Factor–Biased Technical Change and Specialization Patterns

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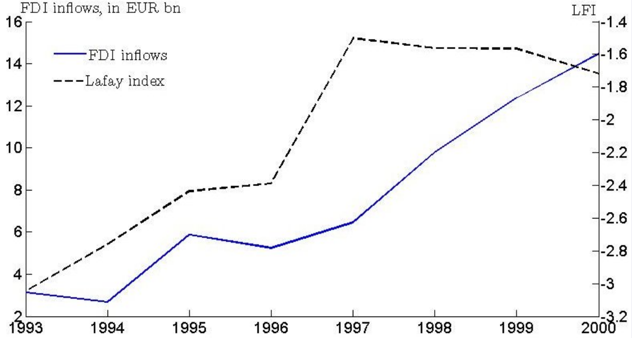
Motivation

- Consider factor-biased technical change (FBTC) framework
  - Acemoglu (2002), 'Directed Technical Change'
  - Price and market size effects fostering technologies $\Rightarrow$ Developing countries to specialize in labor-intensive goods?
- Not always true (CEE countries, Asian tigers, China,...)
  - What needs to be changed in the model?

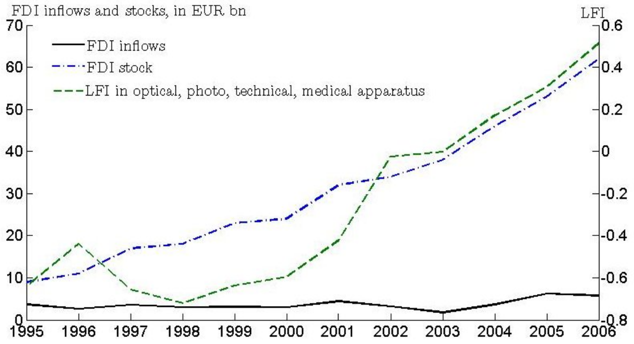
An illustration of the FBTC in the CEE countries (1)

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



An illustration of the FBTC in the CEE countries (2)

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



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Our Suggestion

- - integrate FBTC into a HO–model
- - consider a continuum of final goods
  $\Rightarrow$ CAs related to factor endowments (HO) and induced by their changes (FBTC)
- - following Trefler (1993,1995) consider differences in factor supplies in conjunction with technology differences between countries (factor–abundance in 'effective units')

Further Results

- - similar intuition with the PCA instrument
  (Savin and Winker, 2009)
- - implications for industrial policy:
  factor inflow and market inefficiencies

Production Sector

- A continuum of final goods $Y(z)$ freely traded internationally

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

with p_j - prices of intermediates and A - technology parameter

- Two non-tradable intermediates with CES-type production functions:

$$Y_j = \left[\int_0^{N_j} x_j(n)^{1-\beta} dn\right]^{\frac{1}{1-\beta}}, \qquad j = K, L \quad (2)$$

- Markets of final and intermediate goods - fully competitive
- Markets of machine producers (with N_K and N_L) - monopolistic with

$$x_K(n) = K(n) \text{ and } x_L(n) = L(n)$$

with machines $x_j(n)$ fully used up in production and non-tradable

Static Equilibrium: (N_K, N_L) fixed

- Intermediate producers maximizing profits:

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

  with $q_j(n)$ - prices of machines

- Technology monopolists maximizing profits:

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

  charge a fixed markup $q_j(n) = \frac{w_j}{1-\beta} \equiv q_j$ for all machines

- $\Rightarrow Y_j = N_j^{\frac{\beta}{1-\beta}} j$ and $p_j = \frac{w_j}{1-\beta} N_j^{\frac{\beta}{\beta-1}}$
  (supplies and prices of intermediates)

Equilibrium for a Closed Economy

- Consider $z \in [\underline{z}, \overline{z}]$ so that capital intensity rises with z
- The market clearing condition for z:

$$Y(z) = \alpha \frac{w_L L + w_K K}{p(z)} \tag{3}$$

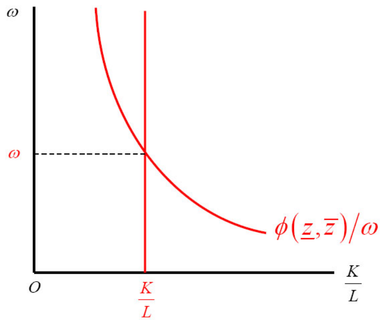
- Together with $Y_j = \int_{\underline{z}}^{\overline{z}} \frac{\partial c(p_K, p_L, z)}{\partial p_j} Y(z)\, dz$ (3) yields factor-market clearing condition:

$$\frac{K}{L} = \frac{w_L}{w_K} \frac{\int_{\underline{z}}^{\overline{z}} z\, dz}{\int_{\underline{z}}^{\overline{z}} (1 - z)\, dz} \equiv \frac{\phi(\underline{z}, \overline{z})}{\omega} \tag{4}$$

  with $\omega \equiv w_K / w_L$
- There exists unique ω that clears factor markets

