LAMETA
Laboratoire Montpelliérain d'Economie Théorique et Appliquée
UMR
Unité Mixte de Recherche

DOCUMENT de RECHERCHE

« The role of market-oriented institutions in the deployment of renewable energies: evidences from Europe »

Julien JACQMIN

DR n°2015-15

Unite de Formation et de Recherche d'Economie
Avenue Raymond DUGRAND C.S. 79606
3 4 9 6 0 MONTPELLIER Cedex 2

E-mail : lameta@lameta.univ-montp1.fr
web : www.lameta.univ-montp1.fr

The role of market-oriented institutions in the deployment of renewable energies: Evidences from Europe*

Julien Jacqmin †

November 5, 2015

Abstract

This paper investigates the link between economic freedom and the production of energy using renewable sources, with a specific focus on European countries. Using a dynamic panel approach, we find that this relationship is positive and significant. The results of our instrumental variable approach indicate further the causal channel between economic freedom and the deployment of renewable energies. Looking at the subcomponents of the economic freedom index, we find that long term price stability and freedom to trade boost the production of renewable energies. However, the importance given to markets, rather than governments, in the economy has no significant impact.

Keywords: Renewable energy, economic freedom index, market-oriented institutions, dynamic panel data

JEL: Q40, Q48, P48

*Funding from Labex Entreprendre at the University of Montpellier is kindly acknowledged. This paper has benefited from discussions and exchanges with Jean-Chistophe Poudou, Edmond Baranes, Benoit Mulkay and audience members at the BAEE Research Workshop on Energy Economics held at CORE.

†HEC Management School / University of Liege email: julien.jacqmin@ulg.ac.be Address: B. 31 - Quartier Agora, Place des Orateurs 3, 4000 Liege, Belgium

1 Introduction

One of the European Union most ambitious goal is to decrease its emission of green house gases. By 2030, it targets to reduce them by 40% compared to the level produced in 1990.[1] Hand in hand with energy efficiency improvements, this can mainly take place thanks to a change in the energy input mix. To achieve this, in October 2014, it has further set key targets for this ambitious plan. By 2030, more than 27% of its electricity production will be from renewable energies, while its current level is at around 10%. Therefore, member states need to quickly react to encourage adequate investments.

Investments in renewable energies have the peculiarities to create both public (as it helps reduce emissions by producing clean energy) and private (as its output can be sold on the electricity market) returns. Recent technological changes, by decreasing the cost of producing renewable capacities, have increased the scope for net private returns to renewable investments. This evolution has favored private investments in renewable energies, especially as this took place jointly with the deregulation of the energy sector. The additional impulses brought by public finance supported schemes such as tax cuts and feed-in-tariffs have further helped private investments. This has led to the emergence of new players in the electricity sector.[2] According to Cardenas-Rodriguez et al. (2015), 96% of the projects promoting renewable energies now depend on private financing sources. However, in the midst of a public finance crisis, many member states have questioned their financial supports. Despite this, investments in renewable energies have not plummeted. One possible explanation is that the quality of market institutions has improved, making this type of investment valuable in the eyes of private investors.

The aim of this paper is to determine the role played by market-oriented institutions as a key driving force behind investments in renewable energies. Market-oriented institutions influence production and transaction costs in several manners. Ill-functioning institutions induce additional implicit costs incurred at the investment stage in the form of longer procedures due to administrative inefficiencies or complicated regulations. They also make the interactions with other private institutions more complicated. For exam-

[1] See European Commission (2014)

[2] See for example Agterbosch et al. (2004) for the Netherlands or Bergek et al. (2013) for Sweden for country specific discussions on the emergence of these new entrepreneurs. See Zenewi and Stoltenberg (2010) and OECD (2011) for policy discussions on the importance of private investments in renewable energies.

ple, it leads to difficulties in accessing the loan market. This is particularly problematic for renewable energies as they face a relatively higher capital cost compared to other energy sources (Lee et al. (2012)). After the initial investment was made, market institutions impact also the reaping of the benefits. Corruption, vague property rights and price instability increase the uncertainties in making money in the short run as well as in the long run. According to these arguments we should observe a positive relationship. However the externalities created by renewable energies, i.e. the reduction in CO2 emission, has the characteristics of a public good. Regulatory interventions can be useful to correct for this market failure. The same hold for the security of electricity supply that is endangered due to the imperfect predictability of renewable intermittent sources like wind and solar energy sources. The missing-money problem, which is particularly stringent for renewable energies, might require as well a state intervention as markets do not provide proper incentives for investments.[3] Hence, the overall impact of market-oriented institutions is unclear and not all types of institutions should affect positively the investments in renewable energies.

Using a database composed of EU member states, this paper highlights the empirical link between the quality of market institutions and the production of renewable energies. As production levels are highly persistent, we use a dynamic panel approach. Controlling for various factors related to the energy market, the socioeconomic and political context, we find a positive and significant relationship between our variables of concerns. We also observe that price stability and freedom to trade are two key market institutions driving this result. To tackle the issue of endogeneity, we finally use an instrumental variable approach using two instruments: the average economic freedom index of their neighboring countries and the share of the population using internet. The rational behind these instruments is that the decision to implement market friendly policies can be influenced by knowledge spillovers from neighboring countries who have implemented these reforms or from better informed citizens thanks to an access to the information available on the internet.

This work is at the frontier of two strains of the economic literature. The first is concerned by the drivers of renewable energy deployment. Most of this growing branch

[3]The missing-money problem relates to the insufficient incentives to build new capacities, i.e. when the high up-front fixed cost owing to an investment is too large compared with the quantity and wholesale price of its output. The intermittence of renewable energies exacerbates this problem by increasing the reliance on the spot market and by creating additional uncertainties about the plant operation. In a competitive energy market, the electricity price will not be large enough to cover its marginal and fixed costs of production for the technology close to the marginal cost.

of the energy economics literature is concerned by the effectiveness of policies directly aimed at increasing investments in renewable energies (see for ex. Delmas and Montes-Santo (2011), Cardenas-Rodriguez et al. (2015), Hitaj (2013) or Smith and Urpelainen (2014)). Few other works have focused on indirect aspects that could influence them such as the market characteristics of other energy sources (Baranes et al. (2015)) or political factors (Cadoret and Padovano (2015)). Brunnschweiler (2010) is the closest work to ours. Focusing on developing countries, she analyzes how financial institutions can boost the development of renewable energies, such as by making the access to external financing sources more complex or at a higher cost. Using another dynamic panel approach, her main result is that having an important commercial bank sector facilitates the rise of renewable energies.

