Estimation of the EU Linear Dynamic Panel Data Model using Bayesian Shrinkage Estimator

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Outline

Introduction

- We focus on the relationship between the stringency of regulation and total factor productivity (TFP) growth.

1 TFP is an efficiency measure that takes into account the Green House Gas (GHG) emissions thought as undesirable output from electricity production process

3 Bayesian estimation of coefficient of regulation variables in oreder to relax the homogeneity assumption relative to the cross section regression coefficients

Empirical Strategy. Nakano & Managi (2008)

- **First stage**
  Malmquist Index based on Data Envelopment Analysis (**DEA**): it evaluate the productivity change of the decision making unit (DMU) between two time periods
- **Second stage**
  Dynamic panel data specification
  Bayesian estimation for the cross-section time series in order to relax the homogeneity assumption for all parameters of the TFP-regulation relationships

First stage

We deal with a set $(\boldsymbol{x_i}; \boldsymbol{y_i})^s$ where:

- $i = 1, .., n$ denotes the n DMUs: 18 countries
- $s = t, t + 1$ denotes two time periods with $t = 2006, ..., 2014$
- $\boldsymbol{x_i} \in R^m$ is the vector of m inputs of each DMU in period s
- $\boldsymbol{y_i} \in R^q$ denotes the vector of q output produced by each DMU in the period s

Notation $(\boldsymbol{x_i}; \boldsymbol{y_i})^t$ and $(\boldsymbol{x_i}; \boldsymbol{y_i})^{t+1}$ designates the DMU i in the two time periods t and $t + 1$ respectively.

Variables in the first stage

Table: Descriptive statistics of variables used in DEA Analysis

Variable		Mean	Std. Dev.	Min	Max	Obs.
Employment	overall	49.31	62.33	.66	306.11	N =162
	between		63.15	.76	283.81	n = 18
	within		9.16	3.48	104.12	T = 9
Electrical	overall	21244.01	23498.89	439	87747	N = 162
Capacity	between		23991.31	451.11	77140.67	n = 18
	within		1923.84	12820.35	31850.35	T = 9
Input	overall	17562.5	21411.83	288.6	87610.8	N = 162
Fuels	between		21819.37	445.14	83783.84	n = 18
	within		2187.63	8202.09	24572.3	T = 9
Electricity	overall	4667.70	7160.48	1.30	26693.99	N = 162
Generation	between		7263.66	5.04	25219.78	n = 18
	within		997.30	468.18	7853.68	T = 9
GGE	overall	216.2852	286.94	1.62	1358.75	N = 162
	between		272.64	1.83	994.61	n = 18
	within		107.24	-80.73	898.70	T = 9

Indirect approach, (Scheele, 2000)

Transforming the values of the undesirable output (Y^u) using a monotone decreasing function f such that the transformed data can be included as normal desirable outputs.

Additive inverse Model

$$f(Y^u) = -Y^u$$

We perform two alternative models:

- *Multiplicative Inverse model* - *MULT* where $f(Y^u) = \frac{1}{Y^U}$.
- *Input model* - *INP* where the undesirable output is treated as input to be minimized

The results confirm the dynamic patterns of TFP found with the Additive Inverse Model.

Linear Program

Each DMU j solves two minimization problems for the time pairs $(t, t+1)$:
The within score in output orientation:

$$\begin{aligned} & \delta^t(\boldsymbol{x_i}, \boldsymbol{y_i})^t = min_{\theta,\boldsymbol{\lambda}}\theta \\ s.t. \qquad & \boldsymbol{x_i^t} \geq X^t\boldsymbol{\lambda}; \qquad (1/\theta)\boldsymbol{y_i^t} \leq Y^t\boldsymbol{\lambda} \\ & L \leq \boldsymbol{e\lambda} \leq U; \qquad \boldsymbol{\lambda} \geq 0 \end{aligned}$$

The inter-temporal score in output orientation:

$$\begin{aligned} & \delta^t(\boldsymbol{x_i}, \boldsymbol{y_i})^{t+1} = min_{\theta,\boldsymbol{\lambda}}\theta \\ s.t. \qquad & \boldsymbol{x_i^{t+1}} \geq X^t\boldsymbol{\lambda}; \qquad (1/\theta)\boldsymbol{y_i^{t+1}} \leq Y^t\boldsymbol{\lambda} \\ & L \leq \boldsymbol{e\lambda} \leq U; \qquad \boldsymbol{\lambda} \geq 0 \end{aligned}$$

The Malmquist Index

- MI is the geometric mean of the two efficiency ratios:

$$MI = \left\{ \frac{\delta^t(\boldsymbol{x_i}, \boldsymbol{y_i})^{t+1}}{\delta^t(\boldsymbol{x_i}, \boldsymbol{y_i})^t} \times \frac{\delta^{t+1}(\boldsymbol{x_i}, \boldsymbol{y_i})^{t+1}}{\delta^{t+1}(\boldsymbol{x_i}, \boldsymbol{y_i})^t} \right\}^{1/2} \tag{1}$$

- MI>1 indicates progress in the total factor productivity (TFP) of the DMU from period t to period $t+1$,
- MI=1 indicates the non variation of the TFP
- MI<1 indicates the deterioration of the TFP.

