Total factor productivity and the terms of trade

Jan Teresieński

European University Institute

8 October 2019
Motivation

- 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.
Motivation

- 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.
Motivation

- 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

Do changes in the terms of trade affect total factor productivity development?

▶ Substitutability channel: Given limited resources, improvements of TOT result in putting more resources in physical goods production at the expense of R&D which slows down TFP growth

▶ Complementarity channel: Improvements in TOT make the economy richer which allows to expand both physical goods production and R&D activity

Empirical analysis supports the first channel - TOT gains slow down TFP growth
Research question and possible channels

Do changes in the terms of trade affect total factor productivity development?

If TOT affect TFP, there can be two possible channels of influence:
Research question and possible channels

Do changes in the terms of trade affect total factor productivity development?

If TOT affect TFP, there can be two possible channels of influence:

- **Substitutability channel**: Given limited resources, improvements of TOT result in putting more resources in physical goods production at the expense of R&D which slows down TFP growth.
Research question and possible channels

Do changes in the terms of trade affect total factor productivity development?

If TOT affect TFP, there can be two possible channels of influence:

- **Substitutability channel**: Given limited resources, improvements of TOT result in putting more resources in physical goods production at the expense of R&D which slows down TFP growth.

- **Complementarity channel**: Improvements in TOT make the economy richer which allows to expand both physical goods production and R&D activity.
Research question and possible channels

Do changes in the terms of trade affect total factor productivity development?

If TOT affect TFP, there can be two possible channels of influence:

- **Substitutability channel**: Given limited resources, improvements of TOT result in putting more resources in physical goods production at the expense of R&D which slows down TFP growth

- **Complementarity channel**: Improvements in TOT make the economy richer which allows to expand both physical goods production and R&D activity

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


▶ Empirical studies on TFP determinants:

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
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

- OECD dataset, time span 1985-2016, annual frequency

- Country-specific for: Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom
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
- OECD dataset, time span 1985-2016, annual frequency
- Country-specific for: Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom
- Negative and significant response on impact for 9 out of 12 countries
Impulse responses of TFP to TOT shocks 1/2
Impulse responses of TFP to TOT shocks 2/2

[Graphs showing impulse responses for Italy, Netherlands, Portugal, Spain, Sweden, and United Kingdom]
Micro evidence

How does the industry level TFP respond to changes in TOT?
Micro evidence

- How does the industry level TFP respond to changes in TOT?
- 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
Micro evidence

- How does the industry level TFP respond to changes in TOT?
- 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
- Competitiveness Research Network (CompNet) firm-level based dataset
- 22 manufacturing industries
- 10 countries: Austria, Belgium, Estonia, Finland, Germany, Italy, Lithuania, Portugal, Slovenia and Spain
- Time span: 1996-2012 (unbalanced panel), annual frequency
Regression results

<table>
<thead>
<tr>
<th>Model</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
</tr>
<tr>
<td>ΔTOT</td>
<td>-0.4923***</td>
<td>-0.4935***</td>
<td>-0.4958***</td>
<td>-0.3179***</td>
<td>-0.4956***</td>
<td>-0.3198***</td>
<td>-0.2857***</td>
<td>-0.2866***</td>
</tr>
<tr>
<td></td>
<td>(.0550)</td>
<td>(.0543)</td>
<td>(.0579)</td>
<td>(.0718)</td>
<td>(.0576)</td>
<td>(.0708)</td>
<td>(.0783)</td>
<td>(.0770)</td>
</tr>
<tr>
<td>Sector dummies</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Country dummies</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year dummies</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Number of obs.</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
</tr>
<tr>
<td>R²</td>
<td>0.0296</td>
<td>0.0599</td>
<td>0.0482</td>
<td>0.0808</td>
<td>0.0802</td>
<td>0.1127</td>
<td>0.0989</td>
<td>0.0766</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sample</th>
<th>Manufact</th>
<th>All</th>
<th>Non-manufact</th>
<th>Manufact</th>
<th>Manufact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>(8)</td>
<td>(9)</td>
<td>(10)</td>
<td>(11)</td>
<td>(12)</td>
</tr>
<tr>
<td>( \Delta TFP )</td>
<td>( \Delta TFP )</td>
<td>( \Delta TFP )</td>
<td>( \Delta TFP )</td>
<td>( \Delta TFP )</td>
<td>( \Delta TFP )</td>
</tr>
<tr>
<td>( \Delta TOT )</td>
<td>-.2866***</td>
<td>-.1019*</td>
<td>.0193</td>
<td>-.2924***</td>
<td>.1562</td>
</tr>
<tr>
<td>Share of exporters</td>
<td></td>
<td></td>
<td></td>
<td>7.0555***</td>
<td>6.8286***</td>
</tr>
<tr>
<td>( \times \Delta TOT )</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Sector dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Country dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Mean TFP</td>
<td>62.0282</td>
<td>55.8045</td>
<td>51.4509</td>
<td>62.3931</td>
<td>62.3931</td>
</tr>
<tr>
<td>Number of obs.</td>
<td>2591</td>
<td>6295</td>
<td>3704</td>
<td>2563</td>
<td>2563</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.0766</td>
<td>0.0678</td>
<td>0.0340</td>
<td>0.1390</td>
<td>0.1452</td>
</tr>
</tbody>
</table>

Standard deviation in parenthesis. * \( p < 0.05 \); ** \( p < 0.01 \); *** \( p < 0.001 \)
Model outline

