2012- 13 / April 2012

Document de travail

THE EVOLUTION OF RENEWABLE ENERGY POLICY IN OECD COUNTRIES: AGGREGATE INDICATORS AND DETERMINANTS

Francesco Nicolli
University of Ferrara

Francesco Vona
OFCE Sciences-Po and Skema Business School

ofce

The Evolution of Renewable Energy Policy in OECD Countries: aggregate indicators and determinants

Francesco Nicolli

University of Ferrara

Francesco Vona[*]

OFCE Sciences-Po and Skema Business School

Abstract

This paper proposes different methods to aggregate heterogeneous policies for renewable energy. We compare time-varying indicators built using principal component analysis with average-based indicators. The main goal of the paper is to account for the evolution of both types of policy indicators with a set of common variables. Our empirical results are consistent with predictions of political-economy models of environmental policies as lobbying, income and, to a less extent, inequality have expected effects on policy. The brown lobbying power, proxied by entry barriers in the energy sector, has negative influence on the policy indicators even when taking into account endogeneity in its effect. The results are also robust to dynamic panel specifications and to the exclusion of groups of countries. Interestingly, too, corruption has only an indirect effect on policy mediated by entry barriers, while the negative effect of inequality is much stronger for the richer countries.

JEL Codes : Q42, Q48, D72, O38.

Keywords: Renewable Energy Policy, Political Economy, Product Market Regulation, Lobbying, Policy Indicators

[*] We wish to thank Lionel Nesta and Alessandro Sapio for particularly useful comments. We have also enjoyed the comments on an extended version of this paper by seminar participants at the Fondazione Enrico Mattei, taking part in the conference 'Innovation, Economic Change and Policies: an out-of-equilibrium perspective' (in honor of Mario Amendola) held in Rome and by Valentina Bosetti, Mario Pianta, Francesca Sanna-Randaccio, Francesco Saraceno, Massimo Tavoni, Elena Verdolini. A special thank you goes to Nick Johnstone for providing the data on REC targets used for this work. Usual disclaimer applies. Corresponding author: francesco.vona@sciences-po.fr.

1. Introduction

Environmental problems typically call for government interventions to tackle market failures associated with pollution and investment in green technologies. The current consensus is that an appropriate combination of policies should be conceived to stimulate the search for new solutions rather than mere compliance with technological standards or fixed pollution targets. In this vein, recent policy strategy combines interventions to correct pollution externalities (e.g. carbon taxes) with policies to stimulate innovation (e.g. R&D subsidies). These sophisticated policy interventions characterize in particular the field of renewable energy, making any evaluation of the policy effort across countries and time problematic.

Policies promoting renewable energy represent the most promising option to mitigate jointly GHG emissions and emerging oil scarcity, and can be evaluated using the rich dataset provided by the International Energy Agency, which contains time-varying information on Renewable Energy Policy (REP henceforth) for OECD countries. Figure 1 provides an overall picture of the evolution of policies in OECD countries, detailing the types of policies applied. The two oil crises of the 70s stimulated policy responses in almost all the developed countries, whereas an abrupt stop in the expansion of these policies occurred when oil prices started falling in the early 80s. A second wave of REP was implemented in the 90s in response to increasing concern for climate change mitigation. With regard to the policy adopted, certain cross-country regularities clearly emerge. A first phase focusing on RD&D (Research, Demonstration and Development) subsidies and grants is followed by a second phase characterized by a greater use of market-based instruments such as taxes, incentives and guaranteed prices and, more recently, tradable permits and renewable energy certificates. At the same time, diversification increased substantially as policies adopted earlier were often kept in use together with new ones. Diversification also makes it difficult to provide an aggregate measure of the effort by each country to favour the transition to renewable energy and to examine policy determinants systematically. In fact, aggregation of heterogeneous policies in a single indicator is not immediate because the available policies are measured either as 0-1 signal or on a continuous scale, e.g. Feed-in tariffs.

[FIG.1 ABOUT HERE]

The first goal of this paper is to build aggregate indicators of REP, which can enable rigorous evaluations of the policy impact on innovation and renewable energy diffusion. Using these indicators, our second goal is to test some predictions of political-economy models of environmental policies (e.g. Fredriksson 1997, Lopez and Mitra 2000). In these models, politicians maximize the probability of being re-elected by setting environmental policy so as to balance the interests of citizens and sector-specific lobbies, including the lobby of environmental activists. The well-established result in both the empirical and theoretical literature is that the weighing factor assigned to these (potentially conflicting) interests depends upon the level of corruption, and this effect may be amplified or mitigated depending on other institutional factors (e.g. Fredriksson and Svensson 2003, Damania et al. 2003). Our empirical analysis shows that the impact of corruption on policy appears entirely mediated by its indirect effect on product market regulation, our proxy for incumbents' lobbying power in the energy sector. Moreover, the degree of entry barriers is, together with a dummy for the first approval of the Kyoto protocol in 1998, the best predictor of REP. Finally, citizens' preferences for a clean environment are better captured using both the first and the second moment of income distribution, consistently with models where the median voter decides on environmental policy (Magnani 2000, Kempf and Rossignol 2007). However, in line with models where environmental quality is a good occupying a higher position in the hierarchical scale (Vona and Patriarca 2011), the negative effect of inequality on environmental policies emerges only for the rich countries.

The next section describes in greater detail the testable predictions derived from political economy models of environmental policy. This section will be followed by a section describing the methodology followed to build our dataset on REP and presenting the principal component analysis used to extract synthetic information from our heterogeneous set of policies. We compare the various countries' policy efforts using both the principal component analysis indicators and a simpler average-based indicator. Section 4 examines the determinants of the policy. The final section draws the conclusions and sets out some possible applications of our indexes to examine patterns of diffusion of renewable energy technologies.

2. Determinants of Renewable Energy Policies

Policy plays a central role in fostering innovative responses to environmental problems. For renewable energy, technological learning is especially important to reduce the cost of energy production from renewable at the level of costs of polluting energy sources. Thus renewable energy policies are intrinsically related to innovation policies. Recent contributions emphasize this connection through the concept of 'double externality' on knowledge and pollution (Jaffe et al. 2005, Fisher and Newell 2008, Acemoglu et al. 2010). In this perspective, a policy targeted to environmental externality alone is likely to reduce firm's competitiveness without fostering innovation, while combining it with a green R&D[1] subsidy could be a way to meet the competitiveness and the sustainability targets alike.

However, precise evaluation of the effect of renewable energy policies on innovation remains primarily an empirical issue. The effect of the policies considered in this paper has been addressed in three recent studies covering OECD countries for the period of mid-70s – mid-00s using the same dataset on energy policies, i.e. the one provided by the International Energy Agency (IEA). In general, policies seemed to have a strong effect on renewable energy technology, but heterogeneous across technologies and policy instruments (Johnstone et al. 2010) and generally weaker on per-capita

1. The need for subsidies and incentives is more pressing when green technologies display a strongly forward-bias profile, i.e. high initial investments in physical capital offset by lower variable costs, as for solar and wind energy.

investment in renewable capacity (Popp et al. 2011)[2]. However, the policy effect appears underestimated without taking into account the endogeneity of the policy support (Vona et al. 2012).

In light of these findings, in particular, it may indeed prove useful to take a step back to look into the politico-economy determinants of renewable energy policy. The mainstream literature builds on the Grossman and Helpman model (1994), where multiple lobbies attempt to capture sector-specific policies by offering perspective bribes to politicians (Fredriksson 1997, Aidt 1998). As for the case of many environmental policies, the existing incumbents in the energy sector prefer less stringent policies and do the best they can to reduce policy stringency, while environmentalists support the approval of ambitious policies. The basic model's prediction is that the extent to which the chosen level of environmental tax differs from the optimal Pigouvian tax depends on the lobbies 'capacity to influence the policy. This, in turn, depends on the weighing factors assigned to the two objectives of aggregate social welfare, which mainly reflects concern for subsequent elections, and to the lobbies' bribes, which reflect the lobbies' capacity to influence specific policy such as environmental policy. The relative value assigned by politicians to the brown lobby bribe has been typically interpreted as dependent on the level of corruption, and the negative impact of corruption on environmental policy has been confirmed by substantial empirical research[3]. As for the green lobby, recent works by Fredriksson et al. (2007) and List and Sturm (2004) show that it has substantial influence on environmental policies.

In the case of energy, first it is to be noted that the polluting sectors are expected to have a greater incentive to form lobbies in order to capture environmental policies (Damania and Fredriksson 2000). Fredriksson et al. (2004) provide empirical support for this prediction, showing that the effect of corruption, i.e. as proxy for lobbying power, on energy intensity is greater in the more energy-intensive sectors. More closely related to REP, case study evidence shows that the existing incumbents tend to oppose approval of ambitious renewable energy policies (e.g. Neuhoff 2005, Jacobsson and Bergek 2004, Nilsson et al. 2004, Lauber and Mez 2004). Since REP mainly entails subsidies and incentives, the opposition of existing lobbies is, in this case, related to technological

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2. Using patent applications in many renewable technologies, Johnstone et al. (2010) show that guaranteed price schemes and investment incentives appear to play a major role in the early phase of technological development, whereas for relatively more mature technologies, e.g. wind, obligation and quantity-based instruments work better. This study also shows that the effect of energy prices, another dimension of the policy, is not statistically significant except in the case of solar energy. Popp et al. (2011) show that, among the policies considered, the dummy for the early ratification of the Kyoto protocol is the one that promoted the most per-capita investment in renewable capacity. Again, however, the effect of the policies is highly heterogeneous across renewable technologies, being much stronger for biomasses, waste and wind.

3. Fredriksson and Svensson (2003) extend the Helpman and Grossman (1994) and Fredriksson (1997) models to include political instability as well. Their model shows that the effect of corruption decreases when political instability increases as incumbent officeholders can less credibly commit to a policy. This prediction is confirmed in their empirical analysis of the stringency of environmental regulation in agriculture. Other aspects of the impact corruption on environmental policies are considered in variants of the same models and tested empirically by Fredriksson et al. (2004), who consider multiple lobbies and their organization costs, Fredriksson and Vollebergh (2009), showing that the effect of corruption is lower in federal systems, and Damania et al. (2003), where the effect of corruption greatly depends on the degree of trade openness.

comparative advantages rather than to the costs of complying with regulations. In fact, whereas the production of energy from renewable sources is decentralized in small-medium sized units, the competences of the existing incumbents are tied to large scale plants using coal, nuclear or gas as primary energy inputs. Moreover, the high sunk costs of large-scale generation further exacerbate the lock-in of incumbents and should fuel their political opposition to the distributed generation paradigm. Therefore, unlike models where deviations from the optimal taxation depend on the politicians' willingness to accept bribes, the bias in the politicians' behavior is, we hold, to be interpreted as depending upon the potential size of the bribe, which is proportional to the monopolistic rents of the energy lobby.

Following on this argument, the recent liberalization of energy markets should have reduced the incumbents' opposition, favoring the adoption of ambitious renewable energy policies. Clearly, one should also expect a stronger effect of entry barriers where corruption levels are high. However, we will show that, rather than being synergetic, the effect of corruption on policy is fully mediated by the indirect effect on entry barriers.

Renewable energy policies are also affected by social welfare considerations and depend on the aggregation of citizens' preferences. Since environmental quality is a normal good[4], the wealthier households demand more stringent environmental policies to satisfy it – a prediction that is consistent with the empirical evidence at both the micro and the macro level (Arrow et al. 1995, Diekmann and Franzen 1999, Dasgupta et al. 2001, Esty and Porter 2005, Oecd 2008[5]). The second moment of income distribution also matters, as recent theoretical and empirical studies have shown[6]. The effect of inequality hinges upon the fact that, given the level of per capita income, a lower level of inequality implies a richer median voter and so greater support for ambitious policies.

