Effectiveness energy covenants: International evidence

Elbert Dijkgraaf (Erasmus School of Economics and SEOR)

Matthijs de Jong (Erasmus School of Economics and SEOR)

Marcel Spijkerman (Erasmus School of Economics and SEOR)

Olivier Tanis (Erasmus School of Economics and SEOR)

Herman Vollebergh (Netherlands Environmental Assessment Agency and Department of Economics, University of Tilburg)

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Abstract

This study evaluates the effectiveness of covenants using a panel of both national and sectoral data from 24 OECD countries between 1978 and 2006. We exploit a uniquely constructed inventory of covenants as well as other instruments like taxes, subsidies and standards to explain changes in respectively energy efficiency, carbon dioxide emissions and the use of renewable energy. Our results show that there is very little statistical evidence for the effectiveness of covenants, even if they contain clear goals and explicit sanctions. In contrast, energy taxes and, to a lesser extent, subsidies and standards, are much more important.

Contact
Prof.dr. Elbert Dijkgraaf
Eramus University Rotterdam
H 8-21
P.O. Box 1738
3000 DR Rotterdam
The Netherlands
Email: dijkgraaf@ese.eur.nl
Tel: 31 10 4082859
Web: http://people.few.eur.nl/dijkgraaf/

1. Introduction

In recent years governments in OECD countries have increasingly included covenants in their policy mix to stimulate energy efficiency, carbon reduction and the use of renewable energy. A covenant is a type of contract in which the covenantor makes a promise to a covenantee to do or not do some action. A typical example in this context is a firm or even sector that promises to the government to reduce its energy use within a given time slot or to generate a given amount of electricity in 5 years. Contrary to standards or taxes, covenants belong to what is called soft law because the agreement essentially is voluntary and enforcement is weak or even absent. Making such promises is not necessarily without bite, however. Much seems to depend on the design of a voluntary agreement (VA). Segerson and Miceli (1998), for instance, show with a theoretical model that covenants can be effective if the regulator uses (credible) threats like the implementation of standards or taxes if the promise is broken. In contrast Glachant (2007) proves that even if a credible threat is possible, regulation through standards or taxes is still more effective. Only if no credible threat is possible due to effective lobbying behaviour covenants might be useful in the policy mix. Lyon and Maxwell (2003) obtain a similar conclusion but also stress that covenants initiated by an industry itself is usually more effective because of the government has more negotiation power in that case.

The empirical literature so far is mainly restricted to U.S. micropanels (e.g. Delmas and Montes, 2007, and Pizer at al., 2008) with much emphasis on the importance of selection effects by comparing participants and non-participants. Only a few of those studies also control for (some) differences in the design of covenants and the use of other instruments (Johnstone et al., 2009, and Bjørner & Jensen, 2002), while the effectiveness of covenants is likely to also depend on their design as well as on their context of implementation, such as sector and country specific circumstances.[1] To study the effectiveness of covenants in this broader setting we compiled a unique data set that not only characterizes 78 covenants in 24 OECD countries in the period 1978 to 2006, but accounts for the implementation of energy taxes, subsidies and standards as well. We also exploit different weighing schemes as well as different sectors (i.e. industry, transport sector, electricity production and

[1] Note that micropanels usually cannot control for differences in covenant design because design characteristics are typically hold constant.

other sectors) to assess the relative importance of different covenants. We evaluate whether covenants have had an impact on energy and CO_2 intensity as well as on the penetration of renewables not only across countries but also across (clusters of) sectors. The panel structure of our data base allows us to control for potential selection effects and endogeneity problems.

We do find very little support for the effectiveness of covenants. In general no effect is found on energy- and CO_2-intensity and on the use of renewable irrespective of whether we control for covenant design or not. Somewhat surprisingly we do not find any effect even for the strictest covenants neither at the country nor at the sector level. This provides support for those who claim that covenants are policies of last resort and are unlikely to have much bite. In clear contrast, tax inclusive energy prices and, to a lesser extent, subsidies and standards, are much more important in changing overall patterns of energy use.

Our paper is organized as follows. The next section shortly reviews the empirical literature. Section 3 explains our selection procedure for our counts of VAs as well as our assessment of their relative importance in more detail. Next we discuss our econometric approach. Section 5 presents our main results and section 6 our sensitivity analysis. Section 7 concludes.

2. Background

Several studies explore the effectiveness of covenants. Table 1 summarizes the empirical literature for energy covenants. Long ago Hartman (1988) estimated the effect of an energy covenant aims to stimulate energy companies to support American consumers in saving energy. He uses data for 658 households, of which 508 were clients of companies participating in the covenant. Hartman finds a reduction of the consumption of energy of 4% between 1977 and 1981 by comparing participants and non-participants.

Lyon and Kim (2006) study 83 American electricity companies, of which 52% participate in the 1605(b) programme. They compare participants and non-participants between 1996 and 2003 but do not find any effect. Delmas en Montes (2007) study the American climate challenge program for electricity companies using data for 133 electricity companies (61% of total electricity production) for 1995-2000 and of which 82 participated in the covenant. Overall they find an insignificant effect.

However, early joiners show a reduction in CO_2 emissions per MWh of 7.5% per year. Late joiners, on the other hand, show a comparable increase in CO_2 emissions per MWh. They conclude that late joiners free ride on the green image created by the early joiners. Pizer et al. (2008) study the American Climate wise covenant and the 1605(b) programme for the industry using data for 900.000 companies of which 4000 participate in the covenant. They find a reduction in energy outlays of 5% between 1994 and 2000, but no reduction in CO_2.

The only study that explores a non-American covenant based on micro-data is Bjørner and Jensen (2002). They use data for 3762 Danish companies in the energy-intensive industry with only 60 participating in the covenant. Companies could get a tax reduction when participating in the covenant, but also face obligations to save energy and a fine if they did not succeed. In that case they had to pay the tax ex post. The authors find a reduction in energy use and CO2-emissions of 9% between 1993 and 1997 (the net effect, excluding the effect of tax reduction, is 6%). According to the authors, the effectiveness is related to the clear threat of higher taxes if the goal was not reached. Interestingly, the effectiveness of the tax itself is comparable to that of the covenant. For subsidies, however, no effect is found.