The role played by market institutions, as measured by economic freedom indices, has been analyzed extensively in the political economy literature (Gwartney et al. (2015)). It has been used to study its impact on growth, inequality, health, entrepreneurship or FDI (see De Haan and Sturm (2000), Benassy-Quere et al. (2007), Nyström (2008) Hall and Lawson (2014)). Closer to our topic of interest, Carlsson and Lundstrom (2003) study its impact on CO2 emissions using cross-sectional data. They observe that price stability and the quality of the legal system in place are two types of market-oriented institutions that improve the quality of the environment. One of their explanation is that these institutions lead to a better allocations of resources and to better consumption decisions.[4] In this paper, we argue that, as the production of electricity is the biggest source of CO2 emissions (more than a third according to Olivier et al. (2014)), the growing importance of renewable energies can partially explain the missing link between the improvement of the quality of market institutions and decreasing CO2 emissions.

We present our database in the next section. Section 3 discusses our estimation strategy. Our main results are exposed in Section 4. In Section 5 we describe various robustness checks. We conclude in Section 6.

[4]Using an extreme bounds analysis, Gassebner et al. (2010) observe a positive correlation between the economic freedom index and the level of pollution. However, they do not look the impact of each subcomponents.

2 Data

To test the relationship between the importance of renewable energies and market institutions, we build up a panel database focusing on European countries collected from various sources. The precise size of our sample is dictated by the availability of our explanatory variable. It is composed of observations of the 28 members of the European Union. We have observations from 2003 to 2012 except for Bulgaria, Croatia, Estonia, Latvia, Lithuania, Malta, Romania and Slovakia for which we have observations only from 2004 or 2005 on. Despite this, we analyze our data as if it was a balanced panel.

As a dependent variable, we use data from EIA (2015) about the quantity of electricity generated from renewable sources (excluding hydropower) measured in kilowatt-hour. As *ren. prod.* is heavily right-skewed and has a non-normal kurtosis, we take its log. However, due to the presence of zeros[5], we add, as often done in the literature, a non-negative constant equal to one for each observations before taking its log. [6]

Our explanatory variable, *ecofree*, is the economic freedom index developed by the Fraser Institute (Gwartney et al. (2015)). It is the most widely used indicator of this type. It has already been used in order to empirically measure the impact of market-oriented institutions on various economic variables. It measures how rightly acquired properties are protected and individuals are free to engage in voluntary transactions. According to this index, the aim of governments is to protect private property and enforce contracts appropriately. The yearly index ranges from 0 to 10, the freer the country the higher the index. It is the aggregation of 5 subcomponents related to (1) the size of government, (2) the legal structure and security of property rights, (3) sound money, (4) freedom to trade with foreigners and (5) regulation of credit, labour and business. Despite its subjectivity, lack of precision and aggregation issues, the index is also perceived as highly influential in the political and academic arena.

We use additional independent variables as control variables. They are managed under three distinct categories: energy market factors, socioeconomic factors and political factors. To control for the characteristics of the energy market, we use 4 different

[5] Only 10 out of 263 dependent variables are equal to zero. Due to this relatively small number of these corner outcomes, we have decided not to analyze them separately from our positive observation with a censored or a truncated approach.

[6] Our results are independent from the choice of this positive constant. Although a constant that is too large shrinks the variability of our dependent variables and has a negative influence on the significance of our results.

variables. *Dem. growth* measures the increase in percentage in the amount of energy consumed. More renewable production should result from an increasing demand in order to fulfill this additional demand. % *nuclear energy* is the share of the production which comes from nuclear sources. As this mode of production is not flexible at all, it does not complement well the use of renewable energy sources which are intermittent and not flexible, as they depend on exogenous weather conditions. A higher (log of) electricity price (*P. elec*) increases the return of the renewable production and, hence, should have a positive impact on our dependent variable. *Tot. Cons.* is the (log of the) level of electricity produced measured in thousand tons of oil equivalent.

We control for two socioeconomic factors. *Deficit* is the level of public deficit measured in percentage of GDP while *GDP/cap* controls for the level of economic development.

Finally, we control for political characteristics. *Left* is a dummy variable which is equal to one whenever the country is run by a leftist government. According to Neumayer (2003), left-wing party tend to be more pro-environment than right-wing parties. Having a left-wing coalition in power should therefore have a positive impact on our dependent variable. *Maj.* is the fraction of seats held by the government in place. A larger majority facilitates the implementation of reforms in all the sectors, including in the energy sector. Hence, we believe that it should positively impact our dependent variable. *Ren. pol.* is controlling for the political importance attached to the renewable sector. It is the number of policies which are implemented in the country (taken from the following 7: economic instruments, regulatory instruments, policy supports, fiscal incentives, tax reliefs, feed-in-tariff and strategic planning). As policies targeted directly towards the sector are not the main focus of this paper, as we are more interested by liberalization reforms, we use this parsimonious approach. However, our results are independent from the way we control for the political support brought to the renewable sector.[7]

In the Appendix, Table A.1 shows some summary statistics and Table A.2 shows the correlations between our variables. Correlation coefficients tend to be rather small, with only one notable exception: *ecofree* and *GDP/cap*. This high degree of correlation will tend to increase our standard deviations and negatively influence the degree of significance of some of our results. One common approach used in the literature focusing on the impact of *ecofree* is to drop *GDP/cap* from the specification. However, this can lead to spurious results. We will only consider this estimation strategy when the

[7] Results available upon request.

coefficient of *ecofree* is not significant in the case where *GDP/cap* is included and the coefficient in both specifications are close to each others.

