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by

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Carbon taxes and trade spillovers within Europe

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Abstract

Carbon taxation has been suggested among the market based policies to tackle climate change since the early 90's, oken associated to ecological tax reforms rationales. Before the advent of emission trading in the EU, some countries introduced forms of carbon taxation, which is still used to deal with non EU ETS sectors. Due to this historical evolution of environmental policies over the last decades, in presence of a 'federal system' that assigns to EU countries the governance of energy and fiscal issues, an heterogeneous set of country driven carbon/energy policy se1ings is present, which can determine effects on growth and trade. We investigate the possible existence of asymmetries among the European Carbon area countries reaction to the policy adoption responsible to combat climate change via carbon usage reduction.

Keywords: **carbon taxation**, **spillovers**, **trade**

1. Introduction

Climate change is the biggest threat to human existence and can only be tackled by bringing down harmful emission. Too much use of fossil fuels have created a worldwide negative externality which is harmful for billions of people. Without policy intervention if markets are lek to operate freely, GHGs will be excessive, due to the fact that there will be insu@cient incentive for firms and households to reduce emissions. So economists suggests the polluter to pay a price on such emission. ftis can be implemented either through a tax on the GHGs especially carbon which acts as a price instrument or a cap-and-trade scheme which acts as a quantity instrument.

A be1er way to bring down carbon emission is to introduce carbon pricing and invest in R&D so economies can make a transition to zero carbon economy. Economists have long debated on optimal carbon pricing and three strands of literature has emerged Direct carbon tax (Weisbach and Metcalf, 2009, Nordhaus, 2006), Cap-and-trade (Keohane, 2009, Stavins, 2007) and an amalgamation of the above (Aldy et al., 2010, Mooij et al. 2002). Finland was the first country to introduce a carbon-tax in 1990 followed by 15 European countries and the range of such taxes varies from € 1 to € 100. Carbon taxes were introduced in two distinct timelines in Europe, one started in early 1900's in the Scandinavian region and the next one followed in mid-2000's in western European countries like Switzerland, Iceland, Ireland and Portugal. fte European climate policy is designed around mainly on the two pillars of EU-ETS and domestic carbon taxes for non-ETS sectors like transportation and household energy consumption.

fte EU-ETS came into effect from 2005 with a primary goal to achieve Kyoto targets and has gone through some changes in three phases. In the first phase, Phase I (pilot phase) cap-and-trade scheme was introduced for CO_2 produced in power stations and energy intensive sectors (oil refineries, steel works and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals), N_2O from production of nitric, adipic and glyoxylic acids and glyoxal and PFCs from aluminium production. Phase II which started in 2008 introduced cap-and-trade scheme for domestic aviation sector and finally Phase III introduced a single EU-wide cap for total emissions and use of auctioning in the allocation of the permits, with some special allowance for selected sectors.

Inside the euro area, fiscal policy is used as a necessary stabilization tool which acts in coordination with national fiscal policies [1]. With reference to Green taxation, Hans Bruyninckx stated: *'We plead very strongly for two things: on the one hand a more systemic understanding of tax systems in an evolving society and secondly we also plead for a beMer understanding of how the whole group of financial instruments, including subsidies and other financial instruments, fit together'* (Simon, 2016)

ftere is in effect a need to understand how the heterogeneous sets of European carbon taxes has affected growth through direct effects and trade spillovers. fte analysis is purposefully relevant for policy makers in the EU and in other federal systems. It is very relevant as in practice, notwithstanding the potential necessity to homogenize fiscal mechanisms, real world situations oken witness fiscal heterogeneity, especially in the environmental realm.

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[1] ftough a central EU fiscal authority do not exists, and EU fiscal decisions are based upon unanimity rules

