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Effects of Macroeconomic Policy on Air Quality: Evidence from the US

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Abstract

This paper examines the effect of economic policy on air quality using US quarterly data from 1973 to 2013. In particular, we analyze the short-run as well as the long-run interactions between fiscal and monetary policy with CO₂ emissions, employing time series techniques of co-integration, Granger multivariate causality and vector error-correction modeling. To take into account possible variations of the effect of economic policy according to the sources of pollution, we distinguish between industrial and residential inflicted CO₂ emissions. In addition, we construct the impulse responses to three linear combinations of fiscal shocks, corresponding to the three scenarios of deficit-spending, deficit-financed tax cuts and a balanced budget spending expansion. Policy implications from the results vary depending on the source of CO₂ emissions.

Keywords: Fiscal policy; monetary policy; environment.

JEL Classification: E52; Q53; Q54; Q56; E62.

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1. Introduction

A large part of Gross Domestic Product (GDP) in many countries, worldwide, is being spent by governments, subsequently determining many macroeconomic variables and welfare in general. Furthermore, in response to the world economic crisis that initiated in 2008, many governments around the world have followed expansionary macroeconomic policy to support and accelerate the recovery of their economies. A number of studies has recently suggested that fiscal spending is also a significant determinant of environmental pollution (Lopez et al., 2011, Islam and Lopez, 2013; Halkos and Paizanos, 2013; Galinato and Islam, 2014; Lopez and Palacios, 2014). The theoretical underpinnings of the interaction mechanisms between fiscal spending, environmental quality, and economic welfare have been analyzed in papers by Heyes (2000), Lawn (2003) and Sim (2006). Furthermore, it is possible that the size of government revenues as well as monetary policy also have an important role in the determination of environmental quality.

Regardless of the evidence that macroeconomic policy may be a significant determinant of environmental quality, this correlation has not been considered comprehensively in the existing literature. On one hand, countries with a large fiscal sector are more probable to have undertaken redistributive payments that enhance equality of income that may in turn lead to greater demand of enhanced environmental quality. In addition, according to Frederik and Lundstrom (2001), if the environment is considered to be a luxury public good it may only be demanded only after more necessary public needs have been addressed, which is more like to occur in countries with greater size of government spending.

It is important to note that the mechanisms through which fiscal spending affect environmental pollution differ regarding to the source of pollution i.e. whether the pollution is production or consumption generated (McAusland, 2008). For the former, Lopez et al.

(2011) recognize four different mechanisms through which a larger level of government expenditure may determine environmental quality. First of all, as already mentioned increased income enhances the demand for reduced environmental pollution (income effect). Furthermore, increased fiscal spending fosters activities that require human capital rather than physical capital which is more detrimental to the environment (composition effect), while increased labor efficiency also tends to reduce environmental pollution (technique effect). Depending on the relationship between fiscal spending and economic growth, increased government expenditure may lead to greater pollution levels in some levels of GDP (scale effect), according to the shape of the Environmental Kuznets Curve (Grossman and Krueger, 1995).

Concerning consumption generated pollution, according to Lopez et al. (2008) fiscal spending on sectors like health and education increases consumers' current and future income and thus may lead to an improvement of environmental quality (income effect). Moreover, government expenditure leads to the establishment and enforcement of appropriate environmental regulations that in turn may lead to the development of institutions that enhance environmental quality (Fullerton and Kim, 2008) particularly in democratic economies which are more likely to adopt stricter environmental rules compared to non-democratic administrations (Galinato and Islam, 2014). Finally, increased public spending may promote investment on and use of public transportation that is considered to impose less environmental pressures compared to than private means of transportation (Zimmerman, 2005 and Islam and Lopez, 2014).

The existent empirical literature offers indeterminate evidence on the estimated effect of fiscal spending on pollution. Considering production generated pollution Bernauer and Koubi (2006) find that an increase in fiscal spending raises emissions, while the quality of governance does not significantly affect this relationship. On the other hand, Frederik and

Lundstrom (2001) report that higher levels of economic freedom are associated with smaller pollution levels when the initial government size is small but increases pollution levels when the initial size is large. Lopez et al. (2011) concentrate on the significance of the composition of public spending on the environment i.e. the percentage of public goods on fiscal spending. They find that increasing the share of public goods in total government spending reduces emission levels.

Furthermore, they report that changes in total government spending, with its composition remaining constant, reduces environmental pollution but the result is insignificant in some specifications. In a similar study, Lopez and Palacios (2010) analyze the importance of fiscal spending and environmental taxes on the pollution levels in European countries reporting a negative effect of the former on the latter, independently of the composition structure of public spending. Regarding consumption based pollution Islam and Lopez (2013) as well as Gallinato and Islam (2014) report that an increase of the share of social and public goods in total government expenditure enhances environmental quality, particularly for governments that have constitute democratic regimes.

Taking into account this theoretical and empirical background, the purpose of the present study is to investigate how macroeconomic policy affects air pollution. The contribution of this paper is the more specific examination of the effects of fiscal policy, taking into consideration three different implementation scenarios, as well as those of monetary policy on environmental quality for the first time. To accomplish this we employ vector autoregression methods, employing a sample of quarterly data for the US economy, covering the period 1973-2013 for CO₂, distinguishing between production- and consumption-generated sources of the pollutant. We estimate the model by using a Vector Autoregression Model, to take into account dynamics in the analyzed relationships.

The next section describes the data employed in the empirical analysis and section 3 presents the suggested econometric methods. The empirical estimated are reported next while the last section presents the conclusions and describes policy implications of the results.

