Environmental Taxes and Economic Growth: Evidence from Panel Causality Tests

Bruce Morley and Sabah Abdullah

No. 04/10

BATH ECONOMICS RESEARCH PAPERS

Department of Economics

UNIVERSITY OF BATH

Environmental taxes and Economic Growth: Evidence from Panel Causality Tests

Bruce Morley[a*] and Sabah Abdullah[b]

[a] Department of Economics, University of Bath, Claverton Down, University of Bath, Bath BA2 7AY UK (bm232@bath.ac.uk)

[b] Department of Economics, University of Bath, Bath BA2 AY and Department of Economic Analysis and Institute of Public Economics, University of the Basque Country Avda. Lehendakari Aguirre 81, 48015 Bilbao, Spain (sa245@bath.ac.uk)

Abstract:

The aim of this study is to determine the causal relationship between environmental taxes and economic growth, using different measures of environmental taxes with GDP as well as adjusted net savings. A panel of European countries and a separate panel of OECD countries are used from 1995 to 2006 and the standard Granger non-causality approach is applied, using panel cointegration and a dynamic panel technique to estimate the error correction models. The results suggest some evidence of long-run causality running from economic growth to increased revenue from the environmental taxes, with also some evidence of short-run causality in the reverse direction. However overall there is little evidence to support the double dividend theory.

Key Words: economic growth; double dividend; environmental taxes; Granger Causality.

J.E.L.: H23, Q5, E60.

* Address for Correspondence: Department of Economics, University of Bath, Bath, UK, BA2 7AY. Tel. + 44 1225 386497, Fax + 44 1226 383423, E-mail: bm232@bath.ac.uk.

1. Introduction

Over the recent past, the European Union (EU) member states in particular and other countries in general have been set voluntary targets for the reduction in pollution and emission of greenhouse gases, which have facilitated the sometimes controversial use of environmental taxes across the world, especially the EU. 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, in order to meet targets set at the 1997 Kyoto protocol to reduce greenhouse gases.

Also, during the 1990s, beginning with the Scandinavian countries, there has been a number of attempts to introduce Environmental Tax Reform (ETR) in EU members. This has involved shifting the burden of taxation away from factors of production to pollution and the users of natural resources, summarised as a move from economic 'goods' to environmental 'bads'. Again, one of the main ways in which EU governments have attempted to do this is through the use of energy taxes, in order to encourage a reduction in carbon emissions.

The aim of this paper is to determine the direction of causality in the long and short run between economic growth and environmentally orientated taxes using two separate datasets for the EU and the Organization for Economic Co-operation and Development (OECD) countries. For the latter dataset, this allows us to not only to include the US in the study, but also use the adjusted net saving (ANS) measure of economic performance, which includes a measure of the environment, instead of gross domestic product (GDP), which is more likely to reflect changes in the environmental taxes than GDP. This paper attempts to contribute to the debate on the effects of environmental taxes on the economy, by using the EU and OECD panel data sets to determine, using standard panel Granger non-causality tests, if there is any causal link between environmental taxes and economic growth[1]. This will in addition provide evidence regarding the effectiveness of the double dividend from the use of environmental taxes[2].

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 of the study.

2. Previous Literature

To date most of the environmental and growth literature has been theory based, either using environmental taxes in an endogenous growth framework as in Bovenberg and De Mooij (1997) or as a general measure of environmental policy as in Ricci (2007). The empirical literature on this issue has mainly concentrated on the use of simulation

[1] This study uses GDP and adjusted net saving to represent economic growth. An alternative approach used in many simulation studies is to use unemployment, which is usually highly correlated with GDP. This study has not used unemployment data as in some countries such as the UK there is a strong argument that it underestimates the true value, as many who are long-term unemployed are on sick benefit instead, so do not appear on unemployment list

[2] The first part of the double dividend is that the imposition of environmental taxes improves the environment, as Bosquet (1990) notes this part is less controversial as most studies believe it is the case that the levels of pollutants are reduced

exercises rather than the use of econometric modelling, due to the lack of suitable macro-data so far.

