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Institute of Economics
Scuola Superiore Sant'Anna

Piazza Martiri della Libertà, 33 - 56127 Pisa, Italy
ph. +39 050 88.33.43
institute.economics@sssup.it

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What's good for the goose ain't good for the gander: cock-eyed counterfactuals and the performance effects of R&D

Alex Coad *
Nanditha Mathew °
Emanuele Pugliese §

* CENTRUM-Catolica Graduate Business School, Lima, Perù
° Institute of Economics, Scuola Sant'Anna, Pisa, Italy, and IBIMET-CNR, Florence, Italy
§ Institute of Complex Systems, CNR, Rome, Italy, and Department of Economics, University of Bath, UK

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What's good for the goose ain't good for the gander: cock-eyed counterfactuals and the performance effects of R&D*

Alex Coad †1, Nanditha Mathew[2,3], and Emanuele Pugliese[4,5]

[1]CENTRUM-Catolica Graduate Business School, Lima
[2]Sant'Anna School of Advanced Studies, Pisa
[3]IBIMET-CNR, Florence
[4]Institute of Complex Systems, CNR, Rome
[5]Department of Economics, University of Bath

Abstract

We investigate the effects of R&D investment on performance outcomes (sales growth and relative profitability) for Indian manufacturing firms. Previous research shows contradictory results - while some studies find a positive effect of R&D on firm performance, some find that firms investing in R&D do not perform significantly better, in some cases, even perform worse than their non-investing counterparts. We claim that the effects of R&D on performance are often mis-specified: The contradictory results are likely due to 1) inverse causality, i.e., firms invest in R&D as a function of sales growth and/or 2) a bias caused by censored data (i.e. R&D investment has a lower bound at zero). We apply endogenous switching regression to tackle the issue of selection and censored data, and the results we observe are sharp: firms investing in R&D would have had less growth and less relative profitability if they had not done so. Interestingly, firms that did not invest in R&D would not have benefited had they done so.

Keywords: R&D investment, Firm performance, Endogenous switching
JEL codes: D22, O32, L25, L6

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† *Corresponding author:* CENTRUM Católica Graduate Business School, Jr. Daniel Alomía Robles 125-129, Urb. Los Álamos de Monterrico, Santiago de Surco, Lima 33, Peru. email:acoad@pucp.edu.pe

1 Introduction

At a macro level there is a general consensus that innovation is the main driver of economic growth, and an important determinant of competitiveness of industries and countries (Dosi, 2007). However, at a micro level - among the firms in developed countries - the evidence is not so clear: the relationship between R&D and firm performance have been investigated by several studies before, but have shown conflicting results - a positive relationship (Hall, 1987; Singh, 1994; Del Monte and Papagni, 2003), no relationship (Geroski, 1995; Geroski et al., 1997; Bottazzi et al., 2001; Stam and Wennberg, 2009) or a negative relationship (Brouwer et al., 1993; Freel and Robson, 2004).

Different solutions have been proposed for the puzzle. While looking at the complex relationship between R&D and firm performance, several studies identified that such a relationship could be specific to some category of firms, or conditional upon a combination of firm characteristics. Quantile regression analyses (Coad and Rao, 2008; Goedhuys and Sleuwaegen, 2010; Hölzl, 2009; Falk, 2012; Mazzucato and Parris, 2015; Capasso et al., 2015; Bianchini et al., 2014; Coad et al., 2016; Santi and Santoleri, 2016) generally find that innovation is only important for fast-growing firms, while for others, R&D investment has no benefits and may even have a negative performance effect. Corsino and Gabriele (2010) suggest that previous difficulties to find a link between innovation and firm growth were due to problems of aggregation, and find significant effects at the business unit level. Demirel and Mazzucato (2012) study the impact of innovation for US pharmaceutical firms and find that a positive impact also depends on several other firm characteristics such as firm size, patenting and persistence in patenting. Taken together, these studies report that not all firms invest in R&D, and moreover they suggest that not all firms should.

We could summarize the previous literature on the performance effects of R&D as finding that, i) although previous work has not reached a consensus that innovation is good for firm performance, ii) nevertheless innovators are very different from non-innovators (Hall et al., 2010; Audretsch et al., 2014). Furthermore, differences between R&D-investors and non-R&D firms according to observed variables can be expected to signal differences in terms of unobserved variables (that the econometrician can never verify). The distinction between non-R&D and R&D-investing firms can be expected to be especially important in our context of firms in a developing country (i.e. India). The irony of the standard econometric approach, however, is that performance benefits from R&D are evaluated by assuming homogeneous effects for innovators and non-innovators, which appears slightly nonsensical. In this article, we emphasize that a non-R&D firm is not a good counterfactual for an R&D firm.

It should be clear, however, that to give policy or strategy indications to firms on the basis of an average effect is sharply in contrast with the observation of heterogeneity: we observe heterogeneous firms, with different capabilities for innovation, and yet one happily assumes that engaging in innovation would have a similar effect on different firms. A non-R&D 'gander' is a poor counterfactual for an R&D-investing 'goose'. In this paper we estimate separately two counter-factual narratives: the effect of investing in R&D for firms that actually decided to do it, and the effect of not investing in R&D for firms that did not. In econometric terminology, we distinguish between the average treatment effect on the treated (ATT), and the average treatment effect on the untreated (ATU), using an endogenous switching model (Maddala et al., 1986; Lokshin and Sajaia, 2004). If the choice to invest in R&D is not exogenous to firm characteristics, standard regression estimates are biased, and the two effects are expected to be very different.

