we obtain the supplies of intermediates:

$$Y_K = N_K^{\frac{\beta}{1-\beta}} K \quad \text{and} \quad Y_L = N_L^{\frac{\beta}{1-\beta}} L \,. \tag{14}$$

Note that $N_K^{\frac{\beta}{1-\beta}} K$ and $N_L^{\frac{\beta}{1-\beta}} L$ can be interpreted as effective endowments of factors K and L. Due to technical progress, physical factor endowments become more productive by increased differentiation in factors as measured by $N_j^{\frac{\beta}{1-\beta}}$. In the following, we will refer to $N_j^{\frac{\beta}{1-\beta}}$ as a measure of factor productivity.

The equilibrium prices for intermediates can now be derived. Perfect competition on the markets for intermediates implies that prices have to be equal to unit costs. With our specification of the production functions in (4), and making use of the markup pricing in (10), the corresponding unit–cost functions are

$$c_j(w_j) = \left[\int_0^{N_j} \left(\frac{w_j}{1-\beta} \right)^{\frac{\beta-1}{\beta}} dn \right]^{\frac{\beta}{\beta-1}} , \quad j = K, L \,.$$

Equality of prices and unit costs then implies

$$p_K = \frac{w_K}{1-\beta} N_K^{\frac{\beta}{\beta-1}} \quad \text{and} \quad p_L = \frac{w_L}{1-\beta} N_L^{\frac{\beta}{\beta-1}} \,. \tag{15}$$

The closed economy

Before we turn to the two-country equilibrium, let us solve the equilibrium for a closed economy producing a range of final goods $z \in [\underline{z}, \overline{z}]$. From our Cobb–Douglas specification of consumer preferences in (2) we derive the market–clearing condition for final products as

$$Y(z) = \alpha \frac{w_L L + w_K K}{p(z)} \,, \tag{16}$$

where $Y(z)$ denotes production of good z. The demands for intermediates are then obtained as

$$Y_K = \int_{\underline{z}}^{\overline{z}} \frac{\partial c(p_K, p_L, z)}{\partial p_K} Y(z)\, dz \quad \text{and} \quad Y_L = \int_{\underline{z}}^{\overline{z}} \frac{\partial c(p_K, p_L, z)}{\partial p_L} Y(z)\, dz \,.$$

Substituting for $Y(z)$ by (16) and with prices equal to unit costs in the final goods sector, these demands can be written as

$$Y_K = \int_{\underline{z}}^{\overline{z}} \alpha \frac{\partial c(p_K, p_L, z)}{\partial p_K} \frac{w_L L + w_K K}{c(p_K, p_L, z)} \, dz$$

and

$$Y_L = \int_{\underline{z}}^{\overline{z}} \alpha \frac{\partial c(p_K, p_L, z)}{\partial p_L} \frac{w_L L + w_K K}{c(p_K, p_L, z)} \, dz \, .$$

Making use of our specification of the unit–cost function in (3) we finally get the relative demand for intermediates as

$$\frac{Y_K}{Y_L} = \frac{p_L}{p_K} \frac{\displaystyle\int_{\underline{z}}^{\overline{z}} z \, dz}{\displaystyle\int_{\underline{z}}^{\overline{z}} (1-z) \, dz} \, . \tag{17}$$

Equilibrium on the market for intermediate goods can then be derived by equating relative supplies (from (14)) with relative demands from (17); applying equilibrium prices of intermediates according to (15), we obtain the factor–market–clearing condition as

$$\frac{K}{L} = \frac{w_L}{w_K} \frac{\displaystyle\int_{\underline{z}}^{\overline{z}} z \, dz}{\displaystyle\int_{\underline{z}}^{\overline{z}} (1-z) \, dz} \equiv \frac{\phi(\underline{z}, \overline{z})}{\omega} \, , \tag{18}$$

with $\omega \equiv w_K / w_L$. The function ϕ has the derivatives $\partial \phi(\underline{z}, \overline{z}) / \partial \underline{z} > 0$, and $\partial \phi(\underline{z}, \overline{z}) / \partial \overline{z} > 0$.

There exists a unique value ω that clears factor markets. Since K/L is independent of ω, and $\lim_{\omega \to 0} \phi(\underline{z}, \overline{z})/\omega = \infty$ and $\lim_{\omega \to \infty} \phi(\underline{z}, \overline{z})/\omega = 0$, there exists a unique equilibrium value of ω. Figure 3 illustrates the equilibrium on factor markets. The equilibrium value of ω depends positively on both $\underline{z}$ and $\overline{z}$. The intuition for this result is as follows: Note that due to our specification of technology for final products in (3), and together with (14), final goods are ordered according to their factor intensities such that capital intensity rises with the index z. Then, any increase in either $\underline{z}$ or in $\overline{z}$ raises the average capital intensity used in production of final goods and, therefore, raises the relative demand for capital at each value of ω; with given factor supplies, this change in the relative demand for capital raises ω.

