R&D EXPENDITURES AND THE ROLE OF GOVERNMENT AROUND THE WORLD*

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Abstract

The goal of this paper is to conduct an empirical investigation on the macro-economic determinants of research and development (R&D) expenditures and to assess the role of government in the light of recent developments brought about by the endogenous growth theory. The sample comprises 88 countries over the 1980s and 1990s. Our results are broadly consistent with the theoretical predictions, although some striking results are uncovered, namely: (i) trade openness has a negative effect on R&D, but this effect is mitigated as per capita GDP and the trade with OECD countries increase; (ii) investment in R&D is negatively associated to investment in physical capital; (iii) governments fund a higher share of R&D in countries suffering more severe market failures, but they do not compensate for variations in private R&D.

Resumen

El objetivo de este artículo es conducir una investigación empírica acerca de los determinantes macroeconómicos del gasto en inversión y desarrollo, y evaluar el papel del gobierno a la luz de los últimos desarrollos que ha aportado la teoría de crecimiento endógena.

La muestra comprende 88 países entre los años 80's y 90's. Nuestros resultados son altamente consistentes con las predicciones teóricas, aunque se han descubierto resultados llamativos, i) la apertura del comercio tiene un efecto negativo en la investigación y desarrollo, pero este efecto es mitigado con el incremento del PIB per cápita y el comercio con países de la OECD, ii) la inversión en investigación y desarrollo está asociada negativamente a la inversión en capital físico, iii) los gobiernos financian una mayor proporción de investigación y desarrollo en países que sufren más severas fallas de mercado, pero no compensan las variaciones en inversión y desarrollo privadas.

Keywords: *research and development.*

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Introduction

Expenditures in research and development (R&D) have been pointed out as a major engine of growth by recent endogenous models which, in contrast to the neoclassical model, claim that economic and institutional factors lie behind the pace of technological progress. However, probably because of data availability, empirical work on the subject has been scarce (a notorious exception is Clarke (2001)). To fill this gap, this paper intends to contribute evidence on the determinants of R&D expenditures for 88 countries over the 1980s and 1990s, using a database assembled by UNESCO[1]. In a sense, our research provides a test about the endogeneity or exogeneity of technological progress: if a systematic relationship between R&D and a set of economic variables is found, evidence would confirm the endogenous literature hypothesis. Furthermore, we go a step beyond by examining another major point made by this wave of models, which argue that in the presence of market failures, such as externalities and monopolistic power, government intervention is needed to ensure that the provision of technology is optimal.

The structure of the paper is as follows: In Section 1, the theoretical foundations of the paper are set up. Section 2 presents some descriptive statistics and stylized facts on the variables under study. Econometric results are discussed in Section 3. Some conclusions close.

Section 1: Underlying Theory

Insatisfaction with some implications of the Solow model paved the way since the mid-80s for the emergence and acceptance of a new set of endogenous growth models That argue that technology is central to long-run growth and that it appears as a result of economic incentives instead of being just imposed ad-hoc into the neoclassical Solovian model. Next, we introduce the rationale behind each of the explanatory variables to be used in this research, which implicitly come from this body of theory.

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[1] We are referring here to formal R&D, which UNESCO defines as “any creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications”. Business enterprise funds include funds allocated to R&D by all firms, organizations and institutions whose primary activity is the market production of goods and services (other than the higher education sector) for sale to the general public at an economically significant price, and those private non-profit institutes mainly serving these firms, organizations and institutions. Government funds refer to funds allocated to R&D by the central (federal), state or local government authorities. These includes all departments, offices and other bodies which furnish but normally do not sell to the community those common services, other than higher education, which cannot be conveniently and economically provided and administer the state and the economic and social policy of the community. Public enterprises funds are included in the business enterprise funds sector. These authorities also include private non-profit institutes controlled and mainly financed by government. The other categories are higher education funds, private non-profit funds, and funds from abroad, which on average represent less than are 5% of total R&D. Of course, technological progress may take other forms, such as learning by doing or ideas.