▶ When MXN model meets endogenous growth theory
▶ Small open economy
▶ Three types of goods:
  ▶ Importable (M)
  ▶ Exportable (X)
  ▶ Non-tradable (N)
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) \( N \)
- Separate technology producing (R&D) sector \( r_e \)
- TFP developed by the R&D producer is used by all sectors (common TFP level)
- Importable good price as numeraire
Households

At time $t$ choose:

- consumption $c_t$
Households

At time $t$ choose:

- consumption $c_t$
- labor supply to importables $l_m^t$, exportables $l_x^t$ and nontradables $l_n^t$ and knowledge production $h_t$ sector
Households

At time $t$ choose:

- consumption $c_t$
- labor supply to importables $l^m_t$, exportables $l^x_t$ and nontradables $l^n_t$ and knowledge production $h_t$ sector
- capital supply to importables $k^m_{t+1}$, exportables $k^x_{t+1}$ and nontradables $k^n_{t+1}$ production sector
Households

At time $t$ choose:

- consumption $c_t$
- labor supply to importables $l^m_t$, exportables $l^x_t$ and nontradables $l^n_t$ and knowledge production $h_t$ sector
- capital supply to importables $k^m_{t+1}$, exportables $k^x_{t+1}$ and nontradables $k^n_{t+1}$ production sector
- level of debt $d_{t+1}$ subject to no Ponzi scheme
Households

At time $t$ choose:

- consumption $c_t$
- labor supply to importables $l^m_t$, exportables $l^x_t$ and nontradables $l^n_t$ and knowledge production $h_t$ sector
- capital supply to importables $k^m_{t+1}$, exportables $k^x_{t+1}$ and nontradables $k^n_{t+1}$ production sector
- level of debt $d_{t+1}$ subject to no Ponzi scheme

To maximize lifetime utility subject to the budget constraint
Households

At time $t$ choose:

- consumption $c_t$
- labor supply to importables $l_t^m$, exportables $l_t^x$ and nontradables $l_t^n$ and knowledge production $h_t$ sector
- capital supply to importables $k_{t+1}^m$, exportables $k_{t+1}^x$ and nontradables $k_{t+1}^n$ production sector
- level of debt $d_{t+1}$ subject to no Ponzi scheme

to maximize lifetime utility subject to the budget constraint

- earning wages $w_t^m$, $w_t^x$, $w_t^n$, $s_t$ for work in the respective industries
Households

At time $t$ choose:

- consumption $c_t$
- labor supply to importables $l_{t}^m$, exportables $l_{t}^x$ and nontradables $l_{t}^n$ and knowledge production $h_{t}$ sector
- capital supply to importables $k_{t+1}^m$, exportables $k_{t+1}^x$ and nontradables $k_{t+1}^n$ production sector
- level of debt $d_{t+1}$ subject to no Ponzi scheme

...to maximize lifetime utility subject to the budget constraint

- earning wages $w_{t}^m$, $w_{t}^x$, $w_{t}^n$, $s_{t}$ for work in the respective industries
- and rents for capital services $r_{t}^{km}$, $r_{t}^{kx}$, $r_{t}^{kn}$ to the respective industries
Households

At time $t$ choose:

- consumption $c_t$
- labor supply to importables $l_t^m$, exportables $l_t^x$ and nontradables $l_t^n$ and knowledge production $h_t$ sector
- capital supply to importables $k_{t+1}^m$, exportables $k_{t+1}^x$ and nontradables $k_{t+1}^n$ production sector
- level of debt $d_{t+1}$ subject to no Ponzi scheme

to maximize lifetime utility subject to the budget constraint

- earning wages $w_t^m$, $w_t^x$, $w_t^n$, $s_t$ for work in the respective industries
- and rents for capital services $r_t^{km}$, $r_t^{kx}$, $r_t^{kn}$ to the respective industries

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

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

Profit maximization:

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

subject to

$$y_t^x = A_t z_t F^x(k_t^x, l_t^x) \quad (1)$$

First order conditions:

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

$$[k_t^x :] \quad tot_t A_t z_t F_1^x(k_t^x, l_t^x) = r_t^x \quad (3)$$
Technology producers

Profit maximization

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

subject to

\[
A_{t+1} - A_t = B A_t z_t h_t^\gamma 
\] (4)

First order condition:

\[
[h_t : ] \quad B A_t z_t^\gamma h_t^{\gamma - 1} = s_t 
\] (5)

gr
Terms of trade process

Terms of trade process

\[
\ln \frac{\text{tot}_t}{\text{tot}} = \rho \ln \frac{\text{tot}_{t-1}}{\text{tot}} + \sigma_{\text{tot}} \epsilon_t
\]

where

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

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

By households first order conditions:

\[-U_{ht} = \lambda_t s_t\]

\[-U_{lt}^x = \lambda_t w_t^x\]
Mechanism - intuition

By households first order conditions:

\[-U_{ht} = \lambda_t s_t\]

\[-U_{lt}^x = \lambda_t w_t^x\]

we have that

\[\lambda_t = -\frac{U_{ht}}{s_t} = -\frac{U_{lt}^x}{w_t^x}\]
Mechanism - intuition

By households first order conditions:

\[-U_{ht} = \lambda_t s_t\]

\[-U_{lt}^x = \lambda_t w_t^x\]

we have that

\[\lambda_t = -\frac{U_{ht}}{s_t} = -\frac{U_{lt}^x}{w_t^x}\]

Using producers’ FOC we substitute out the wages:

\[-\frac{U_{ht}}{BA_t \gamma h_t^{\gamma-1}} = -\frac{U_{lt}^x}{tot_t A_t F_2^x(k_t^x, l_t^x)}\]
Mechanism - intuition