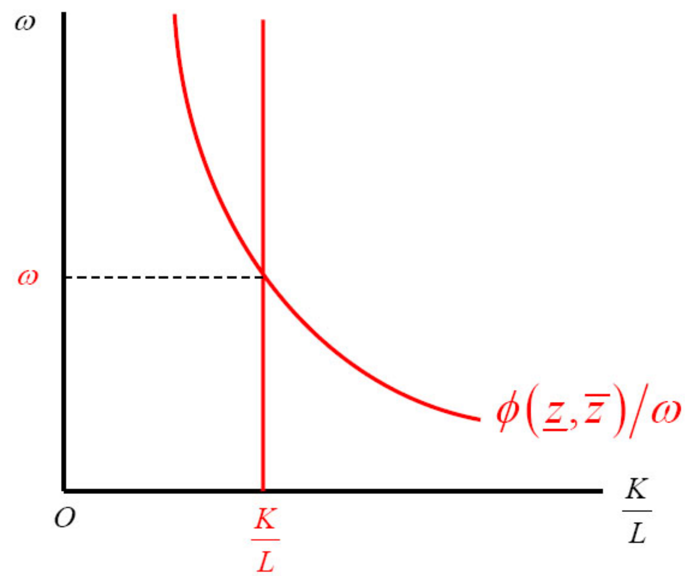

Figure 3: Static equilibrium in the closed economy

The closed–economy equilibrium is now completely determined. With ω determined by (18) and normalizing one factor price to unity, equilibrium prices for intermediate goods are determined by (15), equilibrium machine prices by (10) and final–goods' prices by (3).

Two country model with specialization in production

The equilibrium in the two–country model is to be completed by determining the range of goods that is produced by each country. For that, we assume that the complete range of final goods produced in either country is given by the interval $[0, 1]$. Suppose that the home country produces final products z such that $z \in [0, z']$, while the foreign country produces final products z such that $z \in [z', 1]$. This pattern of specialization implicitly assumes that the home country has CA over the range of goods $z \in [0, z']$, whereas the foreign country has CA over the range of $z \in [z', 1]$ goods. In what follows, we show that this pattern of CAs arises from sufficiently great differences in relative factor supplies. Throughout the analysis, we assume that both countries have access to identical technologies for producing final goods (i.e.: both countries have the same cost function for producing z). However, both factor prices and prices of intermediates will differ due to complete specialization.

Our specialization pattern can be rationalized by sufficiently great differences in relative effective factor endowments with the home country being the labor abundant country. As we will show, equilibrium factor prices then are related by $\omega > \omega^*$, denoting the foreign country's variables with asterisk.

Proof

Our proof is in two steps. *Step I* shows that the above mentioned pattern of specialization arises *iff* $p_K/p_L > p_K^*/p_L^*$. *Step II* shows that for this pattern of specialization to occur in equilibrium, a sufficiently great difference in the relative endowments of effective factors is required.

Step I

In case of specialization, we first have to identify the threshold z' that determines the range of products produced in each country. With perfect competition on the markets for final goods, consumers buy final goods at the cheapest price. In general:

$$p(z) = \min\left\{c(p_K, p_L, z), c(p_K^*, p_L^*, z)\right\}. \tag{19}$$

Hence, there exists at most one $z = z'$, where both countries have identical unit costs in production:

$${p_K}^{z'} {p_L}^{1-z'} = {p_K^*}^{z'} {p_L^*}^{1-z'} \tag{20}$$

In order to prove that assertion, define the function $\psi(z)$ as the ratio of unit costs:

$$\psi(z) \equiv \frac{{p_K}^{z} {p_L}^{1-z}}{{p_K^*}^{z} {p_L^*}^{1-z}}. \tag{21}$$

Straightforward calculation gives:

$$\frac{\psi'(z)}{\psi(z)} = \ln\frac{p_K}{p_L} - \ln\frac{p_K^*}{p_L^*}. \tag{22}$$

Suppose that $p_K/p_L > p_K^*/p_L^*$. Then, ψ is an increasing function implying that $\psi(z') = 1$. Of course, $z' \in [0, 1]$, since otherwise there would be no production at all in one of the countries.

Step II

From (15) we get:

$$\frac{p_K}{p_L} = \omega \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{\beta-1}} .$$

Hence, for $p_K/p_L > p_K^*/p_L^*$ to hold (which we assumed in *Step I*), we require

$$\omega \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{\beta-1}} > \omega^* \left(\frac{N_K^*}{N_L^*}\right)^{\frac{\beta}{\beta-1}} .$$

Substituting for relative factor prices according to (18), we obtain

$$\frac{K^*}{L^*} \left(\frac{N_K^*}{N_L^*}\right)^{\frac{\beta}{1-\beta}} > \frac{\phi(z',1)}{\phi(0,z')} \frac{K}{L} \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{1-\beta}} . \tag{23}$$

Since $\phi(z',1) > \phi(0,z')$, (23) is only fulfilled for sufficiently great differences in relative endowments of effective factors:

$$\frac{K^*}{L^*} \left(\frac{N_K^*}{N_L^*}\right)^{\frac{\beta}{1-\beta}} >> \frac{K}{L} \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{1-\beta}} . \tag{24}$$

Note that (23) implies $\omega > \omega^*$. Figure 4 illustrates the static equilibrium for sufficiently great differences in factor endowments.