Investment Rate: As technology is usually embodied in capital goods, physical capital is expected to positively influence R&D. As a matter of fact, there is a two-way relationship between technology and investment. On one hand, investment creates incentives for technological improvement. For example, the impressive advance in informational technology during the last few decades would not have been possible had the first computers not been built; in other words, capital-intensive hardware fostered technology-intensive software. But on the other hand, technological progress generates productivity gains that turn investment in physical capital more profitable. Providing some fragmentary empirical support, Grossman and Helpman (1994) show that total factor productivity is highest in countries with high investment rates, while Bebczuk (2000a) uses factor analysis to demonstrate that the correlation between productivity and investment is quite high even after accounting for the expected double causality between both of them.

Rule of law: Given that innovations are intrinsically nonrivalrous, have a low marginal cost and are in general easy to reproduce or imitate via reverse engineering, the protection of property rights is as a vital issue to ensure appropriability and encourage further R&D. The index of rule of law, based on surveys with a large number of respondents in each country, hopefully reflects the average perception of agents about the enforceability of contracts, the effectiveness and predictability of the judiciary and the incidence of crime. The one used in this study comes from Kaufmann, Kraay and Zoido-Lobaton (1999), where more details about its construction can be found. Its range is -2.5 to 2.5, with higher values corresponding to better rule of law.

Tertiary school enrollment: Due to its scientific nature, formal R&D is intensive in human capital. Most models of endogenous technological change incorporate this feature (see, for example, Romer (1990)). Evidence on the plausibility of this assumption comes from the fact that, from our database, the simple correlation between R&D expenditures and the number of researchers per million inhabitants is very high (0.83).

Financial Development: Since R&D projects require large amounts of money to be undertaken and revenues are likely to be raised only after a rather long period, financing becomes a sensitive issue. However, firms around the world typically finance a small portion of their investments with external sources of funds, relying instead on internal funds (for the theoretical rationale and evidence on a broad set of countries, see Bebczuk (2000b and 2001). It is to be expected that the difficulty to forecast the future cash flows of R&D projects (see Rosenberg (1996)) and to control the use of funds make the access to outside funding even harder. In any case, it is possible to make the point that the development of financial markets may encourage more R&D not only via direct financing. First, even when projects are self-financed, unexpected expenses might appear during its life. If the firm has no access to credit, premature liquidation at below-cost values may be the only solution (for a similar argument on bank runs, see Diamond and Dybvig (1983)). Consequently, risk-averse entrepreneurs may devote less resources to R&D to avoid potential illiquidity. In a similar vein, the trading of ownership rights in stock markets helps reduce illiquidity risk and diversify the financial risk faced by the entrepreneur. Second, both debt and equity finance, regardless of their weight in total funding, tend to discipline shareholders and managers, thus improving corporate governance and minimizing agency conflicts. This has a double effect: for one, the resulting higher productivity encourages new projects; besides, it turns shareholders less reluctant to finance projects intrinsically hard to scrutinize[2].

Openness: Measured by the sum of exports and imports to GDP, this variable has two opposite effects on R&D. On one hand, countries with a comparative disadvantage in the production of new technology –in turn explained by little human capital and a small starting stock of knowledge– will be induced to move away from R&D activities (see for example Grossman and Helpman (1991)). International trade in intermediate or final technology-intensive goods avoids the duplication of R&D efforts which, while improving the allocation of world resources, tends to deprive some countries from a national R&D industry. But on the other hand, cross-border technology flows may give rise to knowledge spillovers with a favorable impact on domestic R&D.

Manufacturing exports: Compared to most services and agricultural exports, manufacturing exports are relatively technology-intensive. As a result, countries with a trade pattern biased towards these exports will face more demand for R&D expenditures than others.

Foreign Direct Investment (FDI): Incoming FDI has an ambiguous a priori impact on R&D expenditures. On one hand, by bringing new techniques and capital goods, FDI may create positive externalities exploitable by other domestic firms. But on the other hand, firms receiving FDI are likely to compete with domestic producers with lower technological capabilities, which may be driven out of business. Therefore, which of these effects prevails boils down to an empirical question[3,4].