By households first order conditions:

\[-U_{ht} = \lambda_t s_t\]

\[-U_{lt}^x = \lambda_t w_t^x\]

we have that

\[\lambda_t = -\frac{U_{ht}}{s_t} = -\frac{U_{lt}^x}{w_t^x}\]

Using producers’ FOC we substitute out the wages:

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

As \(tot\) goes up, RHS goes down
Mechanism - intuition

By households first order conditions:

\[-U_{ht} = \lambda_t s_t\]
\[-U_{ltx} = \lambda_t w_t^x\]

we have that

\[\lambda_t = -\frac{U_{ht}}{s_t} = -\frac{U_{ltx}}{w_t^x}\]

Using producers’ FOC we substitute out the wages:

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

As \(tot\) goes up, RHS goes down \(\implies\) LHS needs to go down
Mechanism - intuition

By households first order conditions:

\[-U_{ht} = \lambda_t s_t\]

\[-U_{lx} = \lambda_t w^x_t\]

we have that

\[\lambda_t = -\frac{U_{ht}}{s_t} = -\frac{U_{lx}}{w^x_t}\]

Using producers’ FOC we substitute out the wages:

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

As \(tot\) goes up, RHS goes down \(\implies\) LHS needs to go down

\(\implies\) \(h_t\) needs to fall

**with functional forms** **derivation**
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

- Standard calibration of the MXN model following Schmitt-Grohé and Uribe (2018) adjusted for the analyzed countries
Model performance: impulse responses 1/2

- Terms of trade
- TFP t+1
- Output
- Export
- Import
- Trade balance
- Importable output
- Exportable output
- Nontradable output
Model performance: impulse responses 2/2
## Model performance - matching moments

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

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

* over the period 1995-2016

Source: World Development Indicators
SVAR specification

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

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

where

- $TFP_t$ is total factor productivity,
- $TOT_t$ are the terms of trade,
- $\psi_{ii}(L)$ are polynomials of the lag operator,
- $\epsilon_t^{TFP}$ is a structural TFP shock,
- $\epsilon_t^{TOT}$ is a structural terms-of-trade shock

Assumption: shocks are orthogonal and serially uncorrelated.

Our LR restriction corresponds to

$\psi_{12}(1) = 0$
SVAR specification

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

where

- \( TFP_t \) is total factor productivity,
- \( TOT_t \) are the terms of trade,
- \( \psi_{ii}(L) \) are polynomials of the lag operator,
- \( \epsilon_t^{TFP} \) is a structural TFP shock,
- \( \epsilon_t^{TOT} \) is a structural terms-of-trade shock

Assumption: shocks are orthogonal and serially uncorrelated.
SVAR specification

\[
\begin{bmatrix}
TFP_t \\
TOT_t
\end{bmatrix} = \begin{bmatrix}
\psi_{11}(L) & \psi_{12}(L) \\
\psi_{21}(L) & \psi_{22}(L)
\end{bmatrix} \begin{bmatrix}
\epsilon_{t}\text{TFP} \\
\epsilon_{t}\text{TOT}
\end{bmatrix}
\]

where

- $TFP_t$ is total factor productivity,
- $TOT_t$ are the terms of trade,
- $\psi_{ii}(L)$ are polynomials of the lag operator,
- $\epsilon_{t}\text{TFP}$ is a structural TFP shock,
- $\epsilon_{t}\text{TOT}$ is a structural terms-of-trade shock

Assumption: shocks are orthogonal and serially uncorrelated.

Our LR restriction corresponds to $\psi_{12}(1) = 0$
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 \(c\)
- \(\eta_s\) captures the sector fixed effect
- \(\nu_c\) captures the country fixed effect
- \(\gamma_t\) captures the time fixed effect
- \(\varepsilon_{sct}\) is the error term
Impulse responses of TFP to TOT shocks in Belgium
Impulse responses of TFP to TOT shocks in Denmark
Impulse responses of TFP to TOT shocks in Finland
Impulse responses of TFP to TOT shocks in France
Impulse responses of TFP to TOT shocks in Germany

[Graph showing impulse responses over periods for Germany]
Impulse responses of TFP to TOT shocks in Ireland
Impulse responses of TFP to TOT shocks in Italy
Impulse responses of TFP to TOT shocks in Netherlands
Impulse responses of TFP to TOT shocks in Portugal

![Graph showing the impulse responses of TFP to TOT shocks in Portugal. The graph displays the percentage deviation from trend over various periods.](image-url)
Impulse responses of TFP to TOT shocks in Spain

![Graph showing impulse response of TFP to TOT shocks in Spain. The graph plots the percentage deviation from trend against periods, with a peak response around the 5th period.](image-url)
Impulse responses of TFP to TOT shocks in Sweden

![Graph showing the impulse responses of TFP to TOT shocks in Sweden.](image)
Impulse responses of TFP to TOT shocks in the United Kingdom

[Graph showing the percentage deviation from trend over time for the United Kingdom]
Improvements in TOT tend to reduce changes in TFP

<table>
<thead>
<tr>
<th>Model</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
<td>$\Delta \text{TFP}$</td>
</tr>
<tr>
<td>$\Delta \text{TOT}$</td>
<td>-.2894***</td>
<td>-.2861***</td>
<td>-.3076***</td>
<td>-.1081*</td>
<td>-.3069***</td>
<td>-.1057*</td>
<td>-.1022*</td>
<td>-.1019*</td>
</tr>
<tr>
<td></td>
<td>(.0359)</td>
<td>(.0356)</td>
<td>(.0379)</td>
<td>(.0467)</td>
<td>(.0376)</td>
<td>(.0463)</td>
<td>(.0513)</td>
<td>(.0509)</td>
</tr>
<tr>
<td>Sector dummies</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Country dummies</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year dummies</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
## Time span for different countries in micro sample

