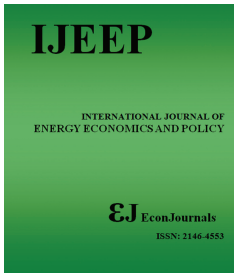

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Green Tax Reform and Employment Double Dividend in European and Non-European Countries: A Meta-Regression Assessment

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ABSTRACT

In this paper we present a meta-regression analysis of simulation studies concerning green tax reform (GTR). Our study investigates the employment effect of GTR across European and non-European countries. The existing literature postulates that employment double dividend (EDD) is achievable; however, the majority of the studies come from European countries. In this paper, we compared the performance of GTR led EDD in European and non-European contexts to observe whether there is any notable difference across country groups. Our results show that both tax and tax revenue recycle policies play a significant role in determining the employment effect. However, the optimal policy mix is not identical for European and non-European countries. Region specific policy design is required for optimal employment effect.

Keywords: Green Tax Reform, Employment, Employment Double Dividend
JEL Classifications: H23; H21; E24; Q52

1. INTRODUCTION

Ecological taxation, also known as green tax or environmental tax, is an alternative form of taxation that addresses the failure of environmental preservation in a free market economy. The negative environmental externalities of free market activities are often not fully accounted for, which is a major impediment in sustainable development (UNDP, 2003). Although some progress has been made towards the path of sustainable development, it is far from what is required and the trend shows a lack of commitment among developed countries (Moran et al., 2008).

A step towards ecological taxation, moving from the contemporary tax regime, is known as a green tax reform (GTR) or a green tax shift. The environmental efficacy of green tax in reducing pollution is well accepted in mainstream economics and is often recommended as an effective tool to internalise the negative externalities of economic development; i.e., pollution. The early empirical evidence in favour of GTR in resolving environmental externalities came from the initiatives taken by the European Union (EU) (Capros et al., 1996). A tax on pollution internalises the external cost of pollution as businesses need to pay for the right to pollute. This helps to implement the "polluter pays" principle by confronting the producer with the economic and social costs generated by pollution.

The notion of an ecological tax was first coined by the British economist, Arthur Cecil Pigou in his book The Economics of Welfare back in 1920. Research interest around the idea of environmental taxation continued to grow and the first major breakthrough came in 1967 when Gordon Tullock pioneered the idea of a possible second dividend of GTR in his article Excess Benefit. The broad literature on the double dividend (DD) hypothesis of GTR spawned from his early work, which was

augmented by the contributions of numerous other researchers (Terkla, 1984; Lee and Misiolek; 1986, Pearce, 1991). In the usual view of DD hypothesis, the first dividend covers the environmental externality of economic activities, whereas the second dividend encompasses the non-environmental welfare benefits; e.g. higher GDP or employment, or lower unemployment rates. However, there is no strict parametric definition of the first or the second dividend. Here, we use the one proposed by Giménez and Rodríguez (2010), in which the first dividend measures the reduction of external cost enabled by the environmental tax and the second dividend measures the welfare benefit that arises from recycling environmental tax revenues. Many researchers have studied a myriad of different approaches to yield non-environmental second dividend, ranging from fiscal benefits (Morris et al., 1999), economic growth (Garbaccio et al., 1999), economic welfare (Jorgenson and Wilcoxen, 1993) and employment (Pearce, 1991).

In this paper, we predominantly focus on the possibility of gaining a second dividend in the form of employment. Pioneered by Pearce (1991), this line of reasoning is often regarded as the employment double dividend (EDD). The pivotal notion of this hypothesis is that an employment driven revenue-neutral tax reform can effectively solve two problems: The environmental problem, by putting a cost on pollution, and the unemployment problem, by curtailing payroll and other distortionary taxes that hinder employment (Pearce, 1991; Repetto et al., 1992; Oates, 1993). With these reductions, labour becomes cheaper in comparison to capital since it is a stylised fact that energy and capital are complementary factors of production in the short run (Finn, 1983). The theoretical consequence of this is a rise in employment on an aggregate level.

Since the realisation of global warming and related negative impacts, there has been a notable paradigm shift in the global community towards cleaner energy production to mitigate climate change. The number of countries that have renewable energy policy targets (173) has doubled between 2008 and 2015 (Sawin et al., 2016). Although energy demand is growing, a fifth of the world's electricity is now produced by renewable energy (Sawin et al., 2018). This shift from burning fossil fuels to using renewable sources for generating energy is still increasing and is expected to double by 2030, compared to 2014 levels (IRENA, 2016). All the leading global economies are continuously increasing their investment in renewable energy with China being the highest annual investor, followed by United States, United Kingdom, Japan and Germany (Appavou et al., 2017). A compound annual growth rate of 15% from 2004 to 2017 in renewable energy investment sets forth the global trend of energy production, shifting from conventional methods of generating energy (Management, 2018).

The net effect of this shift on employment is difficult to gauge. Low carbon intensive technologies have the potential to create more jobs as they are more labour intensive (Fankhaeser et al., 2008). According to Markandya et al. (2016), 530,000 net jobs have been created in the EU due to this structural change. However, there are opposing views on employment effect of renewable energy projects. According to Morris et al. (2009), a large portion of the jobs created through green movements are clerical and they are, therefore, unproductive and unsustainable in the long run. In addition, the rise of automation and artificial intelligence could further increase future unemployment rates (Arntz et al., 2016). The multifaceted costs of unemployment, starting from economic, psychological and social factors have insidious effects on society. The nexus between unemployment and crime is well established in the mainstream literature (Cantor and Land, 1985). Unemployment also entails diminishing self-esteem that ramifies through increased cannabis use and alcohol misuse (Boden et al., 2017). The causal relationship between unemployment and adverse health outcomes is also well recognised (Jin et al., 1995). All these adverse effects of unemployment have economic costs and can become very expensive for the society in general, if left unchecked.

