LATVIJAS BANKA

# How Important is Total Factor Productivity for Growth in CESEE

Konstantīns Beņkovskis (Bank of Latvia)
Ludmila Fadejeva (Bank of Latvia)
Robert Stehrer (Wiener Institut für Internationale Wirtschaftsvergleiche)
Julia Wörz (Oesterreichische Nationalbank)

October 17, 2013

LATVIJAS BANKA

# Motivation

- This is an attempt to analyse the contributions of industry level TFP (interpreted as technological progress) to an economy's growth potential
- Improvements over traditional Solow residual approach
  - allow for changes in utilization of inputs and non-constant returns to scale
  - evaluate TFP at industry level and aggregate via input-output framework
  - take into account open economy characteristics
- Final use analysis allows to study the full effect of TFP on different GDP components
  - Theory postulates that TFP shocks affecting consumption have a different impact than TFP shocks affecting investment
- In addition – analysis of ToT shocks, which are important for open economies

LATVIJAS BANKA

# Bibliography


Basu, S., Kimball, M.S. (1997) *Cyclical Productivity with Unobserved Input Variation*. NBER Working Paper, No. 5915, February.

Basu, S., Fernald, J.G., Shapiro, M.D. (2001) *Productivity Growth in the 1990s: Technology, Utilization, or Adjustment?* NBER Working Paper, No. 8359, July.

Basu, S., Fernald, J.G., Kimball, M.S. (2006) Are Technology Improvements Contractionary? *American Economic Review*, vol. 96, No. 5, December, pp. 1418–1448.

Growth, C., Nunez, S., Srinivasan, S. (2006) *Productivity Growth, Adjustment Costs and Variable Factor Utilisation: the UK Case*. Bank of England Working Paper, No. 295, April.

Fadejeva, L., Melihovs, A. (2009) *Measuring Total Factor Productivity and Variable Factor Utilisation: Sector Approach, the Case of Latvia*. Bank of Latvia Working Paper, No. 3.

Basu, S., Fernald, J.G., Fisher, J., Kimball, M.S. (2010) *Sector-Specific Technical Change*. April. 62 p. Unpublished manuscript. Available: *http://www.worldklems.net/conferences/worldklems2010_basu.pdf*.

LATVIJAS BANKA

# Solow residuals

Total factor productivity is unobserved macroeconomic variable. Therefore it should be measured by using other available data series.

<u>The traditional approach – *the Solow residual*</u>

- The Solow residual (dz) is calculated by subtracting the growth of the primary inputs (weighted by their respective shares in nominal output) from the growth of output.

$$dy = c_M dm + c_K dk + c_L dl + dz$$

The growth rate of output (dy)
– the growth rate of intermediate consumption ($c_M dm$)
– the growth rate of capital input ($c_K dk$)
– growth rate of labour input ($c_L dl$)
---
= total factor productivity ($dz$)

Where *ck*, *cl* and *cm* are the shares of capital and labour in nominal output respectively

LATVIJAS BANKA

# Derivation of TFP at industry level

## Cost minimization problem

- Follow Basu and Kimball (1997)
- Allows for non-constant returns to scale
- Cost minimization problem of a representative firm:
  - adjustment costs for changes in capital and labour
  - may change utilization of inputs (capital, labour)

$$\min_{S,E,H,N,I,R} E\left(\sum_{\tau=0}^{\infty} \beta^{\tau}\left(wLG(E,H)V(S)+wL\Psi(R/L)+P^{I}K\Phi(I/K)+P^{N}N\right)\right)$$

$$Y = F(KS, LHE, N, Z) = Z\left((KS)^{s_K}(LHE)^{s_L}N^{s_N}\right)^{\gamma}$$

$$\dot{K} = (1-\delta(S))K + I$$

$$\dot{L} = R$$

LATVIJAS BANKA

# Derivation of TFP at industry level

## Evaluation of unobserved utilization

- Changes in output are given by:

$$dy = \gamma^{*} d\chi + \gamma^{*} du + dz$$

*changes in output* — *changes in inputs* — *changes in utilization* — ***changes in technology***

- inputs contain capital, total hours worked and intermediate inputs

$$d\chi = s_K dk + s_L (dl + dh) + s_N dn$$

*changes in input* — *changes in capital* — *changes in total hours worked* — *changes in intermediate input*

- unobserved changes in utilisation is a function of observables

$$du = \beta_1 dh + \beta_2 (dp^N + dn - dp^I - dk) + \beta_3 (di - dk)$$

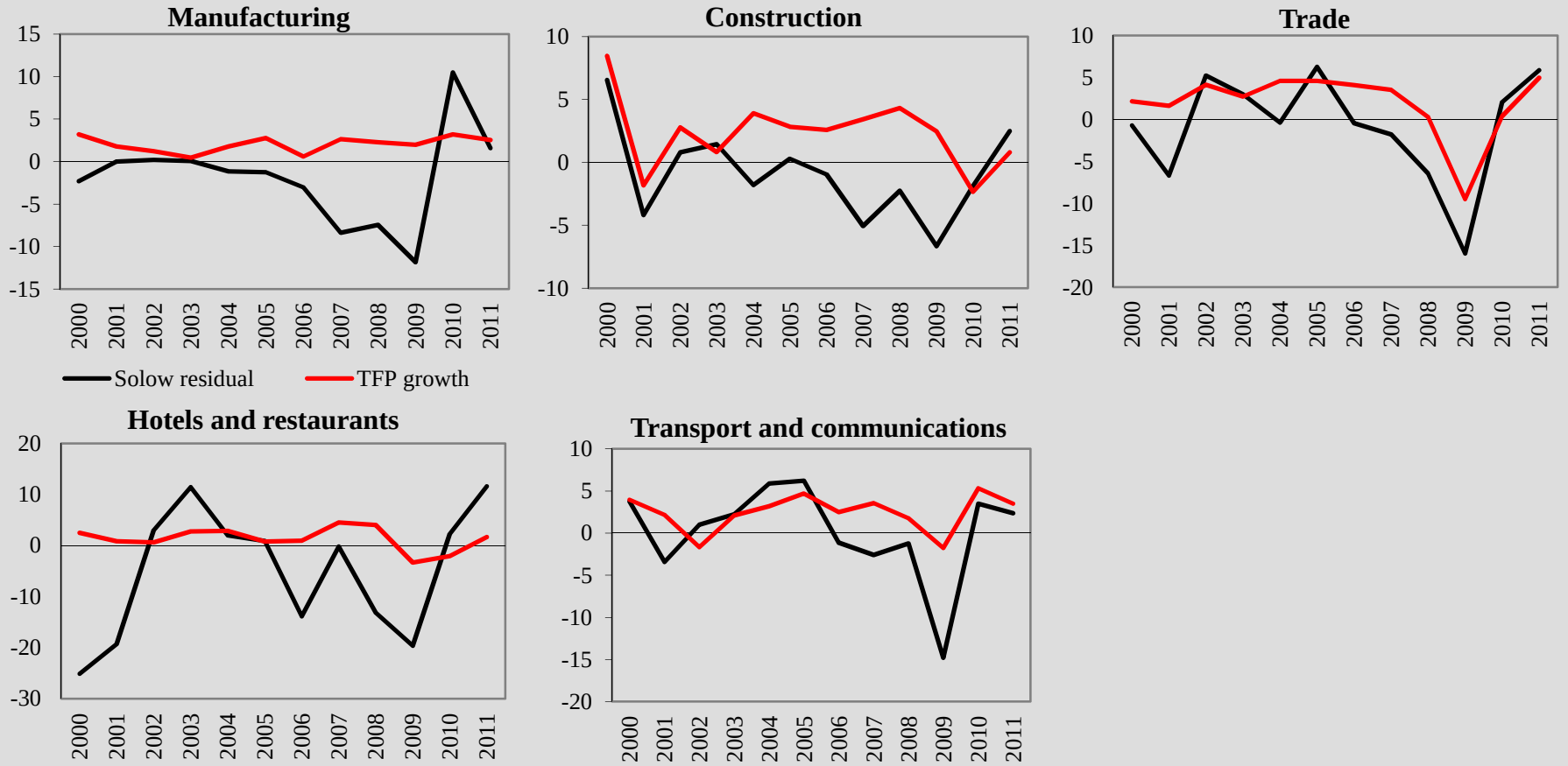
*changes in utilization* — *changes in hours per head* — *changes in intermediate consumption to capital* — *changes in investments to capital*