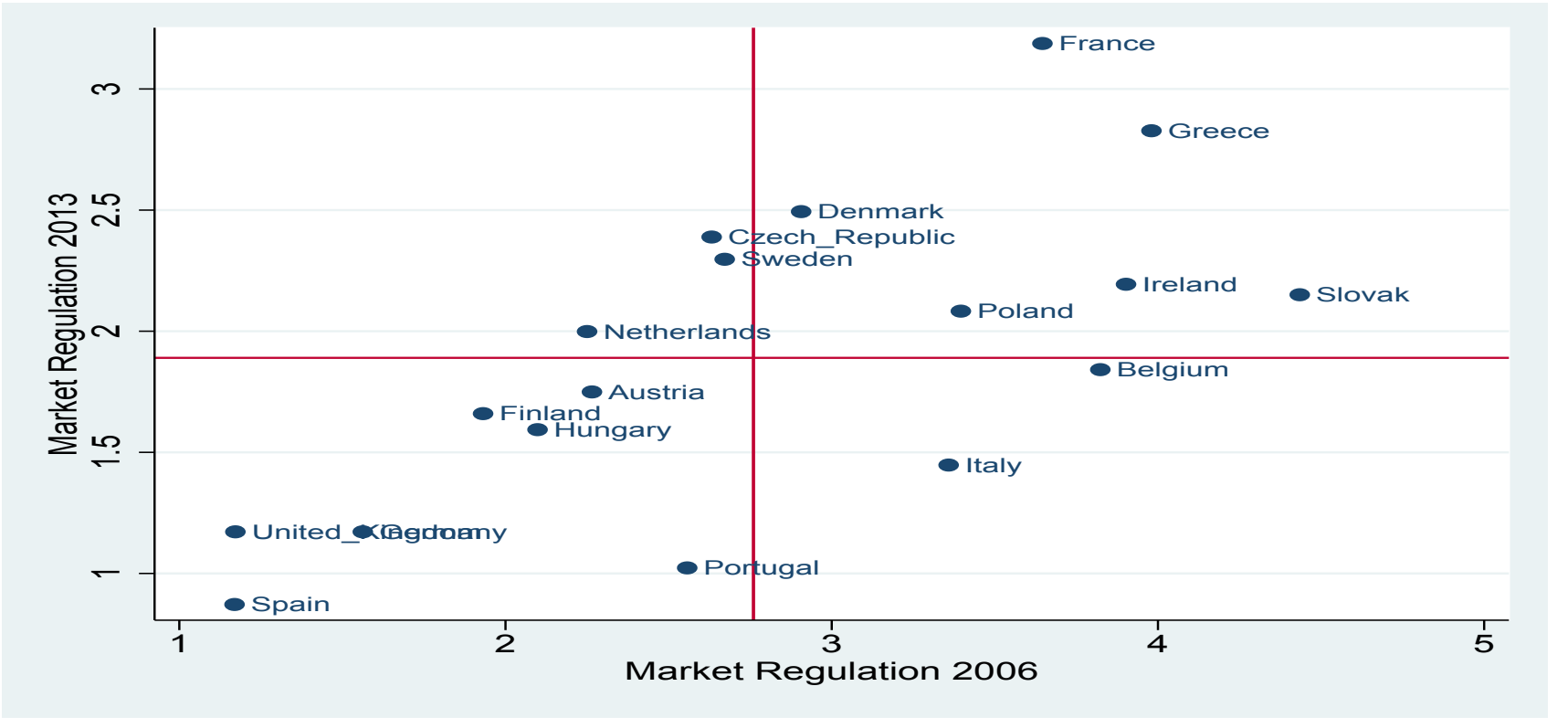
First stage results

Table: Average of the Malmquist Index and its main components

Country	Frontier Shift Ch.	Pure Eff. Ch.	Scale Eff. Ch.	TFP Ch.
Austria	1.049	1	0.994	1.043
Belgium	1.085	1.073	0.973	1.133
Czech Republic	1.001	0.994	0.997	0.992
Denmark	1.004	1	0.991	0.996
Finland	1.005	0.982	0.997	0.984
France	1.113	0.977	1.029	1.119
Germany	0.996	1	1.002	0.998
Greece	0.995	1.011	1.002	1.008
Hungary	0.994	0.978	1.006	0.978
Ireland	0.999	1	0.998	0.996
Italy	1.052	1	1	1.052
Netherlands	1.036	1	1	1.036
Poland	1.046	1	1	1.046
Portugal	1.037	0.978	1	1.015
Slovakia	1.033	1.004	0.982	1.018
Spain	1.026	0.996	1	1.023
Sweden	1.061	0.96	0.988	1.006
United Kingdom	0.99	0.986	1.012	0.988
mean	1.028	0.996	0.998	1.023

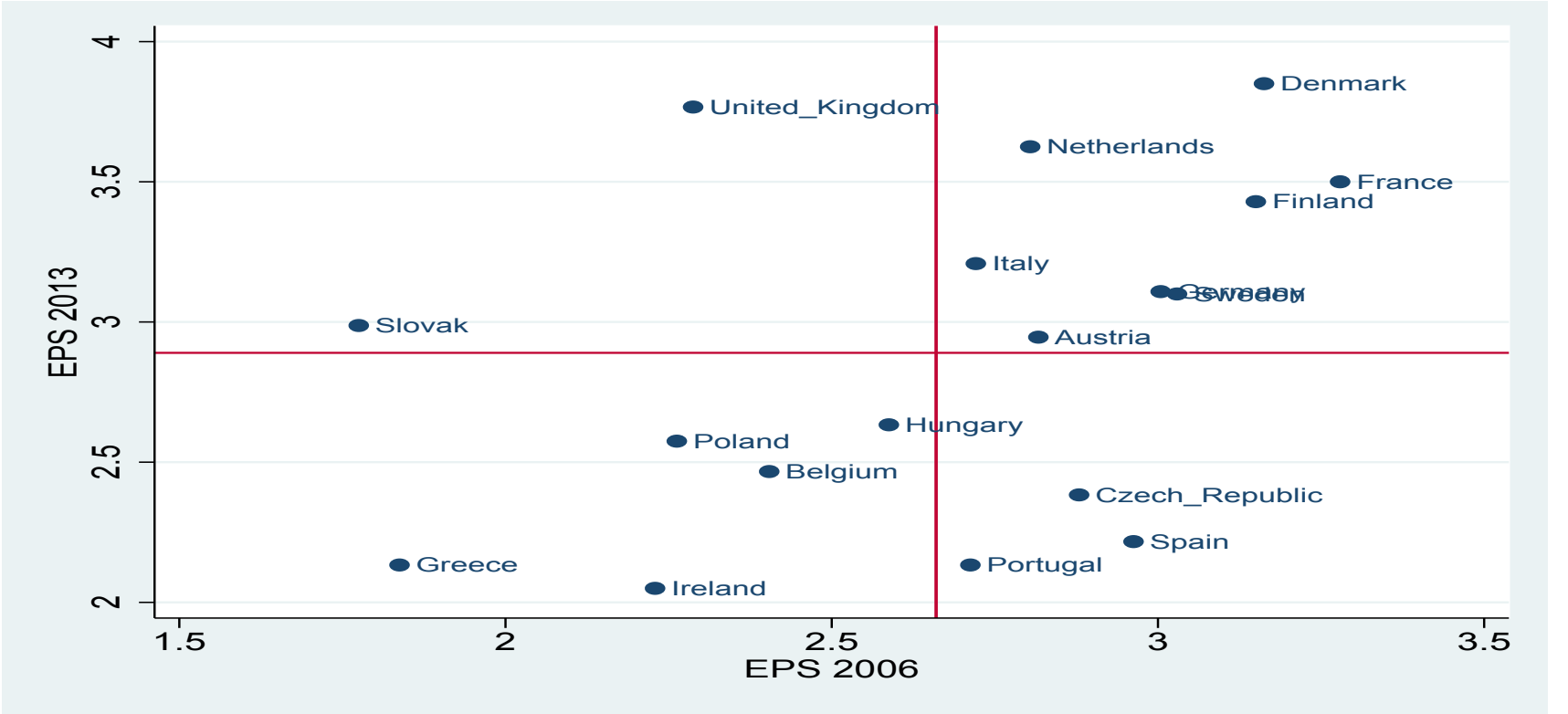
First stage results

Fig.: Changes in the overall sector regulation.



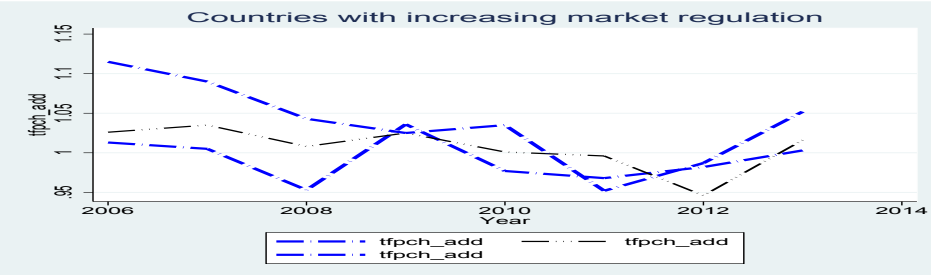
First stage results

Fig.: Changes in environmental policy stringency.