The already weakened global economy faces many impediments under the risk of future contractions of world economic growth (Cashin et al., 2017). Coupled with burgeoning automation and its adverse impact on employment, we believe that any economic policy measure should incorporate the employment effect in the policy design. Hence, we have narrowed our focus to an employment led double dividend, which can be yielded through GTR.

There is a rich body of theoretical work addressing different aspects of GTR driven EDD, but empirical findings are relatively scant. The aim of our paper, therefore, is to establish a nexus between disparate findings from all the contemporary empirical simulation studies on EDD. Several previous meta-regression analyses synthesised the simulation results and studied different aspects of the results. Bosquet (2000) presents a qualitative survey, demonstrating that EDD can be achieved in the short to medium term. The survey of Maxim and Zander (2019) presents the differences between the European and non-European approaches in creating EDD through GTR. The work of Patuelli et al. (2005) shows how strongly certain model characteristics and policy design can influence the possibility of creating EDD. Anger et al. (2010) investigates the implications of contracting bodies on the simulation results concerning EDD.

Our meta-regression analysis complements the existing literature by presenting a comparative analysis of the employment effect between European and non-European countries, identifying the central determinants of the employment effect in these two separate regions. The dominant focus of previous meta-regression analyses has been the European countries, but we employ a large pool of simulation studies coming from non-European countries, which makes this paper unique compared to previous meta-regression analyses[1].

The remainder of the paper is structured as follows. Section two introduces and further discusses the DD hypothesis. Section three defines the methodology and describes the database used

1 Of the simulations studied in this paper, 33.5% are from non-European countries.

in this study. Section four summarises the key findings of the meta-regression analysis and section five provides the concluding remarks and overall policy implications of our findings.

2. GTR AND DOUBLE DIVIDEND

2.1. Prefatory Remarks

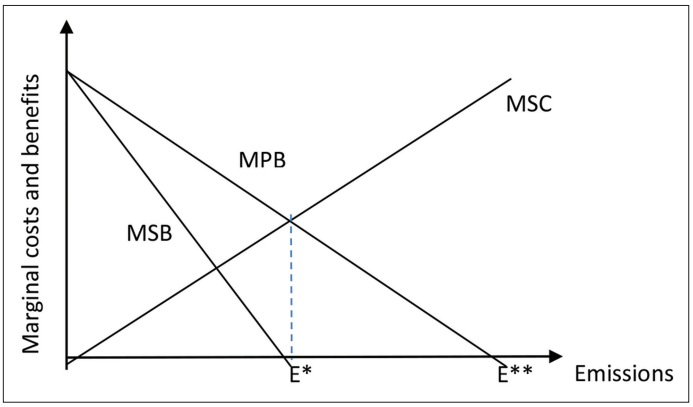
The early version of the DD hypothesis can also be labelled as the "efficiency double dividend," in which the essence of the hypothesis was that a GTR can reduce pollution and at the same time increase economic efficiency[2]. In the early studies encompassing DD, more emphasis was given to the first dividend, assuming that revenue recycling and reduction of other distortionary taxes could automatically improve non-environmental welfare. Figure 1 depicts the rationality behind this assumption under a partial equilibrium approach. The MPB curve represents the marginal private benefit of environmentally damaging activities, the MSB curve represents the marginal social benefit (benefit net of externality), and the MSC curve characterises the marginal social cost of such activities. Without any regulation, private benefit solely determines the level of emissions, which is represented by E** in Figure 1, whereas social optimum E* is determined by the intersection of MSC and MPB. Any amount of emission above E* signifies an inefficient allocation of resources. The level of tax that can bring emissions from E** to E* is the Pigouvian level, as this level of tax can fully internalise the external cost of emissions. Therefore, any tax lower than the Pigouvian level is not distortionary (it is assumed that there is no deadweight loss from green taxes).

However, the arguments against the efficiency of the DD hypothesis continued to mount (Goulder, 1995; Bovenberg and Goulder, 1996; Bovenberg, 1999) and it was later understood that the simple notion of a significant second dividend of GTR is not as meek as it was previously thought. The efficiency led argument can only be true if the existing tax system is inefficient in the first place. Under this scenario, revenue of the contemporary tax system must be completely substituted by the revenue generated from green taxes, as it can create a tax interaction effect otherwise[3]. However, the tax base of green taxes is too narrow, thus making it almost impossible to substitute the revenue of income, payroll and other distortionary taxes with a GTR. Even though green tax has the potential to generate higher revenue by utilising resource rent and expanding to other forms of industrial pollution along with emission of greenhouse gases (GHG), in the current scenario it is unrealistic to expect such a major reform anytime soon. Therefore, any significant second dividend is the result of the net of tax interaction effects, and to create a DD it is important to ensure that the balance is maintained between the economic losses of GTR and the welfare created by revenue recycling (Patuelli et al., 2005).