In sum, both socio-economic and institutional factors affect REP, suggesting that a hybrid political economy model is the most appropriate to account for REP determinants. In particular, our predictions based on perusal of the literature are that both higher entry barriers and inequality should reduce

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4. Actually, this effect is reinforced if environmental quality is a good hierarchically higher in the scale. The idea is that "concern(s) for quality-of-life issues, such as free of speech, liberty and environmental protection... arise only after individuals have met their more basic materialist needs for food, shelter, and safety" (Gelissen 2007, p. 393, see also Inglehart 1995).

5. At the micro level, several studies have also shown that wealthier and more educated households are generally more willing to pay higher prices for renewable energy (Roe et al. 2001, Wiser 2007) and to participate voluntarily in clean energy programs (Rose et al. 2002, Kotchen and Moore 2007, Kotchen 2010).

6. Magnani (2000) shows that, given the level of per capita income, inequality and expenditures on public goods are negatively correlated, as wealthier households are more willing to contribute to the provision of public goods than poor ones. Eriksson and Persson (2003) also derive a partial negative inequality-pollution relationship in a political-economy model where heterogeneous agents decide upon the optimal level of pollution control under the assumption that wealthier individuals are less affected by pollution. Kempf and Rossignol (2007) obtain a similar result in a model where a dynamic trade-off between growth and environmental quality is explicitly considered. McAusland and Carol (2003) derives quite different implications and shows that the effect of inequality depends on both trade openness and the distributions of polluting- and clean-factor endowments. Empirical evidence in Magnani (2000) and Vona and Patriarca (2011) confirms that inequality negatively affects public investment in green R&D.

policy intensity, while higher income should increase it. To test the effects of these factors rigorously, it is crucial to build aggregate indicators of REP indicators. Moreover, the existing studies focus mainly on cross-sectional analysis of environmental policy, neglecting the time dimension, an exception being Fredriksson et al. 2004, which attempts to fill this gap in the literature by analyzing the issue of policy determinants in a dynamic panel dataset.

Aggregate Indicators of Policy for Renewable Energy

Building the Policy Indicators

The dataset made available by the IEA contains detailed country fact sheets to construct dummy variables reflecting the adoption time of selected REP for most OECD countries[7]. A drawback of this dataset is that it provides information on the year of adoption, but does not specify the degree of intensity of the policy adopted. We hence integrate this information using other data sources in all those cases for which policies measured on a continuous scale are available. To the best of our knowledge, this is possible for the following three policy instruments: public renewable R&D expenditure, feed-in tariff schemes and Renewable Energy certificates[8]. Information on the first is also available in the joint IEA-Oecd dataset[9], whereas the main references for feed-in tariff are two reports drawn up by IEA (2004) and Cerveny and Resch (1998), plus some country specific sources[10].Our measure of the stringency of REC targets is the variable constructed by Johnstone et. al. (2010), which reflects share of electricity that must be generated by renewables or covered with an REC.

Johnstone et al. (2010) place particular emphasis on the role of these continuous policy variables for empirical analysis of the determinants of renewable energy innovation and diffusion. However, construction of a synthetic indicator based on these specific REP alone may be misleading for several reasons. Firstly, some countries may be underrepresented if they decide not to adopt guaranteed price schemes or REC targets, but to rely on other instruments for which we have only binary information[11].

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7. http://www.iea.org/textbase/pm/?mode=re
8. Through guaranteed price schemes, the energy authority obliges energy distributors to feed in the production of renewable energy at fixed prices varying according to the various sources (wind, solar, waste..). This system has become widespread in many countries, including Germany, Spain and Denmark, and is considered one the main factors in the development of renewable technologies, especially thanks to the advantage of reducing uncertainty, offering investors long-term security (Reiche et. al., 2002). REC, on the other hand, consists of tradable financial assets, issued by the regulating authority, which certify the production of renewable energy and can be traded among the actors involved. Along with the creation of a certificate scheme, more generally a separate market is established where producers can trade the certificates, creating certificate “supply”, while the demand depends on political choices. The price of the certificate is determined through relative trading between the retailers. The first phase of implementation of REC systems in Europe dates back to the beginning of the 2000s, when many European countries experimented with this instrument in order to meet the targets set by Directive 2001/77/CE.
9. http://stats.oecd.org/index.aspx?r=767491
10. http://www.ren21.net/ and http://www.res-legal.de.
11. An important example is Japan, which during the period analyzed did not adopt any feed-in tariff schemes, but adopted many other REPs, and was the country with the largest energy RD&D budget of the OECD countries (about 3.4 billion dollars) in 2001. Moreover, Japan widely adopted other market-based instruments

Secondly, these three policies have often been adopted in recent years, so relying on them to characterize the long-term evolution of policy effort could prove misleading[12]. Thirdly, the complete exclusion of the other instruments, e.g. tax and investment incentives (see table 1), would offer a rather incomplete picture of the overall policy effort since some of these policies are important to spur renewable energy technology.

On the other hand, with policy dummies it is possible to measure policy effort from a different angle. An indicator based on adoption dummies appears to reflect more closely the overall intention of the government to pursue REP or, more generally, its commitment towards renewable energy. Dummy variables are available for many policies: tax, investment incentives, Obligations, voluntary agreements and European directives. Table 1 in the appendix offers a detailed explanation of each policy, including the continuous ones.

[TABLE 1 ABOUT HERE]

Overall, the appropriate policy index should include both the signaling effect of policy dummies and the stringency of continuous policies. Previous research on aggregate policy indicators attempts to deal with heterogeneous information in a variety of ways. Nicolli et al. (2012) builds an aggregate indicator as the average of a set of policy adoption dummies, sacrificing stringency (available only for a small subset of instruments) for the sake of completeness. Mazzanti and Zoboli (2009) weigh policy signals to account for the cross-country differences in the intensity of the main policy instrument for which they have quantitative information, i.e. landfill taxes[13]. Using survey data, Dasgupta et al. (2001) assigns weights to each policy on a Likert scale, built converting into numeric values the answers given to specific questions in the survey. In general, respondents were asked to grade each answer "high" (2), "medium" (1) or "low" (0) according to their relative perceptions of the intensity of regulation. Also using survey-based data, Esty and Porter (2005) summarizes several policy indicators through common factor analysis in order to collapse the huge set of indicators into two main ones[14].

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like: voluntary agreement between public and private sector; Capital grants, investment incentive for renewable energy installation and production standards. The same holds for Canada and Norway.

12. Especially for RECs, and in some cases also for feed-in tariff schemes, the adoption time is around year 2000, particularly in Europe, where the 2001 EU directive has established precise targets for the share of RES electricity in each EU Member State's supply. As a result an indicator based on this information alone can either present too many zeros or be composed by only on a single variable, e.g. public R&D. Identifying the factor affecting the adoption time of these policies represents an interesting extension of our analysis, but is beyond the scope of this paper.

13. Starting from the available country fact sheet on waste they differentiated between "strategy" and "effective policy", to which were assigned weights equal to 1 and 2 respectively. Similarly, they weighted the landfill tax dummy variable in accordance with the stringency of the instrument.

14. While the indicator of Dasgupta et al. (2001) includes both objective policy measures and self-reported data based on a survey conducted by the United Nations, the indicator of Esty and Porter (2005) uses only the self-reported perception of the stringency of environmental regulation in a survey conducted on managers and policy-makers. The data used by Esty and Porter (2005) are collected within the Environmental Sustainability Index (ESI) project, based on joint collaboration between the Yale Center for Environmental Law and Politics, Center for International Earth Science Information Network at Columbia University and the World Economic Forum. For details: http://www.yale.edu/esi/ and http://www.weforum.org/issues/global-competitiveness.

Given the lack of consensus on the appropriate way to aggregate heterogeneous policies, we propose both methods based on simpler average-based indexes and principal component analysis. With regard to the former method, we propose two indicators. As in Nicolli et al. (2012), the first is the average value of the different policy dummies *(COM_POL)*. The second, instead, considers only the three policies for which we have intensity measures, standardizes them and then takes the unweighted average *(CONT_POL)*. These two indexes reflect, respectively, the overall policy commitment and the intensity of the most relevant policy instruments. They will be used to check the robustness of the results obtained from the principal component analysis indicators.

Principal component analysis is interesting for its ability to extract a small number of sub-indexes (called principal components) from a wide set of variables. The first principal component is the linear combination of the original variables that exhibits the greatest possible variance. In our specific case, we expect the first component to account for the maximum amount of variation of information in the original set of policy proxies. With sequential application of the technique it is possible to identify a second linear combination a second linear combination of the original variables that explain the greater share of the residual variance, and so on[15]. It is to be noted that every component is orthogonal to all the others, and consequently is expected to reflect a different dimension of the original set of variables. To build aggregate indicators, the general rule of thumb is to use only those components that account for a sufficient amount of variance, i.e. generally associated with an eigenvalue greater than 1. To overcome the lack of robustness and accountability of which this technique is usually accused, we constructed three different indicators using principal component analysis[16]. Our favorite indicator considers the average level of the feed-in tariff *(FACT_AV_FEEDIN)*. The second includes the level of the feed-in tariff only for technologies that are more promising and less dependent on resource endowments, i.e. solar, wind, biomass, waste (*FACT_SP_FEED)*. The third combines the previous two by including the average level of feed-in and dummies for the adoption of feed-in for waste, solar, wind and biomass *(FACT_MIX_FEED)*. Note that, for feed-in tariffs, dummies may capture policy intensity better than feed-in levels since the latter have been adjusted downward in countries that adopted it earlier. Also for the other two variables measured on a continuous scale, i.e. REC and R&D, we include both the signal and the intensity to build this indicator. For all these indicators, the analysis generally produces between three and four relevant principal components (i.e. with associated eigenvalue>1) that have been used to build a single indicator as the simple average of the three

15. Principal components are generally normalized, and have mean equal to zero and variance equal to one, which provide a better interpretation of the resulting value, especially when employed in sequent analysis. The components obtained in the analysis are generally rotated to produce more readily interpretable results. The tables presented below refer to an orthogonal (VERIMAX) rotation, but also oblique rotation, not presented in the paper, yields similar results.

16. A major concern is that new factors are built using constant weights that exploit both the cross-country and the time variability. Clearly, building time-specific weight(s?) would be more accurate, but at the cost that interpretation of each factor would change over time. So, for instance, the first factor turns out to be composed mainly of feed-in tariffs for the first two decades and by REC afterwards. Bearing this in mind, we prefer to build factors using time-invariant weights.

components. A brief description of the results of the principal component analysis is presented in the following section.

