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Full Length Research Paper

A dynamic panel data analysis for relationship between private and public investment in R and D

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This paper investigates the relationship between private and public investment in R and D, while taking into account the effect of several instruments policies such as subsidies and taxes. We design a new look of knowledge spillovers and R and D cooperation to explain the contribution of public and private R and D on growth. We propose a heterogeneous dynamic panel data model to consider the effect as well as endogenous. We also distinguish between the estimated long run and short run results. Our results based on a sample of 23 countries over the period 1992 - 2009 indicate that both private and private investment in R and D are complement. By establishing an endogenous growth model, the estimates indicate that public and private R and D depend on the host country's human capital investment and that FDI is a more significant spillover channel than imports.

Key words: R and D investment, technology spillovers, complementarities, economic growth, dynamic panel data, private investment, public investment, R and D cooperation.

INTRODUCTION

Is public R and D complementary to private R and D, or does it substitute for and tend to "crowd out" private R and D? Conflicting answers are given to this question. A framework for analysis of the problem is developed to help organize and summarize the findings of econometric studies based on dynamic panel data from various countries (French, Mexico, Brazil, USA, Japan, Chine, Finland, Canada, Belgium, Australia, Coree, Spain, Turkey, Sweden, Italy, New-Zealand, Denmark, Portugal, Israel, Tunisia, Morocco, Algeria and Egypt). We conclude by offering suggestions for improving future empirical research on this issue.

Most people think that government R and D activities contribute to innovation and productivity, many economists and policy makers have developed the paucity of systematic statistical evidence documenting a direct contribution from public R and D (David et al., 2000). Econometric findings concerning the productivity growth effects of R and D seem to be that there is a significantly positive and relatively high rate of return to R and D investments at both the private and social levels (Cassiman and Veugelers, 2006). In a recent survey, David et al. (2000) suggest that the especially pronounced differential over the returns on tangible capital investments observed at the private level may reflect individual firms' perceptions of especially high private risk in the case of R and D. Public funding of R and D can contribute indirectly, by complementing and hence, stimulating private R and D expenditures.

Economists, continuing in the tradition pioneered by the research of Blank and Stigler (1957), recurrently examine a variety of data for signs as to whether the relationship between public and private R and D investments is on equilibrium characterized by complementarity or by substitution (Wieser, 2005; Xulia et al., 2008). Cassiman and Veugelers (2005), in recent econometric studies,

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suggest that a statistically significant "spillover" effects can stimulate private R and D investment by publicly funded additions to the stock of scientific knowledge. The same idea has been developed by Lopez et al. (2006) and Bernardí and Guadalupe (2007). These authors have added that a minimum level of regional development is required to improve the effectiveness of R and D policies, and they confirm a complementarity between local knowledge and internationalisation in regional technological progress.

Our approach will be to adopt a new econometric approach using a dynamic panel data studies to analyse if public investment in R and D are complement or substitute for private investment in R and D. In literature review, we can conclude that the majority of the econometric studies are concentrated on the impact of public R and D contracts and grants upon private R and D investment by manufacturing firms and industries (Lach, 2000; Christopher, 2005; Eric, 2007). Our study is original that we would like to adopt dynamic panel data for studying relationship between private and public investment in R and D.

Three restricted questions will be asked regarding those investigations. First, is the design of the statistical analysis such that it can yield any reliable findings on the question of whether government R and D expenditures do or do not have a significant and economically impact upon private sector counterparts? Secondly, where the results are credible, may we conclude that government subsidy programs do not displace private R and D investment? Thirdly, how can the econometric findings be reconciled with those of other well-designed studies that addressed ostensibly the same question, yet arrived at different conclusions?

The object of our paper is to give the theoretical and empirical arguments which allow a satisfactory apprehension of the role that the authorities must play in the fields of research and innovation. The activity of R and D represents a significant source of development of new knowledge and technological innovation (Guellec and Van-Pottelsborghe, 1997). The effort towards activity of R and D involves with a great importance and this through several resources devoted to the various sectors and institutions of research. Expenditure of research and development especially constitute a principal source of growth of productivity for innovating countries. Whereas, Sigrid (2005) and Ting (2005) suggest that, for countries, where the activity of R and D misses almost technological knowledge and innovations of which they profit are generally resulting from the importation of equipment and goods of intensives investments in technical progress. At the same times, Chaturvedi and Chataway (2006) recommend that knowledge capabilities and knowledge management can be considered as key resources for firms in both developed and developing countries.

There are less works, the object of which is to study the relation between private and public investment in R and D. We propose a model based on the study of this relation through several indicators. The principal message to retrain from results of this work is that sometimes public investment have been just added to private investment and sometimes have just replaced them and tend to exert and effect of crowding out. The governmental policies can contribute to growth. For these reasons, a policy of innovation must be designed so that the 'state' orders its actions according to a hierarchy of responsibilities. Therefore, it is necessary that government must make a favourable environment for innovation and support of the companies in incentive to be innovated because the company itself constitutes a significant factor of innovation and the resources of the latter are varied such as the R and D or the acquisition of technology.

The policies in favour of the R and D and the innovation changed orientation in the industrialized countries since the beginning of the eighties. The 'states' fiscally supported the companies which financed their expenditure of innovation (Lai et al., 2006). Several legislative measures to support the effort of investment, tax treatment, the expenditure R and D innovation are taken. Which roles can be played by authorities in the fields of research and the innovation? In other words, how can the State act in the fields of the R and D to increase the R and D in private sector?

In this work, we will study the existence of a relation of complementarity or substitutability in the case of 23 countries through an empirical analysis on dynamic panel data. This document brings a new look for studying the public/private relation as regards R and D.

R and D investment and the government's R and D policies

Today, we can observe an expansion of policies of innovations in the developed countries which devote great investment for R and D. What proves the creation of the climates favourable to the level of these countries for the innovation? It is significant that during these last years, companies of high technology or advanced technology's (pharmaceutical, aeronautical…) expenditure of research and development increased significantly. The role of the governmental policies as regards R and D is not to neglect. Indeed, the policies of innovation define specific actions of the 'state', which must encourage the accumulation of a qualified labour on the one hand, and to help the companies achieve better markets' prospect on the other hand. This justifies the need for the public administrations for supporting the R and D (Xulia et al., 2008).

