Centro de Estudios de Desigualdad Social y Gobernanza
Universidad de La Laguna

Income, Energy and the role of Energy Efficiency Governance

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J. Barrera-Santana, G. A. Marrero, F.J. Ramos-Real

- University of La Laguna
- CEDESOG

Understanding the relationship between income and energy is essential for a correct design of energy policy

- For instance, if energy consumption growth is positive associated with GDP growth, energy policy should focus on improving efficiency rather than cutting energy consumption. Otherwise, economic growth may be hampered
- Also, if GDP growth implies more energy consumption, that could increase pollution

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Most works study this relationship drawing on causality tests … great diversity of methodologies used has led to contradictory results

Conservation hypothesis	GDP	→	Energy
Growth hypothesis	GDP	←	Energy
Feedback hypothesis	GDP	↔	Energy
Neutrality hypothesis	GDP		Energy

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Conservation hypothesis	GDP	→	Energy
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Neutrality hypothesis	GDP		Energy

Theoretically:

- Energy is an input
- Income affect the demand of energy

Double causality!

However, none of these works considers an exogenous source of variation as an external instrument to control for double causality bias, which is an ideal approach from a macroeconomic perspective

Do we have an external instrument?

GDP → Energy

GDP ← Energy

NO

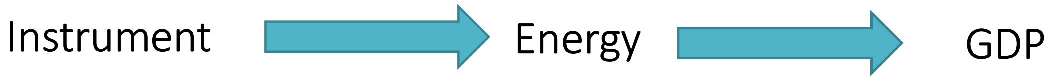
Our strategy?

1. First, find/construct a suitable external instrument for:

Recall: an external instrument must satisfy 2 conditions:

a. Be correlated (and not weakly) with the variable to be instrumented (energy consumption)

b. Its effect over the variable to be explained (income) can only be generated through the instrumented variable (energy)



2. Second, follow Bruckner et al. approach and obtain a suitable instrument for the other side of causality

3. In both cases, estimate by 2sls (controlling by double causality in both cases)

Our strategy?

1. First, find/construct and suitable external instrument for:

GDP ← Energy

Recall: an external instrument must satisfy 2 conditions:

a. Be correlated (and not weakly) with the variable to be instrumented (energy consumption in 1)
b. Its effect over the variable to be explained (income) can only be generated through the instrumented variable (energy)

Instrument → Energy → GDP

2. Second, follow Bruckner et al. approach and obtain a suitable instrument for the other side of causality

GDP → Energy

3. In both cases, estimate by 2sls (controlling by double causality in both cases)

Finding the external instrument:

Many works has shown that governance and institutional quality are two of the most important drivers of energy consumption and, thus, of energy efficiency performance

The WGI is not expected to be a good external instrument for energy … it is not expected that the impact of WGI over income goes only through energy consumption/efficiency

The IEA (2010): there exist significant differences between general governance (WGI, Polity IV) and energy governance