Descriptive evidence

Tables 2 to 4 summarize in detail which are the main variables that 'load' each relevant principal component used in the three main indicators. This step is important to give clear meaning to each principal component as it is usually desirable for variables showing greater similarity to be clustered in the same component. For instance, in the path-breaking labour economics paper of Autor et al. (2003) the two relevant dimensions to cluster several job tasks were cognitive/non-cognitive and routine/non-routine. Here, it is the broad type of policy intervention that matters: price-based (of which purely fiscal instruments is a sub-category), quantity-based and innovation-oriented. Supporting our methodological choice, the generated principal components have a clear interpretation and similar variables are usually clustered together. The component with the highest explanatory power, the first, is mainly a combination of price-based policies[17]. However, unlike our favorite indicator (*FACT_AV_FEED)*, where the first PC contains all price-based policies, feed-in tariffs remain the main policy correlated with the first principal component for the other two indicators, whereas fiscal policies influence the second (resp. third) component for *FACT_SP_FEED* (resp. *FACT_MIX_FEED*). The second principal component is a combination of quantity-based instrument for *FACT_MIX_FEED* and *FACT_AV_FEED.* For *FACT_SP_FEED,* the third is mainly correlated with REC and EU 2001 directive while obligations equally load on the second and the third. The last principal component in terms of explanatory power is always strongly correlated with innovation oriented policies (i.e. R&D intensity and dummies). Finally, the differences among the three indicators are small, as can be seen in the correlations set out in table 5. However, these differences are statistically significant motivating the use of all indicators to validate our results.

[TABLES 2-5 ABOUT HERE]

The evolution of *FACT_AV_FEED* is shown in Figure2 for selected years. As expected, *FACT_AV_FEED* displays a monotonically increasing pattern for almost all countries, with the exceptions of Switzerland and Greece which experience a small decline in year 2005 with respect to 1995. The indicator is fairly stable in most countries up to the beginning of the 90s, after which particularly large increases are observed in the last few decades. Figures 3 and 4 enable comparison of *FACT_AV_FEED* with the two average based indicators *(COM_POL, CONT_POL)*. Although they reflect different aspects of the policy support, the overall trends for these indicators are fairly similar across countries and consistently increasing over time. Denmark represents, however, an important exception. Its high value in both average feed-in level and REC targets renders it an outlier in those indicators that weight these variables more. The transition economies are generally those with lower

17. In all three cases, the first principal component accounts for around 40% of the total policy variance, the second slightly more than 10% and the third and the fourth slightly less than 10%.

policy levels showing no growth together with Greece and New Zealand. The country ranking presented in table 6 is fairly well preserved across the indicators. There are, however, some discrepancies, which are due in certain countries like Japan, Norway and Canada to the absence of a national feed-in tariff scheme (which accounts for a third of the total variability of CONT_POL and has a high loading in the principal component), while cases like the Netherlands and Sweden have a better ranking in indicators based on continuous variables thanks to their higher than average level of REC target and public expenditure in R&D. These considerations also explain the correlation matrixes presented in tables 7-9, which, although confirming the high correlation among the three indicators, well highlight the differences between CONT_POL and COM_POL.

[FIGURES 2-4 ABOUT HERE]

[TABLES 6-9 ABOUT HERE]

Econometric Analysis of the Determinants of the Policy

Explanatory Variables

The review in section 2 identifies three main determinants of REP: GDP per capita (GDP_pc), income inequality (INEQ) and market structure. For the latter two, we use standard data sources (see the appendix). For the former, we use the index of Product Market Regulation (PMR) in the energy sector provided by the Oecd[18]. This index is also built using common factor analysis by combining objective sector-specific policies and regulation from different data sources[19].The PMR index for electricity and gas aggregates three sub-indexes ranging from 0 to 6 (maximum anti-competitive regulation). The first is ownership, which assumes five values: private (=0), mostly private, mixed, mostly public and public (=6).The second is an index of entry barriers that use information on third party access to the grid (regulated=0, negotiated, no access=6) and minimum consumer size to choose supplier freely (from ‘no threshold=0’ to ‘no choice=6’). The third component is vertical integration ranging from unbundling (=0) to full integration (=6). Access to each sub-index allows for evaluation of the importance of each particular aspect of the liberalization process on the energy market. Figure9 displays the evolution of PMR for selected countries. A widespread reduction of PMR occurs as from the early 90s in parallel with a general process of deregulation in many markets. For our purposes, it is worth noting that the PMR indicator has four main advantages over alternative proxies of market power: exogeneity, reliability (Conway and Nicoletti 2006, Nicoletti and Pryor 2006) and the fact that it is time-varying and based on objective measures of regulation.

18. The sectors of interest are those of electricity (ISIC 4010) and, to a lesser extent, Gas (ISIC 4020).

19. The data sources the privatization Barometer of the Fondazione Enrico Mattei, the Integrated data Base of the World Trade Organization and interviews with civil servants in particular areas. For details on the construction of the index and the weighting scheme see, e.g., Conway et al. (2005). The cross-country rankings of the PMR indicator appears substantially unchanged when using different specifications of the weighting scheme (Conway and Nicoletti 2006) and is in line with rankings derived from other indicators of market competition (Nicoletti and Pryor 2006).

To account for the influence of international factors on country's policies, we include a dummy equal to 1 as for the year when the Kyoto protocol was first ratified (in 1998). Previous studies show that the Kyoto dummy has a strong effect on investment in renewable capacity and technology diffusion (Popp et al. 2011, Johnstone et al. 2010). Interestingly, we show here that this effect is partially mediated by an inducement effect on REP at the national level. Energy prices (ENERGY) are also considered in the set of explanatory variables because REPs are usually charged to consumers in terms of higher prices (e.g. the case of feed-in tariff) or energy taxes are jointly decided with policies[20]. In contrast with basic theoretical predictions, ENERGY and PMR are not correlated in our sample, so the inclusion of both does not create problems of interpretation. The same lack of correlation can be observed between GINI and GDP_pc, probably because of the substantial homogeneity of the country sample. A further aspect of the energy market is captured by a dummy equal to 1 if the country had a substantial share of energy from DG before the liberalization process started (see table 10). Since renewable energy involves decentralized energy production, countries with a greater share of DG have not only a comparative advantage in developing renewable energy technology (Vona et al. 2012), but also DG producers are likely to push for more ambitious REC to further exploit this advantage. Finally, the share of green deputies in the parliament captures both people's preferences for environmental quality and a political voice for environmental issues, i.e. the green lobby[21]. Also corruption (CORR) is on the whole insignificant and so not included, but in some specifications. As will be clearer below, CORR represents a suitable instrument for PMR. Corruption data are taken from the transparency Index (transparency international, 1996)[22].

The resulting dataset is a fairly balanced dynamic panel of OECD countries for the period 1970 (but data on PMR are available from 1975) to 2005. Turkey and Mexico are excluded in main regressions as they are outliers in GDP_pc, while for the Slovak Republic and Czech Republic we have data on income only as from 1989. Korea is also excluded due to missing data on INEQ. Finally, note that missing values for PMR, GREEN and ENERGY are concentrated in particular in the middle-income and transition countries. Therefore, differences in results across specifications may be partially related to this bias in the data availability. In Table 11 of the appendix, data sources and basic descriptive for each variable are set out.

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20. The energy price variable has many missing values, particularly in Sweden, Belgium, Czech Republic and Slovak Republic. In the first two cases they were mainly internal values in the time series, which have been imputed as the average of the two adjacent years. For the other two countries this was not always the case and we preferred not to reconstruct the series before 1989 due to extensive lack of data.

21. Estimated coefficients associated with other political factors such as 'share of deputies in other countries', 'government composition', 'government instability' or 'government change' are unstable across indicators. The same holds for other factors affecting preferences for a cleaner environment such as the share of women in parliament (normally women are more pro-environment) and the share of over-65-year-olds in the population (normally older people are less environment-friendly). Finally, Fredriksson et al. (2007) uses the per capita number of green NGOs as proxy for green lobbies. Here this time-invariant variable does not capture any significant effect. Results are available upon request

22. As in Friedrikson and Vollebergh (2009), the existing data have been interpolated using the Hodrick-Prescott filter. Data for Corruption are only available as from year 1980 and we decided to not interpolate backward.

[TABLES 10-11 ABOUT HERE]
[FIGURES 5-6 ABOUT HERE]

Econometric Specification

We use standard panel data techniques to estimates the impact of our variables of interest on policy indicators. More precisely:

$$POLICY_{it} = \beta X_{it} + t_i + \mu_i + \varepsilon_{it},$$

where **Xs** are our covariates, t_i area specific time trends, μ_i country effects and ε_{it} is a purely random effect. As usual in cross-country panel data regressions, the critical choice is between Random (RE) and Fixed Effect (FE) model. The first is consistent but efficient only if country-specific effects are uncorrelated with the covariates, which is unlikely to occur when there are omitted variables. The FE model, instead, tends to wipe out all the cross-country variability, which is absorbed by country dummies; thereby efficiency is largely reduced. The Hausman test allows for discrimination between the two models. Specifically, if the null hypothesis is not rejected, the two models deliver similar results and the RE model is also consistent. In cross-country regressions, a standard way of solving the consistency-efficiency trade-off consists in including fixed effects for homogeneous geographical areas, e.g. the Scandinavian countries, in an RE model (e.g. Caselli and Coleman 2001). This is the route followed in this paper. However, it will be shown that both FE and RE estimates provide quite similar coefficients, suggesting that the trade-off is less severe in our case.

The relationship between the degree of entry barrier and environmental policies may be plagued by reverse causality and omitted variable bias. With regard to the former, a self-reinforcing mechanism can emerge because lowering entry barriers not only decreases the lobbying power of incumbents, but also strengthens new green players that will support more ambitious policies later on. Furthermore, technological improvements may represent an indirect source of endogeneity, as suggested by the seminal paper by Downing and White (1986). Omitted variable bias can be an issue here as we cannot account for all the factors that affect lobbying efforts such as coordination costs[23]. For instance, lobbies can keep affecting energy policy if existing incumbents remain strong after liberalization occurs. We hence use our time varying measure of corruption as an instrument for the degree of PMR. The idea that corruption dampers the process of liberalization is in line with the previous use of corruption as a proxy for the lobbies' capacity to affect environmental policy (e.g. Fredriksson and Svensson 2003). A highly positive correlation between PMR and CORR suggests that CORR is a good candidate to instrument PMR.

23. Unlike Fredriksson et al. (2004), we cannot use the sector size as a proxy for coordination costs that reduce the probability of forming a lobby. In fact, we cannot control for sources of sector-level variability.

Three caveats are in order to detail our empirical strategy further. First, lagged GDP_pc is included to reduce the possible unobservable correlation between the policy indicators and income. Secondly, we always compute cluster-robust standard errors to control for heteroskedasticity in the residuals. Third, standard tests for auto-correlation of the residuals do not reject the null hypothesis of absence of auto-correlation. We check the robustness of our results using the LSDV bias-correction procedure for dynamic panel developed in Nickell (1981), and Kiviet (1995, 1999). This estimator generally outperforms IV and GMM estimators in all these contexts, like the present one, in which N is small and T is long (Judson and Owen, 1999).

Results

In the following tables, we present the main results for each indicator. We focus mainly on the result on indicators built using principal component analysis. To highlight differences across indicators, we present slightly different specifications that enable us to stress those aspects which are more important for a given indicator. Another important caveat is that all the indicators are normalized to ease comparison of the estimated effects[24].