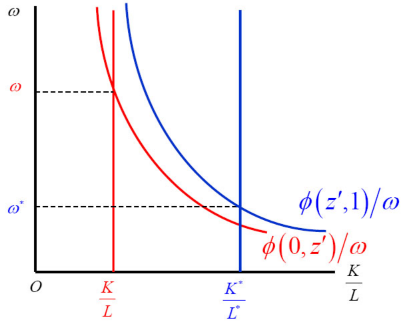
Static Equilibrium on Factor Markets in the Closed Economy

- Since $K/L \nleftarrow \omega$, $\lim_{\omega\to 0}\phi(\underline{z},\overline{z})/\omega = \infty$ and $\lim_{\omega\to\infty}\phi(\underline{z},\overline{z})/\omega = 0$, there exists a unique equilibrium value of ω
- the higher $\underline{z}$ and $\overline{z}$, the higher the equilibrium value of ω



Static Equilibrium in the Two-Country Model

- A complete range of goods for both countries $z \in [0,1]$
- $K^*/L^*\,(N_K^*/N_L^*)^{\frac{\beta}{1-\beta}} >> K/L\,(N_K/N_L)^{\frac{\beta}{1-\beta}} \Rightarrow \omega > \omega^* \Rightarrow$
  $\Rightarrow p_K/p_L > p_K^*/p_L^* \Rightarrow$ home: $z \in [0, z']$, foreign: $z \in [z', 1]$



Proof of the Specialization Pattern

- I: due to $p(z) = \min\{c(p_K, p_L, z), c(p_K^*, p_L^*, z)\}$ with z':

$$p_K^{z'} p_L^{1-z'} = p_K^{*z'} p_L^{*1-z'} \tag{5}$$

home: $z \in [0, z']$, foreign: $z \in [z', 1]$ *iff* $p_K/p_L > p_K^*/p_L^*$

- II: since $\frac{p_K}{p_L} = \omega \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{\beta-1}}$, for $\frac{p_K}{p_L} > \frac{p_K^*}{p_L^*}$ to hold (assume in *Step I*):

$$\omega \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{\beta-1}} > \omega^* \left(\frac{N_K^*}{N_L^*}\right)^{\frac{\beta}{\beta-1}} \Leftrightarrow \frac{K^*}{L^*} \left(\frac{N_K^*}{N_L^*}\right)^{\frac{\beta}{1-\beta}} >> \frac{K}{L} \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{1-\beta}} \tag{6}$$

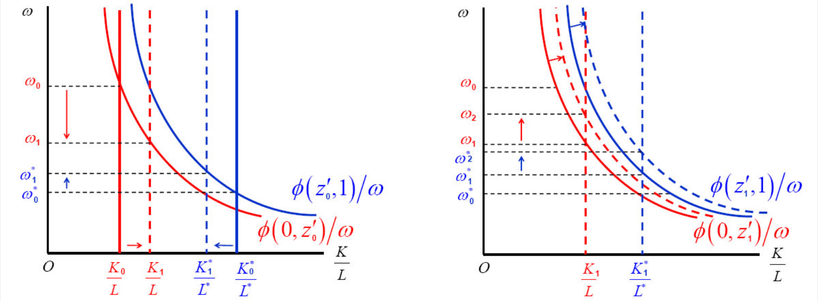
Note that (6) implies $\omega > \omega^*$ (see Figure) □

Trade-Balance Condition and Comparative Statics

- $$\int_0^{z'} (w_L^* L^* + w_K^* K^*) dz = \int_{z'}^1 (w_L L + w_K K) dz. \tag{7}$$
- The condition for the equilibrium specialization threshold as
$$z' = \xi \left(\frac{K}{K^*} \right), \tag{8}$$
with $\xi'(K/K^*) > 0$.
- **Lemma 1.** *For sufficiently great differences in relative effective factor endowments between countries there exists a positive interrelation between the relative capital endowments in the two countries and the equilibrium specialization threshold z' (from (8)).*

Comparative statics in the two-country model

- $K\uparrow, K^*\downarrow \Rightarrow \omega\downarrow, \omega^*\uparrow$
  $\Rightarrow z'\uparrow \Rightarrow \phi(\underline{z}, \overline{z})\uparrow \Rightarrow \omega\uparrow, \omega^*\uparrow$