LATVIJAS BANKA

# Estimates based on LV quarterly data

## TFP growth getting less volatile and procyclical

### TFP growth calculated from IV regression and Solow residuals, %




* Updated results from:

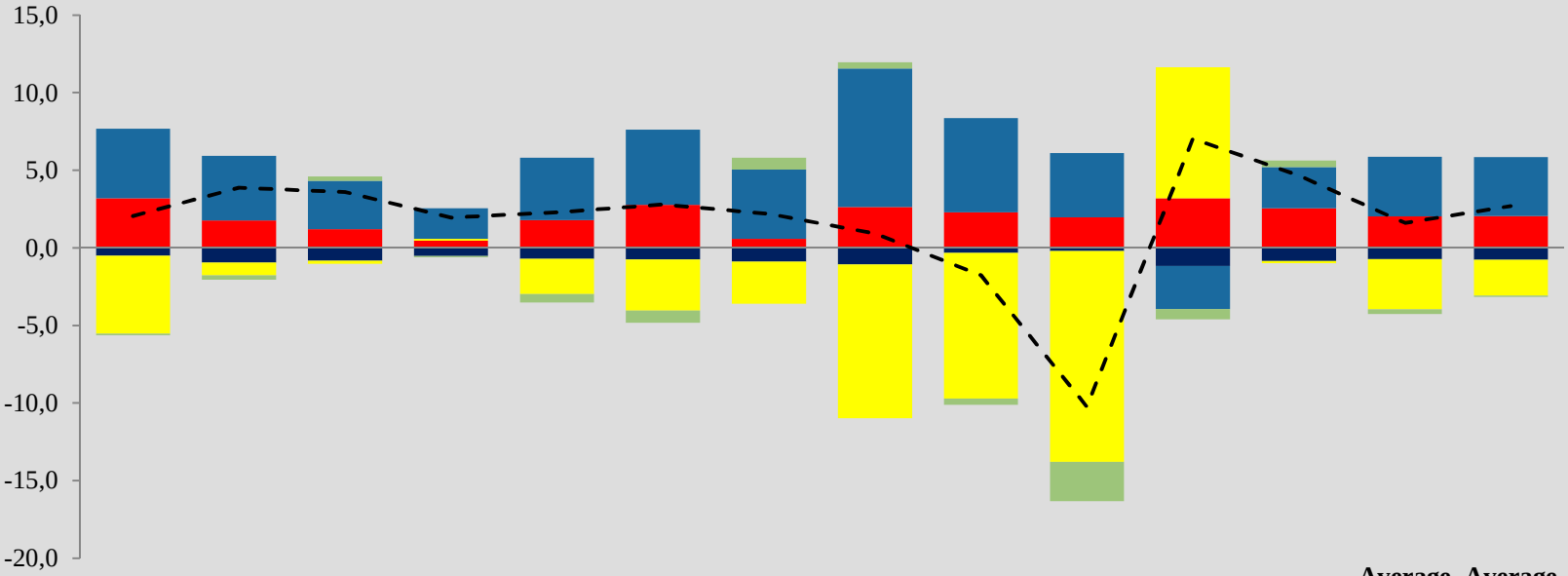
Fadejeva, L., Melihovs, A. (2009) *Measuring Total Factor Productivity and Variable Factor Utilization: Sector Approach, the Case of Latvia*, Bank of Latvia Working Paper 3/2009.

LATVIJAS BANKA

# Estimates based on LV quarterly data

## TFP in manufacturing – positive growth during the crisis

**Contributions to value added growth in manufacturing (% and pp)**




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Average 2000-2011 | Average excl. 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labour growth | -0,1 | -0,3 | 0,3 | -0,1 | -0,5 | -0,8 | 0,8 | 0,4 | -0,4 | -2,5 | -0,7 | 0,4 | -0,3 | -0,1 |
| Capital growth | 4,5 | 4,2 | 3,1 | 2,0 | 4,0 | 4,8 | 4,4 | 8,9 | 6,1 | 4,1 | -2,8 | 2,6 | 3,8 | 3,8 |
| Utilisation of inputs | -5,0 | -0,8 | -0,2 | 0,1 | -2,3 | -3,3 | -2,7 | -9,9 | -9,4 | -13,6 | 8,4 | -0,1 | -3,2 | -2,3 |
| Scale effect | -0,5 | -0,9 | -0,8 | -0,5 | -0,7 | -0,8 | -0,9 | -1,1 | -0,3 | -0,2 | -1,2 | -0,8 | -0,7 | -0,8 |
| TFP growth | 3,2 | 1,8 | 1,2 | 0,5 | 1,8 | 2,8 | 0,6 | 2,6 | 2,3 | 2,0 | 3,2 | 2,6 | 2,0 | 2,0 |
| Value added growth | 2,1 | 3,9 | 3,6 | 1,9 | 2,3 | 2,8 | 2,2 | 0,9 | -1,8 | -10,2 | 7,0 | 4,7 | 1,6 | 2,7 |

* Updated results from:

Fadejeva, L., Melihovs, A. (2009) *Measuring Total Factor Productivity and Variable Factor Utilization: Sector Approach, the Case of Latvia*, Bank of Latvia Working Paper 3/2009.