Eventually, our endogenous determination of the range of available machines will show (see Section 4) that $N_K/N_L < N_K^*/N_L^*$ holds as long as $K/L < K^*/L^*$. This implies that our condition for the above discussed specialization pattern always holds in the long–run equilibrium of the model. The condition also holds in the instantaneous equilibrium as long as relative physical factor endowments do not change too drastically. □

The final condition to completely describe the static equilibrium of the model is the trade–balance condition that requires the value of imports to equal the value of exports. With the home country specializing on $z \in [0, z']$, the trade–balance condition reads:

$$\int_0^{z'} (w_L^* L^* + w_K^* K^*) dz = \int_{z'}^1 (w_L L + w_K K) dz. \tag{25}$$

Since we do not include any constraints on the distribution of foreign trade income between the factors (see (2)), the variables in parentheses in (25) are independent from z'. Hence, the trade–balance condition can be presented as

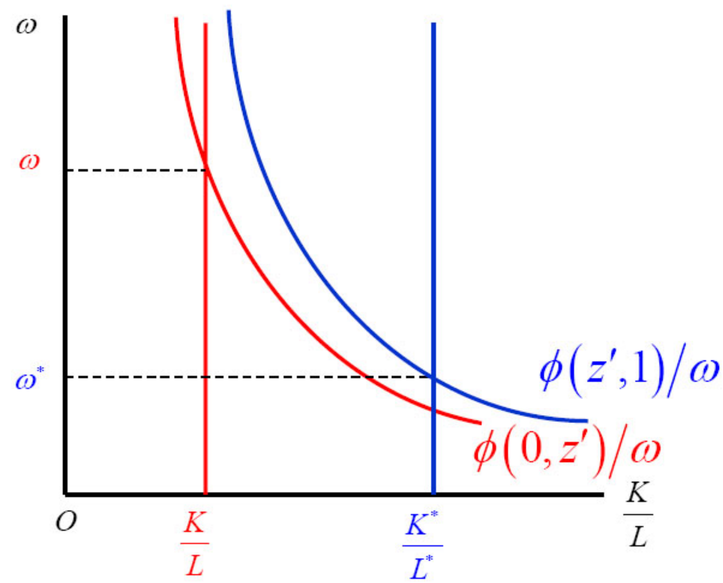

Figure 4: Static equilibrium in the two–country model

follows:

$$\int_0^{z'} dz \Big/ \int_{z'}^1 dz = \frac{w_L L + w_K K}{w_L^* L^* + w_K^* K^*},$$

which is equivalent to:

$$\frac{z'}{1-z'} = \frac{L+\omega K}{L^* + \omega^* K^*}\frac{w_L}{w_L^*}. \tag{26}$$

We can now explicitly solve for the equilibrium value of z'. Using (15) we can rewrite (20) as

$$\frac{w_L}{w_L^*} = \left[\frac{\omega^*}{\omega}\left(\frac{N_K^*}{N_K}\frac{N_L}{N_L^*}\right)^{\frac{\beta}{\beta-1}}\right]^{z'}\left(\frac{N_L^*}{N_L}\right)^{\frac{\beta}{\beta-1}}. \tag{27}$$

From (26), (27) and the factor–market–clearing conditions for both countries (eqs. (18) evaluated for the respective factor endowments and produced ranges of goods for the home country and for the foreign country) we obtain (see Appendix for derivation) the condition for the equilibrium specialization threshold as

$$z' = \xi\left(\frac{K}{K^*}\right)\,, \tag{28}$$

with $\xi'(K/K^*) > 0$.

Lemma 1. *For sufficiently great differences in relative effective factor endowments between countries there exists a negative interrelation between the relative capital endowments in the two countries and the equilibrium specialization threshold z' (from (28)).*

4 Dynamic Equilibrium

We can now solve the steady state of the dynamic equilibrium of the model.

Profit–maximizing technology monopolists producing j-type machines generate more innovations in the sector j ($j = K, L$), where they expect higher profits (higher prices for their machines). Using our results from the static equilibrium given by (14), profits of technology monopolists at each instant can be written as

$$\pi_K = \beta\frac{w_K}{1-\beta}\frac{K}{N_K} \quad \text{and} \quad \pi_L = \beta\frac{w_L}{1-\beta}\frac{L}{N_L}\,.$$

With short–run equilibrium values of the relative factor price determined by (18), relative profits can eventually be written as

$$\frac{\pi_K}{\pi_L} = \left(\frac{N_K}{N_L}\right)^{-1}\phi(\underline{z}, \overline{z})\,. \tag{29}$$

With respect to the production of machines we apply the lab–equipment specification of Rivera-Batiz and Romer (1991). With R_j denoting the spending of R&D for type j machines[6] and η_j being constant scale factors allowing for the costs of innovations in the two sectors to differ, we have

$$\dot{N}_K = \eta_K R_K \quad \text{and} \quad \dot{N}_L = \eta_L R_L\,. \tag{30}$$

In steady state, N_K and N_L grow at the same rate. This implies the technology–

[6]Following Rivera-Batiz and Romer (1991), only the final good is used in generating new innovations.

market–clearing condition

$$\eta_K \pi_K = \eta_L \pi_L \,. \tag{31}$$

From (31) we get relative profits as

$$\frac{\pi_K}{\pi_L} = \frac{\eta_L}{\eta_K} \,.$$

With (29) we solve for the steady–state ratio of N_K and N_L as

$$\frac{N_K}{N_L} = \eta \phi(\underline{z}, \overline{z}) \,, \tag{32}$$

where $\eta \equiv \eta_K / \eta_L$. Hence, the higher the average capital intensity of the range of final goods produced in the economy, the higher the incentives to innovate in type K machines and the higher the long–run ratio N_K/N_L. Specifically, in the equilibrium of the two–country model with the home country specializing on final products $z \in [0, z']$, while the foreign country specializes on final products $z \in [z', 1]$, the long–run ratio N_K/N_L is given by

$$\frac{N_K}{N_L} = \eta \phi(0, z') < \frac{N_K^*}{N_L^*} = \eta \phi(z', 1) \,. \tag{33}$$

The result in (33) is just what we supposed for our analysis of the static equilibrium. Notice that the equilibrium stated above is stable. If equation (31) is not satisfied, machine producers concentrate only on the sector that is more profitable to produce in. Since π_K/π_L is decreasing in N_K/N_L (see (29)) the system always returns to the steady state: if N_K/N_L is higher than in (32) monopolists produce only labor–substituting machines until the system equalities are satisfied, and vice versa.

