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Online Appendix: How should we measure environmental policy stringency?

A new approach

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Online Appendix:

How should we measure environmental policy stringency ?

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Abstract

This is the online appendix to the paper “How should we measure environmental policy stringency? A new approach” (Sauter, 2014). The main paper outlines the general methodology proposed to construct environmental policy indexes and proposes a first implementation of a CO_2 input index and a CO_2 performance index. This online appendix reports the results of the implementation of a SO_2 input index, a SO_2 performance index, a CH_4 input index, a CH_4 performance index as well as the broad GHG input index. All of those indexes have been constructed using the methodology outlined in the main paper.

Keywords: Greenhouse gas emissions, environmental regulation, environmental policy stringency, policy stringency index, CO_2 emissions

1. SO_2 indexes

All the indexes have been constructed using the methodology outlined in the main paper at the example of a CO_2 policy. In case of SO_2 two important comments have to be made:

- 1) For the construction of the narrow SO_2 input index, a total of 240 SO_2 policies have been identified using ECOLEX. Out of those 240 policies, 14 are only applied on a sub-national level.
- 2) For the construction of the SO_2 performance indicator I used the same approach as in the CO_2 case described in the main paper. The database used doesn't report sulphur dioxide but sulphur oxide (SO_X), hence the constructed performance index has to be interpreted as a SO_X performance index. The variables used to construct the sectoral performance indicator and the mean of the pca weights used to construct it are summarized in Table (1):

[☆]JEL classification: Q50, Q53, Q58, C18

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Table 1: Sectoral SO_X performance sub-indicators

Indicator	Description	Mean weight	Dimension
$\frac{\text{sectoral } SO_X \text{ emissions}}{\text{sectoral GDP}}$ 1	Sectoral SO_X per sectoral GDP	0.443	SO_X intensity
$\frac{\text{sectoral } SO_X \text{ emissions}}{\text{sectoral work force}}$ 2	Sectoral SO_X per sectoral workforce	0.411	
EE_t	SO_X efficiency score (profit function)	0.545	SO_2 efficiency
EE_t^*	SO_X efficiency score (revenue function)	0.551	

1.1. SO_2 results

To obtain an overview, Figure (1) displays the evolution of the narrow SO_2 input index and the SO_X performance index by country. Note that due to the different data-sources, not all indexes are available for all countries.

To empirically assess whether the constructed indexes measure what they are supposed to I pursue the same strategy as in the main paper. First I compare the input (performance) index to existing input (performance) indexes and second I compare the input index to the performance index and verify that the expected relation holds. Table (2) reports the pairwise correlations of the country-means³ of the indexes.

The first set of benchmark indexes are the two input indexes measuring Air Policy Stringency constructed by (Knill et al, 2012). Both air policy indexes show a strongly positive and highly significant correlation with the narrow SO_2 input index. The higher SO_2 input policy stringency the higher air policy input stringency, a result which has been expected. As a second benchmark the WEF survey index⁴ is used (Browne et al, 2012). I expect that the opinion of the survey respondents on environmental policy stringency should be positively correlated with the SO_2 input index. This is the case, the correlation is positive and significant. Looking at the performance index, we observe again a positive and significant correlation with the EPI, the overall environmental performance index of Yale. As a second benchmark for the performance index the lead content of gasoline index has been taken. Here we observe a negative and significant correlation. Indicating that a better SO_X performance is paralleled by a lower lead content in gasoline concentration, a result which has been expected.

Looking at the relationship between input and performance index, the strong and highly significant correlation are in accordance with our expectations: a higher SO_2 input stringency goes hand in hand with a higher SO_X performance. Figure (2) plots the mean value of the two indexes by country, including a linear fit and the corresponding

¹Note that this variable has been re-scaled. Each observed value is subtracted from the observed maximum (max) of the variable, then the minimum (min) of the variable is subtracted: (max-observation)-min. With this transformation higher values now indicate a better performance.

²See: footnote 1.

³I use country means and not each observation available to avoid that the pairwise correlations capture trends. In the single observation case (not displayed) the correlations are stronger and more significant but the same overall tendencies hold.

⁴Even if the WEF survey index is not an input index, I use this index as a benchmark due to it's wide usage in the literature.

confidence interval for the mean value of the performance index given the different input index values. One can observe a clear tendency: the higher the mean value of the SO_2 input index, the higher the mean SO_X performance by country. Figure (3) shows the difference between the last and the first year of the performance index on the y-axis and of the input index on the x-axis. Again a simple linear fit and the corresponding confidence interval is displayed. The result goes in the expected direction and is even stronger than in the CO_2 case displayed in the main paper.

As in the CO_2 case discussed in the main paper, results seem to indicate that the indexes measure what they are supposed to.

Table 2: Pairwise correlations of the means of the variables

	Narrow SO2 II	Air Policy II 1	Air Policy II 2	WEF	SOX PI	EPI	lead
Narrow SO2 II	1						
Air Policy II 1	.691**	1					
Air Policy II 2	.661**	.905***	1				
WEF	.411**	-.139	.0466	1			
SOX PI	.605***	.108	.274	.478**	1		
EPI	.298*	.144	.273	.660***	.419**	1	
lead	-.320	-.0938	-.235	-.544***	-.530**	-.553***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: II stands for Input Index, PI for Performance Index. The Narrow SO_2 Input Index and the SO_2 Performance Index have been constructed by the above outlined methodology. The Air Policy Input Index 1 and 2 are taken from Knill et al (2012). The WEF survey index is taken from Browne et al (2012). The Environmental Performance Index (EPI) is taken from Emerson et al (2012) and the lead content of gasoline (Lead) index is taken from Grether et al (2012).

