Empirical evidence on the effectiveness of environmental taxes

by

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Abstract:
The aim of this study is to determine whether environmental taxes affect levels of pollution and energy consumption. Using a panel of EU members and Norway, there is a significant negative relationship between environmental taxes and pollution, but no relationship between taxes and energy consumption.

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1. Introduction

As a result of recent concerns relating to the harmful effects of global warming, policy makers have become increasingly interested in the use of environmental taxation as a means of combating the problem. This research aims to address this issue, by determining whether environmental taxes have had any significant effect on the levels of air pollution and the complimentary phenomenon of energy consumption within the European Union (EU). Over the recent past, the EU members have been set voluntary targets for the reduction in pollution and consumption of hydro-carbon fuels, which have facilitated the sometimes controversial use of environmental taxes across the EU, including the countries that have recently joined.

To date the empirical literature on this issue has mainly concentrated on the use of simulation exercises rather than the use econometric modelling, due to the lack of suitable macro-data. This paper attempts to contribute to the debate on the effectiveness of environmental taxes, by using an EU panel data set to determine if there is any link between environmental taxes and air pollution and therefore whether the EU environmental policy to date has been successful.

The main empirical work on environmental taxation has centred on the use of simulations on the impact of environmental tax reform (ETR) on the environment, use of natural resources and the wider economy. Most of the studies conclude that increased environmental tax and ETR can have beneficial effects on the environment. (see Bosquet (2000)). In addition there has recently been a substantial level of research into determinants of pollution and energy usage. Grossman and Krueger (1995) provided evidence for a non-linear relationship between per capita income and pollution, termed the 'Environmental Kuznets Curve', with an inverted U-shaped relationship. However other studies such as Stern and Common (2001) suggest the relationship could be monotonic, whilst Deacon and Norman (2006) find the relationship tends to be country specific and dependent on the approach used. However as yet there is little evidence of fiscal factors being considered in this area of the empirical literature at the macroeconomic level[1].

Following the introduction, the methodology used in this study is outlined and the form that ETR has taken in the EU member states discussed. The data and results are then examined and finally we suggest some conclusions and policy implications.

2. Methodology

The model of the determinants of both pollution and energy consumption used in this study are partially based on the conventional approach to pollution suggested by Grossman and Krueger (1995), although as Harbaugh *et al*. (2002) suggest there is little theoretical material to determine the correct specification. However based on other studies, the explanatory variables include the common per capita GDP measures in linear and non-linear form. In addition per capita capital formation is also included in the model, to proxy the ratio between capital and labour supply, as measures of capital and investment have proven to be important determinants in other models, as is also the case with population. The final determinant is the environmental tax imposed in each country included in this study. This produces the following relationship, including the squared GDP term and a lagged dependent variable to account for inertia in adjustment to desired or targeted pollution levels:

[1] In a micro-based approach Brannlund *et al*. (2007) assess the use of energy based taxes on energy consumption.

$$poll_{it} = \alpha_0 + \alpha_1 poll_{it-1} + \alpha_2 pcy_{it} + \alpha_3 pck_{it} + \alpha_4 tax_{it} + \alpha_5 pop_{it} + u_{it} \qquad (1)$$

Where $poll_{it}$ is a pollution index (total greenhouse gas emissions) in the first model and energy consumption (tonnes of oil equivalent) in the second complimentary model. pcy_{it} is per capita real GDP, pcy_{it}^2 is per capita real GDP squared, pck_{it} is the per capita capital formation and tax_{it} is environmental taxes expressed as a proportion of both GDP and total tax revenue, pop_{it} is population (All variables in logarithms, except taxes which are expressed as a percentage).

It is often assumed in the empirical literature that per capita income will have a non-linear relationship with pollution, as originally observed by Grossman and Krueger (1995), so a squared per capita GDP measure is also included in the model. They incorporated this variable to account for the inverted U-shaped relationship. The approach adopted here follows other studies, such as Stern and Common (2001) in including both a linear and non-linear squared form of per capita GDP, which should be positively and negatively signed respectively. The per capita capital variable should have a negative relationship, as increasing investment should facilitate the move to more advanced energy efficient production techniques. The environmental taxes should have a negative effect, assuming exemptions have not significantly reduced their effectiveness, as either they encourage more efficient use of resources or a reduction in energy consumption.

In this study the environmental tax revenue as a proportion of GDP and total tax revenue is used as a proxy for the tax rate. The measure of environmental tax revenue is based on the internationally recognised definition used by the Statistical Office of the European Union (Eurostat). An environmental tax is defined as any tax, which has a physical unit as a base and for which there is evidence that it has a specific effect on the environment

Although it is assumed the effect of environmental taxes on pollution and energy consumption should be negative, it may not be significant due to exemptions to energy-intensive industries. A number of studies have suggested that to maintain 'international competitiveness', the effectiveness of these taxes has been reduced through offering exemptions to these industries. Ekins and Speck (1999) note that this is a feature of member states in the EU and has important implications for the effectiveness of these taxes and welfare costs for the economies concerned.