Dynamic Equilibrium

- Technology monopolists innovate in the sector with higher profits:

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

  that together with (4) is equivalent to

$$\frac{\pi_K}{\pi_L} = \left(\frac{N_K}{N_L} \right)^{-1} \phi(\underline{z}, \overline{z}) \quad (9)$$

- Lab equipment model for production of new machines: $\dot{N}_j = \eta_j R_j$
- With technology–market–clearing condition: $\eta_K \pi_K = \eta_L \pi_L$ and (9) the steady-state ratio is

$$\frac{N_K}{N_L} = \eta \phi(\underline{z}, \overline{z}) \quad (10)$$

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

Capital Flows and Resulting Changes in Specialization Patterns

- For $\frac{K}{L} < \frac{K^*}{L^*}$:
  (i) $\omega > \omega^*$
  (ii) $\frac{N_K}{N_L} < \frac{N_K^*}{N_L^*}$
  (iii) $z \in [0, z']$ (home), $z \in [z', 1]$ (foreign)
- Capital flows from foreign (industrialized) to home (transition) economy
  Not fully integrated capital markets $\nRightarrow$ indeterminacy of production
- As $\frac{K}{L} \uparrow$ and $\frac{K^*}{L^*} \downarrow \Rightarrow \omega \downarrow$ and $\omega^* \uparrow$, $z' \uparrow \Rightarrow \frac{N_K}{N_L} \uparrow$ and $\frac{N_K^*}{N_L^*} \uparrow$
  Differentiate the effect on technological progress?
- CAs in capital-intensive goods (from (10) and $\frac{p_K}{p_L} = \omega \left(\frac{N_K}{N_L}\right)^{\frac{\beta}{\beta-1}}$):

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

State-Dependent R&D

- $$\dot{N}_i = \eta_i N_i^{(1+\delta)/2} N_j^{(1-\delta)/2} S_i, \quad i,j \in (L,K), \quad i \neq j \tag{11}$$
  with S_j - limited R&D staff and $\delta \in [0,1]$ - degree of state dependence
- If $\delta = 0 \Rightarrow$ similar as in the lab equipment model
- δ as an extent of KS (inter-sectoral vs. intra-sectoral)
- Assume $\delta^* \to 0$ for foreign country (weak intra-sectoral KS) and $\delta \to 1$ for the home economy (strong intra-sectoral KS) Alternative interpretation (inter-sectoral KS) possible

State-Dependent R&D and Resulting Changes

- $\Rightarrow$ Technology-market-clearing condition:

$$\eta_L N_L^{\delta} \pi_L = \eta_K N_K^{\delta} \pi_K \tag{12}$$

- $\Rightarrow$ Steady-state ratio

$$\frac{N_K}{N_L} = \left(\eta \phi(\underline{z}, \overline{z})\right)^{\frac{1}{1-\delta}} \tag{13}$$

$z' \uparrow \Rightarrow N_K/N_L \rightarrow N_K^*/N_L^*$

- $\Rightarrow$ CAs:

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

Complementing Instruments

- FBTC: technology monopolists compare expected profits
  PCA: advantages in 'undervalued' industries (only for transition)

$$\text{PCA}_{ij} = \frac{p^h_{it}}{p^h_{jt}} \bigg/ \frac{p^f_{it}}{p^f_{jt}} \tag{14}$$

p^h_{it}	price index of good i on the domestic market in period t
p^h_{jt}	price index of good j on the domestic market in period t
p^f_{it}	price index of good i on the foreign market in period t
p^f_{jt}	price index of good j on the foreign market in period t

- Good empirical results on CEE countries (Savin and Winker, 2009)
- FBTC: micro-foundations on the growth of CAs
  PCA: 'account' for trade partners

What industries to stimulate?

- Stimulate innovations in 'technology-intensive' (MEs) or with CAs? (Rodriguez-Clare, 2005)
- Constraints for MEs:
  1. Stochastic nature of innovations
  2. Hazard of CA in foreign economy
- $\Rightarrow$ Stimulate either existing CAs (LDCs) or PCAs (transition)
- Choice of industries more accurate based on PCAs
- Instruments:
  minimization of trade distortions & attraction of foreign investments

Stimulating innovations

- Accumulation of technologies ($\dot{N}_{i,t}$) - crucial
- Monopolistic market of technologies
  $\Rightarrow$ potential market inefficiency (low R&D investments)
  1. Raise incentives to innovate
     ('U-curve' dependence of innovations on competition)
  2. Stimulate KS
     (raise δ)
  3. Invest in infrastructure and education
     (among others, see Savin and Winker, forthcoming)

