Total factor productivity and the terms of trade

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Motivation

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- Terms of trade (TOT) - the ratio of export prices to import prices - is one of the most important drivers of business cycles in open economies
- Total factor productivity (TFP) is a key driving force of growth models and business cycles, often treated as exogenous
- In this paper I ask whether TFP in an open economy responds to changes in TOT and how this response can be explained

Research question and possible channels

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Empirical analysis supports the first channel - TOT gains slow down TFP growth

Related literature

- Endogenous growth literature: Romer (1986, 1990), Uzawa (1965), Lucas (1988)
- Open economy models, importance of terms of trade shocks: Mendoza (1995), Schmitt-Grohé and Uribe (2018)
- Empirical studies on TFP determinants:
  - Macro evidence: Miller and Upadhyay (2000), Alcalá and Ciccone (2004), Kehoe and Ruhl (2008), Gopinath and Neiman (2014)
  - Micro evidence: Galdon-Sanchez and Schmitz (2002) Schmitz (2005), Dunne, Klimek, and Schmitz (2010), Alfaro et al. (2017)
- Resource curse (the Dutch disease): Frankel (2010), Ploeg (2011), Benigno and Fornaro (2014)

Contribution

1. New empirical evidence on how TFP reacts to changes in TOT
   - Macroeconomic evidence based on time series SVAR analysis
   - Microeconomic evidence from industry data
2. Combining open economy models with endogenous growth theory to explain TFP reaction to TOT
   - Exploring the substitutability between physical good production and R&D

Macro evidence

- Bivariate VAR on time series of TFP and TOT
- Identification by long-run restrictions:
  - shock to TFP as the only shock that has a long-run impact on TFP
  - TOT shock has no long run effects on TFP

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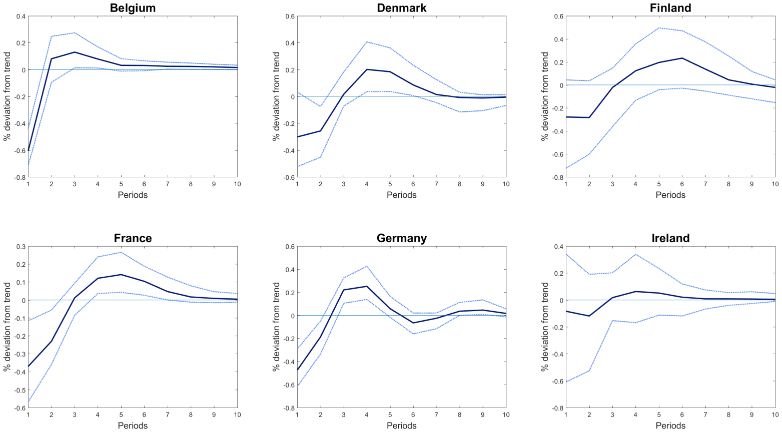
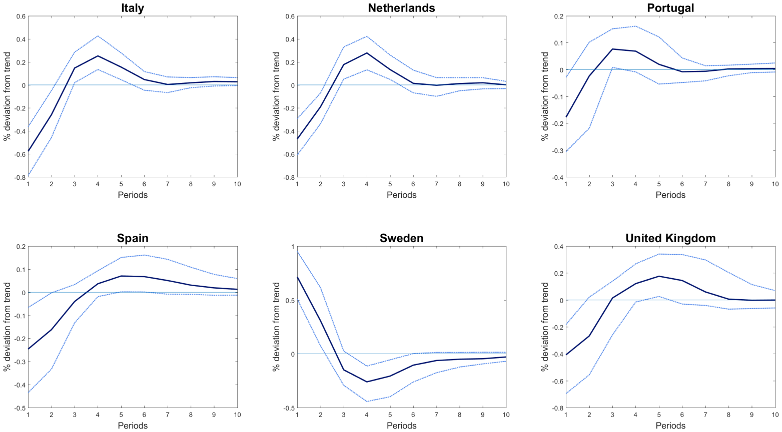
- Negative and significant response on impact for 9 out of 12 countries trade shares spec

Impulse responses of TFP to TOT shocks 1/2



Belgium Denmark Finland France Germany Ireland

Impulse responses of TFP to TOT shocks 2/2



Italy Netherlands Portugal Spain Sweden United Kingdom re

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- TOT - the ratio of the index of export prices to the index of import prices (OECD database)
- TFP computed as Solow residual in production function of the real value added

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- TOT - the ratio of the index of export prices to the index of import prices (OECD database)
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- Competitiveness Research Network (CompNet) firm-level based dataset
- 22 manufacturing industries industries more
- 10 countries: Austria, Belgium, Estonia, Finland, Germany, Italy, Lithuania, Portugal, Slovenia and Spain ts
- Time span: 1996-2012 (unbalanced panel), annual frequency dates spec

Regression results

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP
ΔTOT	**-.4923*** **	**-.4935*** **	**-.4958*** **	**-.3179*** **	**-.4956*** **	**-.3198*** **	**-.2857*** **	**-.2866*** **
	(.0550)	(.0543)	(.0579)	(.0718)	(.0576)	(.0708)	(. 0783)	(.0770)
Sector dummies	NO	YES	NO	NO	YES	YES	NO	YES
Country dummies	NO	NO	YES	NO	YES	NO	YES	YES
Year dummies	NO	NO	NO	YES	NO	YES	YES	YES
Mean TFP	62.0282	62.0282	62.0282	62.0282	62.0282	62.0282	62.0282	62.0282
Number of obs.	2591	2591	2591	2591	2591	2591	2591	2591
R^2	0.0296	0.0599	0.0482	0.0808	0.0802	0.1127	0.0989	0.0766

Standard deviation in parenthesis. Legend: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

TOT improvements associated with **reductions** of changes in TFP

Regression results - robustness

Sample	Manufact	All	Non-manufact	Manufact	Manufact
Model	(8)	(9)	(10)	(11)	(12)
	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP
ΔTOT	-.2866***	-.1019*	.0193	-.2924***	.1562
	(.0770)	(.0509)	(.0671)	(.0772)	(.1307)
Share of exporters				7.0555***	6.8286***
				(1.5989)	(1.5944)
Share of exporters					-1.2193***
x ΔTOT					(.2870)
Sector dummies	YES	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES	YES
Mean TFP	62.0282	55.8045	51.4509	62.3931	62.3931
Number of obs.	2591	6295	3704	2563	2563
R^2	0.0766	0.0678	0.0340	0.1390	0.1452

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lag entrants

Model outline

- When MXN model meets endogenous growth theory
- Small open economy
- Three types of goods:
  - Importable (M) M
  - Exportable (X) X
  - Non-tradable (N) N

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- Separate technology producing (R&D) sector re
- TFP developed by the R&D producer is used by all sectors (common TFP level)
- Importable good price as numeraire

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Households

At time t choose:

