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Long run effect of public grants on the R&D investment:

A non-stationary panel data approach[✧]

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Abstract

From a macroeconomic point of view, the relationship between R&D investment and growth is well-known. At a firm level, extensive literature exists that analyzes the determinants behind R&D investment decision-making –basically comprising economic and financial factors-. Using cointegration techniques, the aim of this paper is analyze the long run effect of public grants on R&D investment for the Spanish case. Classifying the sample according to cointegration, we eliminate the possible existence of spurious correlation using the most suitable econometric techniques. Results in the long-run show that sales possesses a high pro-cyclical component with an elasticity of approximately 0.6. Subsidies generate additionality with an elasticity ranging from 0.17 to 0.2. Nevertheless, the capacity to promote investment for each euro of public funds is greater than the tax credit, with elasticities which can reach 0.7. In addition it worth highlight that we observe a higher impact of subsidies in cointegrated firms that are those with more investment in I+D.

Keywords: R&D, public grants, tax credits, effectiveness, panel data

JEL classification: G31, G32, O32, E44

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1. Introduction

Investment in R&D has positive effects on growth and productivity in the long-run. Despite this, economists have revealed that the level of R&D is less than would be desirable. Two reasons exist for the sub-optimal level of R&D. Firstly, the technological knowledge resulting from the investment has characteristics of a pure public good being partially excludable and non-rival (Arrow, 1962). Consequently, the cost of R&D generates positive externalities which restrict the ability of the investing agent to appropriate completely the private investment arising from new products or processes. In fact, the social return exceeds the private one. Secondly, the investment in R&D affronts important restrictions when obtaining external financing (Hall, 2002). Hence, the risk of failure of the projects may be very high, especially in sectors such as biotechnology, thereby making funding difficult Moreover, the return on investment appears in a lengthier time frame so that financing is also long-term which presents an additional difficulty. Lastly, given the technical level of the investment in R&D, the funders may be subject to limitations in controlling the development of projects. These information asymmetries can be used by investors to orientate their activity towards more risky lines of research. Such asymmetries can be relaxed by signposting the quality of their projects with the selection of a determined capital structure (Goodacre and Tonks, 1995). For example, with a greater proportion of debt in which the lender indicates the expectation that sufficient income will be generated to repay the loan.

Governments use different instruments for reducing the impact of these two market failures on business investment. The usual procedure for correcting problems of appropriability is the regulation of intellectual property rights. In order to soften the impact of financing restrictions, governments use a mixture of financial and fiscal instruments, although in the present paper we concentrate our attention on subsidies and investment incentives. The concession of subsidies is by way of public tenders where projects are assessed by a public agency on the basis of criteria such as quality, region of operations or employment generated. These types of direct aid can condition the viability of the investment especially so in the case of high risk projects (for example, vaccines) and/or for small-scale enterprises. It is expected that these public subsidies stimulate the additionality of the investment. In other words, these projects would not be performed without being subsidized. The tax credit of the investment is of a horizontal nature given that no selection criteria exist as in the case of the subsidies. Consequently, investment projects reduce their marginal costs via taxes. Evidence shows that the tax credit has a positive effect on the investment in R&D (amongst others Yang et al, 2012; Romero et al, 2014; Radas et al, 2015). Moreover tax incentives may prove more effective than subsidies (Carboni, 2011; Romero et al 2014).

Different methodologies exist for analyzing the efficiency of subsidies and credit for investment in R&D such as the Euler equations or Cobb-Douglas or translogarithmic functions. The common characteristic of all these methodologies is that they analyze whether subsidies are complementary to private funding (generating additionality or crowding-in) or to the contrary, they are substitutes (generating crowding-out) (see, amongst others, the surveys of David, Hall and Toole, 2000 and Aerts, Czarnitzki and Fier, 2006). After almost five decades of research, the empirical evidence concerning the effectiveness of public subsidies is far from offering a conclusive answer (see the revision of Zuñiga et al, 2012). Nevertheless , the literature available at firm level tends to reject the full crowding-out hypothesis for R&D inputs, for example in Aerts and Schmidt (2008) for Flanders, González et al. (2005), González and Pazó (2008), Herrera and Heijs (2007)for Spain, Görg and Strobl (2007) for Ireland and Hyytinen and Toivanen (2005) for Finland. Other studies such as Busom (2000) and Herrera and Heijs (2007) for Spain, Lach (2002) for Israel or Wallsten (2000) for USA, accept the existence of partial crowding out. Lastly, there are studies which accept the existence of full crowding-out such as Romero et al (2014) for Spain.

Whatever approach is chosen, the analysis of the efficiency of subsidies faces two significant econometric problems. The first is the possible inconsistency of the estimates due to the existence of endogeneity in the subsidies. The possible cause of said endogeneity derives from the fact that the companies which receive most of the subsidies could at the same time be those that invest the most in R&D. Until the 1990´s however, the majority of studies ignored the endogeneity problems with OLS being the estimator most commonly used (David et al., 2000). Difference-in-differences estimators, sample selection models, instrumental variable and non-parametric matching methods have been the methodologies most utilized to correct endogeneity since the 1990´s. A second econometric question is that some of the results available in the literature could be spurious if we take into account that variables such as R&D or sales often show path dependence indicating the existence of non-stationarity. Moreover the estimation of a model with two or more non-stationary variables generates the so-called spurious regression where the parameters are significant, although in reality no relationship exists between the variables. One way of resolving this problem has been to detrend the series, although Philips (1986) demonstrates that this procedure does not resolve the problem even if the series are integrated. A second procedure is to estimate the model using integrated series in differences. The problem of this procedure is that the information regarding the long-term relationships between variables may be lost.

Using a Cobb-Douglas function, this study analyzes the role of subsidies in long-term investment in R&D, taking into account both the problems of endogeneity as well as the non-stationary characteristics of the variables. With this in mind, we use the Fully Modified OLS (FMOLS) and the Dynamic OLS proposed by Kao and Chiang (1997). These estimators correct the standard pooled OLS for serial correlation and endogeneity of regressors that are normally present in a long-run relationship. The model has been estimated by dividing the sample into cointegrated and non-cointegrated companies. The paper is set out as follows. In section 2 we present the econometric model. The database is described in section 3. The results are presented in section 4. In section 5 we offer a counterfactual scenario. Section 6 concludes.