ftough the carbon prices actually arising from carbon taxes and emission trading schemes are very low, far from the carbon prices recommended by the High-level Commission on Carbon Pricing of the Wold Bank in 2017 (CPLC, 2017), there is significant space for broadening the tax base and increasing rates (EEA, 2020). EEA (2020) analysis suggests that the introduction of a carbon tax improves fiscal sustainability: in climate change mitigation scenarios, the level of deficit is always lower. Fiscal targets are always reached (EEA, 2020, Sustainability transition in Europe in the age of demographic and technological change [2]). A main theme in the interaction between environmental taxation and fiscal sustainability is the call for tax-shiking programmes in which taxes levied on labour are reduced to increase environmental taxes (offset reduced labour tax revenue) achieving a revenue-neutral policy. According to EC (2011): "By 2020 a major shik from taxation of labour towards environmental taxation, including through regular adjustments in real rates, will lead to a substantial increase in the share of environmental taxes in public revenues, in line with the best practice of Member States". fte study regularly quoted in this context (Luptácik M. et al. 2015) neatly shows that a 40 Euro/tCO2 tax could reduce labour costs by 2%. fte potential of revenues generated is 'correlated' with the stringency of policies, i.e. steep increase in energy tax rates / carbon prices – however, stringency caused tax base erosion. Against this background, where environmental taxation was originally proposed to jointly achieve climate and economic goals (employment, fiscal, eventually GDP), we focus on the economic spillovers that an heterogeneous set of environmental policies can generate through trade dynamics.

fte remainder of this paper is divided into five sections, section 2 briefiy reviews literature, section 3 describes our model including the methodology we adopted to take into account cross-country carbon tax based spillovers. Section 4 describes the data and sources, section 5 details the estimation strategy adopted. Section 6 provides our findings and section 7 concludes.

2. Literature review

fte European Union (EU) is a unique economic and political integration project. It begun primarily as a peacekeeping endeavour among six European countries struggling from the akermath of World War II and eventually became a unique community of 27 sovereign countries, which are economically integrated and politically connected via various steps of integration looked over by supranational institutions. Fostering economic ties between its member states is one of the main objectives of the EU's policy of 'creating an ever closer union' (Maastricht Treaty). Moreover, the EU seeks to promote economic, social and territorial cohesion by 'reducing disparities between the levels of development of the various regions' (Art. 174, Maastricht Treaty). fte EU as a block is the second largest economy in the world, biggest net exporter and second largest net importer (including intra-EU trade). In 2018 the 28 EU memeber states exported (imported) a total of € 5474 (€ 5426) billions worth of goods of which 64% (64%) or € 3518 (€3446) billion was with another member state (WEF FORUM). In CO2 emission terms, the EU (member states sumtotal) is the third largest global emi1er.

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[2]references

3

Despite this integration policy, the EU member states demonstrate large heterogeneity with respect to their economic performance. ftis can be blamed on the fact due to existence of different efforts or capabilities in participating in the economic integration process and different levels of investments in RD, Human capital and other key drivers of growth and development (EEA, 2014, 2020). Some profound economic research concluded with heterogeneous outcomes for the member states, such as trade integration (e.g., Badinger, 2005, Baldwin, 2006), monetary integration (e.g., De Grauwe, 2006, Gregoriou et al., 2011), capital market integration (Baele et al., 2004), labour market integration (Nowotny et al., 2009) or institutional integration (Mongelli, 2008)

Aker the Kyoto agreement and recently the Paris Accords one of the goals of EU has been to bring down emission rates inside the union. Some countries, especially in the Scandinavia started taking carbon back in the 90's and these countries were followed by others. ftough most of the member states backed for a EU wide cap-trade scheme but their a1itude towards a Carbon tax has been somehow different. A list of countries inside EU is detailed below in Table 1.

Table 1: EU-Carbon taxes

Country	Year	Rate in 2018 (USD)	Coverage (2019)
Finland	1990	70.65	0.36
Poland	1990	0.16	0.04
Norway	1991	49.30	0.62
Sweden	1991	128.91	0.40
Denmark	1992	24.92	0.40
Slovenia	1996	29.74	0.24
Estonia	2000	3.65	0.03
Latvia	2004	9.01	0.15
Switzerland	2008	80.70	0.33
Ireland	2010	24.92	0.49
Iceland	2010	25.88	0.29
UK	2013	25.71	0.23
Spain	2014	30.87	0.03
France	2014	57.57	0.35
Portugal	2015	11.54	0.29

[Source: World Bank Carbon Group, 2019]

A varying literature exists about the effect of EU-ETS and Carbon taxes on employment, growth, innovation. Since the literature has evolved and expanded over the last 30 years in a substantial manner, we refer to some seminal sources as (Ekins and Speck, 2011, Barde and Owens, 1993, Milne and Andersen, 2014, European Environment Agency, 2005, Sabel and Zeitlin, 2010, {and} Development, 2001