5 Capital Flows and Dynamic CAs

We can now apply our model to the analysis of dynamics of comparative advantages associated with an inflow of capital. In Section 3 we supposed that in the home country capital is the relative scarce factor. Let us also assume here that the foreign country is abundant in capital (like industrialized countries), while the home country is labor abundant (like developing countries or economies in transition). As an example we can take the EU and the CEE countries, respectively.

For sufficiently great differences in relative factor endowments, our model generates the following equilibrium effects: (i) $\omega > \omega^*$, (ii) $N_K/N_L < N_K^*/N_L^*$, and (iii) the home country has CA for final products $z \in [0, z']$, the foreign country for $z \in [z', 1]$.

Suppose now that capital flows into the home country (caused by the differences in relative factor prices).[7] However, we do not assume fully integrated capital markets with full equalization of factor prices. If that were the case, capital–market integration would result in full diversification of the final–goods sector with the well–known indeterminacy of production precluding any analysis of CAs (cf. Dornbusch *et al.* (1980)).

As capital flows into the home country, we observe a decline in ω and an increase in ω^* for given z' (with given N_j's) in the short–run, i.e.: for given pattern of specialization. See left plot in Figure 5 for an illustration (shifts from ω_0 to ω_1 and ω_0^* to ω_1^*, respectively). In the medium–run, for given technologies, the pattern of specialization adjusts. According to Lemma 1, the capital flow from the capital–abundant country to the labor–abundant one generates a change in the pattern of specialization with the latter country specializing on a larger spectrum of final goods and the former country producing a narrower range of goods. This means that z' rises (let us denote the shift on the right plot in Figure 5 from z'_0 to z'_1 with $z'_1 > z'_0$) triggering relative factor prices in both countries to shift upwards (from ω_1 to ω_2 and ω_1^* to ω_2^*). This is due to the property of the function $\phi(\underline{z}, \overline{z})$ described. Thus, in the foreign country, which exports capital, ω^* rises both due to the capital outflow and reduction in the range of final goods produced in the economy (increase in the average capital intensity). In contrast, in the home country ω firstly falls due to the capital inflow, but then rises due to the increase of capital intensity used in production. However, as a whole ω decreases since the capital inflow is the major triggering factor of this dynamics, and the incentive for further capital transfer (difference in the capital income between countries) has to decrease. In the long–run, the shift in z' creates incentives for further innovations ($\dot{N}_j$).

[7] Given the complexity of the model, including differences in factor endowments and technologies between countries, and endogenous technical change, we simplify our analysis to a one–time capital inflow.

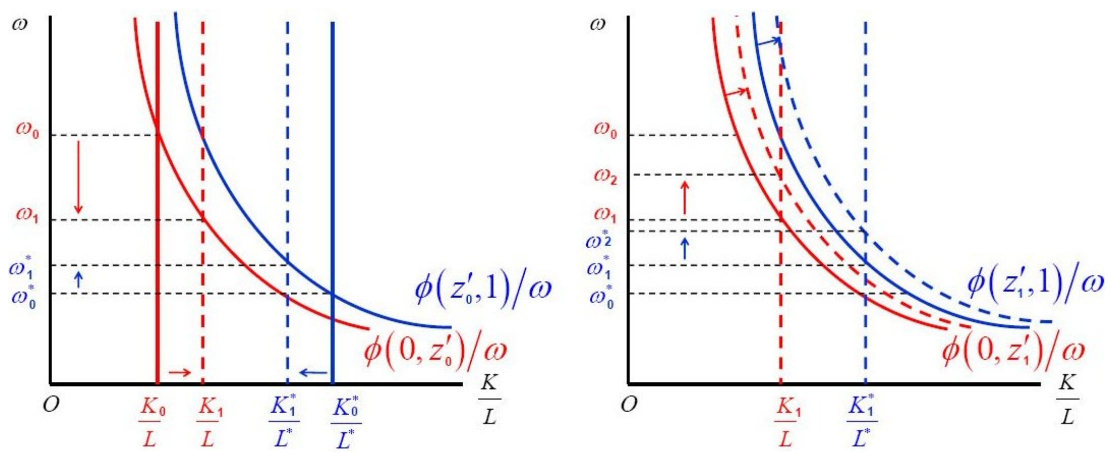

Figure 5: Comparative statics in the two–country model

Lab–equipment model

Due to the increase in the cutoff value z', technology monopolists in both countries get an incentive to innovate in the sector of capital (see (32)). Hence, both N_K/N_L and N_K^*/N_L^* rise and trigger the relative factor prices p_K/p_L in both countries down (this effect is denoted as the 'market size effect'):

$$\frac{p_K}{p_L} = \omega \left(\eta\phi(\underline{z}, \overline{z})\right)^{\frac{\beta}{(\beta-1)}} . \tag{34}$$

Thus, while the 'price effect' of ω boosts CAs in capital intensive goods only in the home economy (reducing CAs abroad), the 'market size effect' acts in both countries identically:

$$\downarrow\downarrow \frac{p_K}{p_L} = \omega \left(\eta\phi(0, z')\right)^{\frac{\beta}{(\beta-1)}} , \quad \uparrow\downarrow \frac{p_K^*}{p_L^*} = \omega^* \left(\eta\phi(z', 1)\right)^{\frac{\beta}{(\beta-1)}}$$

As a result, while the technical change is induced towards capital intensive goods in both countries, CAs in these goods are shifted in favor of the home economy.