<table>
<thead>
<tr>
<th>country</th>
<th>years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>2001-2012</td>
</tr>
<tr>
<td>Belgium</td>
<td>1997-2011</td>
</tr>
<tr>
<td>Estonia</td>
<td>1996-2012</td>
</tr>
<tr>
<td>Finland</td>
<td>2000-2012</td>
</tr>
<tr>
<td>Germany</td>
<td>1998-2012</td>
</tr>
<tr>
<td>Italy</td>
<td>2002-2012</td>
</tr>
<tr>
<td>Lithuania</td>
<td>2001-2011</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1996-2012</td>
</tr>
<tr>
<td>Portugal</td>
<td>2007-2012</td>
</tr>
<tr>
<td>Spain</td>
<td>1996-2012</td>
</tr>
</tbody>
</table>
## Manufacturing industries

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

Source: CompNet
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
## R&D channel - regression

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Correlation $\Delta \log R&amp;D$ with $\Delta \log TOT$</th>
<th>Sample period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>-0.3968</td>
<td>1993-2016</td>
</tr>
<tr>
<td>Denmark</td>
<td>-0.1371</td>
<td>2001-2016</td>
</tr>
<tr>
<td>Finland</td>
<td>-0.1592</td>
<td>1985-2016</td>
</tr>
<tr>
<td>France</td>
<td>0.0021</td>
<td>1985-2016</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.3154</td>
<td>1985-2016</td>
</tr>
<tr>
<td>Ireland</td>
<td>-0.1721</td>
<td>1985-2016</td>
</tr>
<tr>
<td>Italy</td>
<td>0.1228</td>
<td>1985-2016</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-0.1645</td>
<td>1985-2016</td>
</tr>
<tr>
<td>Portugal</td>
<td>-0.0426</td>
<td>1985-2016</td>
</tr>
<tr>
<td>Spain</td>
<td>0.4959</td>
<td>1985-2016</td>
</tr>
<tr>
<td>Sweden</td>
<td>-0.2364</td>
<td>2003-2016</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.0414</td>
<td>1985-2016</td>
</tr>
</tbody>
</table>
Households - maximization problem

\[
\max_{\{c_t, l^m_t, l^x_t, l^n_t, h_t, k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, d_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l^m_t, l^x_t, l^n_t, h_t)
\]

subject to
Households - maximization problem

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

subject to

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

\[
= p_t^\tau \frac{d_{t+1}}{1 + r_t} + (1 - \tau_t)(w_t^m l_t^m + w_t^x l_t^x + w_t^n l_t^n) + s_t h_t + r_t^m k_t^m + r_t^x k_t^x + r_t^n k_t^n + p_t^f (1 - \delta)(k_t^m + k_t^x + k_t^n)
\]
Households - maximization problem

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

subject to

\[p^f_t c_t + p^\tau_t d_t + p^f_t \left[ k_{t+1}^m + k_{t+1}^x + k_{t+1}^n + \Phi_m(k_{t+1}^m - k_t^m) + \Phi_x(k_{t+1}^x - k_t^x) + \Phi_n(k_{t+1}^n - k_t^n) \right] = p^\tau_t \frac{d_{t+1}}{1 + r_t} + (1 - \tau_t)(w_t^m l_t^m + w_t^x l_t^x + w_t^n l_t^n) + s_t h_t + r_t^m k_t^m + r_t^x k_t^x + r_t^n k_t^n + p_t^f (1 - \delta)(k_t^m + k_t^x + k_t^n)\]

\[\lim_{T \to \infty} \left( \prod_{i=0}^{T-1} (1 + r_i)^{-1} \right) \frac{d_{T+1}}{1 + r_T} = 0\]
Households - first order conditions

\[ c_t : \quad U_1(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t p^f \] (6)
Households - first order conditions

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

\[ [l_t^m : ] \quad - U_2(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t (1 - \tau_t) w_t^m \]  (7)
Households - first order conditions

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

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

\[ [l_t^x : ] \quad - U_3(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t (1 - \tau_t) w_t^x \] \quad (8)
Households - first order conditions

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

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

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

\[ [l_t^n :] \quad - U_4(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t (1 - \tau_t) w_t^n \quad (9) \]
Households - first order conditions

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

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

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

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

\[ h_t^x : \quad - U_5(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t s_t^x \] \quad (10)
Households - first order conditions

\[ [c_t :] \quad U_1(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t p^f \] (6)

\[ [l^m_t :] \quad - U_2(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t (1 - \tau_t) w^m_t \] (7)

\[ [l^x_t :] \quad - U_3(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t (1 - \tau_t) w^x_t \] (8)

\[ [l^n_t :] \quad - U_4(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t (1 - \tau_t) w^n_t \] (9)

\[ [h^x_t :] \quad - U_5(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t s^x_t \] (10)

\[ [k^m_{t+1}] \quad \lambda_t [1 + \Phi'_m(k^m_{t+1} - k^m_t)] p^f_t = \beta E_t \lambda_{t+1}[r^m_{t+1} + (1 - \delta + \Phi'_m(k^m_{t+2} - k^m_{t+1})) p^f_{t+1}] \] (11)
Households - first order conditions

\[ [c_t : ] \quad U_1(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t p^f \]