An interesting project funded by the EU were PETRE and COMETRE . oting the report 'Feasibility of implementing a radical ETR and its acceptance' (IEEP, 2009), PETRE - Productivity and Environmental Tax Reform in Europe (2007-2009) explored the economic, environmental and

resource implications, for Europe and the rest of the world, of a large-scale ETR in Europe that could achieve the EU's GHG reduction targets by 2020. IEEP reports that: 'fte findings obtained through the use of 2 macro-econometric models and 6 scenarios suggested that ETR can be effective to achieve the EU GHG reduction targets with broadly neutral or positive economic impacts, and potentially also reduce the consumption of other resources. It was estimated that carbon prices the carbon prices needed to reach the EU GHG targets should be between €53-68/t CO2 (or lower if tax revenues are invested in low carbon technologies) if EU were to reach a 20% GHG reduction by 2020, and about €180-200/tonnes CO2 to achieve the 30% global target. fte effect on GDP was estimated to be small, while it emerged that ETR could increase employment. Overall, the research indicates that a broadly based ETR across Europe could play a very important and cost-effective role in meeting the EU's emission reduction targets for 2020, especially in a context of global cooperation on climate policy'. COMETR – Competitiveness Effects of Environmental Tax Reform (2004-2007) undertook an analysis of the competitiveness impacts of green tax reforms at a sectoral level, using modelling frameworks (bo1om-up and macro-economic) as well as case studies concerning the existing tax reforms which have taken place in the EU and Candidate countries. Evidence shows that 'the double dividend' theory proved true in five EU countries applying ETR. In Sweden, Denmark, the Netherlands, Finland and Germany CO2 and energy taxation over the last 17 years has made a small but positive contribution to economic growth of up to 0.5 per cent, while CO2 emissions have been reduced. In UK the reform has been neutral, but here the scale of the tax rates levied has been modest and it was also the most recent ETR. fte positive contribution to economic growth arises because carbon-energy taxation leads to more e@cient use of energy while at the same time wage costs are lowered. It also leads to improved competitiveness for energy-e@cient businesses and for the development of new products which also can be exported. Taxation of petrol shiks demand to other products and products of a more domestic nature. fte analyses pointed to a difference in outcomes according to whether it is the energy price which is increased or the energy tax. ftis is due to the fact that the revenue from a tax remains in the public purse and can be used to lower other taxes. Furthermore domestic taxes do not affect the prices of imported raw materials and intermediate goods'.

Overall, the two projects pointed out the potential for a double dividend, with some effects on GDP, employment and competitiveness. Trade and competeveness realms, even due to data availability, remained as secondary objectives of the analyses.

We build upon that legacy to focus on the relative overlooked issue of spillover effects related to heterogeneous implementation of carbon taxation, where trade dynamics are at the core of the analysis. Even if some works have focused on the environmental policy effects on trade competitiveness in the EU (**costantini˙green˙2012**), there is still a lack of literature on the spillovers created due to different carbon tax regimes in different EU countries,[3].

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[3]As explained by Prof. Meredith Fowlie, University of California-Berkeley as a discussant for the Metcalf and Jones 2020 paper at Carbon Tax Policy, ASSA 2020 session

3. Identiftcation strategy[4]

We examine the output effects of carbon tax spillovers in EU countries from 1990- 2015. We start with a simple baseline model to assess trading partner's carbon tax policy affect on domestic output. Domestic economic output at time t for country i is determined by

$$log(Y_{it}) = \sum_{k=1,2} \rho_k log(Y_{it-k}) + \sum_{l=0,1,2} \Delta CTS_{it-l} a_l + \sum_{m=1,2} X_{it-m} \eta_m + \lambda_i + \delta_t + s_{it} \quad (1)$$

where Y_{it} is the real domestic output of country i and the lagged values of Y_{it-k} are used to control for underlying dynamics from domestic outcomes (we use natural logs in this case).X_{it_m} is a row vector of control variables to determine short to medium term economic outcomes (log of lagged industrial employment rate, percent of emissions covered). λ_i and δ_i capture unobserved country and time specific shocks, η_{it}.

fte vector of coe@cients a_l captures the effects due to fiscal policies in our case carbon tax from trading partners allowing for a dynamic response of output in own country.