2. Data

The sample we use to estimate the model consists of quarterly data for 12 macroeconomic and environmental variables for the period 1973-2013, for the US economy. There are 164 observations per variable. Following Mountford and Uhlig (2009) the macroeconomic policy variables used are Total Government Expenditure, Total Government Revenue and Interest Rate while additional macroeconomic variables such as Gross Domestic Product, Private Consumption, Real Wages, Adjusted Reserves, Private Non-Residential Investment, PPIC and GDP deflator are employed. All macroeconomic variables are derived from the Federal Reserve Board of St. Louis and the US Bureau of Economic Analysis.

Table 1: Descriptive statistics of the environmental and macroeconomic policy variables, 1973:1 – 2013:4

	CO ₂ IC	CO ₂ RTC	RBPEXP	RBPREV	FFRT
Mean	2.779	3.239	4.298	3.796	5.754
Median	2.796	3.241	4.287	3.750	5.460
Maximum	3.131	3.329	4.623	4.280	17.78
Minimum	2.399	3.099	3.993	3.188	0.070
Std. Dev.	0.175	0.047	0.193	0.234	3.911
Coef. of Var.	0.063	0.015	0.045	0.062	0.680
Observations	164	164	164	164	164

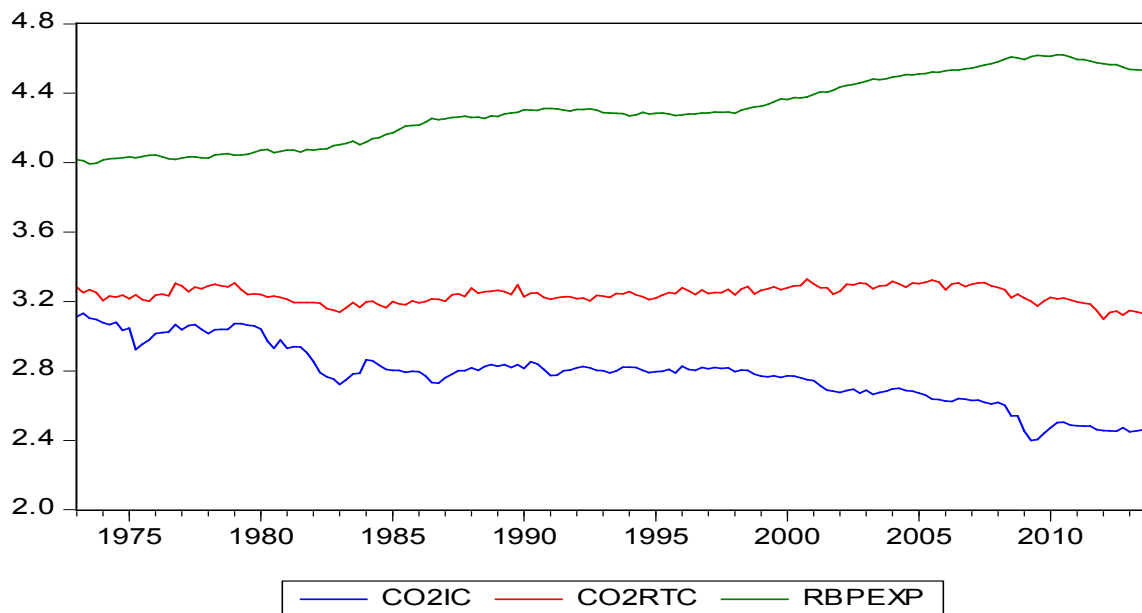
Note: All variables are in logarithms except the interest rate where the level has been used.

The CO₂ data are from the US Environmental Protection Agency and are distinguished in two categories according to their resources, namely production-generated emissions (industrial - CO₂IC) and residential and transport (i.e. consumption generated emissions - CO₂RTC). It is important to study both consumption and production generated pollution since, as already mentioned, the mechanisms through which fiscal spending affects

environmental quality are different and the estimated effect is possibly different both qualitatively and in magnitude.

The descriptive statistics of the environmental and macroeconomic policy variables of the model for the period 1973 to 2013 are presented in Table 1. It is interesting to note that the mean value of the CO₂RTC is higher than that of CO₂IC depicting the fact that residential and transport activities are a relatively greater source of pollution. On the other hand, CO₂IC emissions' variability is larger as shown by the coefficients of variation. Regarding the macroeconomic policy variables we observe that the average value of government spending is greater than that of government revenue, implying that on average the US government followed a deficit financed spending policy. Finally, the interest rate variable is characterized by large volatility. Figure 1 depicts these relationships.

Figure 1: Government expenditure, CO₂IC and CO₂RTC emissions, 1973:1 – 2013:4



3. Methodology

We initially estimate a typical Vector Autoregression Model which may be presented as:

$$\begin{bmatrix} X_t \\ Y_t \end{bmatrix} = \begin{bmatrix} \alpha_{1,0} \\ \alpha_{2,0} \end{bmatrix} + \begin{bmatrix} \beta_{11}^{(1)} & \beta_{12}^{(1)} \\ \beta_{21}^{(1)} & \beta_{22}^{(1)} \end{bmatrix} \begin{bmatrix} X_{t-1} \\ Y_{t-1} \end{bmatrix} + \begin{bmatrix} \beta_{11}^{(2)} & \beta_{12}^{(2)} \\ \beta_{21}^{(2)} & \beta_{22}^{(2)} \end{bmatrix} \begin{bmatrix} X_{t-2} \\ Y_{t-2} \end{bmatrix} + \dots + \begin{bmatrix} \beta_{11}^{(p)} & \beta_{12}^{(p)} \\ \beta_{21}^{(p)} & \beta_{22}^{(p)} \end{bmatrix} \begin{bmatrix} X_{t-p} \\ Y_{t-p} \end{bmatrix} + \begin{bmatrix} u_t \\ v_t \end{bmatrix}$$

