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The Total Factor Productivity of National Innovation Systems in the European Union

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The TFP of NIS in the EU-28

Summary

- Objectives, motivation, method, and data
- The empirical model
- Results and discussion (Estimation; Technical efficiency; Growth and TFP changes decomposition).
- Conclusions

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Objectives, motivation, method, and data

- Innovation is important for economic growth.

- We analyze the productivity and efficiency of the National Innovation Systems (NIS) of the European Union 28 (EU-28) using Stochastic Frontier Analysis (SFA).

- The data come from the European Union (EU) Innovation Union Scoreboard (IUS), which has been developed under the Innovation Union initiative of Europe 2020. It covers the period 2006-2012.

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Objectives, motivation, method, and data

- NIS are a set of institutions and of public and private organizations whose activities and interactions allow to start, import, and disseminate new technologies (Freeman 1987).

- NIS consists of organizations and institutions involved in the process of generating and exchanging knowledge, which determines growth, diffusion and use of innovation (Edquist 1997, 2005).

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Objectives, motivation, method, and data

- National Innovation Capacity (NIC) measures the ability of a country to generate long-term economically viable innovations worldwide (Furman, Porter, and Stern 2002).

- NIC is related with NIS and helped to pave the way to empirical quantitative analyses treating NIS as any other sector, with outputs and inputs, and using parametric and non-parametric techniques (e.g. Nasierowski and Arcelus 1999, 2003, Fagerberg and Sholec 2008, Hu, Yang, and Chen 2014).

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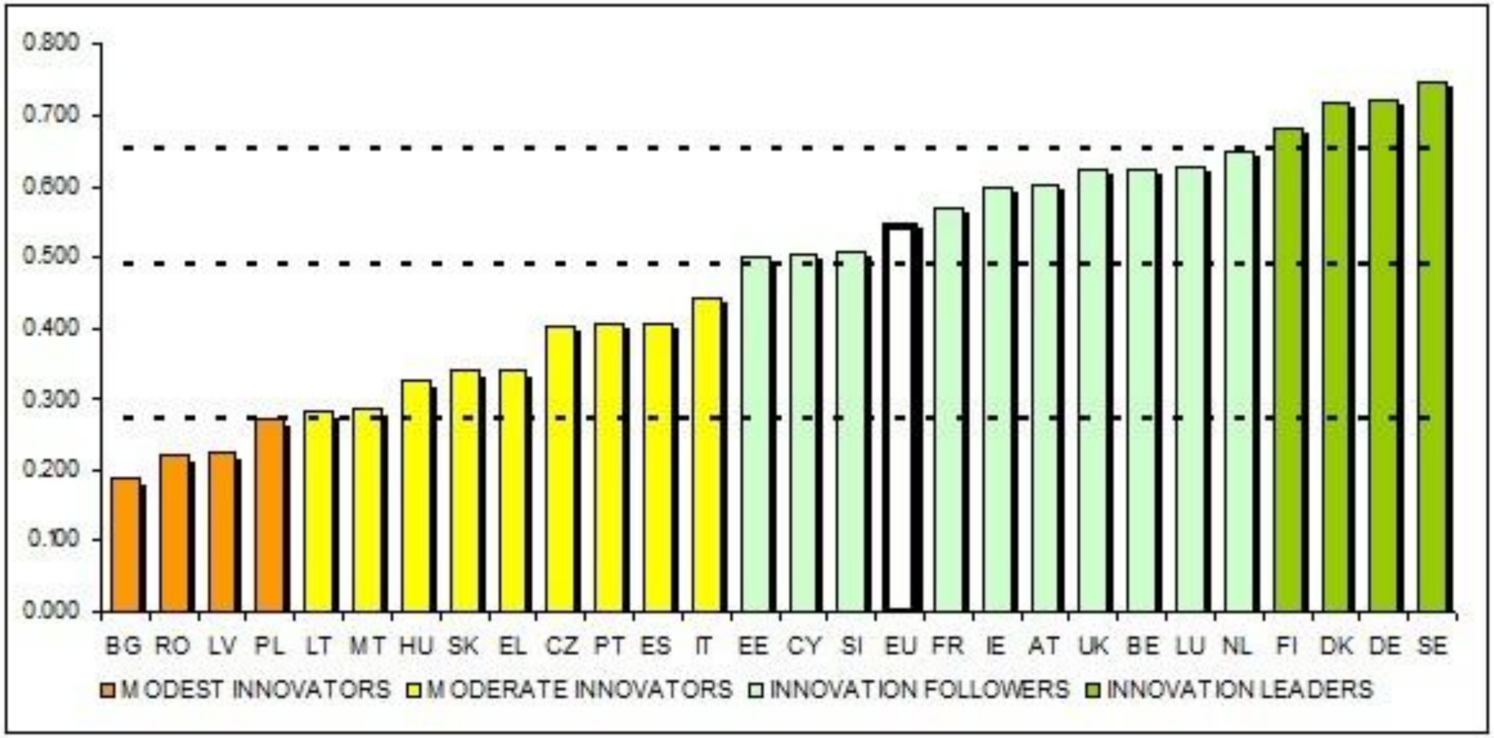
Objectives, motivation, method, and data