Table 12 presents the result for our favorite FACT_AV_FEED indicator. The baseline specification of model I shows that GDP_pc, INEQ and Kyoto[25] are all statistically significant with the expected signs, whereas GREEN is not significant but has the expected positive effect. The second specification also includes PMR which, as expected, negatively influences the policy. Between the RE model augmented with area dummies and the FE one, the difference is generally negligible, as is evident comparing model II (RE) and II (FE). In this case, even if the Hausman test usually rejects the null hypothesis that the RE model is also consistent, Wooldridge (2010) suggests focusing on the RE model. When energy prices and the dummy for DG are also included (model III), the results do not change except for GDP_pc, which turns out to be statistically insignificant. The effect of ENERGY is statistically significant, unlike that of the DG dummy. As shown in model IV, the dummy for DG has a significant effect only when combined in interaction with PMR[26]. In particular, the process of liberalization has a lower impact on the policy support in countries with initially more developed DG system. Model V and VI present our favorite specifications with the PMR indicator split in its three sub-indices. Of those sub-indices, only entry barriers significantly affect policy support. Unlike model III, the dummy for DG now has the expected positive impact on the policy. Moreover, the inclusion of area-specific time trend kills the effect of ENERGY, GDP_pc and, to a lesser extent, INEQ[27]. These

24. Clearly, we checked that this manipulation of the data does not affect our results.
25. Nothing changes in our results by using the exact time of ratification for each country rather than the Kyoto dummy.
26. We also checked the effect of other interaction terms (PMR with instability or PMR with corruption), but find no support for it. Results are available upon request.
27. Results available upon request show that the inclusion of corruption, share of tertiary graduates (the only one that is statistically significant with the expected sign), political instability (measured as five-year moving average

results are fully confirmed when using FACT_MIX_FEED (Table 13) and FACT_SP_FEED (available upon request). The only significant differences between Table 12 and 13 regard the magnitude of the effects: the estimated coefficient of INEQ almost halves with FACT_MIX_FEED but remains significant at cut-off 85%; the effect of GDP_pc is instead larger by around 1/4-1/3; on the other hand, that of PMR and of entry barrier is smaller than for FACT_AV_FEED.

Also for policy commitment indicator, COM_POL, the difference between the RE model augmented with area dummy and the FE model is negligible (see Model I (RE) and I (FE) in table 14), so we favor the RE model with area dummies. Concerning the estimated coefficients, the effect of GDP_pc tends to be substantially stronger than for previous indicators. Compared to FACT_AV_FEED, the impact of GDP_pc is 76% higher in model II and 66% higher in model V. The effect of the Kyoto dummy and the ENERGY prices also tends to be greater using COM_POL, but the differences are less substantial.

Four more notable differences emerge from Table 14 with respect to indicators built using principal component analysis. First, INEQ is not significant and does not even have the expected negative sign. Secondly, the effect of GREEN is statistically significant across most specifications. Third, the inclusion of energy price does not wipe out the effect of GDP_pc. Fourth, PMR has the expected sign, but the associated coefficient is not statistically significant. However, when looking at single components of the PMR index, this effect primarily masks a significantly negative effect of entry barriers counterbalanced by a significantly positive effect of vertical integrated utilities. These findings on PMR sub-indices remain robust to the inclusion of area trends, while the coefficients of GDP_pc and GREEN become insignificant. Finally, in model VI', additional socio-political variables all have the expected sign but only the share of graduates has a statistically significant effect.

Our explanatory variables have a remarkably smaller explanatory power in regressions with the indicator CONT_POL. This result depends on the fact that the policies included in CONT_POL–i.e. REC, average feed-in and R&D per capita—have been implemented quite recently in many countries. Besides, the policy intensity seems unrelated to the factors affecting the timing of adoption. The case of feed-in tariffs helps understand this missing relationship: countries adopting feed-in early generally decrease the level of guaranteed prices after an initial phase of technological and consumer learning[28]. Table 15 shows that the effects of GREEN and, especially, of GDP_pc are weak and often insignificant. In turn, INEQ, ENERGY and PMR continue to show the same impacts. As before, the effect of PMR is lower in countries with a well-established DG system and mainly driven by entry

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of government changes characterized by a significant ideological gap) and women's share in parliament does not contribute to our understanding of REP.

28. Even if our cross-country variability in the timing of adoption of continuous policies is limited, we have tried to estimate a Cox proportional hazard rate model to see more rigorously whether our main variables affect the time of adoption. In fact, the probability of the CONT_POL being adopted earlier increases in the initial level of GDP_pc and decreases in the level of Corruption. However, we prefer not to include this analysis as we believe that the very limited variability of our dependent variable reduces the reliability of these results.

barriers. These findings are robust to the inclusion of a simple time trend, but less so to the inclusion of area specific trends (available upon request). Finally, model I' shows that CORR is significant at 90% level in regressions without PMR.
[TABLES 12-15 ABOUT HERE]

Robustness

A first robustness exercise consists in addressing the possible endogeneity in the effect of PMR. We use Corruption as main exclusion restriction together with the share of members of parliament of right-wing parties and the share of highly educated people in the population. Both these factors should positively affect liberalization: 1. Right wing members of parliament usually promote market deregulation, 2. Highly educated workers benefit most from adoption of new technologies brought about by reductions in entry barriers. Table 16 presents results for the two main principal component-based indicators: FACT_AV_FEEDIN and FACT_MIX_FEED. The chosen instruments all have the expected sign (results available on request), a high explanatory power (the F-test for the first stage well-above the usual cut-off level of 10) and appear truly exogenous (see Hansen tests). The bias in the estimates is negligible for FACT_AV and the magnitude of the effect seems only slightly overestimated in RE regressions with area dummies. With regard to FACT_MIX_FEED, the estimation bias is now negative and slightly larger, amounting to roughly 15%. More in general, the most interesting result of this exercise is that the effect of corruption on policy intensity is fully mediated by its indirect effect on the PMR index. This result is particularly evident looking at the results of the just-identified GMM estimate (column 2 and 4 of Table 16).

The last four columns of Table 16 present the results of a dynamic panel model specification where the lagged dependent variable is included to address problems raised by autocorrelation in the residuals. The results for the INEQ and PMR remain robust for our favorite FACT_AV_FEEDIN indicator, even if the magnitude of the effects is substantially reduced, while GDP_pc turns out to be statistically insignificant. However, if we estimate the baseline RE model with area dummy model of Table 12 model II for years before 1985 (resp. 1980) only, the effect of GDP_pc increases from .043 to .114 (resp. 141). Since, as is well known, the results of dynamic panel models are highly sensitive to initial conditions on the dependent variables (Blundell and Bond 1998), it appears that income directly affects the initial adoption of REP and that its subsequent impact is fully captured by the positive feedback from the past to present policies. Similar results hold for FACT_MIX_FEED, but now Kyoto and GREEN are always statistically significant. With respect to principal component-based indicators, the dynamic specification affects less our results for COM_POL and CONT_POL. Interestingly, the effect of the GREEN lobby becomes much stronger both in the GMM and in the dynamic specification – a result deserving further investigation.

As final exercise, we check robustness for omission of group of countries. Since our panel data are slightly unbalanced and we cannot test the effect of PMR and GREEN for all countries, we check our results in a basic specification with only Kyoto, GDP_pc and INEQ also including Mexico and Turkey (Table 17). Then, while keeping Mexico and Turkey, we add PMR (Table 18). Table 17 shows that the Scandinavian countries and even more the USA drive the results for inequality. In turn, the effect of GDP_pc is slightly stronger when rich Anglo-Saxon and central European countries are excluded. Table 18 confirms the key role of the Scandinavian countries in accounting for the magnitude of the inequality coefficient, but this impact remains significant across specifications. The Scandinavian countries also inflate the size of the PMR coefficient, while Anglo-Saxon and Eastern European countries tend to squeeze it. As a general pattern, the effect of inequality tends to be slightly stronger when rich countries only are considered, while the opposite seems to occur for the effect of GDP_pc. This interpretation is more evident looking at Table 19, where we estimate the baseline RE model with area dummies with an interaction GDP_pc*INEQ. This finding on the reversal of the inequality effect depending on per capita income is in line with the theoretical and empirical findings of Vona and Patriarca (2011) for green technology, which could easily be translated into a political economy theoretical framework[29].

[TABLES 16-19 ABOUT HERE]

Conclusions

This paper proposes principal component analysis to aggregate heterogeneous policies targeted at promoting renewable energy. We compare the indicators built using this technique with simpler average-based indicators. In doing this, we implicitly test whether it is possible to identify a set of variables able to account for the evolution of both types of indicators. We draw inspiration from political economy models of environmental policies and adapt predictions of these models to the case of REP. Our main result is that three main variables common to all indicators can be identified: per capita income, Kyoto and entry barriers. The first reflects a classical preference effect, the second the role of international cooperation and the third the one of energy lobbies. Of the components of the PMR index, entry barrier fully captures the energy lobby's opposition against REP. Results remain robust when instrumenting market regulation and in more demanding dynamic panel specifications. Here, the estimated effects are generally mitigated but less so by taking into account the effect of our relevant variables on the initial level of the dependent variable (especially for GDP_pc). Finally, the effect of the green lobby increases substantially in the dynamic panel specification.

Another important result is that the second moment of the income distribution matters in capturing aggregate preferences for environmental quality, but only for indicators using both quantitative policy measures and policy signals. In line with previous research (Vona and Patriarca 2011), the effect of inequality appears stronger the richer the countries considered, while the opposite occurs for the effect

29. Vona and Patriarca (2011) show that, with a minimum of non-homotheticity in the preferences for environmental quality, the negative effect of inequality on the demand for the green good occurs only for high levels of income per capita.

of GDP_pc. In particular, lowering inequality increases public support for more ambitious REP when basic needs have been met. All together, these results suggest that a hybrid political-economy model of environmental policy, where both competition and lobbying power are important, offers the most accurate explanation of policy determinants. Recent theoretical developments go in this direction and consider more closely both aspects of the political process (e.g. Wilson and Damania 2003).

Except in a few cases, we do not observe the expected theoretical effect of corruption on policy. However, corruption keeps having an effect on policy that is fully mediated by its indirect effect on PMR. This result is important for future and on-going research, where we will analyze the effectiveness of our policy indicators on the diffusion and the development of renewable energy technologies. In particular, the influence that stronger green firms have on the renewable energy policy can be an important source of reverse causality affecting the relationship between policy and renewable energy innovation.