3.1. Measuring cross country carbon tax spillover

fte EU countries are integrated with each other both by product and factor markets, the Union itself is a trade block, so imposition of a tax in one country will lead to effects in another through trade. So we calculate carbon tax spillovers ΔCTS_{it} from the trading partner countries as a weighted sum of carbon tax of the trading partner countries:

$$\Delta CTS_{it} = \sum_{jf=i} - \frac{1}{20} \sum_{s=1990}^{2017} \frac{exp_{ijs}}{exp_{is}} \sum CT_{jt} \quad (2)$$

where CT_{jt} represents the carbon tax of trading partner j in year t. fte term exp_{ijs} represents manufacturing exports of country i towards country j in the year s, the term exp_{is} represents the total manufacturing exports of country i in the year s to rest of the world. Equation (2) weights the foreign carbon tax by the long-run importance of the foreign countries in the exports of country i. fte term inside the parentheses depicts the average share of manufacturing exports of country i towards country j, we average export fiows over our time sample 25 years to take into consideration of measurement errors and endogeneity. fte structure of long-term trade weights is uncorrelated with changes in industrial structures or relative trade costs. ftus the approach identifies fiscal spillover shocks that are solely due to changes in trading partners' carbon tax policies (Nekarda and Ramey, 2011, Goujard, 2017).

Pescatori et al., 2011 introduced a narrative approach to identify 'action-based' episodes of fiscal adjustments in traditional macroeconomic literature that corresponds to discretionary policy choices extraneous to short-term economic developments. ftey comment fiscal policy changes are motivated by the desire to reduce the budget deficit and examine contemporaneous policy

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[4]we tried to keep it simple and followed traditional macroeconomic literature papers, Auerbach and Gorodnichenko, 2012, Auerbach and Gorodnichenko, 2017, Goujard, 2017

documents to establish whether discretionary changes in tax rates and government spending are also motivated by a response to the business cycle or not. fte estimated budgetary impact of the general government consolidation measures is based on contemporaneous historical sources and records.

Spillover shocks computed in equation (2) represents average amalgamation via manufacturing exports but it is not perfectly comparable to domestic fiscal shocks. Proceeding as mentioned by (Auerbach and Gorodnichenko, 2011, Auerbach and Gorodnichenko, 2012) we propose to scale foreign fiscal shocks in our case carbon tax shocks to ease with the comparison between the estimated spillover effects and the traditional multipliers of domestic fiscal policies

$$\Delta CTS_{it}^{*} = \sum_{\substack{if \\ s=1990}}^{2017} \frac{exp_{jb}}{imp_{jb}} \sum\sum \left[\frac{imp_{jb}}{G_{jb}} \right] \sum \cdot \left\{ \frac{CT_{jt} \times GDP_{jt-1b} \times EXCH_{jb}}{GDP_{it-1b} \times EXCH_{ib}} \right\} \tag{3}$$

where GDP$_{jt-1b}$ is the lagged real GDP in the base year b, CTS$_{jt}$ carbon taxes are expressed in percentage points of GDP. fte first term in parentheses is the share of imports of country j coming from country i in base year b. fte term in square brackets represents the size of the total imports of country j in base year b relative to the government spending of country j in base year b. fte term is used to correct for the fact that certain part of government expenditure are always converted into imports from other countries. fte last term in curly brackets represents the size of the government shock in country j as a share of lagged output in country i, where the numerator is equal to the value of the fiscal shock in country j, while the denominator represents the value of real potential GDP of country i in year t and base year b.

ftere is a lack of theoretical literature on the exact size of shocks being transmi1ed from abroad, consolidation package aimed to protect domestic economies might be designed and the indirect effects of government spending on domestic private spending should also be taken into account.

4. Data

Our data on real GDP, industrial employment and exchange rate comes from Penn World tables (Feenstra et al., 2016, data for carbon tax revenue and emissions covered in each sector are collected from a new data set from World Bank: Carbon Pricing Dashboard [5][6]. Data for government expenditure is from Eurostat database [7]. Data for import and export are from WITS database.