The IUS 2014



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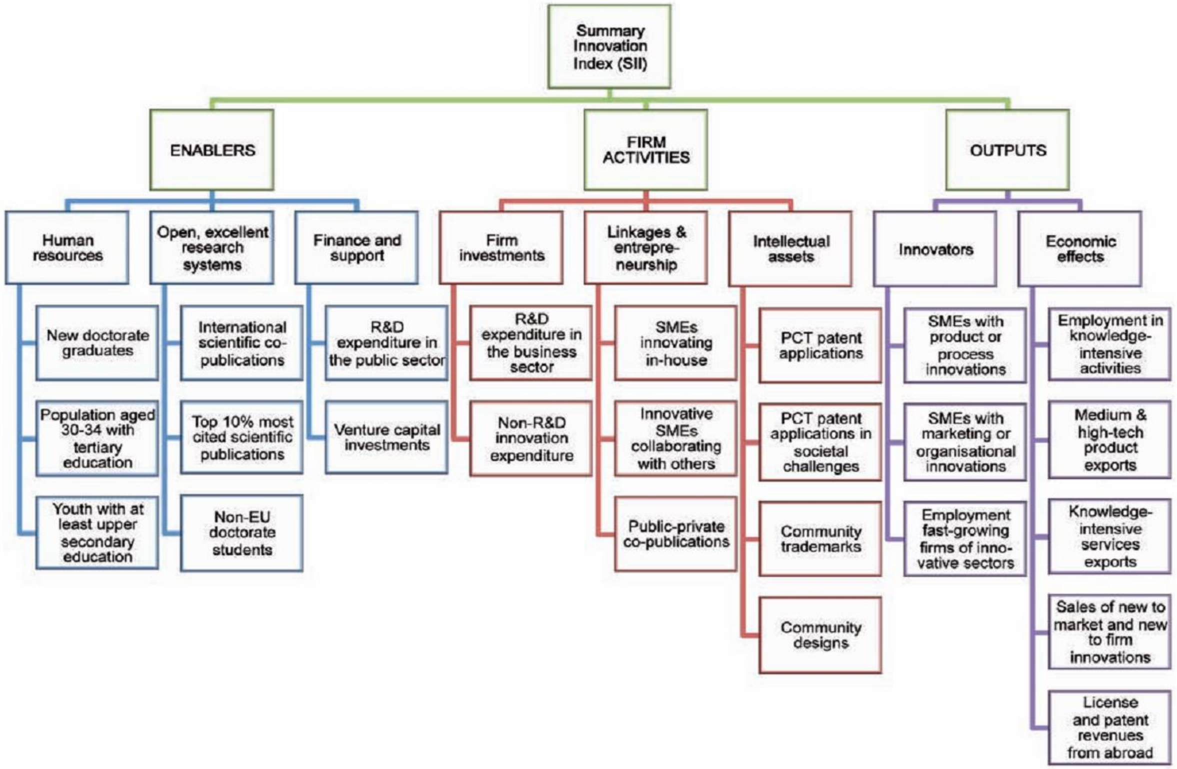
Objectives, motivation, method, and data