2.2. The Need for a Significant Second Dividend

During this post financial crisis era, it is quite rational to assume that economic consolidation is prioritised higher (for most nations) than climate change or environmental preservation. The case of the USA is a noteworthy example that supports this assumption (McCarthy, 2012). In addition, public acceptance of environmental tax policies has always been a challenge due to lack of trust among the general public about a proper use of tax revenue (Dresner et al., 2006a; Dresner et al., 2006b). Such public sentiment makes governments reluctant to employ policies that can potentially create political pressure in the short run, despite having long run welfare benefits. Hence, it is quite necessary for a policy to be able to produce noticeable economic dividend along with the environmental one to get a wider public acceptance. The Australian carbon tax (and how it was repealed in recent times) is another notable example that demonstrates how political motivation can be a major impediment for environmentally beneficial policies to hold. The significance of the Australian scenario is imperative as Australia is the first developed nation (and as of now the only country) to annul carbon tax (Taylor and Hoyle, 2014). These examples provide an insightful depiction, accenting the necessity of a tax policy that can create a strong price signal to achieve the first dividend, accompanied by yielding additional economic benefits for wider public acceptance.

Figure 1: Social optimum level of emissions in partial equilibrium analysis



2.3. GTR versus "Cap-and-Trade"

There is a copious amount of debate between the advocates of cap-and-trade (C&T) and the proponents of tax-based approaches in the literature (Convery and Redmond, 2007; Daskalakis et al., 2009; Ekins, 1996; Hovi and Holtsmark, 2006; Keohane, 2009). Both systems have their merits and demerits as none are free from controversy. In C&T, the initial permits can be grandfathered (allocated for free) or auctioned through a regulatory agency and later traded between pollution generating companies (He et al., 2012). C&T, when grandfathered, is preferred by corporations because it does not drastically increase their short-run costs. The other positive aspect about C&T is that it limits the level of total emissions by putting a cap on them. On the downside, C&T (when grandfathered) cannot create a DD since there is no revenue and hence no financial recycling. Carbon taxes, on the other hand, are an incentive-based system where taxes are levied on the polluter; this falls in the domain of Pigouvian taxes. Therefore, these taxes have the characteristic of influencing human behaviour (Hoeller and Wallin, 1991). Regardless of

2 The efficiency dividend of environmental taxation pivots the notion that the revenue generated from green taxes can enable the government to make the tax system more efficient by reducing other distortionary taxes, such as income tax, thereby creating economic efficiency.

3 The coexistence of green taxes and distortionary taxes can result in a greater welfare loss due to their interactions.

criticism, the simplicity of carbon taxes makes them a far more practical approach with immediate results in controlling emissions (Avi-Yonah and Uhlmann, 2009). Coupled with the DD hypothesis, which carbon tax has the potential to generate, this system has an edge when it comes to creating long-run welfare for the economy. C&T, on the other hand, offers several benefits such as broad participation, equity in an international context, political feasibility, cost effectiveness and control over total emissions (Keohane, 2009). It is to be noted that, theoretically, C&T can also generate a DD through financial recycling; however, for this to happen, carbon allowances must be sold by the government through auction and not grandfathered. Nevertheless, auctioning allowances (instead of giving them for free) diminishes some of the key benefits of C&T. In addition, it raises budgetary uncertainty since the initial price of allowances depends on the outcome of the auction.

It is often argued that C&T is better as an environmental policy in terms of having the effectiveness in curbing carbon emissions, whereas carbon taxes are more efficient because of the ease of their implementation (He et al., 2012). The existing literature, therefore, is widely divided and the key to the puzzle lies in answering one simple question: Can GTR entail a significant and observable economic dividend? The empirical evidence on the existence of a second dividend on a global scale can immensely aid policymakers in setting the future direction of this debate.

The remainder of the paper is structured as follows. Section three defines the methodology and describes the database used in this study. Section four summarises the key findings of the meta-regression analysis and section five provides the concluding remarks and overall policy implications of our findings.

3. METHODS

3.1. Data

The literature on GTR, as well as on its environmental and economic impacts, is rich. However, empirical studies focusing on GTR and its impact on employment are relatively limited and are, therefore, difficult to compile. Assembling the database is thus a challenging task. For studies prior to the year 2004, we rely on the databases used by Patuelli et al. (2005) and Anger et al. (2010) in their meta-analyses[4]. For more recent studies (2004 and later), we conducted in-depth search, which is elaborated on in the next section. Together, in this paper, we have analysed 146 simulations coming from 33 different studies[5]. This large number of simulations have employed various methods with different model assumptions, which we analysed in order to find the central determinants of the employment effect.

3.2. Search Strategy

Because of our interest in finding a tax regime that can potentially create EDD, we intentionally keep the keywords used in the search as narrow as possible. Only the SCOPUS database is used since it is regarded as the largest database for peer reviewed articles and commonly used in literature review. We therefore limit our sources to peer reviewed journal articles written in English for higher authenticity. This may result in some publication bias, but we put more emphasis on the authenticity of the study and the study results. We search titles, abstract and keywords using the following keywords "EDD" OR "GTR" OR "carbon tax" OR "tax revenue recycle" OR "environmental fiscal reform" OR "environmental tax reform" and "employment." Even though most of the contributions to the literature come from European countries, we try to depict notable studies carried out in other parts of the globe. This initial search resulted in 103 relevant papers, which are further analysed using strategies outlined below.

3.3. Inclusion and Exclusion Strategies

We only aim to include simulation studies where the impact of GTR on employment is quantified. Studies about simulations where environmental tax revenue is recycled back to the economy through a tax reform, and in which the impact of that reform on employment is measured, are the only ones included in the database. This is true for 17 out of the initial 103 studies. The existence of the first dividend of environmental tax, which is reduced pollution, is so pervasive in the literature that some studies take it as a stylised fact, analysing only the effect of GTR on non-environmental (second) dividend. We include such studies in our database as long as an employment effect is quantified, regardless of whether the second dividend is defined in terms of employment.