3. Data and Results

The data is all annual and runs from 1995 (the earliest available) to 2006 and includes all the economies that are currently members of the EU[2] and for which there is data, including those that joined the EU recently, such as the transition economies (The list of countries is included in Table 1). Although the data covers the era, when some countries were not direct members of the EU, they were preparing to join and trying

[2] The EU data is used due to the recent availability of its environmental tax data and the extensive literature on the implementation of environmental tax policy in the EU. In addition the definitions of both tax revenue and the pollution index are roughly common across the EU countries in the sample, ensuring the data shares the same features across the variables in the panel. However the data only starts in 1995 for many of the countries in the sample, limiting the dataset to just 300 observations. The data was taken from the *Economic and Social Data Services (ESDS)* website, which contains the *Eurostat* database.

to conform to the more environmentally friendly policies that the EU encouraged over the sample period.

The data is taken from the *Statistics Office of the European Communities* (*Eurostat)* and includes real GDP, capital formation, the total population and the environmental tax revenue relative to both GDP and total tax revenue data. The data on pollution is an index defined as the total greenhouse gas emissions (CO_2 equivalent). The consumption of energy is defined as 'gross inland consumption' in terms of thousands of tonnes of oil equivalent. Table 1 provides the summary tax statistics for each country, the tax revenue statistics suggest that most countries collect about 3% of GDP in environmental taxes, with the Scandinavian countries having the highest mean, whilst the transition countries have the lowest.

Tables 2 and 3 include the results from the Arellano-Bover (1995) two step dynamic panel approach, using lags of the transformed and non-transformed variables in the model as instruments, with Sargan's test accepting the null that the overidentifying restrictions are valid in all cases. In the second stage of estimation any heteroskedasticity is accounted for using robust White period standard errors.

Table 2 contains the results using the measure of pollution as the dependent variable, as well as the two different measures of environmental taxes, the models are estimated with both linear and non-linear GDP measures. In all the results, regardless of specification or definition of the tax variable, environmental taxes have a negative and significant effect on pollution, suggesting as environmental taxes have risen, so air pollution within the EU has, as expected fallen. The sensitivity of the relationship between environmental taxes and the dependent variables depends on the definition of the tax variable, being roughly double for the tax relative to GDP measure. Where a 1% rise in tax relative to GDP produces approximately a 1% decline in pollution. However the tax relative to total taxes is the more significant, which supports the Goulder (1996) finding that when considering environmental taxes, the relationship with other taxes needs to be included.

There is little evidence that per capita GDP in both the linear and non-linear form have had the expected non-linear effect on pollution, which supports Harbaugh *et al*. (2002),who find that the inverted U-shaped relationship between GDP and pollution as suggested by the Kuznets curve approach does not hold between all countries and all model specifications. It could also be due to the role of the EU, as suggested by Deacon and Norman (2006) who suggest EU laws and directives during the 1980s and 1990s have required a single policy response across all member states to reducing pollution, irrespective of levels of an individual nation's income. Table 3. Has energy consumption as the dependent variable and the results suggest that environmental taxes have had little significant effect on energy consumption.

4. Conclusion

This study suggests that the recent introduction of environmental taxes in the EU has had a significantly negative effect on pollution, but limited effect on the use of energy resources. This suggests that the myriad exemptions for energy-intensive sectors of the economy have had only a limited effect on the efficacy of this policy. These results also provide support for those studies suggesting that the consequences of environmental taxes are dependent on the structure of other tax levels, as measuring environmental taxes relative to total taxes has the most significant effect. However there is mixed evidence on levels of income having any effect on pollution and energy consumption, as also found in other studies. The policy implications of these results are that the current use of environmental taxes to reduce the EU's present levels of pollution appear to be having some effect, although the relationship with other taxes needs to be considered. The lack of a significant effect on energy consumption, suggests environmental taxes are not reducing consumption, implying pollution is being reduced through the use of cleaner technologies.

References

Arellano, M., and Bover. O. (1995) Another look at the instrumental variable estimation of error-component models. *Journal of Econometrics*, **68**, 29-51.

Bosquet, B. (2000) Environmental tax reform: Does it work? A survey of the empirical evidence, *Ecological Economics,* **34**, 19-32.

Brannlund, R, Ghalwash, T., and Nordstrom. J. (2007) Increased energy efficiency and the rebound effects on consumption and emissions, *Energy Economics*, **29**, 1-17.