\[ [l^m_t : ] \quad - U_2(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t (1 - \tau_t) w^m_t \]

\[ [l^n_t : ] \quad - U_3(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t (1 - \tau_t) w^n_t \]

\[ [h^x_t : ] \quad - U_5(c_t, l^m_t, l^x_t, l^n_t, h^x_t) = \lambda_t s^x_t \]

\[ [k^m_{t+1} : ] \quad \lambda_t [1 + \Phi'_m(k^m_{t+1} - k^m_t)] p^f_t = \beta E_t \lambda_{t+1} [r^k_{t+1} + (1 - \delta + \Phi'_m(k^m_{t+2} - k^m_{t+1})) p^f_{t+1}] \]

\[ [k^n_{t+1} : ] \quad \lambda_t [1 + \Phi'_x(k^n_{t+1} - k^n_t)] p^f_t = \beta E_t \lambda_{t+1} [r^k_{t+1} + (1 - \delta + \Phi'_x(k^n_{t+2} - k^n_{t+1})) p^f_{t+1}] \]
Households - first order conditions

\[ c_t : \quad U_1(c_t, l_{t}^m, l_{t}^x, l_{t}^n, h_{t}^x) = \lambda_t p^f \]  \hspace{1cm} (6)

\[ l_{t}^m : \quad - U_2(c_t, l_{t}^m, l_{t}^x, l_{t}^n, h_{t}^x) = \lambda_t(1 - \tau_t) w_{t}^m \]  \hspace{1cm} (7)

\[ l_{t}^x : \quad - U_3(c_t, l_{t}^m, l_{t}^x, l_{t}^n, h_{t}^x) = \lambda_t(1 - \tau_t) w_{t}^x \]  \hspace{1cm} (8)

\[ l_{t}^n : \quad - U_4(c_t, l_{t}^m, l_{t}^x, l_{t}^n, h_{t}^x) = \lambda_t(1 - \tau_t) w_{t}^n \]  \hspace{1cm} (9)

\[ h_{t}^x : \quad - U_5(c_t, l_{t}^m, l_{t}^x, l_{t}^n, h_{t}^x) = \lambda_t s_{t}^x \]  \hspace{1cm} (10)

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

\[ k_{t+1}^x : \quad \lambda_t[1 + \Phi'_x(k_{t+1}^x - k_t^x)] p_t^f = \beta E_t \lambda_{t+1}[r_{t+1}^{kx} + (1 - \delta + \Phi'_x(k_{t+2}^x - k_{t+1}^x)) p_{t+1}^f] \]  \hspace{1cm} (12)

\[ k_{t+1}^n : \quad \lambda_t[1 + \Phi'_n(k_{t+1}^n - k_t^n)] p_t^f = \beta E_t \lambda_{t+1}[r_{t+1}^{kn} + (1 - \delta + \Phi'_n(k_{t+2}^n - k_{t+1}^n)) p_{t+1}^f] \]  \hspace{1cm} (13)
Households - first order conditions

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

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

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

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

\[ h_t^x : \quad - U_5(c_t, l_t^m, l_t^x, l_t^n, h_t^x) = \lambda_t s_t^x \] (10)

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

\[ k_{t+1}^x : \quad \lambda_t [1 + \Phi'_x(k_{t+1}^x - k_t^x)] p_t^f = \beta E_t \lambda_{t+1} [r_{t+1}^{kx} + (1 - \delta + \Phi'_x(k_{t+2}^x - k_{t+1}^x)) p_{t+1}^f] \] (12)

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

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

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

First order conditions:

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

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

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

\[
[k_t^n :] \quad p_t^n A_t F_1^n(k_t^n, l_t^n) = r_t^{kn}
\]
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
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.
Effects of TOT on TFP

\[ s_t = \frac{U_{ht}}{U_{l_t}} \text{tot}_t A_t z_t F_2^x (k_t^x, l_t^x) \]
Effects of TOT on TFP

\[ s_t = \frac{U_{ht}}{U_{l_t}} \text{tot}_t A_t z_t F_2^x (k_t^x, l_t^x) \]

By TFP production function:

\[ h_t = \left( \frac{s_t}{B A_t z_t \gamma} \right)^{\frac{1}{\gamma - 1}} = \left( \frac{U_{ht}}{U_{l_t}^x} \text{tot}_t A_t z_t F_2^x (k_t^x, l_t^x) \right)^{\frac{1}{\gamma - 1}} \]
Effects of TOT on TFP

\[ s_t = \frac{U_{ht}}{U_{l_t^x}} \text{tot}_t A_t z_t F_2^x(k_t^x, l_t^x) \]

By TFP production function:

\[ h_t = \left( \frac{s_t}{BA_t z_t \gamma} \right)^{\frac{1}{\gamma-1}} = \left( \frac{U_{ht}}{U_{l_t^x}} \text{tot}_t A_t z_t F_2^x(k_t^x, l_t^x) \right)^{\frac{1}{\gamma-1}} \frac{1}{BA_t z_t \gamma} \]

\[
\frac{dh_t}{dtot_t} = \frac{1}{\gamma-1} \left( \frac{U_{ht}}{U_{l_t^x}} \text{tot}_t A_t z_t F_2^x(k_t^x, l_t^x) \right)^{\frac{1}{\gamma-1}-1} \frac{1}{BA_t z_t \gamma} \left( \frac{A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma} \right)^{\frac{1}{\gamma-1}-1} \frac{U_{ht} h_t - U_{ht} U_{l_t^x} h_t}{(U_{l_t^x})^2} - \frac{1}{\gamma-1} \left( \frac{U_{ht}}{U_{l_t^x}} \text{tot}_t A_t z_t F_2^x(k_t^x, l_t^x) \right)^{\frac{1}{\gamma-1}-1} \frac{A_t z_t F_2^x(k_t^x, l_t^x)}{BA_t z_t \gamma} \frac{U_{ht} U_{l_t^x} h_t}{(U_{l_t^x})^2} - 1 < 0
\]