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- and rents for capital services $r_t^{km}, r_t^{kx}, r_t^{kn}$ to the respective industries

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One-period utility function:

$$U(c, l^m, l^x, l^n, h) = \frac{[c - L(l^m, l^x, l^n, h)]^{1-\sigma} - 1}{1-\sigma}$$

where

$$L(l^m, l^x, l^n, h) = \frac{(l^m)^{\omega_m}}{\omega_m} + \frac{(l^x)^{\omega_x}}{\omega_x} + \frac{(l^n)^{\omega_n}}{\omega_n} + \frac{(h)^{\omega_h}}{\omega_h}$$

HH max problem | HH FOC | M | N

Firms producing exportable goods

Profit maximization:

$$\max_{\{l_t^x, k_t^x\}} tot_t y_t^x - w_t^x l_t^x - r_t^{kx} k_t^x$$

subject to

$$y_t^x = A_t z_t F^x(k_t^x, l_t^x) \tag{1}$$

First order conditions:

$$[l_t^x :] \quad tot_t A_t z_t F_2^x(k_t^x, l_t^x) = w_t^x \tag{2}$$

$$[k_t^x :] \quad tot_t A_t z_t F_1^x(k_t^x, l_t^x) = r_t^{kx} \tag{3}$$

back TFP shock process

Technology producers

Profit maximization

$$\max_{\{A_{t+1},h_t^x\}}\left\{\quad E_0\sum_{t=0}^{\infty}\prod_{i=0}^{t-1}\frac{1}{1+r_i}(A_{t+1}-s_t h_t)\quad\right\}$$

subject to

$$A_{t+1}-A_t=BA_t z_t h_t^{\gamma} \tag{4}$$

First order condition:

$$[h_t :]\quad BA_t z_t \gamma {h_t}^{\gamma-1}=s_t \tag{5}$$

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Terms of trade process

Terms of trade process

$$\ln \frac{tot_t}{\overline{tot}} = \rho \ln \frac{tot_{t-1}}{\overline{tot}} + \sigma_{tot}\varepsilon_t$$

where

- $\overline{tot} > 0$ is the deterministic level of the terms of trade
- $\rho \in (-1, 1)$ is the serial correlation of the process
- $\sigma_{tot} > 0$ is the standard deviation of the innovation to the terms of trade

with estimated $\rho = 0.46$, $\sigma_{tot} = 0.0166$, $R^2 = 0.26$

Interest rate | Market clearing | Competitive equilibrium

Mechanism - intuition

By households first order conditions:

$$-U_{h_t} = \lambda_t s_t$$

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Using producers' FOC we substitute out the wages:

$$-\frac{U_{h_t}}{BA_t \gamma {h_t}^{\gamma-1}} = -\frac{U_{l_t^x}}{tot_t A_t F_2^x(k_t^x, l_t^x)}$$

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As *tot* goes up, RHS goes down

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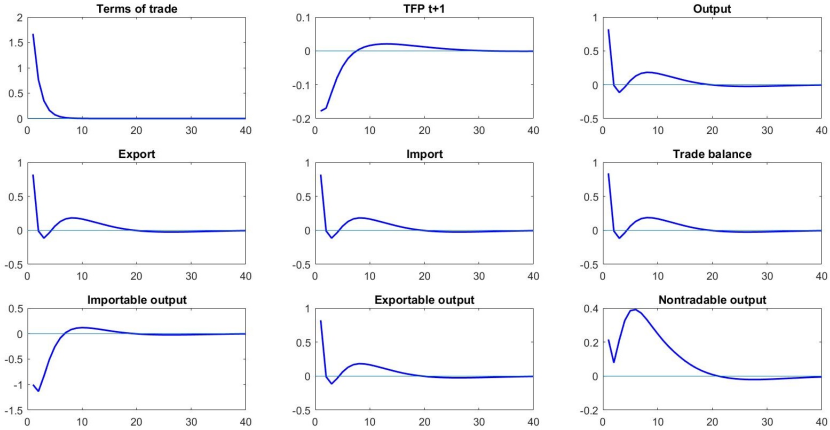
Quantitative analysis

- Analysis of impulse responses of theoretical model variables to the terms of trade shock
- Functional forms: GHH preferences, Cobb-Douglas production function, CES aggregator of composite goods functions
- Standard calibration of the MXN model following Schmitt-Grohé and Uribe (2018) adjusted for the analyzed countries calibration

Model performance: impulse responses 1/2



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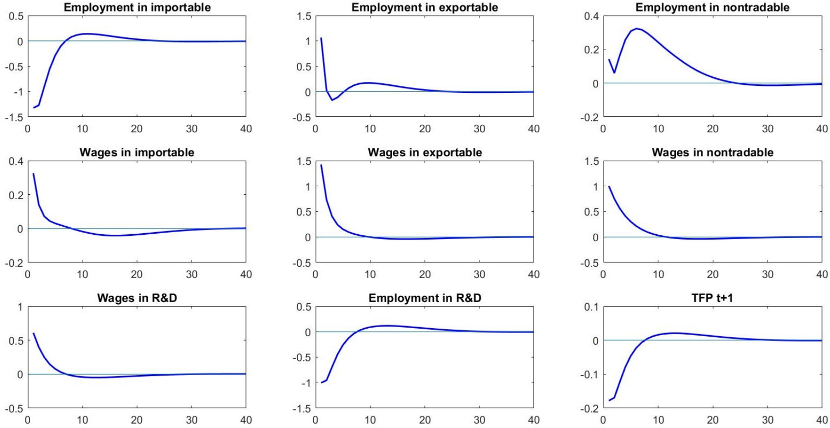
Model performance: impulse responses 2/2



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Model performance - matching moments

Statistic	Data	Model
Targeted moments		
Average share of import in total trade	49.01%	48.54%
Average trade share of nontradables in GDP	62.71%	62.35%
Average trade balance share in GDP	2.38%	2.33%
Non-targeted moments		
Standard deviation output	2.71%	3.70%
Autocorrelation output	0.76	0.79
Standard deviation TFP	1.57%	0.99%
Autocorrelation TFP	0.72	0.73
Standard deviation R&D spending	3.70%	3.06%
Autocorrelation R&D spending	0.70	0.82
Correlation output vs. TFP	0.71	0.79
Correlation output vs. R&D	0.31	0.83

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Conclusions

- In this paper I study how changes in the terms of trade affect total factor productivity
- Empirical evidence both on micro and macro level suggests that changes in TFP decrease as a response to an increase in TOT
- Theoretical model shows that TOT gains increase employment in physical goods production at the expense of labor in technological sector
- This results in less resources employed in knowledge production and slows down the TFP growth

Thank you!