The IUS 2014



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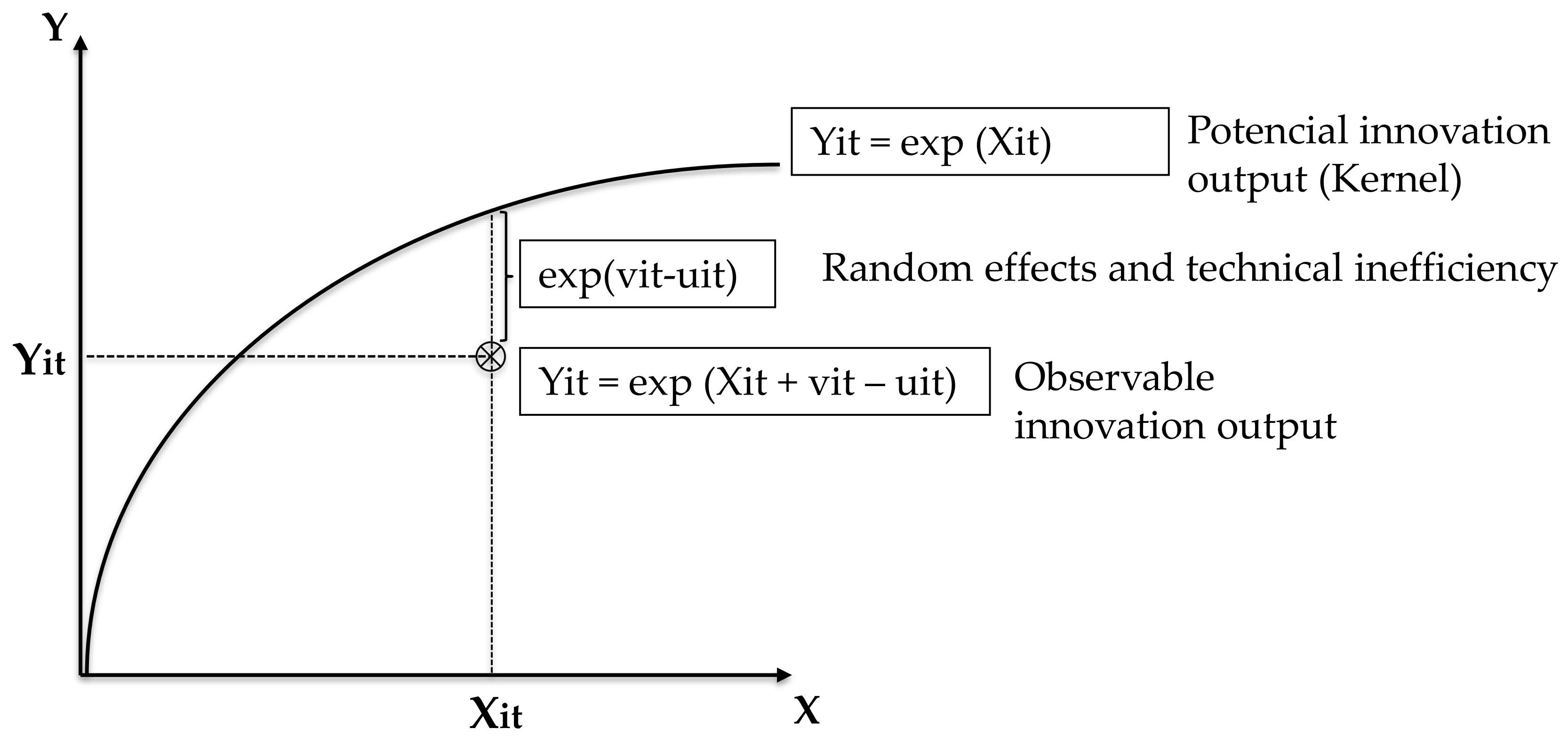
Objectives, motivation, method, and data



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Objectives, motivation, method, and data

- Using the Battese and Coelli (1995) time-varying inefficiency model specification, a Cobb Douglas stochastic frontier is estimated as well as the effects of macroeconomic environmental variables over inefficiency.

- Innovation growth is decomposed into TFP changes, accumulation of inputs, and an unexplained residual component. TFP changes are computed as the sum of technological changes, technical efficiency changes, and scale effects.