LATVIJAS BANKA

# Aggregation of TFP

## Direct and indirect effects

- Industry specific TFP growth represent direct effects of technological change on the economy
  - However, technological changes in one industry is multiplied through interlinkages among sectors
  - Depending on strength and type of interlinkages (i.e. structure of intermediate use) aggregate TFP is affected differently by technology shocks in different industries
- Final use analysis allows to study the full effect of industry TFP growth on different GDP components
  - Theory postulates that TFP shocks affecting consumption have a different impact than TFP shocks affecting investment
- In addition – analysis of ToT shocks, which are important for open economies

LATVIJAS BANKA

# Aggregation of TFP

## Stylized Input-Output table for closed economy

| | | Product 1 | Product 2 | Consumption | Total input |
|---|---|---|---|---|---|
| Domestic | Product 1 | $P_1N_{11}$ | $P_1N_{12}$ | $P_1C_1$ | $P_1Y_1$ |
| | Product 2 | $P_2N_{21}$ | $P_2N_{22}$ | $P_2C_2$ | $P_2Y_2$ |
| Value added | | $VA_1$ | $VA_2$ | ... | $VA$ |
| Total output | | $P_1Y_1$ | $P_2Y_2$ | $P^CC$ | |

$P_i$ is the price of a product $i$
$P^C$ is the price of a consumption basket
$N_{ji}$ is the intermediate input of product $j$ used in the production of $i$
$VA_i$ is the value added of product $i$
$Y_i$ is the gross output of product $i$
$C_i$ is the consumption of product $i$
$C$ is total consumption

LATVIJAS BANKA

# Aggregation of TFP

## Stylized Input-Output table for closed economy

| | | Product 1 | Product 2 | Consumption | Total input |
|---|---|---|---|---|---|
| Domestic | Product 1 | $P_1N_{11}$ | $P_1N_{12}$ | $P_1C_1$ | $P_1Y_1$ |
| | Product 2 | $P_2N_{21}$ | $P_2N_{22}$ | $P_2C_2$ | $P_2Y_2$ |
| Value added | | $VA_1$ | $VA_2$ | ... | $VA$ |
| Total output | | $P_1Y_1$ | $P_2Y_2$ | $P^CC$ | |

Matrix **B**
Represents shares of intermediate inputs in total output

Matrix $\mathbf{s_C}$
Represents structure of final consumption

LATVIJAS BANKA

# Aggregation of TFP

## Derivation of aggregated contribution

- Some mathematical transformations:

$$dy_i = \gamma_i^* \left( s_{Ki} dk_i + s_{Li} \left( dl_i + dh_i \right) + \sum\nolimits_j s_{Nji} dn_{ji} \right) + \gamma_i^* du_i + dz_i$$

$$dc_i = \gamma_i^* \left( s_{Ki} dk_i + s_{Li} \left( dl_i + dh_i \right) + \sum\nolimits_j s_{Nji} dc_j \right) + \gamma_i^* du_i + dz_i$$

$$dc = \gamma s_K dk + \gamma s_L \left( dl + dh \right) + \gamma B^T dc + \gamma du + dz$$

$$dc = \left( \mathrm{I} - \gamma B^T \right)^{-1} \gamma s_K dk + \left( \mathrm{I} - \gamma B^T \right)^{-1} \gamma s_L \left( dl + dh \right) + \left( \mathrm{I} - \gamma B^T \right)^{-1} \gamma du + \left( \mathrm{I} - \gamma B^T \right)^{-1} dz$$

- Aggregated TFP contribution to final use growth (consumtion goods, investment goods, trade goods):

$$dz_C = s_C \left( \mathrm{I} - \gamma B^T \right)^{-1} dz$$

LATVIJAS BANKA

# Aggregation of TFP

## From closed economy to open economy

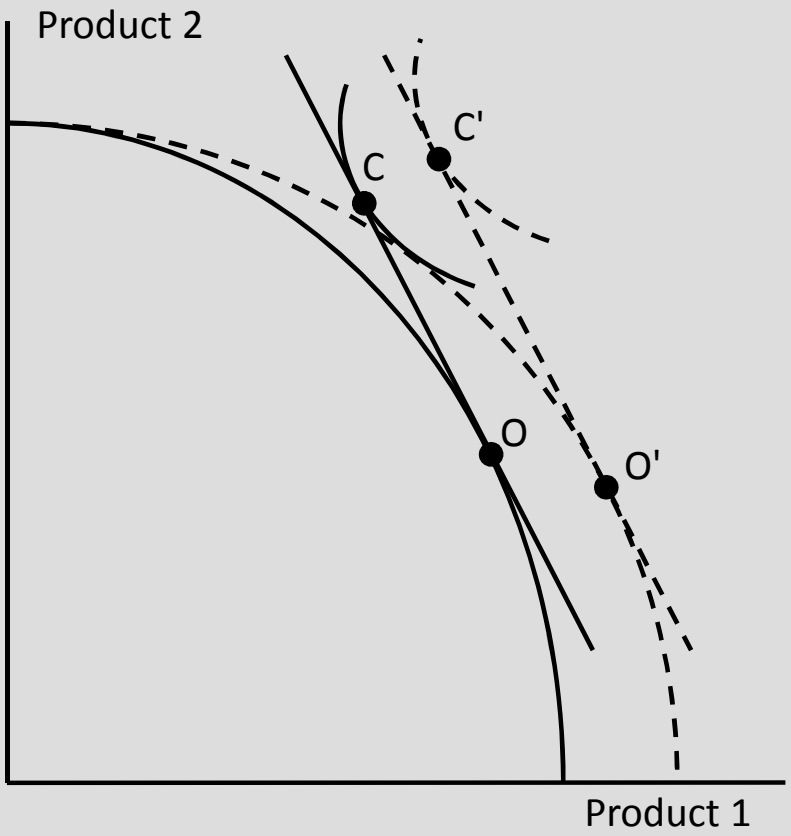
- The input-output framework above has a very restrictive assumption of a closed economy
  - We need to modify the stylized input-output table by including export and import flows
- A "virtual" trade product is added to Input-Output table
  - The process of international trade can be viewed as a synthetic industry: in order to obtain imported goods, a country is forced to involve into export activities.
  - Using production function terminology, exports are the inputs of "virtual" trade industry and imports are the output.
  - ToT can be viewed as a TFP!