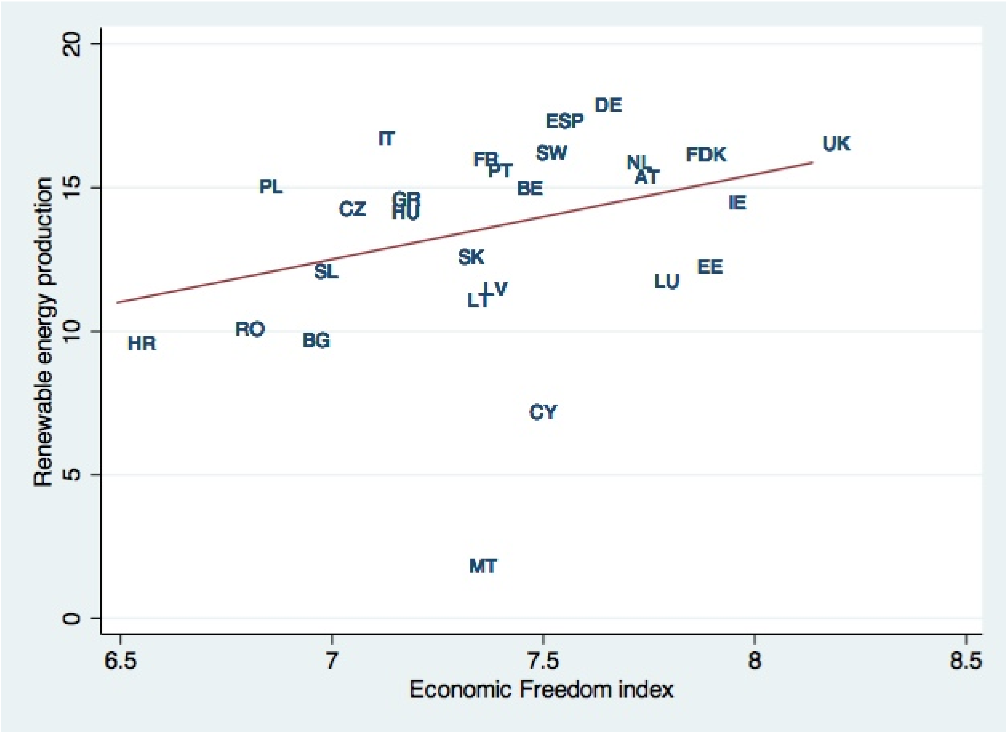

Figure 1
Scatterplot of average renewable production level ($\log(x+1)$) and average economic freedom index with linear best fit (2003-2012)

In Figure 1, we show the correlation between our two variables of interest. On the X-axis we have the per-country average economic freedom index and on the Y-axis we have our average per-country level of renewable energy production between 2003 and 2012. As highlighted by the best linear fit, we clearly observe a positive relationship between them.[8] In the rest of this paper, we will see that this claim stands to more robust empirical specifications.

3 Estimation strategy

Our aim is to estimate the impact of market institutions, as measured by *ecofree*, on the level of production of energy from renewable sources (*ren. prod.*) using aggregate

[8] Note that this relationship is even more striking if we drop Malta and Cyprus from our observations.

data. As the production levels are dependent on the past investments done, we include the first lag of our dependent variable to control for its slow adjustment and persistence. We estimate the following dynamic panel data model:

$$Ren.prod._{it} = \beta_0 + \beta_1 Rene.prod._{it-1} + \beta_2 ecofree_{it-1} + \beta_3 X_{it} + \theta_t + \rho_i + \epsilon_{it}$$

Where $Renewableprod._{it}$ is the level of production from renewable sources in country i in year t, $ecofreedom_{it-1}$ is our economic freedom index, X_{it} are the contemporaneous control variables and ϵ_{it} is an error term. To avoid confounding our variable of interest with country-specific omitted variables that are constant over time or time specific omitted variables constant across countries, we also include year dummies θ_t and country fixed dummies ρ_i. Standard statistical tests prone the inclusion of year and country dummies. Although this does not influence the insight of our results.

It is likely that the effect of the economic freedom index on our dependent variable is not contemporaneous.[9] Before new investments in renewable energies are decided and are effectively producing energy, it might take some times due to administrative and construction delays. Hence, we lagged by one year *ecofree* compared with *ren.. prod..* Beside this economic justification, it is also suggested using the Akaike Information Criterion (AIC) and the Schwartz Criterion (BIC) to lag this independent variable. Although, as we will show in Subsection 5.1, our results are similar using contemporaneous observations or using more lags. Using one year lag has also the advantage of reducing the scope of reverse causality. We will further discuss more in detail the problem of endogeneity in Subsection 5.3.

We estimate our model with a standard two-way fixed effect approach (LSDV). In a dynamic setting, the lagged dependent variable correlates with the error term. On the one hand this causes a downward bias for the autoregressive coefficient. On the other hand, the bias on the independent variables is positive. Due to our small sample size, this can be problematic (Nickell (1981)). While Arellano and Bond (1991) provide a suitable alternative using a GMM approach, it is not well suited for panel with small T which are unbalanced. Given these concerns, we use the bias-corrected estimator (LSDVc) that relies on standard fixed effect with the approximation of the bias as in Judson and Owen (1999), Kiviet (1999) and Bruno (2005). Using simulations, Kiviet (1999) finds that this estimator gives better estimates and lower standard errors than the GMM estimators for

[9]Remark that we also consider that ratings are computed with data from two years before its publishing year.

small panels. LSDVc uses a two-step approach where a consistent estimator is computed in the first stage.[10] The variance-covariance matrix is then computed using a bootstrap procedure with 200 repetitions. It outperforms the analytical approach according to Kiviet (1999).

4 Results

Table 1
Determinants of Renewable energy production

Dep. Variable Ren. Prod.	(1) LSDVC AB	(2) LSDVC AB	(3) LSDVC AB	(4) LSDVC AB	(5) LSDVC BB	(6) OLS	(7) FE
Ren. prod. (t-1)	0.748***	0.771***	0.759***	0.747***	0.794***	0.875***	0.657***
	(0.056)	(0.046)	(0.047)	(0.050)	(0.049)	(0.076)	(0.039)
Ecofree (t-1)	0.855***	0.691**	0.668**	0.698**	0.612*	0.261**	0.826***
	(0.327)	(0.277)	(0.306)	(0.310)	(0.336)	(0.129)	(0.262)
Dem. Growth		0.017***	0.017***	0.017***	0.017***	0.013***	0.017***
		(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
% nuclear energy		0.000	0.000	-0.001	0.000	0.000	-0.003
		(0.007)	(0.007)	(0.007)	(0.008)	(0.002)	(0.008)
P. Elec		0.177	0.192	0.214	0.184	0.170	0.284
		(0.227)	(0.225)	(0.228)	(0.247)	(0.113)	(0.226)
Tot. Cons.		-1.882*	-1.855	-1.684	-1.840	0.217*	-1.421
		(1.118)	(1.129)	(1.237)	(1.327)	(0.118)	(1.249)
Deficit			0.011	0.013	0.012	0.022	0.015
			(0.018)	(0.018)	(0.020)	(0.016)	(0.016)
GDP/cap			0.087	-0.003	-0.046	-0.390***	0.333
			(1.038)	(1.085)	(1.168)	(0.132)	(0.914)
Left				0.112	0.086	0.065	0.143
				(0.119)	(0.133)	(0.062)	(0.109)
Maj.				0.414	0.346	0.619	0.752
				(0.815)	(0.895)	(0.518)	(0.797)
Ren. policies				-0.003	-0.024	-0.037	0.024
				(0.075)	(0.082)	(0.045)	(0.067)
Constant						2.094	10.244
						(1.362)	(13.207)
N	263	263	263	263	263	263	263
ll						-254.689	-206.862

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses

Table 1 shows our main results. The first column only consider the past renewable production and our economic freedom index as explanatory variables. We see that the

[10]We use Arellano-Bond for the most of our paper but similar results are obtained using Blundell and Bond estimators.

first coefficient is positive, smaller than one, and highly significant. This highlights the fact that actual levels of production are highly dependent on the past production levels. We also see that having a higher index leads significantly to a higher level of production.