2. Econometric Model

We consider a heterogeneous panel data model where the cost of investment in R&D is expressed using the following Cobb-Douglas function:

$$R_{it} = \alpha S_{it}^{\beta} X_{kit}^{\delta_k} e_{it}^{\mu_i + v_{it}} \quad , \qquad [1]$$

where R_{it} is the R&D investment, S_{it} are the sales of the firm and X_{it} is a set of exogenous variables. The error component term includes μ_i, i-th time invariant time individual effects, and the idiosyncratic disturbance, v_{it}. Taking logs and adding a set of explanatory variables we obtain the following expression:

$$\ln R_{it} = \alpha + \beta_1 \ln S_{it} + \beta_2 \ln PG_{it} + \beta_3 \ln D_{it} + \beta_4 \ln TC_{it} + \beta_5 MS_{it} + \mu_i + v_{it} \qquad [2]$$

where $\mathrm{PG}_{\mathrm{it}}$ are the public subsidies received by the company, D_{it} captures the weight of external financing, $\mathrm{TC}_{\mathrm{it}}$ is the tax credit available on the R&D investment and, finally, $\mathrm{MS}_{\mathrm{it}}$ which represents the market quota of each company.

As is the usual case in the literature, equation [2] includes sales as the regressor in order to analyze the pro-cyclical or counter-cyclical effect of the investment. A negative shock in the economy will penalize more the investment in R&D of the more restricted companies because they are obliged to use both cash flow and debt in order to survive in the short-run. As suggested by Stiglitz (1993), in these types of companies the investment in R&D will be pro-cyclical while in the unrestricted companies it will be counter-cyclical. The macro evidence referring to the countries of G7 indicates that the cost of R&D is pro-cyclical (amongst others, Walde and Woitek, 2004, Comin and Gertler, 2006, Barlevy, 2007). In this context, the work of Barlevy (2007) and Ouyang (2011) who use data of the US manufacturing industries also reveal the existence of procyclicality. The results are more in line with the idea suggested by Stigliz (1993) who uses microdata. Amongst others, the results of Domadenik et al (2008) for Slovenian companies, Aghion et al. (2012) for French companies and López-García et al. (2012) and Beneito et al (2015) for Spanish companies, find that the expense in R&D is pro-cyclical for restricted companies and counter-cyclical for unrestricted ones.

The subsidies and tax credit of Corporation Tax contributes a portion, more or less great, of all the necessary financing for investment in R&D projects. Consequently, companies should use their own funds and/or debt in order to obtain the desired financial resources. Since the 1950´s (Durand, 1952; Modigliani-Miller, 1958; Miller and Modigliani, 1966 amongst others), economists have questioned whether the relationship between investment decisions and financing is economically relevant. The existence of suitable micro databases and the advancements in data panel techniques, impulse a race for contrasting the existence of financial restrictions for funding the investment in R&D. Usually the models used were based on the Euler equation or the Q of Tobin and included as regressors some measure of financing with own-funds such as cash-flow or the level of debt. An ample number of studies using micro databases for the US, United Kingdom, Japan as well as other countries of Continental Europe have shown that own-funds are relevant to enable companies to invest in both ordinary assets (amongst others, Fazzari et al, 1988; Devereux et al. (1994); Chirinko and Schaller, 1995) and R&D (amongst others, Hall, 1992; Himmelberg and Petersen, 1994; Mulkay et al, 2001; Bloch, 2005; Brown et al, 2009 and Czamitzki and Hotternrott, 2011). Nevertheless, other studies find that no relationship exists between cash flow and investment (Bond et al, 2005) or at least it is very weak (Harhoff, 1998). The results indicate that financial restrictions have been more severe in countries like the US or the United Kingdom than other developed countries like Germany, France or Japan (amongst others, Mulkay et al, 2001). All of this evidence has, however, been subject to some controversy. Firstly it has been argued that cash flow may be capturing information on profit expectations which could prove relevant for investment even in the absence of financial restrictions (Bond et al 2005). Secondly, a normal practice in this type of literature is to estimate models for the subsamples of restricted and unrestricted companies in order to capture possible differences. And this procedure has been strongly criticized because of the possible endogeneity of the variables used to segment the sample such as for example the payment of dividends[1].

Given the aforementioned limitations, in this paper we have opted to include debt in equation [2] as a way of contrasting the role of financing on R&D investment. Economic theory suggests that financing with debt penalizes the investment in R&D via two channels: the volume of debt and the risk premium which companies are obliged to pay (Ogawa, 2004). With respect to the first of these channels, a lower level of debt is a symptom which indicates that the company is restricted due to difficulties for obtaining funding in capital markets. The investment in R&D generates intangible assets which supposes low quality collateral (the major part of the investment in R&D are salaries) provoking the refusal of banks and other lenders to grant funds (Williamsom, 1988; Berger and Udell, 1990; Lev, 2001). For restricted companies, the investment in R&D will probably be pro-cyclical meaning that the relationship between sales and investment will be positive (for example, Bloch, 2005). With respect to the risk premium, one must take into account that the managers, who act in the name of shareholders, possess better information than the bond-holders as to the success of the R&D investment generating the well-known agency problems (Jensen and Meckling, 1976; Leland and Pyle, 1977; Stiglitz y Weiss, 1981). In this situation obtaining an additional euro of funding is only possible if the company is ready to pay a higher risk premium than one that would exist in perfectly competitive markets. It should be noted that Corporation Tax has stimulated financing with debt (amongst others, King, 1977; Auerbach, 1986). The motive is that the financial costs generated by the debt are to a certain limit deductible in the tax while the opportunity cost of own funds is not.[2] The fiscal incentive therefore favors the preference for debt and an increased probability of bankruptcy[3]. In this context, a high risk Premium supposes an obstacle to obtaining the necessary funds to invest in R&D. The evidence on the role played by debt in the investment process is mixed. Singh and Faircloth (2005) and Ogawa (2007), find that the relationship between both variables is negative. Romero et al (2014) unveil a positive relationship respectively for listed and larger companies.

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[1]Precisely, to avoid this problem, Hansen (1999) proposed a fixed effect threshold estimator which was afterwards extended in Caner and Hansen (2004) in order to incorporate the estimation of instrumental variables.

[2]However, in countries like Spain, Germany, Italy, USA, Canada or Japan, this fiscal incentive in favor of financing with debt is usually limited given that a limit exists for deductible interest under Corporate Taxation.

[3]Nevertheless, top managers also possess incentives to maintain the stock of debt at sustainable levels given that bankruptcy could imply their own dismissal.