Hypothesis

An energy governance index can be a convenient instrument

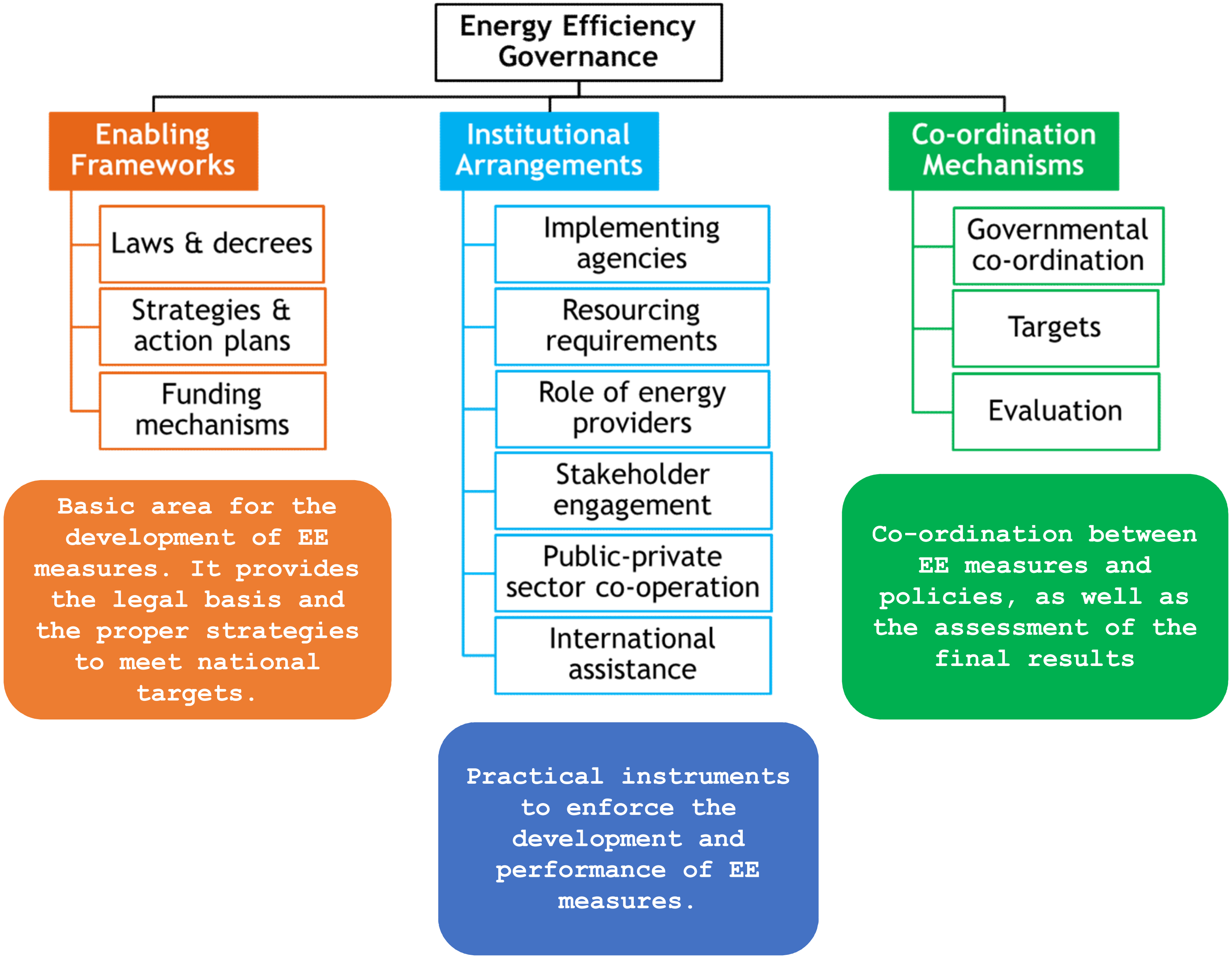
The NEED for an ENERGY GOVERNANCE INDEX (EEGI)

First, we construct and **Energy Governance Indicator** (EEGI) for 32 OECD countries between 2000 and 2015

Second, we use the EEGI to assess the relationship between energy consumption and income

The Energy Efficiency Governance Index

"According to IEA (2010), EE governance is the **combination of the institutional and co-ordination arrangements needed to scale-up EE, added to the legislative frameworks and funding mechanisms**, which works to support the implementation of EE strategies, policies and programmes".


Energy Efficiency Governance
Enabling Frameworks
Laws & decrees
Strategies & action plans
Funding mechanisms
Basic area for the development of EE measures. It provides the legal basis and the proper strategies to meet national targets.
Institutional Arrangements
Implementing agencies
Resourcing requirements
Role of energy providers
Stakeholder engagement
Public-private sector co-operation
International assistance
Practical instruments to enforce the development and performance of EE measures.
Co-ordination Mechanisms
Governmental co-ordination
Targets
Evaluation
Co-ordination between EE measures and policies, as well as the assessment of the final results