These case studies all use micro-data which allows comparisons of participants with a clear business-as-usual case of non-participants. One weak point, however, is that usually no tests are available of the effectiveness of differences in covenant design and comparisons with other instruments because datasets have not enough variation in policies. An alternative research design followed by Johnstone et al. (2009) is to exploit differences between countries and over time. Using country data for a panel of OECD countries they study whether policy instruments influence the number of renewable energy patents for wind, sun, ocean, biomass and waste for 25 countries between 1978 and 2003. They only find a positive effect for waste covenants, while taxes, standards and tradable permits stimulate patents for all renewables.

Although dynamic incentives of covenants as measured through patents are also interesting, the primary objective of most energy covenants is to reduce energy or CO2 (per unit of output) and therefore increase (reduce) energy or CO2 efficiency (intensity).[2] Moreover, differences in design of covenants also seems to play an important role in explaining their effectiveness. For instance, the threat with ex post taxation is likely to be an important explanatory factor behind the success of the Danish VAs even though the theoretical literature assesses the role of threats differently. We follow the approach by Johnstone et al. (2009) while allowing for differences in design of covenants. Ceteris paribus the use of other instruments, we expect covenants to be effective in countries where many covenants are present and that these countries should show lower energy- and CO_2-intensity and more use of renewables. However, we also expect stricter covenants to have more of an impact than less strict ones.

Table 1 Overview empirical studies energy covenants

				Effects on environment[1]		
Authors	Country	Covenant	Counterfactual	Pos.	Neg.	Neutral
Hartman (1988)	USA	Energy savings households	No	Yes	No	No
Bjørner & Jensen (2002)	Denmark	Energy use industry	Tax, subsidy	Yes	No	No
Lyon & Kim (2006)	USA	Climate emissions electricity	No	No	No	Yes
Delmas & Montes (2007)	USA	Climate emissions electricity	No	EJ	LJ	No
Johnstone et al. (2008)	OECD	Renewable energy	Tax, subsidy, tradable permits, standards	1	No	4
Pizer et al. (2008)	USA	Climate emissions industry	No	1	No	1

1. EJ: Early joiners, LJ: Late joiners

3. Measuring Voluntary Agreements

To measure the use of covenants we compiled a new database of VA that were in effect in 24 OECD countries in the years 1978 to 2006. Our starting point is three databases of the IEA related to Renewables, Climate Change and Energy Efficiency (IEA, 2010). In order to be included in our database, the aim of the agreements should

[2] We define energy intensity as the inverse of energy efficiency, i.e. the use of energy per unit of output.

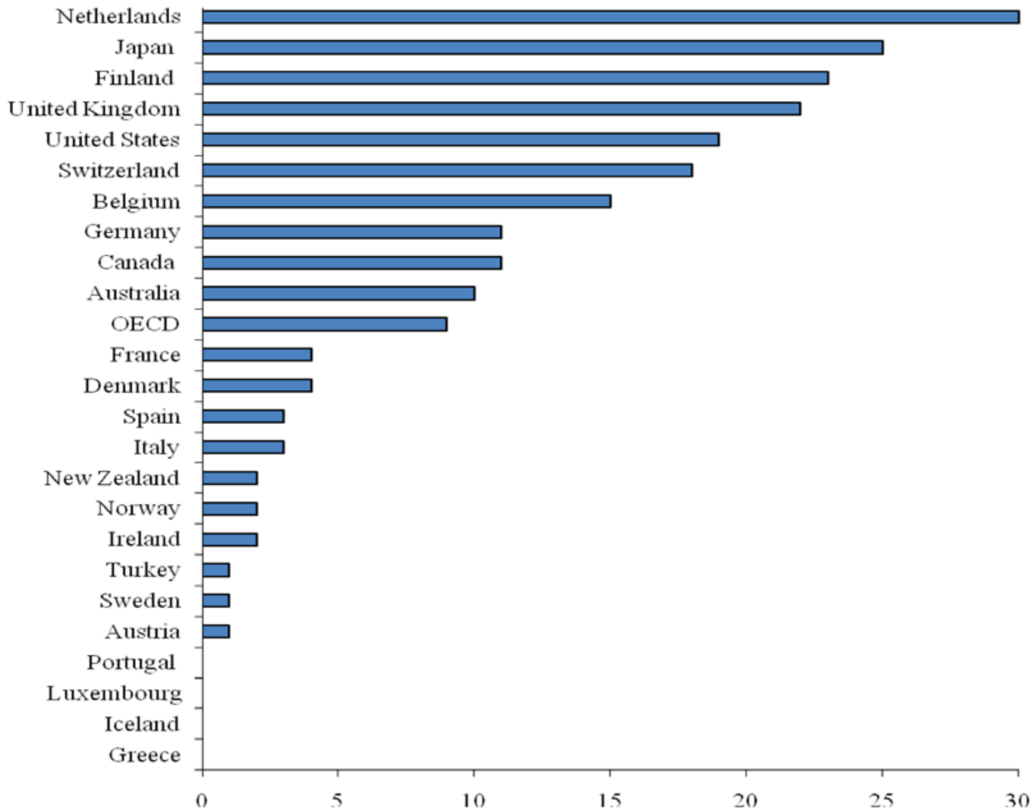
be the reduction of greenhouse gas emissions or a reduction of the use of energy. Based on a literature review and country websites we completed this database, or removed agreements in case a measure could not be described as an agreement. By agreement we mean either agreements or the program in which these agreements are negotiated. An agreement program may contain many different agreements with different sectors. A single agreement may also contain a great deal of sectors. What counts is whether these agreements are established under the same policy.

The IEA describes 212 VAs that are related to energy or CO_2 reduction, of which we classified 78 as a true VA. Regulations that contain a voluntary element are counted (tagged) in the IEA as both regulation and as a VA. We therefore carefully assessed whether a measure can be classified as VA or as a different instrument. In classifying the agreements or programs we used three criteria. The first is that there has to be an agreement between at least two parties, which can be private or public. The agreement must have some degree of freedom for participants in terms of participation or the goals to be met. The third criterion is that participants have to make some effort to reach the goals described in the agreements.

To account for the great variety in the design of covenants, we exploit four different measures for VAs. All measures count the number of agreements at time *t* in country *i* in different ways. The 78 VAs have different starting and end points, so VAs could apply in various consecutive years. If no agreements are active in a country at a specific date the variable takes value 0. As we use annual data we have a total of 696 observations for each measure.