In the next three columns, we show that this result is robust to the progressive introduction of more control variables, even if the level of significance decreases to 5%. First, we control for factors related to the energy market. The coefficient of *dem. growth* is positive and significant at the 1% threshold. This means that an increasing demand makes additional production in renewable energies more likely. The share of energy produced from nuclear energy sources, a mode of production not easily compatible with intermittent energy sources, has close to no impact on our dependent variable. As *p. elec.* is a good proxy of the monetary returns of renewable energy investments, it is no surprise that it has a positive coefficient. However, it is not significant. The level of electricity consumed has a negative impact on our dependent variable. This is significant at the 10% threshold. In regression (3), we control in addition for socioeconomic factors. This does not influence our main results. The deficit of the country of concern does not impact significantly our dependent variable. We observe that wealthier countries tend to produce more using renewable energies but this is not significant. Finally, in (4), we control for various political factors. We have that, as expected, left wing government and government with a large majority in the parliament are more dependent on renewable energy sources. Although this is not significative. We also see that having more policies promoting renewable production has no significant impact on our dependent variable, although it has a negative but small coefficient.

In column (5), we observe that out results are robust to the use of Blundell and Bond estimates in the first step of our estimation procedure, instead of the methodology used by Arellano and Bond. Its impact on our coefficient is also minimal. Note however that the p-value of *ecofree* increases from 0.024 to 0.069.

Finally in column (6) and (7), we show estimates with the ordinary least square and fixed effect model obtained with Huber-White standard errors.[11] We also see that the coefficients of the lagged dependent variable in the FE case gives rise to a negative bias on the coefficient of *ren.prod. (t-1)*, the so-called Nickell bias. It is due to the negative

[11]According to the Hausman specification test, the coefficients using a fixed effect approach significantly differ from a random-effect approach. Remark that we include time dummies in all our specifications but that it does not impact the quality of our results. Our result is both driven by intra and inter group variation. Standard errors are computed by assuming no correlation across countries in the idiosyncratic disturbances. This is more likely to hold with time dummies.

correlation between lagged dependent variable and the standard errors in the context of within group estimators. On the other hand, we observe that the coefficients of our other independent variables are larger under the FE model. Under the OLS model, the bias is positive as our lagged variable is positively correlated with our error terms due to the presence of individual fixed effects. As argued in Bond (2002), the fact that these two approaches lead to biases going in two different directions for $ren.prod.(t-1)$ provides us a useful ex-post check on our main results as we observe that our favorite regressions (regression (4) and regression (5)) lie between these two bounds.

Table 2
Determinants of renewable energy production

Dep. Variable Ren. Prod.	(1) LSDVC AB	(2) LSDVC AB	(3) LSDVC AB	(4) LSDVC AB	(5) LSDVC AB	(6) LSDVC AB
Ren. prod. (t-1)	0.724***	0.781***	0.787***	0.752***	0.699***	0.769***
	(0.049)	(0.049)	(0.051)	(0.048)	(0.05)	(0.05)
size of government (t-1)	-0.123	-0.156				
	(0.101)	(0.106)				
legal system (t-1)	0.191		0.276			
	(0.190)		(0.191)			
sound money (t-1)	0.376**			0.552***		
	(0.181)			(0.165)		
freedom to trade (t-1)	0.399*				0.682***	
	(0.223)				(0.203)	
regulation (t-1)	0.034					0.058
	(0.170)					(0.181)
Dem. Growth	0.017***	0.017***	0.017***	0.017***	0.017***	0.017***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% nuclear energy	-0.006	-0.001	0	-0.005	-0.004	-0.001
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
P. Elec	0.159	0.376*	0.321	0.149	0.232	0.333
	(0.224)	(0.227)	(0.229)	(0.221)	(0.224)	(0.229)
Tot. Cons.	-1.582	-1.679	-1.958	-0.773	-1.749	-1.595
	(1.292)	(1.263)	(1.301)	(1.196)	(1.255)	(1.258)
Deficit	1.292	0.018	0.022	0.007	0.017	0.017
	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.019)
GDP/cap	0.045	1.437	0.792	-0.118	0.508	0.967
	(1.069)	(1.071)	(1.041)	(0.984)	(0.997)	(1.079)
Left	0.124	0.084	0.12	0.06	0.124	0.085
	(0.115)	(0.121)	(0.119)	(0.115)	(0.119)	(0.121)
Maj.	0.705	0.443	0.485	0.705	0.441	0.393
	(0.796)	(0.829)	(0.826)	(0.792)	(0.81)	(0.835)
Ren. policies	-0.042	0.016	0.003	0.009	-0.04	0.02
	(0.075)	(0.075)	(0.076)	(0.071)	(0.075)	(0.077)
N	263	263	263	263	263	263

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses

As discussed in the literature (see for example De Haan et al. (2006)), economic freedom indices are far from being uncontroversial. One major critique concerns the aggregation of different variables into a single index. The methodological procedure is crucial, especially because these variables are not highly correlated.[12]. Looking at the disaggregate level, we can also better disentangle which types of market-oriented institutions play a crucial role in the development of renewable energies. In Table 2, we look at the link between the subcomponents of the index and *ren. prod.*. These are included into five groups where each refers to a different aspect of economic freedom. These areas are: (1) *size of government*, (2) *legal system*, (3) *sound money*, (4) *freedom to trade* and (5) *regulation*. In regression (1) where we include all the subcomponents together, we observe *sound money* and *freedom to trade* have both positive and significant impact. This result is confirmed and further strengthen by looking separately at the impact of each subcomponents.