3.4. Independent Categorical Variables

For comparative analysis, we categorised the simulations based on the following characteristics:

a. Region of study
b. Tax type
c. Model type
d. Recycling method
e. Time period.

Under region of study, the studies are categorised between "Europe" and the "rest of the world." Europe has been the intellectual pioneer in this line of reasoning, and studies coming from outside Europe are a recent phenomenon. Therefore, we included this categorisation to test whether there is any significant difference in central determinants of employment effect across these two regions[6]. Under tax type we have (1) CO_2: Tax based on the emissions of CO_2 gases; (2) EC tax: Tax proposed by the European community; (3) energy tax: Tax based on the use of energy products and (4) others taxes, which are mostly comprised of mixed taxes. Model types include (1) GE: General equilibrium model; (2) M: Macroeconomic model; (3) I/O: Input output model and (4) PE: Partial equilibrium model. Under time period, simulations of 10 years or less are considered as short term and the rest are classified as long-term studies. Also, the static simulations are classified under short term unless the model assumptions explicitly favour a long-term scenario. The final categorisation is based on the recycling method of tax revenue, which includes (1) SSC: Reduction of employer's social security contribution, payroll taxes or any other form of labour tax; (2) LSTH: Lump-sum

4 Inclusion and exclusion strategies are detailed in the following section.
5 A summary of the database is presented in Appendix A.
6 It is referred as the "country variable" in the following sections.

transfer to household/industry; (3) PIT: Personal income tax; (4) CT: Capital tax; (5) VAT: value added tax and (6) other recycles. Table A1 in Appendix A provides an illustration of the database and the key characteristics of the simulations used in this study.

3.5. Analysis

This section explains the methodological approach we pursue and the assumptions we are making in greater detail. One of the key features of our study is that we tried to unify the findings from different country specific simulations and categorised them accordingly. The country of study is not an intrinsic part of the simulation design, but certainly has the potential to be a determinant of the simulation results, especially since non-European countries have tax structures and macroeconomic policies that vary greatly. A meta-regression analysis by Patuelli et al. (2005) covered simulations that used an array of different non-environmental dividends, whereas the analysis of Anger et al. (2010) focused on the employment dividend but was limited to European countries. EU countries have several common standards and unification laws, and there is some degree of homogeneity in simulation characteristics. Hence, the effect of the country variable in our scenario requires more investigation for interactions by country groups. Investigating interaction terms is quite rational as the country of study may have an impact on the introduction of new taxes or proposed tax recycling policies. Also, it is possible that different tax policies interact with financial recycling methods in influencing the employment effect. We emulate the meta-regression method used in Patuelli et al. (2005), where the authors used tax type, recycling method and the interaction effect of these two variables to construct the meta-regression model. In our case, we modify the model by including country variables and their interaction effects. We investigate the other moderator variables ("model type" and "time period") to verify whether they cause substantial changes to employment effect and found none of them to be significant[7]. With all binary moderator variables and one continuous dependent variable (employment), and because of our interest in understanding the interaction effect between country variables and other moderator variables, we use the ordinary least squares (OLS) approach to construct our model. The basic meta-regression model can therefore be written as:

$$Y_j = \varphi + \sum_{k=1}^{N} \beta_k Z_{jk} + \sum_{k=1}^{N} \sum_{l=1}^{N} \beta_{kl} Z_{jk} Z_{jl} + \varepsilon_j$$

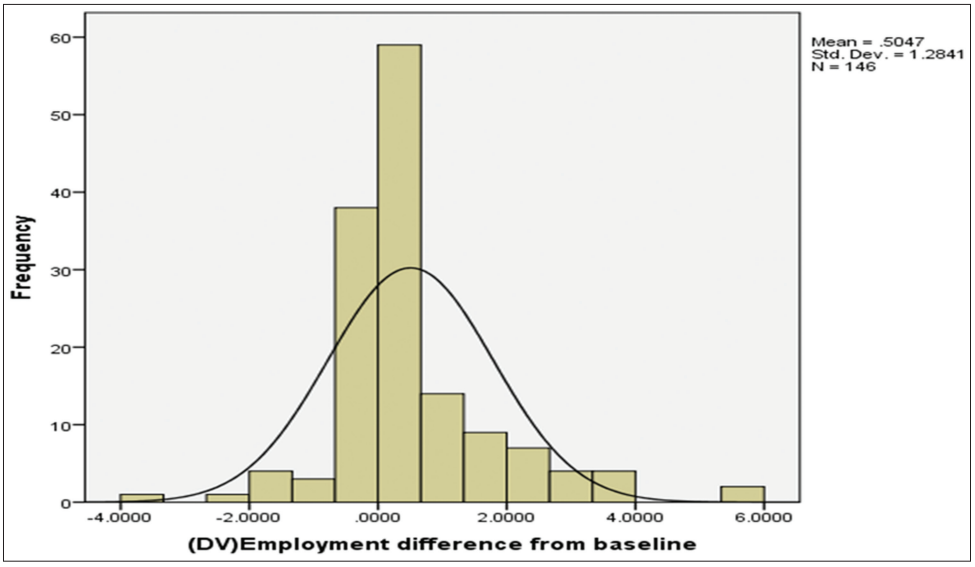
Here, Y is the vector of effect size (employment effect), φ denotes the average employment variation for average study characteristics, β_k is the meta-regression coefficient incorporating the main effect of kth study characteristic Z_k, β_{kl} is the meta-regression coefficient for interaction terms between the generic variables Z_k and Z_l, and ε_j reflects the disturbance term.