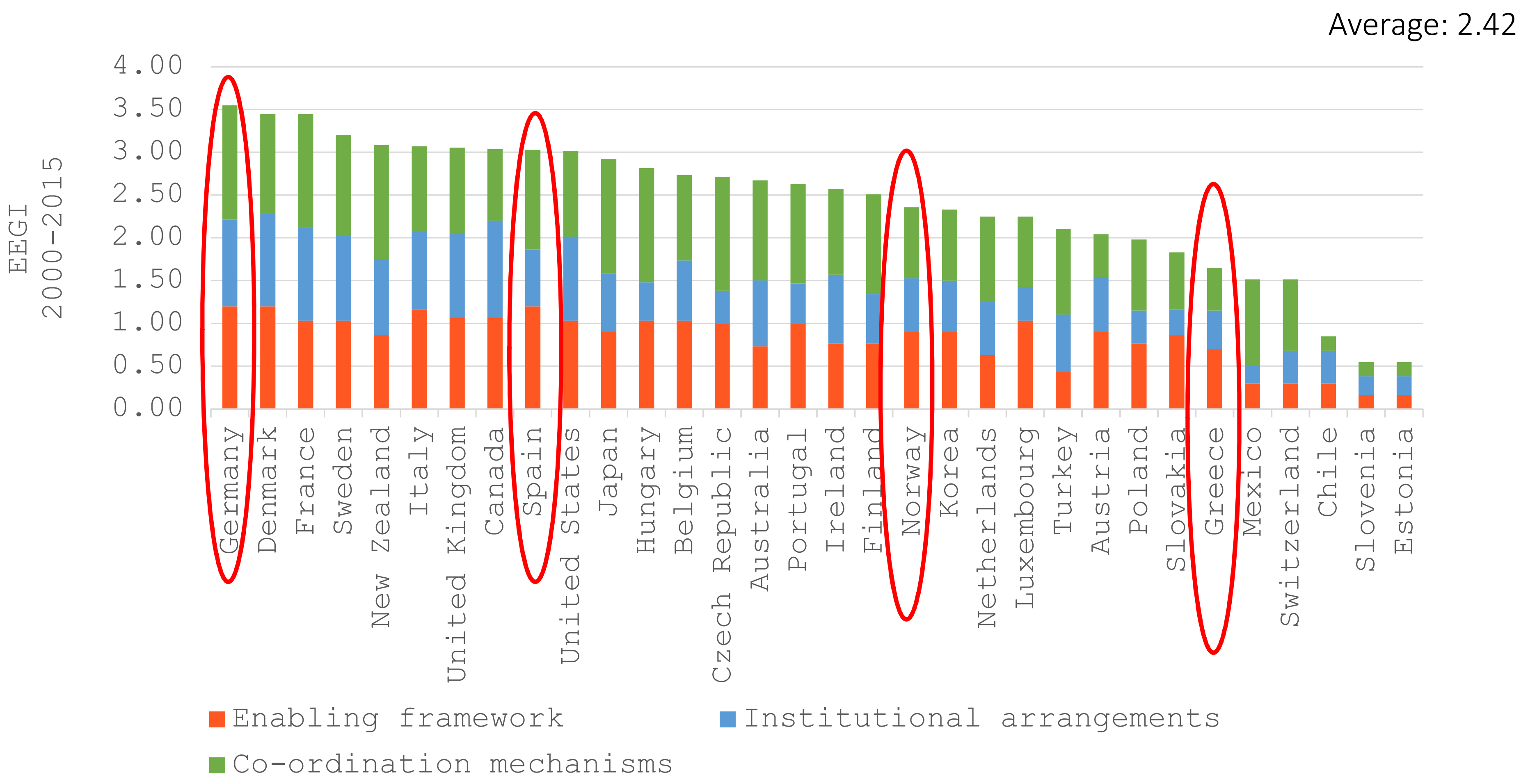
For “most” of these dimensions, we gather information from the IEA’s Energy Efficiency Database (2016)

Analyze almost **1,800 entries on EE measures** for 32 OECD countries

These 1,800 entries cover measures implemented for the **2000-2015 period.**

Next, we follow Dabla-Norris et al. (2012) to construct our composite index on EE governance.

- For each EE aspect and according with the policy measure implemented, we generate a rank of countries and provide a number from 0 (zero implementation) to 4 (fully implemented) for each country
- We repeat this action for all categories and, finally, we aggregate the scores into Pillars and finally into the EEGI



Average: 2.42
EEGI
2000-2015
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Germany
Denmark
France
Sweden
New Zealand
Italy
United Kingdom
Canada
Spain
United States
Japan
Hungary
Belgium
Czech Republic
Australia
Portugal
Ireland
Finland
Norway
Korea
Netherlands
Luxembourg
Turkey
Austria
Poland
Slovakia
Greece
Mexico
Switzerland
Chile
Slovenia
Estonia
Enabling framework
Institutional arrangements
Co-ordination mechanisms

Empirical approach (from energy to income)

1

$$\Delta \ln(y_{it}) = \lambda_i + \delta_t + \varphi \Delta ln(e_{it}) + u_{it}$$

Empirical approach (from energy to income)

1

$$\Delta \ln(y_{it}) = \lambda_i + \delta_t + \varphi \Delta ln(e_{it}) + u_{it}$$

0

Fist step $\Delta \ln(e_{it}) = \theta_i + \phi_t + \beta Z_{it} + w_{it}$

$EEGI_i$

$EEGIOil_{it} = EEGI_i \cdot OilPShocks_t$

Second step: estimate (1) by 2SLS

Empirical approach (from income to energy)

2 $$\Delta ln(e_{it}) = \eta_i + \kappa_t + \pi \Delta \ln(y_{it}) + \nu_{it}$$

Brückner (2013) and Ciccone et al. (2012)

$$\Delta ln(y_{it})^{*} = \Delta \ln(y_{it}) - \hat{\varphi} \Delta ln(e_{it})$$

The instrument: the adjusted per capita GDP growth series to changes in energy consumption growth (the residual in (1))

Equation (1) must be estimated by a consistent approach!)