if we define Z_t as $Z_t = \begin{bmatrix} X_t \\ Y_t \end{bmatrix}$ then we have

$$Z_t = \alpha + \beta_1 Z_{t-1} + \beta_2 Z_{t-2} + \dots + \beta_p Z_{t-p} + e_t$$

where Z_t is a vector including the system variables; $\beta_1, \beta_2, \dots, \beta_p$ are parameters; α is the deterministic element of the VAR model; e_t is the vector of random errors distributed with zero mean and Ω variance matrix. If the variables are non-stationary but are integrated of order 1 [i.e. I(1)] and co-integrated then a Vector Error Correction Model (VECM) should be employed instead. The VECM restricts the long-run behavior of the endogenous variables to converge to their co-integrating relationships while allowing for short-run adjustment dynamics and the deviation from the long-term equilibrium is gradually corrected by the co-integration term.

For constructing the impulse responses we use the Generalized Impulse Responses approach which unlike the conventional impulse response method typically employs a Cholesky decomposition of the positive definite covariance matrix of the shocks; the advantage of the generalized impulse response analysis is that it does not require orthogonalization of shocks. Since the resulting impulse responses are invariant to the ordering of the variables in the VAR, this approach gives unique and robust results. We then estimate bootstrap confidence intervals that allow us to identify the significance of the reported effects.

Furthermore, we employ an alternative identification method using sign restrictions, as proposed by Mountford and Uhlig (2009). This identification method handles several issues that often occur when using vector autoregressions to identify policy shocks. First of all, there is the issue of separating changes in variables that are the result of actual fiscal policy shocks as opposed to those that capture the variability of fiscal variables in response to the business cycle shocks. Then, there is the difficulty of defining a fiscal policy shock since

unlike monetary policy that usually refers to a change in interest rates, there are many different ways that fiscal policy may be implemented. Finally, the fact that there is usually a delay between the planning and implementation of fiscal policies may cause movements in macroeconomic variables that do not relate to the actual implementation of the former.

To solve the first issue we identify monetary policy and business cycle shocks that are orthogonal to a fiscal policy shock, separating the automatic responses of fiscal variables to those shocks. For the second problem, we consider fiscal policy shocks that range between a government spending and a government revenue shock, or any linear combination of those like balanced budget expansionary policies. To deal with announcement effect we restrict the behaviour of impulse responses, by imposing the restriction that the macroeconomic and environmental variables of interest do not respond for a one year period and only then begin to vary for a specified period.

To enhance the identifying power of the model we restrict responses for four quarters after the initial shock ruling out short-term changes in government expenditure that do not constitute part of a specific fiscal policy. However, to avoid any bias in the estimated results, it is important to note that there are no sign restrictions imposed on the reaction of the environmental variables.

4. Empirical Results

Table 2 summarizes the results of the Granger causality tests between CO₂ emissions and the macroeconomic variables as well as per capita income. In performing the tests, 2 lags were used in the regressions since this is the optimal number of lags in the VAR model as indicated by the Akaike (AIC) and Schwarz Information Criteria (SC)¹. We reject the hypothesis that RBPEXP does not Granger cause CO₂IC but the same does not hold for CO₂RTC. However, there is evidence that government expenditure is caused by changes in

¹ For details see Halkos (2006, 2011).

emissions of the latter sources. One plausible explanation for that is that since CO₂RTC emissions are greater than CO₂IC government expenditure responds to variations in emissions from these sources.

On the other hand, government revenue affects both CO₂IC and CO₂RTC levels however, is not caused by any of them. Interestingly, monetary policy proxied by the interest rate does not affect either pollutants' emission levels but seems to be preceded by variations in industrial CO₂ emissions. Finally, there is support for a bivariate causal relationship between CO₂IC and per capita income, while there seems to be no relationship between GDP and CO₂RTC emissions. This depicts the Environmental Kuznets Curve (EKC) relationship between GDP and pollution levels. Specifically, for high income countries, like the United States, there is evidence in the literature of a large effect of GDP on production generated pollution but the curve is rather flat in the relationship with consumption generated pollution (Halkos, 2003 and Martinez-Zarzoso and Bengochea-Morancho, 2003).

Before turning to the estimation of the vector autoregression model we check the time series properties of all the variables employed in our analysis. To accomplish that we use stationarity tests like the Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests, reported in table 3.

The ADF test is based on the following data generation process:

$$\Delta X_t = a + \gamma X_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta X_{t-j} + \varepsilon_t$$

$$\Delta X_t = \alpha + \beta T + \gamma X_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta X_{t-j} + \varepsilon_t$$

The term Δ is the first differences operator; the variable that is examined is symbolized by X_t ; t depicts time and T is the linear trend; the lag order is expressed by p ; and the white noise error term is symbolized by ε_t ; We report two processes with intercept as well as with intercept and trend. We test the hypothesis that $H_0: \gamma=0$ against its alternative that $\gamma \neq 0$

comparing the estimated τ -values with the critical values of the MacKinnon tables and with rejection of the null hypothesis that the variable under consideration does not have a unit root. On the other hand if the variable is found to be stationary in first differences, it is integrated of order one i.e. I(1). Finally, application of the Phillips-Perron test takes into account higher order serial correlation, while the choice of the optimum number of lags used is based on an application of the Akaike (AIC) and Schwarz (SC) criteria.