5. Estimation strategy

In this section, we specify the non-parametric model Local linear dummy variable estimation (LLDVE) method which was first proposed by Li et al., 2011 (and eventually also applied by

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[5]we convert nominal tax rates to real tax rates by dividing with GDP defiator (data from Penn World Tables)

[6]data for emissions were given as a share of global GHG, we converted the data to percentage and deducted from 1, thus giving us emission data not covered due to introduction of carbon tax
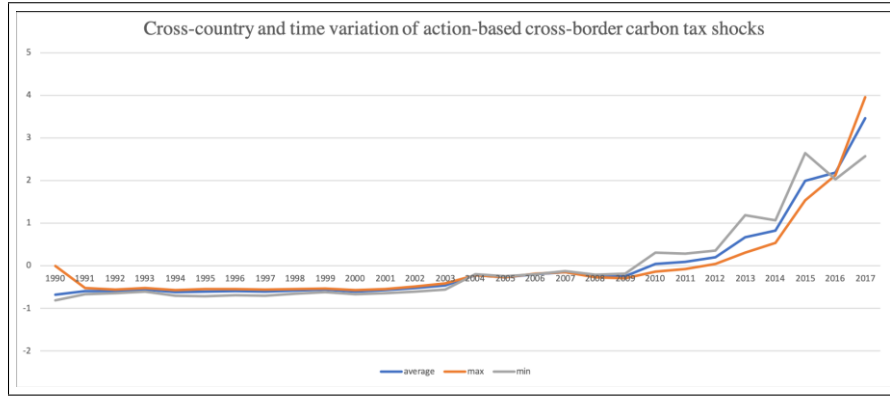
[7]we use 2011 as base year

Figure 1

Silvapulle et al., 2017 and Awaworyi Churchill et al., 2019).

fte LLDVE model can be explained as following, let $Y_{i,t}$ is the dependent variable with $i = 1, 2, \ldots., N$ and $t = 1, 2, \ldots.T$ are cross-sectional and time representations and $X_{i,t} = (X_{it,1}, X_{it,2}, \ldots., X_{it,d})^T$ are a set of d independent variables, then the basic model can be wri1en as

$$Y_{it} = f_i(t) + X_{it}^T \beta_t + a_i + s_{it} \tag{4}$$

Assuming $f(t/T) = f_i(t/T)$ for all i a cross-sectional specific trend function and $\beta_t = \beta(t/T) = (\beta_{t,1}, \ldots.\beta_{t,d})^T$ being an unknown time-varying coe@cient vector, a_i unknown individual effect (where $\sum_{i=1}^{N} a_i = 0$) and s_{it} being stationary for each i. fte LLDVE technique estimates individual trend functions through fi1ed residuals as prescribed by Phillips, 2001 with some basic basic assumptions, (i) e_{it} satisfies martingale differences over the time dimensions; (ii) e_{it} are independent of X_{it}; (iii) e_{it}'s are cross-sectionally dependent for each i; (iv) X_{it} and a_i can be correlated. Using the above assumptions Eq.(4) can be wri1en as

$$Y = f + B(X, \beta) + Da + s \tag{5}$$

where $Y = (Y_1^T, Y_2^T, \ldots., Y_N^T)^T$ with $Y_i = (Y_{i1}, Y_{i2}, \ldots., Y_{iT})^T$, $s = (s_1^T, s_2^T, \ldots., s_N^T)^T$ with $s = (s_{i1}, s_{i2}, \ldots., s_{iT})^T$ all for $i = 1, 2, \ldots, N$, $f = I_N \otimes (f_1, f_2, \ldots f_T)^T$, $a = (a_1, a_2, \ldots, a_N)^T$, $D = I_N \otimes I_T$ and $B(X, \beta) = (X_{11}^T \beta_1, \ldots X_{1T}^T \beta_T, \ldots X_{N1}^T \beta_1, \ldots X_{N1}^T \beta_T)$, I_k is a $k \times 1$ vector of ones and $\otimes$ is the Kronecker product. Assuming $\sum_{i=1}^{N} a_i = 0$ Eq. (4) can be re-wri1en as

$$Y = f = B(X, \beta) + D_* a_* + s \tag{6}$$

where $a_* = (a_2, \ldots., a_N)^T$ and $D_* = (-\bar{I}_{N-1}, I_{N-1})^T \otimes \bar{I}_T$ fte final assumption, $\beta_t = (\beta_1(t/T), \beta_2(t/T), \cdots.\beta_d(t/T))^T$ for $t = 1, 2, \ldots.T$, provided an unknown smooth function τ with $\tau = t/Ts(0, 1]$ given $f_t = f(t/T)$

LLDVE type models are very much sensitive to bandwidth selection, we select the bandwidth by leaving one unit out least square cross-validation method as suggested by Li and Racine, 2009 and Silvapulle et al., 2017.