As long as \( U_{ht} h_t U_{l_t^x} > U_{ht} U_{l_t^x} h_t \iff \frac{U_{ht} h_t}{U_{ht}} h_t > \frac{U_{l_t^x} h_t}{U_{l_t^x}} h_t \)
Effects of TOT on TFP

\[ s_t = \frac{U_{ht}}{U_{l_t}^X} \text{tot}_t A_t z_t F_2^X (k_t^X, l_t^X) \]

By TFP production function:

\[ h_t = \left( \frac{s_t}{BA_t z_t^\gamma} \right)^{\frac{1}{\gamma-1}} = \left( \frac{U_{ht} \text{tot}_t A_t z_t F_2^X (k_t^X, l_t^X)}{BA_t z_t^\gamma} \right)^{\frac{1}{\gamma-1}} \]

\[ \frac{dh_t}{dtot_t} = -\frac{1}{\gamma-1} \left( \frac{U_{ht}}{U_{l_t}^X} \text{tot}_t A_t z_t F_2^X (k_t^X, l_t^X) \right)^{\frac{1}{\gamma-1}-1} \frac{A_t z_t F_2^X (k_t^X, l_t^X)}{BA_t z_t^\gamma} \left( \frac{U_{ht} h_t U_{l_t}^X - U_{ht} U_{l_t}^X h_t}{(U_{l_t}^X)^2} \right) < 0 \]

As long as \( U_{ht} h_t U_{l_t}^X > U_{ht} U_{l_t}^X h_t \) \( \iff \) \( \frac{U_{ht} h_t}{U_{ht}} h_t > \frac{U_{l_t}^X h_t}{U_{l_t}^X} h_t \)

\[ \frac{dA_{t+1}}{dtot_t} = \frac{dA_{t+1}}{dh_t} \frac{dh_t}{dtot_t} < 0 \]
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
Import, export and market clearing

Import:

\[ m_t = a^m_t - y^m_t \]

Export:

\[ x_t = tot_t(y^x_t - a^x_t) \]

Nontradables:

\[ a^n_t = y^n_t \]

Final goods:

\[ c_t + k^m_{t+1} + k^x_{t+1} + k^n_{t+1} - (1 - \delta)(k^m_t + k^x_t + k^n_t) + \Phi_m(k^m_{t+1} - k^m_t) + \Phi_x(k^x_{t+1} - k^x_t) + \Phi_n(k^n_{t+1} - k^n_t) = H(a^\tau_t, a^n_t) \]

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

\[ m_t - x_t + p^\tau_t d_t = p^\tau_t \frac{d_{t+1}}{1 + r_t} \]

which is the economy-wide resource constraint.
Competitive equilibrium

A competitive equilibrium is
Competitive equilibrium

A competitive equilibrium is

a set of prices \( \{ {r_t^k}^m, {r_t^k}^x, {r_t^k}^n, w_t^m, w_t^x, w_t^n, s_t, p_t^f, p_t^T, p_t^n, r_t \} \) \( \infty t=0 \),
Competitive equilibrium

A competitive equilibrium is

a set of prices \( \{r^m_t, r^n_t, r^m_t, w^m_t, w^n_t, s_t, p^m_t, p^n_t, p^\tau_t, r_t\}_{t=0}^\infty \),

an allocation \( \{k^m_{t+1}, k^n_{t+1}, l^m_t, l^n_t, h_t, A_{t+1}, y^m_t, y^n_t, y^\tau_t, c_t, a^m_t, a^n_t, a^\tau_t, m_t, x_t, d_{t+1}\}_{t=0}^\infty \),

and a tax system \( \{\tau_t\}_{t=0}^\infty \) which solve households and firms optimization problem such that markets clear given the initial conditions \( k^m_0, k^n_0, d_0, A_0, \ldots \) and the stochastic processes \( \{\tau_t, z_t\}_{t=0}^\infty \).
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 \( \{ k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, l_t^m, l_t^x, l_t^n, h_t, A_{t+1}, y_t^m, y_t^x, y_t^n, c_t, a_t^m, a_t^x, a_t^n, a_t^\tau, m_t, x_t, d_{t+1} \}_{t=0}^\infty \), a sequence of multipliers \( \{ \lambda_t \}_{t=0}^\infty \), and a tax system \( \{ \tau_t \}_{t=0}^\infty \).
Competitive equilibrium

A competitive equilibrium is

a set of prices \( \{ r_{km}^t, r_{kx}^t, r_{kn}^t, w_{mt}, w_{xt}, s_t, p_f^t, p_t^T, p_n^t, r_t \}_{t=0}^{\infty} \),
an allocation \( \{ k_{t+1}^m, k_{t+1}^x, k_{t+1}^n, l_{t}^m, l_{t}^x, l_{t}^n, h_t, A_{t+1}, y_{t}^m, y_{t}^x, y_{t}^n, c_t, a_{t}^m, a_{t}^x, a_{t}^n, a_{t}^T, m_t, x_t, d_{t+1} \}_{t=0}^{\infty} \),
a sequence of multipliers \( \{ \lambda_t \}_{t=0}^{\infty} \),
and a tax system \( \{ \tau_t \}_{t=0}^{\infty} \)