Table 2: Granger Causality tests of bivariate relationships

Variables	CO ₂ IC		CO ₂ RTC	
	F statistic	Probability	F statistic	Probability
RBPEXP does not Granger Cause CO2	4.713	0.010**	0.198	0.820
CO2 does not Granger Cause RBPEXP	0.163	0.849	3.284	0.040**
RBPREV does not Granger Cause CO2	5.949	0.003***	3.864	0.023**
CO2 does not Granger Cause RBPREV	0.447	0.639	0.896	0.410
FFRT does not Granger Cause CO2	2.017	0.136	0.510	0.601
CO2 does not Granger Cause FFRT	4.320	0.014**	0.398	0.671
RGDPC does not Granger Cause CO2	21.56	0.000***	2.038	0.133
CO2 does not Granger Cause RGDPC	5.579	0.004***	1.399	0.249

Significant at 5% *Significant at 1%.

Table 3: Unit root ADF and Phillips-Perron tests – Quarterly data 1973:1 – 2013:4

Variables	Deterministic	ADF		Phillips-Perron	
		Level	Difference	Level	Difference
CO ₂ IC	Intercept	0.718	0.000	0.693	0.000
	Trend and intercept	0.383	0.000	0.337	0.000
CO ₂ RTC	Intercept	0.347	0.000	0.096	0.000
	Trend and intercept	0.698	0.000	0.292	0.000
RBPEXP	Intercept	0.675	0.005	0.796	0.000
	Trend and intercept	0.424	0.021	0.806	0.000
RBPREV	Intercept	0.346	0.000	0.216	0.000
	Trend and intercept	0.090	0.000	0.294	0.000
FFRT	Intercept	0.376	0.000	0.451	0.000
	Trend and intercept	0.013	0.000	0.067	0.000
RGDPC	Intercept	0.815	0.000	0.787	0.000
	Trend and intercept	0.784	0.000	0.791	0.000
RCON	Intercept	0.674	0.000	0.729	0.000
	Trend and intercept	0.920	0.000	0.934	0.000
RNRESIN V	Intercept	0.589	0.000	0.652	0.000
	Trend and intercept	0.945	0.000	0.957	0.000

Note: All values reported are probabilities.

In all levels there is no evidence of stationarity in levels and all the time series used are integrated of order one at the conventional 5% significance level (Table 3). If the variables are also cointegrated we may proceed with the estimation of the Vector Error

Correction Model (VECM). For that reason we first run the Johansen cointegration test (see Table 4) to determine the number of cointegrating relations, assuming that all trends are stochastic.

Table 4: Johansen Cointegration test

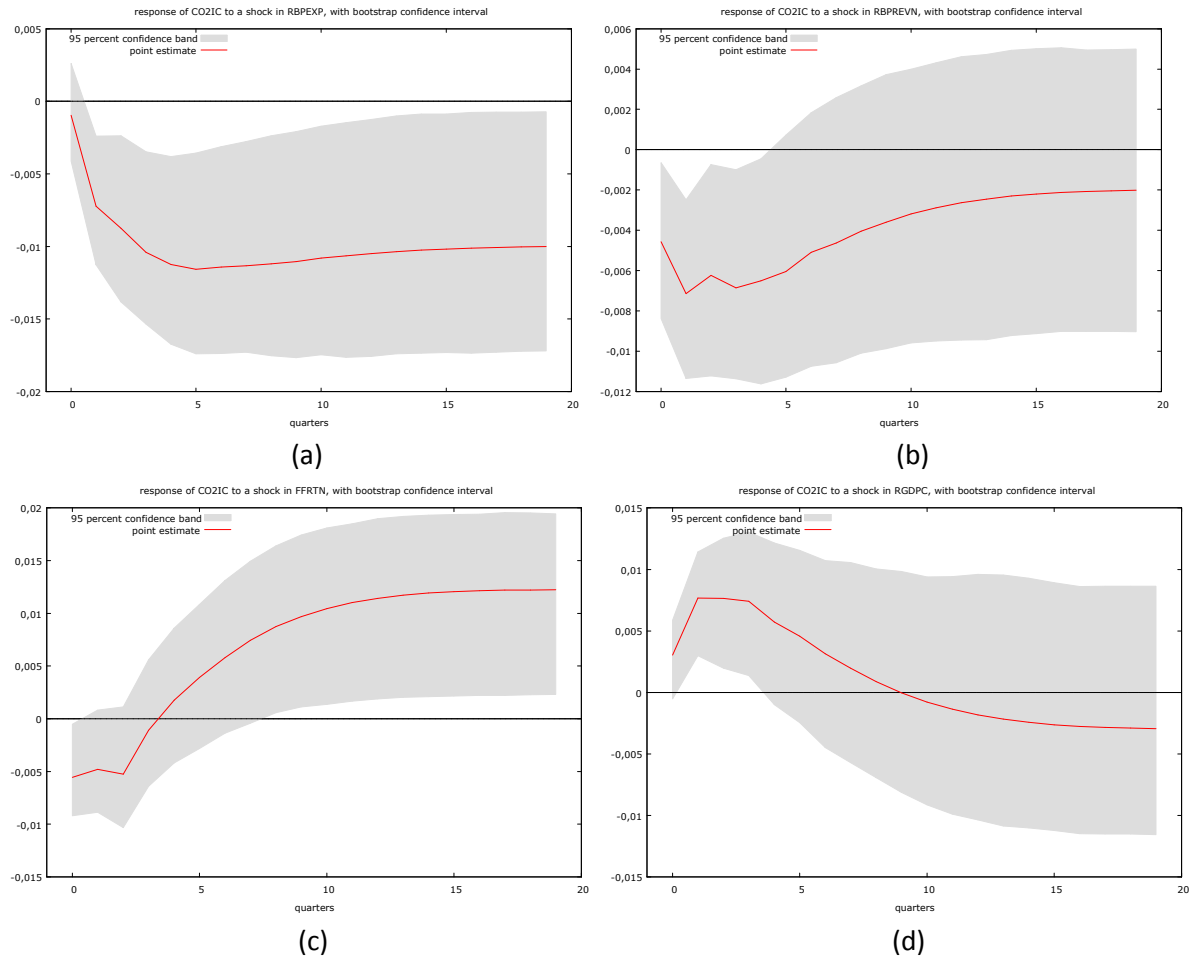
Hypothesized No. of CE(s)	Trace test		Max Eigenvalue	
	Trace Statistic	Probability	Max-Eigen Statistic	Probability
$H_0: r = 0$	210.563	0.000***	54.183	0.032**
$H_0: r \leq 1$	156.379	0.000***	47.567	0.035**
$H_0: r \leq 2$	108.812	0.004***	35.988	0.134
$H_0: r \leq 3$	72.824	0.028**	27.685	0.228
$H_0: r \leq 4$	45.138	0.088*	19.569	0.371