Thus, which are the reasons of the government aid and the mechanisms the alternate ones available to the public administrations to support the R and D? To answer these questions we try to analyze the justification of the government aid with the R and D starting from the economic theories of growth (Veugelers et al., 2005).

Neoclassic growth theory

For Neo-classic theory of growth, technical progress is supposed to be exogenous factors. With the balance of long term, population growth and technical progress determine the level of the growth rate. This implies, according to the basic assumptions, that the long-term growth rate is stable, and given in an exogenous way. Within this framework, the impact of an action of the authorities is practically ignored (Solow 1956, 1960).

The Neo-classic theory of the growth supposes that the economy starts from a weak relationship between capital and labour. Just as the marginal returns on capital are decreasing. What reduces the encouragement to be invested in the new capital? (Griliches, 1969). Thus each new unit of capital produces a lower income and less large savings. In the long run, there will be absence of incentive to invest. In short, we can say that the assumptions which underlie the Neo-classic theory are not realistic. The technological change is not always an exogenous factor outside the market, determined by an unknown process. To the 20th centuries, a good number of discoveries and progress were carried out in the commercial sector by companies with lucrative goal and not by public administrations or universities where research is directed by non-commercial forces. Markets are seldom in perfect competition, moreover, the private sector is not capable to produce all the desired goods and services, because some of them are goods public and certain others produce external effects (Solow, 1956, 1960).

Endogenous growth theory

The endogenous theory of growth recommends the relaxation of certain Neo-classic assumptions and incorporates the failures of the market. However, the economic growth in the long run is directed by the accumulation of the factors of production founded this faith on knowledge, in particular, human capital, training, R and D and innovation (Griliches, 1995). The endogenous models of growth are characterized by a great diversity of the resources selected such as: the investment in physical capital, human capital, public capital, and labour division, learning by doing, research and the technological innovation (Romer, 1990).

The endogenous theory of growth recommends that technical progress rises from the R and D carried out by companies with lucrative goals. Research and Development constitute a significant factor of production process. In short, the assumptions according to which the determining factors of long-term growth are endogenous with the decision-making process constitute one of the principal exemptions from Neo-classic theory of growth and involve significant effects on the policy (Jason et al., 2008; Gorg et al., 2007). Indeed, if long-term growth is directed by factors of production based on the knowledge which belongs to the normal structure of costs of the company, then, by changing the cost of these factors by direct subsidies of tax incentives or of marketing policies, the public administrations can influence the long-term growth. These theories provide a framework of analysis of growth and its determinants which can also be used to study the incidence of public policies on economic growth and investments in R and D (Becker and Pain, 2002; Busom, 2000).

R and D investment and market imperfection

Economic theory and empirical proof show that technical progress, because of its incidence on the factors of production, constitutes key element in the long run determining economic growth; in certain countries, it represents even the most significant element. However, it is not a question of an economic justification of the official intervention for allocate the resources in favour of R and D. But, this intervention in a market economy is justified by incapacity of market to distribute resources in an efficient or acceptable way as regards social aspects. With regard to the investment in R and D, external effects and market imperfections testify the incapacity of market, and the effects are felt not only beyond particular companies but also beyond national borders.

In a market economy, a company will not invest in a project if it knows that it can not adapt the possible receipts. However, if it cannot adapt a portion of these receipts, it will invest if this portion is enough to make a profitable investment. Asymmetrical information and imperfect competition constitute two other kinds of imperfections of market involving under investment in R and D. For example, asymmetrical information prevents effective operation of capital market. Indeed, it can involve rationing of appropriations as well as abandonment of investments in R and D projects with strong chances of success. Thanks to the financing plan and the continuation of investments in the project having weak chances of success.

RESEARCH METHODOLOGY

Our study contributes to the empirical literature -which is discussed here- on the analysis of the existence of a relation between private and public investment in R and D and their real effect on economic growth; do public funds substitute or complement private R and D expenditure? We derive our econometric specification from a function including interactions between internal and external R and

D in the augmentation of the knowledge stock. The model also takes into account potential productivity convergence by including lagged productivity levels. Our study's inferences are based on a dynamic panel data model, which allows us to control for the existence of unobserved fixed effects that are likely to affect R and D decisions. Estimation is carried out by several consistent dynamic panel data methods, among which generalized method of moments, which allows for the presence of weakly endogenous explanatory variables. In this way the analysis can take into account both degree and possibility effects of R and D to address the issue of optimal combinations of R and D expenditures.

In this paper, we contribute the first panel data study exploring complementarity between public R and D and private R and D in a dynamic panel framework. We examine the impact of internal and external R and D on economic growth in sixteen-year panel for 23 developed and developing countries[1]. Our data base sets are taken from various sources(OCDE, 1999a, b; World Bank, 2009; http://epp.eurostat.ec.europa.eu/.; http://www.uis.unesco.org/.; http://www.cepii.fr/francgraph/bdd/chelem.htm.). Tables 1 indicate a summary of different variables which are taken in our specification.

Concerning our data base, it is taken from various sources. In fact, several difficulties were encountered during the data base collection. In certain cases we noticed a great difference between the data bases that led us to check the origin and the data confidentiality. The second difficulty is based on the availability of some variables of the model and for some especially well defined countries at one period for example variable R and D. To cure these difficulties, R and D was calculated for various (especially developing countries) on the basis of imported equipment good near their principal trade partners.

Complementarities versus substitutability between private and public R and D

Theoretical work did not succeed in slicing on favourable or unfavourable effect using certain political instruments on the level of R and D in private sectors. The results of each model strongly depend on its structure and its assumptions. Empirical work, leads to homogeneous results and identifies a positive effect of public R and D on that private (David et al., 2000). With an aim of knowing the relation between public and private R and D we give an overall picture of the activities of R and D in world. Indeed, we attach more importance to activity of public and private R and D in the most significant poles in world.

After the significant increase in the budget of R and D of the 'states' linked during the fifties, Blanck and Stigler (1957) were among the first which raise the question about the existing relation between the public and private R and D. Thus, using a sufficiently broad sample of companies, the authors try to test the existence of a relation of complementarity or substitutability between private and public investment as regards R and D. Indeed, the implications of study are still significant until the policies of R and D today because a relation of complementarity is justified for the public funds whereas substitution is observed like a "misallocation".