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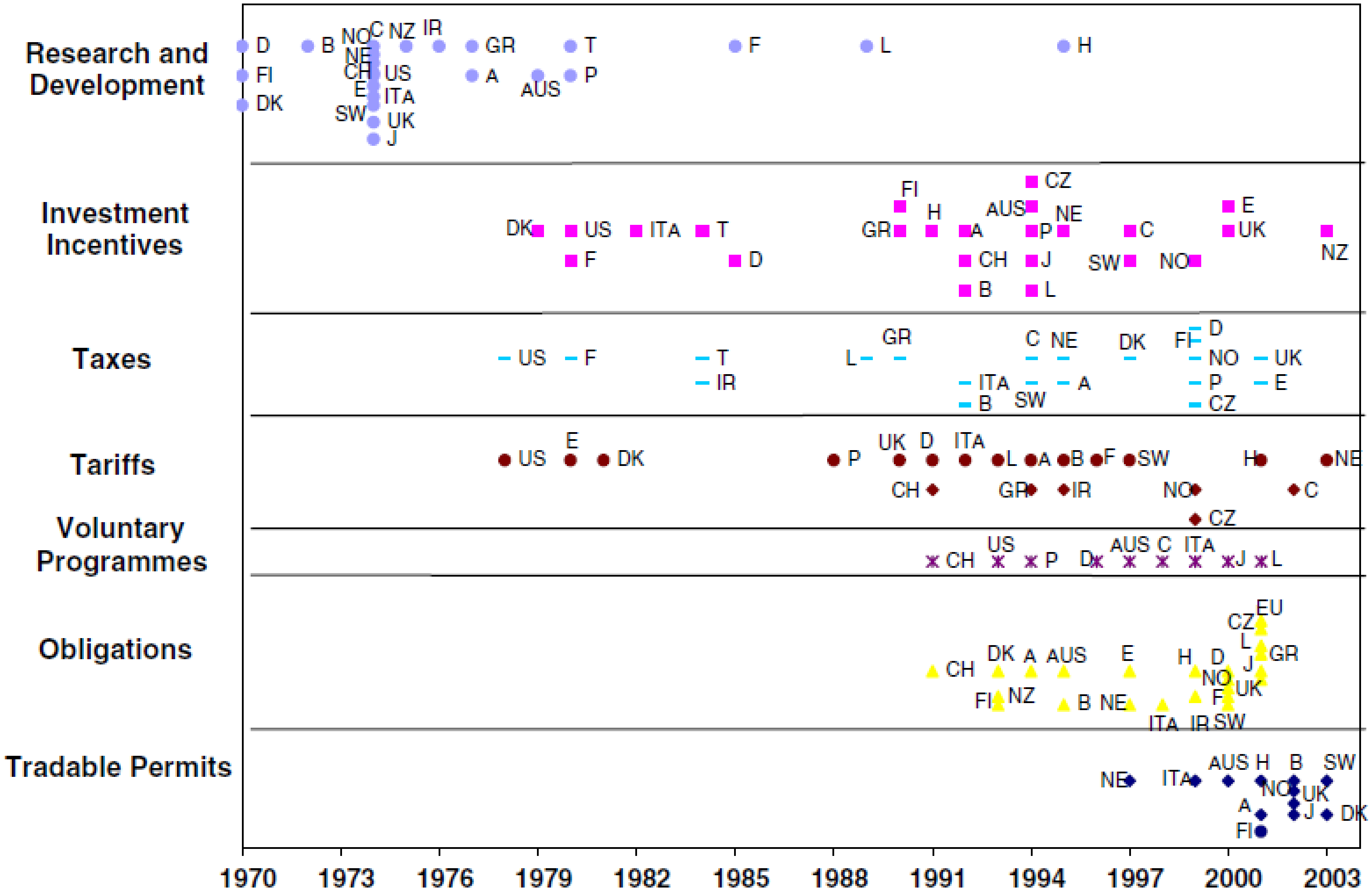
Figure 1. Patterns of policy adoption in selected OECD countries



Source: IEA (2004), as in Johnstone et. al. (2009). *AUS* Australia, *C* Canada, *FI*Finland, *GR* Greece, *ITA* Italy, *L* Luxembourg, *NO* Norway, *SW* Sweden, *UK* United Kingdom, *A* Austria, *CZ* Czech Rep., *F* France, *H* Hungary, *J* Japan, *NE* Netherlands, *P* Portugal, *CH* Switzerland, *US* United States,*B* Belgium, *DK* Denmark, *DE* Germany, *IR* Ireland, *NZ* New Zealand, *E* Spain, *T* Turkey

Table 1. Summary of the main Policies

Instrument	Brief explanation	Variable Construction	Source
Investment incentives	Capital Grants and all other measures aimed at reducing the capital cost of adopting renewable energy technologies. May also take the form of third party financial arrangements, where central governments assume part of the risk or provide low interest rate on loans. They are generally provided by State budgets.	Dummy Variable	International Energy Agency
Tax Measure	Economic instruments used either to encourage production or discourage consumption. They may have the form of investment tax credit or property tax exemptions, in order to reduce tax payments for project owner. An example is the US production Tax credit for wind (1992). Excises are not directly accounted here unless they were explicitly created to promote renewables (for example excise tax exemptions).	Dummy Variable	International Energy Agency
Incentive tariff	Price systems that guarantee above market tariff rates. In such cases, the Environmental authority generally sets a premium price to be paid for power generated from renewables.Some countries (UK, Ireland) developed a so called bidding system schemes in whichthe most cost effective offer is selected to receive a subsidy. This last specific case is also accounted in the dummy, due to its similarity to the feed-in systems.	Dummy Variable	International Energy Agency
Feed-in Tariff	Guaranteed price that may vary by technology. (Wind, Solar, Ocean, Geothermal, Biomass, Waste, Hydro).	Level of price guaranteed (USD, 2006 prices and PPP) (Dummy Variable also available)	International Energy Agency Cerveny and Resch (1998) Country specific sources
Voluntary program	These programs generally operate through agreement between government, public utilities and energy suppliers, that agree to buy energy generated from renewable sources. One of the first voluntary program was in Denmark in 1984, when utilities agreed to buy 100MW of wind power.	Dummy Variable	International Energy Agency
Obligations	Obligation and targetstake generally the form of quota systems that place an obligation on producers to provide a share of their energy supply from renewable energy. These quota are not necessarily covered by a tradable certificate.	Dummy Variable	International Energy Agency
Tradable Certificate	Renewable energy Certificates (REC) are used to track or document compliance with quota system and can generally be traded in specific markets. As a result, at national level part of the total electricity produced generally must either be generated by renewables or covered with a renewable energy certificate.	Share of electricity that must be generated by renewables or coveredwith a REC. Dummy Variable also available.	Data made available by Nick Johnstone, OECD Environment Directorate
Public Research and Development	Public financed R&D program disaggregated by type of renewable energy	public sector per capita expenditures on energy R&D (USD, 2006 prices and PPP). (Dummy Variable also available)	International Energy Agency
EU directive *2001*/77/EC	Established the first shared framework for the promotion of electricity from renewable sources at European level.	Dummy Variable	European Commission

Table 2. First Principal Component Analysis results

FACT_AV_FEED	Variables included	Eigenvalue	Share of variance Explained
First	Average Feed-in tariff(Value) Tax Measure (Dummy) Investment incentive (Dummy) Voluntary program (Dummy) Incentive tariff (Dummy)	3.633	0.403
Second	Obligation (Dummy) EU Directive 2001 (Dummy) REC target (Value)	1.159	0.128
Third	Public R&D (Value)	1.0209	0.113

Table 3. Second Principal ComponentAnalysis results

FACT_SP_FEED	Variables included	Eigenvalue	Share of variance Explained
First	Feed-in tariff wind(Value) Feed-in tariff solar(Value) Feed-in tariffbiomass(Value) Feed-in tariff waste(Value) Incentive tariff (Dummy)	4.796	0.399
Second	Tax Measure (Dummy) Investment incentive (Dummy) Voluntary program (Dummy) Obligation (Dummy)	1.7023	0.141
Third	EU Directive 2001 (Dummy) Obligation (Dummy) REC target (Value)	1.191	0.099
Fourth	Public R&D (Value)	1.008	0.084

Table 4. Third Principal ComponentAnalysis results

FACT_MIX	Variables included	Eigenvalue	Share of variance Explained
First	Feed-in tariff wind (Dummy) Feed-in tariff solar (Dummy) Feed-in tariffbiomass (Dummy) Feed-in tariff waste (Dummy) Average Feed-in tariff (Value) Incentive tariff (Dummy)	6.3606	0.424
Second	EU Directive 2001 (Dummy) Obligation (Dummy) REC target (Value)	2.127	0.141
Third	Tax Measure (Dummy) Investment incentive (Dummy) Voluntary program (Dummy)	1.347	0.089
Fourth	Public R&D (Value) Public R&D (Dummy)	1.124	0.075

Table 5. Correlations among the policy Indicators based on Factors in selected countries