The approach to environmental taxation in the EU has concentrated on the use of taxes to improve the environment, whilst using the revenue raised to reduce the distortionary taxation on labour and production. This policy is often regarded as producing the double dividend whereby the environment is improved and at the same time the economy benefits through the reduction in these distortionary taxes (Bosquet (2000)). However other studies (Myles, 2000) argue that for the double dividend to occur, the tax system must be inefficient, in which case a better policy would be to improve the system, rather than tax the pollutants. Nevertheless, Fisher and Van Marrewijk (1998) illustrated a theoretical model which suggests that pollution taxes can result in a double dividend.

In addition to the double dividend approach, other studies have suggested further justifications for a positive causal effect from environmental policies to economic growth. Ricci (2007) suggests a number of ways in which measures to improve the environment can enhance economic growth, such as the prospect of a better environment may encourage saving. Pautrel (2009) suggests when the reduced effects of pollution on health are taken into account, the effects of the environmental policy can be positive on the economy.

The main empirical work on environmental taxation and economic growth has centred around the use of simulations on the impact of ETR on the environment, use of natural resources and the wider economy, although Leiter *et* al. (2009) have also used the same EU environmental tax data as a determinant of investment. In their study they find that environmental tax revenue, as an example of an environmental regulation, has a positive but diminishing effect on investment. In one study on the EU (Andersen, 2007) the energy-environment-economy (E3) model was employed to calculate the effect of a carbon-energy tax on economic growth where a positive contribution of such taxes for both the environment and the economy was found, in sum the 'double dividend' theory holds as energy is used efficiently and results in increased economic growth, as long as the energy taxes were used to reduce distortionary taxes, such as labour. Also, studies like Patuelli *et al.* (2005) and Anger *et al.* (2010) focussed on a meta-analytical approach in analyzing the effects of environmental taxes on the economy and double dividend, which involves the use of regression techniques to determine the effects from simulation studies within the current literature on the double dividend. As far as we know there have been no econometric studies in general or Granger non-causality studies in particular on the relationship between environmental taxes and economic growth[3].

3. Environmental Taxes and Economic Growth

Pearce (1991) originally referred to the 'double dividend' theory, where there are two positive benefits of environmental taxes: increased environment protection and reduced distortionary taxes on the economy. This theory has on the one hand won over environmentalists who support taxes on environmental externalities and claiming

[3] There is an extensive literature on the effects of various taxes other than environmental, on economic growth, such as Lee and Gordon (1995), which tend to find a negative relationship between taxes and economic growth, although it depends on the form of the taxation. The most distortionary taxes are usually considered to be taxes on labour and capital

that revenue recycling of this tax in the economy offsets distotionary taxes for labour and firms. Economists on the other hand, have argued environmental or pollution taxes affect economic development thereby reducing the competitiveness of firms. Goulder (1995) distinguishes two forms of double dividend namely: weak and strong. The former, a less controversial one than the latter, describes revenue recycling of environmental tax to lower distortionary taxes hence providing a greater efficiency gains than handing back a lump sum to those who pay the tax.

Environmental taxes can affect the economy in a number of ways, but if the double dividend holds, we would expect the environmental taxes to have a positive and significant effect on the economic growth, whether measured by GDP or adjusted net savings. Causality could also run in the opposite direction from GDP to taxes, as a rise in the income and wealth of a country increases the ability and inclination of a country to pay the higher environmental taxes.

3.1. Environmental Tax Measures

The measure of environmental tax revenue is based on the internationally recognised definition used by the Statistical Office of the European Union (Eurostat) and accepted by the main international bodies, such as the OECD. 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[4]. In this study the EU data is

[4] As recognised in other studies, there is some debate over what counts as a tax, in particular the use of earmarked sources of revenue, as discussed in Newbery and Santos (1999). For the benefit of this study we rely on the definitions used by Eurostat, which is common across all the countries in the study. As

environmental tax revenue as a proportion of GDP and total tax revenue is used as a proxy for the tax rate.

The data on environmental tax revenue is predominantly comprised of taxes on transport and energy products, such as the duty charged on hydrocarbons in the transport sector, as well as the industrial sector. It also includes the fossil fuel levy, which is a tax on electricity generated using fossil fuels. A recently introduced tax is the climate change levy, including petroleum, gas, coal and electricity. Further related tax sources include vehicle excise duty, the VAT applied to petroleum and the air passenger duty, which applies to air travel within the European Economic Area (EEA), but at a lower rate with countries outside the EEA. The transport taxes relate to the ownership and use of motor vehicles, which makes it comparable to the OECD data. However taxes on aeroplane flights are also included. The taxes refer to both recurrent and one-off taxes, such as road tax and sales of equipment respectively.