Through time and with the improved scientific methods in particularly studies of Jason et al. (2008), it became clearly that the final situation towards the effect of the public funds of R and D cannot be made. Thus, in general, two fields can be identified and which are used to analyze the relation between private investment and public in research and development with knowing quantitative and qualitative studies. On the one hand, for the qualitative studies, data are frequently based on the investigations. On the other hand, for the quantitative studies, they are based on macro and micro-economic information of a significant number of companies (Cassiman and Veugelers, 2006). In this last context, David et al. (2000) give highlights of economic surveys with an aim of analyzing the net impact of public research and development on private R and D. Thus, such illustrative example of statistics of the found results, and among 14 studies, only two indicates a substitution effect at the overall level. On the level of the companies, results are less clear, that is, in 9 studies of 19, there is a substitution effect.

Today, several activities of R and D are carried out on the level of the services sector. On the one hand, this is due to the external sources of the strategies of manufacturing industries in the eighties. On the other hand, the transformation of information and technology of communication get more opportunities for innovating sectors. So the governments help more and more activities of R and D in several sectors with an aim of stimulating technological performances of their countries. Thus, several examples can be quoted. At this level, for the nineties and more precisely in 1999, the total expenditure of R and D of Germany is 47 billion dollars where 66% of this amount is invested by private industries, 18% by government and the remainder are invested by foreign companies.

Thus, Claudia (2008) suggest that an international comparison on behalf of public programs of R and D shows that Germany is one of principal countries which grant funds for the technological performance. At this level, manufacturing industry plays a very significant role concerning R and D. For example, the strategic planning of the national research evaluation in Thailand as indicated that Jarunee (2008) is to allocate the budget to support the research programmes and projects. Jarunee suggest that to improve the model evaluation framework for R and D investments, the public hearing forum was organised. From there, a question emerges up to what point evolution of public funds of R and D makes it possible to stimulate R and D carried out by private sector, and on which level results are checked? Recently, an econometric micro study tackled the question of the impact of political instruments about activity of R and D deprived on the level of companies.

In the nineties, Busom (2000) applies dummies variables in its model suggested to measure the impact of government aid to R and D carried out by private sector. In its turn, Lach (2000) could test the impact of programs of R and D on the amount of investment in both cases, with or without public supports. Tahir et al. (2008) adopted a combined decision model for R and D by using both qualitative and quantitative information for project portfolio selection. In their model Tahir et al. (2008) suggest that the efficient projects with higher feasibility portfolio selection, our specification take account of all private project in R and D for more precision with public R and D relationship.

Several other studies are more precisely interested in testing the effects of public subsidies in R and D on the amount of deprived investment (Lai et al., 2006; Hans and Almas, 2005; Christopher, 2005). The major goal of these studies is to know if public subsidies of research and development can have an effect of reduction or increase in the expenditure of R and D. Most of results suggest that public subsidies of R and D on the level of several industries showed that there is a small tendency to the effect of ousting "Crowding out". In addition, it seems not to have any effect or degree of complementarity.

Next, we empirically test the fundamental relation which we seek to analyze in the case of 23 countries for the period of 1992 - 2009. In other words, we test the existence of a relation of complementarity and check the result.

Empirical validation: Dynamic panel data

There are several econometrics approaches, so we are going to follow a typical approach, while holding account of some

Table 1. Summary table of the various variables of model.

Variables	Description	Empirical measurement
Input and output of innovation		
Public R and D (G)	Domestic expenditure R and D (DIRD% GDP)	Logarithm of R and D expenditure in percentages of Gross Domestic Product (GDP)
Private R and D (R)	Outside expenditure R and D in provenance of commercial partners	Logarithm of private R and D expenditure
Exogenous variables		
Foreign direct investment (IDE)	FDI stocks data	IDE for countries (i) in year (t)
Added Value (VA)	Added Value for each countries in year (t)	VA for countries (i) in year (t)
Importation (M)	Importation amount for each countries	M for countries (i) in year (t)

determinants of private research and development. The theoretical works that studied this question propose models founded on several political instruments. These works show that these policies can have a negative/positive impact on the expenses deprived in R and D. Nevertheless, very little study to these days, value the impact of these research efforts. As for the empiric works, they showed a positive effect of political instruments on private level of research and development. However, these works come up against several limits essentially bound to the used methods econometrics and to the choices of indicators that represent the variable private R and D.

The objective of this work is to test the impact of an action of public policies empirically on the evolution of R and D in private sector while trying to surmount limits. The modelling that we follow to measure the effect of the R and D deprived on the public one; while taking into account some determinants of private R and D; is the one of Bettina et al. (2002). This modelling has also been applied by Busom (2000) and Lach (2000). The gait of these authors can be summarized as follows:

Private R and D = ß* public R and D + control variables + e

The underlying logic is simple: If the coefficient β* has a positive sign we can say that public R and D are complementary for private R and D. In other words, an increase of 1% of public research and development level entails a growth of β*% of private R and D. On the contrary, if β* has a negative sign we can say that there is a relation of substitutability between public and private R and D. In this part we try, to give a general setting for the models to estimate while putting accent on some remarks and inconveniences of these models. We apply a dynamic panel data model. Finally, after having estimated the model we analyze results.

In our survey we present in fact, a brief of empirical literature on the relation private and public R and D. We propose empirical tests on panel of 23 countries between 1992 and 2009. We specify for it a dynamic model, which we estimate by different methods, notably generalized moments method (GMM).

Dynamic panel data: Definition and evaluations method

Dynamic models are characterized by presence of one or several endogenous variables delayed among explanatory variables. Our specified model is a dynamic panel model given by:

$$y_{it} = \alpha\ y_{it-1} + \beta\ 'x_{it} + v_{it} \qquad (1)$$

Under another forms one was writing our model as:

$$R_{it} = \alpha R_{it-1} + \beta_1 G_{it} + \beta_2 M_{it} + \beta_3 VA_{it} + \beta_4 IDE_{it} + \mu_i + v_{it} \quad (2)$$

where; y_{it-1} : Endogenous variable appears in the regression as being a retarded explanatory variable. In other words, present stocks of research and development of country (i) are explained by stocks of research of the period (t-1), X: Represent the vector of exogenous variables; these variables are added value (VA), public research (G), import (M), foreign direct investment (IDE) and private research; (α, β): Designate parameters to estimate, μ_i : Constitute individual heterogeneity as: μ_i i.i.d. ~ N [(0, 1)], And: $v_{i,t}$ is stochastic term as: $v_{i,t}$~ i.i.d. [(0, 1)], $y_{i,t}$ is the logarithm of volume of R&D in country (i), $x_{i,t}$ is determinant vector of R and D, μ_i is the specific effect of country (i). This specific effect can be a stationary or uncertain effect.