Trade in GDP

Country	Average share of exports+imports in GDP over 1985-2016
Austria	83.46
Belgium	134.73
Denmark	81.97
Estonia	143.01*
Finland	66.54
France	49.93
Germany	61.41
Ireland	150.78
Italy	46.73
Lithuania	117.08*
Netherlands	121.25
Portugal	65.32
Slovenia	118.99*
Spain	49.81
Sweden	74.66
United Kingdom	52.18

* over the period 1995-2016

Source: World Development Indicators back back

SVAR specification

$$\begin{bmatrix} TFP_t \\ TOT_t \end{bmatrix} = \begin{bmatrix} \psi_{11}(L) & \psi_{12}(L) \\ \psi_{21}(L) & \psi_{22}(L) \end{bmatrix} \begin{bmatrix} \epsilon_t^{TFP} \\ \epsilon_t^{TOT} \end{bmatrix}$$

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where

TFP_t is total factor productivity,

TOT_t are the terms of trade,

$\psi_{ii}(L)$ are polynomials of the lag operator,

ϵ_t^{TFP} is a structural TFP shock,

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Our LR restriction corresponds to $\psi_{12}(1) = 0$ back

Regression specification

$$\Delta TFP_{sct} = \alpha + \beta \Delta TOT_{ct} + \eta_s + \nu_c + \gamma_t + \varepsilon_{sct}$$

where

- TFP_{sct} is the total factor productivity in time t, sector s and country c
- TOT_{ct} are the terms of trade in time t and country c
- η_s captures the sector fixed effect
- ν_c captures the country fixed effect
- γ_t captures the time fixed effect
- ε_{sct} is the error term

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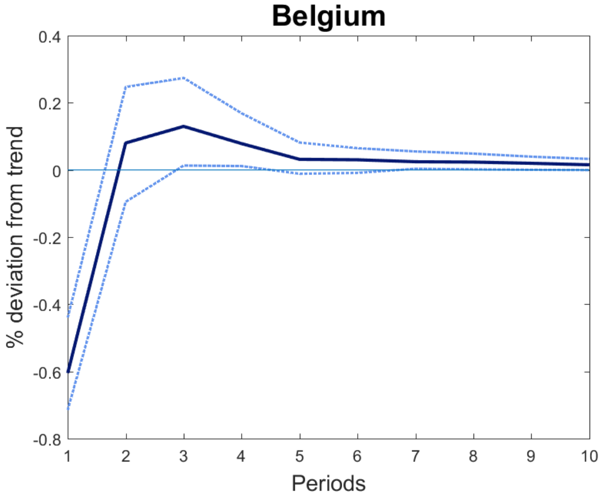
Impulse responses of TFP to TOT shocks in Belgium



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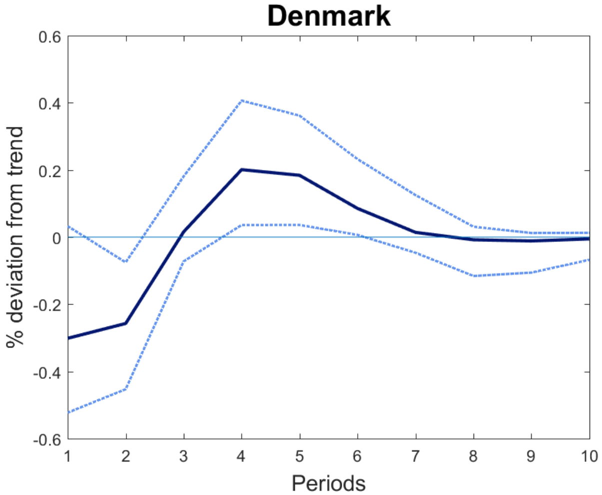
Impulse responses of TFP to TOT shocks in Denmark



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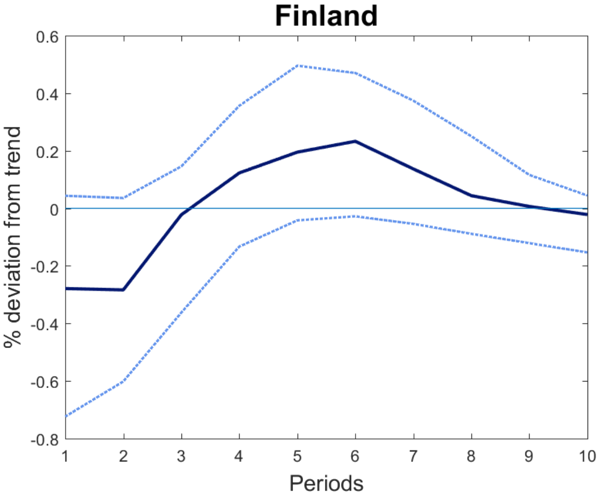
Impulse responses of TFP to TOT shocks in Finland



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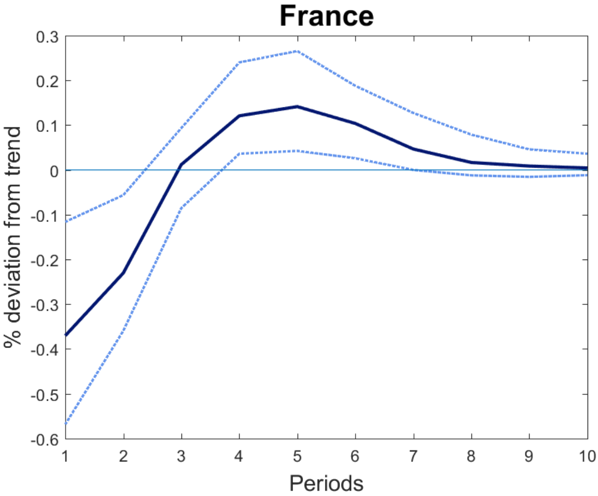
Impulse responses of TFP to TOT shocks in France



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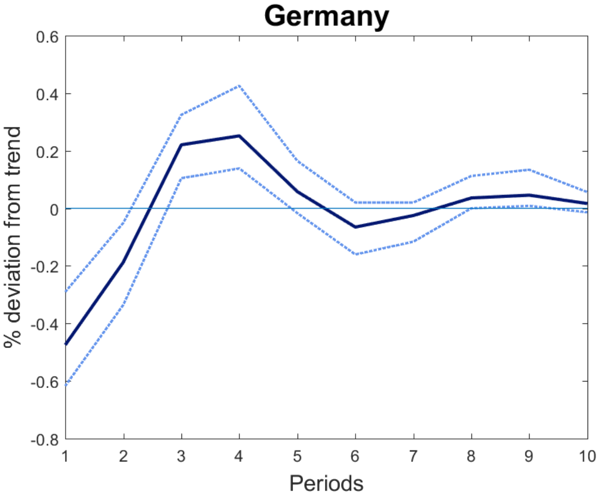
Impulse responses of TFP to TOT shocks in Germany