Second step: estimate (2) by 2SLS

Empirical approach (from income to energy)

To test the validity of our instruments:

- Hansen J-test of overidentifying restrictions, which assesses whether the instruments only affect the endogenous variable through the instrumented variable (i.e., the exclusion restriction).

- The Chi-square underidentification test of Sanderson-Windmeijer (SW) in order to assess if our instruments are properly correlated with the endogenous regressor … The rejection of the null hypothesis supports identification, although not necessarily the absence of weak identification (Kleibergen & Paap, 2006).

- Third, the Cragg-Donald Wald F-statistic complements the SW test to check the weakness of the instruments.

0

First stage: Energy consumption (over EEGI)

	First-Stage equation: pc energy growth vs. energy efficiency governance			
	$\Delta lnTPEC_{pc}$			
	(e) OLS	(f) OLS	(g) OLS	(h) OLS
$EEGI_i$	-0.006 (0.007)	-0.006 (0.015)		
$OilEEGI_{it}$		-0.020 (0.011)	-0.023 (0.002)	-0.020 (0.017)
Year FE	Yes	Yes	Yes	Yes
Country FE	No	No	No	Yes
Number of observations	480	480	480	480

Increasing the EEGI in one standard deviation (i.e., 0.785 points, 1/3 of its average score, which is 2.42) would lead to a **reduction in energy consumption annual growth close to 0.5 p.p. … in other specifications this reduction can be about 0.65 p.p.**

All instrument tests work properly: exclusión restriction; underidentification; weak instruments

The meaning of increasing the EEGI by one standard deviation varies across countries

- For example, in a country with a low developed Enabling Frameworks area (e.g., Netherlands or Turkey), energy governance can be easily improved by **drafting additional laws and decrees that cover new sectors** (e.g., building, industry, appliances) or by **expanding the existing regulation**

- On the contrary, a country with an underdeveloped Co-ordination Mechanisms area (e.g., Austria) can easily improve its energy governance score by **defining evaluation mechanisms** that help policy-makers to verify the development of their strategic plans and the achievement of their energy targets

1

From Energy to GDP (second step)

		$\Delta lnGDP_{pc}$	
		(a) OLS	(b) OLS
$\Delta lnTPEC_{pc}$		0.231 (0.000)	0.181 (0.000)
Underidentification test	Sanderson-Windmeijer Chi-sq		
Weak identification test	Cragg-Donald F		
	Stock-Yogo 10%		
	Stock-Yogo 15%		
	Stock-Yogo 20%		
	Stock-Yogo 25%		
Overidentification test	Hansen J (p-value)		
Year FE		Yes	Yes
Country FE		No	Yes
Number of observations		480	480

- Increasing per capita TPEC growth by 1 p.p. would increase per capita GDP growth, on average, by 0.2 p.p.
- However, if per capita GDP growth has a significant effect on per capita energy growth, this OLS point estimate can be severely biased.

1

From Energy to GDP (second step)

		ΔlnGDP$_{pc}$					
		(a) OLS	(b) OLS	(c) 2SLS	(d) 2SLS	(e) 2SLS	(f) 2SLS
ΔlnTPEC$_{pc}$		0.231 (0.000)	0.181 (0.000)	1.019 [0.000]	0.960 [0.000]	0.901 [0.001]	0.881 [0.006]
Underidentification test	Sanderson-Windmeijer Chi-sq			7.660 (0.007)	15.850 (0.000)	9.610 (0.002)	6.380 (0.012)
Weak identification test	Cragg-Donald F			9.740	8.675	9.816	7.469
	Stock-Yogo 10%			16.38	19.93	16.38	16.38
	Stock-Yogo 15%			8.96	11.59	8.96	8.96
	Stock-Yogo 20%			6.66	8.75	6.66	6.66
	Stock-Yogo 25%			5.53	7.25	5.53	5.53
Overidentification test	Hansen J (p-value)			Exactly-identified	(0.785)	Exactly-identified	Exactly-identified
Year FE		Yes	Yes	Yes	Yes	Yes	Yes
Country FE		No	Yes	No	No	No	Yes
Number of observations		480	480	480	480	480	480

- Increasing per capita energy by 1p.p. is associated with an average pcGDP growth of 0.9-1 p.p.
- The **energy consumption growth driven by energy efficiency governance** shows a stronger effect on income growth than total energy consumption growth.
- **Our interpretation:** The fraction of energy consumption driven by energy efficiency governance is related with improvements in energy efficiency and the consequent impact on overall productivity might explain this result.