State–dependent R&D

In order to differentiate the impact of z' on technological progress in the two countries we need to consider state–dependent (also called knowledge–driven) R&D (see Acemoglu (2002) and Romer (1990) for discussion) instead of the lab–

equipment specification[8].

Let us assume that economic growth due to R&D cannot be maintained simply by increasing R&D expenditure (R). Thus, we take the production functions of new machines as follows:

$$\dot{N}_i = \eta_i N_i^{(1+\delta)/2} N_j^{(1-\delta)/2} S_i, \quad i, j \in (L, K), \quad i \neq j, \tag{35}$$

where $S \geq S_L + S_K$ is a limited R&D staff (scientists) that cannot be extended and $\delta \in [0, 1]$ measures the degree of state dependence. It can be shown that when $\delta = 0$, further results are similar to the ones stated above. However, if $\delta > 0$, results can vary significantly. Thus, for $\delta = 1$ improvements in labor intensive machines make future innovations in this industry cheaper without any effect on the other sector.

One can interpret δ as an extent of inter–sectoral knowledge spillovers (KSs). However, there is a clear tradeoff between inter– and intra–sectoral KSs in (35). If $\delta = 0$, both sectors equally benefit from current research in one of them, but this research affects future production in the respective sector to a smaller extent. In contrast, if $\delta = 1$, one sector exhibits higher gains from inventions in this sector without any impact on the other one.

In this paper we argue that both $\delta = 0$ and $\delta = 1$ are extreme cases. In the context of the economic globalization it is both unlikely that two sectors do not jointly benefit from technical progress in one of them ($\delta \neq 1$)[9] or make an equal use of technological improvements made in any of the sectors ($\delta \neq 0$).

In the following we assume that $\delta^* \to 0$ for the industrialized country (weak intra-sectoral KSs) and $\delta \to 1$ for the developing economy (strong intra-sectoral KSs). The reason for this is that considering the industrialized country as the one possessing a larger knowledge stock in a given technology a new idea might not generate the same spillovers as when this stock is relatively small (Jones 1995). This assumption is considered to be the major one because of the evidence that

[8]Both approaches present the supply side of innovations, which is referred in the literature to the 'innovation possibilities frontier' or the 'state dependence', putting the dynamics of future R&D in dependance on the present situation (for more details see also Kennedy (1964)).

[9]In the last decades a number of studies have confirmed KSs stimulating technological progress within a given location (Romer 1990, Boshuizen *et al.* 2009). Among mechanisms reinforcing economic growth are, e.g., knowledge diffusion across innovative companies and labor market matching. For an overview of the mechanisms see Serrano and Cabrer (2004).

knowledge flows more easily within sectors than between them (Keller 2002).[10]

Furthermore, equations (31-32) with $\delta > 0$ have the following form:[11]

$$\eta_L N_L^{\delta} \pi_L = \eta_K N_K^{\delta} \pi_K, \tag{36}$$

$$\frac{N_K}{N_L} = \left(\eta \phi(\underline{z}, \overline{z})\right)^{\frac{1}{1-\delta}} . \tag{37}$$

Hence, the relative prices can now be expressed as follows:

$$\frac{p_K}{p_L} = \omega \left(\eta \phi(\underline{z}, \overline{z})\right)^{\frac{\beta}{(\beta-1)(1-\delta)}} . \tag{38}$$

Based on equation (38) we can differentiate between the incentives for technology monopolists to innovate in the sector of type K machines as long as $\delta \in (0, 1)$. In fact, if $\delta = 0$ equations (36-37) can be reduced back to (31-32). In contrast, if $\delta = 1$ the stability condition is not satisfied (Section 4). Hence, no stable equilibrium can be achieved.

In comparison to the results from (32), an important distinction here is the rate of FBTC. Because of $(1 - \delta)$ in (37-38), the technological progress in capital intensive goods and CAs in this sector are both amplified depending on the KS' extent. Therefore, benefits both from technology improvements and price reductions are potentially higher for the home country than for the foreign one (that translates in a further increase in z' in the long–run).[12] This finding explains the convergence effect in productivity ($N_K/N_L \to N_K^*/N_L^*$) one observes in the CEE countries over the last decades accompanied by the remarkable growth in CAs in capital intensive goods (Zaghini 2005).

Remember, in (35) we specified S as a limited resource. Hence, for a sustained

[10]Alternatively, we could imply that inter–sectoral spillovers are stronger for the advanced country (where tighter technological linkages between industries are expected, e.g., electronics and automotive industry). Hence, the latter interpretation for $\delta > \delta^*$ is also seen to be plausible.

[11]The transformations presented in (36-37) can be obtained similar to (31-32) with the distinction that $\pi_K/\pi_L = \eta_L N_L^{\delta}/\eta_K N_K^{\delta}$.

[12]If, in contrast, one would assume $\delta < \delta^*$ (i.e.: the home country being unable to generate more KSs and produce innovative goods), a divergence effect in productivity will be obtained. Thus, KSs are considered as a key factor of success for technological catch–up in developing countries. Similarly, contrasting Far Eastern and Latin American countries, Castaldi and Dosi (2008) stress the role of patterns of information distribution and interaction (resulting in different learning capabilities of individuals and organizations) for economic growth.

growth we need other factors (N_L and N_K) to become more productive over time or, in other words, accumulate these factors. This is by all means a more time-consuming process than the one presented in (30). Therefore, impacts of the price and the market size effects must be differentiated in time. While the price effect comes into force quickly, the market size effect follows with a time lag that is dependent, e.g, on the distance to frontier for each particular country, on the inefficiencies presented on the market of technology monopolists in those countries.