In our meta-regression analysis, we use the percentage variation of employment from baseline scenarios as the dependent variable. A positive variation of employment, therefore, signifies the effectiveness of the tax reform policy used in the simulation, as it shows greater efficacy in creating employment over the baseline scenario. One of the key challenges in our analysis is standardising the dependent variable. The results of dynamic simulations are intertemporal, which allows us to easily standardise them to annual terms. However, static simulations have no time boundaries. The static results are then categorised into short- and long-term, depending on model assumptions, although an exact standardisation in annual terms is not possible. This explains the non-normal distribution of our dependent variable shown in Figure 2. According to Lix et al. (1996), false positive rates are unaffected, which is due to non-normality when the deviation is moderate; therefore, our use of the methodological approach is not in violation of any fundamental assumptions.

Finally, we omit any discussion on the environmental dividend, as this has already been investigated numerous times in the past, with well-established evidence supporting its existence. We take

7 Results are available from the authors upon request.

Figure 2: The shape of distribution of DV



it as a stylised fact, and only analyse the non-environmental employment dividend.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

The environmental and employment effects of all the simulations we have analysed are summarised in Table 1, categorised between European and non-European countries. With respect to the simulations of the employment effect, 66.4% come from European countries, whereas those reporting an environmental effect comprise 78.9% of the sample. Out of the 146 simulations we analysed regarding the employment effect, 95 measured an environmental effect and 20 were from non-European countries. This underlines the fact that studies on EDD in non-European countries, which has started in recent years following European footsteps, are generally accepting the environmental dividend as a stylised fact and primarily focus on the (non-environmental) second dividend. The comparison of environmental and employment effects between European and non-European countries conforms with the findings of Anger et al. (2010) as it shows higher emissions reduction in non-European countries is coupled with lower employment effect, exhibiting a negative relationship (Table 1).

Because of the study design, we hypothesise significant differences across groups of countries; therefore, we investigated the difference in employment effects. We did not detect equal variances while assessing the simulation characteristics (Levene's test significance: 0.017 and 0.002 for environmental and employment effects, respectively). This suggests that heteroscedasticity is present, which is often expected in meta-regression studies (Stanley and Jarrell, 1989) and, therefore, we employed robust estimation techniques.

Table 2 shows that there are no significant differences in environmental effects across groups of countries (t = 0.607, df = 24.05, P-value = 0.550), but we do find differences in employment effects (t = 2.597, df = 141.527, P-value = 0.01). This means that country groups are more homogeneous in terms of environmental effects, and the difference in employment effects can be explained by other variables (study characteristics). This gives us the basis for further analysis to understand the significance of country groups. Understanding the central determinants of the employment effect across different regions is imperative for optimal policy measures. This understanding can entail suitable GTR design for different regions, which can yield the maximum employment dividend.

4.2. Regression Results

In our final regression model, as per the study design, we include all the tax type and tax recycle type variables, along with the country variable. The main effect of all the variables are investigated. We also examine the interaction effects between variables. We exclude the EC tax in our exploration of interaction effects as this is a tax used in European countries only. We also exclude LSTH, Other recycles, PIT and CT from the investigation of interaction effects due to an insignificant number of cases across two country groups.

We adjusted our regression results using a heteroscedasticity consistent standard error estimator (Hayes and Cai, 2007). The results of OLS show that our model should be constructed using SSC, VAT and Country*VAT. We also find the interaction between SSC and CO_2 to be significant at 10% (P = 0.0520); however, this was excluded that from our model. The interaction between these two variables should be investigated further in future studies. The parameter estimations are presented in Table 3. The final equation can therefore be written as follows:

$$Y_j = \varphi + \beta_1 SSC + \beta_2 \text{VAT} + \beta_3 \text{Other taxes} + \beta_{42} Country*VAT_2 \quad (1)$$

Table 1: Group statistics for variables of interest

Effect of GTR	Country	n	Mean	Std. deviation	Std. error mean
Environmental effect	European Country	75	−5.249936	4.9056959	0.5664610
	Rest of the world	20	−6.272025	7.0937374	1.5862079
Employment effect	European country	97	0.668408	1.4380341	0.1460102
	Rest of the world	49	0.180678	0.8269784	0.1181398

Table 2: T-test for environmental and employment effects by countries

Effect of GTR		Levene's test for equality of variances		t-test for equality of means						
		F	Sig	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence Interval of the difference	
									Lower	Upper
Environmental effect	Equal variances assumed	5.9	0.017	0.749	93	0.456	1.022	1.365	–1.689	3.733
	Equal variances not assumed	48		0.607	24.055	0.550	1.022	1.684	–2.454	4.498
Employment effect	Equal variances assumed	9.9	0.002	2.196	144	0.030	0.488	0.222	0.0486	0.927
	Equal variances not assumed	39		2.597	141.527	0.010	0.488	0.188	0.116	0.859

Table 3: Parameter estimates

Variable	β	t	P-value
Intercept	−0.3605	−3.2241	0.0016
Recycling type: SSC	1.1270	5.9748	0.0000
Recycling type: VAT	1.5137	2.9249	0.0040
Tax type: Other taxes	0.7614	3.2049	0.0017
Country*VAT	−1.6291	−3.1686	0.0019
Number of observations		146	
Goodness of fit		R^2=0.3561	
F value		12.6249	

Our results conform with the findings of Patuelli et al. (2005): Reduction of SSC as a form of tax revenue recycle yields employment dividend. We also find that SSC does not interact with the country variable, which means that the use of SSC is independent of the region of study. This policy works equally well in both European and non-European countries. We find the use of VAT reduction as a recycling policy to have a notable employment effect. The nexus between VAT reduction and employment has been studied in the European context (see Hutton and Ruocco, 1999; Majocchi, 1996; O'Connor, 2013) and confirms the potential of VAT reduction in increasing employment. However, our results suggest that VAT reduction under GTR is an effective policy only in the European context and counterproductive when used in non-European countries. One of the possible explanations is that the wages are indexed to the price level, and the elasticity of wages to the price level is higher in the European context but not so much for the non-European countries. Future studies should examine these differences in greater detail.