Demand factors: Although the underlying theory on R&D focuses on supply side considerations, one cannot disdain the potential role of demand factors. Specifically, the rate of growth and its standard deviation may be relevant variables for R&D projects. Along with per capita income, real GDP growth may be relevant to determine the market size for future inventions, which in turn is decisive to forecast the project's profitability, especially in the face of the heavy fixed costs involved. Regarding GDP growth volatility, innovation is an extremely risky business, as both the final outcome and its acceptance by consumers are uncertain at the time of undertaking the project. Given the irre-

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2 An indirect channel is that the investment in human capital may be lower if prospective students or their parents face liquidity constraints. But including school enrollment this factor is already accounted for.

3 We chose gross instead of net foreign direct investment because, as a result of the nonrivalry property of technology, one can expect that outcoming FDI does not reduce the domestic stock of knowledge.

4 Besides its impact on formal R&D, FDI is likely to promote informal R&D through learning by doing and personal contacts.

versibility of R&D investment, resulting from its industry-specific and intangible nature, the discount factor applied to these projects may be higher in volatile environments. Suitable hedge instruments could, of course, help to cope with uncertainty, but it is clear that markets are incomplete, specially so for this kind of investment.

Stock of knowledge: The modern theoretical framework stresses that innovation is dependent upon the accumulated stock of knowledge (Romer (1990), Caballero and Jaffe (1993)). The intuition rests on the nonrivalous and non-excludability of knowledge, and goes on by claiming that researchers build on previous technology to create new ones. As a result, the more advanced the initial technology, the more productive researchers are, and hence more resources are likely to be devoted to R&D.

SECTION 2: DESCRIPTIVE STATISTICS AND STYLIZED FACTS

Table 1 displays means and standard deviations of the variables to be used in the econometric estimation. The sample includes a maximum of 88 countries and averages for the 1980 and 1990 decades.

Expenditures in R&D are only 0.96% of GDP for the whole sample. Compared to investment in physical capital, this figure appears to be quite small. However, as noted by Grossman and Helpman (1994), it must be borne in mind that, unlike R&D, about three quarters of annual investment is devoted to depreciation of the existing capital stock. Yet another distinctive feature of R&D lies in the fact that its productive impact is higher the higher the initial stock of knowledge, while no such relationship can be established between the flow and the stock of capital. After dividing countries in four categories by GDP the following stylized facts emerge:

(a) R&D expenditures increase with per capita GDP. Differences are noticeable: countries with GDP lower than $2,000 have an average of 0.57% against 1.6% in the case of the richest countries (GDP higher than $12,000);
(b) In turn, GDP appears to be positively correlated with a large number of variables suspected to explain R&D, such as rule of law, financial development, school enrollment, growth volatility, manufacturing exports, and foreign direct investment;
(c) R&D government funding exceeds, on average, 50% of total funding, but this share decreases from 62.6% in the poorest countries in the sample to 45.2 in the richest ones.

SECTION 3: ESTIMATION

3.1. Total R&D

Table 2 displays the main results from the econometric estimation on the determinants of R&D expenditures. The estimation was conducted using pooled ordinary least squares, and White's heteroskedastic-consistent estimators are