6 Discussion

6.1 Parallel with PCAs

The main assumption of the model stated that allows us to reveal factors directing a technical bias between sectors is the assumption on technology monopolists comparing expected profits from their investments in different technologies. A similar intuition has the concept of prospective comparative advantages (PCAs) (see Savin and Winker (2009)) that forecast CA dynamics in transition economies.

The PCAs are based on differences in relative prices of products in different countries. For the PCA to be efficient one needs to know the direction that relative prices follow in the future. Assuming price convergence in the long–run, PCAs identify potential CAs in industries, where final goods are undervalued in comparison to the international price level. Hence, in the future these industries are potentially profitable for investors. In a similar way, the FBTC concept 'directs' technical progress towards industries expecting factor inflow and, consequently, an increase in the intensity of its employment (Section 4).

The PCA index provided good results in forecasting CAs on the example of CEE countries. Most of the 'successful' industries, where these countries managed to gain CAs, were undervalued in comparison to the EU.

In fact, there is a large body of empirical evidence that the CA dynamics is driven by the competitive advantages measured by means of, e.g, unit labor costs, R&D intensity or real exchange rates (see, e.g., Wziatek-Kubiak and Winek (2005)). An important distinction of the PCA method is that it encompasses more information on the competitiveness of goods and distinguishes between industries of a particular economy, 'substituting' the mentioned indicators.

In contrast, our model does not 'substitute' the PCA index, but 'complements' it. Practically, the model sheds light on the micro–foundations explaining the rapid growth of CAs in technologically advanced industries of the CEE countries. Thus, for transition economies the concept explains the behavior of technology monopolists that produce innovations in capital intensive technologies, strengthening CA formation in respective industries.

However, technical change biases alone should not be considered as sufficient to benefit from CAs. Otherwise, we would observe CAs in the EU accession countries on a much larger variety of goods. There must be a different factor 'allowing' transition economies to form CAs towards their trade partners. The simple reason for this is the fact that we need to account not only for the technical progress in the home country (with capital inflow), but also for the state of technology in the foreign economy (exporting capital) as well as for other factors, responsible for CAs between countries, including, e.g., scale of production, consumption preferences.

Therefore, for transition economies a primary condition for CAs to arise is a presence of unrealized CAs assuring that they potentially have an advantage towards other economies in a particular sector. And a good instrument available to forecast the unexploited advantages is the PCA index.

6.2 Implications for Industrial Policy

Combining our model and the PCA index in one concept we refer to a well–known discussion in the theory of industrial organization: should countries stimulate innovations in high technological industries or in sectors with strongest CAs (see, e.g., Rodriguez-Clare (2005)).

Considering high technological industries as the ones with highest 'Marshallian externalities' (MEs), which present benefits from KSs between companies in the same (or related) industries, Rodriguez-Clare (2005) identifies two constraints for policies promoting industries, where MEs are expected to be stronger.

First, in contrast to CAs, MEs are not an intrinsic feature of particular industries. A large variety of factors (including technologies used and country–specific characteristics) influences MEs' success. In fact, both MEs and FBTCs depend on firms' innovative activity and are stochastic in their nature. Hence, no 'guaranteed' benefits from these processes exist.

Second, even if an industry exhibits strong MEs, benefits generated from these externalities can be also attributed to another country specializing in this industry. If the foreign economy exhibits a CA in this sector, it can neutralize benefits for the home country (for a formal prove see Rodriguez-Clare (2005)).

As a result, a general approach for countries stimulating their economic growth is to promote industries with natural CAs and not those with stronger MEs. For the least developed countries this simply means that they should stimulate predominantly agriculture and mining industries. Fortunately, transition economies, as e.g., CEE countries or certain members of the Commonwealth of Independent States (e.g., Russia, Belarus), have a better choice.

As discussed by Savin and Winker (2009), transition economies may exhibit CAs not realized yet due to various distortions in their trade relations. Directing technical progress towards capital intensive industries, these countries can enhance their natural CAs in corresponding industries with an additional 'technical advantage' generated by the FBTC Since the technical advantage is stochastic, it should be considered as a 'complementary' factor. Hence, the main decisions on development priorities are more accurate based on the PCA analysis.

Based on the analysis of capital–market integration presented in Section 5, transition economies can stimulate technical progress in capital intensive industries by enhancing factor mobility and attracting foreign investments. The CEE countries have successfully solved this task and have improved their industrial structure of foreign trade. For other economies in transition (as, e.g., Russia) this remains a major challenge in their aim to modernize the economy.

The PCA analysis made on the example of Russia in the period 2002–2007 revealed the following industries as the ones with PCAs: electronic equipment, machinery building, railway equipment and pharmaceutical industry (Savin and Winker 2009). However, realization of these advantages is not as straightforward as it might seem at first sight.

Based on the analysis presented above, there are two main conditions for this. First, it is necessary to minimize trade distortions[13] of Russia with its main trading partners. This can be made, e.g., by joining the WTO or by forming a free trade agreement with the EU (both scenarios are well discussed in literature, see, e.g., Brenton *et al.* (1997) and Jensen *et al.* (2007)). Second, to stimulate

[13]Under trade distortions numerous tariff and non–tariff restrictions as well as exchange rate misalignments are meant.