Deacon, R. and C. Norman, (2006) Does the Environmental Kuznets curve describe how individual countries behave? *Land Economics*, **82**, 291-315.

Ekins, P. and Speck, S. (1999) Competitiveness and exemptions from environmental taxes in Europe, *Environmental and Resource Economics*, **13**, 369-396.

Goulder, L. (1996) Effects of carbon taxes in an economy with prior tax distortions: An intertemporal general equilibrium analysis, *Journal of Environmental Economics and Management,* **29**, 271-297.

Grossman, G. and Krueger, A. (1995) Economic growth and the environment, *Quarterly Journal of Economics*, **110**, 353-377.

Harbaugh, W., Levinson, A. and Molloy Wilson, D. (2002) Re-examining the empirical evidence for an environmental Kuznets curve, *Review of Economics and Statistics*, **84**, 541-551.

Stern, D. and Commons M. (2001) Is there an environmental Kuznets curve for sulfur? *Journal of Environmental Economics and Management*, **41**, 162-178.

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Table 1. Summary Statistics regarding tax revenue (%)

	% of GDP		% of total tax	
Country	**mean**	**variance**	**mean**	**variance**
Austria	2.44	0.05	5.66	0.25
Belgium	2.34	0.01	5.20	0.06
Czech Republic	2.57	0.02	7.30	0.07
Cyprus	3.02	0.26	9.92	1.02
Denmark	5.23	0.17	10.66	0.64
Estonia	1.77	0.20	5.50	2.72
Finland	3.13	0.02	6.93	0.12
France	2.56	0.04	5.85	0.20
Germany	2.38	0.03	5.93	0.27
Greece	2.53	0.19	8.01	2.69
Hungary	2.99	0.06	7.72	0.30
Ireland	2.69	0.10	8.61	0.52
Italy	3.16	0.09	7.59	0.50
Latvia	2.29	0.22	7.59	2.74
Lithuania	1.80	0.12	6.12	1.38
Luxembourg	2.87	0.01	7.51	0.14
Malta	3.48	0.10	11.94	3.55
Netherlands	3.82	0.02	9.79	0.17
Norway	2.44	0.53	5.70	2.76
Poland	2.21	0.12	6.55	1.68
Portugal	3.19	0.06	9.41	0.97
Slovakia	1.94	0.70	6.66	1.55
Spain	2.12	0.02	6.22	0.31
Sweden	2.85	0.01	5.72	0.05
United Kingdom	2.83	0.06	7.82	0.51

Table 2 Dynamic panel models of pollution

	1	2	3	4
Poll(-1)	0.686*	0.654*	0.664*	0.632*
	(56.227)	(29.400)	(52.722)	(31.941)
Pcy	-0.002	-0.319*	0.009	-0.311*
	(0.077)	(1.996)	(0.340)	(2.253)
Pcy^2		-0.031*		-0.031*
		(2.061)		(2.443)
pcK	0.027	0.016	0.024	-0.013
	(1.121)	(0.710)	(0.949)	(0.520)
pop	0.378*	0.655*	0.332*	0.630*
	(4.770)	(4.627)	(3.582)	(4.767)
Taxy	-1.074*	-1.411*		
	(3.089)	(4.169)		
Taxt			-0.538*	-0.600*
			(4.541)	(4.834)
J-statistic	21.410	21.815	21.577	22.008
OIR(Sargan)	0.315	0.294	0.306	0.284
Observations	300	300	300	300

Notes**:** Variables are as in Equation (4), a * (**) indicates significance at the 5%(10%) levl. OIR is the Sargan test for overidentifying restrictions, with the p-value included. All models estimated using GMM and orthogonal deviations, with White period instrument weighting matrix and standard errors and covariance matrix. The instruments include the second lag of the dependent variable and first lags of the explanatory variables in both the transformed and untransformed form.

Table 3 Dynamic panel models of energy consumption

	1	2	3	4
En (-1)	0.455*	0.434*	0.427*	0.446*
	(26.540)	(20.784)	(21.490)	(16.187)
Pcy	0.001	0.191	-0.014	0.143
	(0.014)	(0.331)	(0.195)	(0.226)
Pcy^2		0.016		0.013
		(0.306)		(0.225)
pcK	0.028	0.012	0.038	0.028
	(0.454)	(0.184)	(0.705)	(0.521)
population	1.056*	0.950**	1.164*	0.994*
	(6.076)	(1.809)	(6.707)	(2.010)
Taxy	0.0104	0.097		
	(0.604)	(0.037)		
Taxt			0.363	0.268
			(0.748)	(0.350)
J-statistic	18.410	18.415	18.931	18.879
OIR(Sargan)	0.495	0.495	0.461	0.465
Observations	300	300	300	300

Notes: See Table 2.