LATVIJAS BANKA

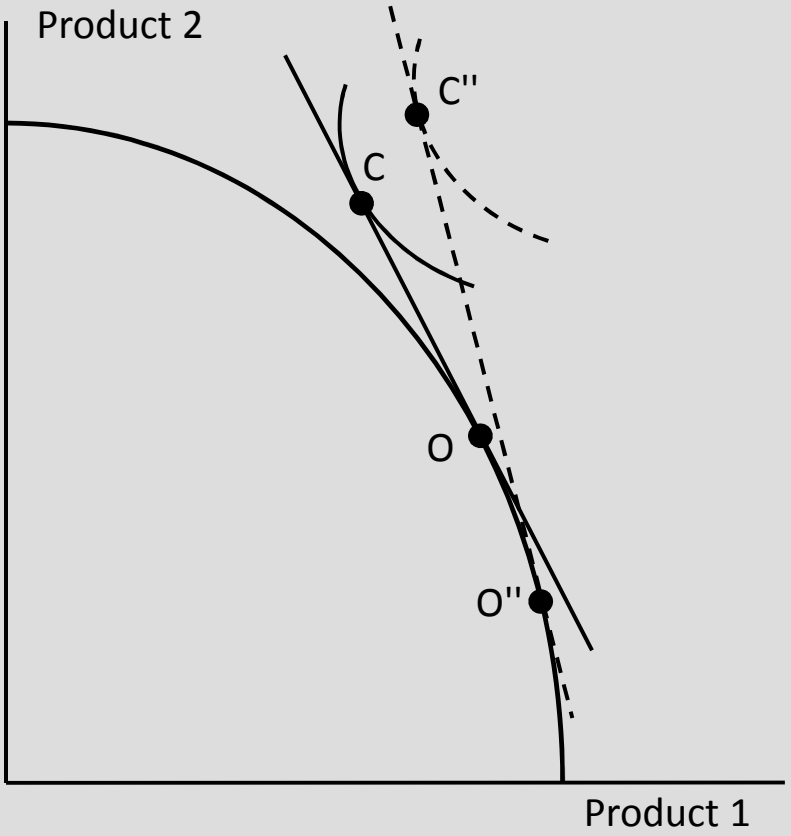
# Aggregation of TFP

## Role of Terms of Trade

**a. Positive TFP shock**




**b. Improvement in ToT**



LATVIJAS BANKA

# Aggregation of TFP

## Stylized Input-Output table for open economy

| | | Product 1 | Product 2 | Trade product | Consumption | Total input |
|---|---|---|---|---|---|---|
| Domestic | Product 1 | $P_1N_{11}$ | $P_1N_{12}$ | $P_1X_1$ | $P_1C_1$ | $P_1Y_1$ |
| | Product 2 | $P_2N_{21}$ | $P_2N_{22}$ | $P_2X_2$ | $P_2C_2$ | $P_2Y_2$ |
| Trade product | | $P^M{}_1M_1$ | $P^M{}_2M_2$ | ... | $P^M{}_CC^M$ | $P^MM$ |
| Value added | | $VA_1$ | $VA_2$ | ... | ... | $VA$ |
| Financial account | | ... | ... | $P^MM–P^XX$ | ... | ... |
| Total output | | $P_1Y_1$ | $P_2Y_2$ | $P^MM$ | $P^CC$ | |

Matrix **B**

Represents shares of intermediate inputs in total output

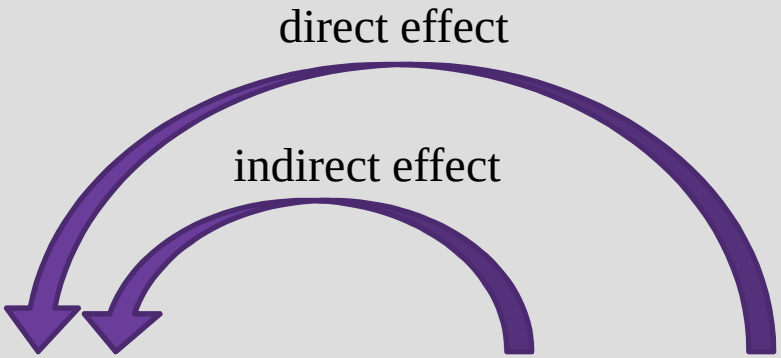
Matrix $\mathbf{s_C}$

Represents structure of final consumption

LATVIJAS BANKA

# Aggregation of TFP

## Main equation




$$dz_C = s_C \left( \mathrm{I} - \gamma B^T \right)^{-1} dz$$

TFP contribution to growth of final consumption

structure of final consumption

structure of intermediate inputs

Industry TFP + ToT

LATVIJAS BANKA

# Description of the database

## WIOD – World Input-Output Database

- Harmonized input-output tables (WIOD)
- Industry level data on output, capital, labour
- 35 industries (NACE, rev.1)
- 40 countries:
  - 27 EU members
  - 13 major countries
- Annual data for 1995-2009

LATVIJAS BANKA

# Estimation of TFP at industry level

## Estimation strategy

- Regression to estimate:

$$dy_{it} = b_0 + \gamma^* d\chi_{it} + b_1 dh_{it} + b_2\left(dp_{it}^N + dn_{it} - dp_{it}^I - dk_{it}\right) + b_3\left(di_{it} - dk_{it}\right) + \xi_{it}$$

$$dz_{it} = b_0 + \xi_{it}$$

  - Data organized in industry-specific panel datasets
  - Country-specific fixed effects
  - Estimated by TSLS
    - Instruments: external demand, interest rates, real exchange rate, budget balance, world commodity prices

LATVIJAS BANKA

# Estimation of TFP at industry level

## Estimation results

| Industry | Coefficients | | | | No. of countries | No. of obs. | Sargan-test (p-value) |
|---|---|---|---|---|---|---|---|
| | dχ | dh | $dn+dp^N-$ $-dk-dp^I$ | di-dk | | | |
| Agriculture, Forestry and Fishing | 0.032 | -0.029 | 0.928*** | 0.018 | 40 | 360 | 0.620 |
| Mining and Quarrying | 0.548*** | 0.171 | 0.121 | -0.019 | 40 | 393 | 0.684 |
| Food, Beverages and Tobacco | 1.076*** | 0.155 | -0.049 | 0.012 | 40 | 407 | 0.017 |
| Textiles and Textile Products | 0.909*** | 0.052 | 0.122 | -0.004 | 40 | 398 | 0.254 |
| Leather and Footwear | 0.940*** | 0.040 | 0.180* | 0.021 | 39 | 350 | 0.463 |
| Wood and Products of Wood and Cork | 0.975*** | 0.296 | 0.199 | -0.034 | 40 | 394 | 0.669 |
| Pulp, Paper, Printing and Publishing | 1.001*** | 0.103 | 0.031 | 0.003 | 40 | 407 | 0.080 |
| Refined Petroleum, Chemical Products | 0.998*** | 0.007 | -0.082 | 0.012 | 40 | 404 | 0.019 |
| Rubber and Plastics | 0.936*** | 0.112*** | 0.120* | -0.007 | 40 | 407 | 0.705 |
| Other Non-Metallic Mineral | 0.997*** | 0.398 | 0.087 | -0.018 | 40 | 404 | 0.226 |
| Basic Metals and Fabricated Metal | 0.841*** | 0.275 | 0.132 | -0.009 | 40 | 407 | 0.327 |
| Machinery, n.e.c. | 0.852*** | 0.447** | 0.230 | -0.051** | 40 | 407 | 0.112 |
| Electrical and Optical Equipment | 1.159*** | 0.099 | -0.113 | -0.009 | 40 | 401 | 0.685 |
| Transport Equipment | 0.497*** | -0.073 | 0.734*** | -0.069 | 40 | 399 | 0.599 |
| Manufacturing, n.e.c; Recycling | 0.924*** | 0.281 | 0.147 | -0.034 | 40 | 396 | 0.479 |
| Electricity, Gas and Water Supply | 0.572*** | -0.036 | 0.305** | 0.011 | 40 | 403 | 0.134 |
| Construction | 0.942*** | 0.132 | 0.163* | -0.030 | 40 | 404 | 0.983 |
| Trade | 0.745*** | 0.110 | 0.360** | 0.005 | 40 | 407 | 0.169 |
| Hotels and Restaurants | 0.919*** | 0.038 | 0.419 | -0.026 | 40 | 394 | 0.508 |
| Transport | 0.909*** | 0.189 | 0.155* | 0.004 | 40 | 402 | 0.494 |
| Post and Telecommunications | 1.168*** | 0.075 | -0.028 | -0.015 | 40 | 404 | 0.392 |
| Financial Intermediation | 1.131*** | 0.174 | -0.154 | -0.015 | 40 | 401 | 0.504 |
| Real Estate Activities | 1.103*** | 0.015 | -0.083 | -0.012 | 40 | 407 | 0.925 |
| Other Business Activities | 1.177*** | 0.527** | -0.180 | 0.006 | 40 | 405 | 0.562 |
| Public Administration and Defence | 0.773*** | 0.137 | 0.088 | 0.006 | 39 | 392 | 0.463 |
| Education | -0.684 | -0.065 | 0.502 | 0.055 | 40 | 401 | 0.908 |
| Health and Social Work | 0.021 | 0.439 | 0.160 | -0.084* | 40 | 394 | 0.649 |
| Other Social Services; Employed Persons | 1.377* | -0.827 | 0.073 | -0.088 | 40 | 401 | 0.346 |