3.2. Transport Taxes

In European areas, the transport and energy taxes initially served as an energy security measure however in recent years the trend has shifted towards an environmental one (Davoust, 2008). There are about 375 environmentally related taxes in the OECD and about 90% of the revenues received from these taxes relate to motor vehicle fuels and motor vehicles (OECD, 2006). Among the EU 27 member states, the energy tax represents 75% of the environmental taxes of which 80% of this tax are from fuel taxes found in the transport sector (Eurostat, 2009). There is large variation in the fuel

noted earlier this is a macro based study using aggregated data for both taxes, pollution and energy consumption, data on a more disaggregated level is not currently available.

tax burden among the EU member states, in particular with regard to the proportion of transport taxes. In the transportation sector, two commonly used fuels are diesel and gasoline. The former is predominantly used in commercial vehicles such as freight transport whereas the latter which is unleaded and consumed in private vehicles. The estimated CO_2 emission in gasoline is at 22.2 pounds/gallon compared to diesel at 19.4 pounds/gallon (US Environmental Protection Agency (EPA) 2005).

On the one hand, an increase in transportation taxes impacts on households and firms which in effect changes the mode of transport i.e. from private to public transport. On the other hand, this type of tax is primarily for revenue generation where the revenue obtained from this transport related tax is said to be recycled back to the transportation sector for the construction and maintenance of roads. Indeed, about 2-2.5% of GDP is revenue raised from environmentally related fees and charges, of which about 90% of the revenue stems from taxes on motor vehicle fuel tax and motor vehicles (OECD, 2006). For this study the transport taxes i.e. the fuel taxes from diesel and unleaded gasoline for commercial use were obtained from the IEA in percentages and were converted into US$ per litre for the years 1995-2006 (IEA, 2008).

3.3. Adjusted Net Savings

This study also incorporates adjusted net savings (ANS) also referred to as genuine savings which measures the economic growth in a sustainable manner. The difference between GDP and ANS is that the former measures the physical capital whereas the latter incorporates the monetary values of physical, human, natural and social capital as well as the stock of knowledge. The dataset is found at the World Bank in the

World Development Indicators (WDI), which contains all country-level and regional data as estimated by the World Bank (2008).

There was a strong need among academics, researchers and international institutions in particular the World Bank, to establish an indicator that accounts for sustainability in economic development as GDP per capita was an insufficient criterion. The World Bank calculates ANS as: total net national saving and education expenditure minus the resource rents (depletion of energy, minerals and forest) and carbon dioxide (CO_2) damage. Since the ANS index was established numerous discussions have emerged about its properties. Studies such as Hamilton and Clemens (1999) suggest that 'genuine saving' is a useful indicator of sustainability however others like Pillarisetti (2005) argue that environmental sustainability needs to be examined in a global context and that natural capital should be treated independently of physical and human capital. In one recent empirical study by Gnègnè (2009) where he examined ANS and welfare changes, he points out that the World Bank ANS is a step forward in understanding sustainability though more effort is required to improve it.

4. Methodology

Although the specific techniques differ, the general approach to Granger non-causality tests, either using time series or panel data, involve the application of cointegration techniques with the subsequent error correction model (ECM) used to test for short and long-run causality (Granger *et al.* 2000)[5]. When following this approach, the first step involves testing for a panel unit root and in this study the popular Im Pesaran and Shin (IPS) test is used. If the variables are found to be I(1),

[5] Examples of panel causality tests include Apergis (2004).

we then need to test for cointegration, in this case using the Kao (1999) test. This test is used instead of the Pedroni test as although it can only be used in a bi-variate context, Gutierrez (2003) suggests in a homogenous panel it has higher power than the Pedroni tests when, as in this study, the time series component is relatively short. Given the following model:

$$y_{it} = \gamma_0 + \gamma_1 e_{it} + \varepsilon_{it} \tag{1}$$

Where y_{it} is GDP (in logarithms) and e_{it} is the environmental tax (if testing for causality running the opposite direction, e_{it} would be the dependent variable). The Kao test (1999) is then used to test for cointegration and is based on a panel version of the ADF test on the residual (ε_{it}):