Lastly, in equation [2] we include as a regressor the market quota given that those companies with larger quotas will have incentives to spend more on preventive R&D. In line with the suggestion of Schumpeter (1939), companies invest in R&D in order to maintain their leadership in the market in which they operate. This idea follows on from the need of companies to obtain extra profits for financing the investment when financial restrictions exist. The work of Hall & Vopel (1997) and Blundell, Griffith and Van Reenen (1999) finds that companies with larger market quotas innovate more, although the relationship may not be lineal. In this sense, the possible entry of new competitors will force companies to increase their investment in R&D (Aghion, Blundell, Griffith, Howith & Prantl, 2009).

Prior to the estimation of the model we performed the following steps. Firstly, we verify that the variables included in expression [2] are not stationary. Next, we study the existence of a single cointegration relationship between said variables. Lastly, for the sample of cointegrated companies we estimate the model using the FMOLS and DOLS estimators proposed by Kao and Chiang (1997).

2.1 Panel unit root and cointegration testing

The R&D investment series often shows path dependence that indicates the existence of non-stationarity. At the same time, in some cases we observe non-stationarity in the explanatory variables of the model. Here we address this issue using panel unit root and cointegration tests developed by recent panel time series literature. The first step is to test for the stationarity of the variables under consideration, namely, R&D investment, sales, public subsidies, tax credits and external debt. To test for the presence of a unit root in each panel series, we employ the unit root test of Harris-Tzavalis (1999)[4]. The Harris-Tzavalis (HT) unit root test assumes that the time dimension is fixed and could be small, which is the most common situation with micro data. The authors have shown that their test has favorable size and power properties for N greater than 25, improving as time dimension increases for a given N.

[4]The panel unit root tests are estimated with the Harris-Tzavalis option in tests implemented by xtunitroot command in Stata. Hlouskova and Wagner (2006) provide a complete literature review about the types of unit-root tests available with xtunitroot and Baltagi (2013) also discusses those tests.

The statistic is based on the OLS estimator of the parameter ρ in the regression model:

$$y_{it} = \rho y_{i,t-1} + z_{it}^{'}\gamma_i + \varepsilon_{it}, \qquad [3]$$

Where ρ is the autoregressive parameter, the term $z_{it}^{'}\gamma_i$ allows for panel-specific means and trends and ε_{it} represents the error term, which is independent and identically distributed normal with constant variance across panels. The null hypothesis $H_0 : \rho = 1$ is that series y_{it} contains a unit root in all the panels while the alternative indicates that the series are stationary. Harris and Tzavalis derived the mean and standard error of ρ for equation [3] under the null hypothesis when neither panel-specific means nor time trends are included, when only panel-specific means are included and when both panel-specific means and time trends are included. The asymptotic distribution of the statistic is justified when the number of panel is relatively large, as in our case.

As we mentioned previously, the HT test assumes that T is fixed whereas N goes to infinity. In our empirical research we focus on the analysis of micro data, with a small time dimension and a large number of individuals. In this context, we must take into account the relative sizes in both dimensions and the relative speeds at which they tend to infinity. Therefore, we also consider the Fisher-type augmented Dickey and Fuller (1979) (ADF) panel unit root test. The Fisher panel unit root test is based on the methodology proposed by Maddala and Wu (1999) and combines the p-values from the panel-specific unit root tests using the four methods proposed by Choi (2001). The null hypothesis being tested is that all panels contain a unit root. For a finite number of panels, the alternative is that at least one panel is stationary, while as the number of individuals tends to infinity the number of panels that do not have a unit root should grow at the same rate under the alternative hypothesis.

If the null hypothesis of a unit root test is not rejected the series could be integrated. Specifically, when the integration of order one is found in the variables of interest, we next proceed to test for cointegration between them. For cross sectional data we follow the Engle-Granger (1987) two-step (residual-based) cointegration test. More recently several authors have extended this method in a panel setting. The most popular test in the context of panel data models are those by Pedroni (1999), Pedroni (2004) and Kao (1999). The cointegration test is essentially a test of unit roots implemented on the residuals obtained from equation [2]. In the presence of a cointegrating relationship, the residuals are expected to be stationary. Furthermore, in our empirical analysis the null hypothesis of no cointegration (unit root in the residuals) is tested using the ADF-type test.

2.2 Robustness of the cointegration test and break point identification

In order to check the robustness of the results with the cointegration test we perform an analysis of stability. With this aim in mind, we determine the optimal break point applying a structural change test to the statistics that we have obtained previously using a cointegration test in compare with the sample division generated by that test. We perform this stability analysis on statistics from the cointegration test using the Stata command suchowtest. The command suchowtest performs successive F-tests on stability (Chow (1960) tests) on cross-section and time series. This test is based on moving each sample break point forward by one observation each time. It provides the probability of rejecting the null hypothesis of equality of the coefficients across the sub-samples corresponding to different break points.[5]

The suchowtest command allows us to perform a stability analysis on the ADF statistics to compare the subsamples obtained from this econometric approach with those from the cointegration tests. Unlike the traditional Chow test for detecting the presence of structural break, this command finds the break point endogenously, providing a threshold by using the information from the data. In sum, this method seems to be more reasonable for the purpose of finding a break point without information a priori.

2.3 Cointegrated panel estimation

After dividing the sample up in accordance with cointegration criteria, we apply the most convenient econometric techniques in the estimation of the panel data models for both subsamples. In the presence of cointegration we base our estimations on the panel data methods discussed by Kao and Chiang (1997), the fully-modified OLS (FMOLS) and the dynamic OLS (DOLS) estimates for panel cointegrated regression models. These authors first proposed the DOLS panel estimator and compare its small sample

[5] Berthelemy and Varoudakis (1996) describe the theoretical background behind this command.

properties with a FMOLS derived in Pedroni (1996).[6] Under some assumptions, Kao and Chiang (2000) derive the limiting distributions for the FMOLS and DOLS and also investigate their finite sample properties, highlighting that the last is a more promising estimator in cointegrated panel regression models.