8

6. Results

6.1. Parametric panel data results

6.1.1. Tests

We start by testing for Cross-sectional dependence (CSD) using the test suggested by Bailey et al., 2016, the results are shown in Table 2, show that the test reject the null hypothesis of cross-sectional independence along with the values of alpha provides the degree of cross-sectional dependence. From the values of alpha we can easily comment our data sample has strong degree of cross-sectional dependence [8]

Table 2: Test for cross-sectional dependence, Bailey et al., 2016

variable	CD	p-value	alpha	std.err
gdp	87.900	0.000	0.9836	0.0342
lagged gdp[9]	87.900	0.000	1.005	0.3464
spillover 1	87.708	0.000	1.0057	0.2047
spillover 2	87.809	0.000	1.0057	0.05083
lagged emp	51.260	0.000	0.987	0.0332
carbon tax em.	87.856	0.000	1.0057	0.086

[fte null hypothesis is that there is cross-sectional independence across countries in the panel.]

We then test for stationarity of our variables using second-generation panel unit root tests, results are provided in table 3. Due to the presence of strong cross-sectional dependence in our data we use these second-generation unit root tests, these tests use multi-factor error structure using heterogeneous factor loadings to model various forms of cross-sectional dependence. Pesaran, 2007 (CADF, CIPS)[Table: 3]; Bai and Ng, 2004 (PANIC) and Reese and Westerlund, 2016 (PANICCA) [Table: 4] to investigate more in-depth sources of unit roots among the variables. PANIC decomposes each variable into deterministic, common and idiosyncratic components, so that the origin of the cause of non-stationarity can be traced i.e., whether it arises from common component or the idiosyncratic component or both.

Bai and Ng, 2004 requires the number of common factors needed to represent the cross-sectional dependence, we assume only one common factor following Westerlund and Urbain, 2015 which indicates small number of unobserved common factors are su@cient enough to deal in macroeconomic examples. fte test PANICCA is mix of both Bai and Ng, 2004 and Pesaran, 2007, in which they use Cross-sectional Averages instead of Principal component estimates as used by Bai and Ng, 2004 to proxy for factors by pooling individual ADF t statistics on defactored residuals to test for nonstationarity of the idiosyncratic components

6.1.2. Estimation results

One of the easiest ways to deal with unit-specific heterogeneity is time-invariant fixed-effects, but the basic assumption behind fixed-effects is that the unobserved heterogeneity is constant

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[8]for a be1er explanation please look Ertur and Musolesi, 2017, Chakraborty and Mazzanti, 2019

Table 3: Second generation panel unit root tests- CADF and CIPS

Variables	CADF[+]	CIPS[+]
gdp	-2.120	-2.525
lagged gdp	-2.341	-3.221
spillover 1	-1.013	-5.060
spillover 2	-0.941	-3.169
lagged emp.	-1.632	-1.476
carbon tax em.	1.328	0.310

(+: statistics).

Critical values, CADF: -2.080 (cv10), -2.160 (cv5), -2.300 (cv1)

CIPS: -2.04 (10%), -2.11(5%), -2.23 (1%)

Table 4: Second generation panel unit root tests- PANIC PANICCA

Variables	PANIC**			
	ADF	P_a	P_b	PMSB
gdp	0.6899	0.8156	0.9106	1
lagged gdp	1	0.6026	0.6279	09687
spillover 1	0.6657	0.1168	0.1527	0.3799
spillover 2	0.5687	0.2905	0.3491	0.2499
lagged emp.	0.8192	0.7018	0.7435	0.9768
	PANICCA**			
	ADF	P_a	P_b	PMSB
gdp	0.593	0.6902	0.7529	0.9963
lagged gdp	0.0001	0.4646	0.4585	0.8796
spillover 1	0.9394	0.1845	0.1986	0.4552
spillover 2	0.6334	0.2115	0.2855	0.2584
lagged emp.	0.9849	0.7209	0.7694	0.9885

(**) p-values.

over time, which is strict assumption in regard to spillover studies. Presence of unobserved heterogeneity and cross-sectional dependence can cause inferential problems in nonstationary panels. We borrow five estimation techniques of the common correlated effects from Pesaran, 2006, Chudik and Pesaran, 2015 and Eberhardt et al., 2013. In table 5, we demonstrate the results from three types of estimators which are static of nature, mean group (**MG**), common correlated effects mean group (**CCEMG**) and augmented mean group (**AMG**)

We present the results of dynamic heterogeneous type case in table 6, we used three estimators namely, DCCE-OLS and DCCE-GMM using Chudik and Pesaran, 2015, Ditzen, 2018 and Neal, 2015.