Evaluation method

The evaluation of the model by traditional methods Ordinary Least Square "OLS" and within gives biased and non convergent values because of inter-relationship between retarded endogenous variable and individual heterogeneity. We try to demonstrate for the case of a simple model the inconveniences of these methods of evaluations. For dynamic panel model, within transformations and OLS are biased and non-convergent estimators. We assume the simple specification:

$$y_{it} = \alpha y_{it-1} + \mu_i + v_{it}$$

Let us pose $|\alpha|$ p 1 and that y_{it} is stationary then:

$$\hat{\alpha} = \frac{\sum_{i=1}^{N}\sum_{t=1}^{T} y_{it}\, y_{it-1}}{\sum_{i=1}^{N}\sum_{t=1}^{T} y^2_{it-1}} = \alpha + \frac{\sum_{i=1}^{N}\sum_{t=1}^{T} (\mu_i + v_{it})\, y_{it-1}}{\sum_{i=1}^{N}\sum_{t=1}^{T} y^2_{it-1}}$$

$\hat{\alpha}$ is convergent if:

$$\underset{N \longrightarrow \infty}{p\lim} \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(\mu_i + v_{it}\right) y_{it-1} = 0$$

$$\underset{N \longrightarrow \infty}{p\lim} \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(\mu_i + v_{it}\right) y_{it-1}$$

$$= \frac{1}{T} \frac{1-\alpha^{2T}}{1-\alpha} \operatorname{cov}\left(y_{i0}, \mu_i\right) + \frac{\sigma_\mu}{T(1-\alpha)^2} \left[(T-1) - T\alpha + \alpha^T\right]$$

$$\underset{N \longrightarrow \infty}{p\lim} \frac{1}{NT} \Sigma_{i=1}^{N} \sum_{t=1}^{T} y^2{}_{it-1} =$$

$$\frac{1}{T} \frac{1-\alpha^{2t}}{1-\alpha} \frac{\Sigma_{i=1}^{N} y_{i0}}{N} + \frac{\sigma^2 \mu}{T(1-\alpha)^2} \frac{1}{T} \left[T - 2\frac{1-\alpha^{2t}}{1-\alpha} + \frac{1-\alpha^{2t}}{1-\alpha^2}\right]$$

$$+ \frac{2}{T(1-\alpha)} \left[\frac{1-\alpha^{2t}}{1-\alpha} - \frac{1-\alpha^{2t}}{1-\alpha^2}\right] \operatorname{cov}(y_{i0}, \mu_i) +$$

$$+ \frac{\sigma^2 \mu}{T((1-\alpha)^2)^2} \left[(T-1) - T y^2 + \alpha^{2T}\right]$$

In summary, the bias is positive and increases with the variance of the specific effect. Indeed, $y_{i,t}$ is function of $v_{i,t}$ and $y_{i,t-1}$ is also. $y_{i,t-1}$ is an explanatory variable correlated with stochastic term. It introduces a bias in the value of OLS. Even as putting hypothesis that stochastic terms are not correlated, this value is non-convergent. For within case we consider the following transformation:

$$y_{it} - \bar{y}_{i.} = \alpha \left(y_{it-1} - \bar{y}_{i.-1}\right) + \left(v_{it} - \bar{v}_{i.-1}\right)$$

With:

$$\begin{cases} E\left(v_{it} v_{js}\right) = 0 \quad \text{si i = j et si t = s} \\ E\left(v_{it} v_{js}\right) \neq 0 \qquad \textit{ifnot} \end{cases}$$

While posing as in Baltagi (1995):

$$\bar{y}_{i.-1} = \frac{\Sigma y_{it-1}}{T-1}$$

Thus we can write that:

$$\hat{\alpha} = \frac{\Sigma_{i=1}^{N} \sum_{t=1}^{T} \left(y_{it} - \bar{y}_{i.}\right)\left(\bar{y}_{it-1} - \bar{y}_{i.-1}\right)}{\Sigma_{t=1}^{N} \sum_{i=1}^{T} \left(\bar{y}_{it-1} - \bar{y}_{i.-1}\right)^2}$$

$$= \alpha + \frac{\Sigma_{i=1}^{N} \sum_{t=1}^{T} \left(\bar{y}_{it-1} - \bar{y}_{i.-1}\right) \left(v_{it} - \bar{v}_{i.}\right) / NT}{\Sigma_{i=1}^{N} \sum_{t=1}^{T} \left(\bar{y}_{it-1} - \bar{y}_{i.-1}\right)^2 / NT}$$

The numerator is convergent when the second term converges towards zero.

The numerator of the second term:

$$\underset{N \longrightarrow \infty}{p\lim} \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(\bar{y}_{it-1} - \bar{y}_{i.-1}\right) \left(v_{it} - \bar{v}_{i.}\right)$$

$$= \frac{-\sigma^2{}_v}{T^2} \frac{(T-1) - T\alpha + \alpha^T}{(1-\alpha)^2}$$

And the denominator:

$$\underset{N \longrightarrow \infty}{p\lim} \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(\bar{y}_{it-1} - \bar{y}_{i.-1}\right)^2 =$$

$$\frac{-\sigma^2{}_v}{1-\alpha^2} \left(1 - \frac{1}{T} \frac{2\alpha}{(1-\alpha)^2} \frac{(T-1) - T\alpha + \alpha^T}{T^2}\right)$$

The estimator of OLS dummy variable is convergent if T is infinite. If T is fixed, N, the estimator is non-convergent.

Our model should not be estimated by the method of OLS and LSDV due to the fact that estimating by these methods lead to ad hoc results. Which are then adequate methods to estimate our model? We propose below two methods which consist in obtaining consistent estimators.