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + \sum_{j=1}^{k} \gamma_j \Delta\varepsilon_{i,t-j} + v_{it} \tag{2}$$

This can be used to produce the following ADF statistic, where $\hat{\sigma}_v^2$ is the estimated variance and $\hat{\sigma}_{0v}^2$ is the estimated long-run variance of the error term and follows the standard normal distribution. τ_{ADF} is the ADF statistic for equation (2):

$$ADF = \frac{\tau_{ADF} + \sqrt{6N}\hat{\sigma}_v / (2\hat{\sigma}_{0v})}{\sqrt{\hat{\sigma}_{0v}^2 / (2\hat{\sigma}_v^2) + 3\hat{\sigma}_v^2 / (10\hat{\sigma}_{0v}^2)}} \tag{3}$$

The long-run relationship and consequent error correction term is then based on a dynamic OLS or DOLS model[6]. Then as noted by Granger *et al*. (2000), the long-run causality can be measured by the significance of the error correction term, whilst the short-run causality can be measured by the joint significance of the lagged explanatory variables. This gives the following specification:

$$dy_{it} = \alpha_0 + \sum_{q=1}^{n} \alpha_{iq} de_{it-q} + \sum_{q=1}^{n} \beta_{iq} dy_{it-q} + \delta\varepsilon_{it-1} + u_{1it} \tag{4}$$

$$de_{it} = \phi_0 + \sum_{q=1}^{n} \phi_{iq} de_{it-q} + \sum_{q=1}^{n} \gamma_{iq} dy_{it-q} + \lambda\varepsilon_{it-1} + u_{2it} \tag{5}$$

Where dy_{it} is the differenced real per capita GDP and is equivalent to economic growth and de_{it} is the differenced environmental tax. The ε_{it} is the error term from the DOLS estimate and represents the error correction term, which is assumed to be negative. As with Granger *et al*. (2000), long-run causality is measured by the standard t-statistic, whilst the lagged explanatory variables measure short-run causality, in this case using a t-test.

These non-causality ECM models are then calculated using the Arellano-Bover approach (1995) to dynamic panels, to remedy the potential problem of correlation between the lagged dependent variable and fixed effects, which could induce bias in the results. The Arellano-Bover dynamic panel removes the individual effects in the panel, using orthogonal deviations, where Generalised Method of Moments (GMM) is

[6] DOLS involves estimating the long run bi-variate relationship with the inclusion of a lead and lag of the differenced explanatory variable and has better properties than other competing techniques

used to estimate the model. Bond (2002) suggests the Arellano-Bover approach may have some advantages over other approaches to dynamic panel models, as it has better small-sample properties.

In addition we expect the error correction term to be negative to ensure the model is stable and the coefficient represents the speed of adjustment following an exogenous shock. To test the overidentifying restrictions imposed by the use of GMM, we use the Sargan test. In addition we use time dummy variables to model the time series fixed effects, as in part this models the business cycle and also it models the rapid changes in environmental regulations in the EU recently. A test of joint significance of these dummy variables shows they are highly significant.

5. Data and Results

The data used in this study is annual and runs from 1995 to 2006, starting in 1995 as this is the earliest data available for the environmental tax measures. The EU panel consists of twenty three countries all from the European Union[7] All the EU data is taken from *Eurostat* at the *European Communities,* consisting of environmental taxes as a percentage of GDP as well as total tax revenue. In addition we have used transport taxes again as a percentage of GDP and total taxes, to compliment the OECD database of diesel and gas taxes. The GDP is real per capita GDP. The OECD

[7] The countries used are listed in Table 1. and are limited by the data availability for some countries. However the data includes transition economies too, who were required to improve their environments as a condition for joining the EU during the 1990s. European data is used as it is compatible across all the countries used and the variables used are defined in a similar way across these countries.

dataset consists of all OECD countries where there was sufficient data (See Table 2), the diesel and gas taxes are also taken from the OECD where the taxes are defined as the level of tax in dollars per gallon of gas/deisel. The adjusted net savings data is as explained earlier taken from the World Bank.