1

From GDP to Energy

		$\Delta lnTPEC_{pc}$	
		(a) OLS	(b) OLS
$\Delta lnGDP_{pc}$		0.482 (0.000)	0.459 (0.000)
Underidentification test	Sanderson-Windmeijer Chi-sq		
Weak identification test	Cragg-Donald F		
	Stock-Yogo 10%		
	Stock-Yogo 15%		
	Stock-Yogo 20%		
	Stock-Yogo 25%		
Overidentification test	Hansen J		
Year FE		Yes	Yes
Country FE		No	Yes
Number of observations		480	480

- Increasing per capita GDP by 1p.p. is associated with an increase in per capita TPEC around 0.47p.p.
- This positive effect is the one usually obtained in the literature (Masih & Masih, 1996; Fatai et al., 2004; Esseghir & Khouni, 2014; among others)
- Recall that these works (as our OLS estimates) do not control for double causality.

1

From GDP to Energy

		ΔlnTPEC$_{pc}$					
		(a) OLS	(b) OLS	(c) 2SLS	(d) 2SLS	(e) 2SLS	(f) 2SLS
ΔlnGDP$_{pc}$		0.482 (0.000)	0.459 (0.000)	-3.242 [0.000]	-2.837 [0.000]	-2.477 [0.000]	-2.992 [0.000]
Underidentification test	Sanderson-Windmeijer Chi-sq			14.540 (0.000)	17.350 (0.000)	20.830 (0.000)	18.160 (0.000)
Weak identification test	Cragg-Donald F			62.157	78.221	98.427	84.769
	Stock-Yogo 10%			16.38	16.38	16.38	16.38
	Stock-Yogo 15%			8.96	8.96	8.96	8.96
	Stock-Yogo 20%			6.66	6.66	6.66	6.66
	Stock-Yogo 25%			5.53	5.53	5.53	5.53
Overidentification test	Hansen J			Exactly-identified	Exactly-identified	Exactly-identified	Exactly-identified
Year FE		Yes	Yes	Yes	Yes	Yes	Yes
Country FE		No	Yes	No	No	No	Yes
Number of observations		480	480	480	480	480	480

- We obtain negative coefficients (elasticities) ranging from -2.84 to -3.24, which implies that increasing the per capita GDP growth by 1p.p. is associated, on average, with a reduction of per capita energy growth by about 2.9p.p. … this is a lot!!
- Controlling by double causality (isolating the increase of GDP from energy –the other side of causality), development implies more efficiency, and that implies more energy efficiency and less energy consumption

Final remarks

The existence of a bidirectional causal relationship between energy consumption and income growth is verified in our sample of OECD countries.

The causal relationship obtained from energy consumption growth (driven by energy governance) to income growth is positive and its elasticity is almost equal to one.

However, the causal relationship obtained from economic growth to energy consumption is highly negative.

Improving the use of energy driven by the improvement of energy efficiency governance shows a double benefit on the economy.

- It favors energy efficiency and income growth
- The consequent improvement of income growth would reduce per capita energy consumption

Energy efficiency governance is the main driver for the existence of these two positive effects simultaneously.

Therefore, since economic growth and energy consumption are essential aspects for the abatement of environmental damage, our results indicate that energy governance can play a remarkable role for decoupling carbon emissions from GDP growth.

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Appendix

Supplementary materials

Data collection

- Huge **collection effort** (WEC, IEA, IRENA…)
- Main block: IEA database
- 32 OECD countries; > 1,800 entries
- *"Entry"* = **Qualitative** and **descriptive** information regarding a specific policy, law, strategy, plan, programme… SCORING CRITERA REQUIRED

Filter

- In force between 2000-2015
- > 1,700 entries
- E.g.: USA (169 entries), Spain (47 entries) or Estonia (4 entries)