Anderson and Hsiao method

Anderson and Hsiao (1982) proposed, initially, to write the model from first difference to eliminate individual heterogeneity. They propose for the transformation two instruments.

$$\hat{\alpha}_{vi}(1) = \frac{\Sigma_{i=1}^{N} \sum_{t=3}^{T} \left(y_{it} - y_{it-1}\right)\left(y_{it-2} - y_{i.-3}\right)}{\Sigma_{i=1}^{N} \sum_{t=1}^{T} \left(y_{it} - y_{i.-2}\right)\left(y_{it-2} - y_{i.-3}\right)} \tag{3}$$

And

$$\hat{\alpha}_{vi}(2) = \frac{\sum_{i=1}^{N}\sum_{t=3}^{T}\left(y_{it}-y_{it-1}\right)y_{it-2}}{\sum_{i=1}^{N}\sum_{t=1}^{T}\left(y_{it}-y_{i.-2}\right)y_{it-2}} \quad (4)$$

The two values are convergent when N and T $\longrightarrow \infty$. However, an inter-relationship always persists between endogenous variable in first difference and residual term. Authors proposed to resort to the method of instrumental variables to surmount this problem. Thus, they propose to use instrument endogenous variable with two lags or his first differences. These instruments are correlated with explanatory variable and are not with residual term. To get more efficient results, Arellano and Bond (1991) approach permits to get a value of generalized moments "GMM" more efficient.

Arellano and Bond approach

Arellano and Bond (1991) are the first in 1991 to proposed an extension of GMM introduced initially by Hansen (1982), to the case of panel data for a simple model AR (1):

$$y_{it} = \alpha y_{it-1} + \mu_i + v_{it} \quad (5)$$

Where $|\gamma| \pi \ 0$

We consider the case where temporal dimension is small while individual dimension (N) is important. However, we consider that individual effects are stationary and we assume traditional hypotheses for residues. In difference models, model (5) can be written as:

$$\Delta y_{it} = \alpha \Delta y_{it-1} + u_{it} \qquad |\gamma| \text{ p } 0 \quad (6)$$

where $u_{it} = v_{it} - v_{it-1}$.

We test for every individual of the linear restrictions of type:

$$E\left[\left(\Delta y_{it} - \alpha \Delta y_{it-1}\right) y_{it-j}\right] = 0 \qquad for \quad j = 2,...,t; t = 3,...T \quad (7)$$

The gait of Arellano and Bond, in presence of the exogenous variables, consists in estimating the model in difference:

$$\Delta y_{it} = \sum_{k=1}^{p} \alpha_k \Delta y_{i(t-k)} + \beta'(L) X_{it} + \Delta v_{it} \quad (8)$$

Moment conditions and instruments matrix are given respectively by:

$$\begin{cases} E\left(y_{it-\tau} \Delta v_{is}\right) = 0 \quad pour \ \tau \geq 2, \ t = 2,3,....T \\ E\left(X_{it-\tau} \Delta v_{it}\right) \neq 0 \quad pour \tau \geq 2, \ t = 2,3,....T \end{cases} \quad (9)$$

$$Z = \begin{pmatrix} Z_{ip} & 0 & 0 & \ddots & . & . & 0 \\ 0 & Z_{ip+1} & . & \cdots & . & . & . \\ . & . & . & .\cdot & . & . & . \\ \Delta X_{ip+2} & \Delta X_{ip+3} & . & \cdots & . & . & \Delta X_{iT} \end{pmatrix} \quad (10)$$

The preceding dynamic model (8) can be rewritten for each individual in the following form:

$$y_i = W_i \delta + \tau_i \mu_i + V_i \quad (11)$$

Where τ is a vector of parameter and W_i is a matrix that contains the retarded dependent variable and explanatory variables. The method proposed by these author's permits to get a GMM in two stages is written in following form:

$$\hat{\delta} = \left[\left(\sum_i W_i^{*'} Z_i\right) A_N \left(\sum_i Z'_i W_i^{*}\right)\right]^{-1} \left(\sum_i W_i^{*'} Z_i\right) A_N \left(\sum_i Z_i y_i^{*}\right) \quad (12)$$

However, to have the previous value GMM, it is necessary to pass by a first stage that consists in making wished transformation (first difference or orthogonal deviation), to find and to use instruments matrix and to achieve a first evaluation named "evaluation of first stage". This stage corresponds to an evaluation that permits to provide estimated residues after transformation. In the first stage, the values are gotten while using H_i as:

$$H_i = \hat{v}_i^{*} \hat{v}_i^{*'} \quad (13)$$

$$H_i = \begin{pmatrix} 2 & -1 & .... & 0 \\ -1 & 2 & . & . \\ 0 & . & . & -1 \\ 0 & 0 & ....-1 & 2 \end{pmatrix}$$

And

$$A_N = \left(\frac{1}{N}\sum_i Z'_i H_i Z_i\right)^{-1} = Z'\left(I_N \ddot{A} H\right) Z \quad (14)$$

The objective of transformation is, as at Anderson and Hsiao (1982), to eliminate individual heterogeneity of the model. The number of instrument increases in the time for every individual. In the case where explanatory variables x_{it} existed in the model, it correlated with heterogeneity individual μ_i. Optimal instruments matrix corresponding Z_i is equal to:

$$\begin{pmatrix} y_{i1} & x_{i1} & x_{i2} & 0 & 0 & 0 & 0 & .. & 0 & 0 & 0 .... & 0 & 0 \\ 0 & 0 & 0 & y_{i1} & x_{i1} & x_{i2} & x_{i3} & .. & 0 & 0 & 0 ..... & 0 & . \\ . & . & . & . & . & . & . & .. & . & . & . ..... & . & . \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & .. & y_{i1} & y_{i(T-2)} & x_{i1} .... & ... & x_{i(T-1)} \end{pmatrix}$$

Arellano and Bond (1991) propose a test verifying the absence of autocorrelation of first and second order. Thus, if distribution is non auto-correlated, this test gives a value of residues differentiated negative and significant to first order and non significant to the second order. This test that is based on auto-covariance of residues follows a normal law N (0,1) under hypothesis H_0. Otherwise, authors propose the test of validity of instruments of Sargan (1988). The statistical test equal to:

$$S = \left(\sum \hat{v}_i^{*'} Z_i \right) AN \left(\sum Z' \hat{v}_i^{*} \right) \qquad (15)$$

EMPIRICAL RESULTS

The unit root tests became a current step for analysis of time series stationnarity. However, practical application of these tests on panel data is recent. The tests most frequently used are those of Levin and Lin (1992) and of Im et al. (2003) (We take in abbreviation, Levin Lin test as LL and Im Peasaran Shin as IPS. iid means identical and independent distributed).