In our empirical research we apply FMOLS and DOLS estimators under equation (2) for the cointegrated subsample of firms, implying that the disturbance terms are stationary and regressors follow an integrated process of order one. These estimation methods provide the most reasonable estimators in a panel regression model as follows:

$$y_{it} = \alpha_i + \beta x_{it} + u_{it}, \qquad [4]$$

Where x_{it} is an integrated process of order one and u_{it} are the stationary disturbance terms. Under these assumptions, (4) describes a system of cointegrated regressions. Under some assumptions, the FMOLS is constructed making some corrections for endogeneity and serial correlation to the OLS estimator following the expression:

$$\hat{\beta}_{FMOLS} = \left[\sum_{i=1}^{N} \sum_{t=1}^{T} \left(x_{it} - \bar{x}_i' \right)\left(x_{it} - \bar{x}_i' \right)' \right]^{-1} \left[\sum_{i=1}^{N} \left(\sum_{t=1}^{T} \left(x_{it} - \bar{x}_i' \right) \hat{y}_{it}^{+} - T \hat{\Delta}_{\varepsilon u}^{+} \right) \right], \qquad [5]$$

Where $\hat{y}_{it}^{+}$ is the corrected y_{it} series for endogeneity and $\hat{\Delta}_{\varepsilon u}^{+}$ represents the correction term assuming serial correlation between u_{it} and an error term ε_{it}. To construct the DOLS estimator Kao and Chiang (2000) assume that the process u_{it} can be projected on to ε_{it}:

$$u_{it} = \sum_{j=-\infty}^{\infty} c_{ij} \varepsilon_{it+j} + v_{it}, \qquad [6]$$

In practice, leads and lags may be truncated. Introducing this constraint and substituting [6] into [4] they get:

$$y_{it} = \alpha_i + \beta x_{it} + \sum_{j=-q_1}^{q_2} c_{ij} \varepsilon_{it+j} + v_{it}, \qquad [7]$$

[6]Kao, Chiang and Chen (1999) analyze the impact of the research and development investment on economic growth using a panel FMOLS estimator in comparison with the panel DOLS estimator.

Therefore, the DOLS $\hat{\beta}_{DOLS}$ estimator is obtained applying a OLS estimation on the following regression:

$$y_{it} = \alpha_i + \beta x_{it} + \sum_{j=-q_1}^{q_2} c_{ij} \Delta x_{it+j} + v_{it} \, , \qquad [8]$$

Consequently, to perform the $\hat{\beta}_{DOLS}$ estimator we embed the panel regression model [4] into a dynamic model.

3. Data

In this study we use the data from the Survey of Business Strategies (Encuesta de Estrategias Empresariales (henceforth, ESEE)), for the period 1990 a 2009. The ESEE is a representative sample of Spanish manufacturing companies. In order to analyze the role of subsidies in the continuity of R&D we use an unbalanced panel of 237 companies which have been interviewed during at least 15 years. Concretely, 78.5% had been interviewed during 18 years with another 58.0% during 20 years. The dataset used includes information on the markets in which the companies operate, as well as costs and revenue and balance sheet structure.

For the investment variable in R&D (R_{it}) referred to in expression [2], we use the total sum of current costs and the investment in R&D. The ESEE does not distinguish between current costs and capital, although it estimates that approximately 60% corresponds to salaries (INE (National Institute of Statistics), several years). Sales (Y_{it}) include total annual gross sales of each company. The public subsidies (PG_{it}) include total annual subsidies received for R&D from the different levels of Spanish government as well as the European Union. The variable tax credit (TC_{it}) measures the average tax saving (reduction of the tax burden under Corporation Tax) generated by each Euro of investment in R&D. This percentage has been calculated individually for each company taking into account the applicable legislation for each year. Debt (D_{it}) includes the weight of long-term external debt in the liabilities of each company. Finally, the market share (MS_{it}) is the mean of the market quota of the markets in which each company operates on a yearly basis.

For illustrative purposes, Table 1 shows the main characteristics of the companies analyzed offering cross-section data for the years 1995, 2000, 2005 and 2009. The average size of the companies in the sample is large with an average number of workers of over 650 (the median is situated at a number close to 300 workers). The companies with a larger dimension are those operating in sectors such as metallurgy, heavy equipment and car manufacturing where the number of workers is substantially higher. For example, some of the companies of the car sector available in the sample have over 12,000. Because of this, the average market quota of the companies analyzed is high, although this indicates a clear reduction in the cross-sections analyzed situating itself at 23.9% in 2009.

The number of companies investing in R&D has hardly changed in the years 1995, 2000 and 2005.On the other hand, the year 2009 shows an important reduction attributable to the profound economic crisis which affected Spain from the end of 2008 onwards. About a third of the companies in the sample investing in R&D received subsidies, although said percentage increased slightly in 2009 reaching 40.6%. With respect to the previous cross-sections, in that year there were virtually no changes in the number of companies receiving subsidies whilst the number of companies investing in R&D declined. The data revealed the absence of a defined pattern with respect to the average subsidy received by each company. Hence, for each Euro of investment in R&D, the subsidies financed 16,97% of said investment in 1995, 9.46% in 2000, 4.06% in 2005 and 21.54% in 2009. The savings from the tax credit have been subject to normative changes introduced in the tax legislation since the 1990's.

Table 1. Descriptive statistics

	1995	**2000**	**2005**	**2009**
R&D investment (miles €)	2,556.5	4,433.7	5,021.9	5,894.1
Sales (miles €)	142,077.8	207,912.8	240,446.6	163,094.9
Public grants (miles €)	434.5	419.8	204.2	1,270.9
Tax credits (%)	25.4	37.7	44.1	38.8
Debt level (%)	35.1	36.2	35.6	36.3
Market share (%)	34.8	31.9	25.2	23.9
Empresas con R&D investment (porcentaje de la muestra)	225 (94.9%)	231 (97.4%)	222 (93,6%)	177 (74.6%)
Empresas que reciben subvenciones (porcentaje de las empresas que invierte en I+D)	72 (32.0%)	83 (35.1%)	73 (32.8%)	72 (40.6%)
Número de asalariados (mediana)	689 (298)	746 (328)	729 (330)	668 (285)

Source: own elaboration

4. Main results

In order to perform estimates using the appropriate econometric techniques for correcting the problem of cointegration, we start by checking the order of integration of the different variables and the cointegration amongst them. We then present the estimations of the parameters of both subsamples of the cointegrated and non-cointegrated firms using in each case the corresponding panel data model techniques.

4.1 Integration and cointegration

Table 2 reports the estimation of equation [2] by OLS. The parameter coefficients present the expected signs. The sales together with the fiscal incentives affect the R&D investment positively. In addition, we observe that tax credits are more effective in promoting private R&D investment than public subsidies. Next we introduce some tests for heteroscedasticity and autocorrelation. A battery of residual-based tests supports the absence of heteroscedasticity and serial correlation in residuals. In the presence of cointegration, OLS is biased (Kao and Chiang, 2000). Therefore, next we present some cointegration tests.