	FACT_AV_FEED	FACT_SP_FEED	FACT_MIX
FACT_AV_FEED	1.0000		
FACT_SP_FEED	0.9639*	1.0000	
FACT_MIX	0.9350*	0.9545*	1.0000

Figure 2. FACT_AV_FEED

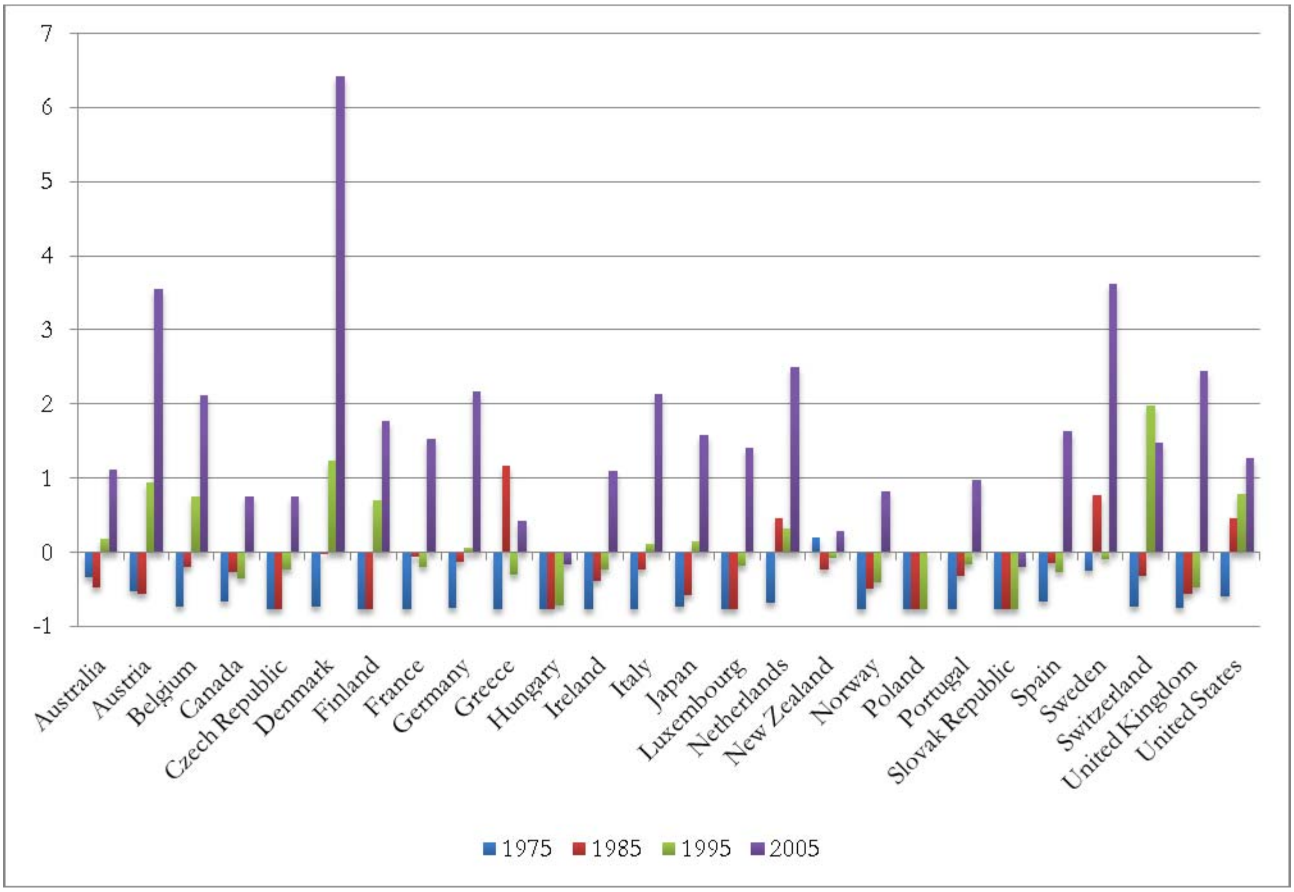


Figure 3. COM_POL

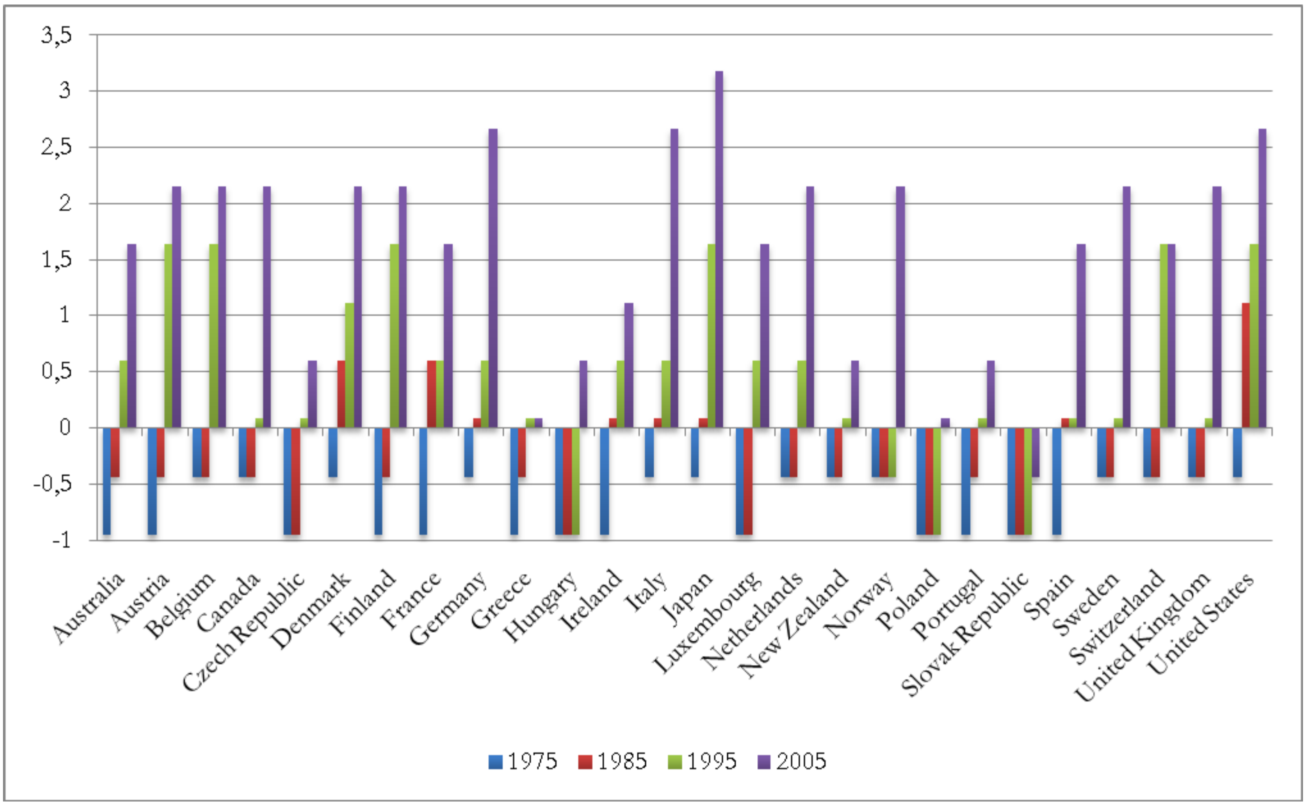


Figure 4. CONT_POL

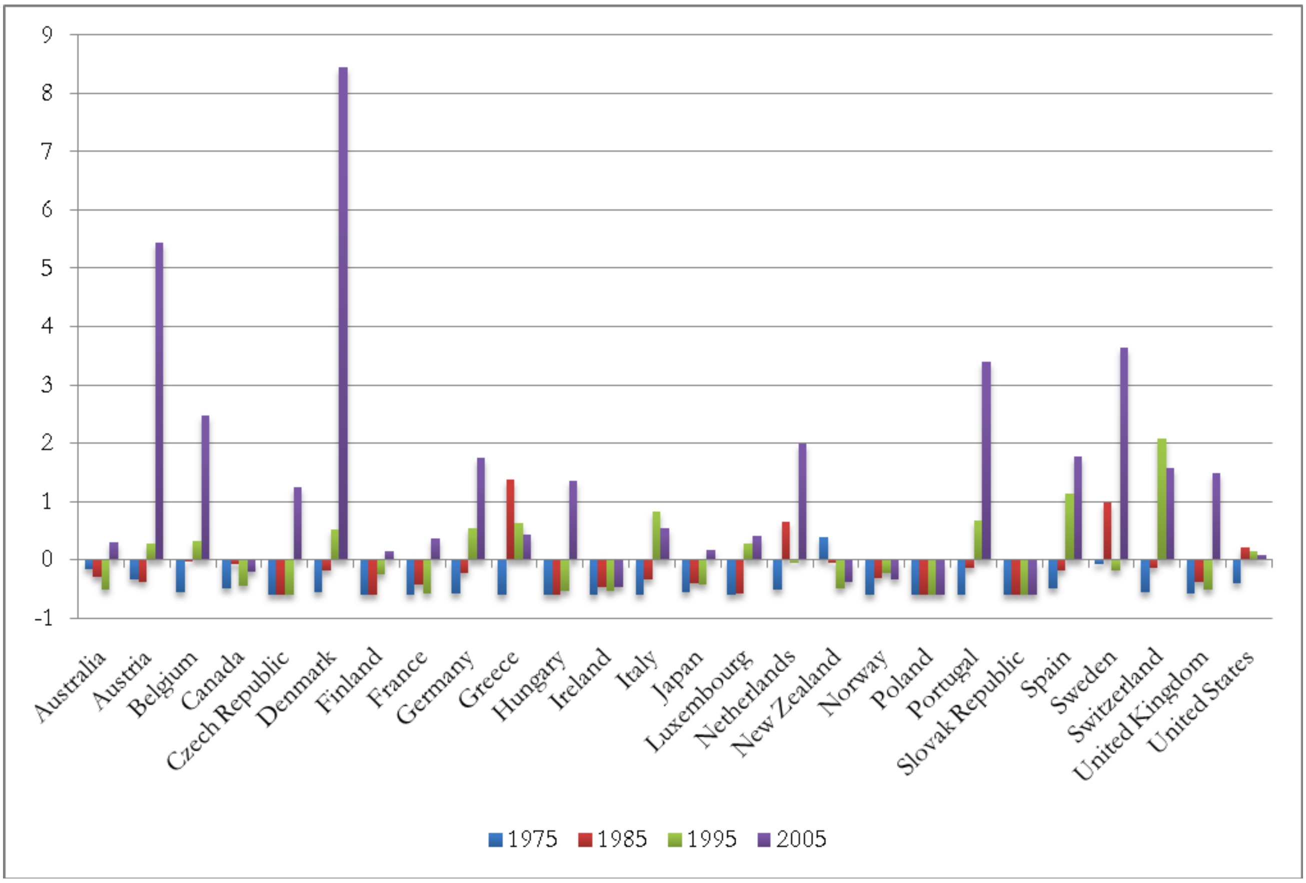


Table 6. Country ranking according to the different indicator. Year 2005

Ranking	FACT_AV_FEEDIN		COM_POL		COUNT_POL	
1	Denmark	6.427	Japan	3.185	Denmark	8.448
2	Sweden	3.636	Germany	2.668	Austria	5.436
3	Austria	3.551	United States	2.668	Sweden	3.634
4	Netherlands	2.507	Italy	2.668	Portugal	3.402
5	United Kingdom	2.447	Austria	2.150	Belgium	2.465
6	Germany	2.179	Belgium	2.150	Netherlands	1.999
7	Italy	2.150	Canada	2.150	Spain	1.774
8	Belgium	2.125	Denmark	2.150	Germany	1.745
9	Finland	1.775	Finland	2.150	Switzerland	1.571
10	Spain	1.640	Netherlands	2.150	United Kingdom	1.485
11	Japan	1.590	Norway	2.150	Hungary	1.359
12	France	1.538	Sweden	2.150	Czech Republic	1.250
13	Switzerland	1.486	United Kingdom	2.150	Italy	0.550
14	Luxembourg	1.409	Australia	1.633	Greece	0.437
15	United States	1.274	France	1.633	Luxembourg	0.418
16	Australia	1.120	Luxembourg	1.633	France	0.364
17	Ireland	1.113	Spain	1.633	Australia	0.311
18	Portugal	0.990	Switzerland	1.633	Japan	0.166
19	Norway	0.827	Ireland	1.116	Finland	0.138
20	Czech Republic	0.757	Czech Republic	0.598	United States	0.083
21	Canada	0.751	Hungary	0.598	Canada	-0.214
22	Greece	0.425	New Zealand	0.598	Norway	-0.341
23	New Zealand	0.300	Portugal	0.598	New Zealand	-0.389
24	Poland	0.022	Greece	0.081	Ireland	-0.463
25	Hungary	-0.152	Poland	0.081	Slovak Republic	-0.600
26	Slovak Republic	-0.193	Slovak Republic	-0.436	Poland	-0.600

Table 7. Correlations among the policy Indicators based on Factors in selected countries. Years 1970-2005

	FACT_AV_FEED	COM_POL	CONT_POL
FACT_AV_FEED	1.0000		
COM_POL	0.7722*	1.0000	
CONT_POL	0.8584*	0.4938*	1.0000

Table 8. Correlations among the policy Indicators based on Factors in selected countries. Year 1990

	FACT_AV_FEED	COM_POL	CONT_POL
FACT_AV_FEED	1.0000		
COM_POL	0.7500*	1.0000	
CONT_POL	0.7230*	0.3236	1.0000

Table 9. Correlations among the policy Indicators based on Factors in selected countries. Year 2005