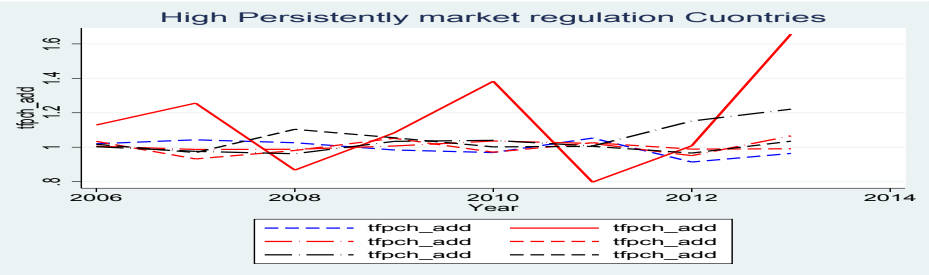


First stage results

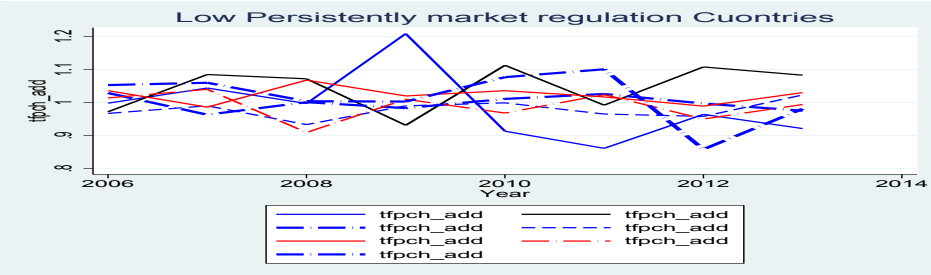
Fig.: Country specific Malmquist index evolution by different changes in the degree of sector regulation.



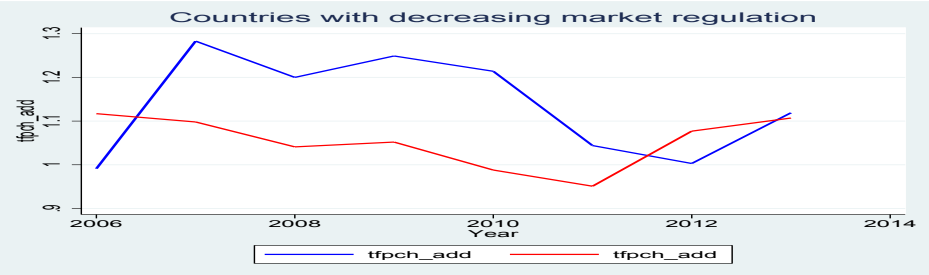
(a) Countries with increasing sector regulation.



(b) Countries with persistently high sector regulation.



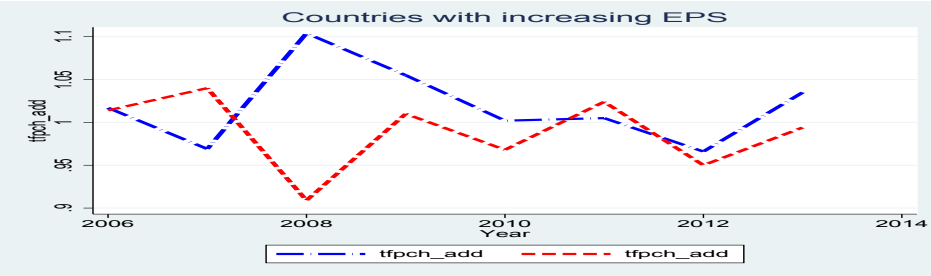
(c) Countries with persistently low sector regulation.



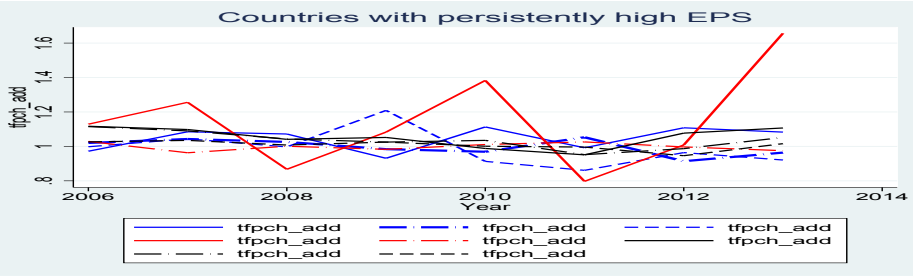
(d) Countries with decreasing sector regulation.

First stage results

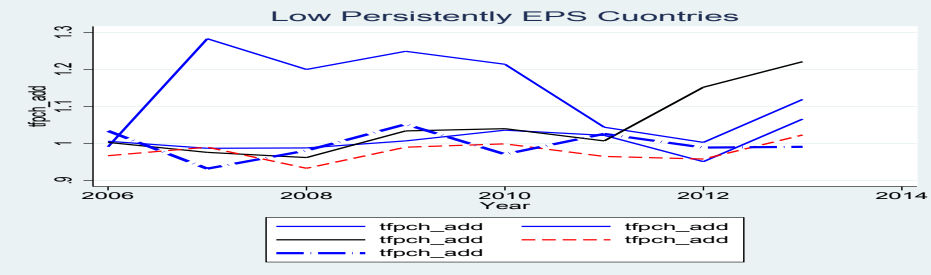
Fig.: Country specific Malmquist index evolution by different changes in the degree of environmental policy stringency.



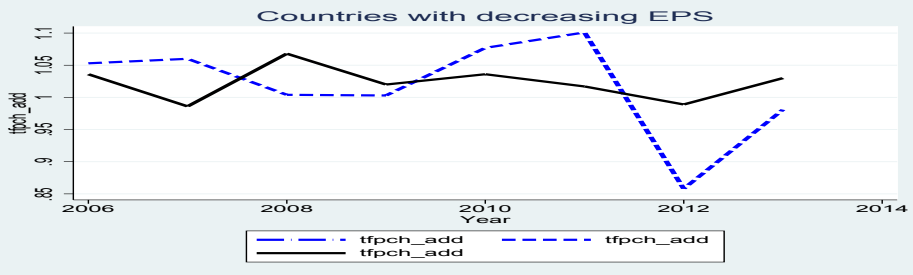
(A) Countries with increasing EPS.



(B) Countries with persistently high EPS.



(C) Countries with persistently low EPS.



(D) Countries with decreasing EPS.