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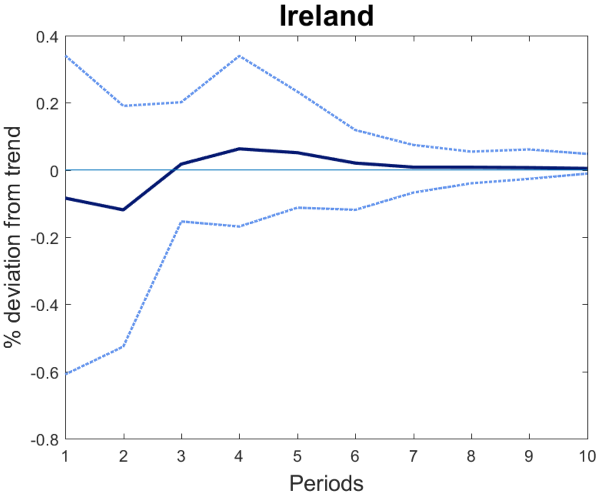
Impulse responses of TFP to TOT shocks in Ireland



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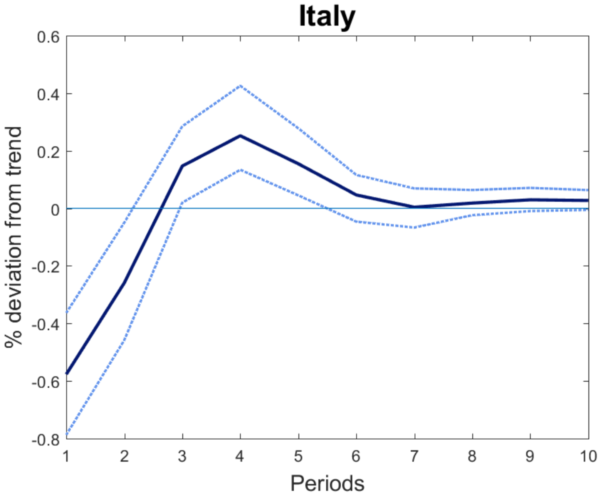
Impulse responses of TFP to TOT shocks in Italy



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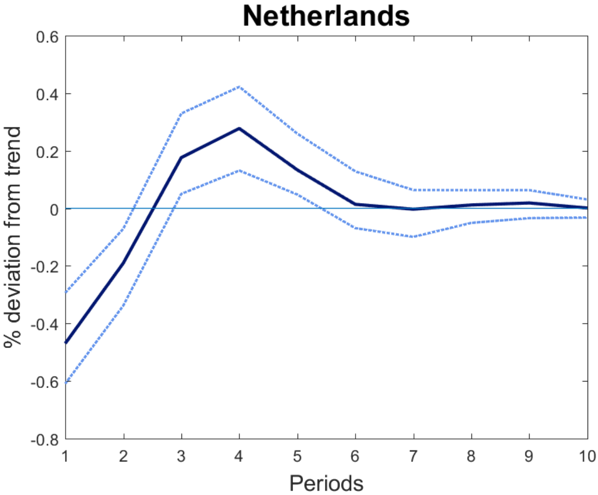
Impulse responses of TFP to TOT shocks in Netherlands



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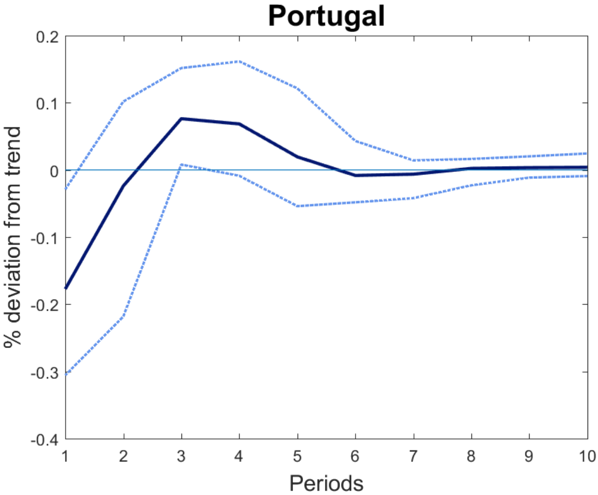
Impulse responses of TFP to TOT shocks in Portugal



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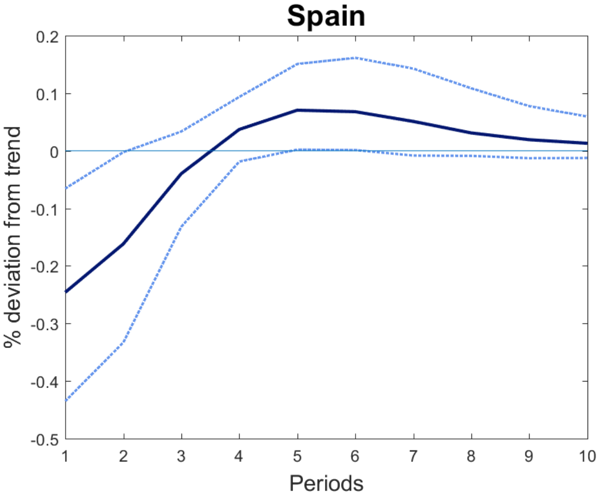
Impulse responses of TFP to TOT shocks in Spain



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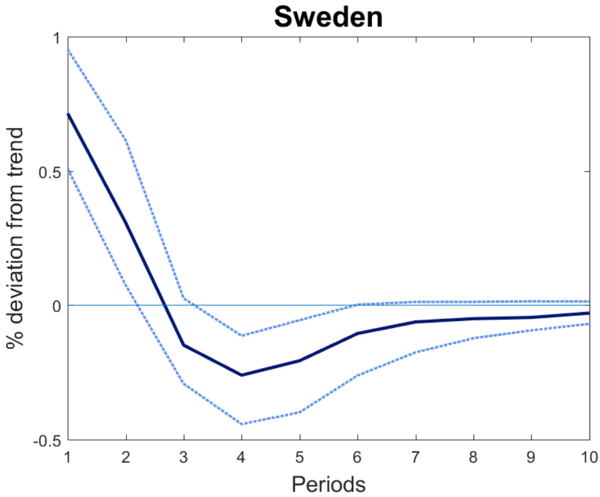
Impulse responses of TFP to TOT shocks in Sweden



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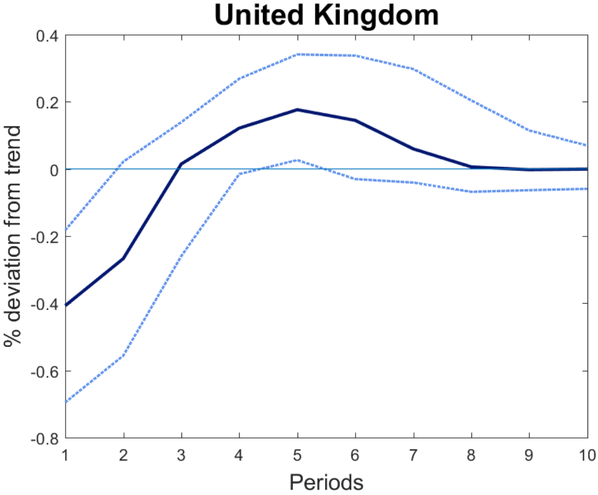
Impulse responses of TFP to TOT shocks in the United Kingdom