CAs in technologically advanced industries, inflow of scarcer factor (K) is required. Thus, according to our model, CAs can be stimulated with no artificial price distortions or other potentially inefficient public interventions. Instead, for transition economies to attract FDI, in parallel with (already available) natural resources and relatively cheap labor force, policy liberalization (including, among others, transparent regulatory framework, ease of market entry and exit) and political stability are of great importance (Mizanur Rahman 2010).

There is also one more instrument stimulating economic growth in the model we want to address in this study. Due to the form of production functions specified in (4) and the assumption of state dependent R&D (35), the rate of economic growth of any particular economy is crucially dependent on accumulation of technologies (N_i) that increase factor efficiency. Since we assume that machine–producers are monopolists, it is important to consider the problem of potential market inefficiency resulting in a low rate of investments in R&D.

Since 'technology monopolists' produce new varieties of machines over time ($\dot{N}_{i,t}$), they obviously need to accumulate funds for their R&D activity. Hence, enforcing perfect competition is no good solution to stimulate the monopolists. There is a long discussion in the theory of industrial organization on whether competitive pressure induces or reduces innovative output of companies. During the last decade, the idea of an inverse 'U–curve' dependence of innovative activities on the competition intensity has become the prevailing concept (see Aghion *et al.* (2005) and Bucci and Parello (2009)). It was empirically confirmed that in contrast to monopoly, competition raises incentives to innovate, but an excessive competitive pressure damages innovative performance. Therefore, a balanced public regulation policy is required to stimulate 'technology monopolists'.

Furthermore, public authorities can implement a variety of other measures to support 'technology producers'. One of the main instruments is to stimulate the above mentioned knowledge spillovers (denoted with the δ parameter in our model). Doing this, authorities potentially enhance the benefits on technological progress and CAs. Among measures stimulating KSs, one could think about investments in human capital that increases the absorptive capacity of companies (Borensztein *et al.* 1998, Bilbao-Osorio and Rodriguez-Pose 2004, Bijsterbosch and Kolasa 2010) and knowledge diffusion centers (e.g., CORDIS and Innovative Relay Centres) that transfer knowledge between research and industry, and promote cooperation between companies.

Further public measures can include improvements in infrastructure (in particular, transport and telecommunication) widely recognized as significant factors stimulating cooperation and innovative activity of companies (see, e.g., Cainelli *et al.* (2006)). For both an overview of the methods that can be implemented and an empirical estimate of their influence based on the Russian regional data see Savin and Winker (forthcoming).

7 Conclusion

In this paper we integrate technology–based with factor endowment–based views on trade in modelling effects resulting from capital–market integration. We demonstrate that the model suggested effectively explains the capital–biased technical change observed in a number of developing and transition economies over the last decades. Furthermore, accounting for the state–dependant R&D processes, we can differentiate in time the effects of capital inflow on specialization patterns explaining the time lags in CA responses observed empirically.

We demonstrate that the model has a similar idea as the PCA instrument: relative profitabilities of goods determine future direction of technical progress and, consequently, CA dynamics. Moreover, this study extends the PCA index providing an additional information on CA formation. Together, this model and the PCA index constitute a good instrument explaining the success of the CEE countries in diversifying their foreign trade structure.

In addition, a series of measures for countries being in the period of transition (e.g., Russia) to realize their potential CAs is discussed. In particular, effective measures on trade liberalization together with attraction of scarce factors (capital) are meant. Since the market of technology innovations is potentially inefficient (monopolistic), this study supports public measures to stimulate innovative activity of companies. This can be achieved by stimulation of knowledge spillovers and a variety of other instruments (see, among others, Savin and Winker (forthcoming) for a discussion).

To keep the exposition simple, this paper has a number of simplifying assumptions. An obvious generalization is to introduce CES–type production functions and allow for factors and machines to compliment each other in production. So far, a specific case of technological process was considered. Another interesting direction for future research would be to account for international KSs transferred by, e.g., multinational enterprizes endogenizing the rate of the spillovers (δ). Finally, the most important area for future research is an empirical assessment of the effects resulting from the capital–market integration in developing countries. In particular, having industry–based data, one could measure the effect of capital inflow on R&D intensity and, consequently, on CA formation quantitatively.[14]

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Appendix

Derivation of the condition for z' (Lemma 1)

This appendix shows how the specialization threshold z' is related to factor endowments. From (26) follows that

$$\frac{z'}{1-z'} = \frac{w_L}{w_L^*}\frac{L}{L^*}\frac{1+\omega\frac{K}{L}}{1+\omega^*\frac{K^*}{L^*}}. \tag{39}$$

Substituting for w_L/w_L^* by (27), we obtain

$$\frac{z'}{1-z'} = \left[\frac{\omega^*}{\omega}\left(\frac{N_K^*}{N_K}\frac{N_L}{N_L^*}\right)^{\frac{\beta}{\beta-1}}\right]^{z'}\left(\frac{N_L^*}{N_L}\right)^{\frac{\beta}{\beta-1}}\frac{L}{L^*}\frac{1+\omega\frac{K}{L}}{1+\omega^*\frac{K^*}{L^*}}. \tag{40}$$

[14] Hitherto, to the best of our knowledge, only the effect of FDI on productivity level (measured either as labor or total factor productivity) was considered in literature (see among others, Holland and Pain (1998), Barrell and Holland (2000), Smarzynska Javorcik (2004), Bijsterbosch and Kolasa (2010)).