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The empirical model

Based on Battese and Coelli (1995) time-varying inefficiency model, we consider a Cobb-Douglas production function with one variable input:

$$(1)\ \ln y_{it} = \gamma + \alpha \ln x_{it} + \theta t + V_{it} - U_{it}$$

$$(2)\ u_{it} = \delta Z + w_{it}$$

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The empirical model

Technical efficiency:

$$(3)\ TE_{it} = \exp(-u_{it}) = \exp[-(\delta Z + w_{it})]$$

Decomposition of innovation growth:

$$(4)\ \dot{y}_{it} = T\dot{F}P + \dot{x}_{it} + Res_{it}$$

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The empirical model

Decomposition of TFP growth:

(5) $T\dot{F}P = \mathrm{T}\Delta + S\Delta + TE\Delta$

$T\Delta = \theta$; $S\Delta = (\alpha - 1)\dot{x}_{it}$; and $TE\Delta = -\frac{\partial u_{it}}{\partial t} = -\left(\sum_{i=1}^{k} \frac{\delta_i \, \partial z_{it}}{\partial t} + \frac{\partial w_{it}}{\partial t}\right)$

The parameter α yields the returns to scale of the innovation frontier.

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The empirical model

- The following macroeconomic environmental variables have been considered to explain technical inefficiency:

  $GDPpc_{it}$ – Per capita real GDP

  g_{it} – Annual growth rate of real GDP

  i_{it} – Long run sovereign debt yields

  G_{it} – Gini coefficient

  Sw_{it} – Share of wage income in GDP

  π_{it} – Inflation rate

  Ur_{it}– Unemployment rate

  D_{it} – Government decentralization

  t - Time.

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The empirical model

Data description

	Name	Mean	StdDev	Min	Max
Frontier variables					
Output	*x*	0.47	0.17	0.11	0.83
Input	*y*	0.44	0.17	0.17	0.79
Time	*t*	4	2	1	7
Environmental variables					
Gross domestic product (GDP) per capita	*GDPpc*	21136	13970	3200	70400
Annual growth rate of real GDP	*g*	1.25	4.41	-17.95	12.23
Sovereign debt yields	*i*	4.93	2.40	0.57	22.50
Gini coefficient	*G*	29.61	3.87	22.70	38.90
Share of wages income in GDP	*Sw*	46.17	5.95	33.18	58.65
Inflation rate	*Π*	3.03	2.20	-1.70	15.30
Unemployment rate	*Ur*	8.54	3.93	2.80	25.00
Government decentralization	*D*	23.30	12.98	1.24	65.90
Time	*t*	4	2	1	7

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Results and Discussion (Estimation)

Number of observations = 196							
Number of Countries = 28							
Number of Years = 7							
Observations per country: Minimum = 7							
Maximum = 7							
Average = 7							
Log Likelihood = 66.9692							
Prob $> \chi^2 = 0.000$							
Wald χ^2 (2) = 85.00							

Variable		Coefficients	Standard Error	z	$P > \|z\|$	95% Confidence Interv	
						Lower	Upper
Frontier							
constant	γ	-0.210699	0.0474968	-4.44	0.000	-0.3037914	-0.11760
ln x	$\propto$	0.3442970	0.0430808	9.15	0.000	0.3098610	0.478734
t	θ	-0.008547	0.0072377	-1.18	0.238	-0.0227300	
Environmental							
GDPpc	δ_1	-0.000060	0.0000159	-3.84	0.000	-0.0000092	-0.00002
g	δ_2	-0.030688	0.0107509	-2.85	0.004	-0.0517602	-0.00961
i	δ_3	-0.114812	0.0309742	-3.71	0.000	-0.1755213	-0.05410
G	δ_4	0.052973	0.0110580	4.79	0.000	0.0313000	0.07464
Sw	δ_5	-0.024300	0.0091768	-2.65	0.008	-0.042287	-0.00631
π	δ_6	0.048004	0.0174025	2.76	0.006	0.0138958	0.08211
Ur	δ_7	0.050739	0.0150295	3.38	0.001	0.0212825	0.08019
D	δ_8	0.025130	0.0074935	3.35	0.001	0.0104432	0.03981
t	δ_9	-0.070301	0.0266621	-2.64	0.008	-0.1225583	-0.01804
	σ_u	0.2536209	0.0346249	7.32	0.000	0.1940783	0.33143
	σ_v	0.1317718	0.0109474	12.04	0.000	0.111971	0.15507
	$\lambda = \frac{\sigma_u}{\sigma_v}$	1.924699	0.038777	49.64	0.000	1.848697	2.00070

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Results and discussion (Estimation)

α = 0.35 indicates that returns to scale of innovation are decreasing.