The first component measures the *size of government*. A country with a higher rating in this dimension tends to rely on market forces, rather than on governments, to allocate resources, goods and services. In regression (2), we see that a higher rating leads to a decrease in the production of renewable energies. This relates to the idea that government budgets and political forces can play a positive role on the deployment of renewable energies. However this relationship is not significant. The second components relates to the quality of the legal system and the security of property rights. A country with a better protection of property rights, an unbiased judicial system and an effective enforcement of law will score higher in this dimension, as it ensures an efficient functioning of markets. The sign of *legal system* is positive as this would facilitate the investments in renewable energies by easing the reaping of its benefits, however, it is not significant. The third component, entitled *sound money*, highlights the important role of money in exchanges. Price distortions created by high inflation or volatility can alter the scope of long term contracts. Suffering less from these problems lead to a higher rating in this component. In regression (4), we see that scoring high in *sound money* has a positive and significant impact at the 1% threshold on the level of renewable production levels. The important role of long term price stability to support renewable energies is not a surprise if we look at their economic characteristics. The production of renewable energies requires a high fixed investment, related to the installation of its capacities, however their variable costs are restricted to operation and maintenance costs, as they require freely available inputs

[12] *Size of government* is negatively correlated with the 4 other subcomponents of the index, while these same 4 components are all positively correlated

such as wind and solar power. Hence, the rentability of these investments is positive only in the very long run and depends largely on price stability. This result echoes the missing money problem that is particularly acute for renewable energy sources. It recalls the results of Brunnschweiler (2010) for developing countries. The fourth component is related to the freedom to trade internationally. This rating is computed using data on tariffs, the efficiency of the administration, the ease of convertibility of currencies and the presence of control in the movement of physical and human capital. In regression (5), we find that this rating has a positive and significant impact on our dependent variable. The final component relates to the regulatory restraints that limit the freedom of exchange in credit, labor and domestic markets. It gives a higher rating to countries where the private banking system plays a bigger role, labor markets regulations such as minimum wage or hiring/firing restrictions are scarce, barriers of entry are limited and prices are determined by competitive forces. In regression (6), we see that this rating has a small but positive impact on the production. However, this is not significant.

5 Robustness analysis

5.1 With respect to different lags, dependent and control variables

A first robustness check concerns our lag specification. In the previous two tables of results, we assumed that it took one year before the freedom index had an influence on the production of renewable energies. In Table 3, we first consider, in regression (1), 4 lagged observations of *ecofree* altogether. We see that the only coefficient that is significant is the one of *ecofree (t-1)*, as retained in our previous specifications. In regression (2) to (5), we consider each lag structure separately. We see that each have a positive coefficient. The one with one year lag is significant at the 5% threshold and the one with three years at the 10% threshold.

We then look at the share rather than at the level of the electricity production from renewable sources. One major issue is that, due to the correlation of *GDP/cap* and *ecofree(t-1)*, the standard errors of our explanatory variable increase. Dropping *GDP/cap* from our control variables has a small impact on our estimate but leads to a result significant at the 5% threshold level. Hence, this means that our results are not

Table 3
Determinants of renewable energy production

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	LSDVC	LSDVC	LSDVC	LSDVC	LSDVC	LSDVC	LSDVC
	AB	AB	AB	AB	AB	AB	AB
	ren.prod.	ren.prod.	ren.prod.	ren.prod.	ren.prod.	ren.prod.%	ren.prod.
Ren. prod. (t-1)	0.729***	0.755***	0.747***	0.755***	0.733***		0.744***
	(0.053)	(0.051)	(0.05)	(0.051)	(0.051)		(0.061)
Ren. prod. % (t-1)						1.029***	
						(0.039)	
Ecofree (t)	-0.004	0.363					
	(0.398)	(0.358)					
Ecofree (t-1)	0.626*		0.698**			0.175**	0.313*
	(0.368)		(0.31)			(0.068)	(0.173)
Ecofree (t-2)	-0.1			0.755			
	(0.349)			(0.051)			
Ecofree (t-3)	0.315				0.505*		
	(0.335)				(0.287)		
Dem. Growth	0.017***	0.017***	0.017***	0.017***	0.017***	-0.001**	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0)	(0.003)
% nuclear energy	-0.002	-0.001	-0.001	-0.002	-0.002	-0.006***	-0.018
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.002)	(0.012)
P. Elec	0.169	0.311	0.214	0.256	0.216	0.028	0.044
	(0.236)	(0.228)	(0.228)	(0.234)	(0.233)	(0.062)	(0.114)
Tot. Cons.	-1.52	-1.504	-1.684	-1.488	-1.31	-0.592*	0.44
	(1.249)	(1.26)	(1.237)	(1.261)	(1.242)	(0.343)	(0.746)
Deficit	0.013	0.012	0.013	0.017	0.017	0.007*	-0.001
	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.004)	(0.009)
GDP/cap	-0.365	0.702	-0.003	0.413	0.031		
	(1.233)	(1.116)	(1.085)	(1.143)	(1.182)		
Left	0.102	0.122	0.112	0.072	0.065	-0.024	-0.037
	(0.129)	(0.126)	(0.119)	(0.121)	(0.119)	(0.03)	(0.057)
Maj.	0.436	0.41	0.414	0.353	0.437	-0.199	-0.347
	(0.831)	(0.826)	(0.815)	(0.828)	(0.824)	(0.209)	(0.545)
Ren. policies	-0.017	0.011	-0.003	0.013	-0.006	0.022	0.079
	(0.078)	(0.075)	(0.075)	(0.077)	(0.078)	(0.019)	(0.051)
Entry							-0.035
							(0.048)
Public ownership							-0.06
							(0.082)
Vertical integration							0.051
							(0.066)
Market structure							-0.081**
							(0.038)
N	263	263	263	263	263	261	203
ll						-254.689	-206.862

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses

spurious.

Ecofree only focuses on aggregate global market-oriented institutions. It does not focus on a specific market. In this next robustness check we add new energy market factors that control for the regulatory framework specific to the country, even though this was already, but only partially, controlled for via our country and year effects. For this purpose, we use 4 new control variables from the OECD indicators of regulation in energy, transport and communications (ETCR). *Entry* measures the extent with which the electricity market is liberalized. *Public ownership* measures the ownership structure of the largest companies active in the generation, transmission, distribution and supply of electricity. *Vertical integration* measures the degree of vertical integration in the industry. Finally, *market structure* is an index built on the market share of the largest company in the various stages of the electricity market. They are all between 0 and 6, 6 meaning that it is a tightly regulated sector. As data is only available every 5 years, we handle missing observations by replacing them by their linear interpolation. Due to the same issue of correlation discussed before, we drop *GDP/cap*, as its presence impacts our standard errors but not our coefficient. In regression (7) of Table 3, we find that, considering the new control variables reduces the coefficient of *ecofree(t-1)*. We have that only *market structure* is significant. It means that a higher concentration of the sector leads to lower levels of production using renewable energies. These low levels of significance are mainly due to the presence of year effects and the small within group variance of these four indicators, in part due to the large amount of missing data.