Evaluating (18) for the two countries we get

$$\omega \frac{K}{L} = \frac{\int_0^{z'} z \, dz}{\int_0^{z'} 1 - z \, dz} = \frac{z'}{2 - z'} \quad \text{and} \quad \omega^* \frac{K^*}{L^*} = \frac{\int_{z'}^1 z \, dz}{\int_{z'}^1 1 - z \, dz} = \frac{1 - z'^2}{(1 - z')^2} \,. \tag{41}$$

From (40) and (41) we derive the inverse of the condition for z':

$$\frac{K^*}{K} = \frac{(1 + z')}{(1 - z')} \left(\frac{1}{z'}\right)^{\frac{1+z'}{z'}} \left(\frac{1}{2 - z'}\right)^{\frac{1-z'}{z'}} (1 - z')^{\frac{2}{z'}} \left(\frac{N_K^*}{N_K}\right)^{\frac{\beta}{\beta-1}} \left[\left(\frac{N_L^*}{N_L}\right)^{\frac{\beta}{\beta-1}} \frac{L}{L^*}\right]^{\frac{1-z'}{z'}} . \tag{42}$$

Remembering that our specialization pattern can be rationalized *iff*

$$\frac{K}{L}\left(\frac{N_K}{N_L}\right)^{\frac{\beta}{1-\beta}} << \frac{K^*}{L^*}\left(\frac{N_K^*}{N_L^*}\right)^{\frac{\beta}{1-\beta}} \Leftrightarrow \frac{K^*}{K}\left(\frac{N_K^*}{N_K}\right)^{\frac{\beta}{1-\beta}} >> \frac{L^*}{L}\left(\frac{N_L^*}{N_L}\right)^{\frac{\beta}{1-\beta}} , \tag{43}$$

we can show that z' is monotonously increasing in K/K^*.

For that purpose, let us rewrite (42) as follows:

$$\kappa = \underbrace{\frac{(1 + z')}{(1 - z')} \left(\frac{1}{z'}\right)^{\frac{1+z'}{z'}} \left(\frac{1}{2 - z'}\right)^{\frac{1-z'}{z'}} (1 - z')^{\frac{2}{z'}}}_{g(z')} \underbrace{\varphi^{\frac{1-z'}{z'}}}_{h(z')} \tag{44}$$

denoting $K^*/K(N_K^*/N_K)^{\frac{\beta}{1-\beta}}$ with κ and $(N_L/N_L^*)^{\frac{\beta}{1-\beta}} L/L^*$ with φ. Thus, we need to show that κ is monotonously decreasing in z' $\forall \varphi$ as long as (43) holds.

While $g(z')$ in (44) is a monotonously decreasing function in z', the behavior of the complete function is dependent on the value of φ in $h(z')$. In particular, the r.h.s. of (44) remains monotonously decreasing as long as φ is greater than a critical value of about 0.21 while it shows a spike in its performance otherwise.[15] The properties of (44) are illustrated in Figure 6 for different φ values.[16] Important, however, is that $\forall \varphi < 0.21$ the ambiguity in z' we obtain (as on the right plot of Figure 6) is always for values below 1 in κ, i.e. in the interval, where our

[15] This result is obtained via a simulation study and is also confirmed analytically.

[16] On the left plot of Figure 6 $\kappa \in (\infty, 0]$.

model is not applicable (without sufficiently great differences in relative effective factor endowments) since from (43) $\kappa >> 1/\varphi$ must hold.[17] Hence, in accord with our assumptions z' is monotonously increasing in K/K^*:

$$\xi'(K/K^*) > 0 \tag{45}$$

for the relevant set of parameter values. □

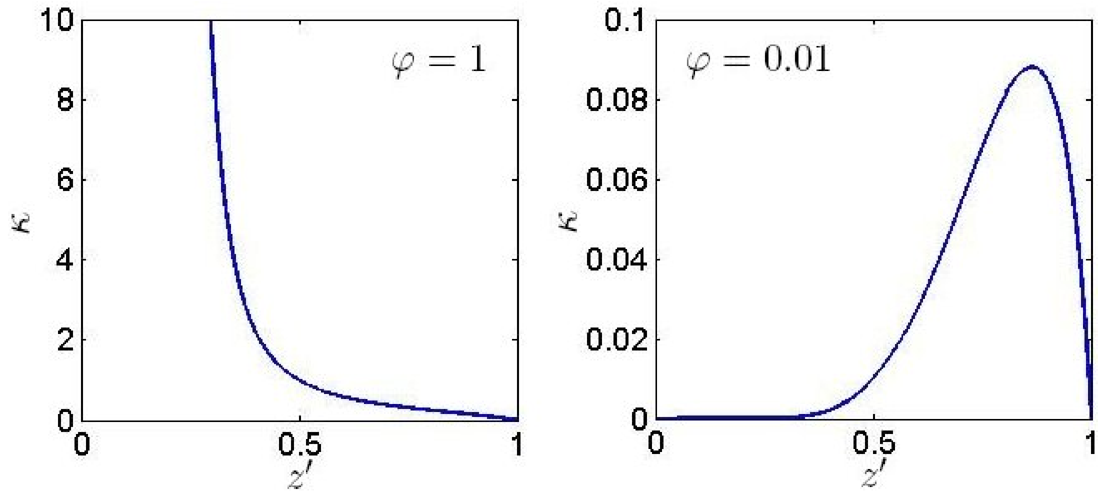

Figure 6: Interrelationship between z' and κ for different φ

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[17] More results on the simulation study for (44) can be obtained on request.

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