Table 2 - R&D determinant factors. Dependent variable: $\ln R_{it}$

Variables	***Parameters***	***OLS***
Constant	C	0.11 (0.63)
Sales	$\ln Y_{it}$	0.58 (37.64)**
Public grants	$\ln Sub_{it}$	0.17 (24.83)**
Tax credits	$\ln Tax_{it}$	0.47 (10.18)**
External Debt	$\ln Debt_{it}$	0.01 (0.47)
Market share	D	0.05 (1.59)*
Joint significance F-test		F (5,4734)=1,428.40
R^2		0.55
Engle´s LM test of ARCH residuals		$\chi^2(1)$ = 439.90
Breusch-Godfrey test for higher-order serial correlation in residuals		$\chi^2(1)$ = 319.63
Durbin´s alternative test for serial correlation in residuals		$\chi^2(1)$ = 986.61
Durbin-Watson test for first order serial correlation in residuals		d (6,4740)= 1.17
DF test for residuals		-43.31 [0.00]
Number observations		4,740

T-statistic in parenthesis
*Parameter significant at 90%
**Parameter significant at 95%
Source: Own elaboration

Table 3 reports the panel integration tests for each of the model's variables. The first column shows the results of the Harris-Tzavalis test while the second column of the table shows the Augmented Dickey-Fuller test. In all cases the tests fail to reject the null hypothesis of the presence of a unit root, indicating that all series are stationary for the complete sample of firms. Nevertheless these tests do not grant information with respect to stationarity in cross-sectional units (firms). Furthermore, in our panel context the possibility that some firms may have different orders of cointegration should be taken into account.

Table 3: Panel unit root tests

Variable	***HT test statistic***	***ADF test statistic***
I+D Investment	0.51 [0.00]	-35.92 [0.00]
Sales	0.60 [0.00]	-34.98 [0.00]
Public grants	0.37 [0.00]	-33.12 [0.00]
Tax credits	0.34 [0.00]	-43.92 [0.00]
External Debt	0.49 [0.00]	-34.06 [0.00]

P-value in brackets
Source: Own elaboration

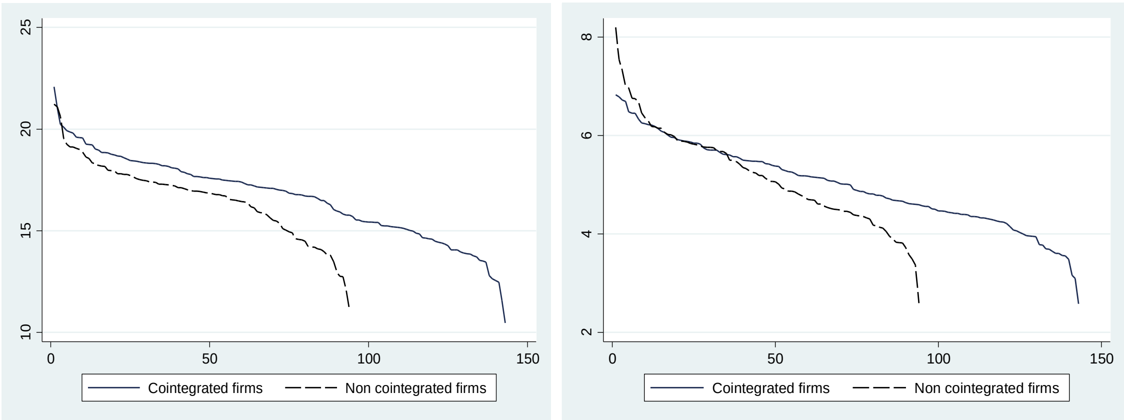
To deal with the cointegration test by firms, as mentioned previously, we proceed with two steps. We first use the ADF test to establish the integration order of the series. We present in Appendix 1 the histograms of statistics and p-values of variables for each firm. We observe that these series are integrated of order one for a subsample of firms according to the ADF statistics and p-values.

The next step is to perform the cointegration test amongst these series by firms. As discussed, we follow the Engle-Granger procedure, which contrasts the stationarity of residuals in the relationship between variables integrated of order one. Appendix 2 shows the histograms of ADF statistics and p-values for the residuals. Those firms that exhibit stationary residuals in a relationship between integrated variables of order one are cointegrated. According to these criteria, we observe that 143 firms in a sample of 237 are cointegrated (60%). The first thing to note is that this subsample represents a wide range of the Spanish manufacturing firms considered, characterized by a similar growing trend in the R&D investment series and fiscal policies.7 In this sense it should be pointed out that 45% of cointegrated firms receive fiscal incentives, public subsidies and tax credits, in comparison with 35% in the rest of the sample.

[7]In this situation it becomes necessary to estimate cointegrated panel models in order to avoid the existence of spurious correlation in the analysis of the effect of fiscal policies on R&D investment.

In Figure 1 we observe the distribution of R&D investment and sales dividing the sample in accordance with the criteria of cointegration. In general, cointegrated firms are those with a higher level of R&D investment and sales and a greater number of firms in the lower distribution level of in both series. Consequently, the income level generated by sales permits increasing private R&D investment. In this sense, as already mentioned, fiscal incentives contribute in a similar way to improving the investment in new technologies, with cointegrated firms proving to be those benefiting more from both fiscal incentives.

Figure 1- Distribution of R&D investment and sales



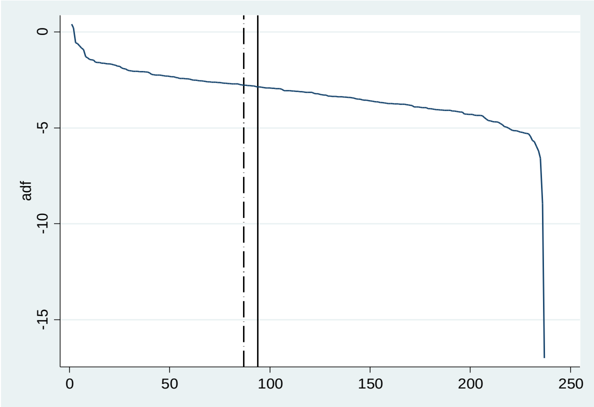
Source: Own elaboration

4.2 Stability analysis with threshold models

We perform a stability test for the sample of firms sorted in decreasing order according to ADF statistics from the unit root test. We base the stability analysis on successive structural Chow tests on the complete sample in order to obtain a break point and compare it with the disaggregation obtained using cointegration test criteria. Figure 2 shows the obtained break point at the 5% significance level (dash line), which is located very close to the sample division from the cointegration analysis (continuous line).