The first measure is a simple count of the covenants for each country. This count, however, is somewhat limited because it does not take into consideration that some VAs apply to several sectors at the same time whereas others only apply to one sector. Therefore our second measure counts the number of sub-covenants for each single agreement and thus allows for differences in the number of sectors that have negotiated an agreement separately or collectively. So this count is not simply the actual number of sub-covenants, but rather reflects the number of sectors that participate. For consistency the sector definitions are based on the NACE 1.1 codes. Figure 1 shows the overall number and distribution of these energy sub-covenants across countries in our sample in 2006. Clearly large variation exists. The Netherlands uses covenants most intensively, followed by Japan, Finland, the United Kingdom (U.K.) and the U.S. Countries like Greece, Iceland, Luxembourg and Portugal do not use covenants at all. Note that we do not have any covenant in our data set before the beginning of the 1990s (see also section 4).

Figure 1. Use of energy sub-covenants in OECD countries, 2006.



The other two measures also take the reach or depth of a covenant into account. The third measure is similar to the simple count but also includes dimensions that describe the strictness and reach of the agreements. According to this measure all agreements start with a score of 0.25 and they can gain an additional score of 0.25 points for each of three aspects: i) if the agreement is a national agreement; ii) if the agreement has explicit measurable goals; iii) if the results are externally validated. If all aspects are true, an agreement can attain a maximum of 1 point.

The final measure is based on a subjective assessment of the VAs. We classify the covenants in four types which were subsequently counted as separate variables. The classification is based on the number of sectors included, the targets set, the use of sanctions for not reaching the goals, and other relevant aspects that might influence the impact of the agreements. Due to the great variety in the agreements (subjective) judgements are unavoidable. For instance, a goal of 10 percent reduction is a major target in some cases, but in others easy to reach. Strictness does not only depend on the goals set, but also on the timeline for reaching these goals. Our Type 1 agreements have limited goals and restricted to a few sectors without sanctions, while Type 4 agreements have strict goals, sanctions and include most sectors in the economy. Type 2 and 3 agreements lack either sanctions, ambitious goals, or are limited to only a few sectors.

Additionally for each type we create variables that measure certain characteristics of a VAs to assess whether a particular characteristic improves its effectiveness or not. Such characteristics are explicit goals, sanctions or external validation. Only if an agreement type reflects this characteristic it generates a count. Combining these characteristics with the four types described above we obtain 12 additional variables. This allows us to test for all different design elements seperately. For instance, we can estimate whether a Type 4 agreement with external validation performs better than a general Type 4 agreement or whether agreements with sanctions perform better than agreements without sanctions.

Table 2 Number of covenant measures by country and sector level

	Country	Industry	Transport	'Other'	Electricity	Renewables
Covenants (unweighted)	78	43	18	39	31	31
Subconvenants	245	223	na	na	na	na
Covenants (weighted)	64.25	36.75	14.75	31.5	25.75	25.75
Covenants (type)						
- I (less stringent)	27	9	8	15	6	6
- II	24	14	5	15	11	11
- III	11	7	0	2	5	5
- IV (most stringent)	17	14	5	6	9	9
Covenants (characteristics)						
- explicit goals	55	33	14	28	23	23
- sanctions	24	16	4	8	9	9
- external validation	46	30	9	22	20	20

Table 2 summarizes our counts for the different measures of the VAs. Note that a particular covenant might apply to different sectors and therefore the counts for the different sectors need not add up to the overall number of covenants in the column for country. Clearly covenants are used in all sectors with one exception for the Transport sector. This sector, however, is much more homogeneous than, for instance, the Industrial sector. Note also that we have at least some positive counts for almost all our measures in all sectors.

VAs are not the only policy instrument to reduce energy intensity or CO_2-intensity. Indeed, countries typically differ in their use of instrument mixes over time (OECD, 2003). Therefore this study explicitly controls for the relative effectiveness of covenants by including also other policy instruments, such as regulation, subsidies and taxes. By comparing the use of different instruments between countries we are able to establish a counterfactual, whereas the comparison over time and between countries provides a business as usual scenario. Because of the panel structure we are also able to compare the situation in each country before and after the use of VAs, but we can also compare the use of these agreements with countries that do not use these agreements or at a different points in time.

4. Econometric Methodology and Data

To assess the effectiveness of VAs we exploit three different dependent variables that measure the potential outcomes of such agreements. These variables are energy-intensity, CO_2-intensity or the share of renewable energy for country or sector *i* at time *t*. We compare the effect of VAs in 24 OECD countries in the period 1978 to 2006 both at the national level as well as for clusters of sectors. The different sectors we use in our estimations are industry, the transport sector, electricity production and ‘other sectors’. ‘Other sectors’ consist of agriculture, commercial and public services, residential and non-specified other sectors. This classification follows the OECD energy balances classification that is also used for the energy and CO_2- intensity measures.

We study levels in our dependents as explained by the implementation of covenants relative to other instruments applied by the regulatory agents in different countries. We fit the following fixed effects model

$$E_{i,t} = \alpha + \beta_1 C_{i,t} + \beta_2 P_{i,t} + \beta_3 X_{i,t} + \beta_4 E_{i,t-1} + \beta_5 T_{i,t} + \delta D_{\mathrm{i}} + \varepsilon_{i,t} \qquad (1)$$

where $E_{i,t}$ represents energy-intensity, CO_2- intensity or the share of renewable energy for country or sector *i* at time *t*. $C_{i,t}$ is our measure of the VAs. $\boldsymbol{P}_{i,t}$ represents our vector of policy control variables, such as regulation, subsidies and (tax inclusive) energy prices,. $\boldsymbol{X}_{i,t}$ is a vector of other control variables, $T_{i,t}$ is a country or sector specific time trend, δD_i is a full set of country fixed effects dummies, and, finally, $\varepsilon_{i,t}$ is the normally distributed error term (with $\varepsilon_{i,t} \sim N(0; \sigma_{i,t})$). We estimate this model separately on the national level as well as for the different subsectors.

Both energy-intensity and CO_2-intensity are measured as the logarithm of the levels to avoid heteroskedasticity problems. To correct for potential serial correlation and the inability to adapt a large share of technology or capital in the short term, we include the lagged value of the dependent variable. We also add country specific time trends, both linear and quadratic, to correct for autonomous developments in energy intensity of countries, such as technological change.[3]. Finally, we estimate (1) using OLS.