	FACT_AV_FEED	COM_POL	CONT_POL
FACT_AV_FEED	1.0000		
COM_POL	0.5762*	1.0000	
CONT_POL	0.8492*	0.2339	1.0000

Figure 5. Trend of PMR for selected countries

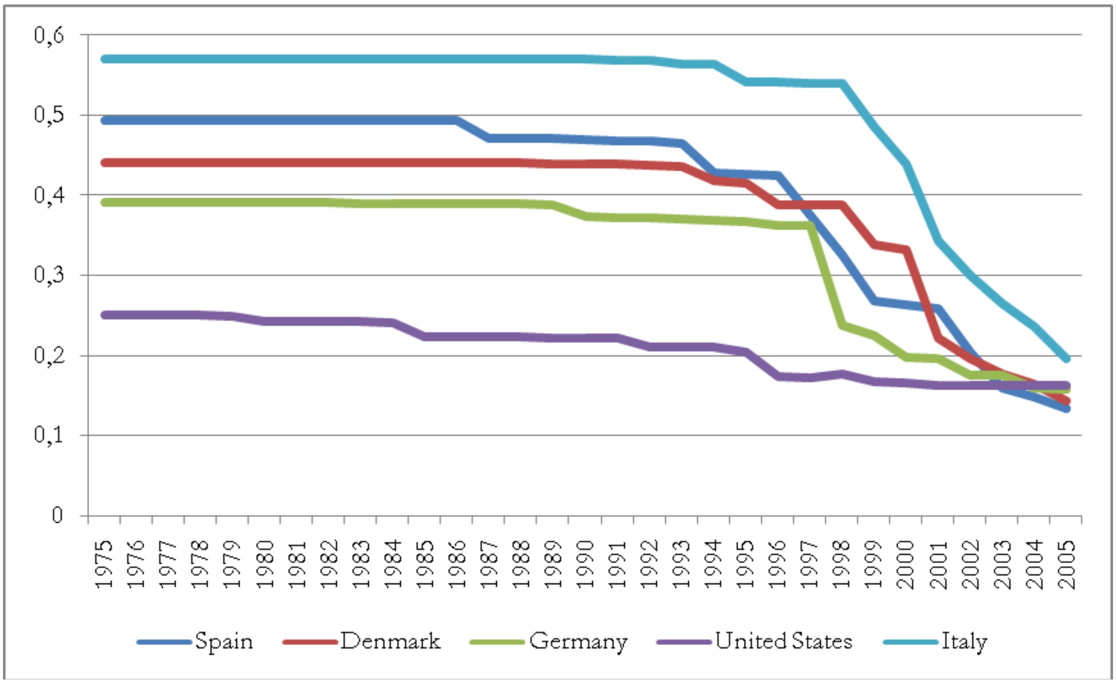


Figure 6. Trend of PMR for selected countries

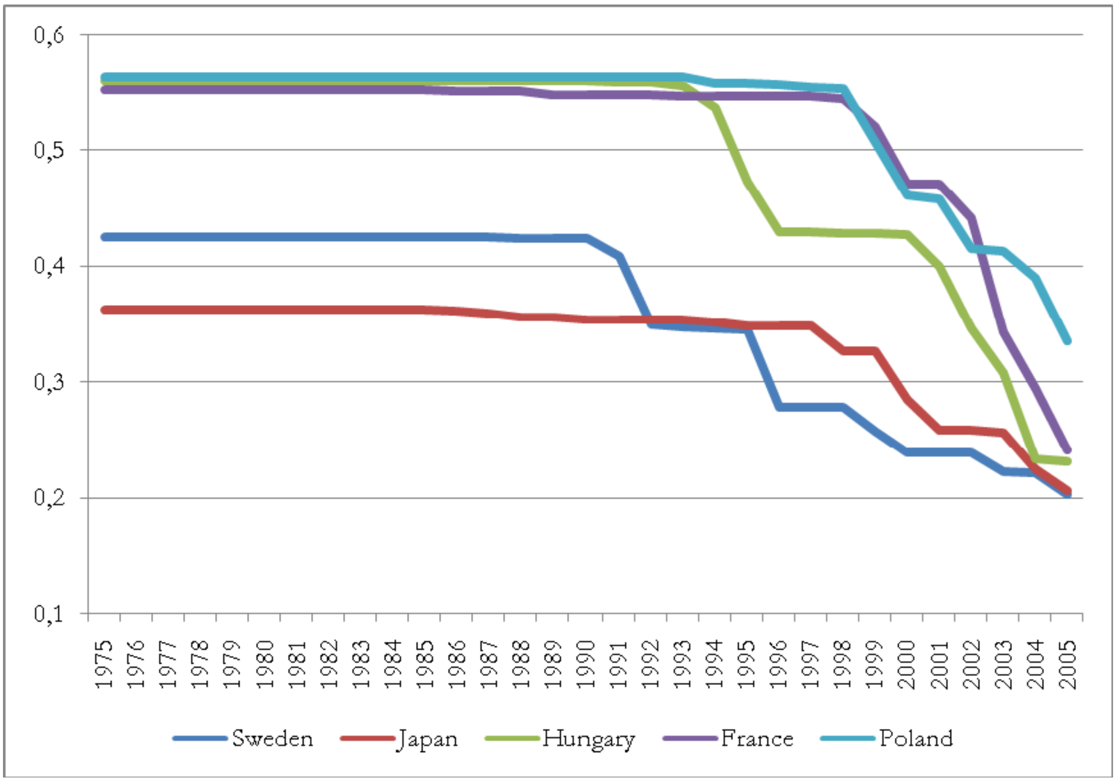


Table 10. Energy Markets before liberalization

Country	Share of DG before liberalization	Non monopoly system before liberalization
Australia	0	0
Austria	1	1
Belgium	0	1
Canada	0	0
Czech Republic	1/2	1
Denmark	2	1
Finland	0	1
France	0	0
Germany	2	1
Greece	0	0
Hungary	0	1
Ireland	0	0
Italy	0	0
Japan	0/1	0
Luxembourg	0	1
Mexico	0	0
Netherlands	2	1
New Zealand	1	1
Norway	0	1
Poland	1	1
Portugal	1	0
Slovak Republic	0	1
Spain	1	0
Sweden	2	1
Switzerland	0	1
Turkey	0	1
United Kingdom	0	0
UnitedStates	0	0

DG=Distributed generation, 2 is high share, 0 low
Monopoly before liberal.: 0 no, 1 yes, shadow: difficult to classify
Sources: IEA country reviews, IEA 'Lesson from lib. Mkt.'

Table 11. Descriptive statistics and Sources

Acronim	Description	Obs.	Mean	St. Dev.	Min	Max	Source
FACT_AV_FEEDIN	Policy index based on factor analysis (Standardized)	936	0	1	-0.769	6.427	
FACT_SP_FEEDIN	Policy index based on factor analysis (Standardized)	936	0	1	-0.778	5.367	
FACT_MIX	Policy index based on factor analysis (Standardized)	936	0	1	-1.044	4.267	
COM_POL	Policy index based on dummy variables (Standardized)	936	0	1	-0.953	3.184	
CONT_POL	Policy index based on continuous variables (Standardized)	936	0	1	-0.600	8.448	
GDP	GDP per capita, thousands US 1990 Dollars, ppp. (Missing data for Czech and Slovak republic before 1990)	899	23.272	8.971	6.045	71.16	OECD
Gini coeff.	Gini Coefficient	889	27.571	4.377	15.061	38.72	Standardized World Income Inequality Database (SWIID)
Kyoto Dummy	Dummy variable that takes on a value of 0 prior to the approval of the Kyoto protocol and 1 thereafter	936	0.25	0.433	0		
Green	share of green deputies in the parliament	792	1.311	2.623	0	13.33	World bank
PMR Electr. (Std)	Product Market regulation in the energy sector (Standardized in the analysis)	775	0.4709	0.178	0.074	1	OECD
Energy Prices	Energy end use price, USDppp/unit (Households)	753	0.1085	0.046	0.0190	0.256	International Energy agency
DG before Liberalization	Share of distributed generation before liberalization	936	0.576	0.756	0	2	International Energy agency
PMR Entry	Product Market regulation in the energy sector sub-index: entry barriers	798	4.685	2.182	0	6	OECD
PRM Public Ownership	Product Market regulation in the energy sector sub-index: Public ownership	806	4.464	1.821	0	6	OECD
PMR Vertical Integration	Product Market regulation in the energy sector sub-index: Vertical integration	806	4.719	1.940	0	6	OECD
Corruption	Corruption index that ranges from 0 (highly corrupt) to 10 (highly clean). (Available from 1980)	676	7.235	1.831	1.497	9.959	World Resource Institute dataset
Higher Education	log of % of population aged 15 or over with complete higher education	936	0.1160	0.081	0	0.331	Cohen and Soto dataset
Political instability	Political instability index	721	-0.001	0.455	-3	3	Comparative Political Data Set I
Woman participation	share of female deputies in the parliament	776	14.854	11.16	0	45.3	Comparative Political Data Set I

Table12. Dependent variable: FACT_AV_FEEDIN

Specification	I	II (RE)	II (FE)	III (RE)	III (FE)	IV	V	VI	VI’
one year lag GDP	0.0461**	0.0451**	0.0463**	0.0292	0.0196	0.0332*	0.0301**	0.0198*	0.0226
	(0.0194)	(0.0209)	(0.0208)	(0.0216)	(0.0231)	(0.0187)	(0.0157)	(0.0120)	(0.0235)
Ginicoeff.	-0.0458*	-0.0844**	-0.1142***	-0.0799**	-0.1111***	-0.0822***	-0.0703**	-0.0699**	-0.0436**
	(0.0263)	(0.0344)	(0.0373)	(0.0325)	(0.0344)	(0.0273)	(0.0309)	(0.0287)	(0.0199)
Kyoto Dummy	0.9771***	0.6058***	0.5069**	0.6097***	0.5639***	0.4219**	0.5289***	0.5216***	0.5890***
	(0.2074)	(0.1723)	(0.1902)	(0.1593)	(0.1755)	(0.1831)	(0.1996)	(0.1884)	(0.1378)
Green	0.0349	0.0471	0.0449	0.0358	0.0374	0.0282	0.0402	0.0304	-0.0378
	(0.0369)	(0.0377)	(0.0380)	(0.0390)	(0.0399)	(0.0386)	(0.0378)	(0.0383)	(0.0333)
PMR Electr. (Std)		-0.4768***	-0.6429***	-0.4340***	-0.6218***	-0.1955*			
		(0.1670)	(0.2126)	(0.1629)	(0.1960)	(0.1201)			
Energy Prices				5.2821*	5.6067*	4.117**		5.3322**	6.0683
				(2.8469)	(2.983)	(1.950)		(2.3563)	(3.9402)
DG beforeLiberalization				0.1416		-0.2083	0.2971**	0.2081	0.1836
				(0.1783)		(0.2545)	(0.1325)	(0.1422)	(0.1374)
Kyoto*PMR						-0.2955**			
						(0.1467)			
DG bef Lib*PMR						0.2795*			
						(0.1533)			
PMR Entry							-0.1510***	-0.149***	-0.1395***
							(0.0536)	(0.0534)	(0.0534)
PRM Public Ownership							-0.0009	0.0008	-0.0003
							(0.0549)	(0.0591)	(0.0481)
PMR Vertical Integration							-0.0076	0.0119	-0.0424
							(0.0784)	(0.0773)	(0.0743)
Country FE	No	No	Yes	No	Yes	No	No	No	No
Area FE	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Area Trend	No	No	No	No	No	No	No	No	Yes
Observation	726	634	634	617	617	617	660	643	643
Hausman test			26.62 (0.000)		28.20(0.000)				

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.

Table 13. Dependent variable: FACT_MIX

Specification	I	I'	II (RE)	II (FE)	III	IV	V	VI	VI'
one year lag GDP	0.0690***	0.0553***	0.0510**	0.0548**	0.0336	0.0381**	0.0395***	0.0286**	0.0200
	(0.0167)	(0.0138)	(0.0235)	(0.0253)	(0.0233)	(0.0381)	(0.0152)	(0.0135)	(0.0152)
Ginicoeff.	-0.0257*	-0.0142	-0.0449*	-0.0670**	-0.0394*	-0.0381*	-0.0337*	-0.0339*	-0.0124
	(0.0156)	(0.0211)	(0.0272)	(0.0304)	(0.0240)	(0.0210)	(0.0199)	(0.0202)	(0.015)
Kyoto Dummy	0.8463***	0.8408***	0.6759***	0.5899***	0.6746***	0.5697***	0.6312***	0.6149***	0.4949***
	(0.1435)	(0.1217)	(0.1235)	(0.1390)	(0.110)	(0.1148)	(0.1520)	(0.1377)	(0.1334)
green			0.0473	0.0445	0.0340	0.0254	0.0451	0.0338	-0.0361
			(0.0309)	(0.0310)	(0.0312)	(0.0285)	(0.0311)	(0.0313)	(0.0240)
PMR Electr. (Std)			-0.32468**	-0.4380**	-0.2703**	-0.1124			
			(0.1301)	(0.1659)	(0.1286)	(0.1099)			
Energy Prices					6.2667***	5.365***		6.2837***	4.4830*
					(1.618)	(1.361)		(1.265)	(2.5393)
DG beforeLiberalization					0.1189	-0.1530	0.3052***	0.2007*	0.1823**
					(0.1208)	(0.1587)	(0.1127)	(0.1149)	(0.0949)
Kyoto*PMR						-0.1328			
						(0.1174)			
DG bef Lib*PMR						0.2236**			
						(0.0919)			
PMR Entry							-0.0931**	-0.0913**	-0.1022***
							(0.0466)	(0.0456)	(0.0372)
PRM Public Ownership							0.0003	0.0038	0.0149
							(0.0452)	(0.0484)	(0.0435)
PMR Vertical Integration							-0.0170	0.0059	-0.0202
							(0.0572)	(0.0572)	(0.0477)
Corruption		0.0737*							
		(0.0409)							
Country FE	No	No	No	Yes	No	No	No	No	No
Area FE	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Area Trend	No	No	No	No	No	No	No	No	Yes
Observation	829	656	634	634	617	617	660	643	643
Hausman test				27.63 (0.000)					

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.