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Regression results - all sectors

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP	ΔTFP
ΔTOT	-.2894***	-.2861***	-.3076***	-.1081*	-.3069***	-.1057*	-.1022*	-.1019*
	(.0359)	(.0356)	(.0379)	(.0467)	(.0376)	(.0463)	(. 0513)	(.0509)
Sector dummies	NO	YES	NO	NO	YES	YES	NO	YES
Country dummies	NO	NO	YES	NO	YES	NO	YES	YES
Year dummies	NO	NO	NO	YES	NO	YES	YES	YES

Improvements in TOT tend to reduce changes in TFP

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Time span for different countries in micro sample

country	years
Austria	2001-2012
Belgium	1997-2011
Estonia	1996-2012
Finland	2000-2012
Germany	1998-2012
Italy	2002-2012
Lithuania	2001-2011
Slovenia	1996-2012
Portugal	2007-2012
Spain	1996-2012

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Manufacturing industries

Manufacture of food products
Manufacture of beverages
Manufacture of tobacco products
Manufacture of textiles
Manufacture of wearing apparel
Manufacture of leather and related products
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Manufacture of paper and paper products
Printing and reproduction of recorded media
Manufacture of chemicals and chemical products
Manufacture of basic pharmaceutical products and pharmaceutical preparations
Manufacture of rubber and plastic products
Manufacture of other nonmetallic mineral products
Manufacture of basic metals
Manufacture of fabricated metal products, except machinery and equipment
Manufacture of computer, electronic and optical products
Manufacture of electrical equipment
Manufacture of machinery and equipment
Manufacture of motor vehicles, trailers and semitrailers
Manufacture of other transport equipment
Manufacture of furniture
Other manufacturing

Source: CompNet back

Non-manufacturing industries

Repair and installation of machinery and equipment
Construction of buildings
Civil engineering
Specialised construction activities
Wholesale and retail trade and repair of motor vehicles and motorcycles
Wholesale trade, except of motor vehicles and motorcycles
Retail trade, except of motor vehicles and motorcycles
Land transport and transport via pipelines
Water transport
Air transport
Warehousing and support activities for transportation
Postal and courier activities
Accommodation
Food and beverage service activities
Publishing activities
Motion picture, video and television programme production, sound recording and music publishing activities
Programming and broadcasting activities
Telecommunications
Computer programming, consultancy and related activities
Information service activities
Real estate activities
Legal and accounting activities
Activities of head offices; management consultancy activities
Architectural and engineering activities; technical testing and analysis
Scientific research and development
Advertising and market research
Other professional, scientific and technical activities
Veterinary activities
Rental and leasing activities
Employment activities
Travel agency, tour operator and other reservation service and related activities
Security and investigation activities
Services to buildings and landscape activities
Office administrative, office support and other business support activities

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R&D channel - regression

Country	Regression coefficient	Standard error	R^2	Sample period
Belgium	0.1729	1.2130	0.0009	1993-2016
Denmark	-0.8980	1.0650	0.0483	2001-2016
Finland	-1.6031**	0.5321	0.2323	1985-2016
France	0.5047	0.2476	0.1217	1985-2016
Germany	-0.2844	0.2231	0.0514	1985-2016
Ireland	-0.8496	0.5512	0.0734	1985-2016
Italy	0.3336	0.2688	0.0488	1985-2016
Netherlands	-0.1765	0.4769	0.0045	1985-2016
Portugal	-1.7011	0.8601	0.1154	1985-2016
Spain	0.9430*	0.4534	0.1260	1985-2016
Sweden	-0.9075	1.3203	0.0379	2003-2016
United Kingdom	0.2211	0.4163	0.0093	1985-2016

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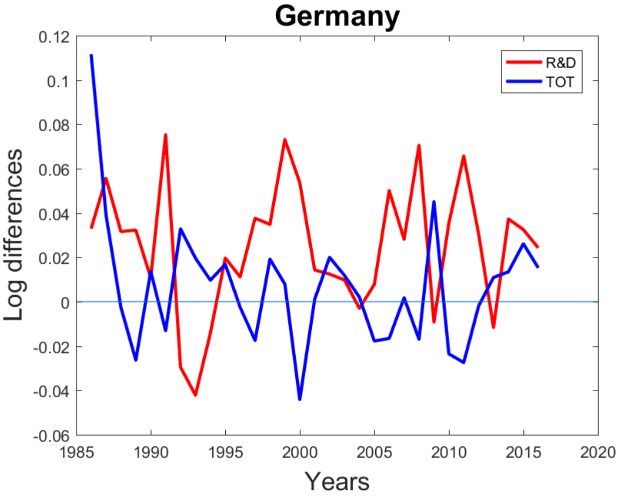
R&D channel



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R&D channel - correlations

Country	Correlation Δ log R&D with Δ log TOT	Sample period
Belgium	-0.3968	1993-2016
Denmark	-0.1371	2001-2016
Finland	-0.1592	1985-2016
France	0.0021	1985-2016
Germany	-0.3154	1985-2016
Ireland	-0.1721	1985-2016
Italy	0.1228	1985-2016
Netherlands	-0.1645	1985-2016
Portugal	-0.0426	1985-2016
Spain	0.4959	1985-2016
Sweden	-0.2364	2003-2016
United Kingdom	0.0414	1985-2016

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Households - maximization problem

$$\max_{\{c_t, l_t^m, l_t^x, l_t^n, h_t, k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, d_{t+1},\}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t^m, l_t^x, l_t^n, h_t)$$

subject to

Households - maximization problem

$$\max_{\{c_t, l_t^m, l_t^x, l_t^n, h_t, k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, d_{t+1},\}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t^m, l_t^x, l_t^n, h_t)$$

subject to

$$p_t^f c_t + p_t^\tau d_t + p_t^f \left[k_{t+1}^m + k_{t+1}^x + k_{t+1}^n + \Phi_m(k_{t+1}^m - k_t^m) + \Phi_x(k_{t+1}^x - k_t^x) + \Phi_n(k_{t+1}^n - k_t^n)\right]$$

$$= p_t^\tau \frac{d_{t+1}}{1 + r_t} + (1-\tau_t)(w_t^m l_t^m + w_t^x l_t^x + w_t^n l_t^n) + s_t h_t + r_t^{km} k_t^m + r_t^{kx} k_t^x + r_t^{kn} k_t^n + p_t^f (1-\delta)(k_t^m + k_t^x + k_t^n)$$