Our dependent variables are measures for energy efficiency or intensity based on the OECD energy balances (OECD, 2009b). Energy use is measured by total energy consumption in oil equivalents and we obtain energy intensity by dividing consumption with some measure of the overall 'size' of the economy or sector. We use Gross Domestic Product (GDP) for the national level, value added for the industry, and the number of inhabitants for the transport sector and other sectors. GDP is in 1990 International Geary-Khamis dollars from Maddison (2009). Value added is taken from OECD data in 2000 PPP dollar (OECD, 2009a) and the number of inhabitants is taken from the world development indicators (World Bank, 2009). For our measure of CO_2 intensity we multiply energy consumption by CO_2 emissions for each fuel type. Note that countries with rich (low) natural energy resources can combine high energy consumption with a low (high) CO_2 intensity.

For the electricity sector we exploit a measure for the efficiency of energy production, i.e. the amount of energy used to produce one unit of electricity. More specifically this indicator is the sum of all energy used by electricity production in oil equivalents divided by total electricity consumption (also derived from the OECD energy balances database). Finally, we use the share of energy that is produced from renewable sources. In these figures hydropower and nuclear energy are not taken into account because some countries heavily rely on these renewable sources. See Table 3 for a full set of descriptive statistics for our five dependent variables.

[3] Vollebergh et al. (2009) show that country specific time trends play a crucial role in explaining differences in CO_2 emissions between OECD countries. We use both linear and quadratic time trends to allow for potential non-linearities of these autonomous developments

Table 3. Descriptive statistics dependent variables

	Unit	Average	St.dev.	Min	Max
Energy-intensity					
- Country	TCF/GDP	0.25	0.10	0.12	0.72
- Industry	TFC/Value added	0.26	0.16	0.06	1.65
- Transport	TFC/Inhabitant	1005	666	134	5965
- Other sectors	TFC/Inhabitant	1752	903	229	5671
- Electricity	Energy input per unit	2.52	0.70	1.09	3.97
CO_2-intensity					
- Country	TCF/GDP	0.16	0.07	0.05	0.65
- Industry	TFC/Value added	0.16	0.13	0.02	1.55
- Transport	TFC/Inhabitant	831	557	114	4998
- Other sectors	TFC/Inhabitant	965	510	133	2423
- Electricity	CO_2 input per unit	1.46	1.03	0.00	3.99
Renewables	Share in electricity production	3.12	4.04	0.01	29.40

In our analysis we compare the effectiveness of the agreements against other policy measures including regulations and subsidies. The regulations measure is a simple count of regulations (or programs containing regulations) as reported by the IEA databases for Renewables, Climate Change and Energy Efficiency (IEA, 2010). Each standard for energy- and CO2-efficiency and renewables reported by the IEA for a specific country generates one count. One example is a minimum standard for the share of renewable for electricity producers. If possible we explicitly link such regulation to the relevant sectors in our analysis.

Data for subsidies are constructed using the Energy technology R&D budgets 2008 from the IEA (2009) Beyond 2020 database. All subsidies are in PPP 2007 dollars and weighed for each country by the total final consumption, or the final consumption of each sector in a country. The subsidy measure used for the national level is a summation of all subsidies included in the database. The database also contains subsidies for the industry and the transport sector. For ‘other sectors’ we rely on subsidies for both residential and other sectors. For the electricity industry we use subsidies related to fossil fuels and electricity production, such as distribution and combustion techniques.

Table 4. Descriptive statistics independent variables

	Unit	Average	St.dev.	Min	Max
In all models:					
- Covenants					
- total unweighted	Number	0.89	1.64	0	11
- subcovenants	Number	2.94	6.71	0	34
- total weighted	Number	0.76	1.39	0	9.25
- types	I (most limited)	0.34	0.72	0	4
	II	0.29	0.86	0	6
	III	0.09	0.36	0	3
	IV (most stringent)	0.17	0.42	0	3
- Standards (Total)	Number	1.38	2.43	0	15
- Subsidies (total)	Dollar per toe	2.65	2.19	0	13.30
- Energy prices (tax incl.)	Index (2000=100)	114.98	22.91	51.18	214.70
- Population density	Inhabitants per hectare	1.22	1.19	0.02	4.82
- Openness economy	Import + export as % GDP	70.23	43.73	8.87	326.60
- Average temperature	Celsius	11.20	4.47	2.58	22.29
- Average precipitation	Mm	730.9	274.0	125.5	2266.9
- Rural population	Share in total population	26.31	12.14	2.68	58.00
- Fertility	Number of birth per women	1.76	0.43	1.15	4.43
- Population < than 15	Share in total population	20.39	4.42	13.78	40.93
Used in sensitivity analyses:					
- St. dev. Temperature	Celsius	6.63	1.62	0.98	10.91
- St. dev. precipitation	Mm	481.4	236.7	122.7	1573.9
- Air passengers	Per inhabitant	1.11	1.11	0.03	11.91
- Mortality	Death per 1000 inhabitants	9.16	1.52	5.90	12.60
- Long term interest rate	%	8.01	6.49	0.09	72.15

We also include tax inclusive energy prices to control for differences in energy tax policies. Assuming companies only calculate with the total price of energy regardless of whether prices change due to taxes or other factors, we use tax inclusive energy prices to control for such differences.[4] Different price indexes using IEA (2009)

[4] One might even argue that net of tax energy prices across OECD countries would reflect world market prices and that variations in prices would only be due to differences in taxation across countries.

correct for price levels.[5] At the national level we use the price index for both industry and households for all energy types. For the industry and the electricity production sector we use a price index for the industry for all energy types. And finally, we exploit an industry price index for oil products for the transport sector, whereas for ‘other sectors’ a price index was used for all energy types based on household prices.

Covenants are subject to negotiation and therefore the degree to which parties can influence governments to change effectiveness of the VAs in their own favour. In order to correct for this possibility we multiplied in a sensitivity analysis all agreement measures described above by the corruption perception index of Transparency International. Additional control variables used are average temperature and standard deviation of the temperature based on data from Klein Tank et al. (2002). These data are supplemented by our own calculations based on daily temperature observations from various stations per country. The average precipitation and standard deviation of the precipitation is taken from the Historical Climatology Network (GHCN-Monthly database). Based on monthly averages yearly averages have been calculated. Further control variables used are population density, the percentage of inhabitants in rural areas, the number of air passengers, mortality, fertility and openness of the economy, defined as imports plus exports divided by GDP. These are taken from the World development indicators database. Finally, capital market interest rates were taken from the Main Economic indicators database of the OECD. For some countries however, such as Greece and Turkey, observations were missing. Descriptive statistics for all independent variables at the national level are presented in Table 4 (see Appendix A for a full set of descriptive statistics for all variables, i.e. including different sectors).