Recently, several procedures of unit root tests and cointegration were developed for panel data models. The addition of individual dimension to temporal dimension offers an advantage, in practical application of unit root and cointegration tests (Pedroni, 1999, 2004).

The checking of non-stationary properties for all panel variables leads us to study the existence of a long run relation between these variables. The cointegration study by applying Pedroni cointegration tests based on unit root tests on residues estimated. cointegration tests on panel data consist in testing the presence of unit root in the estimated residues. However, the problem of fallacious regressions, of the time series, also arises in the case of panel data (Tykhonenko, 2007). First step is to test unit root for each of series.

Unit root tests

Levin and Lin (1992), consider the following model:

$y_{i,t} = \rho_i y_{i,t-1} + Z'it\, \gamma + ui,t$ (i=1, …, N; t=1, …, T) (16)

where $Z_{i,t}$ is the deterministic component and $u_{i,t}$ is a stationary process; μ_i is the fixed effect.

The Levin and Lin (1992) tests assume that ui,t are iid $(0,\sigma^2_u)$ and ρi=ρ for all i. The LL test is restrictive in the sense that it requires ρ to be homogeneous across i. Im et al. (1997) (IPS) allow for a heterogeneous coefficient of $y_{i,t-1}$ and propose an alternative testing procedure based on averaging individual unit root test statistics. IPS suggested an average of the augmented Dickey-Fuller (ADF) tests when $u_{i,t}$ is serially correlated with different-t series. Correlation properties across cross-sectional units, that is,

$$u_{i,t} = \sum_{j=1}^{p_i} \alpha_{ij} u_{it-j} + \varepsilon_{it} .$$

Substituting this $u_{i,t}$ in (1) we get:

$$y_{i,t} = \rho_i y_{it-1} + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{it-j} + z'_{it}\gamma + \varepsilon_{it} \qquad (17)$$

The null and for all countries i the alternative hypothesis are:

Ho: $\rho_i = 1$
Ha: $\rho_i < 1$

For at least one i, the IPS t-bar statistic is defined as the average of the individual ADF statistic as:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^{N} t_{\rho i}$$

where tρi is the individual t-statistic of testing Ho: ρi = 1 in (18). It is known for a fixed N as T → ∞.

$$t_{\rho i} \Rightarrow \frac{\int_0^1 W_{iz} dW_{iz}}{\left[\int_0^1 W_{iz}^2 \right]^{1/2}} = t_{iT} \qquad (18)$$

IPS assumes that t_{iT} are iid (iid means identical and independent distributed) are have finite mean variance. Then:

$$\frac{\sqrt{N}\left(\frac{1}{N} \sum_{i=1}^{N} t_{iT} - E[t_{iT} / \rho_i = 1] \right)}{\sqrt{Var[t_{iT} / \rho_{i=1}]}} \Rightarrow N(0,1) \qquad (19)$$

As N→ ∞ central limit theorem. Hence:

$$t_{IPS} = \frac{\sqrt{N}\left(\bar{t} - E[t_{iT} / \rho_i = 1] \right)}{\sqrt{Var[t_{iT} / \rho_{i=1}]}} \Rightarrow N(0,1) \qquad (20)$$

As T→ ∞ followed by N→ ∞ sequentially, the values of E[tiT/ρi=1] and Var[tiT/ρi=1] have been computed by IPS simulations for different values of T and ρ′is. As applying test on our complete model our results is summarized in Table 2.

Table 2. Unit root tests.

Statistics	R	G	M	VA	IDE
Levin-Lin ADF stat	-2.35771	-0.34312	1. 80911	1.48967	-1.67447
IPS ADF stat	-2.29622	1.77303	2.17516	1.640659	-1.57222

Table 3. Unit root tests for R (private R andD).

Pool unit root test: Summary				
Series: R				
Method	**Statistic**	**Prob.****	**Cross-sections**	**Obs**
Null: Unit root (assumes common unit root process)				
Levin, Lin and Chu t*	-2.35771	0.0092	1	74
Breitung t-stat	-2.84504	0.0022	1	73
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-2.29622	0.0108	1	74
ADF - Fisher Chi-square	9.21996	0.0100	1	74
PP - Fisher Chi-square	13.0702	0.0015	1	162
Null: No unit root (assumes common unit root process)				
Hadri Z-stat	2.00286	0.0226	1	184

** Probabilities for Fisher tests are computed using an asympotic Chi.

The application of the tests of unit root LL and IPS shows that the whole of the statistical series is affected of a unit root. It should be noted that the number of maximum delay is fixed at 3; the selection of the numbers of delay for each individual is programmed by Pedroni for these two tests. In this issue we indicate that we have tested unit root tests for each of variables, in Table 3 we indicate an example for private R and D noted by R.

The second step consists on estimation of the whole specification, for more precision we use a comparative study between several methods.

Generalized and instruments method

By using Anderson and Hsiao method, our model in first difference becomes:

$$R_{it} - R_{it-1} = \alpha\left(R_{it} - R_{it-1}\right) + \beta_1\left(G_{it} - G_{it-1}\right) + \beta_2\left(M_{it} - M_{it-1}\right) + \beta_3\left(y_{it} - y_{it-1}\right) + \beta_4\left(IDE_{it} - IDE_{it-1}\right) + v_{it} - v_{it-1}$$

When we use $R_{i,t-2}$ and $R_{i,t-2}$ - $R_{i,t-3}$ as instrument gives results in Tables 4 and 5 respectively.

After we have estimate model by Anderson and Hsiao (1982) method and to get more efficient results, we try to apply the approach of Arellano and Bond (1991) that permits to get a generalized moment GMM more efficient.