Among all the different tax types, only "other taxes" came out as a significant predictor. This tax type mostly consists of mixed taxes and, therefore, according to our analysis, a mixed tax approach of GTR is more effective in creating employment dividend over a single tax approach. None of the tax type variables, however, interacted with the country variable, showing that tax type has no country specific influence in generating EDD.

The interaction of country variable with tax revenue recycle policy is an interesting insight, underlying the importance of country specific policy mix for optimal results. We found that a uniform tax reform policy for employment dividend to be less optimal. With a goodness of fit of 0.3561, our results show that the null hypothesis of country homogeneity for employment effect should be rejected.

5. CONCLUSIONS

In this paper, we aimed to shed light on a possible solution to a major global economic challenge: Curbing pollution, measured in the form of carbon emissions while avoiding unemployment. A GTR led EDD can offer an effective remedy to the aforementioned challenges, and in this meta-regression analysis we critically analysed the existing empirical literature of EDD and studied the central determinants of it.

The EU was the first to take major strides towards a GTR. Starting as early as 1996, the European Environmental Agency embodied the idea of EDD since involuntary unemployment was a rising concern all over Europe (de Miguel and Manzano, 2011). However, we have observed that research interest into GTR and EDD in both developing countries and countries outside of Europe has grown in recent decades. This gave us the opportunity to compare the simulation design and results of European and non-European countries. We did not find any major significance of some of the intrinsic components of simulation design, such as type of model and simulation duration on employment. However, we observed notable differences in the employment effect between European and non-European countries and therefore, policy mix should be designed considering the country effect for optimal employment results. Even though Europe has been the forerunner in contributing to the literature of GTR and EDD, our results suggest that an emulation of the European model by non-European countries may result in suboptimal consequences.

Further region-specific studies are needed to find out the central determinants of EDD in different regions and continents with different macroeconomic structures. In our meta-regression analysis, we only categorised simulations between European and non-European countries due to a limited number of available simulation studies conforming to our study design. A larger sample with a broader categorisation of region and further details of the labour market assumptions could increase the robustness of statistical tests and help to understand the primary determinants of employment in the context of environmental tax reform. Nevertheless, this paper clearly confirms the employment dividend of GTR in a global scale and highlights some of the differences in the employment effect between the two regions in response to different policy measures.

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Appendix A

Table A1: Database summary

Source	Model	Region of study	Model type	Tax type	Tax Recycle type	Time period	Number of simulations
Bach *et al*. (1994)	DIW	European	M	Energy tax	SSC	Short term	1
Bardazzi (1996)	INTIMO	European	IO	Other taxes	SSC	Short term	3
	INTIMO	European	IO	Other taxes	SSC	Short term	
	INTIMO	European	IO	Energy tax	SSC	Short term	
Barker *et al*. (1993)	HERMES/MIDAS/DRI	European	M	EC tax	PIT	Short term	12
	HERMES/MIDAS/DRI	European	M	EC tax	PIT	Short term	
	HERMES/MIDAS/DRI	European	M	EC tax	VAT	Short term	
	HERMES/MIDAS/DRI	European	M	EC tax	VAT	Short term	
	HERMES/MIDAS/DRI	European	M	EC tax	PIT	Long term	
	HERMES/MIDAS/DRI	European	M	EC tax	VAT	Long term	
	HERMES/MIDAS/DRI	European	M	Other taxes	VAT	Short term	
	HERMES/MIDAS/DRI	European	M	Other taxes	VAT	Short term	
	HERMES/MIDAS/DRI	European	M	Other taxes	PIT	Short term	
	HERMES/MIDAS/DRI	European	M	Other taxes	PIT	Short term	
	HERMES/MIDAS/DRI	European	M	Other taxes	VAT	Long term	
	HERMES/MIDAS/DRI	European	M	Other taxes	PIT	Long term	
Barker and Köhler (1998)	E3ME	European	M	Energy tax	SSC	Long term	1
Carraro *et al*. (1996)	WARM	European	GE	EC tax	SSC	Long term	6
	WARM	European	GE	EC tax	SSC	Long term	
	WARM	European	GE	EC tax	SSC	Long term	
	WARM	European	GE	EC tax	SSC	Long term	
	WARM	European	GE	EC tax	SSC	Long term	
	WARM	European	GE	EC tax	SSC	Long term	
Holmlund and Kolm (2000)	None	Non-European	GE	Energy tax	SSC	Short term	8
	None	Non-European	GE	Energy tax	SSC	Short term	
	None	Non-European	GE	Energy tax	SSC	Short term	
	None	Non-European	GE	Energy tax	SSC	Short term	
	None	Non-European	GE	Energy tax	SSC	Short term	
	None	Non-European	GE	Energy tax	SSC	Short term	
	None	Non-European	GE	Energy tax	SSC	Short term	
	None	Non-European	GE	Energy tax	SSC	Short term	
Jansen and Klaassen (2000)	HERMES	European	M	EC tax	SSC	Short term	3
	E3ME	European	M	EC tax	SSC	Short term	
	GEM-E3	European	GE	EC tax	SSC	Short term	
Kemfert and Welsch (2000)	LEAN-TMC	European	GE	CO_2	LSTH	Long term	4
	LEAN-TMC	European	GE	CO_2	LSTH	Long term	
	LEAN-TMC	European	GE	CO_2	SSC	Long term	
	LEAN-TMC	European	GE	CO_2	SSC	Long term	
Mabey and Nixon (1997)	EGEM; SLEEC; EGEME; EGEMX	European	M	CO_2	PIT	Long term	6
	EGEM; SLEEC; EGEME; EGEMX	European	M	CO_2	PIT	Long term	

(Contd...)