5. Main results

Estimating the effect for covenants without any controls generates an insignificant positive effect (see Model (1) in Table 5). The coefficient for covenants only has its expected negative sign, though it is still insignificant, if we also include our control variables, in particular our lagged dependent variable. Adding non-linear time trends yields somewhat better results, in particular for some of our control variables (see Models (2) and (3) in Table 5). Interestingly, adding our policy variables but

[5] If information was incomplete we used alternate sources, like data on world market prices for coal in some years.

excluding our unweighted covenants measure has a strong additional explanatory effect. Moreover, all policy variables have the expected negative sign. So more rules, higher tax inclusive energy prices and more subsidies reduce the energy intensity of countries (see Model (4)). Adding covenants to this model, however, simply adds nothing to the explanatory power. This suggest that VAs do contribute little to the improvement in energy intensities at the country level.

Table 5 Estimation results energy intensity for unweighted covenant variable

Variable	(1)	(2)	(3)	(4)	(5)
Covenants	0.0022	-0.0015	-0.0001		0.0011
	(0.0024)	(0.0019)	(0.0025)		(0.0024)
Rules				-0.0041**	-0.0042**
				(0.0018)	(0.0018)
Taxes				-0.0005***	-0.0005***
				(0.0001)	(0.0001)
Subsidies (scaled)				-0.0026*	-0.0027*
				(0.0014)	(0.0015)
Population density		-0.0373	-0.6358***	-0.2981	-0.2919
		(0.1117)	(0.1875)	(0.2004)	(0.2010)
Openness		-0.0002	-0.0008***	-0.0008***	-0.0008***
		(0.0002)	(0.0002)	(0.003)	(0.0003)
Average temperature		-0.0109***	-0.0141***	-0.0135***	-0.0135***
		(0.0019)	(0.0019)	(0.0019)	(0.0019)
Average precipitation		0.0000**	0,0000	0,0000	0.0000
		(0.0000)	(0.0000)	(0.0000)	(0.0000)
Share of rural population		0.0003	0.0072**	0.0025	0.0026
		(0.0015)	(0.0036)	(0.0037)	(0.0037)
Fertility		0.0095	0.0505***	0.0751***	0.0752***
		(0.0116)	(0.0173)	(0.0186)	(0.0186)
Share of youth		-0.0026	0.0015	-0.0003	-0.0004
		(0.0023)	(0.0034)	(0.0036)	(0.0036)
Lagged energy-intensity		0.7183***	0.5336***	0.4669***	0.4680***
		(0.0286)	(0.0312)	(0.0341)	(0.0342)
Time Trend	YES	YES	YES	YES	YES
Non-linear Time Trend	NO	NO	YES	YES	YES
Fixed effects	YES	YES	YES	YES	YES
Number of obs	696	696	696	596	596
Groups	24	24	24	24	24

*Note: *,** and *** means significance at 10%, 5% en 1%. Standard errors within parenthesis*

Table 6 shows our estimation results of the main model with the unweighted covenant variable.[6] In all cases the coefficients for the covenants variables are insignificant. There is no evidence that covenants have a positive or negative influence on energy-

[6] Appendix B contains the full estimation results for one of the models as an example.

intensity, CO_2-intensity or the share of renewables. As we do find significant results for the other variables, this is probably not the result of a lack of data or a misspecified model. Indeed, for rules, which are measured in the same way as the covenant variable significant results are found in four cases. More rules leads to a lower energy-intensity for the transport sector and for the economy in total and to a lower CO_2-intensity for the transport sector. Furthermore, the share of renewables increases if the number of rules increases. For energy taxes (measured as prices) we find significant results in seven cases. Higher taxes lead to lower intensities and a higher share of renewables. Also for subsidies, significant results are found for both energy- and CO_2-intensity.

Table 6 Estimation results policy variables, unweighted covenant variable

Variable	Country	Industry	Other	Transport	Electricity
Energy-intensity					
Covenants	0.0011	-0.0023	-0.0033	-0.0139	-0.0377
	(0.0024)	(0.0076)	(0.0058)	(0.0110)	(0.0227)
Rules	-0.0042**	-0.0064	-0.0030	-0.0124*	-0.0099
	(0.0018)	(0.0062)	(0.0037)	(0.0074)	(0.0119)
Taxes	-0.0005***	-0.0001	-0.0013***	-0.0004***	-0.0001
	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0003)
Subsidies	-0.0026*	0.0012	0.0183	-0.0159**	-0.0021
	(0.0015)	(0.0059)	(0.0134)	(0.0067)	(0.0128)
CO_2-intensity					
Covenants	0.0010	0.0073	0.0024	-0.0138	0.0182
	(0.0035)	(0.0115)	(0.0092)	(0.0112)	(0.0282)
Rules	-0.0029	-0.0003	0.0025	-0.0142*	-0.0130
	(0.0026)	(0.0093)	(0.0059)	(0.0076)	(0.0149)
Taxes	-0.0006***	0.0000	-0.0014***	-0.0004***	-0.0006
	(0.0002)	(0.0002)	(0.0003)	(0.0001)	(0.0004)
Subsidies	-0.0030	-0.0163*	0.0049	-0.0154**	0.0109
	(0.0021)	(0.0089)	(0.0211)	(0.0068)	(0.0159)
Renewables					
Covenants	-0.0377	(-)	(-)	(-)	(-)
	(0.1384)				
Rules	0.1982**	(-)	(-)	(-)	(-)
	(0.0784)				
Taxes	0.0070***	(-)	(-)	(-)	(-)
	(0.0023)				
Subsidies	0.1293	(-)	(-)	(-)	(-)
	(0.1777)				

*Note: *,** and *** means significance at 10%, 5% en 1%. Standard errors within parenthesis*

The insignificant result for covenants could be due to mixing effective and ineffective covenants. It could be the case that more stringent covenants do have influence on intensities and renewables, while lax covenants have no influence. If there are to many covenants of the last category in our dataset, the total result could be insignificant. Table 7 therefore presents results with estimations that discriminate between the four types of covenants (with type 1 the least and type 4 the most stringent type). None of the coefficients for the four types, however, is significant. Only when the types are restricted to type 1 and the covenant has a clear threat, validation or explicit goal, some coefficients are significant. But these coefficients are only significant at 10%. Furthermore, it is strange that effects are only found for the least stringent type. Thus, this provides only very minor evidence of some effects of covenants.