5.2 With respect to other samples

In Table 4, we look at how our main results differ when looking at subsamples of our database. Note that this can impact the significance of our results as it decreases our number of observations. We first split our data into two subsamples depending on the year of our observations. We use the year of the subprime crisis as limit. Analyzing regression (1) and (2), we see that our main result is mainly driven by our post-2007 observations as it has a positive and significant sign. Second, we split our data on a geographic basis, depending on which side of the former Iron curtain they where. We see, from regression (4), that only the subsample with countries located on the West of the Iron curtain have a significant coefficient for *ecofree(t-1)*. Hence, our results are for the most driven by recent observations from Old Europe.

Table 4

Determinants of renewable energy production

Dep. Variable	(1)	(2)	(3)	(4)
Ren. Prod.	LSDVC	LSDVC	LSDVC	LSDVC
	AB	AB	AB	AB
	Post 2007	Pre 2007	East	West
Ren. prod. (t-1)	0.518***	1.184***	0.44***	0.933***
	(0.111)	(0.053)	(0.114)	(0.052)
Ecofree (t-1)	1.162**	-0.155	0.475	0.609**
	(0.501)	(0.381	(0.613)	(0.292)
Dem. Growth	0.017	0.02***	0.01	0.018***
	(0.01)	(0.001)	(0.01)	(0.002)
% nuclear energy	0.015	-0.002	0.007	0.005
	(0.059)	(0.007)	(0.011)	(0.028)
P. Elec	0.279	0.489	0.532	0.183
	(0.393)	(0.651)	(1.367)	(0.222)
Tot. Cons.	-5.581*	-2.184	-3.346	-3.437*
	(3.288)	(1.417)	(2.229)	(1.94)
Deficit	0.074	0.033*	-0.052	0.014
	(0.061)	(0.018)	(0.05)	(0.019)
GDP/cap	4.335	-0.99	2.554	2.005
	(3.41)	(1.303)	(2.192)	(1.422)
Left	0.135	-0.074	0.099	-0.078
	(0.23)	(0.131)	(0.25)	(0.114)
Maj.	1.908	0.362	0.344	0.511
	(1.694)	(1.009)	(1.431)	(0.948)
Ren. policies	0.094	-0.271**	-0.132	0.139
	(0.165)	(0.105)	(0.125)	(0.099)
N	130	133	95	168

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses

5.3 With respect to endogeneity

One remaining issue is endogeneity which can be due to reverse causality, measurement errors or omitted variables. In our case, as discussed previously, reverse causality is mitigated as there is a one year lag between our dependent variable and our independent variable of concern. Fixed effects also help attenuate the bias created by omitted variables. However, they only help control for unobserved but fixed omitted variables. Even if additional unobserved variables are indirectly considered via our lagged dependent variable, it does not give us sufficient grounds to claim that endogeneity is not a problem in our estimations.

To tackle this issue we use an instrumental variable approach with two sets of instruments, both of which are not directly related with our dependent variable (*ren. prod.*) but which are correlated with our explanatory variable (*ecofree*). Due to our European sample and our panel data approach many of the instruments used in the literature looking at the impact of institutions cannot be used. This is true for instruments using pre- or post- colonial historical data (such as settlers mortality, legal origin or indigenous population density) as well as for geographical data (such as latitude and longitude, which in addition might as well be correlated with the production of renewable energies as they relate to the presence of sun and wind).

Following the literature on the determinants of market institutions, we use two instruments that vary in the cross section and over time. The first, *av. ecofree (t-2)*, is the average economic freedom index of the countries with whom they share a borderline with one year lag. The main economic motivation to use this variable as an instrument comes from the way reforms can be contagious across borders as a consequence of strategic interactions among governments. Using like us the economic freedom index, the spatial diffusion of pro-market reforms has been empirically observed by Gassebner et al. (2011).[13] The second, *internetusers%*, is the share of a country's inhabitants with an internet access. The relationship between the extent of digital divide and the economic freedom index is based on the ground that telecommunication networks reduce information asymmetries by improving the global exchange of knowledge (through interactions among citizens, with various media and government institutions). These greater information spillovers, possible thanks to the internet, allow access to knowledge

[13]Analyzing the determinants of renewable energy production, this spatial correlation has also been used as an instrument by Smith and Urpelainen (2014). However, in their case, the variable instrumented was the level of feed-in tariff.

for all and prevent one party from monopolizing opportunities by pushing for economic reforms. As empirically assessed by Baliamoune-Lutz (2003) and Thompson and Garbacz (2007), we would then expect a positive correlation between internet access and our freedom index. Finally, we would expect our two instruments to influence *ren. prod.* only via a change in our endogenous variable, *ecofree (t-1)*.

Table 5
Determinants of renewable energy production

Dep. Variable Ren. Prod.	(1) 2SLS First stage	(2) 2SLS Second stage
Ren. prod. (t-1)	0.013	0.476***
	(0.014)	(0.037)
Ecofree (t-1)		0.89*
		(0.541)
Dem. Growth	-0.001	0.006*
	(0.001)	(0.003)
% nuclear energy	0.001	-0.0001
	(0.001)	(0.005)
P. Elec	0.036	0.064
	(0.057)	(0.147)
Tot. Cons.	0.029	-1.951**
	(0.305)	(0.764)
Deficit	0.001	-0.008
	(0.004)	(0.01)
GDP/cap	1.49***	1.356
	(0.21)	(1.003)
Left	-0.07***	0.085
	(0.025)	(0.074)
Maj.	0.074	0.105
	(0.187)	(0.473)
Ren. policies	0.013	-0.014
	(0.016)	(0.043)
Av. Ecofree (t-2)	0.218***	
	(0.055)	
internet users %	0.006**	
	(0.002)	
constant	-9.638	
	(3.103)	
N	263	263
Weak identification test	F-stat	10.83
Overidentification test	p-value	0.163
Durbin-Wu-Hausman test	p-value	0.173

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses

As our model is overidentified, our instruments can be validated by a series of statistical tests. First, their validity is confirmed by the Sargan test of overidentification. With a p-value of 0.163, we fail to reject the hypothesis according to which our excluded instruments are valid, i.e. they are uncorrelated with the error terms of our second stage regression. A second issue concerns the relationship between our excluded instruments and our endogenous variable. From regression (1) in Table 5, we see that they both positively and significantly influence *ecofree (t-1)*. The other significant variables also have the expected signs. Wealthier countries have a higher index and left wing governments tend to make less pro-market reforms. Weak identification is further analyzed with the F-statistic against the null hypotheses that our instruments are irrelevant in the first stage is 10.83. It is above the standard threshold of 10 in the case where two instruments are used (Stock and Yogo (2005)). Based on these tests, our instruments are both valid and relevant, even if the usual disclaimer holds.