Conclusions

- Explain capital-biased technical change in developing countries
- Differentiate effects in time (time lag in CA response)
- Among main stimulating instruments:
  1. Attraction of lacking production factor
  2. Mitigation of market inefficiency

Further Research

- Generalization of technologies
- Allow for international KS and endogenize δ
- Empirical investigation: $[\frac{K}{L}\uparrow\rightarrow\frac{N_K}{N_L}?\rightarrow\frac{p_K}{p_L}?]$

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Consumer Problem

- Identical preferences in all countries of the CRRA-type

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

ρ - rate of time preference, θ - intertemporal elasticity of substitution

- C - Cobb-Douglas type consumption aggregator over a continuum of z

$$\ln C(t) = \int_{z \in Z} \alpha \ln d(z,t)\, dz \tag{15}$$

$d(z,t)$ denotes consumption of z at time t

Apply PCA on CEE countries

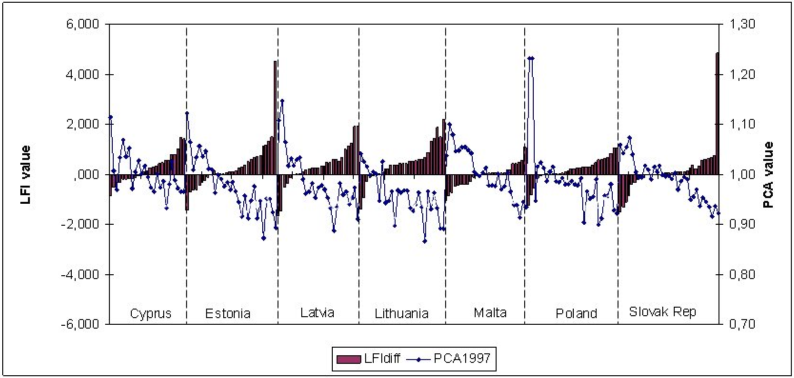
- Poland, the Czech Republic, Hungary, Slovenia, Slovak Republic, Cyprus, Malta, Lithuania, Latvia and Estonia
  - similar structural problems of economies
  - CAs in medium and high-tech industries

Explanatory power of the PCA:

$$\mathrm{LFI}_{ij}^{diff} = \alpha + \beta \mathrm{PCA}_{ij}^{1997} + \varepsilon$$

	Total sample	Subsample 1	Subsample 2
β	-9.98	-15.79	-11.04
Std. Error	0.74	1.78	1.29
P-value	0.000	0.000	0.000
R^2	0.48	0.49	0.49
N	200	81	74

Figure: Correlation between the LFI value difference and the PCA index.



PCA of the Russian Federation

- Calculation features
  - Data: based both on CPI and PPI
  - significant exchange rate distortion of the Russian ruble

Discussion

- Clothing sector: overvalued consumer prices due to undervalued ruble and high import tariffs
- Petroleum products: prices below market level
- Pharmaceutical industry, manufacturing of electronic equipment and machinery
- Motor vehicles and railway equipment: government support and competitive output?!

Objective

- Select relevant factors explaining the innovative performance of Russian regions
- Mixed evidence on the effectiveness of different instruments
- Unobserved heterogeneity and possible endogeneity of regressors

Log-linear form

$$lnY_i = \alpha + \beta_1 lnPMC_i + \beta_2 lnSME_i + \beta_3 lnFO_i + \beta_4 lnEP_i + \beta_5 lnInfra_i + \beta_6 lnSAbs_i + \beta_7 lnSN_i + \beta_8 lnCV_i + u_i$$

The optimization problem

$$y_{it} = \alpha\iota_{NT} + (x_{it}^{opt})'\beta + u_{it}$$

- $(x^{opt})' = x'\tau^{opt}$ is the optimal model specification
- τ is a vector of ones and zeros (possible solution)
- Akaike's (AIC), Bayesian (BIC) and Hannan-Quinn (HQIC)

$$\text{IC} = \ln(\widehat{\sigma}^2) + f(h, NT)$$

- $\tau^i \rightarrow \tau^{opt}$ as $NT \rightarrow \infty$

Complexity

- Discrete nature of the problem → multiple local optima
- Large dimensional search space (2^K) for *k=80*