Table A1: (*Continued*)

Source	Model	Region of study	Model type	Tax type	Tax Recycle type	Time period	Number of simulations
	EGEM; SLEEC; EGEME; EGEMX	European	M	CO_2	PIT	Long term	
	EGEM; SLEEC; EGEME; EGEMX	European	M	CO_2	SSC	Long term	
	EGEM; SLEEC; EGEME; EGEMX	European	M	CO_2	SSC	Long term	
	EGEM; SLEEC; EGEME; EGEMX	European	M	CO_2	SSC	Long term	
De Mooij and Bovenberg (1998)	Mobile capital; Fixed capital	European	GE	Energy tax	SSC	Long term	12
	Mobile capital; Fixed capital	European	GE	Energy tax	SSC	Long term	
	Mobile capital; Fixed capital	European	GE	Energy tax	SSC	Long term	
	Mobile capital; Fixed capital	European	GE	Energy tax	CT	Long term	
	Mobile capital; Fixed capital	European	GE	Energy tax	CT	Long term	
	Mobile capital; Fixed capital	European	GE	Energy tax	CT	Long term	
	Mobile capital; Fixed capital	European	GE	Energy tax	Other recycles	Short term	
	Mobile capital; Fixed capital	European	GE	Energy tax	Other recycles	Short term	
	Mobile capital; Fixed capital	European	GE	Energy tax	Other recycles	Short term	
	Mobile capital; Fixed capital	European	GE	Energy tax	SSC	Short term	
	Mobile capital; Fixed capital	European	GE	Energy tax	SSC	Short term	
	Mobile capital; Fixed capital	European	GE	Energy tax	SSC	Short term	
Roson (2003)	Dynamic general equilibrium model of Italy	European	GE	CO_2	SSC	Short term	2
	Dynamic general equilibrium model of Italy	European	GE	CO_2	CT	Short term	
Pereira and Pereira (2014)	DGEP	European	GE	CO_2	LSTH	Long term	4
	DGEP	European	GE	CO_2	VAT	Long term	
	DGEP	European	GE	CO_2	PIT	Long term	
	DGEP	European	GE	CO_2	SSC	Long term	
Kilimani (2014)	UgAGE	Non-European	GE	Other taxes	Other recycles	Short term	6
	UgAGE	Non-European	GE	Other taxes	Other recycles	Short term	
	UgAGE	Non-European	GE	Other taxes	Other recycles	Short term	
	UgAGE	Non-European	GE	Other taxes	Other recycles	Long term	
	UgAGE	Non-European	GE	Other taxes	Other recycles	Long term	
Source	Model	Region	Model type	Tax type	Tax Recycle type	Time period	
	UgAGE	Non-European	GE	Other taxes	Other recycles	Long term	
Conrad and Löschel (2005)	GEM-E3	European	GE	CO_2	SSC	Short term	4
	GEM-E4	European	GE	CO_2	SSC	Short term	
	GEM-E5	European	GE	CO_2	LSTH	Short term	
	GEM-E6	European	GE	CO_2	LSTH	Short term	

(Contd...)

Table A1: (*Continued*)

Source	Model	Region of study	Model type	Tax type	Tax Recycle type	Time period	Number of simulations
Bach *et al*. (2002)	LEAN	European	GE	Energy tax	SSC	Long term	2
	PENTA-RHEI	European	M	Energy tax	SSC	Long term	
Pollitt *et al*. (2014)	E3MG	Non-European	M	CO_2	PIT	Long term	9
	E3MG	Non-European	M	CO_2	PIT	Long term	
	E3MG	Non-European	M	CO_2	PIT	Long term	
	E3MG	Non-European	M	CO_2	PIT	Long term	
	E3MG	Non-European	M	CO_2	PIT	Long term	
	E3MG	Non-European	M	CO_2	PIT	Long term	
	E3MG	Non-European	M	CO_2	PIT	Long term	
	E3MG	Non-European	M	CO_2	PIT	Long term	
	E3MG	Non-European	M	CO_2	PIT	Long term	
Bosello and Carraro (2001)	WARM	European	M	Energy tax	SSC	Short term	8
Source	Model	Region	Model type	Tax type	Tax Recycle type	Time period	
	WARM	European	M	Energy tax	SSC	Short term	
	WARM	European	M	Energy tax	SSC	Short term	
	WARM	European	M	Energy tax	SSC	Short term	
	WARM	European	M	Energy tax	SSC	Long term	
	WARM	European	M	Energy tax	SSC	Long term	
	WARM	European	M	Energy tax	SSC	Long term	
	WARM	European	M	Energy tax	SSC	Long term	
Manresa and Sancho (2005)	Static general equilibrium model of Spain	European	GE	EC tax	SSC	Short term	6
	Static general equilibrium model of Spain	European	GE	EC tax	SSC	Short term	
	Static general equilibrium model of Spain	European	GE	EC tax	SSC	Short term	
	Static general equilibrium model of Spain	European	GE	EC tax	SSC	Short term	
	Static general equilibrium model of Spain	European	GE	EC tax	SSC	Short term	
	Static general equilibrium model of Spain	European	GE	EC tax	SSC	Short term	
André *et al*. (2005)	Static general equilibrium model of Spain	European	GE	CO_2	SSC	Short term	3
	Static general equilibrium model of Spain	European	GE	CO_2	PIT	Short term	
	Static general equilibrium model of Spain	European	GE	Other taxes	SSC	Short term	
Saveyn *et al*. (2011)	GEM-E3	European	GE	CO_2	SSC	Long term	3
	GEM-E4	European	GE	CO_2	SSC	Long term	
	GEM-E5	European	GE	CO_2	SSC	Long term	