Table 1 includes the summary statistics for both transport and total environmental taxes relative to GDP and total tax revenue, both follow a similar pattern overall. As is evident the countries that use environmental taxes the most tend to be Scandinavian. Denmark relies on these taxes more than any other country, with about 5% of GDP and 10% of total tax revenue being collected in the form of environmental taxes. Transport taxes tend to make up about 1% of GDP and 2% of total tax revenue, with a relatively low variance across the EU. In general some of the Eastern European countries collect the lowest proportions, with the Baltic states being the lowest. The same pattern is followed with the OECD dataset as shown in Table 2, in that the UK, Switzerland and Norway have the highest average taxes on its fuel, with the USA not surprisingly having the lowest.

The results for the IPS panel unit root tests are presented in Table 3 and show that overall all three variables contain a unit root, suggesting the need to difference these variables before testing for non-causality. The cointegration tests are contained in Table 4 for the EU dataset and Table 5 for the OECD dataset, with the Kao test for cointegration results on the EU dataset showing evidence of a stable long-run cointegrating relationship only when taxes are the dependent variable and taxes are as a proportion of GDP. However, when GDP is the dependent variable there is no evidence of a long-run relationship. Nevertheless with the OECD dataset, there is evidence of a stable long-run relationship between environmental taxes and GDP/ANS, but again only when the tax variables are the dependent variable.

Based on these results we conclude that although there is some evidence of a stable long-run relationship when the taxes are the dependent variable, there is no evidence for it when GDP/ANS are the dependent variables. Where there is evidence of cointegration, the error correction term will be included in the non-causality tests, but excluded where there is no evidence as in Granger *et al*. (2000).

Tables 6 and 7 contains the results from the GMM estimation of the ECMs using the Arellano-Bovver approach and the results indicate little evidence of any short-run causal effect running from the environmental taxes or transport taxes[8] to economic growth using the EU or OECD data, as evidenced by the lack of significance of the lagged explanatory variable. This offers tentative support for other studies which find either little or ambiguous evidence of the double dividend as noted in Bosquet (2000) and Anger *et al*, (2010). However there is evidence of short-run causality from GDP to environmental taxes relative to GDP and transport taxes relative to total taxes, but it is negatively signed, which may be due to overall tax revenue rising during times of economic growth, so requiring less need for the environmental taxes.

[8] Energy and pollution tax data was also available, but produced similar results to transport taxes so are not included. Results available from the authors on request.

The significant error correction term backs up the evidence of long-run causality running from GDP to general environmental taxes relative to GDP, suggesting as countries become richer, they are more inclined to use environmental taxes. The Sargan test of the overidentifying restrictions indicates the null is accepted in all cases, suggesting the instruments used in the GMM estimation are acceptable. In addition the F-test on the joint significance of the time dummies, suggests all are jointly significant so need to be included in the causality tests.

Using the OECD dataset, the significant error correction terms suggest there is long-run causality running from GDP to the gas and diesel taxes, which again backs up the cointegration tests. There is also a positive short-run effect from GDP to diesel taxes, which may suggest as the economy grows, the use of freight increases, which increases the tax taken from diesel. The adjusted net savings data suggests much the same as GDP, although there is evidence of short run causal effects from the gas taxes to the net savings, which is negative. This suggests that in the short term greater use of gas taxes may harm aspects of the economy.

The error correction terms are negative when causality runs to the environmental taxes indicating stability although the speed of adjustment depends on the measure used, being between 20 and 50% of adjustment back to the long-run in a year. These results accord with other studies that suggest results are sensitive to the measurement of the environmental variables (See Jeppesen, List and Folmer, 2002), although diesel and gas taxes tend to be more significant than the general environmental tax measures used by the EU.