Pseudocode for Genetic Algorithms

Generate initial population K of solutions, initialize G_{max} and C
for $g = 1$ to G_{max} **do**
    Sort chromosomes in K
    Select $K^{'} \subset K$ (parents), select $K^{*} \subset K$ (elitist)
    initialize $K^{''} = \emptyset$ (set of children)
    for $c = 1$ to C **do**
        Select individuals $x^{parent1}$ and $x^{parent2}$ at random from $K^{'}$
        Apply cross-over to $x^{parent1}$ and $x^{parent2}$ to produce x^{child}
        $K^{''} = K^{''} \cup x^{child}$
    end for
    $K = (K^{'}, K^{''}, K^{*})$
    Mutate $K \setminus K^{*}$ at 8 random points
end for

Genetic Algorithms

- Population of 500 chromosomes
- 50% survival rate
- 10 best solutions are 'elitist' (preserved)
- Superior parents selected more often
- 10 last children are mutated 'elitist' chromosomes

Genetic Algorithms

- Compare single-point crossover and uniform crossover.

$$
\begin{aligned}
x^{parent1} &= (1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0 \quad \dots \quad 1)_{1\times k} \\
x^{parent2} &= (\boldsymbol{1} \quad \boldsymbol{0} \quad \boldsymbol{1} \quad \boldsymbol{0} \quad \boldsymbol{1} \quad \boldsymbol{1} \quad \boldsymbol{0} \quad \dots \quad \boldsymbol{1})_{1\times k} \\
\hline
mask_1 &= (0 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0 \quad 1 \quad \dots \quad 1)_{1\times k} \\
mask_2 &= (1 \quad 0 \quad 0 \quad 1 \quad 1 \quad 1 \quad 0 \quad \dots \quad 0)_{1\times k} \\
\hline
x^{child1} &= (\boldsymbol{1} \quad 1 \quad 0 \quad \boldsymbol{0} \quad \boldsymbol{1} \quad \boldsymbol{1} \quad 0 \quad \dots \quad 1)_{1\times k} \\
x^{child2} &= (1 \quad \boldsymbol{0} \quad \boldsymbol{1} \quad 1 \quad 0 \quad 1 \quad \boldsymbol{0} \quad \dots \quad \boldsymbol{1})_{1\times k}
\end{aligned}
$$

- We find: the uniform crossover is more consistent in providing accurate results.

Genetic Algorithms

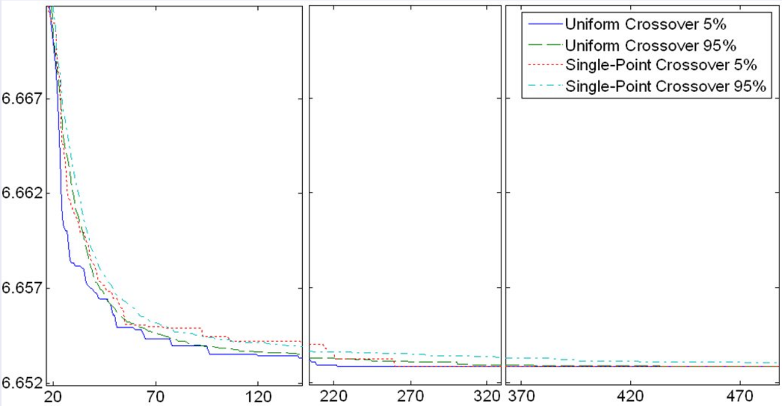


Table: Testing Hypotheses

Hypotheses		Regressors selected[1]	
Product Market Competition	√	Granted patents 0.24^{**}	Advanced technologies used 0.23^{**}
Scale of Production	×		
Form of Ownership	√	FDI 0.05^{**}	Private investments in fixed capital 0.01^{*}
Economic Performance	√	Aggregated net profit in GRP 0.03^{***}	
Infrastructure	√	Density of rail roads 0.15^{***}	
Absorption of Spillovers	√	Graduates from technical schools and colleges -0.05^{**}	
Spillovers in Neighbor Regions	√	Innovative output (N) 0.29^{***}	Granted patents (N) -0.33^{***}
Control Variables	×		

[1] Results obtained with no group penalty according to HQIC, X assumed as endogenous
***,**,* Statistically significant, respectively, at the 1, 5 and 10% level

Some Results

(+) Advanced technologies used
$\Rightarrow$ Catching-up strategy: -implement foreign technologies;
-reduce 'distance to frontier';
-use 'advantage of backwardness'.

(+) FDI
$\Rightarrow$ Promote the transfer of new knowledge;
$\Rightarrow$ Increase efficiency.

Further Results

(-) Graduates from technical schools and colleges
$\Rightarrow$ Stimulate cooperation with industry;
$\Rightarrow$ Public authorities as a coordinator.

(-) Granted patents in neighbor regions
$\Rightarrow$ Promote the knowledge diffusion between regions.