Table7 Effects covenant types (coefficients for covenant variables)

	Type	Energy-intensity	CO_2-intensity	Renewables
Covenant type	I	-0.0008	-0.0005	0.2179
		(0.0039)	(0.0057)	(0.3918)
	II	0.0023	0.0029	-0.1395
		(0.0047)	(0.0068)	(0.3923)
	III	0.0039	-0.0001	-0.1350
		(0.0089)	(0.0130)	(0.6846)
	IV	-0.0036	-0.0014	-0.2354
		(0.0063)	(0.0092)	(0.3017)
Threat and type	I	-0.0123*	-0.0184*	(-)
		(0.0072)	(0.0106)	
	II	-0.0131	-0.0181	-0.2177
		(0.0109)	(0.0160)	(0.9581)
	III	0.0013	-0.0055	(-)
		(0.0123)	(0.0181)	
	IV	0.0025	0.0094	-0.6228
		(0.0093)	(0.0136)	(0.5704)
Validation and type	I	-0.0104*	-0.0145	(-)
		(0.0061)	(0.0089)	
	II	-0.0031	-0.0058	-0.0083
		(0.0067)	(0.0098)	(0.5878)
	III	0.0064	0.0017	(-)
		(0.0108)	(0.0158)	
	IV	-0.0019	-0.0050	-0.2156
		(0.0064)	(0.0094)	(0.2980)
Explicit goals and type	I	-0.0095*	-0.0124	0.4142
		(0.0054)	(0.0079)	(0.3663)
	II	0.0035	0.0040	-0.2360
		(0.0056)	(0.0082)	(0.4019)
	III	0.0050	0.0013	-0.2346
		(0.0089)	(0.0130)	(0.6901)
	IV	-0.0023	0.0002	-0.1982
		(0.0063)	(0.0092)	(0.3026)

*Note: *,** and *** means significance at 10%, 5% en 1%, (-) means that model is not estimated due to a low number of relevant observations. Standard errors between brackets.*

Lack of significance could also be due to measurement errors in the covenant variables. Table 8 therefore tests whether alternative measurements lead to different results as we now not only present the results for the unweighted variables, but also for the weighting schemes with subconvenants and weighted covenants. In none of the cases we find significant results.

Table 8 Effects covenants alternative weighting schemes

Variable	Total	Industry	Other	Transport	Electricity
Energy-intensity					
Unweighted	0.0011	-0.0023	-0.0033	-0.0139	-0.0377
	(0.0024)	(0.0076)	(0.0058)	(0.0110)	(0.0227)
Subcovenants	-0.0001	0.0002	(-)	(-)	(-)
	(0.0005)	(0.0007)			
Weighted	-0.0002	-0.0055	-0.0037	-0.0202	-0.0091
	(0.0029)	(0.0083)	(0.0065)	(0.0125)	(0.0273)
CO_2-intensity					
Unweighted	0.0010	0.0073	0.0024	-0.0138	0.0182
	(0.0035)	(0.0115)	(0.0092)	(0.0112)	(0.0282)
Subcovenants	-0.0003	0.0008	(-)	(-)	(-)
	(0.0043)	(0.0011)			
Weighted	-0.0012	0.0019	0.0012	-0.0202	0.0181
	(0.0007)	(0.0125)	(0.0102)	(0.0127)	(0.0340)
Renewables					
Unweighted	-0.0377	(-)	(-)	(-)	(-)
	(0.1384)				
Subcovenants	(-)	(-)	(-)	(-)	(-)
Weighted	-0.0382	(-)	(-)	(-)	(-)
	(0.1688)				

*Notes: *,** and *** means significance at 10%, 5% en 1%, (-) means that model is not estimated due to a low number of relevant observations. Standard errors between brackets.*

6. Sensitivity Analysis

Our fixed effects model captures time-invariant effects related to differences that might affect both the use of VAs and the energy and CO_2 intensity between countries. Factors that vary over time and influence both the use of VAs and energy or CO_2 intensity, however, might cause endogeneity problems. Woolridge (2002) provides a test for strict endogeneity based on the use of lagged or leading variables. Strict endogeneity means that explanatory variables are correlated with the error term in different periods. We tested for strict endogeneity, but found no evidence (results are available on request). Another source of simultaneity lies in unobserved variables that change over time. More specifically, countries may use VAs if they do not have the intention to really change their reduction goals, as agreements are less strict than for instance regulations. The VAs measures might then not capture the effectiveness, but rather the motivation for countries to increase their efficiency. However, because a variety of countries is used in the analysis it is unlikely that every country has the same motivation. In order to test for this we also did a separate country analysis, but found no remarkable results compared with the panel estimations.

In order to asses the validity of the model and our assumption, but also to determine whether VAs might influence energy and CO_2 intensity in different ways we perform various sensitivity analyses. These analyses test the robustness of the results found in the main analyses. We test whether the agreements might have a delayed effect on efficiency by using lags of variables that measure the use and intensity of VAs. We also test for anticipation effects by taking up leads of these variables. This test also gives an indication of possible endogeneity problems. We also tested whether a combination of policy instruments is (more) effective by using interaction terms of the VAs and other policy instruments. We test for the chosen period through a Chow breakpoint test and run the estimations again taking different possible breakpoints into account. In the main model we use linear and quadratic country specific time trends. We test alternative specifications with a general trend and a trend for different clusters of countries. Moreover we test the model with only a linear trend. Furthermore we perform separate analyses for each country. We also analyse the model itself through Monte Carlo analysis where we simulate the effect of VAs in order to see if our model picks up these effects.

Table 9 presents a summary for all sensitivity analyses. In total we estimated 2,246 different coefficients for covenant variables. We found only 92 significant results. As we test at 5%, this is even less than the number of expected significant coefficients if they are based on coincidence. Furthermore, the found significant coefficients are quite random if we look at the specifications. We conclude therefore, that we have none or very minor evidence that covenants have a significant influence on energy-intensity, CO_2-intensity and the share of renewables. As this conclusion could be the result of the models we have chosen, we tested with Monte Carlo analysis whether our models can pick up rather small changes. It showed that the models could detect a total change of not more than 0.3%.

As policies in general can contain various instruments high correlation between these instruments is possible. In the dataset there is especially high correlation between regulation and voluntary agreements (0.67). This might cause multicolinearity issues. For this reason we also estimated our model with the different policy and agreement measures separately.

Table 9 summarizes also the results for the other policy variables.[7] The largest share of significant results is found for taxes, but also for subsidies and rules a larger share than 5% is found. This means that there is evidence that these instruments are influential.