LATVIJAS BANKA

# Estimation of TFP at industry level

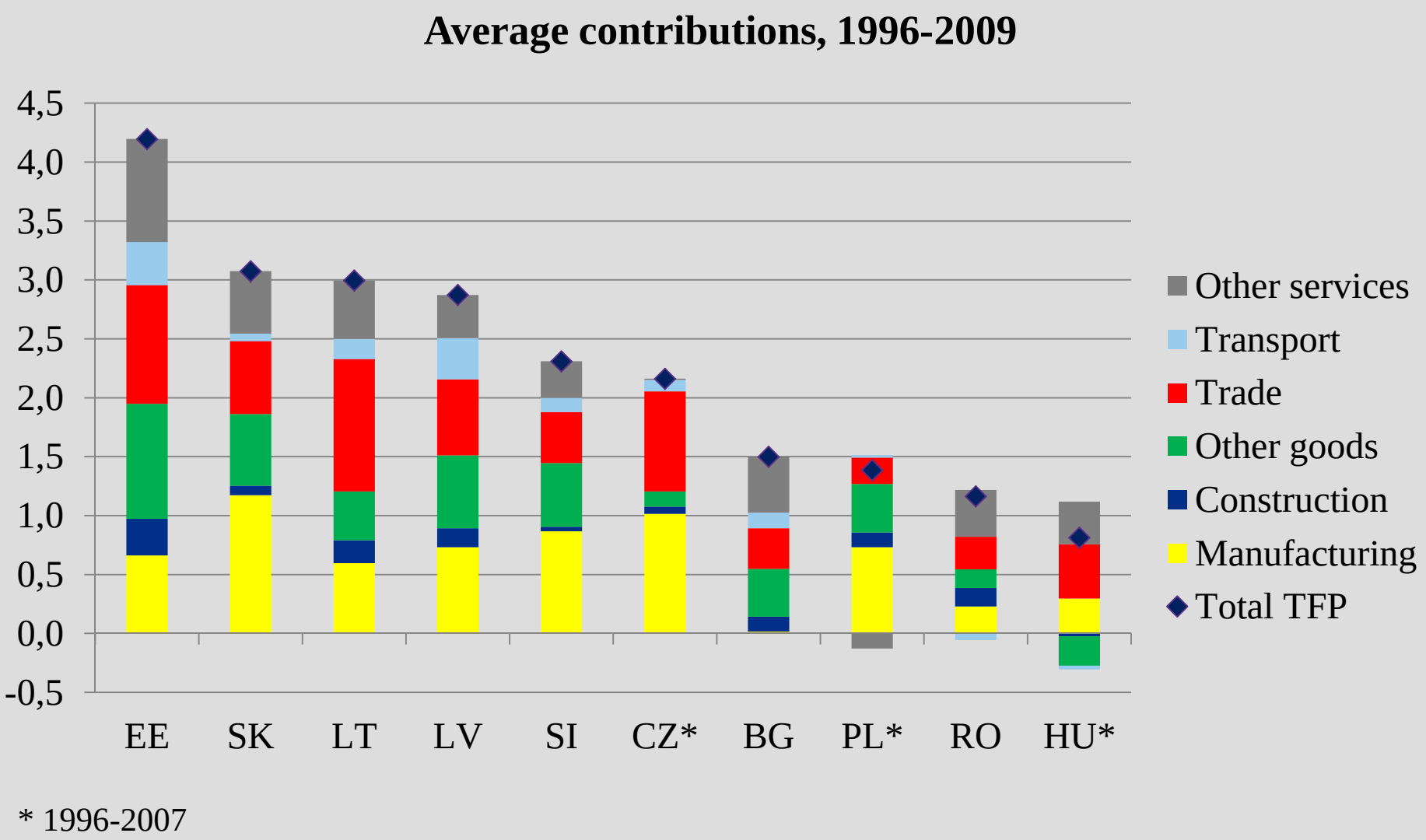
## Estimated TFP are less correlated with changes in output

| Industry | Solow residual | TFP adjusted for varying utilization |
|---|---|---|
| Agriculture, Forestry and Fishing | 0.100 | 0.137 |
| Mining and Quarrying | 0.206 | 0.754 |
| **Food, Beverages and Tobacco** | **0.149** | **0.039** |
| **Textiles and Textile Products** | **0.110** | **-0.003** |
| **Leather and Footwear** | **0.284** | **-0.147** |
| **Wood and Products of Wood and Cork** | **0.375** | **-0.121** |
| **Pulp, Paper, Printing and Publishing** | **0.134** | **0.009** |
| Refined Petroleum, Chemical Products | 0.058 | 0.259 |
| **Rubber and Plastics** | **0.247** | **0.056** |
| **Other Non-Metallic Mineral** | **0.362** | **0.004** |
| Basic Metals and Fabricated Metal | 0.076 | 0.089 |
| **Machinery, n.e.c.** | **0.315** | **0.070** |
| **Electrical and Optical Equipment** | **0.248** | **0.064** |
| Transport Equipment | -0.094 | -0.302 |
| **Manufacturing, n.e.c; Recycling** | **0.282** | **0.134** |
| Electricity, Gas and Water Supply | 0.271 | 0.281 |
| **Construction** | **0.289** | **0.065** |
| **Trade** | **0.270** | **-0.007** |
| **Hotels and Restaurants** | **0.280** | **-0.166** |
| Transport | 0.306 | 0.035 |
| **Post and Telecommunications** | **0.386** | **0.077** |
| Financial Intermediation | 0.300 | 0.333 |
| **Real Estate Activities** | **-0.048** | **0.037** |
| Other Business Activities | 0.211 | 0.253 |
| Public Administration and Defence | 0.001 | 0.119 |
| Education | 0.325 | 0.501 |
| Health and Social Work | 0.311 | 0.793 |
| **Other Social Services; Employed Persons** | **0.417** | **-0.061** |
| **Overall** | **0.176** | **0.085** |