The first column shows the number of cointegrating relations under the null hypothesis. The first block reports the trace statistics and the second block reports the maximum eigenvalue statistics. To determine the number of cointegrating relations conditional on the assumptions made about the trend, we can proceed sequentially until we fail to reject. The trace statistic indicates 3 cointegrating equations, while the maximum eigenvalue statistic indicates 1 cointegrating equation. Hence, following the most conservative statistic, we estimate the VECM assuming 1 cointegrating equation. In addition, performance of the AIC and SC criteria combined with an application of the Portmanteau Autocorrelation Test showed that the preferable length of lags for the model is 2. Finally, the estimated VAR is stable (stationary) since all roots have modulus less than one and lie inside the unit circle.

The error correction term, that represents the adjustment towards long run equilibrium, is statistically significant in both the environmental variables' equations and in most of the other cases implying long-run causality. The forecast error variance decomposition and impulse response functions analysis are key to analyzing the estimated results. The impulse response functions depict the way a series respond to an innovation in another variable or itself over time. These innovations of the variables are captured by shocks

in the error terms of the model's equations. To ensure that the innovations are orthogonal to the ordering of the VAR we construct Generalized Impulses (Pesaran and Shin, 1998). The generalized impulse responses are depicted in Figures 2 and 3.

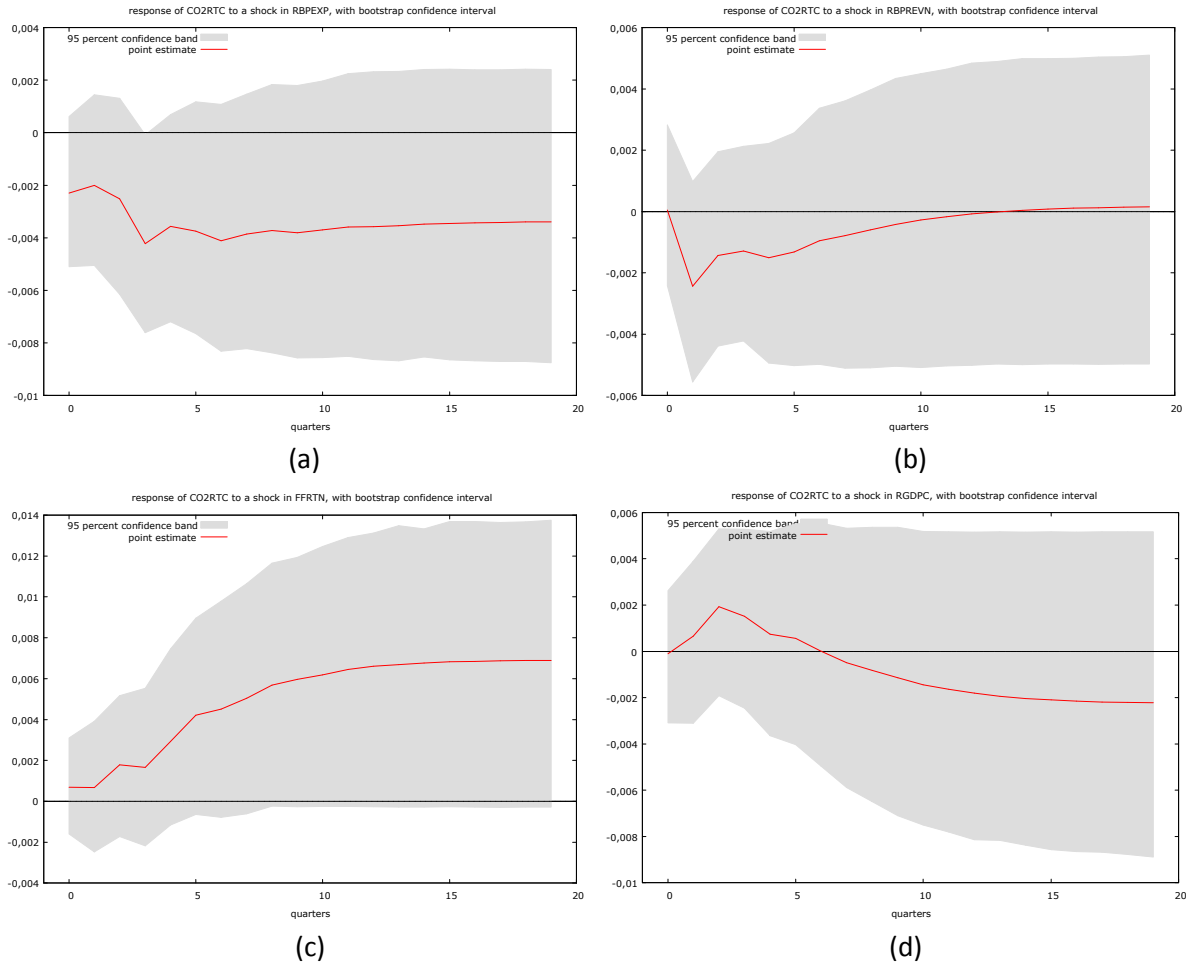
Figure 2: Impulse responses of CO₂IC to (a) RBPEXP, (b) RBPREV, (c) FFRT and (d) GDPc