Table 9 Sensitivity analyses: number of significant and total coefficients policy variables

	Rules		Taxes		Subsidies		Covenants	
	Sig.	Tot.	Sig.	Tot.	Sig.	Tot.	Sig.	Tot.
Basic models	79	264	164	264	38	133	31	646
- plus delay and anticipation effects	34	142	96	142	17	78	13	781
- plus logarithms and other exogenous variables	40	198	143	198	27	102	18	360
- plus other specification trend variables	15	213	126	213	29	111	27	390
- plus stand alone policy variables	7	11	6	11	6	11	3	69
Total	175	828	535	828	117	435	92	2246

Notes: Sig.: significance at minimal 5% and correct sign (compared with expected), Tot.: total number of estimated coefficients policy variables.

7. Conclusions

Future research: The possibility of spillovers as described by Lyon en Maxwell (2007) can also influence the estimated effects of VAs. Spillovers occur when effects from the use of VAs spill over to countries that do not use these agreements. Comparing countries that use agreements with countries that do not then leads to biased estimates of the effect of agreements. At this point we have no ways to correct for possible spillovers.

[7] Note that the total number of estimated coefficients is lower for taxes and rules as several specifications have more than one covenant variables and that the total number of coefficients for subsidies is still lower as we estimated less models including subsidies as not for all years information is available for subsidies.

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Appendix A. Descriptive Statistics

Table A1. Descriptive statistics dependent variables

	Unit	Average	St.dev.	Min	Max
Energy-intensity					
- Total	TCF/GDP	0.25	0.10	0.12	0.72
- Industry	TFC/Value added	0.26	0.16	0.06	1.65
- Transport	TFC/Inhabitant	1005	666	134	5965
- Other sectors	TFC/Inhabitant	1752	903	229	5671
- Electricity	Energy input per unit	2.52	0.70	1.09	3.97
CO_2-intensity					
- Total	TCF/GDP	0.16	0.07	0.05	0.65
- Industry	TFC/Value added	0.16	0.13	0.02	1.55
- Transport	TFC/Inhabitant	831	557	114	4998
- Other sectors	TFC/Inhabitant	965	510	133	2423
- Electricity	CO_2 input per unit	1.46	1.03	0.00	3.99
Renewables	Share in electricity production	3.12	4.04	0.01	29.40

Table A2. Descriptive statistics policy variables

	Unit	Average	St.dev.	Min	Max
Covenants (unweighted)					
- Total	Number	0.89	1.64	0	11
- Industry	Number	0.29	0.77	0	7
- Transport	Number	0.11	0.40	0	3
- Other sectors	Number	0.28	0.93	0	7
- Electricity	Number	0.19	0.49	0	3
- Renewables	Number	0.19	0.49	0	3
Rules					
- Total	Number	1.38	2.43	0	15
- Industry	Number	0.35	0.80	0	6
- Transport	Number	0.21	0.54	0	4
- Other sectors	Number	0.76	1.36	0	8
- Electricity	Number	0.49	1.16	0	8
- Renewables	Number	0.49	1.16	0	8
Taxes					
- Total	Index (2000=100)	114.98	22.91	51.18	214.70
- Industry	Index (2000=100)	125.28	31.74	67.92	258.73
- Transport	Index (2000=100)	117.63	31.13	31.86	258.30
- Other sectors	Index (2000=100)	110.29	23.50	60.02	228.82
- Electricity	Index (2000=100)	103.53	36.50	54.64	261.81
- Renewables	Index (2000=100)	116.58	33.02	56.43	239.94
Subsidies					
- Total	Dollar per toe	2.65	2.19	0	13.30
- Industry	Dollar per toe	0.35	0.46	0	2.89
- Transport	Dollar per toe	0.33	0.44	0	3.49
- Other sectors	Dollar per toe	0.23	0.25	0	1.60
- Electricity	Dollar per toe	0.45	0.57	0	6.34
- Renewables	Dollar per toe	0.37	0.35	0	2.21

Table A3. Descriptive statistics alternative weighting schemes covenants

	Unit	Average	St.dev.	Min	Max
Covenants (subcovenants)					
- Total	Number	2.94	6.71	0	34
- Industry	Number	2.50	6.36	0	34
Covenants (weighted)					
- Total	Number	0.76	1.39	0	9.25
- Industry	Number	0.25	0.65	0	6.00
- Transport	Number	0.10	0.37	0	2.75
- Other sectors	Number	0.23	0.79	0	6.00
- Electricity	Number	0.16	0.42	0	2.75
- Renewables	Number	0.16	0.42	0	2.75
Covenants (types)					
- Total	I (most limited)	0.34	0.72	0	4
	II	0.29	0.86	0	6
	III	0.09	0.36	0	3
	IV (most stringent)	0.17	0.42	0	3
- Industry	I	0.03	0.17	0	2
	II	0.10	0.44	0	4
	III	0.02	0.15	0	1
	IV	0.14	0.39	0	3
- Transport	I	0.02	0.15	0	1
	II	0.03	0.17	0	1
	III	0.00	0.00	0	0
	IV	0.06	0.24	0	1
- Other sectors	I	0.05	0.29	0	3
	II	0.13	0.60	0	5
	III	0.01	0.09	0	1
	IV	0.08	0.27	0	1
- Electricity	I	0.04	0.20	0	2
	II	0.04	0.23	0	2
	III	0.02	0.15	0	1
	IV	0.10	0.31	0	2

Table x4. Descriptive statistics control variables

	Unit	Average	St.dev.	Min	Max
In all models:					
- Population density	Inhabitants per hectare	1.22	1.19	0.02	4.82
- Openness economy	Import + export as share GDP	70.23	43.73	8.87	326.60
- Average temperature	Celsius	11.20	4.47	2.58	22.29
- Average precipitation	Mm	730.9	274.0	125.5	2266.9
- Rural population	Share in total population	26.31	12.14	2.68	58.00
- Fertility	Number of birth per women	1.76	0.43	1.15	4.43
- Population younger than 15	Share in total population	20.39	4.42	13.78	40.93
Used in sensitivity analyses:					
- St. dev. temperature	Celsius	6.63	1.62	0.98	10.91
- St. dev. precipitation	Mm	481.4	236.7	122.7	1573.9
- Air passengers	Per inhabitant	1.11	1.11	0.03	11.91
- Mortality	Death per 1000 inhabitants	9.16	1.52	5.90	12.60
- Long term interest rate	%	8.01	6.49	0.09	72.15

Appendix B. Example estimation results full model

In Table A.1 we include the full estimation results of one of the model as an example. Results for fixed country effects are not included and are available on request.