(Contd...)

Table A1: (*Continued*)

Source	Model	Region of study	Model type	Tax type	Tax Recycle type	Time period	Number of simulations
Welsch and Ehrenheim (2004)	LEAN_2000	European	GE	Energy tax	SSC	Long term	1
Bossier and Bréchet (1995)	HERMES	European	M	EC tax	SSC	Short term	1
Felder and Van Nieuwkoop (1996)	Static general equilibrium model of Switzerland	European	GE	CO_2	LSTH	Short term	6
	Static general equilibrium model of Switzerland	European	GE	CO_2	LSTH	Short term	
	Static general equilibrium model of Switzerland	European	GE	CO_2	SSC	Short term	
	Static general equilibrium model of Switzerland	European	GE	CO_2	SSC	Short term	
	Static general equilibrium model of Switzerland	European	GE	CO_2	SSC	Short term	
	Static general equilibrium model of Switzerland	European	GE	CO_2	SSC	Short term	
Vandyck and Van Regemorter (2014)	Dynamic regional CGE model of Belgium, based on GEM-E3	European	GE	Energy tax	SSC	Long term	2
	Dynamic regional CGE model of Belgium, based on GEM-E4	European	GE	Energy tax	LSTH	Long term	
Markandya *et al*. (2013)	Static general equilibrium model of Spain	European	GE	CO_2	LSTH	Short term	3
	Static general equilibrium model of Spain	European	GE	CO_2	CT	Short term	
	Static general equilibrium model of Spain	European	GE	CO_2	SSC	Short term	
Ciaschini *et al*. (2012)	Static bi-regional CGE model of Italy	European	GE	Other taxes	PIT	Short term	4
	Static bi-regional CGE model of Italy	European	GE	Other taxes	PIT	Short term	
	Static bi-regional CGE model of Italy	European	GE	Other taxes	Other recycles	Short term	
	Static bi-regional CGE model of Italy	European	GE	Other taxes	Other recycles	Short term	
Sahlén and Stage (2012)	Static CGE model of Namibia	Non-European	GE	Other taxes	VAT	Short term	5
	Static CGE model of Namibia	Non-European	GE	Other taxes	VAT	Short term	
	Static CGE model of Namibia	Non-European	GE	Other taxes	SSC	Short term	
	Static CGE model of Namibia	Non-European	GE	Other taxes	LSTH	Short term	
	Static CGE model of Namibia	Non-European	GE	Other taxes	LSTH	Short term	
Lee *et al*. (2012)	E3MG	Non-European	M	CO_2	PIT	Long term	2
	E3MG	Non-European	M	CO_2	Other recycles	Long term	
O'ryan *et al*. (2005)[1]	ECOGEM-Chile	Non-European	GE	Other taxes	LSTH	Short term	1

(Contd...)

Table A1: (*Continued*)

Source	Model	Region of study	Model type	Tax type	Tax Recycle type	Time period	Number of simulations
Mirhosseini *et al*. (2017)	Static CGE model of Iran	Non-European	GE	Energy tax	LSTH	Short term	3
	Static CGE model of Iran	Non-European	GE	Energy tax	CT	Short term	
	Static CGE model of Iran	Non-European	GE	Energy tax	SSC	Short term	
Bor and Huang (2010)	EnFore-CGE-Taiwan	Non-European	GE	Energy tax	LSTH	Short term	5
	EnFore-CGE-Taiwan	Non-European	GE	Energy tax	Other recycles	Short term	
	EnFore-CGE-Taiwan	Non-European	GE	Energy tax	Other recycles	Short term	
	EnFore-CGE-Taiwan	Non-European	GE	Energy tax	Other recycles	Short term	
	EnFore-CGE-Taiwan	Non-European	GE	Energy tax	Other recycles	Short term	
Van Heerden *et al*. (2006)	Static CGE model of South Africa	Non-European	GE	CO_2	VAT	Short term	8
	Static CGE model of South Africa	Non-European	GE	CO_2	Other recycles	Short term	
	Static CGE model of South Africa	Non-European	GE	CO^2	Other recycles	Short term	
	Static CGE model of South Africa	Non-European	GE	Energy tax	VAT	Short term	
	Static CGE model of South Africa	Non-European	GE	Energy tax	Other recycles	Short term	
	Static CGE model of South Africa	Non-European	GE	Energy tax	Other recycles	Short term	
	Static CGE model of South Africa	Non-European	GE	Other taxes	VAT	Short term	
	Static CGE model of South Africa	Non-European	GE	Other taxes	Other recycles	Short term	
Liu and Lu (2015)	CASIPM-GE	Non-European	GE	CO_2	Other recycles	Short term	2
	CASIPM-GE	Non-European	GE	CO2	Other recycles	Short term	