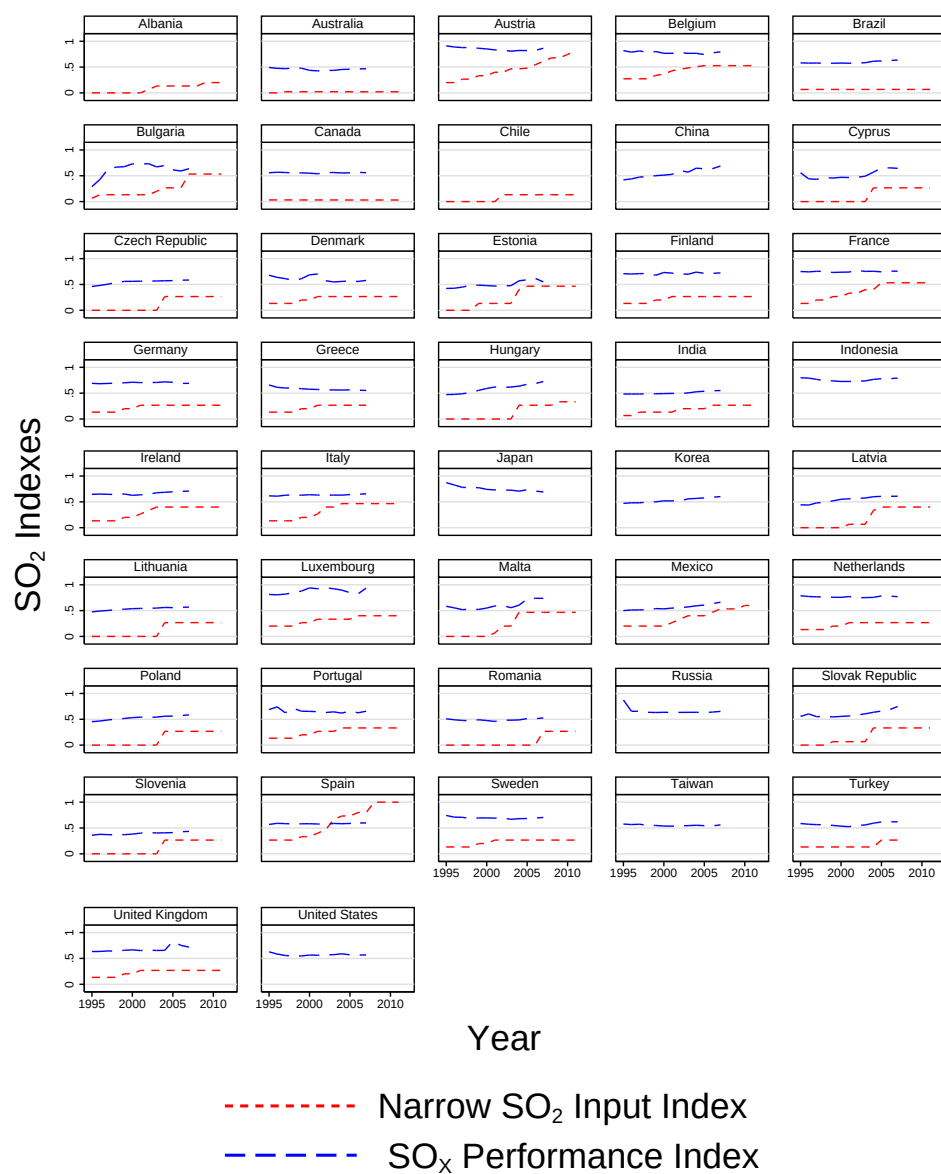


Figure 1: The SO_2 input indexes and the SO_X performance index by country

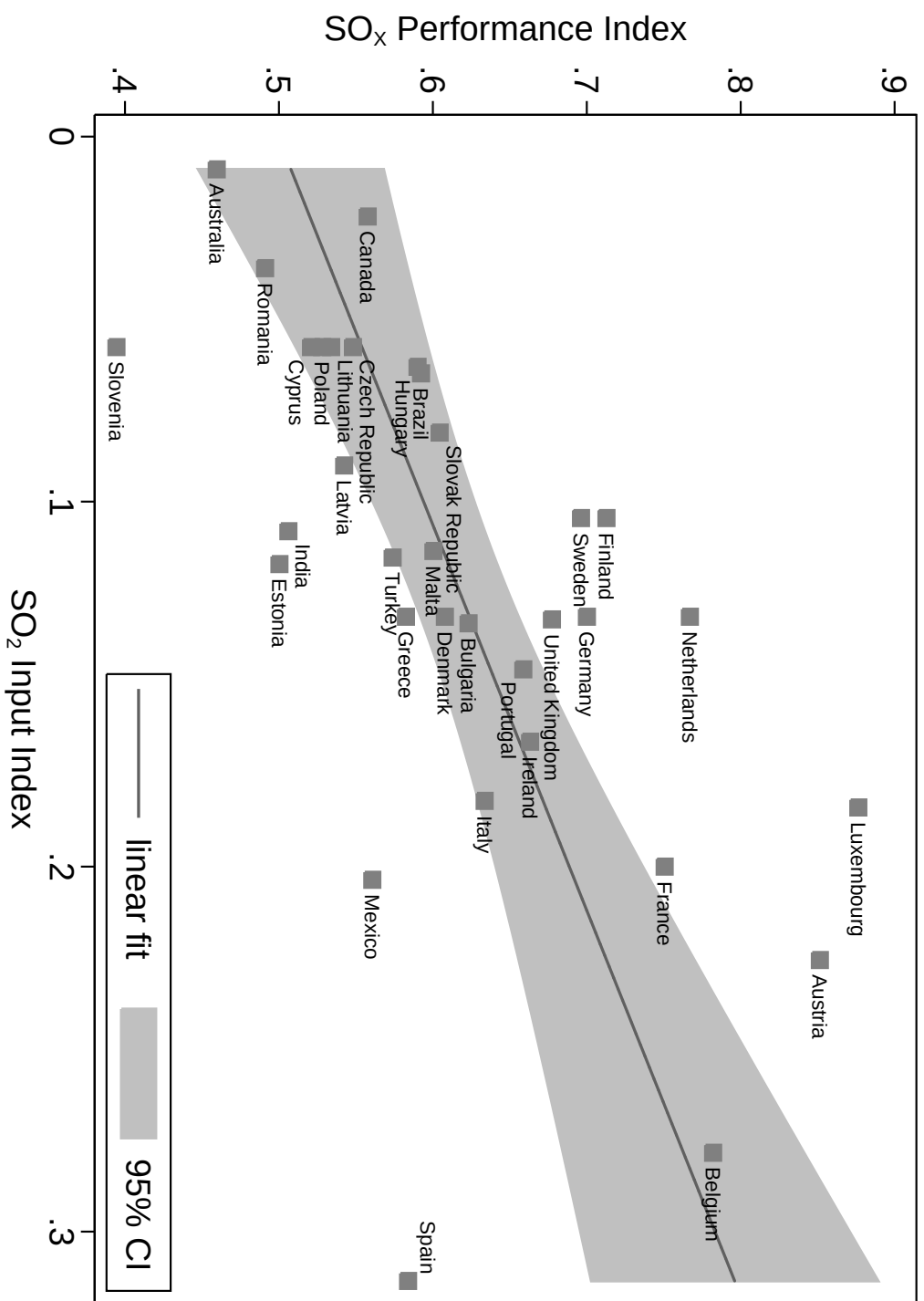


Figure 2: Mean of the narrow SO_2 input index and the SO_x performance index by country