The Second Stage

$$\Delta \boldsymbol{MI_i} = \beta_i \Delta \boldsymbol{X_i} + \gamma_j \Delta \boldsymbol{Z_i} + \boldsymbol{u_i}$$

where:

$i = 1 \ldots 18$ countries;

$\boldsymbol{X_i}$ is the $T \times k$ matrix of the key explanatory variables including the lagged dependent variable for $\boldsymbol{MI_i}$ and the regulation variables

$\boldsymbol{Z_i}$ is the $T \times 3$ matrix of the set of controlling variables

β_j is a $k \times 1$ vector of random parameters

$\boldsymbol{u_i}$ is the error term including the fixed effect.

Variable in the second stage

Table: Descriptive statistics of regressors used in the second stage

Variable		Mean	Std. Dev.	Min	Max	Observation
PMR	overall	2.239	0.811	0.871	4.434	N: 144
	between		0.705	1.016	3.445	n: 18
	within		0.430	1.480	3.764	T: 8
EPS	overall	2.777	0.543	1.4	4.133	N: 144
	between		0.440	2.075	3.592	n: 18
	within		0.333	1.811	3.623	T: 8
EPS-Market	overall	1.998	0.640	0.383	3.983	N=144
	between		0.493	1.025	2.865	n=18
	within		0.422	0.614	3.314	T=8
EPS-Non-Market	overall	3.556	0.907	1.625	5.500	N=144
	between		0.812	2.078	5.328	n=18
	within		0.442	2.477	4.727	T=8
R&D intensity	overall	0.033	0.029	0.000	0.143	N: 144
	between		0.028	0.001	0.107	n: 18
	within		0.011	-0.01	0.070	T: 8
CHP penetration	overall	0.166	0.136	0	0.786	N: 144
	between		0.125	0.030	0.462	n: 18
	within		0.059	-0.04	0.586	T: 8
pca fuelmix	overall	0.020	1.179	-2.68	2.717	N: 144
	between		0.633	-1.30	1.052	n: 18
	within		1.004	-3.44	4.042	T: 8

Wald Test for the Equality of Slope Parameters.

Table: Wald Test for the Equality of Slope Parameters.

Model	Number of Restrictions	Statistic	p-value
I	34	49.840246	0.039
II	34	49.967438	0.038
III	51	70.124945	0.029
IV	68	90.22933	0.033
V	85	109.69593	0.037
VI	85	108.62296	0.043

H_0: Slopes parameters are equal among cross sections.
We use Stata 15 to run tests, this software performs a Wald test distributed as a χ^2 with degrees of freedom equal to the number of restrictions.

Bayesian Approach and cross-country heterogeneity

The country's unobservable structural differences are captured decomposing the slope coefficients β_i in two elements: the direct effect of regulatory variables β and the indirect effect ν_i (the effect of the omitted country specific variable)

$$\beta_i = \beta + \nu_{ij} \qquad i = 1, ..., 18;$$
$$\beta_i \sim N(\beta, \sigma_\beta^2)$$

Bayesian Estimator

$$\beta_{\mathbf{i}}^{\star} = \left(\frac{\mathbf{1}}{\sigma_{\mathbf{i}}^2} \mathbf{X}_{\mathbf{i}}' \mathbf{X}_{\mathbf{i}} + \sigma^{-1}) \right)^{-1} \left(\frac{\mathbf{1}}{\sigma_{\mathbf{i}}^2} \mathbf{X}_{\mathbf{i}} \mathbf{X}_{\mathbf{i}} \widehat{\beta}_{\mathbf{i}} + \sigma^{-1} \beta \right)$$

Bayesian Results

Table: Bayesian Regulation effect for the electricity sector, on MI.

Dependent Variable: MI	M1	M2	M3	M4	M5	M6
L.MI	-0.1977***	-0.2346***	-0.211***	-0.2434***	-0.1953***	-0.1942***
	0.0291	0.0339	0.025	0.0096	0.0095	0.0096
PMR	-0.0313***		-0.0244**	-0.0005	-0.0274***	-0.0135***
	0.0073		0.0113	0.0031	0.0033	0.0032
EPS		-0.0194***	-0.0269***			
		0.0071	0.0069			
EPS-Market				-0.0184***	-0.0139***	-0.0193***
				0.0004	0.003	0.0031
EPS-Non-Market				-0.0123***	-0.0126***	-0.0184***
				0.0021	0.0031	0.0032
PMR*EPS-M					-0.0033	
					0.0033	
PMR*EPS-N-M						-0.0133***
						0.0031
R&D	-0.5713	-0.0816	-0.1136	-0.0033	-0.201	-0.1698
	1.2254	1.2524	1.2755	1.299	1.4272	1.4848
CHP	-0.0724	-0.0626	-0.0656	-0.0755	-0.0711	-0.0653
	0.2134	0.2069	0.2096	0.2107	0.2196	0.2192
Fuelmix	0.0081	0.0071	0.0073	0.007	0.0076	0.0073
	0.0075	0.0074	0.0075	0.0075	0.0077	0.0079
U1:sigma2	0.012	0.0128	0.013	0.0047*	0.0044*	0.0019
	0.0105	0.0088	0.0089	0.0025	0.0024	0.0019
U2:sigma2			0.0417	0.0106	0.0118	0.0139
			0.0561	0.0102	0.0114	0.0124
U3:sigma2				0.0107	0.0107	0.0086
				0.0077	0.0083	0.0062
					0.011	0.0095
					0.0075	0.0073
sigma2	0.0449	0.0464	0.0107	0.0148***	0.0156***	0.0153***
	0.0483	0.0652	0.0088	0.0022	0.0023	0.0023

Fig.: Country specific indirect effect of PMR index on MI.