LATVIJAS BANKA

# Aggregated TFP

## Contributions to value added growth

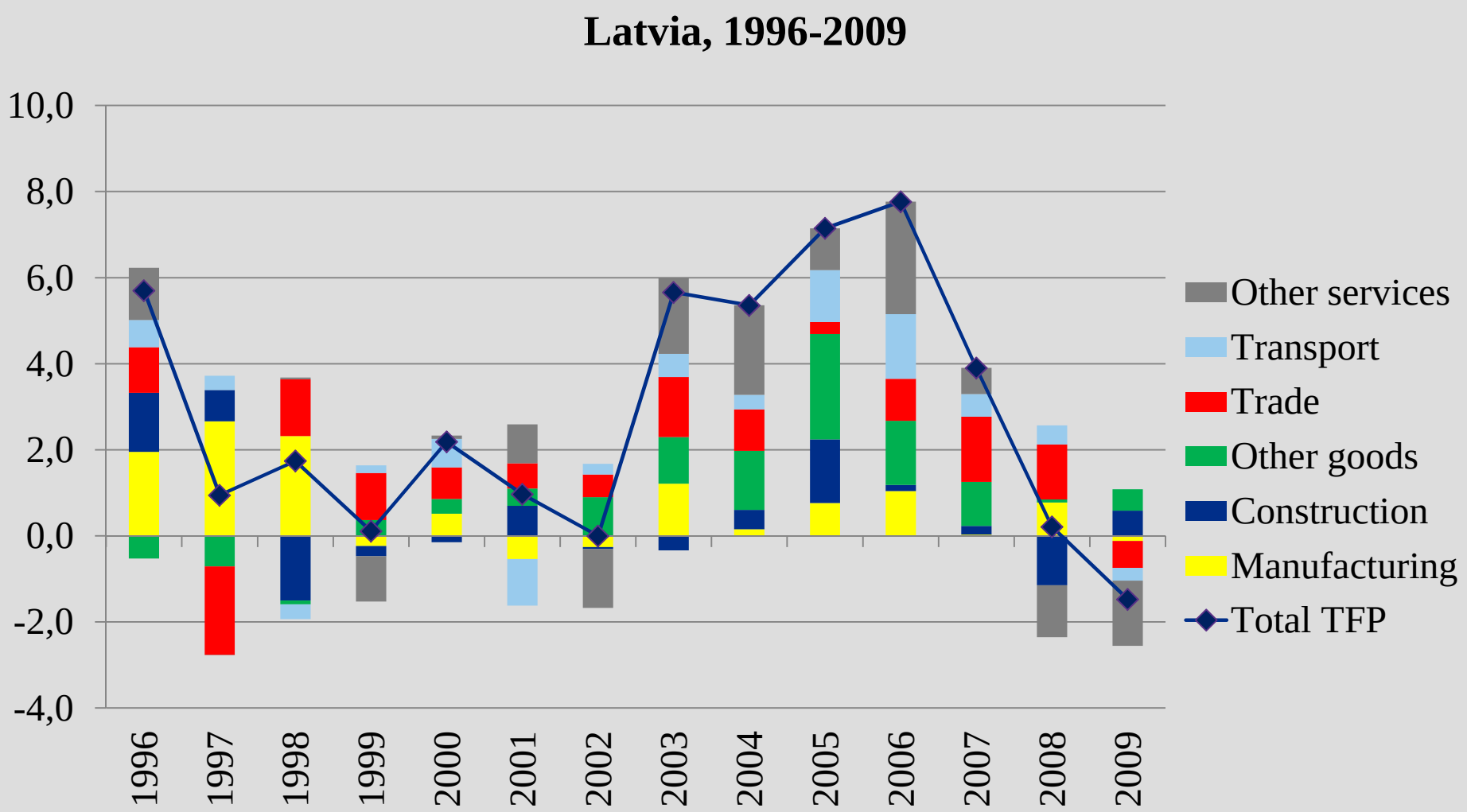



* 1996-2007

LATVIJAS BANKA

# Aggregated TFP

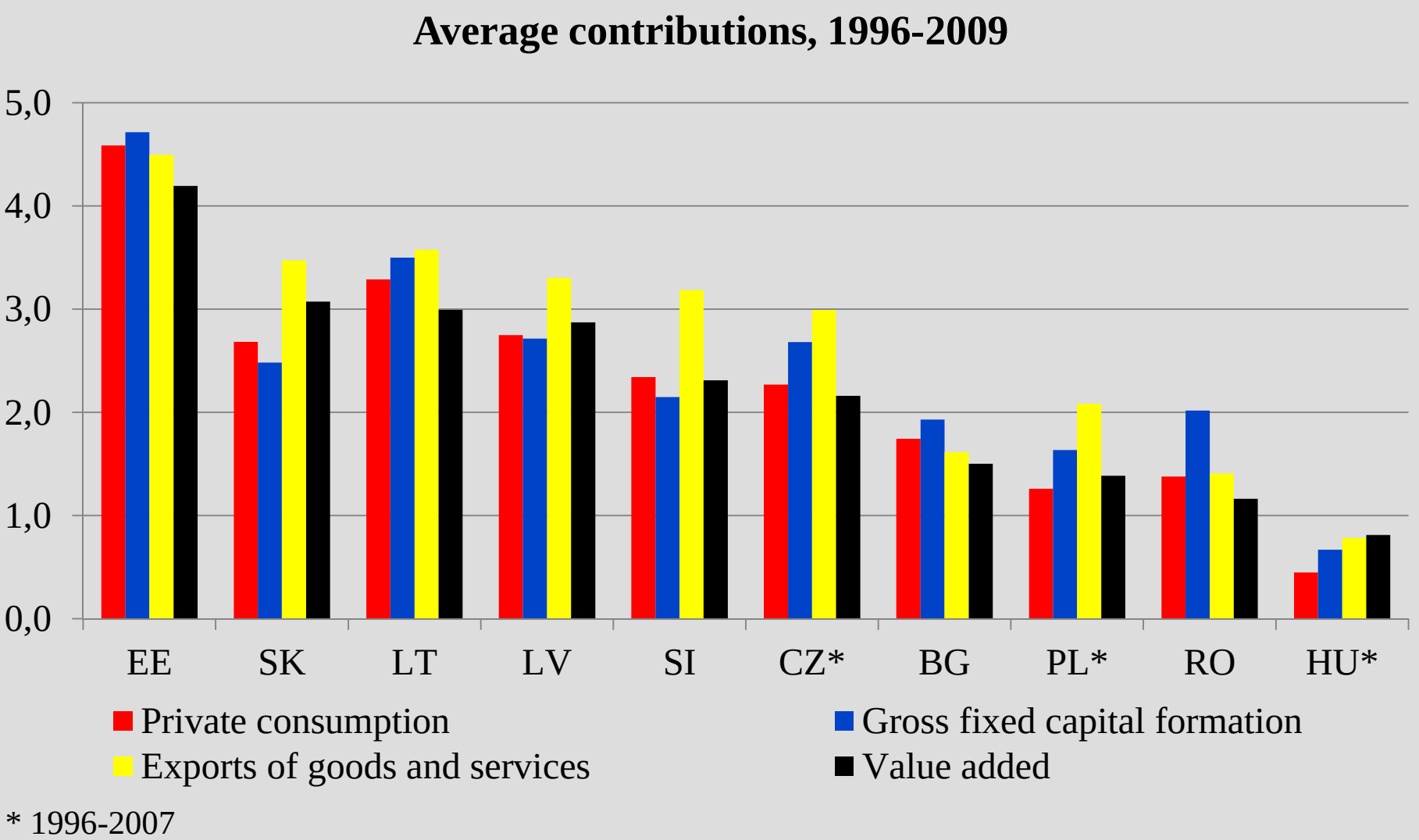
## Contributions to value added growth



LATVIJAS BANKA

# Aggregated TFP

## Contributions to different final use components



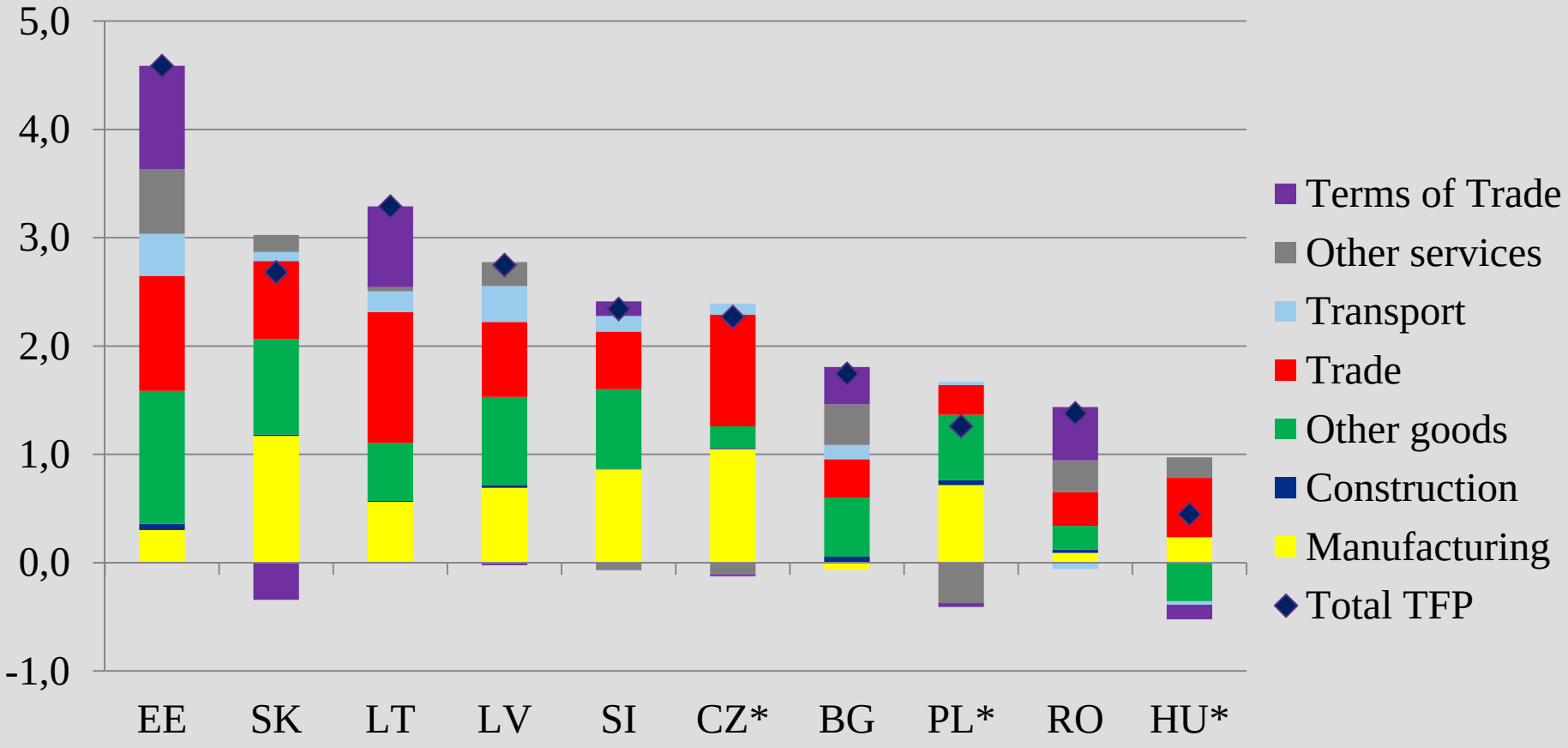

* 1996-2007

LATVIJAS BANKA