After a one Standard Deviation (S.D.) increase of government expenditure, production generated CO₂ pollution declines after arriving at a peak of -0.012 in 6 quarters and then remains constant at about -0.011. On the other hand, CO₂IC declines after a 1 S.D. shock of tax cuts, meaning that a decline of RBPREV reduces production generated CO₂ emissions which reaches a maximum of -0.008 after 2 quarters. However, from the 5th quarter onwards this effect is not statistically significant. Regarding monetary policy, following a decrease of the interest rate, CO₂IC, slightly falls on impact and then begins to rise after the

8th quarter stabilizing at -0.012. Finally, CO₂IC starts increasing after a positive shock in income but this effect is significant only until the 3rd quarter.

Figure 3: Impulse responses of CO₂RTC to (a) RBPEXP, (b) RBPREVN, (c) FFRT and (d) GDPc



Regarding consumption generated CO₂ emissions a one S.D. increase of government expenditure has no effect, while the same is also true for a shock in government revenue, monetary policy and per capita income.

In general, the effect of macroeconomic policy is greater, in significance and absolute values, on production generated pollution compared to that on consumption generated pollution, a result that is in line with other recent studies (Halos and Pianos, 2013; Islam and Lopez, 2013). The reason of the difference in the significance and magnitude of the

estimated effects of fiscal policy on CO₂IC and CO₂RTC depends on the mechanisms through which different types of pollutants respond to these policies.

The forecast error variance decomposition is shown in Figure 4. According to the results government expenditure explains more than 15% of CO₂IC emissions fluctuations, while only 1% of CO₂RTC variability. Concerning government revenue shocks they explain about 4.5% and 1.9% of the fluctuations in CO₂IC and CO₂RTC respectively. Finally, monetary policy shocks explain a much larger percentage of CO₂IC fluctuations rather than of CO₂RTC. It is interesting to note that the importance of GDPC in explaining fluctuation in emission levels is lower than that of government expenditure, particularly for CO₂IC.

4.1 Policy analysis

In taking into examination the effects of fiscal policy shocks and following the methodology proposed by Mount ford and Huling (2009), we consider different fiscal policy shocks as different linear combinations of the basic fiscal policy shocks, focusing on three fiscal policies that are often used, namely a deficit financed tax cut, a balanced budget spending and a deficit expenditure shock. But it has to be clear that other scenarios of interest may be analysed in this way as well. By denoting $r_{aja}(k)$ as the response at horizon k of variable j to the impulse vector a , then the above policy requires that

$$0.01 = \sum_{j=0}^k (r_{GS,BGS}(k-j)BGS_j + r_{GS,BGR}(k-j)BGR_j) \quad \text{for } k = 0, \dots, K$$

$$0 = \sum_{j=0}^k (r_{GR,BGS}(k-j)BGS_j + r_{GR,BGR}(k-j)BGR_j) \quad \text{for } k = 0, \dots, K$$

Where $K = 4$, GS and GO represent government expenditure and government revenue respectively, and Bags and Bagri are correspondingly the scale of the standard basic government spending and revenue shocks in period j .