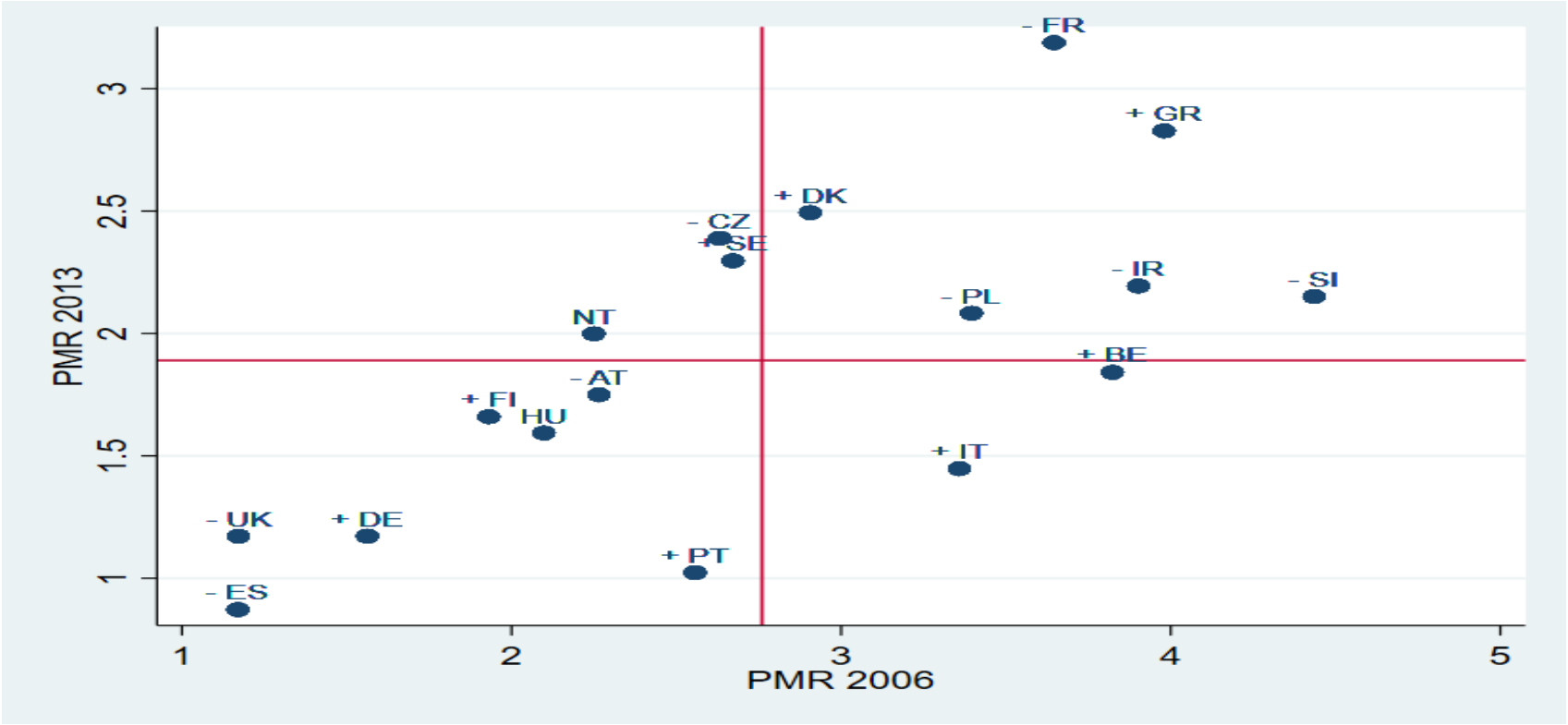


Fig.: PMR

Fig.: Country specific indirect effect of EPS index on MI.

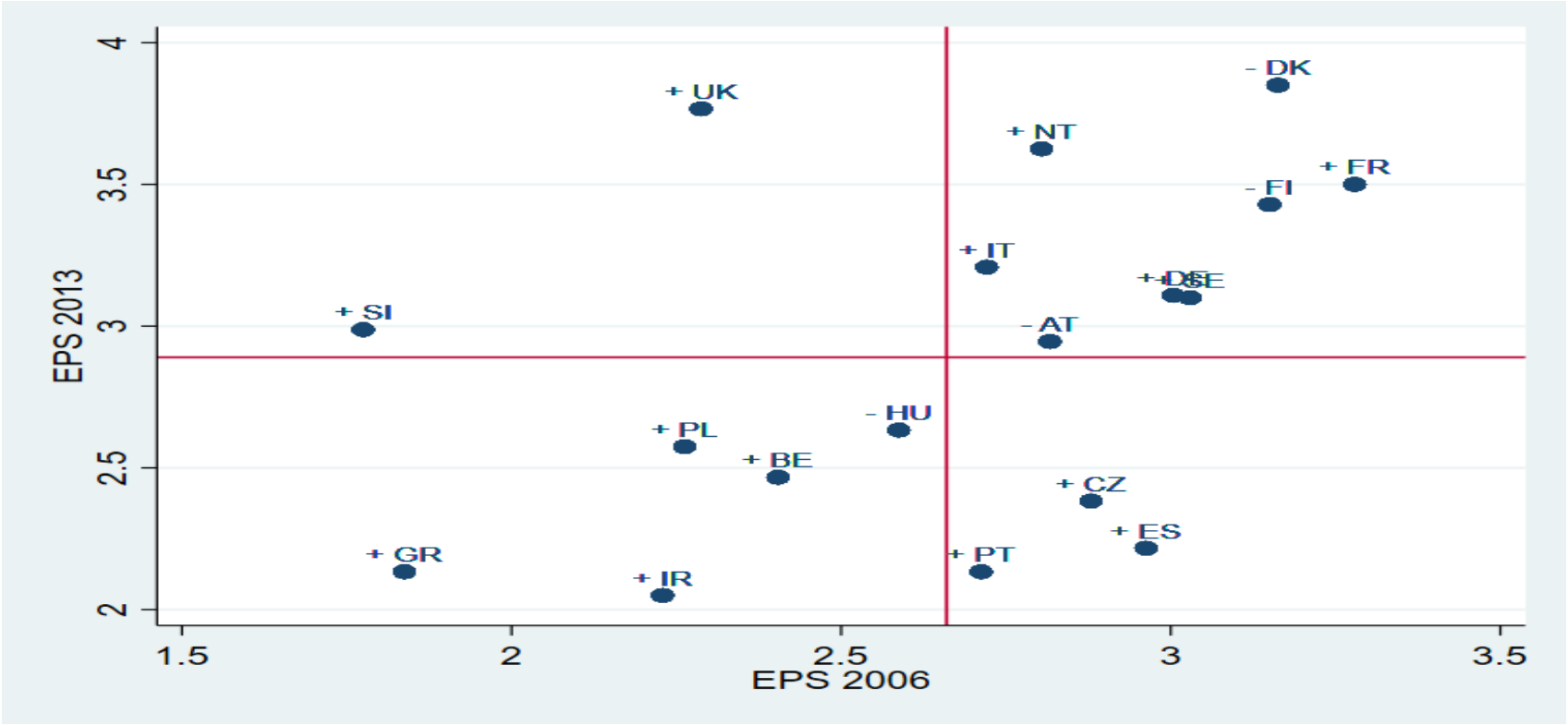


Fig.: EPS

Fig.: Country specific indirect effect of EPS-Market index on MI.