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 \( \{ tot_t, z_t \}_{t=0}^{\infty} \).
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

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

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

Production functions:

\[ F^m(k^m, l^m) = (k^m)^{\alpha_m} (l^m)^{1-\alpha_m} \]
\[ F^x(k^x, l^x) = (k^x)^{\alpha_x} (l^x)^{1-\alpha_x} \]
\[ F^n(k^n, l^n) = (k^n)^{\alpha_n} (l^n)^{1-\alpha_n} \]
Functional forms

Utility function:

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

where

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

Production functions:

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

CES composite goods aggregators:

\[ G(a_t^m, a_t^x) = \left[ \chi_m(a_t^m)^{1 - \frac{1}{\nu_{mx}}} + (1 - \chi_m)(a_t^x)^{1 - \frac{1}{\nu_{mx}}} \right]^{\frac{1}{1 - \frac{1}{\nu_{mx}}}} \]
\[ H(a_t^\tau, a_t^n) = \left[ \chi_\tau(a_t^\tau)^{1 - \frac{1}{\nu_{\tau n}}} + (1 - \chi_\tau)(a_t^n)^{1 - \frac{1}{\nu_{\tau n}}} \right]^{\frac{1}{1 - \frac{1}{\nu_{\tau n}}}} \]
## Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>Coefficient of the relative risk aversion</td>
<td>2</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Subjective discount factor</td>
<td>0.95</td>
</tr>
<tr>
<td>$\omega_m$</td>
<td>Importable goods labor supply elasticity</td>
<td>1.455</td>
</tr>
<tr>
<td>$\omega_x$</td>
<td>Exportable goods labor supply elasticity</td>
<td>1.455</td>
</tr>
<tr>
<td>$\omega_n$</td>
<td>Nontradables goods labor supply elasticity</td>
<td>1.455</td>
</tr>
<tr>
<td>$\omega_h$</td>
<td>Technology sector labor supply elasticity</td>
<td>1.455</td>
</tr>
<tr>
<td>$\alpha_m$</td>
<td>Capital share in importable goods sector</td>
<td>0.33</td>
</tr>
<tr>
<td>$\alpha_x$</td>
<td>Capital share in exportable goods sector</td>
<td>0.33</td>
</tr>
<tr>
<td>$\alpha_n$</td>
<td>Capital share in nontradable goods sector</td>
<td>0.25</td>
</tr>
<tr>
<td>$\nu_{mx}$</td>
<td>The elasticity of substitution between exportable and importable absorption</td>
<td>1</td>
</tr>
<tr>
<td>$\chi_m$</td>
<td>The importables share parameter</td>
<td>0.9</td>
</tr>
<tr>
<td>$\nu_{\tau n}$</td>
<td>The elasticity of substitution between tradable and nontradable absorption</td>
<td>0.5</td>
</tr>
<tr>
<td>$\chi_\tau$</td>
<td>The tradable share parameter</td>
<td>0.36</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Capital depreciation rate</td>
<td>0.1</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Parameter governing the debt elasticity of the country premium</td>
<td>0.08</td>
</tr>
<tr>
<td>$r^*$</td>
<td>World interest rate</td>
<td>0.04</td>
</tr>
<tr>
<td>$d$</td>
<td>Steady state debt</td>
<td>4.9</td>
</tr>
<tr>
<td>$\bar{d}_{tot}$</td>
<td>Steady state TOT</td>
<td>1</td>
</tr>
<tr>
<td>$\rho_{tot}$</td>
<td>TOT autocorrelation coefficient</td>
<td>0.46</td>
</tr>
<tr>
<td>$\sigma_{tot}$</td>
<td>Standard deviation of TOT process innovation</td>
<td>0.0166</td>
</tr>
<tr>
<td>$\rho_z$</td>
<td>Autocorrelation coefficient of technology shock</td>
<td>0.72</td>
</tr>
<tr>
<td>$\sigma_{tot}$</td>
<td>Standard deviation of technology shock innovation</td>
<td>0.0114</td>
</tr>
<tr>
<td>$B$</td>
<td>Shift parameter of the knowledge production function</td>
<td>1</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Parameter of the knowledge production function</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Model performance: impulse responses 1/2
Model performance: impulse responses 2/2
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 \( \rho = 0.72, \sigma_{\text{tot}} = 0.0114 \)
Mechanism explicitly - functional forms

By households first order conditions:

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

\[
[c - L]^{-\sigma} (l^x)^{\omega_x - 1} = \lambda_t w_t^x
\]
Mechanism explicitly - functional forms

By households first order conditions:

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

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

we have that

\[
\lambda_t = \frac{[c - L]^{-\sigma(h)} \omega_h^{-1}}{S_t} = \frac{[c - L]^{-\sigma(l^x)} \omega_x^{-1}}{W_t^x}
\]
Mechanism explicitly - functional forms

By households first order conditions:

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

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

we have that

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

Using exporters FOC we substitute out the wages:

\[ \frac{(h_t)^{\omega_h^{-1}}}{\mu_t B A_t \gamma h_t \gamma^{-1}} = \frac{(l^x)^{\omega_{x}^{-1}}}{t o t_t A_t F_2^x (k_t^x, l_t^x)} \]
Mechanism explicitly - functional forms

By households first order conditions:

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

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

we have that

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

Using exporters FOC we substitute out the wages:

\[
\frac{(h_t)^{\omega_h - 1}}{\mu_t B A_t \gamma h_t^{\gamma - 1}} = \frac{(l^x)^{\omega_x - 1}}{tot_t A_t F_2^x (k^x_t, l^x_t)}
\]