Figure 4: Variance decomposition of the the environmental variables

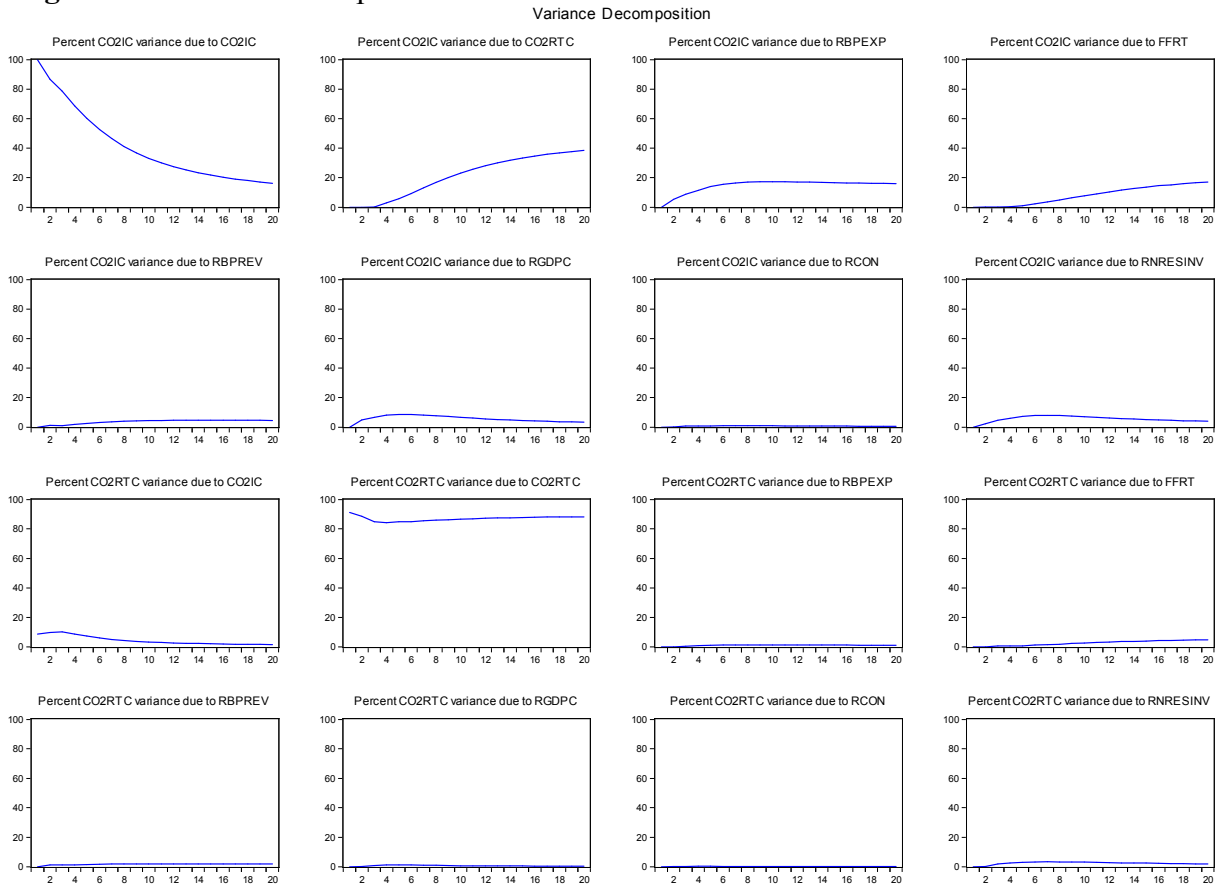


Figure 5: The deficit-financed tax cut policy scenario where government revenue is reduced by 1% for one year while government expenditure remains unchanged.

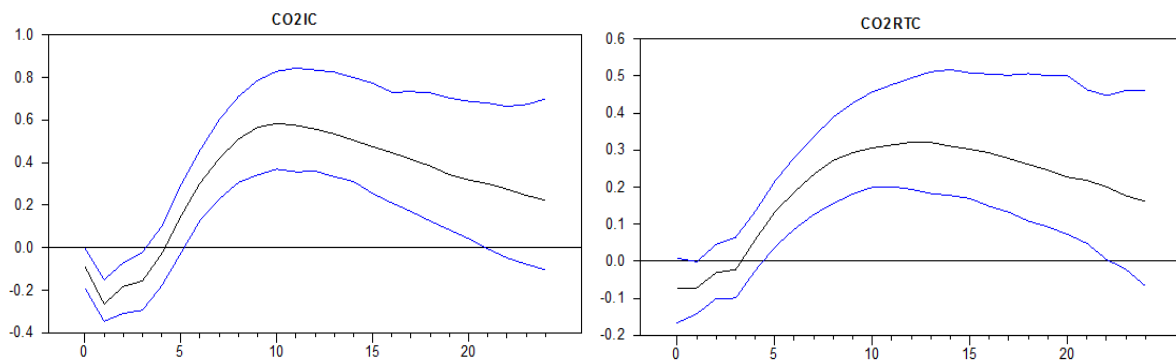


Figure 5 displays the impulse response functions for a tax cut financed by deficit. The policy scenario is designed as a sequence of basic fiscal shocks such that tax revenues are reduced by 1% and government expenditure is constant for four one year after the first shock. The tax cut initially decreases CO₂IC emissions but starting from the 5th quarter and until the

20 quarter production generated pollution significantly increases. For CO₂RTC there is a reduction on impact and on the 1st quarter, however there is a significant positive impact from the 5th to the 21st quarter.

Figure 6: The deficit spending policy scenario where government expenditure is raised by 1% for one year with government revenues remaining constant.

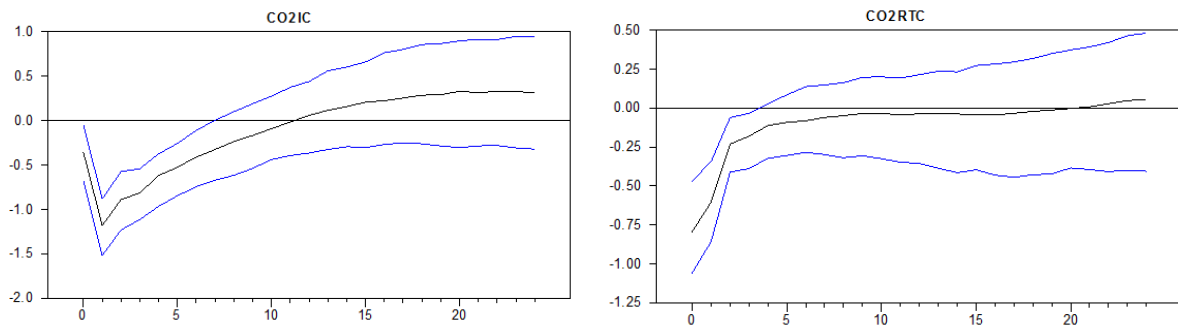
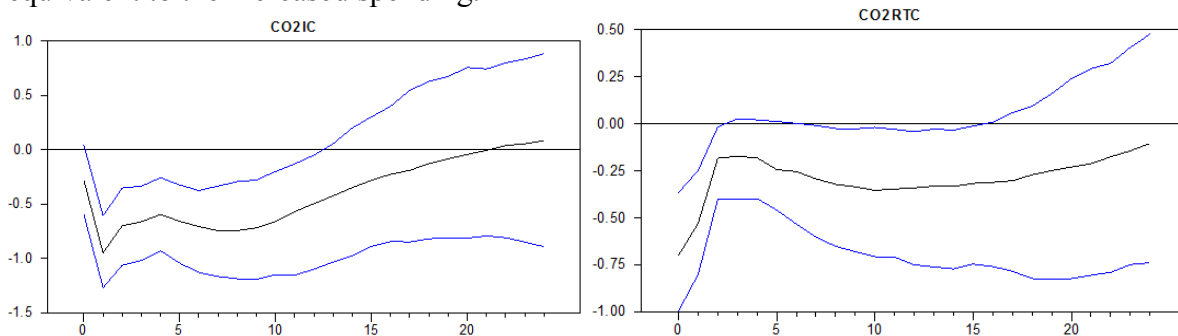