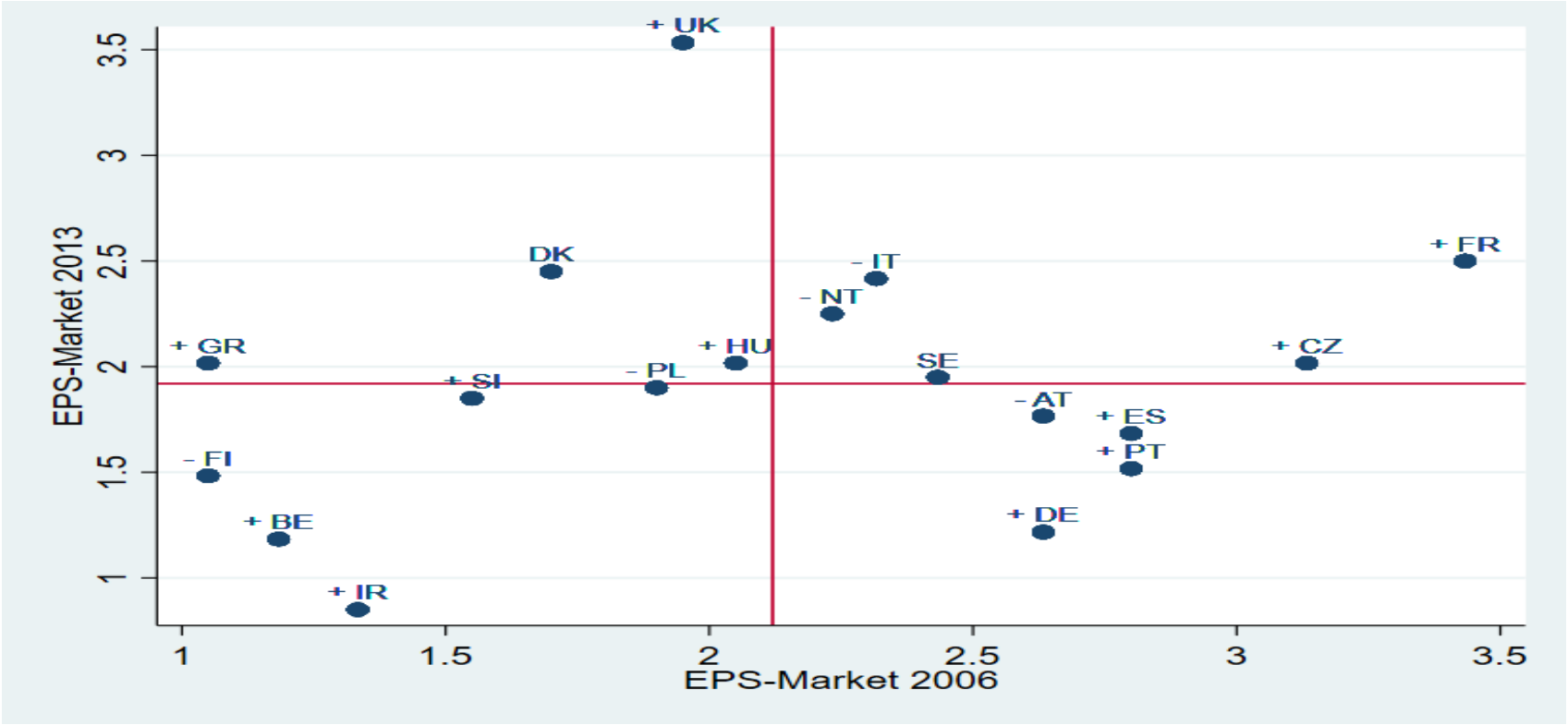


Fig.: EPS-Market

Fig.: Country specific indirect effect of EPS-Non-Market index on MI.

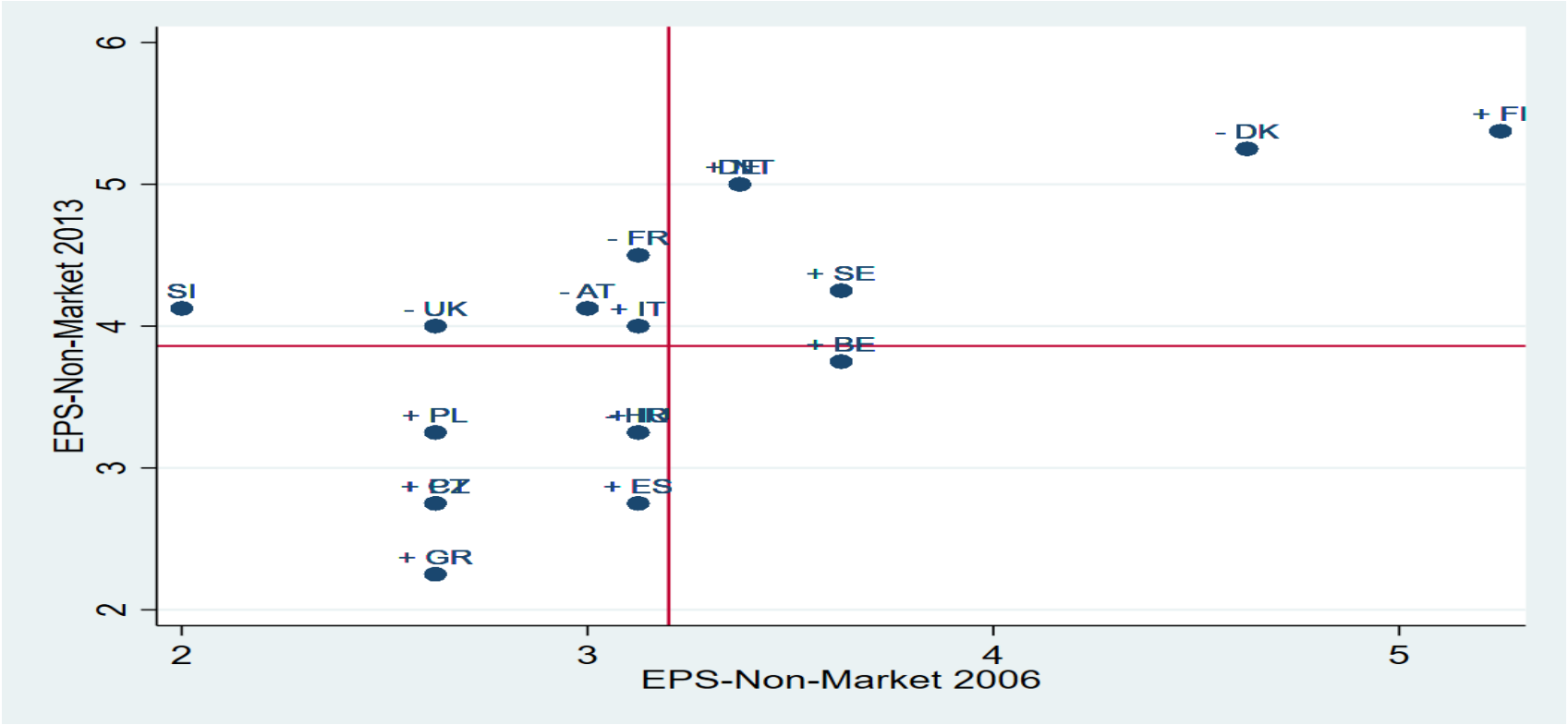
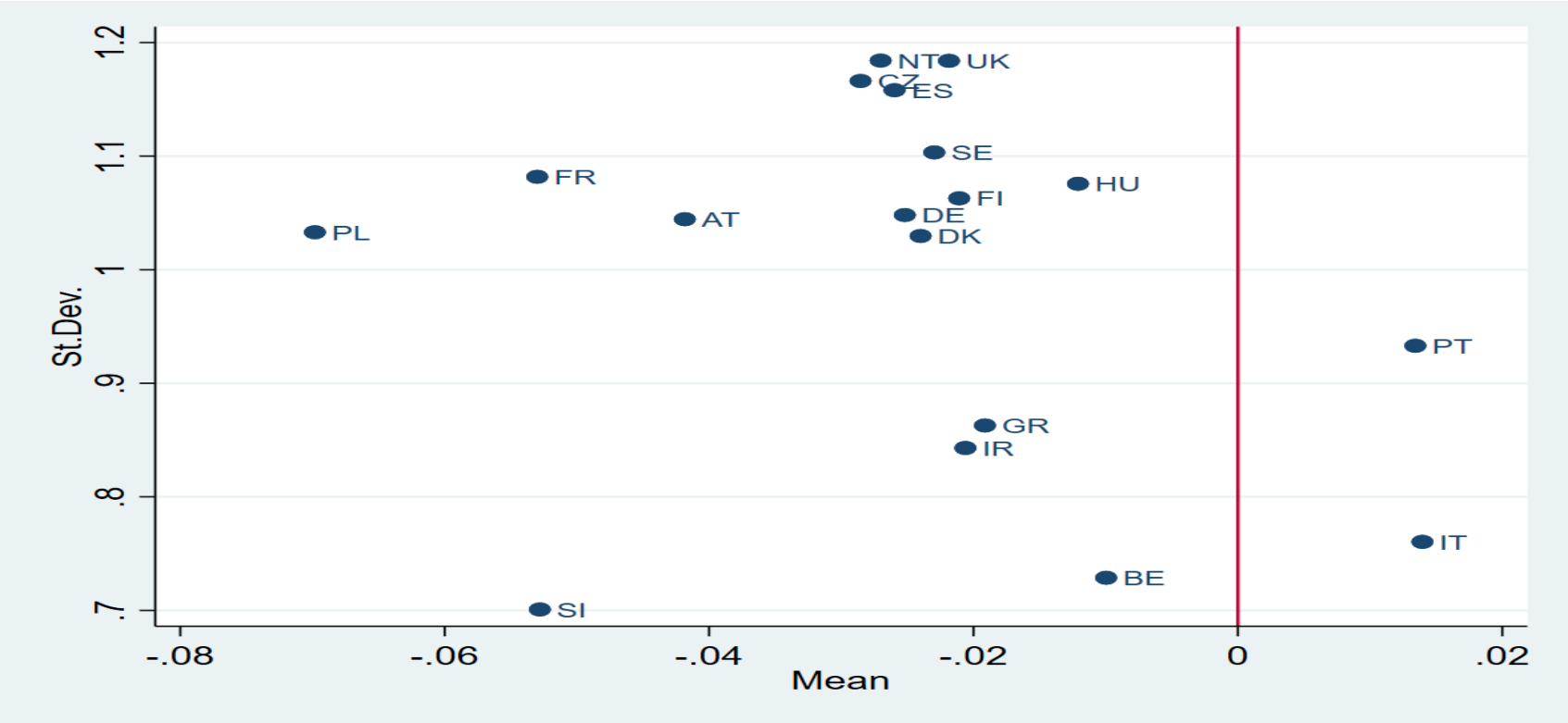