Classification

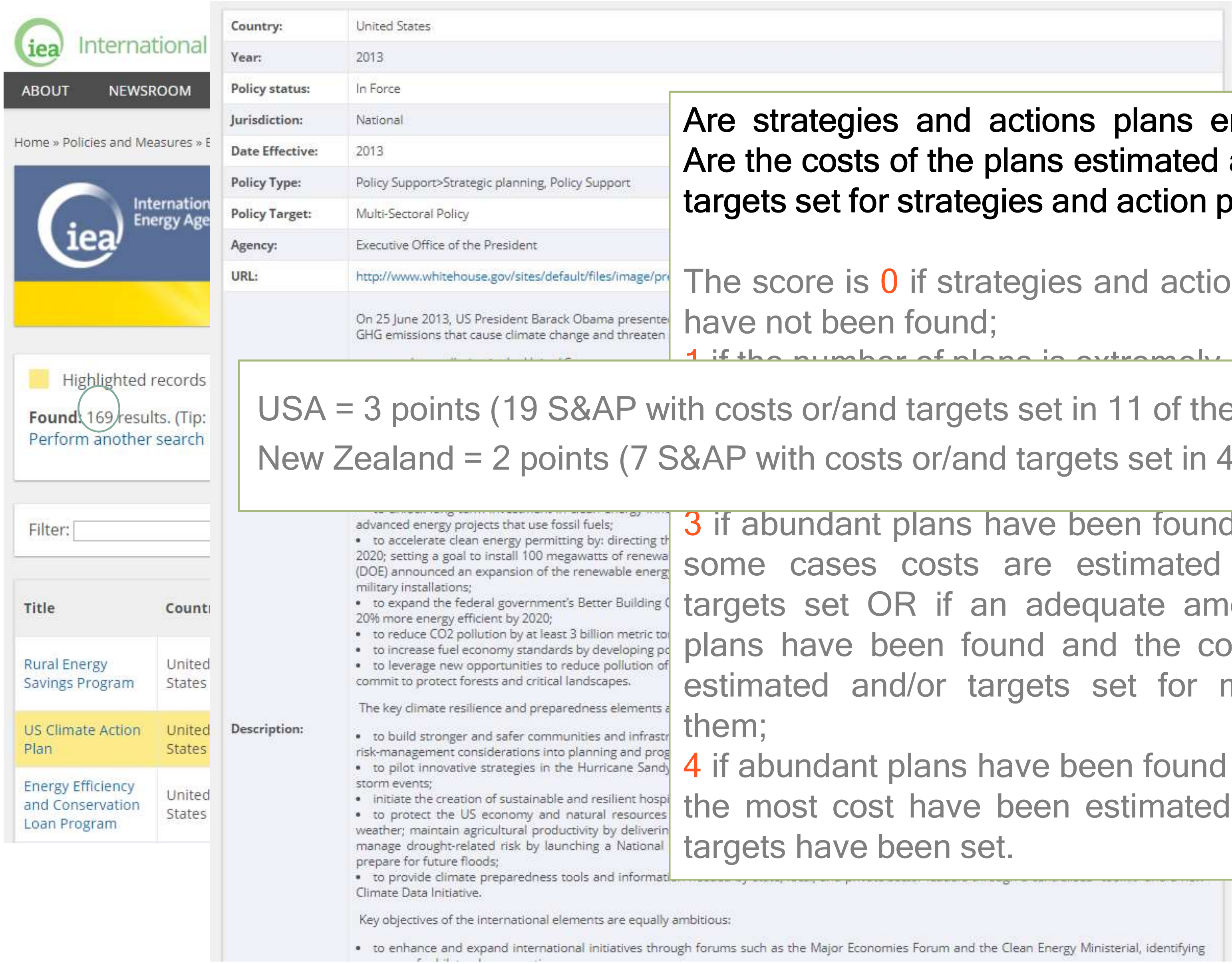
- Descriptive/qualitative information. Each entry has been **carefully read** in order to relate this with the correct EE governance and area and, concretely, with the correct indicator.

Scoring

- There are no previous EE governance scores or indicators. Therefore, the scores obtained are **relative scores** (between the countries in the sample).
- 0-4 Scale for each indicator (E. Dabla-Norris et al., 2012)
- Subjectivity is minimized through the establishment of **strict evaluation criteria for each indicator.**

Aggregation

- Three sub-indices: one sub-index by each EE governance area, calculated as the corresponding indicators average.
- One overall index (average of the three sub-indices).