The evaluation that we present in Table 6 corresponds to the GMM evaluation of Arellano and Bond (1991). The empirical evaluations confirm the positive effect of the R and D on growth of R and D of different country (positive and significant effect in all evaluations). However, identification of effects of other variables is far from being obvious according to different evaluations, a positive and significant effect in of Anderson and Hsiao evaluation of which public research are affected by a positive and significant value (0.034631350) with a (T-Stat = 2.11157) in the same way (1.91820030) with a (T-Stat = 1.90250), therefore these results verify the existence of a positive and significant relation between the two variables. For GMM method in first difference the variable spends public research is positive and significant (1.20891059), (T-Stat = 2.90728).

For orthogonal deviation results are indicated in Table 7, from this table we can conclude that private R and D is affected with a positive and significant coefficient. All variable are significant in 5% level, we can say that if we have a supplementary unit added to public R and D it can increase private R and D by 30%. So all countries are invited to appreciate and encourage activities in private

Table 4. Anderson and Hsiao method with $R_{i,t-2}$ as instrument.

	Coeff	T-Stat	Signif
R (-2)	1.043741733	2.61851	0.01862671
G	0.034631350	2.11157	0.01255140
M	0.117410800	3.10834	0.00507352
VA	0.261604184	1.09045	0.02905193
IDE	0.068683520	2.10772	0.01555534

Table 5. Anderson and Hsiao method with $R_{i,t-2}$ - $R_{i,t-3}$ as instrument.

	Coeff	T-Stat	Signif
R (-2)-R (-3)	4.02020750	2.11480	0.0226709
G	1.91820030	1.90250	0.03925921
M	1.86404603	2.34064	0.01364196
VA	1.25706985	2.84950	0.02590034
IDE	0.55898626	3.09396	0.02520837

Table 6. Arellano and Bond method in first difference.

	Coeff	T-Stat	Signif
R(-1)	0.52001865	0.46582	0.64180074
G	1.20891059	2.90728	0.03425802
M	1.36345220	2.36785	0.01333684
VA	1.15210478	1.29346	0.36944694
IDE	1.14085022	2.15794	0.02465192

Sargan test: Ch^2 (20) =25.78 (0.001).

Table 7. Arellano and Bond method in orthogonal deviation.

	Coeff	T-Stat	Signif
R(-1)	0.30035445	1.96465	0.0000001
G	0.20561059	2.90728	0.0000002
M	1.25333220	2.36785	0.0000000
VA	1.03430478	1.29346	0.0000000
IDE	0.19056744	2.15794	0.0000000

sector for R and D.

DISCUSSION AND CONCLUSION

In our survey, we tried to put accent on private and public investment in R and D, for the case of 23 countries which presents different levels of R and D. We tried to clarify relation that exists between private and public research. This empirical survey wanted to give account, the effects of different determinants on private investment in R and D and to know if public and private investments in R and D are complement or substitute.

Econometric approach consists in the regression of some measures of private R and D on public R and D with some control variables. The evaluation that we presented in our work corresponds to GMM evaluation in first difference and in orthogonal deviation. We prefer to refer to results of this evaluation because it permits to eliminate rigorous way all bias to none observed individual heterogeneity and offer, a better efficiency of results. Empiric evaluations confirm a positive effect of public R and D in different country (positive and meaningful effect in all evaluations). Results of our empiric survey are relative for our sample and they go in the sense of results of ulterior studies, which showed that there is a positive and meaningful relation between private and public investment in R and D.

Although, a model including a whole of variables is tested with generally admitted estimators, the accent is related to dynamic panel data analysis. This approach makes it possible to study a model with theoretical lesson on R and D cooperation. Based on Arellano and Bond (1991) estimator, econometric specification of this dynamic model combines the use of instrumental variables and generalized moment method. The use of instrumental variables makes it possible to obtain consistent estimators because it solves the problems of correlations between lagged variable, constant and errors terms provided that errors terms are not correlated in time (Anderson and Hsiao, 1982). GMM makes it possible to obtain efficient estimators (Arellano and Bond, 1991).

All results are in favor of a positive relation between private and public R and D which can be assumed by a complementarities between them. In our study we have indicate that all variables are stationary by an application of unit root tests that can contribute to search cointegration relation between them and determinate the number of these relation. Another important think, we can give the impact of public R and D to private R and D for each country to specify the nature of relation and how private R and D contributes for public sector. In summary, all countries must stimulate private sector in R and D activities to promote economic growth and integrate a new innovation system which can go with their own economic environment.

The studies available on R and D cooperation are often limited to a static approach. However, the most recent work (Autant and Massard, 1999; Cozzi, 1999; Cassiman and Veugelers, 2002) enriches the analysis by the use of a dynamic approach to apprehend relations of R and D cooperation for various studies.

The panel econometrics model makes it possible to control observations heterogeneity in their individual dimensions either by taking account of a specific effect or by taking account of non-observable specific effect 'random effects'. Temporal dimension is taken account by introduction of dummy variables.

In this work, we examine the relation between private and public R and D and growth in various countries. On a sample of 23 countries, the results obtained using GMM in dynamic panel show that impact R and D cooperation on growth varies according to indicator of internal expenditure of research and development 'DIRD' of each country taken in the sample. On the basis of this last indicator, it arises from the estimates that the increase in percentage of this indicator led to 0.427 point of additional growth.

The application of LL and IPS unit root tests shows that the whole of statistical series is affected of a unit root. It should be noted that the number of maximum lags is fixed at three. Selection of the numbers of lags is programmed by Pedroni. The checking of non stationary properties for all variables of panel leads us to study the existence of a long run relation between these variables. From results of cointegration tests of Pedroni we can notice that the whole of statistics are lower than the breaking value of normal law for a threshold of 5%(-1.64). So the whole of these tests requires the existence of a cointegration relation.

Some studies put in value of other factors that can be important as: competition in the market, public politics and cooperation concerning R and D between firms. Cooperation in R and D is a part of the new strategies developed by firms in more global and competitive economic environment. These last factors are not to be disregarded and can be a subject of future research concerning the relation between public and private investment in R and D.

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REFERENCES

Anderson TW, Hsiao C (1982). Formulation and Estimation of Dynamic Models Using Panel Data." J. Econ., 18: 47-82.

Arellano M, Bond S (1991). Some test of specification for panel data: Monte Carlo evidence and application to employment equations." Rev. Econ. Stud., 58: 277-297.