Households - maximization problem

$$\max_{\{c_t, l_t^m, l_t^x, l_t^n, h_t, k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, d_{t+1},\}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t^m, l_t^x, l_t^n, h_t)$$

subject to

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$$= p_t^\tau \frac{d_{t+1}}{1+r_t} + (1-\tau_t)(w_t^m l_t^m + w_t^x l_t^x + w_t^n l_t^n) + s_t h_t + r_t^{km} k_t^m + r_t^{kx} k_t^x + r_t^{kn} k_t^n + p_t^f (1-\delta)(k_t^m + k_t^x + k_t^n)$$

$$\lim_{T\to\infty} \left(\prod_{i=0}^{T-1} (1+r_i)^{-1}\right) \frac{d_{T+1}}{1+r_T} = 0$$

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Households - first order conditions

$$[c_t :] \quad U_1(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t p^f \tag{6}$$

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$$[l_t^m :] \quad -U_2(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t(1-\tau_t)w_t^m \tag{7}$$

Households - first order conditions

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$$[l_t^x:] \quad -U_3(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t (1-\tau_t) w_t^x \tag{8}$$

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$$[l_t^n :] \quad -U_4(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t(1-\tau_t)w_t^n \tag{9}$$

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$$[k_{t+1}^m :] \quad \lambda_t [1 + \Phi_m'(k_{t+1}^m - k_t^m)] p_t^f = \beta E_t \lambda_{t+1} [r_{t+1}^{km} + (1 - \delta + \Phi_m'(k_{t+2}^m - k_{t+1}^m)) p_{t+1}^f] \tag{11}$$

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$$[l_t^x :] \quad - U_3(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t (1 - \tau_t) w_t^x \tag{8}$$

$$[l_t^n :] \quad - U_4(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t (1 - \tau_t) w_t^n \tag{9}$$

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$$[k_{t+1}^n :] \quad \lambda_t [1 + \Phi_n'(k_{t+1}^n - k_t^n)] p_t^f = \beta E_t \lambda_{t+1} [r_{t+1}^{kn} + (1 - \delta + \Phi_n'(k_{t+2}^n - k_{t+1}^n)) p_{t+1}^f] \tag{13}$$

$$[d_{t+1} :] \quad \lambda_t p_t^\tau = \beta (1 + r_t) E_t \lambda_{t+1} p_{t+1}^\tau \tag{14}$$

Firms producing importable goods

Profit maximization:

$$\max_{\{l_t^m, k_t^m\}} y_t^m - w_t^m l_t^m - r_t^{km} k_t^m$$

subject to

$$y_t^m = A_t z_t F^m(k_t^m, l_t^m)$$

First order conditions:

$$[l_t^m :] \quad A_t F_2^m(k_t^m, l_t^m) = w_t^m$$

$$[k_t^m :] \quad A_t F_1^m(k_t^m, l_t^m) = r_t^{km}$$

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Firms producing nontradable goods

Profit maximization:

$$\max_{\{l_t^n, k_t^n\}} p_t^n y_t^n - w_t^n l_t^n - r_t^{kn} k_t^n$$

subject to

$$y_t^n = A_t z_t F^n(k_t^n, l_t^n)$$

First order conditions:

$$[l_t^n :] \quad p_t^n A_t F_2^n(k_t^n, l_t^n) = w_t^n$$

$$[k_t^n :] \quad p_t^n A_t F_1^n(k_t^n, l_t^n) = r_t^{kn}$$

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Exporting, R&D, innovation and productivity

- Bishop and Wiseman (1999): involvement in export markets has a positive impact on innovation
- Criscuolo et. al. (2010): exporters have more innovation outputs than non-exporters due to higher R&D
- Aw et. al. (2011): exporting boosts productivity; exporting firms investing in R&D having higher productivity compared to exporters not investing in R&D
- Harris (2011): in both manufacturing and services, being involved in exporting increases the probability that a firm was engaged in spending on R&D

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Growth rate of the technology

Since

$$A_{t+1} - A_t = BA_t^{\theta} {h_t}^{\gamma}$$

Then the growth rate of the technology is given by

$$g_t^A = \frac{A_{t+1} - A_t}{A_t} = BA_t^{\theta-1} {h_t}^{\gamma}$$

Itself grows at

$$\frac{g_{t+1}^A - g_t^A}{g_t^A} = \gamma n + (\theta - 1) g_t^A$$

where $n = \frac{h_{t+1} - h_t}{h_t}$. To have a stable growth path, i.e., $\frac{g_{t+1}^A - g_t^A}{g_t^A} = 0$ which is positive we need either $n = 0$ and $\theta = 1$ or $\theta < 1$ for $n > 0$. In the latter case

$$g_t^A = \frac{\gamma n}{1 - \theta}$$

We assume the former. back

Effects of TOT on TFP

$$s_t = \frac{U_{h_t}}{U_{l_t^x}} tot_t A_t z_t F_2^x(k_t^x, l_t^x)$$

Effects of TOT on TFP

$$s_t = \frac{U_{h_t}}{U_{l_t^x}} tot_t A_t z_t F_2^x(k_t^x, l_t^x)$$

By TFP production function:

$$h_t = \left(\frac{s_t}{BA_t z_t \gamma}\right)^{\frac{1}{\gamma-1}} = \left(\frac{\frac{U_{h_t}}{U_{l_t^x}} tot_t A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma}\right)^{\frac{1}{\gamma-1}}$$

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$$\frac{dh_t}{dtot_t} = \frac{-\frac{1}{\gamma-1}\left(\frac{\frac{U_{h_t}}{U_{l_t^x}} tot_t A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma}\right)^{\frac{1}{\gamma-1}-1} \frac{\frac{U_{h_t}}{U_{l_t^x}} A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma}}{\frac{1}{\gamma-1}\left(\frac{\frac{U_{h_t}}{U_{l_t^x}} tot_t A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma}\right)^{\frac{1}{\gamma-1}-1} \frac{A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma} \frac{U_{h_t h_t} U_{l_t^x} - U_{h_t} U_{l_t^x h_t}}{(U_{l_t^x})^2} - 1} < 0$$

As long as $U_{h_t h_t} U_{l_t^x} > U_{h_t} U_{l_t^x h_t} \iff \frac{U_{h_t h_t}}{U_{h_t}} h_t > \frac{U_{l_t^x h_t}}{U_{l_t^x}} h_t$

Effects of TOT on TFP

$$s_t = \frac{U_{h_t}}{U_{l_t^x}} tot_t A_t z_t F_2^x(k_t^x, l_t^x)$$

By TFP production function:

$$h_t = \left(\frac{s_t}{BA_t z_t \gamma}\right)^{\frac{1}{\gamma-1}} = \left(\frac{\frac{U_{h_t}}{U_{l_t^x}} tot_t A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma}\right)^{\frac{1}{\gamma-1}}$$