6. Conclusion

These results provide some evidence of a long-run causal effect from GDP and net adjusted savings to environmental and/or transport taxes, however there is little evidence of long-run causality in the other direction with the EU or OECD environmental tax data. This suggests there is little evidence that an expansion of environmentally friendly policies will enhance economic growth through the double dividend. The policy interpretation is that more smart approaches for efficient instruments to promote sustainable economic growth and at the same time managing the natural resources and controlling pollution levels efficiently is required. Hence, the link between environmentally related taxes and environmental development in association with revenue recycling is important. For instance, in some OECD countries, the motor fuel and motor vehicles taxes are spent on the construction or maintenance of roads and other activities such as: installation of noise-protection walls, development of bicycle lanes and improvement in public transport (OECD, 2006). Hence, future research can assess the magnitude of such revenue recycling in environmental development against the levels of the tax burden for countries.

Also, with the OECD data, both diesel and gas taxes have no long-run causal effect on output. There is also no causal relationship from gas or diesel taxes to adjusted net savings, suggesting that our failure to find support for the double dividend is not due to limitations with GDP as a measure of welfare. Unfortunately, there is no data on the use of biofuels over this time period, which is an important area for future research as more data becomes available. Overall the evidence suggests richer countries are more able to afford the costs associated with the environmental taxes, although as with other results the effect is sensitive to the measure of the environmental policy used.

In summary, this study suggest for country's to meet their pollution targets, environmental taxes and the associated increase in renewable energy will probably need to continue but it is imperative to link these actions to economic development. Moreover, future research will need to concentrate on more countries, such as the specific USA data and China and over longer time periods as the data becomes available for the exploration of the underlying effects of changes in environmental taxes to environmental externalities.

REFERENCES

Andersen, M.S., 2007. Carbon-energy taxation contributed to economic growth. National Environment Research Institute News.

Anger, N., Bohringer, C., A. Loschel, 2010. Paying the piper to call the tune? A meta-regression analysis of the double-dividend hypothesis. Ecological Economics, (forthcoming).

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

Apergis, N., 2004. Inflation, output growth, volatility and causality: Evidence from panel data and the G7 countries. Economics Letters, 83, 185-191

Bond, S., 2002. Dynamic panel data models: A guide to micro data methods and practice. Portuguese Economic Journal 1, 141-162

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

Bovenberg, A, de Mooij, R., 1997. Environmental tax reform and endogenous growth. Journal of Public Economics, 63, 207-237.

Davoust, R., 2008. Gasoline and diesel prices and taxes in industrialized countries. Note de l'ILFRI. Available at: http://www.ifri.org/files/Energie/Davoustang.pdf.
[Accessed on 06/3/2010]

Fisher, E.O., van Marrewijk, C., 1998. Pollution and economic growth. Journal of International Trade & Economic Development, 7, 155-69

Eurostat, 2009. EU27 Tax Ratio at 39.8% of GDP in 2007.Available from: http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/2-22062009AP/EN/222062009-AP-EN.PDF. [Accessed on 04/3/2010]

Goulder, L. H., 1995, Environmental taxation and the 'Double Dividend': A reader's guide. International Tax and Public Finance 2, 157-184

Gnègnè, Y, 2009. Adjusted net saving and welfare change. Ecological Economics, 68, 1127-1139

Granger, C.W.J., Huang, B., C.W. Yang, 2000. A bivariate causality between stock prices and exchange rates: Evidence from recent Asian flu. Quarterly Review of Economics and Finance, 40, 337-355

Gutierrez, L. 2003, On the power of panel cointegration tests: a Monte Carlo comparison, Economics letters 80, 105-111.

Hamilton, K., Clemens, M., 1999. Genuine savings rates in developing countries. The World Bank Economic Review, 13, 333-356.

International Energy Agency (IEA), 2008. Energy prices & taxes, Quarterly statistics, Paris, France: International Energy Agency (IEA)

Jeppesen, T., List, J., Folmer, H. 2002. Environmental regulations and new plant location decisions: Evidence from meta-analysis. Journal of Regional Science, 42, 19-49

Kao, C., 1999. Spurious regression and residual based tests for cointegration in panel data. Journal of Econometrics, 90, pp. 717-738.

Lee, Y , Gordon, R. 2005. Tax structure and economic growth. Journal of Public Economics, 89, 1027-1043

Leiter, A.M, Parolini, A., H. Winner, 2009. Environmental regulation and investment: Evidence from European Industries, Faculty of Economics and Statsitics University of Innsbruck Working Papers 2009-04.