Looking at the split with respect to the ADF statistics, the results illustrated in Figure 2 may reflect great similarities between both methods and allow us to check for robustness. The data clearly reveals the existence of a break point in the cointegration statistics in our sample of firms very similar to that obtained according to cointegration criteria. The stability analysis allows for a robustness check of the disaggregation based on cointegration analysis and reveals that this is a very stable result.

Figure 2- Stability analysis: sample sorted by ADF Statistics (1990-2009)



Source: Own elaboration

4.3 Results

We estimate the parameters of equation (2) dividing the full sample according to cointegration and the results are reported in Table 4. As discussed, in columns one and two of the table we present alternative estimators for cointegrated firms, FMOLS and DOLS. We then use both cointegrated panel models to assess the robustness of the results. In the third column of the table we present estimations for non-cointegrated firms using the Least-Square Dummy Variable (LSDV) estimator which is equivalent to *within* or Fixed Effects (FE). In the last column we perform the LSDV estimator for those firms contained in the group of firms determined by the break point arising from the structural change test that includes part of the subsample of cointegrated firms. This estimation allows us to compare the results from the sample applying stability analysis with those using the cointegration criterion. As a robustness check, Table 5 replicates these estimates for those companies which make use of both subsidies and tax credits in investment.

The results show that sales have a positive effect on the investment in R&D for both cointegrated and non-cointegrated companies. The parameter oscillates between 0.57 and 0.62 indicating a high response in the output of companies to the investment in R&D. A large portion of the literature available includes the sales variable in increments as a regressor instead of in levels meaning that the parameter is directly comparable. Albeit our result is in line with the 0.761 found by Domadenik et al (2008) for the Slovenian companies which also uses sales in levels. The positive and significant value of said parameter indicates that in the long-term investment in R&D is pro-cyclical. Said procyclicality is a symptom showing that the companies analyzed affront financial restrictions when investing in R&D in the long-run. The estimates do not allow us to draw conclusions regarding the impact of debt in the companies. In the cointegrated companies, the parameter is negative with both estimators, although only significant with DOLS. The opposite is true for the cointegrated companies, resulting positive and significant.

The estimates of Table 4 show a positive and significant effect of subsidies on R&D investment. In the cointegrated companies the parameter oscillates between 0.17 when we use the DOLS estimator and 0.20 when we use FMOLS –the value being approximately a half (0.9) for the non-integrated companies-. The elasticities obtained with both estimators clearly demonstrates that subsidies stimulate the investment in R&D although the impact is moderate. The positive value of this parameter reflects the existence of additionality: each Euro of public expenditure in subsidies in the long-run generates up to a maximum of 20 cents of investment in R&D. The results obtained allows us therefore to reject the full crowding-out hypothesis for R&D.

The estimates show that the tax credit for investment also generates additionality. The elasticity of the investment in R&D with respect to the tax credit differs substantially for the cointegrated companies oscillating between 0.31 with the DOLS estimator and 0.72 with the FMOLS one. These parameters are in any case superior to those obtained for subsidies. Therefore, the results indicate that in the long-run a tax credit is more efficient than subsidies in order to promote investment. Thus, in aggregate terms, a Euro of tax credit generates at the margin more investment in R&D than a Euro of subsidies. The tax credit is therefore the most adequate public policy instrument if the aim of the government is to increase the aggregated investment in R&D. Nevertheless, if the government wishes to take into account the quality of investments then they should guide themselves with additional criteria apart from the elasticity of investment with respect to subsidies and credit. Basically, they should measure the social return generated by the projects receiving public funds via subsidies in compare with those that benefits from tax credits. Lastly, contrary to the expected, the market quota does not have significant effects on investment in R&D. These results therefore demonstrate that leading companies in the sector do not undertake investment in R&D with preventive aims in the face of rival companies. Likewise, it should be pointed out that applying cointegrated panels estimation as a correction of spurious correlations, the effect of fiscal incentives maintain the positive sign being the tax credits the most effective one. Additionally, cointegrated firms, that exhibit a more stable trend in I+D investment and fiscal incentives, are those with a highest impact of subsidies. On the contrary, we observe in non cointegrated firms that the most intense effect comes from tax credits, particularly if we focus on DOLS estimator.

In terms of a robustness check, Table 5 presents the results for those companies that use both subsidies and tax credits. The number of observations in this sub-sample is approximately half of the total sample used in Table 4. It is highly probable that the quality of R&D investment projects undertaken by companies in this sub-sample will have, on average, a greater value than the total sample. The reason is that the projects of the subsidized companies were ranked by the public agency responsible for assigning public funds based on different criteria, such as for example its technological impact or its effects on employment or regional development. For the cointegrated companies, the results obtained in Tables 4 and 5 are very similar so that the results can be considered as robust. The only exception is the tax credit where the parameter estimated declines slightly for the FMOLS estimate in cointegrated companies. In this way, the tax credit parameter estimated with FMOLS and DOLS presents a smaller dispersion in the sub-sample tan that observed in the total sample.

Table 4 - Full sample results

	Cointegrated firms		***Non cointegrated firms LSDV***	
Variables	***FMOLS***	***DOLS***	***All***	***Break point******
Sales	0.57 **	0.58 **	0.62 **	0.62 **
	(41.85)	(38.21)	(36.40)	(33.67)
Public grants	0.20 **	0.17 **	0.09 **	0.09 **
	(13.79)	(13.23)	(6.27)	(6.08)
Tax credits	0.72 **	0.31 **	0.53 **	0.56 **
	(8.51)	(8.37)	(12.98)	(12.98)
Debt	-0.01	-0.08 **	0.06 **	0.07 **
	(-0.15)	(-2.48)	(1.95)	(2.13)
Market share	0.03	-0.005	-0.02	-0.04
	(0.50)	(-0.11)	(-0.50)	(-0.71)
R^2	0.59	0.47	0.97	0.97
Number observations	2,299	2,288	1,880	1,740

T-statistic in parenthesis
*Parameter significant at 90%
**Parameter significant at 95%
*** Sample of non cointegrated firms, considering those below the break point.
Source: Own elaboration