Figure 7: The balanced budget policy scenario where government expenditure is increased by 1% for one year and government revenues raised so that the increased returns are equivalent to the increased spending.



The impulse responses for a deficit spending fiscal policy scenario are depicted in Figure 6. This policy scenario combines the basic fiscal shocks in such a way that fiscal expenditure rises by 1% and tax revenues are constant for one year. The deficit spending scenario reduces production and consumption generated CO₂ emissions during the first seven and three quarters respectively, however the effect is much smaller in the latter.

Finally, the balanced budget expenditure policy requires both tax returns and government spending to rise in such a way that the increase in returns and spending is equalized for each quarter for one year period (Figure 7). These show that instantly there is a

relatively important reduction effect on both production and consumption generated pollution which lasts until the 12th and 16th quarters respectively and then ceases to be significant.

The effects of the three policy scenarios are summarized in Table 5. Even though, the greatest decrease of emissions from both sources, occur after a quarter in the deficit spending policy scenario, this policy deteriorates environmental quality in the mid-term period. Thus, assuming that the enhancement of environmental quality constitutes a priority there is evidence that a spending expansion is preferable and in particular a balanced budget expenditure increase is the preferable expansionary fiscal due to it having a more sustainable effect. Once more, there is evidence that following a spending expansion, the decrease of CO₂ emissions from production sources is greater in absolute values than for those emissions that are considered to be consumption generated.

Table 5: Effect of the fiscal policy scenarios on environmental variables

	1 qrt	4 qrts	8 qrts	12 qrts	20 qrts	Minimum	Maximum
CO2Ic							
Deficit-financed tax cut	-0.24*	-0.01	0.56*	0.58*	0.36*	-0.24* (qrt 1)	0.61* (qrt 10)
Deficit Spending	-1.18*	-0.59*	-0.20	0.07	0.21	-1.18* (qrt 1)	0.24 (qrt 22)
Balanced Budget	-0.91*	-0.58*	-0.73*	-0.48*	-0.04	-0.91* (qrt 1)	0.07 (qrt 24)
CO2RTc							
Deficit-financed tax cut	-0.08*	0.09	0.26*	0.31*	0.21*	-0.08* (qrt 1)	0.31* (qrt 12)
Deficit Spending	-0.54*	-0.10	-0.09	-0.07	0.00	-0.78* (qrt 0)	0.08 (qrt 24)
Balanced Budget	-0.46*	-0.21	-0.29*	-0.30*	-0.24	-0.70* (qrt 0)	-0.13 (qrt 24)

Note: * indicates significance at the 5% level.

5. Discussion and conclusions

This paper, employing quarterly data for the US economy for the period 1973 - 2013 and using vector autoregressions, examines the effect of macroeconomic policy on pollution. The results confirm the existence of a correlation between fiscal expenditure and pollution that has been identified in recent theoretical and empirical studies. In addition, it provides for the first time evidence regarding the relationship between monetary policy and environmental degradation. We report a significantly negative effect of government expenditure on both the

production and consumption generated emissions of CO₂, in line with other recent studies that provide evidence of a non-positive effect of fiscal spending on environmental quality. Finally, monetary policy only has an effect on production-generated pollution.

The quantitative differences and significance levels of the estimated effects of fiscal spending on CO₂IC and CO₂RTC could be attributed to the different mechanisms through which the production and consumption generated pollutants are influenced by the different macroeconomic policies adopted. For example, for consumption related pollutants environmental regulations the use of environmental policies is more difficult as the primary tool to reduce these is the implementation of environmental taxes, which are often avoided as they are not politically popular.

The importance of the analysis is highlighted given the current emphasis on expansionary macroeconomic policy as a tool to alleviate the adverse effect of the recent economic crisis. In many countries there has been a sharp increase of public expenditure, while at the same time the share of public goods in total government expenditure has increased with government focusing more on environmental quality as well as health and education systems. That said, our results provide evidence that increasing government expenditure could render the efforts to improve environmental quality easier and more cost efficient than is currently assumed.

Thus, even if no changes are implemented in environmental regulation and rules, increasing the size and composition of fiscal expenditure towards public goods could lead to a reduction of, mainly, production- but also consumption-generated pollution. On the other hand, if tax-cuts, as recommended by Mountford and Uhlig (2009) and expansionary monetary policy are to be followed, they should be accompanied by the enforcing appropriate environmental regulation, particularly for production-generated pollution, if environmental degradation is to be avoided.

Further extensions of this analysis could be directed to the examination of the relationship between macroeconomic policy and pollution in countries with different characteristics than that of the US. In addition, there is a gap in the literature concerning the theoretical underpinnings of the relationship between fiscal and monetary policy expansions on pollution, which could be established taking into account our results and lead to normative judgments regarding these relationships.

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