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As long as $U_{h_t h_t} U_{l_t^x} > U_{h_t} U_{l_t^x h_t} \iff \frac{U_{h_t h_t}}{U_{h_t}} h_t > \frac{U_{l_t^x h_t}}{U_{l_t^x}} h_t$

$$\frac{dA_{t+1}}{dtot_t} = \frac{dA_{t+1}}{dh_t} \frac{dh_t}{dtot_t} < 0$$

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Interest rate

Interest rate is assumed to be given by

$$r_t = r^* + p(d_{t+1})$$

with debt-elastic premium,
where

- r^* is the world interest rate
- the function $p(.)$ is assumed to be increasing and takes the form

$$p(d) = \psi(e^{d-\bar{d}})$$

where $\bar{d}$ is the steady state level of debt

back back

Import, export and market clearing

Import:

$$m_t = a_t^m - y_t^m$$

Export:

$$x_t = tot_t(y_t^x - a_t^x)$$

Nontradables:

$$a_t^n = y_t^n$$

Final goods:

$$c_t + k_{t+1}^m + k_{t+1}^x + k_{t+1}^n - (1-\delta)(k_t^m + k_t^x + k_t^n) + \Phi_m(k_{t+1}^m - k_t^m) + \Phi_x(k_{t+1}^x - k_t^x) + \Phi_n(k_{t+1}^n - k_t^n) = H(a_t^\tau, a_t^n)$$

Then from households' budget constraint and by firms making zero profits:

$$m_t - x_t + p_t^\tau d_t = p_t^\tau \frac{d_{t+1}}{1+r_t}$$

which is the economy-wide resource constraint. back

Competitive equilibrium

A competitive equilibrium is

Competitive equilibrium

A competitive equilibrium is

a set of prices $\{r_t^{km}, r_t^{kx}, r_t^{kn}, w_t^m, w_t^x, w_t^n, s_t, p_t^f, p_t^\tau, p_t^n, r_t\}_{t=0}^{\infty}$,

Competitive equilibrium

A competitive equilibrium is

a set of prices $\{r_t^{km}, r_t^{kx}, r_t^{kn}, w_t^m, w_t^x, w_t^n, s_t, p_t^f, p_t^\tau, p_t^n, r_t\}_{t=0}^{\infty}$, an allocation $\{k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, l_t^m, l_t^x, l_t^n, h_t, A_{t+1}, y_t^m, y_t^x, y_t^n, c_t, a_t^m, a_t^x, a_t^n, a_t^\tau, m_t, x_t, d_{t+1}\}_{t=0}^{\infty}$,

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an allocation $\{k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, l_t^m, l_t^x, l_t^n, h_t, A_{t+1}, y_t^m, y_t^x, y_t^n,$
$c_t, a_t^m, a_t^x, a_t^n, a_t^\tau, m_t, x_t, d_{t+1}\}_{t=0}^{\infty}$,
a sequence of multipliers $\{\lambda_t\}_{t=0}^{\infty}$,
and a tax system $\{\tau_t\}_{t=0}^{\infty}$

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a sequence of multipliers $\{\lambda_t\}_{t=0}^\infty$,
and a tax system $\{\tau_t\}_{t=0}^\infty$

which solve households and firms optimization problem

such that markets clear

given the initial conditions $k_0^m, k_0^x, k_0^n, d_0, A_0, tot_{-1}, z_{-1}$

and the stochastic processes $\{tot_t, z_t\}_{t=0}^\infty$.

back

Functional forms

Utility function:

$$U(c, l^m, l^x, l^n, h) = \frac{[c - L(l^m, l^x, l^n, h)]^{1-\sigma} - 1}{1 - \sigma}$$

where

$$L(l^m, l^x, l^n, h) = \frac{(l^m)^{\omega_m}}{\omega_m} + \frac{(l^x)^{\omega_x}}{\omega_x} + \frac{(l^n)^{\omega_n}}{\omega_n} + \frac{(h)^{\omega_h}}{\omega_h}$$

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back

Production functions:

$$F^m(k^m, l^m) = (k^m)^{\alpha_m}(l^m)^{1-\alpha_m}$$
$$F^x(k^x, l^x) = (k^x)^{\alpha_x}(l^x)^{1-\alpha_x}$$
$$F^n(k^n, l^n) = (k^n)^{\alpha_n}(l^n)^{1-\alpha_n}$$

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back

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$$F^n(k^n, l^n) = (k^n)^{\alpha_n}(l^n)^{1-\alpha_n}$$

CES composite goods aggregators:

$$G(a_t^m, a_t^x) = \left[\chi_m (a_t^m)^{1-\frac{1}{\nu_{mx}}} + (1-\chi_m)(a_t^x)^{1-\frac{1}{\nu_{mx}}}\right]^{\frac{1}{1-\frac{1}{\nu_{mx}}}}$$

$$H(a_t^\tau, a_t^n) = \left[\chi_\tau (a_t^\tau)^{1-\frac{1}{\nu_{\tau n}}} + (1-\chi_\tau)(a_t^n)^{1-\frac{1}{\nu_{\tau n}}}\right]^{\frac{1}{1-\frac{1}{\nu_{\tau n}}}}$$