Baltagi B, James MG *(*1995). A Dynamic Demand Model for Liquor: The Case for Pooling." Rev. Econ. Stat., 77 (3): 545-554.

Becker B, Pain N (2002). What determines industrial R&D expenditure in the UK?" National Institute of Economic and social research NIESR, Discussion, p. 211,

Blank D, Stigler G (1957). The demand and supply of scientific personnel." New York, National Bureau of Economic Research.

Bernardí C, Guadalupe S (2007). Innovation and R&D spillover effects in Spanish regions: A spatial approach." Res. Pol., 36: 1357-1371.

Busom I (2000). An empirical evaluation of the effects of R&D subsidies." Econ. Innova. New Technol., 9: 111-148.

Cassiman B, Veugelers R (2006). In search of complementarity in Innovation Strategy: Internal R&D, Cooperation in R&D and external technology Acquisition." Manage. Sci., 52 (1): 68–82.

Chaturvedi K, Chataway J (2006). "Strategic integration of knowledge in Indian pharmaceutical firms: creating competencies for innovation." Int. J. Bus. Innova. Res., 1(1-2): 27–50.

CHELEM: http://www.cepii.fr/francgraph/bdd/chelem.htm

Christopher AL (2005). Market structure and endogenous productivity growth: how do R&D subsidies affect market structure?" J. Econ. Dynam. Control, 29: 187–223.

Claudia S (2008). Complementarities of innovation activities: An empirical analysis of the German manufacturing sector." Res. Policy, 37(9): 1492-1503.

Eric CW (2007). R&D efficiency and economic performance: A cross-country analysis using the stochastic frontier approach." J. Pol. Model, 29 (2):345-360.

Eurostat: Statistics on research and development, http://epp.eurostat.ec.europa.eu/.

Griliches Z (1995). R&D and Productivity: Econometric Results and Measurement Issues" in Paul Stoneman (ed.), Handbook of the Economics of Innovation and Technological Change, Blackwell, pp. 52-89.

Griliches Z (1969). Capital skill complementarity". The Rev. Econ. Statist., 51 (4): 465-468.

Guellec D, Van-Pottelsberghe B (1997). "Does Government Support Stimulate Private R&D?" OECD Econ. Stud., 29 (2): 95-122.

Görg H, Strobl E (2007). The effect of R&D subsidies on private R&D." Econ., 74: 215-234.

Hansen LP (1982). Large Sample Properties of Generalized Method of Moments Estimators." Econometrica, 50 (4):1029-1054.

Hans L, Almas H (2005). The impact of public funds on private R&D investment: New evidence from a firm level innovation study." MIT *Discussion Paper*, ISSN 1795-5300 (3): 1-26.

Im K, Pesaran MH, Shin Y (2003). Testing for unit roots in heterogeneous panels." J. Econ., 115: 53-74

INS: National Statistics Institute Tunisia, http://www.ins.nat.tn/

Jarunee W (2008). Building effective research evaluation systems to assist R&D investment decisions." Int. J. Bus. Innova. Res., 2 (2):123 –140.

Jason CH, Eduardo SS (2008). A model of R&D valuation and the design of research incentives insurance." Mat. Econ., 43 (3):350–367.

Lach S (2000). Do R&D subsidies stimulate or displace private R&D? Evidence from Israel', *NBER* working paper n°7943, Cambridge.

Lai M, Peng S, Bao Q (2006). Technology spillovers, absorptive capacity and economic growth." China. Econ. Rev., 17: 300–320.

Levin A, Chien-Fu L (1992). Unit root tests in panel data: Asymptotic and finite sample properties', Department of Economics, University of California at San Diego, Discussion, pp.92-93.

Lopez-Bazo E, Requena F, Serrano G (2006). Complementarity between local knowledge and internationalisation in regional technological progress." J. Regl. Sci., 46: 901-930.

OCDE (1999a). « The OCDE stand database for industrial analysis », Paris.

OCDE (1999b). « Main sciences and technology indicators » 1999/1, Paris.

Paul AD, Bronwyn HH, Andrew AT (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence." Res. Pol., 29: 497-529.

Pedroni P (1999). Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors." Oxford Bull. Econ. Stat., 61: 653-670.

Pedroni, Peter. 2004. "Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis." Econometric Theory, 3: 579-625.

Ranjapour R, Karimi TZ (2008). Evaluation of the income convergence hypothesis in ten new members of the European Union: A panel unit root approach." Panoecon., 55 (2):157-166.

Romer P (1990). Endogenous technological change". J. Poli. Econ., 98 (2): 71-102.

Sargan JD (1988). Contributions to Econometrics', Vols. 1 & 2. (Ed. E.

Maasoumi). Cambridge: Cambridge University Press.
Sigrid S (2005). Cooperative and non-cooperative R&D in experimental duopoly markets. Int. J. Indust. Organ., 23(1-2): 63-82.
Solow, Robert (1957) "Technical change and the aggregate production function". Rev. Econ. Stat., 39: 312-320.
Solow R (1960) Investment and technological progress" Stanford, CA: Stanford University Press, p. 63-87.
Tahir, Conka, Ozalp Vayvay, Bahar Sennaroglu. 2008. "A combined decision model for R&D project Portfolio selection." Int. J. Bus. Innova. Res., 2(2): 190-202.
Ting G (2005). Foreign direct investment and growth under economic integration." J. Int. Econ., 67(1): 157-174.
Tykhonenko A (2007). La persistence des écarts de richesse au sein de l'Europe élargie: l'apport de l'économétrie des panels hétérogènes non-stationnaires." Panoeconomicus, 54(1): 69-86.
UNESCO: UIS Data, Institute for Statistics S&T database, http://www.uis.unesco.org/.
Veugelers R, Cassiman B (2005). R&D Cooperation between Firms and Universities, some empirical evidence from Belgium Manufacturing." Int. J. Indust. Organ., 23(5-6): 355-379.
Wieser R (2005). Research and Development Productivity and Spillovers: Empirical Evidence at the Firm Level." J. Econ. Surveys, 19: 587-621.
World Bank: World Development Indicators CD-ROM – 2009.
Xulia G, Consuelo P (2008). Do public subsidies stimulate private R&D spending?" Res. Policy, 37: 371-389.