Based on the second stage of our regression, we see that the coefficient of our instrumented variable, *ecofree*, is equal to 0.89 which is close to what we obtained in our base results in Table 1 which was 0.826 for the fixed effect model. However, as the two-stage approach is less efficient, we see a decrease in efficiency which leads to a level of significance of only 10% . Based on the Durbin-Wu-Hausman test, the null hypothesis of the exogeneity of *ecofree* cannot be rejected. This means that endogeneity is not an issue and that we can rely on our initial results of Table 1.

6 Conclusion

This paper examines the role of institutions in the deployment of renewable energies, with a specific focus on market-oriented institutions as measured by the Economic Freedom Index. We conclude, using several alternative empirical models, that they play a positive and significant role. Looking at the subcomponents of the index, we see that this is driven by various aspects such as a stable monetary system that creates long term price stability and effective administration processes (as included in the *freedom to trade* component). On the other hand, the importance given to markets compared to governments has a negative but non-significant impact.

The main limitation of this work is our aggregate approach. First, we look at country-level data, and only at EU member states. Second our index gives only an imprecise picture of market-based institutions. We hope that this paper will encourage future works to go deeper in analyzing which institutions, with more precision, matter to promote the renewable energy sector.

References

Agterbosch, S., W. Vermeulen, and P. Glasbergen (2004). Implementation of wind energy in the Netherlands: the importance of the social-institutional setting. *Energy Policy*, 32, 2049–2066.

Arellano, M. and S. Bond (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Review of Economic Studies*, 58(2), 277–297.

Baliamoune-Lutz, M. (2003). An analysis of the determinants and effects of ICT diffusion in developing cuntries. *Information and Technology for development*, 10, 151–169.

Baranes, E., J.-C. Poudou, and J. Jacqmin (2015). Non-renewable and intermittent renewable energy sources: Friends and foes? FAERE working paper 2015.02.

Beck, T., G. Clarke, A. Groff, P. Keefer, and P. Walsh (2001). New tools in comparative politial economy: The database of political institutions. *World Bank Economic Review*, 15(1), 165–176.

Benassy-Quere, A., M. Coupet, and T. Mayer (2007). Institutional determinants of foreign direct investment. *The world economy*, 30(5).

Bergek, A., I. Mignon, and G. Sundberg (2013). Who Invests in Renewable Electricity Production? Empirical Evidence and Suggestions for Further Research. *Energy Policy*, 56, 568–581.

Bond, S. R. (2002). Market-oriented institutions and policies and economic growth: A critical survey. *Portuguese Economic Journal*, 1(2), 141–162.

Brunnschweiler, C. N. (2010). Finance for renewable energy: an empirical analysis of developing and transition economies. *Environment and development economics*, 15, 241–274.

Bruno, G. S. (2005). Approximating the bias of the LSDV estimator for dynamic unbalanced panel data models. *Economics Letters*, 87(3), 361–366.

Cadoret, I. and F. Padovano (2015). The political economy of renewable energies. Condorcet center for political economy working paper 2015-01-crc.

Cardenas-Rodriguez, M., I. Hascic, N. Johnstone, J. Silva, and F. A. (2015). Renewable energy policies and private sector insvestment: Evidence from financial microdata. *Environmental and resource economics*, pages 1–26.

Carlsson, F. and S. Lundstrom (2003). The effect of economic and political freedom on co2 emissions. Dpt of economics, Goteborg University, working papers in economics 29.

De Haan, J., S. Lundstrom, and J. Sturm (2006). Market-oriented institutions and policies and economic growth: A critical survey. *Journal of Economic Surveys*, 20(2).

De Haan, J. and J. Sturm (2000). On the relationship between economic freedom and economic growth. *European Journal of political economy*, 16(2), 215–241.

Delmas, M. A. and M. Montes-Santo (2011). U.S. State Policies for renewable Energy: Context and Effectiveness. *Energy Policy*, 39(2273-2288).

EIA (2015). International Energy data and analysis.

European Commission (2014). A policy framework for climate and energy in the period from 2020 to 2030. Technical Report COM(2014) 15.

Eurostat (2015). Eurostat database.

Gassebner, M., N. Gastion, and J. Lamla (2011). The inverse domino effect: Are economic reforms contagious? *International economic review*, 52(1), 183–200.

Gassebner, M., M. Lamla, and J. Sturm (2010). Determinants of pollution: What do we really know? *Oxford economic papers*, 67(3), 516–546.

Gwartney, J., R. Lawson, and J. Hall (2015). *Economic freedom of the world: 2015 annual report*. Fraser Institute.

Hall, J. C. and R. A. Lawson (2014). Economic freedom of the world: An accounting of the literature. *Contemporary Economic Policy*, 32(1), 1–19.

Hitaj, C. (2013). Wind power development in the United States. *Journal of Environmental Economics and Management*, 65(3), 394–410.

IRENA (2015). Global renewable energy policies and measures database.

Judson, R. A. and A. L. Owen (1999). Estimating dynamic panel data models: a guide for macroeconomists. *Economics Letters*, 65(1), 9–15.

Kiviet, J. (1999). Expectations of expansions for estimators in a dynamic panel data model; some results for weakly exogenous regressors. In *Analysis of Panels and Limited Dependent Variable Models*, edited by C. Hsiao, K. Lahiri, L. Lee, and M. Pesaran. Cambridge University Press, Cambridge.

Lee, A., O. Zinaman, J. Logan, M. Bazilian, D. Arent, and R. L. Newmark (2012). Interactions, Complementarities and Tensions at the Nexus of Natural Gas and Renewable Energy. *The Electricity Journal*, 25(10), 38–48.

Neumayer, E. (2003). Are left-wing party strenght and corporatism good for the environment? evidence from panel analysis of air pollution in OECD countries. *Ecological Economics*, 45, 203–220.

Nickell, S. J. (1981). Biases in Dynamic Models with Fixed Effects. *Econometrica*, 49(6), 1417–26.