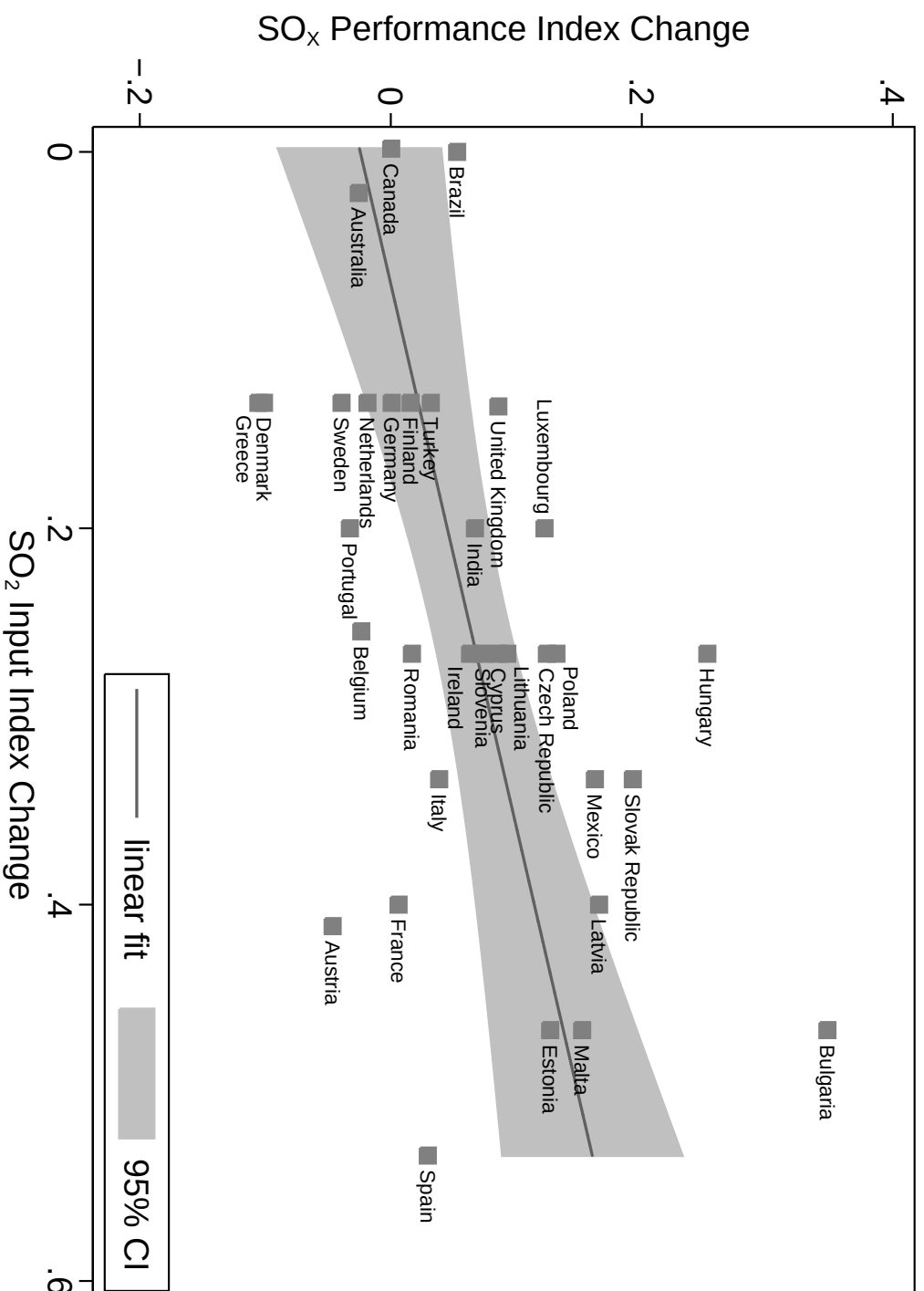


Figure 3: Change of the Narrow SO_2 input index and of the SO_x performance index from the first to the last year in the sample

2. CH_4 Indexes

All the indexes have been constructed using the methodology outlined in the main paper at the example of a CO_2 policy. In case of CH_4 two important comments have to be made:

- 1) For the construction of the CH_4 input index, a total of only 53 CH_4 policies have been identified using ECOLEX. Out of those 53 policies, 6 are applied on a sub-national level. This really limited number of CH_4 policies and therefore the small variation in the CH_4 input index limit the use of the narrow methane input index considerably.
- 2) For the construction of the CH_4 performance indicator I used the same approach as in the CO_2 case described in the main paper. The variables used to construct the sectoral performance indicator and the weights used to construct it are summarized in Table (3):

Table 3: Sectoral CH_4 performance sub-indicators

Indicator	Description	Mean weight	Dimension
$\frac{\text{sectoral } CH_4 \text{ emissions}}{\text{sectoral GDP}}$ ⁵	Sectoral CH_4 per sectoral GDP	0.453	CH_4 intensity
$\frac{\text{sectoral } CH_4 \text{ emissions}}{\text{sectoral work force}}$ ⁶	Sectoral CH_4 per sectoral workforce	0.449	
EE_t	CH_4 efficiency score (profit function)	0.529	CH_4 efficiency
EE_t^*	CH_4 efficiency score (revenue function)	0.538	

2.1. CH_4 results

Figure 4 displays the evolution of the CH_4 input and performance indicator by country. Given the absence of a lot of methane specific laws the input index displays a very limited variability over time and space.

Table 5 displays the pairwise correlation of the means of the variables. The narrow CH_4 index is positively and significantly correlated with the Air Policy indexes of Knill et al (2012). There is no significant correlation between the CH_4 input indicator and the WEF index. The small number of explicit CH_4 laws seems to limit the input indicator approach considerably. Looking at the performance indicator, there is a positive and significant correlation between the CH_4 performance indicator and the EPI of Yale. And a negative and significant correlation between the performance index and the lead content of gasoline. Both results indicate that the performance index is measuring what he is supposed to.

⁵Note that this variable has been re-scaled. Each observed value is subtracted from the observed maximum (max) of the variable, then the minimum (min) of the variable is subtracted: (max-observation)-min. With this transformation higher values now indicate a better performance.

⁶See: footnote 5.

For the sake of completeness I included Figure 5 and 6 despite the fact that comparisons between the performance and input index make only limited sense given the small numbers of explicit CH_4 laws. The correlation between the two is positive but not significant and Figure 5 displays a relationship which goes in the expected direction. Figure 6 however displays a result which is not in accordance with the expectation.

Overall, the CH_4 performance indicator seem to work as intended. However, the small number of explicit CH_4 laws clearly exemplifies one of the limits of the proposed input index approach.

Table 4: Pairwise correlations of the means of the variables

	Narrow CH4 II	Air Policy II 1	Air Policy II 2	WEF	CH4 PI	EPI	lead
Narrow CH4 II	1						
Air Policy II 1	.710**	1					
Air Policy II 2	.769**	.905***	1				
WEF	.0778	-.139	.0466	1			
CH4 PI	.255	-.00817	.139	.430**	1		
EPI	.0264	.144	.273	.660***	.409*	1	
lead	-.161	-.0938	-.235	-.544***	-.355*	-.553***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: II stands for Input Index, PI for Performance Index. The Narrow CH_4 Input Index, the Broad GHG Input Index and the CH_4 Performance Index have been constructed by the above outlined methodology. The Air Policy Input Index 1 and 2 are taken from Knill et al (2012). The WEF survey index is taken from Browne et al (2012). The Environmental Performance Index (EPI) is taken from Emerson et al (2012) and the lead content of gasoline (Lead) index is taken from Grether et al (2012).