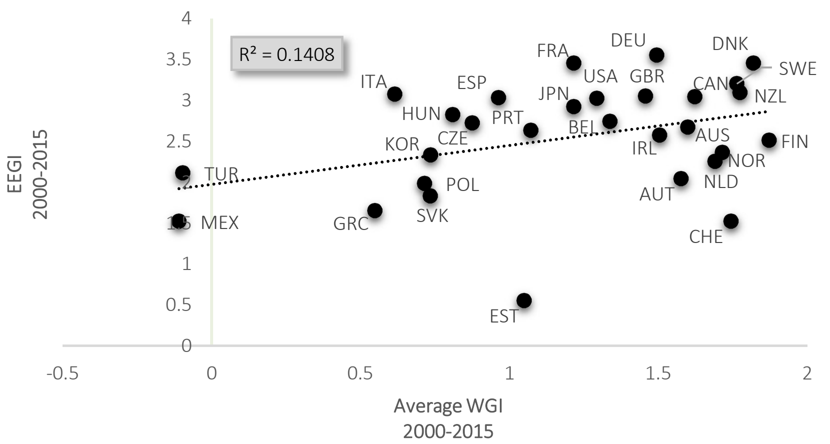
Are strategies and actions plans enough? Are the costs of the plans estimated and the targets set for strategies and action plans?

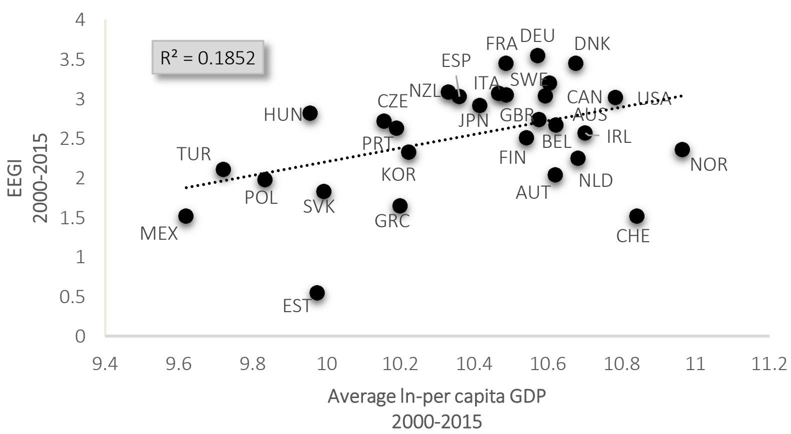
The score is 0 if strategies and action plans have not been found;
1 if the number of plans is extremely limited;

USA = 3 points (19 S&AP with costs or/and targets set in 11 of them)

New Zealand = 2 points (7 S&AP with costs or/and targets set in 4 of them)

3 if abundant plans have been found and in some cases costs are estimated and/or targets set OR if an adequate amount of plans have been found and the costs are estimated and/or targets set for most of them;
4 if abundant plans have been found and for the most cost have been estimated and/or targets have been set.


R² = 0.1408
EEGI
2000-2015
Average WGI
2000-2015
ITA
HUN
ESP
PRT
CZE
KOR
TUR
POL
SVK
MEX
GRC
EST
FRA
DEU
USA
JPN
GBR
BEL
IRL
DNK
SWE
CAN
NZL
AUS
FIN
NOR
NLD
AUT
CHE


R² = 0.1852
EEGI
2000-2015
Average ln-per capita GDP
2000-2015
HUN
TUR
POL
MEX
SVK
EST
CZE
PRT
KOR
GRC
ESP
NZL
ITA
FRA
DEU
SWE
JPN
GBR
DNK
CAN
USA
AUS
BEL
IRL
FIN
AUT
NLD
NOR
CHE

PANEL A		ΔlnGDP$_{pc}$			
		(a) 2SLS	(b) 2SLS	(c) 2SLS	(d) 2SLS
ΔlnTFEC$_{pc}$		1.216 [0.000]	1.165 [0.000]	1.109 [0.001]	1.091 [0.006]
Underidentification test	Sanderson-Windmeijer Chi-sq	9.270 (0.002)	21.410 (0.000)	10.55 (0.001)	7.290 (0.007)
Weak identification test	Cragg-Donald F	9.562	8.243	9.035	6.899
	Stock-Yogo 10%	16.38	19.93	16.38	16.38
	Stock-Yogo 15%	8.96	11.59	8.96	8.96
	Stock-Yogo 20%	6.66	8.75	6.66	6.66
	Stock-Yogo 25%	5.53	7.25	5.53	5.53
Overidentification test	Hansen J	Exactly-identified	(0.776)	Exactly-identified	Exactly-identified
Year FE		Yes	Yes	Yes	Yes
Country FE		No	No	No	Yes
Number of observations		480	480	480	480