Table 5 – Firms with both public grants and tax credits

	Cointegrated firms		*Non cointegrated firms*
Variables	***FMOLS***	***DOLS***	***LSDV***
Sales	0.59 **	0.59 **	0.65 **
	(38.35)	(27.85)	(26.77)
Public grants	0.19 **	0.17 **	0.12 **
	(12.34)	(11.97)	(7.12)
Tax credits	0.34 **	0.29 **	0.42 **
	(5.65)	(5.85)	(7.05)
Debt	0.01	-0.06 *	0.01
	(0.14)	(-1.43)	(0.13)
Market share	-0.04	-0.06	0.11 *
	(-0.55)	(-0.96)	(1.63)
R^2	0.58	0.58	0.98
Number observations	1,216	1,040	720

T-statistic in parenthesis
*Parameter significant at 90%
**Parameter significant at 95%
Source: Own elaboration

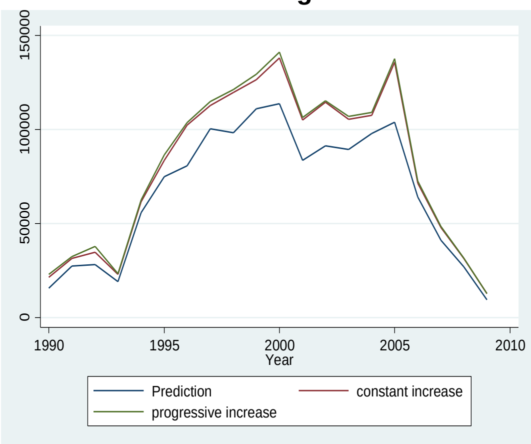
4.4 Some counterfactuals

Next, we will present some counterfactuals scenarios. Using the performed estimations we obtain the average predicted values of R&D investment along the considered period. In order to get predicted values with different levels of public subsidies and tax credits, we introduce changes in those values in accordance with the following two criteria. Firstly, we simulate the impact on investment in R&D resulting from a linear increase of 20% in the amount of subsidies received (constant increase). This process has also been chosen for the case where the tax credit applied by the company for R&D increases by 20%. Secondly, we replicate the previous two simulations for the case where the percentage increase of both subsidies as well as tax credits, coincides each year with the rate of growth of investment in R&D of each company (progressive increase). This counterfactual scenario therefore allows the comparison of two completely different policies aimed at promoting investment. One favors the investment effort of each company (progressive increase), whilst the other (constant increase), is committed to offering the same awards to all the companies. The results of this counterfactual exercise for cointegrated and non-cointegrated companies are shown in graphs 3a, 3b, 4a and 4b. The axes of these graphs show the aggregated level of investment in R&D for each of the years analyzed.

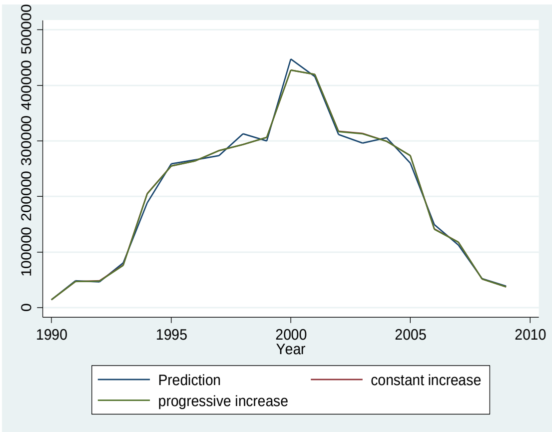
The graphs permit us to reach the following conclusions. Firstly, the counterfactual profile of the cointegrated and non-cointegrated companies presents important differences. The profile of the non-integrated companies has an inverted U-shaped form, peaking in the year 2000. In the case of the cointegrated companies, peaks are observed in 2000 and 2005. Secondly, as can be seen in graph 3a, hardly any differences exist in the levels of aggregated investment reached when applying a constant increase as well as a progressive increase on subsidies. For the economic period of expansion between the years 1995 and 2005, both mechanisms would achieve a clear increase in investment above the predicted levels, at the same time generating additionality. Thirdly, as can be seen in graph 4, the impact on aggregated investment in the cointegrated companies is greater when we apply a progressive increase rather than a constant increase on the tax credit. Nevertheless, the levels of aggregated investment reached with said simulations are below the predicted values for the years 1995 to 2005. In other words, in contrast to subsidies, an increase in the generosity of the fiscal credit does not ensure a greater capacity of Corporate Taxation to promote investment in R&D.

Figure 3: Simulated R&D investment varying the public grants

3a. Cointegrated firms



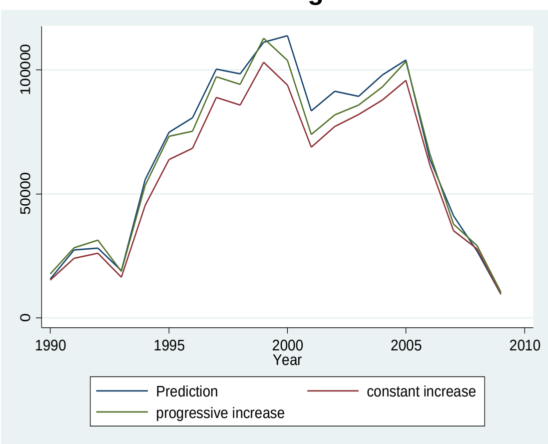
3b. Non cointegrated firms



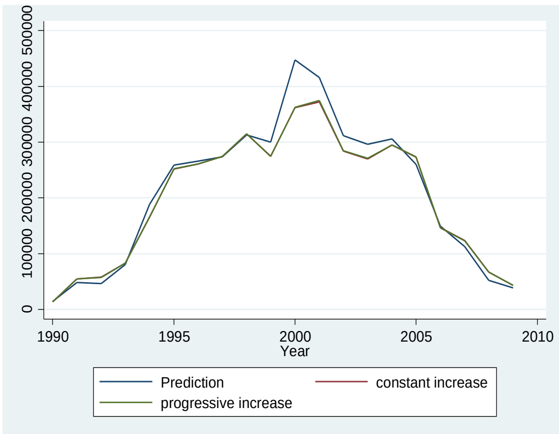
Source: Own elaboration

Figure 4: Simulated R&D investment varying the tax credits

4a. Cointegrated firms



4b. Non cointegrated firms



Source: Own elaboration

4. Conclusions

This paper has analyzed the determinants of the investment in R&D in Spain paying particular attention to the role of subsidies. For this purpose we use a sample of manufacturing companies for the period 1990 to 2009. Using a Cobb-Douglas function, the model has been estimated for cointegrated and non-cointegrated companies. The results show that the investment in R&D is pro-cyclical with elasticity close to 0.6. This result suggests that the companies analyzed face financial restrictions when investing in R&D. The positive and significant value of subsidies shows that they generate additionality. The elasticity of the investment in R&D with respect to subsidies oscillates between 0.17 and 0.2. The tax credit existing in Corporation Tax also generates additionality with an elasticity that reaches in some cases a value of 0.7. Moreover the results indicate that the efficiency of tax credits is superior to that of subsidies. Thus, each Euro of public funds generates more investment in R&D in the case of tax credits rather than subsidies.