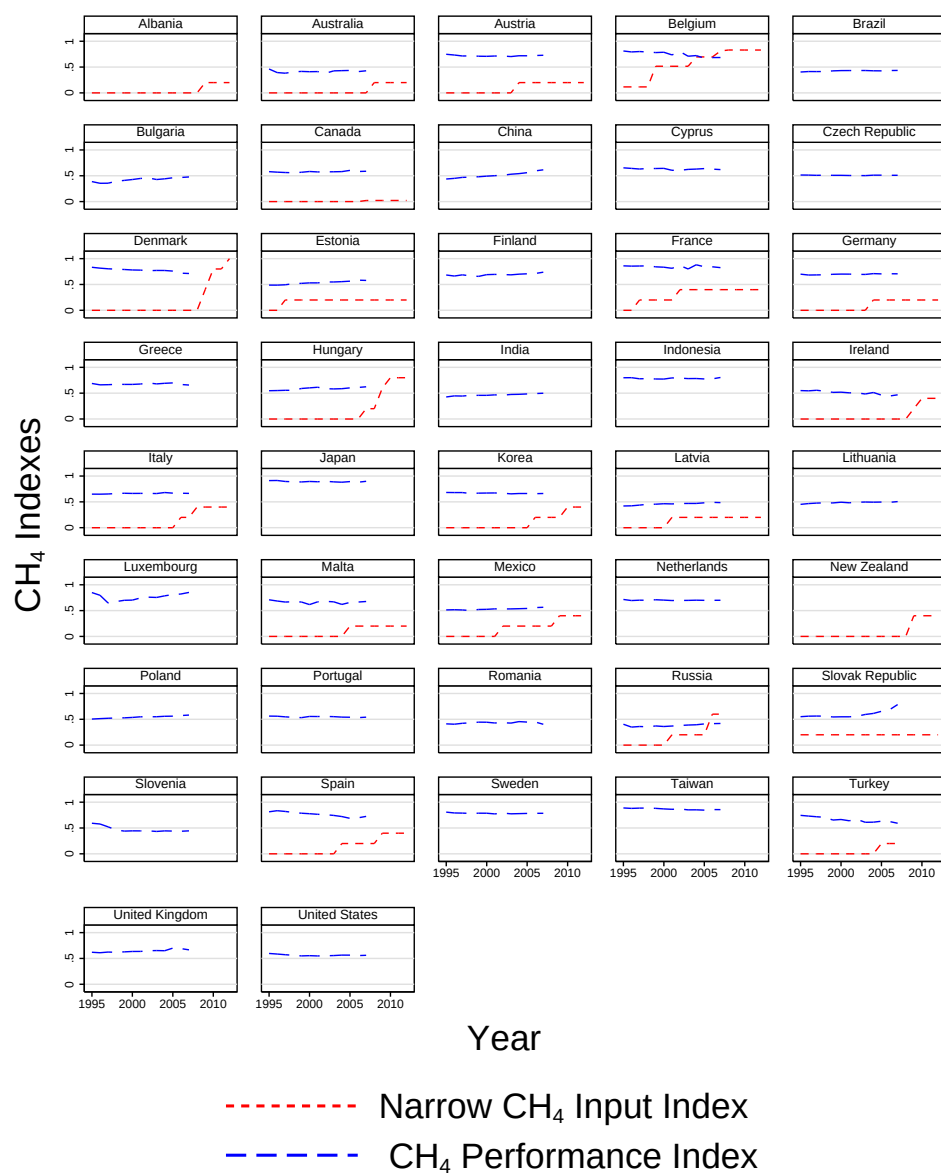


Figure 4: The CH_4 input indexes and the CH_4 performance index by country

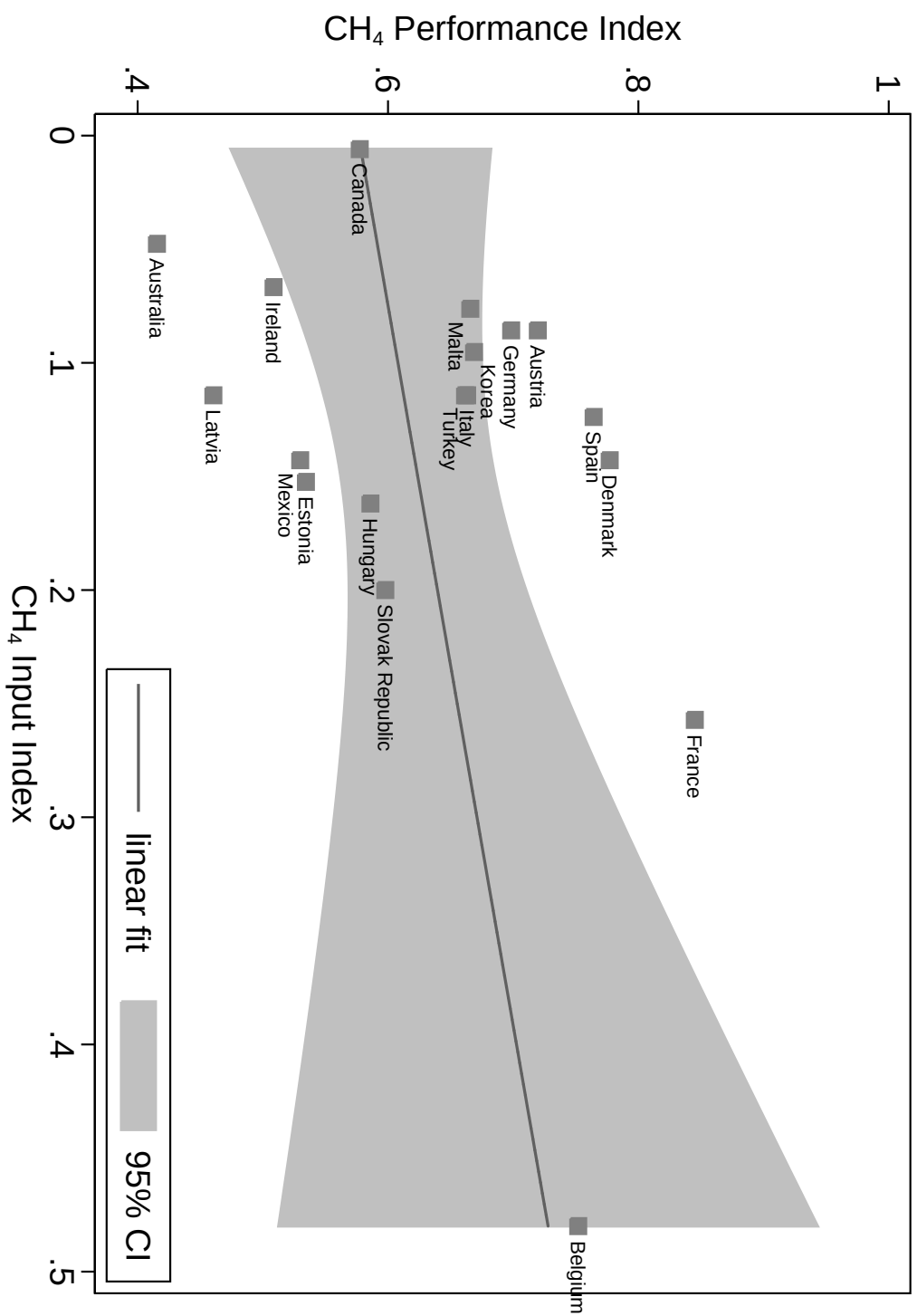


Figure 5: Mean of the Narrow CH_4 input index and of the CH_4 performance index by country

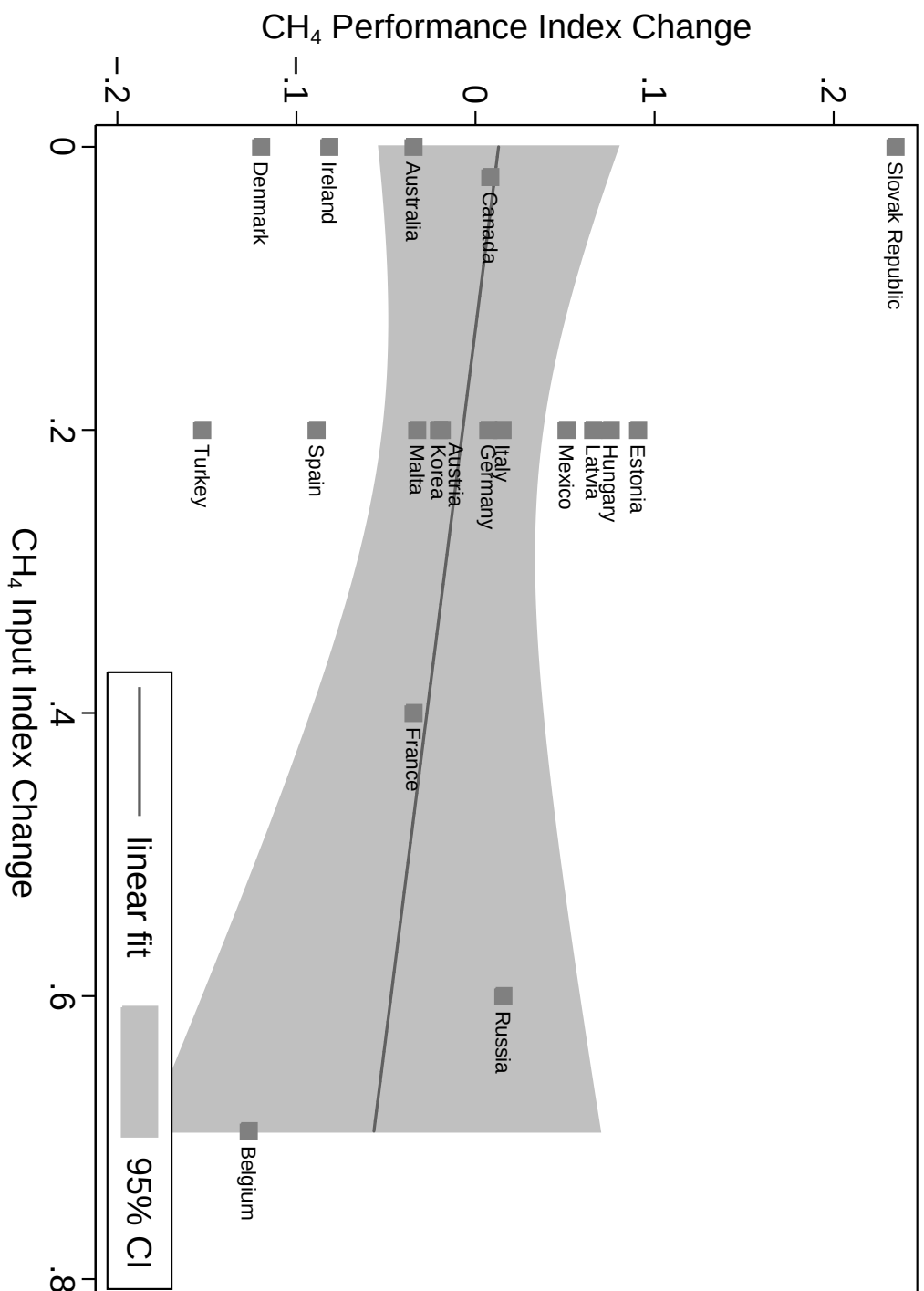


Figure 6: Change of the Narrow CH_4 input index and of the CH_4 performance index from the first to the last year in the sample

3. Broad GHG input index

The methodology and the data used to construct the broad GHG input index, as well as its conceptual advantages and disadvantages compared to gas specific input indexes are discussed in detail in the main paper. The following outlines the results of the empirical assessment of the broad input index.