TABLE 1
DESCRIPTIVE STATISTICS

Variables	Obs	Whole sample	GDPpc<=$2000	GDPpc>$2000 & <=$5000	GDPpc>$5000 & <=$12000	GDPpc>$12000
Expenditures in R&D as a % of GDP	128	0.96 *0.82*	0.57 *0.54*	0.56 *0.52*	1.08 *0.79*	1.60 *0.87*
Corporate sector-financed R&D as a % of total	78	43.2 *19.5*	29.9 *19.8*	44.7 *19.3*	40.5 *22.2*	50.1 *13.7*
Government-financed R&D as a % of total	95	52.6 *22.8*	62.6 *29.3*	53.1 *22.6*	53.5 *23.5*	45.2 *14,9*
Tertiary school enrollment	127	24.4 *17.2*	14.6 *15.0*	15.6 *7.2*	27.2 *10.0*	39.5 *19.0*
Real per capita GDP in 1985 US dollars	123	6416.3 *5524.8*	816.3 *700.0*	3363.4 *896.0*	8308.5 *2318.8*	14528.6 *2089.2*
Real GDP growth	119	3.2 *2.4*	4.0 *2,4*	3.2 *1.8*	2.6 *2,5*	3.1 *2,6*
Standard deviation of the growth rate	119	3.9 *3.3*	5.1 *4.3*	4.8 *2.9*	2.8 *1.4*	2.8 *3.4*
Investment rate as a % of GDP	122	22.6 *6.2*	21.2 *7.1*	24.8 *5.6*	23.8 *6.4*	21.1 *4.5*
Credit to the private sector as a % of GDP	126	49.5 *37.6*	25.8 *22.3*	36.8 *28.8*	60.3 *34.2*	76.5 *40.5*
Rule of law	126	0.44 *0.95*	-0.34 *0.62*	-0.04 *0.67*	0.84 *0.73*	1.30 *0.70*
Exports plus imports as a % of GDP	120	69,2 *50.2*	60.3 *34.6*	67.8 *29.9*	79.9 *66.7*	70.8 *60.4*
Exports as a % of GDP	122	33.7 *25.6*	27.6 *18.1*	32.2 *14,0*	39.6 *34.1*	36.5 *30.8*
Imports as a % of GDP	125	35.2 *25.2*	31.9 *17.8*	35.5 *lk7*	41.2 *33.8*	33.1 *29.2*
Manufacturing exports as a % of total	124	51.6 *28.3*	42.8 *29.2*	48.2 *24.8*	61.0 *25.3*	55.0 *30.5*
Gross foreign direct investment as a % of GDP	121	2.1 *2.8*	0.6 *0.8*	0.9 *0.7*	2.2 *2.5*	4.6 *3.9*

Sources: R&D data: UNESCO; macroeconomic variables: World Development Database; Rule of law: Kaufmann D, A. Kraay and P. Zoido-Lobaton (1999).

TABLE 2

DEPENDENT VARIABLE: R&D EXPENDITURE AS A PERCENTAGE OF GDP

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Investment rate	-0.020	-0.026	-0.018	-0.026	-0.025	-0.025	
	(-2.182)	(-2.673)	(-1.842)	(-2.528)	(-2.386)	(-2.847)	
Rule of law	0.227	0.224	0.192	0.175	0.220	0.112	
	(3.164)	(3.023)	(2.643)	(2.229)	(3.324)	(1.679)	
Terciary school enrollment	0.0087	0.0100	0.0076	0.0093		-0.0002	
	(1.72)	(1.757)	(1.362)	(1.467)		(-0.04)	
Credit to the private sector	0.0079	0.0083	0.0085	0.0093	0.0098	0.0087	
(as a % of GDP)	(3.316)	(3.549)	(3.311)	(3.953)	(3.935)	(4.25)	
Manufacturing exports	0.0091	0.0091	0.0088	0.0085	0.0087	0.0085	
(as a % of total exports)	(4.139)	(4.129)	(3.796)	(3.765)	(3.605)	(3.633)	
Total exports plus imports	-0.0015	-0.0015	-0.0026	-0.0026	-0.0034	-0.0012	
(as a % of GDP)	(-1.908)	(-1.896)	(-2.387)	(-2.369)	(-3.049)	(-1.566)	
Trade with OECD*GDP[a]	3.96E-06	4.23E-06	4.23E-06	4.54E-06	5.54E-06	8.48E-07	
	(1.929)	(1.912)	(1.957)	(1.941)	(2.468)	(0.394)	
Gross Foreign Direct			0.062	0.064	0.078		
Investment (as a % of GDP)			(1.789)	(1.89)	(2.167)		
Standard deviation of	-0.0046	-0.0047	-0.0058	-0.0077	-0.0097	0.0234	
GDP growth	(-0.1174)	(-0.189)	(-0.2117)	(-0.306)	(-0.369)	(1.503)	
Real GDP growth rate		0.028		0.037	0.026	0.024	
		(1.183)		(1.362)	(1.153)	(1.189)	
Technology parameter[b]						0.01347	0.00012
						(3.348)	(9.288)
Constant	0.452	0.436	0.403	0.402	0.525	0.065	0.298
	(2.458)	(2.306)	(2.007)	(1.988)	(2.955)	(0.361)	(3.646)
N° of observations	96	96	89	89	89	92	109
F-statistics (p-value)	31.43 (0.000)	29.51 (0.000)	28.74 (0.000)	26.46 (0.000)	26.57 (0.000)	35.37 (0.000)	158.2 (0.000)
R-squared	0.758	0.762	0.762	0.769	0.759	0.810	0.569