Likewise, it is worthwhile noting that after correcting for the possible existence of spurious correlations via the use of cointegration techniques, the positive effect of fiscal incentives is maintained, with tax credits being more effective than subsidies. Additionally, we also observe that the cointegrated companies present a more stable evolution with respect to investments in R&D as well as incentives, whilst subsidies affect the remaining companies to a greater extent. In the case of the tax credit the opposite is true, more so if we center our attention on the DOLS estimator.

Lastly, the counterfactual results show that an increase in the average level of subsidies would increase the aggregated level of investment in R&D for the group of cointegrated companies generating additionality in those companies with more stable levels of investment in R&D. This result is independent of whether said increases award all companies or instead award more intensely those which invest more in R&D. To the contrary, an increase in the generosity of the tax credit does not ensure an increase in the aggregated levels of investment.

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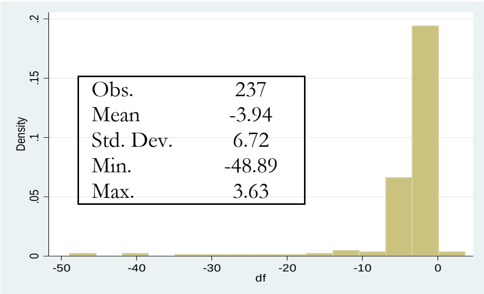
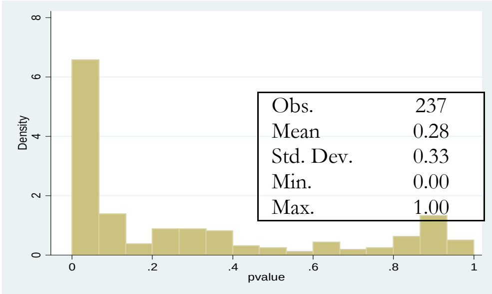
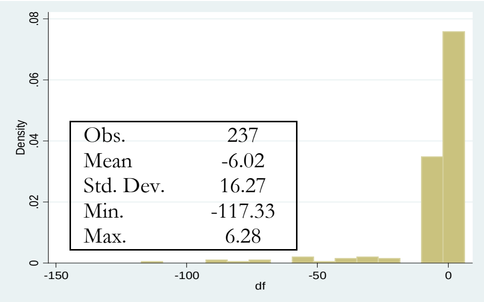
Appendix 1: DF-Tests by firms

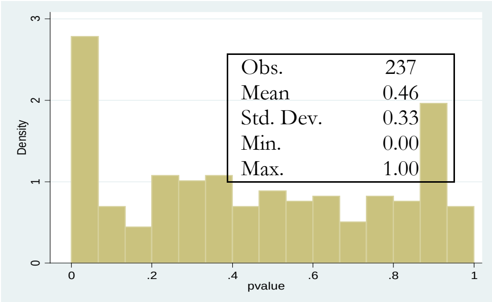
R&D INVESTMENT



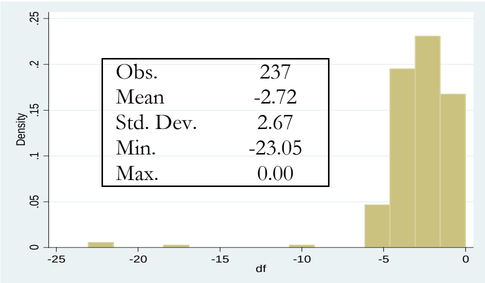


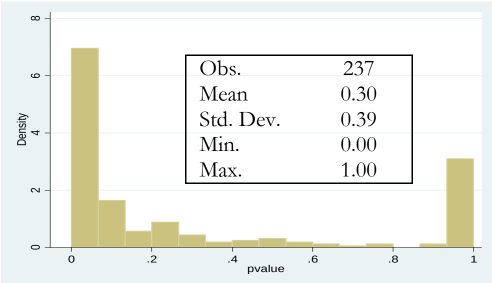
GDP



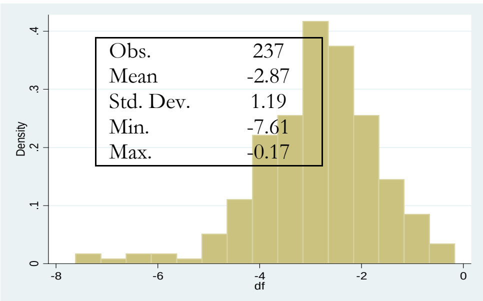


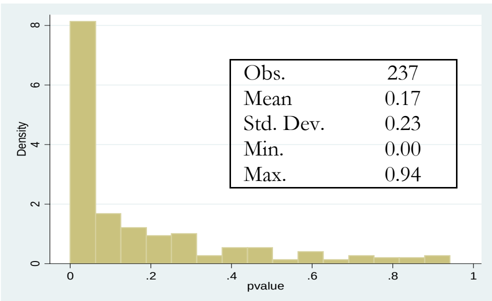
PUBLIC GRANTS



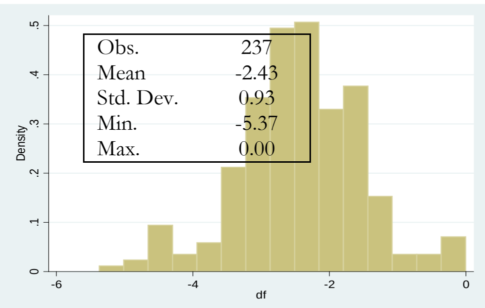


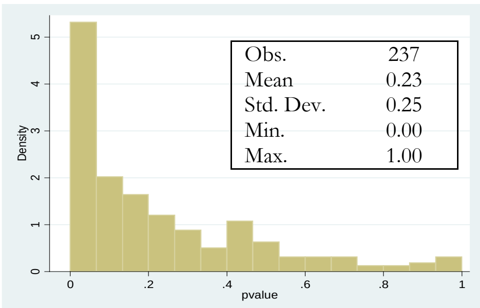
TAX CREDITS





EXTERNAL DEBT





Appendix 2: Cointegration tests residuals