# Aggregated TFP

## Contributions to consumption growth

**Average contributions, 1996-2009**

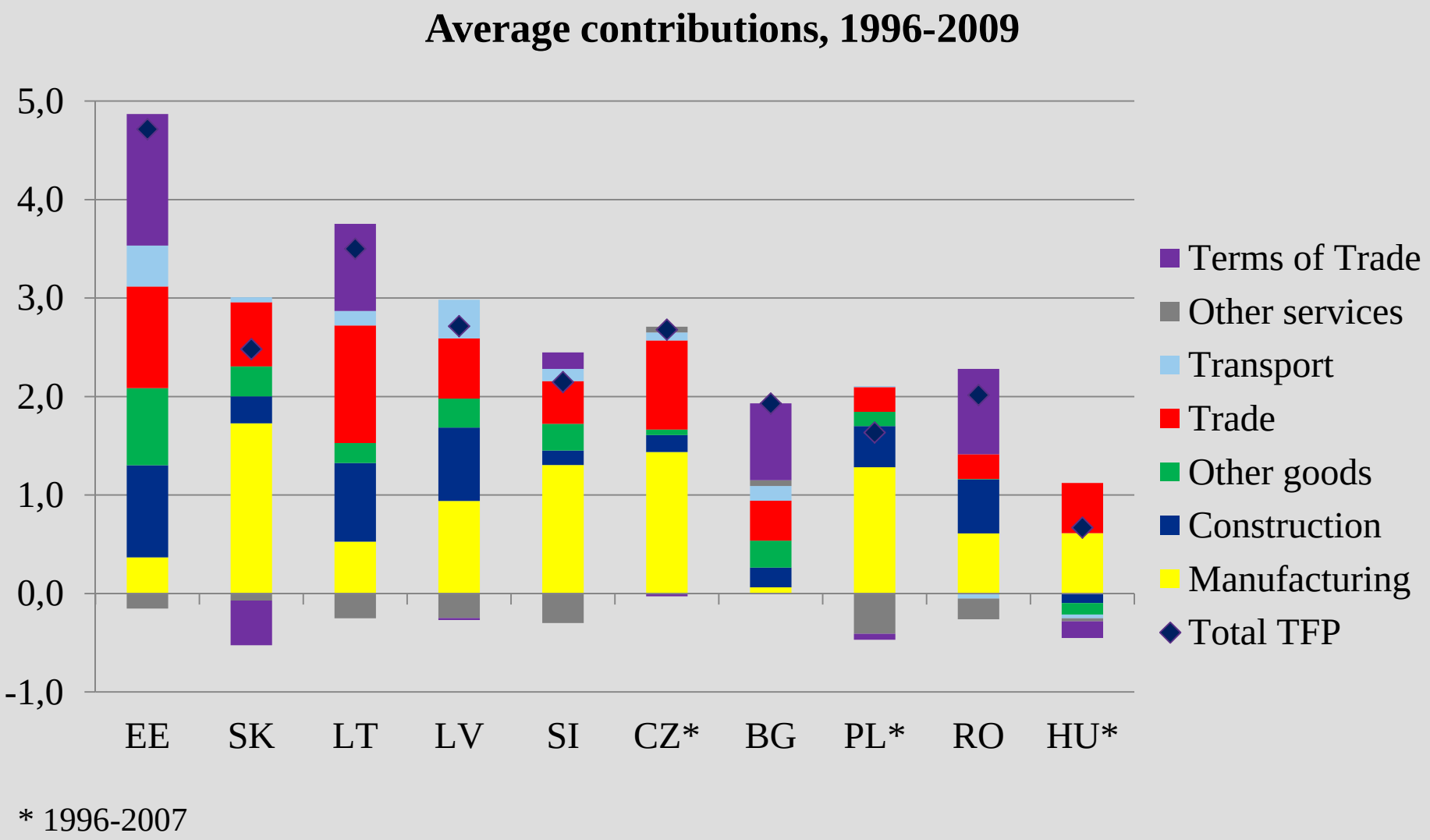



* 1996-2007

LATVIJAS BANKA

# Aggregated TFP

## Contributions to investment growth



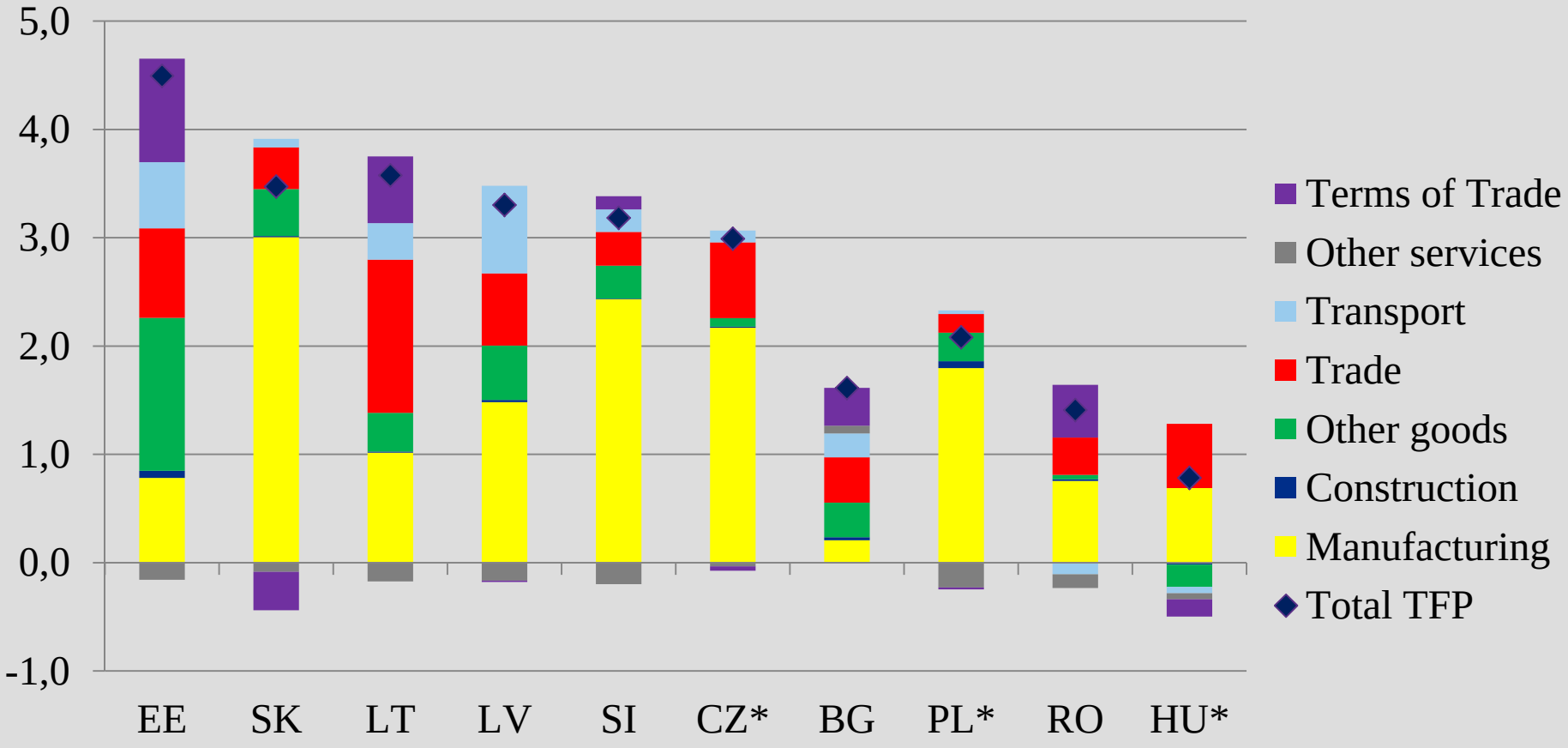

* 1996-2007

LATVIJAS BANKA

# Aggregated TFP

## Contributions to exports growth

**Average contributions, 1996-2009**




* 1996-2007

LATVIJAS BANKA

# Conclusions

- Large differences in TFP growth in the region:
  - Might be driven by technological convergence
  - Some important differences in sectoral composition as well
- Highest TFP growth observed for exports and investment products
  - Despite high degree of openness, ToT do not play a significant role in growth of final demand
- Accounting for changes in utilisation leads to more stable estimated TFP growth
  - However, annual frequency of data in WIOD is an obstacle