Nyström, K. (2008). The institution of economic freedom and entrepreneurship: evidence from panel data. *Public choice*, 136, 269–282.

OECD (2011). *OECD green growth studies: Energy.* OECD publishing.

Olivier, J., G. Janssens-Maenhout, M. Muntean, and J. Peters (2014). *Trends in global CO2 emissions: 2014 report.* PBL Netherlands environmental assessment agency.

Smith, M. G. and J. Urpelainen (2014). The effect of feed-in tariffs on renewable electricity generation: An instrumental variables appraoch. *Environmental and resource economics*, 57(3), 367–392.

Stock, J. and M. Yogo (2005). Testing for weak instruments in linear IV regression. In *Identification and Inference for Econometric Models: Essays in Honor of Thomas J. Rothenberg*, edited by J. Stock and D. Andrews. Cambridge University Press.

Thompson, H. G. and C. Garbacz (2007). Mobile, fixed line and Internet service effects on global productive efficiency. *Information Economics and policy*, 19.

Zenewi, M. and J. Stoltenberg (2010). Report of the Secretary General's high-level advisory group on climate change financing. Technical Report 11, United nations.

Appendix

Table A.1
Summary statistics

Variables (N=263)	Mean	Standard deviation	Min	Max	Source
Ren. Cap.($log(1+x)$)	13.842	3.556	0.000	18.564	EIA (2015)
Ecofree	7.421	0.383	6.350	8.410	Gwartney et al. (2015)
Dem. groth	2.709	25.249	−68.408	377.778	Eurostat (2015)
% nuclear energy	19.578	23.480	0.000	80.535	Eurostat (2015)
P. Elec (log)	−1.996	0.378	−2.816	0.307	EIA (2015)
Tot. Cons (log)	10.253	1.429	6.769	12.771	Eurostat (2015)
Deficit	−3.090	4.025	−30.600	5.300	Eurostat (2015)
GDP/cap (log)	9.988	0.394	8.923	11.133	Eurostat (2015)
left	0.278	0.449	0.000	1.000	Beck et al. (2001)
maj.	0.560	0.071	0.357	0.743	Beck et al. (2001)
Ren. policies	5.943	1.478	0.000	7.000	IRENA (2015)

Table A.2
Correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	Ren. Cap.($log(1+x)$)	1.000	–	–	–	–	–	–	–	–	–	–
(2)	Ecofree	0.224	1.000	–	–	–	–	–	–	–	–	–
(3)	Dem. groth	−0.234	−0.006	1.000	–	–	–	–	–	–	–	–
(4)	% nuclear energy	0.131	−0.112	−0.093	1.000	–	–	–	–	–	–	–
(5)	P. Elec (log)	0.463	0.261	−0.010	−0.144	1.000	–	–	–	–	–	–
(6)	Tot. Cons (log)	0.780	0.036	−0.249	0.291	0.274	1.000	–	–	–	–	–
(7)	Deficit	−0.024	0.285	−0.013	0.077	−0.025	−0.072	1.000	–	–	–	–
(8)	GDP/cap (log)	0.356	0.513	0.007	−0.117	0.580	0.160	0.165	1.000	–	–	–
(9)	left	0.205	−0.061	−0.056	0.045	0.035	0.184	−0.236	−0.026	1.000	–	–
(10)	maj.	0.042	0.137	−0.050	0.240	−0.070	0.054	0.137	0.084	−0.159	1.000	–
(11)	Ren. policies	0.594	0.319	−0.099	−0.007	0.533	0.313	−0.110	0.592	0.139	−0.009	1.000

Documents de Recherche parus en 2015

DR n°2015 - 01: Antoine BERETTI, Charles FIGUIERES et Gilles GROLLEAU
« An Instrument that Could Turn Crowding-out into Crowding-in »

DR n°2015 - 02: Laure KUHFUSS, Julie SUBERVIE
« Do Agri-environmental Schemes Help Reduce Herbicide Use? Evidence from a Natural Experiment in France »

DR n°2015 - 03: Stéphane MUSSARD, Fattouma SOUISSI-BENREJAB
« Gini-PLS Regressions »

DR n°2015 - 04: Julien JACQMIN, Mathieu LEFEBVRE
« Does sector-specific experience matter? The case of European higher education ministers »

DR n°2015 - 05: Nicolas QUEROU, Agnes TOMINI
« Marine ecosystem considerations and second-best management »

DR n°2015 - 06: Philippe DELACOTE, Elizabeth J. Z. ROBINSON et Sébastien ROUSSEL
« Deforestation, Leakage and Avoided Deforestation Policies: A Spatial Analysis »

DR n°2015 - 07: Marie-Eve YERGEAU, Dorothée BOCCANFUSO et Jonathan GOYETTE
« Conservation and Welfare: Toward a Reconciliation of Theory and Facts »

DR n°2015 - 08: Ange NSOUADI, Jules SADEFO KAMDEM et Michel TERRAZA
«Analyse temps-fréquence du co-mouvement entre le marché européen du CO2 et les autres marchés de l'énergie »

DR n°2015 - 09: Rachida HENNANI
« Can the Lasota(1977)'s model compete with the Mackey-Glass(1977)'s model in nonlinear modelling of financial time series? »

DR n°2015 - 10: Selly AMAL KERIM, Hélène REY-VALETTE, Françoise SEYTE et Dorothée BOCCANFUSO
« A Subjective View of Governance Iindicators »

DR n°2015 - 11: Nicolas QUEROU, Antoine SOUBEYRAN et Raphael SOUBEYRAN
« Moral Hazard and Capability »

DR n°2015 - 12: Dimitri DUBOIS, Mathieu DESOLE, Stefano FAROLFI, Mabel TIDBALL et Annie HOFSTETTER
« Does Environmental Connotation Affect Coordination Issues in Experimental Stag Hunt Game? »

DR n°2015 - 13: Edmond BARANES, Stefan BEHRINGER et Jean-Christophe POUDOU
« Mobile Access Charges and Collusion under Asymmetry »

DR n°2015 - 14: Gabriela SIMONET, Julie SUBERVIE, Driss EZZINE-DE-BLAS, Marina CROMBERG et Amy DUCHELLE
« Paying smallholders not to cut down the Amazon forest: Impact evaluation of a REDD+ pilot project»

DR n°2015 - 15: Julien JACQMIN
« The role of market-oriented institutions in the deployment of renewable energies: evidences from Europe »

Contact :

Stéphane MUSSARD : mussard@lameta.univ-montp1.fr