Fig.: EPS-Non-Market

Fig.: Scatter Plot of Mean and Standard Deviation of the Combined Effect of Direct Effect and the Country-Specific Estimates.



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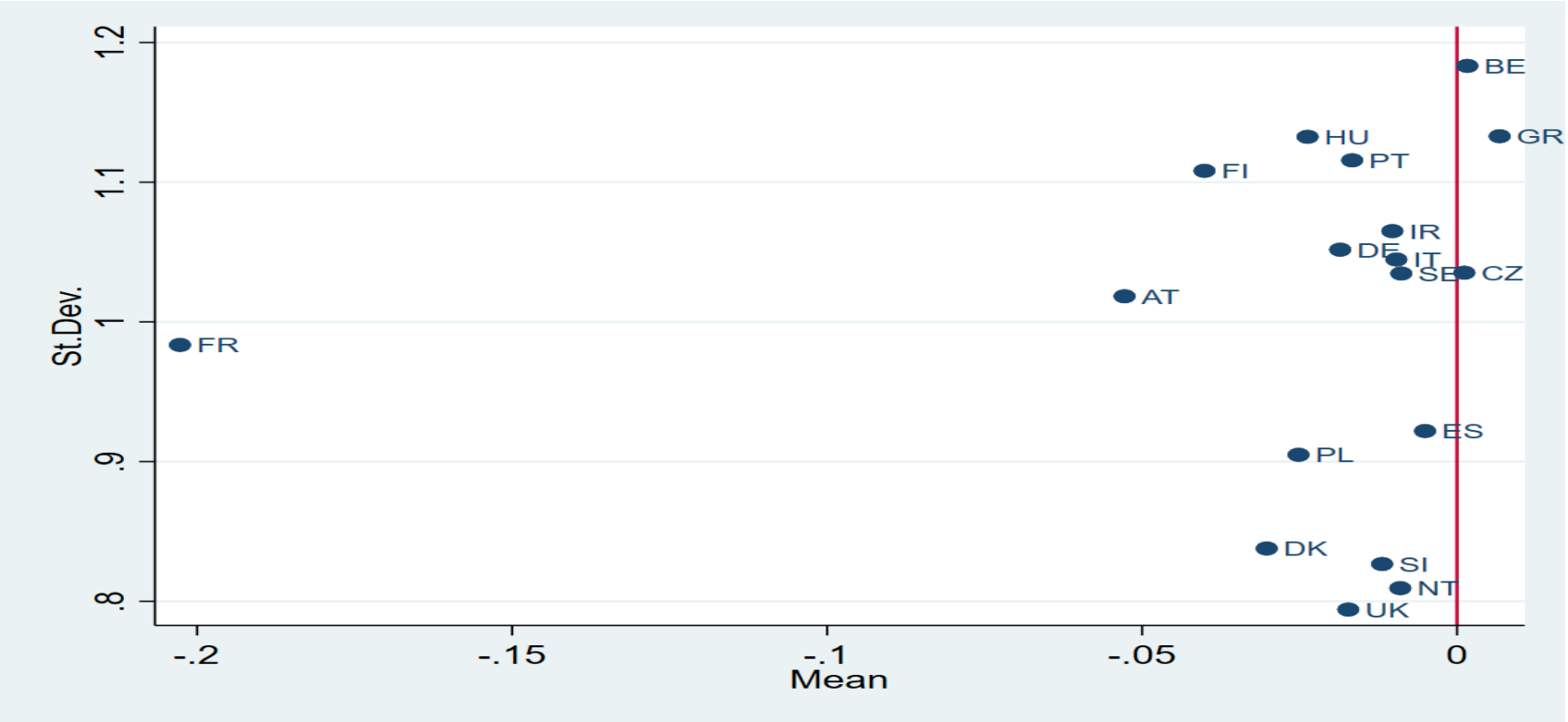