* In parenthesis, White‘s heteroskedastic-consistent t-statistics.

[a] Exports plus imports to OECD countries over exports plus imports to non-OECD countries multiplied by per capita GDP. See text.

presented in parenthesis. To minimize possible endogeneity biases, we adopt the usual procedure of instrumentalizing the explanatory variables with lagged values. The first observation in place is that R-squares and F-statistics yield high values, suggesting that the specification chosen explain a great deal of the variation of R&D expenditures. Nevertheless, as outlined later on, multicollinearity is a serious drawback that prevent us from making bolder statements about the individual effect of some explanatory variables.

The first striking finding is that the investment rate has a strong *but negative* relationship with R&D, clashing with the conventional wisdom that the both of them are complementary inputs. A plausible explanation is that countries engage more actively in R&D only after the diminishing returns of physical capital start threatening the country's growth prospects. In this sense, investment seems to take place in a sequential fashion, with intensive physical (and probably human capital) investment first and R&D later on[5]. As expected, the protection of property rights, proxied by the rule of law index, appears to be crucial to foster R&D[6]. Tertiary school enrollment also influences positively R&D, although its effect is significant at a 10% confidence level. Credit to the private sector exerts the positive effect predicted by the theory, but one cannot discard that the highly significant effect be partially capturing the effect of some omitted variables.

The trade-related variables estimates are noteworthy too. Openness (measured by the sum of exports and imports to GDP) reduces national R&D, lending support to the hypothesis that countries with comparative disadvantage in the production of new technology –in turn explained by little human capital and a small starting stock of knowledge- will be induced to move away from R&D activities (see for example Grossman and Helpman (1991)). International trade in intermediate or final technology-intensive goods avoids the duplication of R&D efforts which, while improving the allocation of world resources, will deprive some countries from a national R&D industry. Nevertheless, cross-border technology flows may give rise to knowledge spillovers with a favorable impact on domestic R&D. It is empirically difficult to disentangle the former from the latter effect, though. In any case, one should expect that countries with a high initial stock of knowledge and those with intense trading vis-à-vis OECD countries (which are likely to have a superior technological base) will benefit the most from such spillovers. Accordingly, we constructed an interaction variable equal to the ratio (Trade with OECD countries/Trade with non-OECD countries) times per capita GDP under the assumption that GDP is a good proxy for the stock of knowledge (this discussion is resumed below). The claim is supported by the positive and significant coefficient in the regressions. Foreign direct investment has a positive effect, implying that on the whole it does not substitute for domestic R&D. Econometrically, the inclusion of this variable (regressions 3, 4 and 5) turns the education variable non-significant, which is in line with the high correlation between FDI and education (see Borensztein, De

5 This is consistent with the upward trend in industrial R&D in OECD countries depicted by Grossman and Helpman (1991a) and others.

6 Other indices of institutional quality, such as corruption and regulatory framework are highly correlated to rule of law, so they were not used in the final regressions.

Gregorio and Lee (1998)). Less controversial, the share of manufacturing exports to total exports seems to boost R&D, as these exports are relatively intensive in technological goods.