Table 5: Static heterogeneous estimation results

Variable	MG	CCEMG	AMG
spillover 1	-1.246***(-7.63)	-0.955***(-2.58)	0.205***(3.02)
spillover 2	0.496***(5.56)	0.554*(1.90)	-0.082***(-2.88)
lagged emp.	1.149***(140.99)	1.066***(9.14)	0.799***(146.3)
carbon tax em.	-4.029***(6.57)	0.220 (0.41)	-0.7268(-1.71)
RMSE	0.2864	0.065	0.0774
CD test	0.000	0.584	0.978
CIPS	0.031	0.000	0.000
Obs.	672	672	672

Values inside parenthesis indicate

Table 6: Dynamic heterogenous estimation results

Variable	DCCE	DCCE-GMM
lagged gdp	-0.24 (-1.44)	-0.492 (-1.44)
spillover 1	-4.44* (-1.81)	-4.42*(-1.81)
spillover 2	-0.164(-0.20)	-0.164(-0.20)
lagged emp.	0.580(1.02)	0.580(1.02)
carbon tax em.	-0.648 (-1.35)	-0.648 (-1.35)
CD test	0.000	0.000
CIPS test	0.000	0.000
Obs.	600	600

6.2. Non-parametric estimation results

Figures 2-7 presents the local linear estimates, alongwith the 90% confidence intervals. fte common trend function has been increasing for our sample of countries over the time period, though from 2010 onwards the increase has fia1ened. fte lagged gdp variable showed a steep
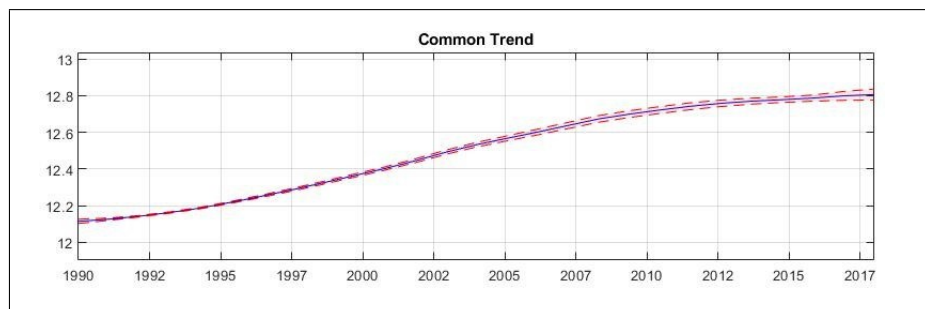

Figure 2

increase from 1990-1995 and then a fiat period till 2002 and a temporary dip till 2011 with a sharp increase till the end of our sample.
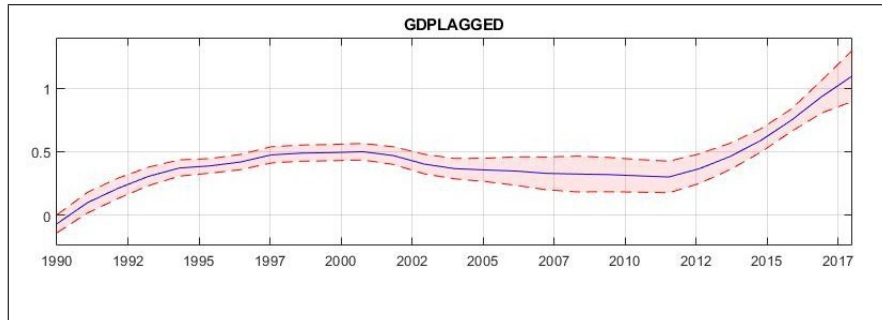
11