The same strategy as for all the other indexes is followed. First the broad GHG input index is compared to other input indexes as well as to the WEF survey index. Second the relationship between the broad GHG input index and a general performance index (the Yale EPI) is tested.

Table 5: Pairwise correlations of the means of the variables

	Broad GHG II	Broad GHG II, tax	Air Policy II 1	Air Policy II 2	WEF	EPI	Lead
Broad GHG II	1						
Broad GHG II, tax	.880***	1					
Air Policy II 1	.166	.274	1				
Air Policy II 2	.231	.414	.905***	1			
WEF	.484***	.329*	-.139	.0466	1		
EPI	.493***	.416**	.144	.273	.660***	1	
lead	-.490**	-.448**	-.0938	-.235	-.544***	-.553***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: II stands for Input Index. The Broad GHG Input Index and the broad GHG Input Index, tax have been constructed by the above outlined methodology. The Air Policy Input Index 1 and 2 are taken from Knill et al (2012). The WEF survey index is taken from Browne et al (2012). The Environmental Performance Index (EPI) is taken from Emerson et al (2012) and the lead content of gasoline (Lead) index is taken from Grether et al (2012).

As shown in Table 5, the broad GHG input index is positively but not significantly correlated to the two air policy input indexes of Knill et al (2012). The lack of significance might be explained by an only partly overlapping sample. The GHG input index is on the other hand positively and highly significantly correlated to the WEF survey index, a result which has been expected. Moreover, comparing the overall broad GHG input index to the version of it where only tax laws have been retained shows also – not surprisingly – a highly positive and significant correlation. It seems that overall the broad GHG input index is measuring what he is supposed to.

Comparing the GHG input index to two general performance indexes yields the expected results, there is a highly positive and significant correlation with the environmental performance index of Yale and a negative and highly significant correlation with the lead content of gasoline index. Those findings are supported by the results displayed in Figure 7 and Figure 8. As a next step, a general GHG performance index - constructed using the same methodology as for the gas specific ones - should be implemented to further strengthen the results.