As for the demand factors, neither GDP growth nor its standard deviation display any significant coefficient in the regressions shown, reinforcing the conventional approach emphasizing supply factors and long-run profitability. However, care must be taken as output volatility is inversely correlated to some of the variables included in the estimation, making it hard to isolate its individual effect on R&D. By eliminating some of the control variables, the standard deviation of the growth rate displays a negative and significant sign at a 1% confidence level[7].

Being an unobservable variable, the stock of knowledge will be proxied by the steady-state condition of the Solow model assuming a Cobb-Douglas production function. Under this setup, $A=y/[s/(g+d+n]^{(1-b)/b}$, where A is the usual technology parameter, y stands for per capita GDP, s is the investment rate, g is the rate of growth of total factor productivity (assumed to be equal to 2% per annum), d is the depreciation rate (assumed to be equal to 5% of the capital stock), n is the population growth rate, and b is the product elasticity of capital (assumed to be equal to 40%). Although the estimation yields the expected positive sign at conventional confidence levels, it must be noted from regression (6) that a number of control variables lose significance. The explanation is that our estimation of A is highly correlated with per capita GDP, which in turn is closely associated to education, instability, and rule of law, among others[8]. As a matter of fact, as shown in regression (7), A explains on its own about 56% of the variability of R&D expenditures. However, the noticeable commonality between this and other macroeconomic variables renders the estimation poorly informative, suggesting that regressions (1) through (5), where there is an specific underlying theory behind each of the explanatory variables, shed more light on the issue at hand than regressions (6) and (7).

3.2. Government and R&D

The recognition that governments has a role to play in the R&D market dates back at least to Arrow (1962). As usual, government intervention is warranted whenever market failures are present. Romer (1990b) highlights two supporting arguments, namely, the existence of externalities from previous research and the monopolistic market structure created by the presence of considerable fixed costs. Additionally, Aghion y Howitt (1998) claim that excessive

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[7] The semi-deviation was also included in some regressions (not reported) in order to test whether downside risk is the relevant volatility measure. Results did not vary.

[8] In order to find a suitable instrument for A, we tried the following alternative measure, suggested by Easterly and Levine (2001) in the spirit of Mankiw, Romer and Weil (1992). From a regression of the log per capita GDP on the log $[s/(g+d+n]^{(1-b)/b}$, we included dummies for different regions using the estimated coefficients as proxies of the relative technological level of each region. As expected, the implicit OECD productivity was more than three times higher than in other countries. However, this variable was once again highly correlated with per capita GDP, and hence results did not change in any significant way.

creative destruction might result when innovations are vertical, that is, new inventions substitute rather than complement previous ones.

Unfortunately, it is problematic to unveil this kind of market failures using macroeconomic data. Nevertheless, there exist other market failures that call for government intervention. For instance, a deficient rule of law prevents the researcher to reap the full benefit created by his invention, thus discouraging private R&D[9]. Unlike rule of law, which to a large extent is a public good, financial development is mostly provided by decentralized markets. However, modest financial depth derives from institutional and legal problems of a public nature that exacerbate informational asymmetries between borrowers and lenders (see for example La Porta and Lopez de Silanes (1998)). By the same token, output growth volatility is detrimental to R&D because markets are incomplete, as they do not allow agents to insure themselves against all possible states of nature (see, for example, Obstfeld and Rogoff (1996)). Tertiary education, because of its externalities (see Lucas (1988)) and the influence of liquidity constraints (see De Gregorio (1992)), is also likely to be provided at suboptimal levels.

Next, we show our econometric results in Table 3[10]. Since it is not conceivable for the government share in R&D to have any effect on the explanatory variables, contemporaneous values are used in the estimation. In columns (1) through (4), each of the four variables (rule of law, credit, the standard deviation of growth rate, and tertiary education) enter significantly with the expected sign, thus implying that the above hypotheses are well grounded. But the correlation among such variables prevents us from extracting reliable individual estimates when all variables are included, as in regression (5). A partial remedy, employed in regression (6), is to use the principal component technique, obtaining once again a supportive result. A time dummy was also included in all of the regressions, and the coefficient estimate suggests that the government share fell down in the 1990s vis-à-vis the 1980s. One can conjecture that this reflects the increasing role of the private sector in economic activity and the growing concern about fiscal balance worldwide[11].