Table A.1 Model with energy-intensity as left-hand side variable (subsidies not included)

	Unweighted		Subconvenants		Weighted	
Variable	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Covenants	0,0002	0,9200	0,0003	0,5000	-0,0012	0,6850
Rules	-0,0046	0,0120	-0,0046	0,0120	-0,0045	0,0130
Taxes	-0,0005	0,0000	-0,0005	0,0000	-0,0005	0,0000
Population density	-0,4015	0,0310	-0,4087	0,0280	-0,4016	0,0310
Openness	-0,0005	0,0080	-0,0005	0,0070	-0,0005	0,0100
Average temperature	-0,0144	0,0000	-0,0143	0,0000	-0,0144	0,0000
Average precipitation	0,0000	0,0810	0,0000	0,0790	0,0000	0,0810
Share of rural population	0,0089	0,0110	0,0090	0,0100	0,0089	0,0110
Fertility	0,0575	0,0010	0,0578	0,0010	0,0573	0,0010
Share of youth	-0,0022	0,5120	-0,0021	0,5320	-0,0022	0,5160
Lagged energy-intensity	0,4902	0,0000	0,4891	0,0000	0,4890	0,0000
Linear trend Australia	-0,0186	0,0230	-0,0184	0,0160	-0,0202	0,0150
Linear trend Austria	-0,0264	0,0000	-0,0264	0,0000	-0,0266	0,0000
Linear trend Belgium	0,0121	0,0700	0,0127	0,0560	0,0114	0,0860
Linear trend Canada	-0,0100	0,1000	-0,0095	0,1130	-0,0106	0,0800
Linear trend Denmark	-0,0178	0,0090	-0,0177	0,0090	-0,0180	0,0080
Linear trend Finland	-0,0108	0,0760	-0,0112	0,0600	-0,0115	0,0600
Linear trend France	0,0041	0,5510	0,0042	0,5400	0,0038	0,5770
Linear trend Germany	-0,0265	0,0000	-0,0262	0,0000	-0,0270	0,0000
Linear trend Greece	0,0465	0,0000	0,0468	0,0000	0,0465	0,0000
Linear trend Iceland	-0,0021	0,7490	-0,0020	0,7630	-0,0021	0,7480
Linear trend Ireland	-0,0092	0,2130	-0,0092	0,2160	-0,0094	0,2070
Linear trend Italy	-0,0253	0,0020	-0,0252	0,0020	-0,0259	0,0020
Linear trend Japan	0,0035	0,7780	0,0047	0,7050	0,0026	0,8300
Linear trend Luxembourg	-0,0706	0,0000	-0,0708	0,0000	-0,0707	0,0000
Linear trend Netherlands	-0,0061	0,5180	-0,0070	0,4610	-0,0065	0,4910
Linear trend Norway	-0,0303	0,0000	-0,0302	0,0000	-0,0306	0,0000
Linear trend New Zealand	0,0313	0,0000	0,0314	0,0000	0,0312	0,0000
Linear trend Portugal	0,0168	0,0300	0,0170	0,0290	0,0168	0,0300
Linear trend Spain	0,0113	0,1900	0,0115	0,1800	0,0108	0,2090
Linear trend Sweden	0,0111	0,0600	0,0110	0,0620	0,0110	0,0610
Linear trend Switzerland	0,0334	0,0170	0,0345	0,0140	0,0332	0,0170
Linear trend Turkey	0,0419	0,0010	0,0422	0,0010	0,0415	0,0010
Linear trend Gr.-Brit.	-0,0112	0,0780	-0,0099	0,1330	-0,0116	0,0680
Linear trend USA	-0,0195	0,0020	-0,0190	0,0020	-0,0204	0,0020

	Unweighted		Subconvenants		Weighted	
Variable	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Non linear trend Australia	0,0002	0,0600	0,0002	0,0420	0,0003	0,0380
Non linear trend Austria	0,0004	0,0000	0,0004	0,0000	0,0004	0,0000
Non linear trend Belgium	-0,0002	0,0620	-0,0002	0,0480	-0,0002	0,0790
Non linear trend Canada	0,0001	0,2600	0,0001	0,2900	0,0001	0,2140
Non linear trend Denmark	0,0002	0,0730	0,0002	0,0740	0,0002	0,0660
Non linear trend Finland	0,0001	0,1700	0,0001	0,1490	0,0001	0,1310
Non linear trend France	0,0000	0,8150	0,0000	0,8010	0,0000	0,8550
Non linear trend Germany	0,0004	0,0020	0,0003	0,0020	0,0004	0,0010
Non linear trend Greece	-0,0006	0,0000	-0,0006	0,0000	-0,0006	0,0000
Non linear trend Iceland	0,0001	0,1870	0,0001	0,1910	0,0001	0,1860
Non linear trend Ireland	0,0000	0,8170	0,0000	0,8150	0,0000	0,7940
Non linear trend Italy	0,0004	0,0000	0,0004	0,0000	0,0004	0,0000
Non linear trend Japan	0,0001	0,6830	0,0000	0,7890	0,0001	0,6090
Non linear trend Luxembourg	0,0009	0,0000	0,0009	0,0000	0,0009	0,0000
Non linear trend Nederland	0,0003	0,0240	0,0003	0,0180	0,0003	0,0200
Non linear trend Norway	0,0004	0,0000	0,0004	0,0000	0,0004	0,0000
Non linear trend New Zealand	-0,0004	0,0000	-0,0004	0,0000	-0,0004	0,0000
Non linear trend Portugal	0,0000	0,6840	0,0000	0,6750	0,0000	0,6800
Non linear trend Spain	-0,0001	0,4330	-0,0001	0,4180	-0,0001	0,4770
Non linear trend Sweden	-0,0002	0,0150	-0,0002	0,0150	-0,0002	0,0160
Non linear trend Switzerland	-0,0004	0,0500	-0,0004	0,0420	-0,0004	0,0520
Non linear trend Turkey	-0,0003	0,0140	-0,0003	0,0130	-0,0003	0,0160
Non linear trend Gr.-Brit.	0,0001	0,3220	0,0001	0,4650	0,0001	0,2850
Non linear trend USA	0,0002	0,0610	0,0002	0,0590	0,0002	0,0430
Constant	-0,2517	0,2750	-0,2521	0,2740	-0,2470	0,2840