As \(tot\) goes up, RHS goes down
Mechanism explicitly - functional forms

By households first order conditions:

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

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

we have that

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

Using exporters FOC we substitute out the wages:

\[ \frac{(h_t)^{\omega_h^{-1}}}{\mu_t B A_t \gamma h_t^{\gamma-1}} = \frac{(l^x)^{\omega_x^{-1}}}{t o t_t A_t F^x_2(k^x_t, l^x_t)} \]

As \textit{tot} goes up, RHS goes down \implies LHS needs to go down
Mechanism explicitly - functional forms

By households first order conditions:

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

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

we have that

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

Using exporters FOC we substitute out the wages:

\[ \frac{(h_t)^{\omega - 1}}{\mu_t BA_t \gamma h_t^{\gamma - 1}} = \frac{(l)^{x - 1}}{tot_t A_t F^x_2(k_t^x, l_t^x)} \]

As \( tot \) goes up, RHS goes down \( \Rightarrow \) LHS needs to go down \( \Rightarrow \) \( h_t \) needs to fall
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!
### New entrants


<table>
<thead>
<tr>
<th>Model</th>
<th>(14)</th>
<th>(15)</th>
<th>(16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Delta TFP$</td>
<td>$\Delta TFP$</td>
<td>$\Delta TFP$</td>
</tr>
<tr>
<td>$\Delta TOT$</td>
<td>$-1.2218^*$</td>
<td>$-1.1935^*$</td>
<td>$-1.3117^*$</td>
</tr>
<tr>
<td></td>
<td>(.6020)</td>
<td>(.6028)</td>
<td>(.6391)</td>
</tr>
<tr>
<td>New entrants</td>
<td></td>
<td>.0001428</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.0001499)</td>
<td></td>
</tr>
<tr>
<td>$\Delta$ New entrants</td>
<td></td>
<td></td>
<td>-.0005477</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.0006245)</td>
</tr>
<tr>
<td>Sector dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Country dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Mean TFP</td>
<td>62.2994</td>
<td>62.2994</td>
<td>62.2994</td>
</tr>
<tr>
<td>Number of obs.</td>
<td>260</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.2564</td>
<td>0.2596</td>
<td>0.1870</td>
</tr>
</tbody>
</table>

Standard deviation in parenthesis. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robustness - openness of the industry

<table>
<thead>
<tr>
<th>Sample</th>
<th>Manufacturing (8)</th>
<th>Manufacturing (17)</th>
<th>Manufacturing (18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
<td>ΔTFP</td>
</tr>
<tr>
<td>ΔTOT</td>
<td>-.2866***</td>
<td>-.2924***</td>
<td>.1562</td>
</tr>
<tr>
<td></td>
<td>(.0770)</td>
<td>(.0772)</td>
<td>(.1307)</td>
</tr>
<tr>
<td>Share of exporters</td>
<td>7.0555***</td>
<td>6.8268***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.5989)</td>
<td>(1.5944)</td>
<td></td>
</tr>
<tr>
<td>Share of exporters x ΔTOT</td>
<td>-1.2193***</td>
<td></td>
<td>-1.2193***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.2870)</td>
</tr>
<tr>
<td>Sector dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Country dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Mean TFP</td>
<td>62.0282</td>
<td>62.3931</td>
<td>62.3931</td>
</tr>
<tr>
<td>Number of obs.</td>
<td>2591</td>
<td>2563</td>
<td>2563</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0766</td>
<td>0.1390</td>
<td>0.1452</td>
</tr>
</tbody>
</table>

Standard deviation in parenthesis. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
## Robustness - lagged changes in TOT

<table>
<thead>
<tr>
<th>Sample</th>
<th>Manufact</th>
<th>Manufact</th>
<th>Manufact</th>
<th>Manufact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>(8)</td>
<td>(18)</td>
<td>(19)</td>
<td>(20)</td>
</tr>
<tr>
<td>$\Delta TFP$</td>
<td>$\Delta TFP$</td>
<td>$\Delta TFP$</td>
<td>$\Delta TFP$</td>
<td></td>
</tr>
<tr>
<td>$\Delta TOT$</td>
<td>$-.2866^{***}$</td>
<td>$-.3059^{***}$</td>
<td>$-.3697^{***}$</td>
<td>$-.4180^{***}$</td>
</tr>
<tr>
<td></td>
<td>(.0770)</td>
<td>(.0822)</td>
<td>(.0859)</td>
<td>(.0989)</td>
</tr>
<tr>
<td>Lagged $\Delta TOT (t-1)$</td>
<td>.0469</td>
<td>.0560</td>
<td>.0797</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0797)</td>
<td>(.0836)</td>
<td>(.0932)</td>
<td></td>
</tr>
<tr>
<td>Lagged $\Delta TOT (t-2)$</td>
<td>-.1792*</td>
<td>-.1888*</td>
<td>.0692</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0840)</td>
<td>(.0903)</td>
<td>(.1043)</td>
<td></td>
</tr>
<tr>
<td>Lagged $\Delta TOT (t-3)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sector dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Country dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year dummies</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Mean TFP</td>
<td>62.0282</td>
<td>62.0282</td>
<td>62.0282</td>
<td>62.0282</td>
</tr>
<tr>
<td>Number of obs.</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
<td>2591</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0766</td>
<td>0.1387</td>
<td>0.1278</td>
<td>0.1182</td>
</tr>
</tbody>
</table>

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