Provided that the government assumes an ancillary role, the question remains as to whether the state manages to overcome the suboptimal supply of R&D generated by the private sector. A simple but illuminating econometric exercise consists in running a regression of government expenditures on corporate R&D expenditures. A coefficient of minus one would mean that the government fully compensates for a deficient private provision, while a coefficient equal to zero would imply that it does not counteract. The actual estimation is shown in Table 4. The estimated compensation coefficient is just 0.31, suggest-

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9 This is different from the externality underlined by Romer (1990), which has to do with the nonrivalrous property of research for scientific purposes. In our case, the problem lies on the imperfect excludability for commercial uses. Actually, Romer implicitly assumes that the patent system fully protects property rights.

10 For a recent work examining the empirical relationship between private and federal basic research in the US, see Diamond (1999).

11 When regional dummies are included, Latin America is the one region that seems to have higher government share than others, even after controlling for the whole set of explanatory variables.

TABLE 3
DEPENDENT VARIABLE: GOVERNMENT-FINANCED R&D AS A PERCENTAGE OF TOTAL

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Rule of law	-9.563 (-4.371)				-0.167 (-2.26)	
Credit to the private sector		-0.244 (-4.541)			-5.275 (-1.735)	
Standard deviation of GDP growth			2.886 (3.522)		0.361 (0.311)	
Tertiary school enrollment				-0.4818 (-2.959)	-0.024 (-0.151)	
Time dummy	-12.67 (-2.957)	-11.88 (-2.772)	-13.63 (-2.995)	-7.151 (-1.411)	-11.499 (-2.36)	-9.591 (-2.287)
Principal component						-0.417 (-5.019)
Constant	92.79 (8.236)	99.42 (8.88)	78.88 (6.41)	82.66 (6.747)	94.807 (8.639)	94.399 (8.946)
Observations	111	107	104	107	97	97
F-test (p-value)	15.61 (0.000)	107(0.000)	10.33 (0.000)	8.66 (0.000)	10.31 (0.000)	20.48 (0.000)
Adjusted R-squared	0.199	0.222	0.129	0.115	0.298	0.274

* In parenthesis, White‘s heteroskedastic-consistent t-statistics.

TABLE 4
DEPENDENT VARIABLE: GOVERNMENT-FINANCED R&D AS A PERCENTAGE OF GDP

Variables	
Corporate R&D over GDP	0.313 (7.337)
Constant	0.30 (8.116)
Observations	94
F-test (p-value)	53.83 (0.000)
Adjusted R-squared	0.362

* t-statistics in parenthesis

ing that for $1 dollar less of private R&D, public R&D *decreases* by an additional $0.31. This finding provides a reasonable rationale for the observed negative correlation between R&D expenditures and per capita GDP and the positive association between the latter and the share of government to total R&D: it is apparent that poorer countries have poorer fundamental and deeper market failures which result in less private R&D. As governments do not undo but magnify the retraction of private R&D, on balance such countries end up having less R&D than more developed countries.

Conclusions

Grounded in the contributions of the endogenous growth theory, this paper tried to offer evidence on the economic and institutional factors that lie behind the cross-country variation in R&D expenditures in the 1980s and 1990s. Closely linked to this subject, we examine the role of government in supplementing private R&D in the presence of market failures. In short, we find that the stylized fact according to which countries devote more resources to R&D when they reach an advanced stage of development is in turn explained by several variables exhibiting high correlation with per capita GDP, such as rule of law, education, and foreign direct investment. The negative correlation of R&D with the investment rate and trade openness (although decreasing as GDP and trade with OECD countries increases) stand out as the more controversial, yet robust, results.

Regarding the role of government, we conclude that, in line with recent theoretical developments, market failures give room to an active participation of governments in the R&D market. However, they do not undo but reinforce the lack of private R&D.

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