The estimate of the time parameter θ is not significant, which means that there were no shifts in the innovation frontier (technological progress) in the period of analysis.

From the estimates of σu and σv we take that 78.7 percent of the variance of the stochastic frontier is determined by technical inefficiency.

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Results and discussion (Estimation)

All the estimates of the macroeconomic environmental variables explaining technical inefficiency are significant at less than 1 percent level of significance. In general, the signs are as expected.

Real GDP per capita has a negative sign. The increase in the living standards of a country reduces technical inefficiency.

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Results and discussion (Estimation)

Economic growth has a negative impact in technical inefficiency. Hasan and Tucci (2010) found that the higher the number of innovative companies, the greater the country rate of economic growth.

Interest rates have a negative impact in technical inefficiency. Fang, Tian, and Tice (2014) found that an increase in liquidity (lower interest rates) causes a reduction in the level of future innovation.

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Results and discussion (Estimation)

The Gini coefficient indicates a positive relationship between economic inequality and technical inefficiency. The share of wages in income decreases technical inefficiency. Hatipoglu (2012) found a negative relationship between economic inequality and innovation activities.

Inflation increases technical inefficiency. By distorting relative prices, inflation increases overall inefficiency.

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Results and discussion (Estimation)

Unemployment increases technical inefficiency.

Contrary to expectations, government decentralization increases technical inefficiency. In the EU, more developed Member States, with higher levels of innovation, have more government decentralization. Blöchliger and Egert (2013) found a positive relationship between fiscal decentralization and GDP per capita.

The negative sign of time implies that as time goes by technical inefficiency is reduced.

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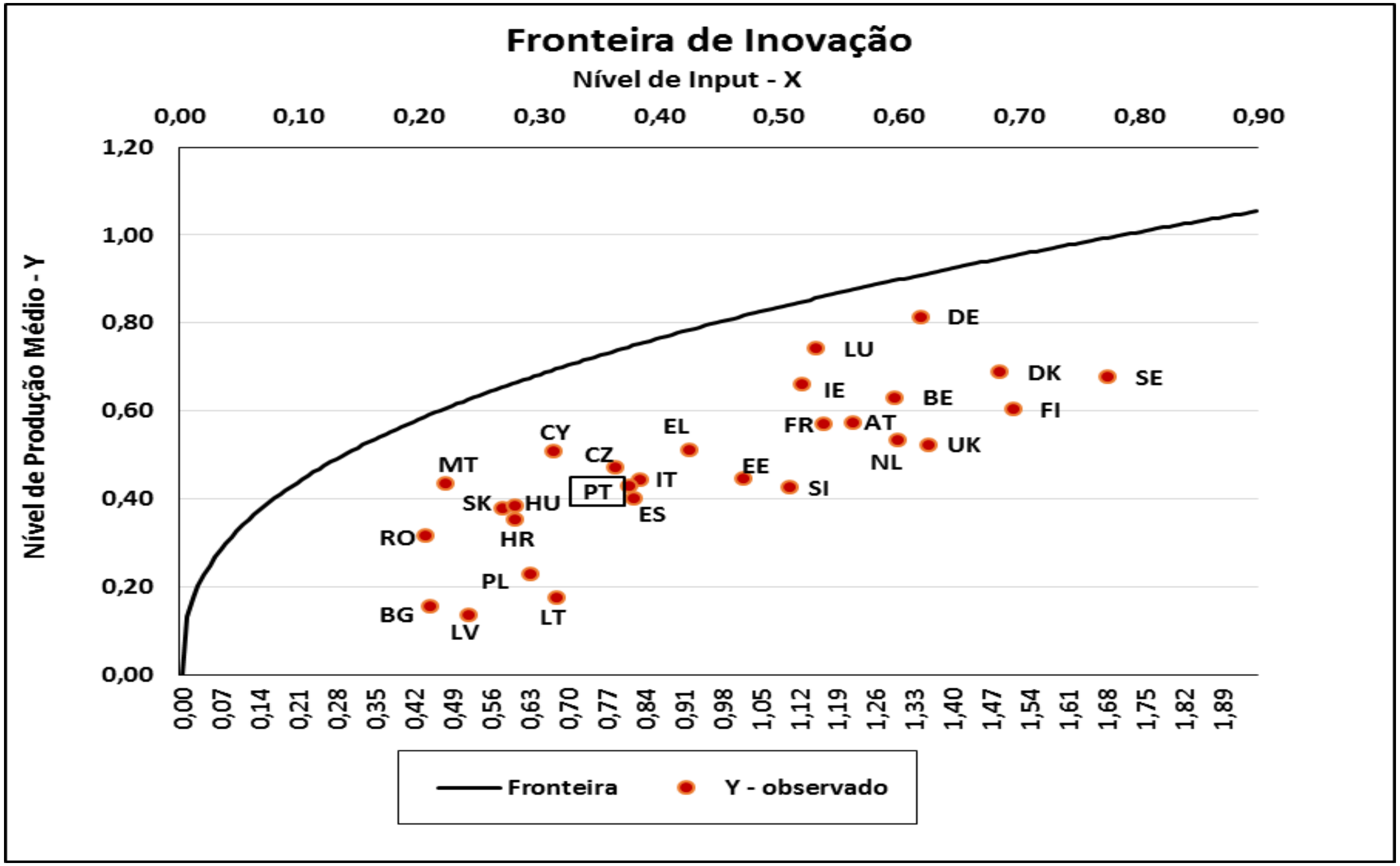
Results and discussion (Technical efficiency)