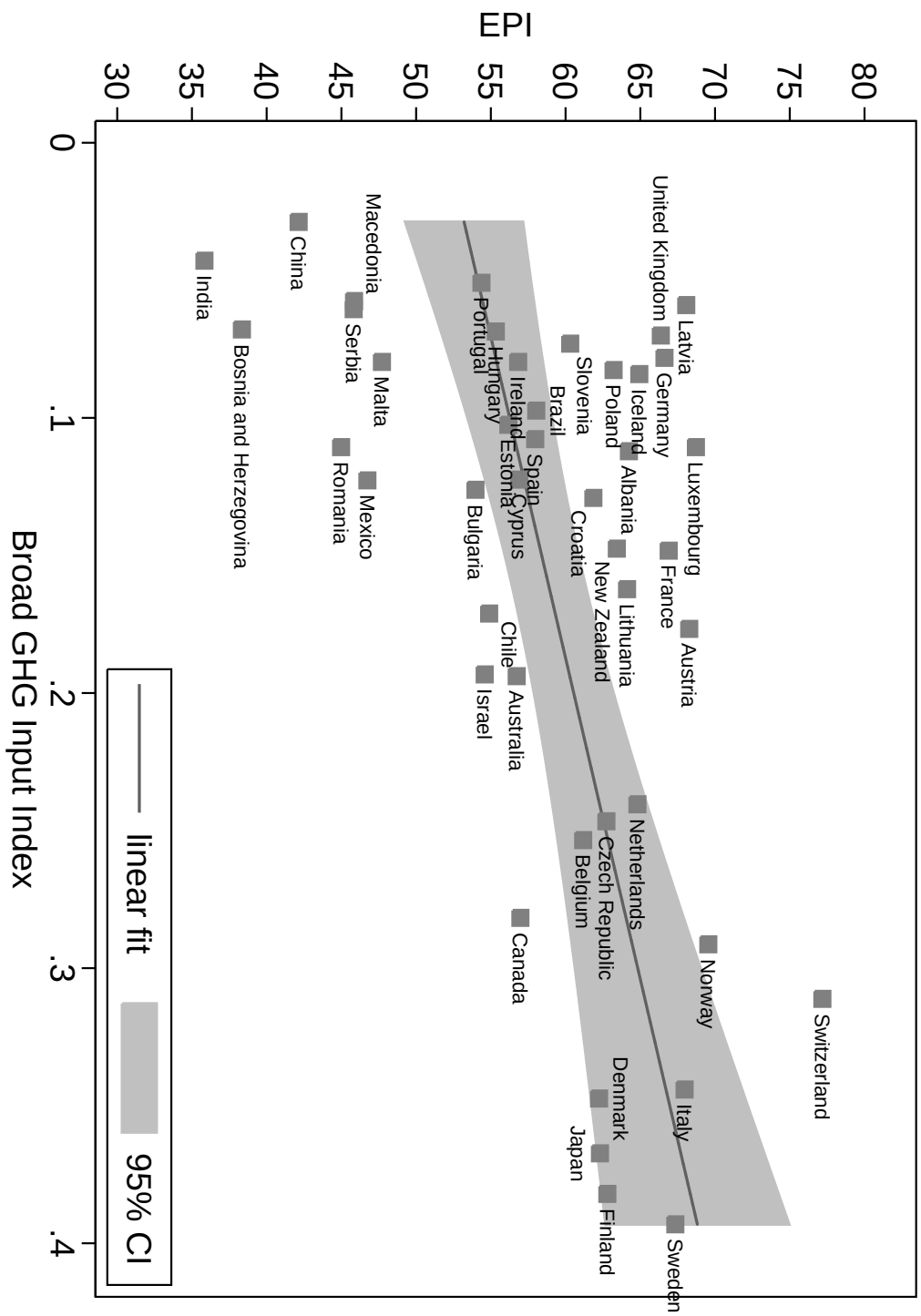


Figure 7: Mean of the Broad GHG input index and of the EPI

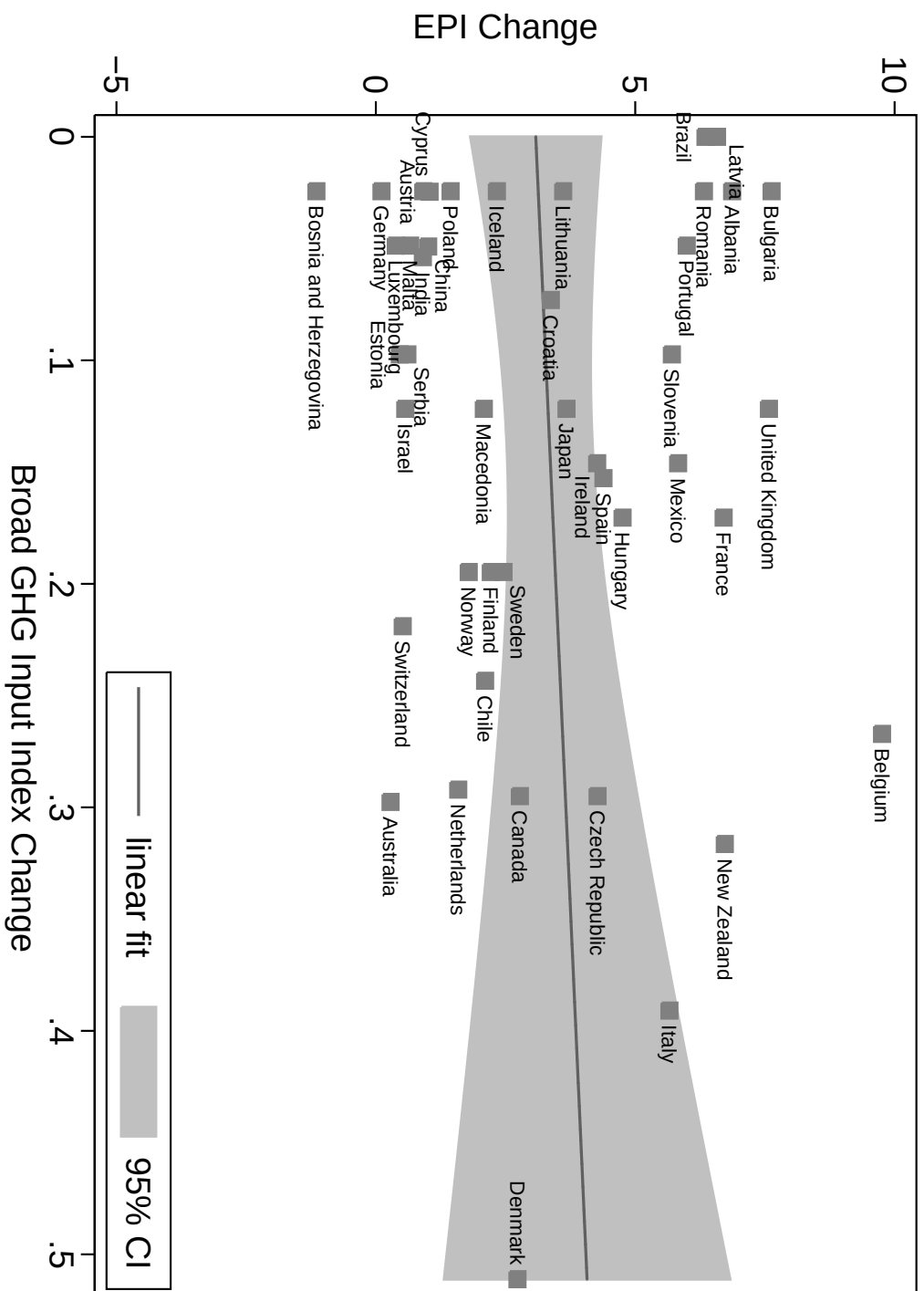


Figure 8: Change of the Broad GHG input index and of the EPI from the first to the last year in the sample (2000-2010)

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