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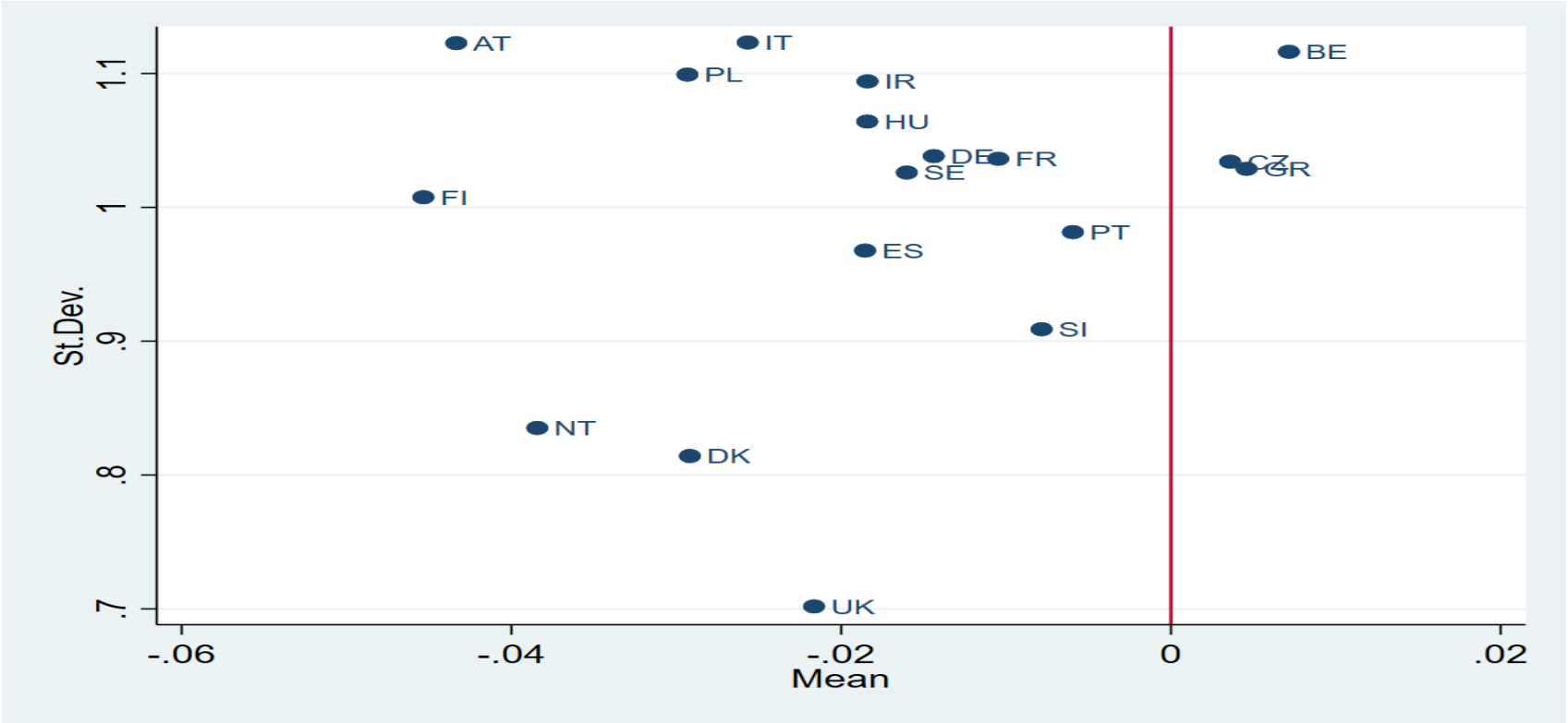

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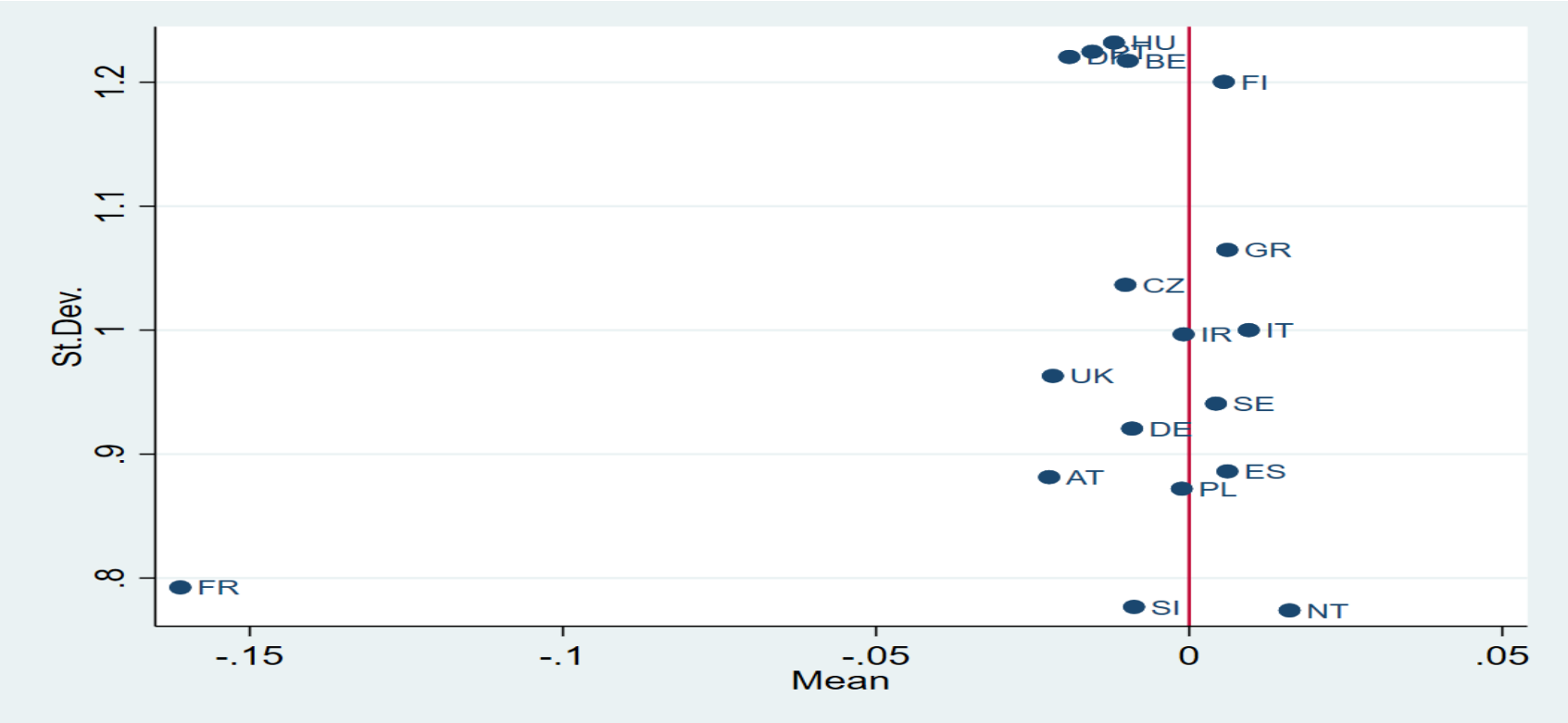

Fig.: EPS-Non-Market

Conclusions

Country Heterogeneity

- The effects of regulations on the electricity sector's performance result from differences and asymmetries due to the country specific responses.
- Significant heterogeneity of each country response to common regulatory structure, both in the levels and in the standard deviations, highlighting a non unidirectional behavior.
- Countries with deregulated market (i.e., Belgium, Denmark, Greece, and Italy) have PMR that positive affect country specific responses.
- EPS-Market and EPS-Non-Market indexes can have opposite effects in the same country.

Thank you for your attention