Innovation production frontier



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Results and discussion (Technical efficiency)

Ranking	Code	Country	TE
1	LU	Luxemburg	0.99
2	DE	Germany	0.97
3	IE	Ireland	0.97
4	BE	Belgium	0.97
5	AT	Austria	0.96
6	SE	Sweden	0.95
12	FI	Finland	0.94
13	EL	Greece	0.93
18	PT	Portugal	0.85
21	ES	Spain	0.82
24	RO	Romania	0.70
25	PL	Poland	0.48
26	LT	Lithuania	0.39
27	BG	Bulgaria	0.38
28	LV	Latvia	0.32

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Results and discussion (Technical efficiency)

Luxembourg is the leader in terms of technical efficiency, followed by Germany and Ireland.

Germany is the leader in innovation output.

Sweden leads the accumulation of innovation input.

Portugal occupies the 18th position in the TE ranking, above Spain.

In the last TE ranking positions we find the countries of the eastern enlargement of the EU.

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Results and discussion
(Growth and TFP changes decomposition)

Code	Country	$\dot{y}$	$T\dot{F}P$	$T\dot{F}P$			$\dot{x}$	Res
				$T\Delta$	$TE\Delta$	$S\Delta$		
DE	Germany	0.91	1.46	0.00	1.62	-0.16	0.25	-0.80
ES	Spain	1.15	-0.37	0.00	0.51	-0.88	1.35	0.17
LU	Luxemburg	1.35	-0.37	0.00	3.23	-3.60	5.54	-3.82
PT	Portugal	2.93	-4.17	0.00	0.54	-4.71	7.25	-0.15
SE	Sweden	1.26	2.93	0.00	3.73	-0.80	1.23	-2.90

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Results and discussion
(Growth and TFP changes decomposition)

Germany grew slightly in the innovation output (0.91 percent), due to increased productivity (1.52 percent) and input accumulation (0.25 percent).

Portugal had a significant increase in the innovation output (2.93 percent) resulting from input accumulation (7.25 percent), which offset the decrease in productivity (-3.88 percent).

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Conclusions

The production of innovation in the EU-28 exhibits diminishing returns to scale.

There were no shifts in the innovation frontier (technological progress) in the period of analysis (2006-2012).

Per capita income, the rate of economic growth and the reduction of income inequality reduce innovation technical inefficiency. Lower interest rates, inflation, unemployment and (excessive?) decentralization increase innovation technical inefficiency.

The TFP of NIS in the EU-28

Conclusions

Concerning the technical efficiency ranking, Luxembourg is the leader, followed by Germany and Ireland. Portugal occupies the 18th position, above Spain.

In the period under analysis (2006-2012), the growth of innovation in the EU-28 was determined by the change in technical efficiency, the accumulation of inputs and unexplained residual factors. Germany grew slightly in terms of the innovation output, mostly due to changes in TFP, while Portugal had a significant increase, mostly due to the accumulation of input.