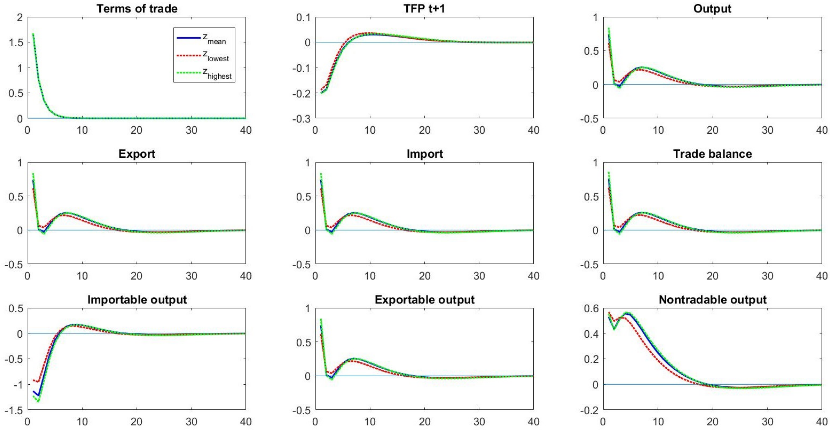
back

Calibration

Parameter	Description	Value
σ	Coefficient of the relative risk aversion	2
β	Subjective discount factor	0.95
ω^m	$\frac{1}{\omega^m - 1}$ = Importable goods labor supply elasticity	1.455
ω^x	$\frac{1}{\omega^x - 1}$ = Exportable goods labor supply elasticity	1.455
ω^n	$\frac{1}{\omega^n - 1}$ = Nontradables goods labor supply elasticity	1.455
ω^h	$\frac{1}{\omega^h - 1}$ = Technology sector labor supply elasticity	1.455
α_m	Capital share in importable goods sector	0.33
α_x	Capital share in exportable goods sector	0.33
α_n	Capital share in nontradable goods sector	0.25
ν_{mx}	The elasticity of substitution between exportable and importable absorption	1
χ_m	The importables share parameter	0.9
$\nu_{\tau n}$	The elasticity of substitution between tradable and nontradable absorption	0.5
χ_τ	The tradable share parameter	0.36
δ	Capital depreciation rate	0.1
ψ	Parameter governing the debt elasticity of the country premium	0.08
r^*	World interest rate	0.04
$\bar{d}$	Steady state debt	4.9
$\overline{tot}$	Steady state TOT	1
ρ_{tot}	TOT autocorrelation coefficient	0.46
σ_{tot}	Standard deviation of TOT process innovation	0.0166
ρ_z	Autocorrelation coefficient of technology shock	0.72
σ_{tot}	Standard deviation of technology shock innovation	0.0114
B	Shift parameter of the knowledge production function	1
γ	Parameter of the knowledge production function	0.4

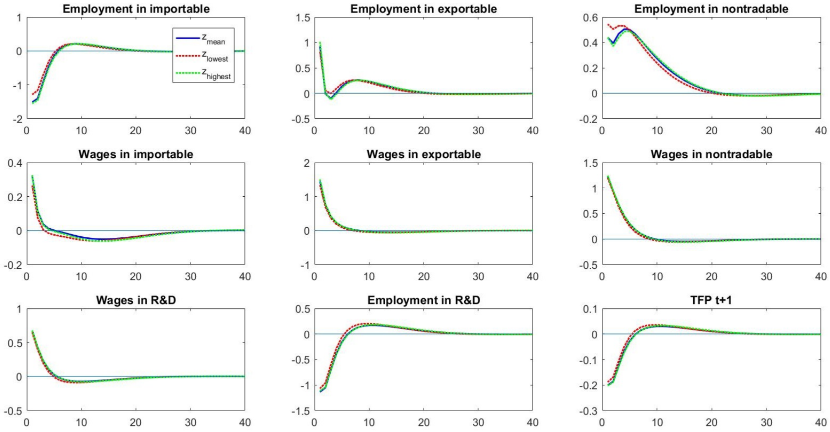
back

Model performance: impulse responses 1/2



back

Model performance: impulse responses 2/2



back

Total factor productivity shock process

Total factor productivity shock process

$$\ln \frac{z_t}{\bar{z}} = \rho_z \ln \frac{z_{t-1}}{\bar{z}} + \sigma_z \varepsilon_t$$

where

- $\bar{z} > 0$ is the deterministic level of total factor productivity
- $\rho_z \in (-1, 1)$ is the serial correlation of the process
- $\sigma_z > 0$ is the standard deviation of the innovation to the TFP shock process

with estimated $\rho = 0.72$, $\sigma_{tot} = 0.0114$

back back

Mechanism explicitly - functional forms

By households first order conditions:

$$[c - L]^{-\sigma}(h)^{\omega_h - 1} = \lambda_t s_t$$

$$[c - L]^{-\sigma}(l^x)^{\omega_x - 1} = \lambda_t w_t^x$$

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we have that

$$\lambda_t = \frac{[c-L]^{-\sigma}(h)^{\omega_h-1}}{s_t} = \frac{[c-L]^{-\sigma}(l^x)^{\omega_x-1}}{w_t^x}$$

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Using exporters FOC we substitute out the wages:

$$\frac{(h_t)^{\omega_h - 1}}{\mu_t B A_t \gamma {h_t}^{\gamma - 1}} = \frac{(l^x)^{\omega_x - 1}}{tot_t A_t F_2^x(k_t^x, l_t^x)}$$

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As *tot* goes up, RHS goes down

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As *tot* goes up, RHS goes down $\implies$ LHS needs to go down

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As *tot* goes up, RHS goes down $\implies$ LHS needs to go down $\implies$ h_t needs to fall back

Mechanism

- Terms of trade shocks affect the incentives to develop new and better technology
- Terms of trade improvement increases demand for labor in physical exportable goods production, as well as employment in the sector
- But it also decreases demand for labor in R&D production, so that employment in this subsector drops
- This substitution effect has a negative impact on future TFP
- Terms of trade gains reduce technological effort!

re

New entrants

Analysis for: Germany (2011-2012), Portugal (2008-2012), Spain (2007-2012)

Model	(14)	(15)	(16)
	ΔTFP	ΔTFP	ΔTFP
ΔTOT	-1.2218*	-1.1935*	-1.3117*
	(.6020)	(.6028)	(.6391)
New entrants		**.0001428**	
		(.0001499)	
Δ New entrants			**-.0005477**
			(.0006245)
Sector dummies	YES	YES	YES
Country dummies	YES	YES	YES
Year dummies	YES	YES	YES
Mean TFP	62.2994	62.2994	62.2994
Number of obs.	260	260	260
R^2	0.2564	0.2596	0.1870

Standard deviation in parenthesis. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

back

Robustness - openness of the industry

Sample	Manufacturing	Manufacturing	Manufacturing
Model	(8)	(17)	(18)
	ΔTFP	ΔTFP	ΔTFP
ΔTOT	-.2866***	-.2924***	.1562
	(.0770)	(.0772)	(.1307)
Share of exporters		7.0555***	6.8286***
		(1.5989)	(1.5944)
Share of exporters x ΔTOT			-1.2193***
			(.2870)
Sector dummies	YES	YES	YES
Country dummies	YES	YES	YES
Year dummies	YES	YES	YES
Mean TFP	62.0282	62.3931	62.3931
Number of obs.	2591	2563	2563
R^2	0.0766	0.1390	0.1452

Standard deviation in parenthesis. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

back

Robustness - lagged changes in TOT

Sample	Manufact	Manufact	Manufact	Manufact
Model	(8)	(18)	(19)	(20)
	ΔTFP	ΔTFP	ΔTFP	ΔTFP
ΔTOT	**-.2866*** **	**-.3059*** **	**-.3697*** **	**-.4180*** **
	(.0770)	(.0822)	(.0859)	(.0989)
Lagged ΔTOT (t-1)		.0469	.0560	.0797
		(.0797)	(.0836)	(.0932)
Lagged ΔTOT (t-2)			-.1792*	-.1888*
			(.0840)	(.0903)
Lagged ΔTOT (t-3)				.0692
				(.1043)
Sector dummies	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES
Mean TFP	62.0282	62.0282	62.0282	62.0282
Number of obs.	2591	2591	2591	2591
R^2	0.0766	0.1387	0.1278	0.1182

Standard deviation in parenthesis. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

back