Myles, G., 2000, Taxation and Economic Growth. Fiscal Studies, 21, 141-168

Patuelli, R., Nijkamp, P., Pels, E., 2005. Environmental tax reforms and the double dividend: A meta-analytical performance assessment. Ecological Economics, 55, 564-583

Pautrel, X., 2009, Pollution and life expectancy: How environmental policy can promote growth. Ecological Economics, 68, 1040-1051

Pearce, D., 1991. The role of carbon taxes in adjusting to global warming. Economic Journal, 101, 938-948

Pillarisetti, J.R., 2005. The World Bank's 'genuine savings' measure and sustainability. Ecological Economics, 55, 599–609

Ricci, F., 2007. Channels of transmission of environmental policy to economic growth. Ecological Economics, 60, 688-699

OECD, 2006. The political economy of environmentally related taxes, policy brief, OECD. Available at: http://www.oecd.org/dataoecd/26/39/38046899.pdf [Accessed on 03/10/2009]

US Environmental Protection Agency (EPA), 2005. Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel. Office of Transportation and Air Quality, Report no: EPA420-F-05-001

World Bank, 2008. World Development Indicators 2008. The World Bank, Washington.

Table 1. Summary Statistics regarding tax revenue for EU (%)

	Total environmental taxes				Transport Taxes			
	% of GDP		% of total tax		% of GDP		% of total tax	
Country	mean	var	mean	var	mean	Var	mean	Var
Austria	2.44	0.05	5.66	0.25	0.79	0.01	1.82	0.04
Belgium	2.34	0.01	5.20	0.06	0.66	0.00	1.47	0.01
Czech	2.57	0.02	7.30	0.07	0.29	0.01	0.83	0.05
Cyprus	3.02	0.26	9.92	1.02	1.93	0.06	6.51	2.11
Denmark	5.23	0.17	10.66	0.64	2.04	0.04	4.14	0.13
Estonia	1.77	0.20	5.50	2.72	0.17	0.01	0.53	0.06
Finland	3.13	0.02	6.93	0.12	1.06	0.02	2.35	0.10
France	2.56	0.04	5.85	0.20	0.61	0.00	1.40	0.02
Germany	2.38	0.03	5.93	0.27	0.37	0.00	0.92	0.00
Greece	2.53	0.19	8.01	2.69	0.82	0.01	2.57	0.09
Hungary	2.99	0.06	7.72	0.30	0.37	0.02	0.97	0.13
Ireland	2.69	0.10	8.61	0.52	1.25	0.01	3.99	0.06
Italy	3.16	0.09	7.59	0.50	0.45	0.00	1.09	0.03
Latvia	2.29	0.22	7.59	2.74	0.22	0.02	0.74	0.28
Lithuania	1.80	0.12	6.12	1.38	0.66	0.04	2.26	0.47
Luxembourg	2.87	0.01	7.51	0.14	0.13	0.00	0.33	0.00
Malta	3.48	0.10	11.94	3.55	2.13	0.06	7.36	2.23
Netherlands	3.82	0.02	9.79	0.17	1.34	0.01	3.43	0.02
Poland	2.21	0.12	6.55	1.68	0.22	0.00	0.64	0.04
Portugal	3.19	0.06	9.41	0.97	1.00	0.01	2.94	0.09
Spain	2.12	0.02	6.22	0.31	0.41	0.00	1.21	0.00
Sweden	2.85	0.01	5.72	0.05	0.33	0.00	0.66	0.00
UK	2.83	0.06	7.82	0.51	0.54	0.00	1.51	0.03

Notes: Var is the variance.

Table 2. Summary Statistics for OECD (in US$ per litre)

	Diesel taxes		Gas taxes	
Country	mean	variance	mean	variance
Austria	0.36	0	0.69	0.01
Belgium	0.37	0	0.82	0.01
Czech	0.31	0.01	0.54	0.01
Finland	0.36	0	0.85	0.01
France	0.45	0	0.89	0.01
Germany	0.46	0.01	0.83	0.01
Greece	0.31	0	0.57	0.02
Hungary	0.40	0.02	0.80	0.05
Ireland	0.41	0.01	0.68	0.01
Italy	0.48	0	0.86	0.01
Netherlands	0.42	0	0.94	0.02
Norway	0.53	0.01	0.95	0.01
Poland	0.25	0	0.50	0.01
Portugal	0.41	0.01	0.74	0.03
Slovak	0.40	0.01	0.57	0.01
Spain	0.35	0	0.62	0.01
Sweden	0.39	0	0.81	0.01
Switzerland	0.57	0	0.61	0.01
UK	0.75	0.01	0.89	0.02
USA	0.13	0	0.12	0

Notes: These values represent the amount of tax in a litre of fuel in US dollars.