Figure 3

Figure 4 suggests the relationship between Spillover 1 and GDP oscillated around 0 for most of the period. Figure 5, similarly shows the relationship between Spillover 2 and GDP, which was quiet similar to Spillover 1, only in this case the confidence interval was bit more tight.
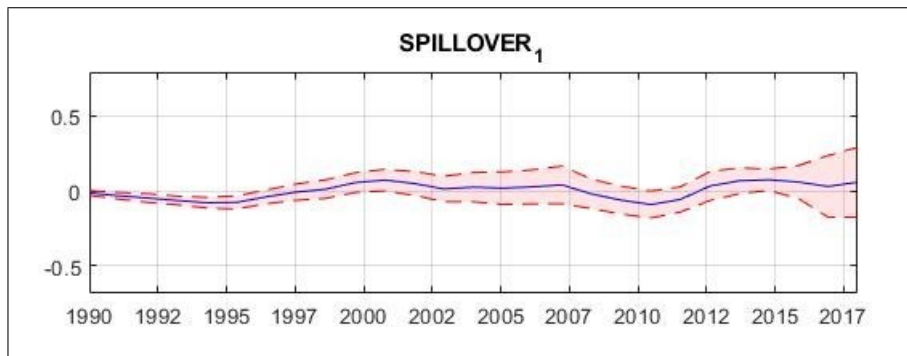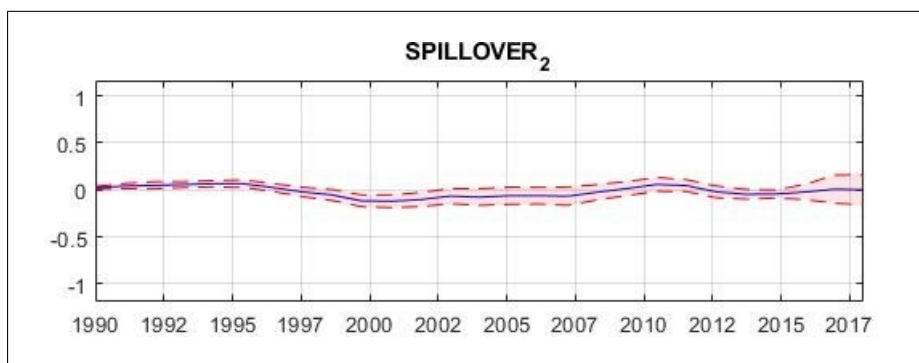

Figure 4

Figure 5

7. Conclusion

We have examined the spillover effects of carbon tax on gross domestic output inside Europe using a non-parametric panel data framework. Our estimates show that the relationship between
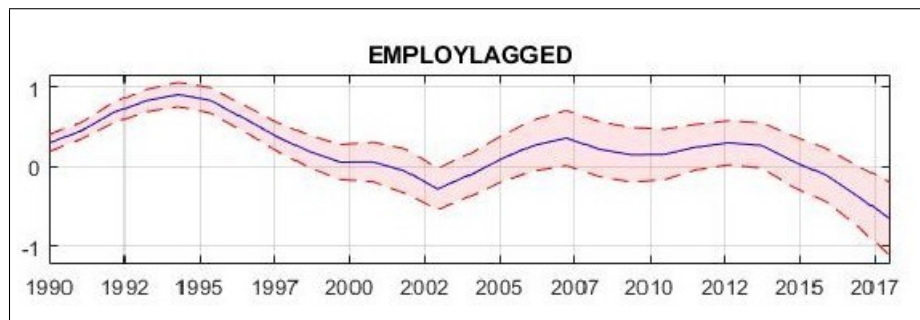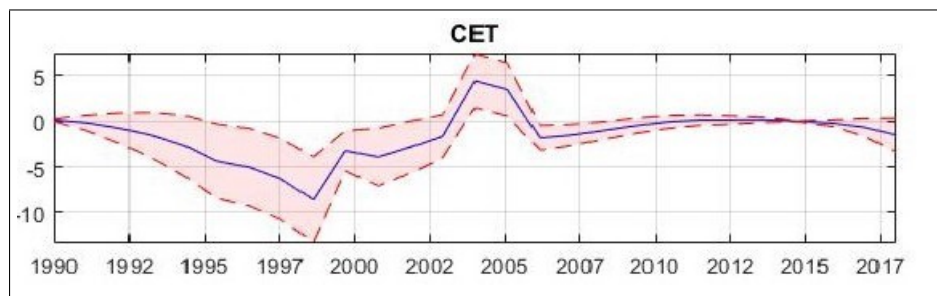
12

Figure 6

Figure 7

two types of trade based carbon tax spillovers have very negligible positive effects on growth. Atleast for Europe, we cannot conclude that carbon tax has any effect of gdp growth.

13

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