PANEL B		ΔlnTFEC$_{pc}$			
		(a) 2SLS	(b) 2SLS	(c) 2SLS	(d) 2SLS
ΔlnGDP$_{pc}$		-3.225 [0.000]	-2.867 [0.000]	-2.527 [0.000]	-3.113 [0.000]
Underidentification test	Sanderson-Windmeijer Chi-sq	9.320 (0.002)	11.170 (0.001)	13.580 (0.000)	10.660 (0.001)
Weak identification test	Cragg-Donald F	42.648	52.261	64.741	52.226
	Stock-Yogo 10%	16.38	16.38	16.38	16.38
	Stock-Yogo 15%	8.96	8.96	8.96	8.96
	Stock-Yogo 20%	6.66	6.66	6.66	6.66
	Stock-Yogo 25%	5.53	5.53	5.53	5.53
Overidentification test	Hansen J	Exactly-identified	Exactly-identified	Exactly-identified	Exactly-identified
Year FE		Yes	Yes	Yes	Yes
Country FE		No	No	No	Yes
Number of observations		480	480	480	480

Note The method of estimation in panels A and B is both Two-Stage Least Squares (2SLS). P-values are reported in parentheses; below the 2SLS estimates p-values in square brackets are reported based on the Anderson-Rubin test of statistical significance. In Panel A, the dependent variable is the yearly ln- change in real per capita GDP and the independent variable is the yearly ln-change in per capita Total Final Energy Consumption (TFEC). In Panel B, we use the same variables but their roles are swapped. In Panel A, the instrumental variable in column (a) is the $EEGI_i$; in column (b), both the $EEGI_i$and the $EEGIOil_{it}$; in columns (c) and (d), the $EEGIOil_{it}$. In Panel B, the instrumental variables are the yearly ln-change in per capita GDP series that are adjusted for the reverse effect that the yearly ln-change in per capita TFEC has on GDP series. Stock-Yogo's maximal IV sizes for Cragg-Donald F statistic are based on Stock & Yogo (2005).

1

From Energy to GDP

Test of exclusion restriction: energy and income growth extended with instruments

		$\Delta lnGDP_{pc}$	
		(a) 2SLS	(b) 2SLS
$\Delta lnTPEC_{pc}$		0.881 [0.006]	1.039 [0.000]
$EEGI_i$		-0.001 (0.771)	
$OilEEGI_{it}$			0.003 (0.794)
Underidentification test	Sanderson-Windmeijer Chi-sq	6.710 (0.010)	6.130 (0.013)
Weak identification test	Cragg-Donald F	7.474	7.397
	Stock-Yogo 10%	16.38	16.38
	Stock-Yogo 15%	8.96	8.96
	Stock-Yogo 20%	6.66	6.66
	Stock-Yogo 25%	5.53	5.53
Overidentification test	Hansen J	Exactly-identified	Exactly-identified
Year FE		Yes	Yes
Country FE		No	No
Number of observations		480	480

Turns highly non-significant when Energy growth is included in the the regression

All tests (exclusion restriction, underidentification, weak instruments) work properly

0 First stage: Energy consumption (over EEGI)

	Reduced-form model: pc income growth vs. energy efficiency governance				First-Stage equation: pc energy growth vs. energy efficiency governance			
	$\Delta \ln GDP_{pc}$				$\Delta \ln TPEC_{pc}$			
	(a) OLS	(b) OLS	(c) OLS	(d) OLS	(e) OLS	(f) OLS	(g) OLS	(h) OLS
$EEGI_i$	-0.006 (0.000)	-0.006 (0.000)			-0.006 (0.007)	-0.006 (0.015)		
$OilEEGI_{it}$		-0.018 (0.007)	-0.021 (0.001)	-0.018 (0.010)		-0.020 (0.011)	-0.023 (0.002)	-0.020 (0.017)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	Yes	No	No	No	Yes
Number of observations	480	480	480	480	480	480	480	480

Assuming an oil price growth of 10%, now a **one standard deviation of the *EEGI* has an impact on energy consumption growth of about -** This impact is now about -0.63p.p.

Discussion

An interesting paper addressing an actual and highly relevant concern. The results of this work may be of great interest to society. However, I think that the author could introduce some important changes in order to further increase his contribution to the literature:

- Updating main models. The references used are quite old
- Some really strong assumptions that could bias your results are made. For instance, considering that the modern North Korea's development could be similar to the ancient South Korea's growth. The contexts are completely different
- In fact, looking at the absolute figures like GDP could contribute to further increase this bias. Control variables, different scenarios/sensitivity analysis, and many other consideration should be taken into account in order to avoid biased or unsuitable estimates.

The authors have undoubtedly identified these and other pitfalls, but additional discussion and robustness checks should be implemented. In any case, I insist on the fact that this work is of great interest to a broad readership, addressing highly relevant problems.