Table 3. IPS Unit root tests

	EU			OECD			
Variable	Description	level	differenced	Variable	Description	level	differenced
Y	real GDP per capita	4.126	-2.663*	Y	real GDP per capita	2.414	-2.271*
taxt	total environment taxes to total taxes	0.785	-5.993*	Ans	Adjusted net saving	3.614	-2.866*
taxy	total environment taxes to total GDP	0.278	-5.879*	Dtax	diesel tax	0.775	-2.246*
trantaxt	transport taxes to total taxes	-0.212	-8.383*	Gtax	gas tax	1.395	-1.657*
trantaxy	transport taxes to total GDP	-0.171	-8.131*				

Notes: * indicates significance at the 5% level (one tailed test). Lag length determined by modified Akaike Information Criteria.

Table 4. Tests for Cointegration

Test Statistic	Y/tax	Tax/Y
Y/taxy	1.732	-2.973*
Y/taxt	1.846	-1.374
Y/trantaxt	2.136	0.661
Ytrantaxy	1.833	-1.096

Notes: * indicates rejection of the null hypothesis of no cointegration at the 5% level.In the first and second columns, the dependent variable in the cointegrating relation is first followed by the explanatory variable.

Table 5. Tests for Cointegration in OECD Dataset

Test Statistic	tax→y	y→tax
Y/Dtax	3.151	-4.226*
Y/Gtax	3.119	-6.180*
ANS/Dtax	-0.397	-4.105*
ANS/Gtax	-0.716	-6.025*

Notes: See Table 3.* indicates rejection of the null hypothesis of no cointegration

Table 6. Granger Causality Tests with EU Data

Causality direction	ECT (t-statistic)	Lag coefficient (t-statistic)	Sargan (p-value)	F-test (time dummies)
TAXT→Y		-0.005(3.848)*	0.244	48.153*
Y→TAXT		-0.443 (0.368)	0.298	69.828*
Y→TAXY	-0.360 (5.994)*	-0.938 (2.140)*	0.712	69.242*
TAXY→Y		-0.011 (3.531)	0.318	56.060*
TRTAXT→Y		-0.047 (0.039)	0.485	25.447*
Y→TRTAXT		-0.017 (4.524)*	0.290	3.871*
TRTAXY→Y		-1.174 (0.302)	0.497	19.167*
Y→TRTAXY		0.0003 (0.146)	0.178	5.290*

Notes: See Table 3. ECT is the error correction term. The instruments used in the GMM estimation were the second lag of the dependent variable and the yearly dummies. The fourth column contains the p-value for the Sargan test for overidentifying restrictions, the fifth column is a F-test on the joint significance of the time dummies.

Table 7. Granger Causality Tests with OECD Data

Causality direction	ECT (t-statistic)	Short-run causality	Sargan test (p-value)	F-test (time dummies)
DTAX→Y		-0.003 (0.084)	0.252	84.021*
Y→DTAX	-0.273 (5.708)*	1.493 (1.870)**	0.235	104.787*
GTAX→Y		0.029 (1.418)	0.242	103.805*
Y→GTAX	-0.457 (4.951)*	-0.069 (0.114)	0.473	174.00*
DTAX→NS		0.194 (0.981)	0.361	49.841*
NS→DTAX	-0.285 (3.614)*	-0.057 (0.329)	0.277	148.286*
GTAX→NS		-0.335 (2.497)*	0.501	25.491*
NS→GTAX	-0.466 (5.319)*	-0.042 (0.408)	0.319	110.721*

Notes: See Table 3 The instruments used in the GMM estimation were the second lag of the dependent variable and the yearly dummies. The fourth column contains the p-value for the Sargan test for overidentifying restrictions, the fifth column a F-test on joint significance of the time dummies