Table 14. Dependent variable: COM_POL

Specification	I (RE)	(FE)	II	III	IV	V	VI	VI’
one year lag GDP	0.0715***	0.0761***	0.0819***	0.0633***	0.0506***	0.03397**	-0.0006	0.0289**
	(0.0213)	(0.0210)	(0.021)	(0.0207)	(0.0186)	(0.0148)	(0.0104)	(0.0113)
Ginicoeff.	0.0196	0.0164	0.0181	0.0199	0.0238	0.0264	0.0107	0.0239
	(0.0201)	(0.0201)	(0.027)	(0.0279)	(0.0257)	(0.0267)	(0.0178)	(0.0302)
Kyoto Dummy	0.9196***	0.8896***	0.7587***	0.7553***	0.7677***	0.7735***	0.5191***	0.6541***
	(0.1678)	(0.1649)	(0.135)	(0.1272)	(0.1544)	(0.1320)	(0.1567)	(0.1396)
Green	0.0379	0.0345	0.0501**	0.0429*	0.0533**	0.0436**	0.0009	0.0300
	(0.0245)	(0.0243)	(0.024)	(0.0232)	(0.0219)	(0.0209)	(0.0195)	(0.0207)
PMR Electr. (Std)			-0.0730	-0.0565				
			(0.094)	(0.0858)				
Energy Prices				5.6178***		7.5481***	0.8310	5.6569**
				(1.3486)		(1.397)	(2.314)	(2.411)
DG before Liberalization				0.0410	0.2282**	0.0868	0.0535	0.0101
				(0.0821)	(0.1033)	(0.0976)	(0.0896)	(0.1043)
PMR Entry					-0.1036**	-0.1010**	-0.0806**	-0.0813**
					(0.0491)	(0.0460)	(0.0351)	(0.0425)
PRM Public Ownership					-0.0242	-0.0304	-0.0404	-0.0286
					(0.0455)	(0.0440)	(0.0333)	(0.0497)
PMR Vertical Integration					0.0641	0.0927*	0.0761*	0.0992**
					(0.0519)	(0.0491)	(0.0388)	(0.0506)
Corruption								0.0110
								(0.0778)
Higher Education								5.036**
								(1.9502)
Political instability								-0.0336
								(0.0956)
Woman partecipation								0.0215
								(0.0145)
Country FE	No	Yes	No	No	No	No	No	No
Area FE	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Area Trend	No	No	No	No	No	No	Yes	No
Observation	726	726	634	617	660	643	643	571
Hausman test		13.81(0.000)						

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.

Table 15. Dependent variable: CONT_POL

Specification	I (RE)	I (FE)	I’	II	III	IV	V	VI
one year lag GDP	0.0208	0.0293	0.0221	0.0015	-0.0333	-0.0027	0.0002	0.0058
	(0.0166)	(0.0182)	(0.0206)	(0.0268)	(0.0310)	(0.0271)	(0.0225)	0.0288
Ginicoeff.	-0.0523*	-0.0717*	-0.0606	-0.1314**	-0.1275**	-0.1097*	-0.1093**	-0.0905**
	(0.0312)	(0.0371)	(0.0459)	(0.0528)	(0.048)	(0.0439)	(0.0501)	0.0450
Kyoto Dummy	0.7076***	0.6699***	0.61065***	0.2922*	0.3673**	0.1770	0.3494**	0.5442***
	(0.2185)	(0.2074)	(0.1705)	(0.1638)	(0.1633)	(0.1665)	(0.157)	0.136
Green	0.0336	0.0300	0.0369	0.0384	0.0283	-0.0055	0.0435	0.0455
	(0.0464)	(0.0473)	(0.0561)	(0.0498)	(0.0549)	(0.0519)	(0.0518)	0.0559
PMR Electr. (Std)				-0.7665**	-0.7376**	-0.3917**		
				(0.3649)	(0.3572)	(0.1727)		
Energy Prices					7.4434*	3.3101		10.927**
					(4.2108)	(3.4392)		5.218
DG before Liberalization								
DG bef Lib*PMR						0.6624*		
						(0.2903)		
PMR Entry							-0.071	-0.075*
							(0.051)	0.040
PRM Public Ownership							0.0560	0.0432
							(0.1217)	0.1233
PMR Vertical Integration							-0.1378	-0.1251
							(0.1297)	0.1251
Corruption			0.2428*					
			(0.125)					
Time Trend								-0.0419
								0.0260
Country FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area FE	Yes	No	No	No	No	No	No	No
Observation	726	726	725	633	617	617	660	643
Hausman test		18.93(0.000)						

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.

Table 16. Robustness

Specification	I	II	III	IV	V	VI	VI	VIII	IX	X
one year lag GDP	0.0338**	0.0346**	0.0341*	0.0402***	0.0413***	0.0448*	0.0032	0.0030	0.0082**	-0.0047
	(0.0167)	(0.0173)	(0.0205)	0.0139	(0.014)	(0.0267)	(0.0068)	(0.0049)	(0.0043)	0.0079
Ginicoeff.	-0.1062***	-0.1021***	-0.1026**	-0.0594***	-0.0583***	-0.0538*	-0.0188**	-0.0063	0.0079	-0.0220*
	(0.0231)	(0.0235)	(0.0422)	0.0161	(0.0168)	(0.0325)	(0.0095)	(0.0071)	(0.0051)	0.0127
Kyoto Dummy	0.4912***	0.5185***	0.5153**	0.5532***	0.5598***	0.5843***	0.1704**	0.1448***	0.0888**	0.1010
	(0.116)	(0.1241)	(0.1919)	0.0963	(0.1003)	(0.1387)	(0.0678)	(0.0464)	(0.0346)	0.0811
Green	0.0543***	0.0464***	0.0464	0.0475***	0.0443***	0.0441	0.0126	0.0131*	0.0161**	0.0096
	(0.0166)	(0.0179)	(0.0429)	0.0153	(0.0157)	(0.0348)	(0.0106)	(0.0073)	(0.0054)	0.0130
PMR Electr. (Std)	-0.6839***	-0.6901***	-0.6989***	-0.5700***	-0.5473***	-0.4801**	-0.1099**	-0.0431	0.0349	-0.1404**
	(0.2329)	(0.2548)	(0.2368)	0.167	(0.180)	(0.1809)	(0.0557)	(0.0400)	(0.0284)	0.0705
Lag Dependent Variable							0.8765***	0.9034***	0.9363***	0.9247***
							(0.0309)	(0.0278)	(0.0263)	0.02917
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	545	545	545	545	545	545	613	613	613	613
F First step	36.89(3,517)	95.30 (1,519)		36.89(3,517)	95.30 (1,519)					
Hansen test	0.2162	0.000		0.1792	95.30					
Dependent Variable	FACT_AV_ FEEDIN	FACT_AV_ FEEDIN	FACT_AV_ FEEDIN	FACT_MIX	FACT_MIX	FACT_MIX	FACT_AV_ FEEDIN	FACT_MIX	COM_POL	CONT_POL
Instruments	Corruption, Right Party, high Educ	Corruption	RE with area dummy estimation	Corruption, Right Party, high Educ	Corruption	RE with area dummy estimation				

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.
In column VI-X we used the stata routine xtlsdvc implemented by Bruno (2005), initializing the bias correction using standard one-step Arellano-Bond (1991) estimator with no intercept, and following Kiviet (1999), we forced a bias approximation up to N−1T−2.

Table 17. Dependent variable: FACT_AV_FEEDIN

	oneyearlag GDP	Ginicoeff.	Kyoto
AllCountries	0.0597***	-0.0336*	0.7981***
No Scandinavian	0.0568***	-0.0140	0.6867***
No Anglo	0.0626***	-0.0261	0.8718***
No Cent EU	0.0724***	-0.0364*	0.5753***
No Medierranean	0.0569***	-0.0347	0.8393***
No East	0.0562***	-0.0338	0.8839***
No Poor	0.0553***	-0.0461**	0.9224***
No Denmark	0.0553***	-0.0201	0.7394***
No Austria	0.0593***	-0.0360**	0.7545***
No Hungary	0.0589***	-0.0347*	0.8224***
No UnitedStates	0.0594***	-0.0288	0.8191***
Country FE	No	No	No
Area FE	Yes	Yes	Yes

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.

Table 18. Dependent variable: FACT_AV_FEEDIN

	oneyearlag GDP	Ginicoeff.	Kyoto	PMR Electr. (Std)
AllCountries	0.0548***	-0.0609***	0.6012***	-0.4019***
No Scandinavian	0.0649***	-0.0292**	0.5404***	-0.2217**
No Anglo	0.0759**	-0.0471***	0.4802***	-0.5381***
No Cent EU	0.0366**	-0.0610**	0.5451***	-0.4189***
No Medierranean	0.0545***	-0.0677***	0.7020***	-0.3734***
No East	0.0485***	-0.0883***	0.6905***	-0.4889***
No Poor	0.0575***	-0.0792***	0.5900***	-0.4224***
No Denmark	0.0511***	-0.0461***	0.5958***	-0.3277***
No Austria	0.0540***	-0.0620***	0.5906***	-0.3615***
No Hungary	0.0520***	-0.0683***	0.6234***	-0.4383***
No UnitedStates	0.0520***	-0.0683***	0.6234***	-0.4383***
Country FE	No	No	No	No
Area FE	Yes	Yes	Yes	Yes

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.

Table 19. Robustness: interactions Gini*GDP

Specification	I	II	III	IV
one year lag GDP	0.1851**	0.1643**	0.2211**	0.1100*
	(0.0905)	(0.0867)	(0.1065)	0.0614
Ginicoeff.	0.0385	0.0549	0.1001	0.0400
	(0.0659)	(0.0688)	(0.0814)	0.0609
Kyoto Dummy	0.6598***	0.7205***	0.4889***	0.7592***
	(0.1594)	(0.1145)	(0.1339)	0.1320
Green	0.0328	0.0358	0.0154	0.0595**
	(0.0388)	(0.0334)	(0.0507)	0.0292
PMR Electr. (Std)	-0.4767***	-0.3223***	-0.5375**	-0.0658
	(0.1569)	(0.1242)	(0.2728)	0.0911
Gini*GDP	-0.0048**	-0.0039*	-0.0075**	-0.0009
	(0.0023)	(0.0023)	(0.0032)	0.0019
Country FE	No	No	No	No
Area FE	Yes	Yes	Yes	Yes
Observation	634	634	634	634
Dependentvariable	FACT_AV_FEEDIN	FACT_MIX	COM_POL	CONT_POL

Cluster Robust standard error, cluster unit country. *,**,*** indicate significance at respectively 10%, 5% and 1% level.