We contribute to the literature by explicitly distinguishing between the benefits of R&D for R&D-investing firms and the benefits of R&D for non-R&D firms. To our knowledge, we are the first to distinguish between the ATT and the ATU, using endogenous switching models,[1] in evaluating the effects of innovation on firm performance (measured in terms of sales growth and financial performance). Previous work has usually implicitly assumed that the benefits of R&D are the same for innovators and non-innovators alike. The selection bias involved has been often ignored in the literature (Hall et al., 2010). The most notable exception is the literature stemming from Crépon et al. (1998) that attempted to properly estimate the elasticity of additional R&D and patenting by addressing the selection bias involved within a multi-equation setup. Even this latter literature, however, eventually falls back on computing the effect of innovation activities on performance as an average effect for all firms.

Our results robustly show that the ATU is not significant, while the ATT is positive and significant. In other words, non-R&D 'ganders' should not be encouraged to invest in R&D, while R&D-investing 'geese' are doing the right thing. The implications for policy are obvious: just because it may be worthwhile to encourage R&D-investing firms to engage further in R&D, nevertheless it could be a waste of money to encourage randomly-selected non-innovators to invest in R&D.

The paper proceeds as follows. Section 2 describes our data, Section 3 presents our methodology and contains the results, and Section 4 concludes.

2 Data and description of variables

Although the majority of research into determinants and outcomes of firm innovation has focused on rich industrialised countries (Crowley and McCann, 2017), we focus on a developing country context. We analyse the PROWESS database, provided by the Centre for Monitoring the Indian Economy (CMIE). The data covers both public listed and unlisted firms. The main source of this database is

[1] Some recent papers have applied endogenous switching models to contexts of the economics of innovation. Horbach and Rennings (2013) address the debate surrounding whether new environmental technologies are 'job-killers', and apply an endogenous switching model to investigate how environmental innovation affects employment growth, using German Community Innovation Survey data. Similarly, Kunapatarawong and Martínez-Ros (2016) apply a switching model to the case of how green innovation affects employment growth, where non-innovative firms are not observed. Gkypali and Tsekouras (2015) investigate whether R&D-investing firms decide to export, and the effects this has on their productivity. Sapio (2015) applies a switching model to investigate possible congestion effects of renewable energy production. Crowley and McCann (2017) build on the CDM model (Crépon et al., 1998) and employ an endogenous switching model within a production function approach to investigate the effects of innovative activity on productivity, distinguishing between transition- and innovation-driven European economies. However, to our knowledge, we are the first to apply endogenous switching models to the case of R&D investment and firm performance, where we distinguish between the performance effects – in terms of sales growth and financial performance – for R&D investors compared to non-R&D firms.

annual reports of companies, which include balance sheets and profit and loss accounts. Even though Prowess do not cover the universe of all firms, it is the most comprehensive database available on Indian firms. The companies covered account for around 70 percent of industrial output, 75 percent of corporate taxes, and more than 95 percent of excise taxes collected by the Government of India. In the present study we use data on firms in the manufacturing sector and the time period is from 1990 to 2013. Previous studies on this same database include Topalova and Khandelwal (2011) and Goldberg et al. (2010).

We use a binary variable to proxy firms' innovativeness that takes value 1 if the firm invested in R&D and 0 otherwise. Indeed among Indian firms, most of the heterogeneity in R&D activities is related simply to the presence of formal R&D activities in the firm. To analyze the effect of patenting or R&D intensity would not capture the core of the signal. In particular we do not expect patenting to play any role. As pointed out by Cohen and Levinthal (1990) and Volberda et al. (2010), R&D has two different purposes: i) the production of new knowledge and ii) the development of the firm's absorptive capacity, i.e. the ability of the firm in using knowledge developed elsewhere. In a developing country we expect that most of the utility for the firm comes from the development of its absorptive capacity, while patenting activities only proxy the production of original information. Therefore, the presence of an R&D department is a crucial distinction between innovative and not innovative firms. Our binary variable for R&D reflects a focus on the decision to invest in R&D, rather than the amount. In any case, endogenous switching regression (Lokshin and Sajaia, 2004) requires a binary switching variable.

To investigate the effect of R&D spending of firms on firm performance, we look at two dimensions of performance – firm growth and relative firm profitability. Here, we will not look at the intermediate structural channels between R&D and different measures of firm performance, like the relation with measures of productivity, but only at the final variable of interest for the firm, the intensive and extensive margin of profit. This is because the links between productivity, profitability and growth are not trivial (Dosi et al., 2015) and not of interest in this analysis. Table 1 provides details of variables, their definitions and summary statistics. Table 2 shows some summary statistics for firms belonging to the two groups - those that invest in R&D and those that do not. Looking at the variables of interest, there are differences between the firms that invest in R&D and others, motivating further our careful econometric estimation. Figure 1 illustrates the differences between R&D-investors and non-R&D firms, in terms of the variables size and age. R&D investing firms are visibly older and larger than their non-R&D counterparts.

Notice that, in the total sample, about one-quarter of the firms engage in R&D activities. This hints that there might be more heterogeneity between R&D-investors and non-R&D firms, than within the category of R&D-investing firms. To assume that the benefits of innovative activity are the same across all firms, when 76% of firms do not invest in any R&D, should raise some econometricians' bushy eyebrows.

As a further description of the data, table 3 reports the annual transition matrix, describing the number and share of firms that switch their R&D activities on and off. We can see, unsurprisingly,

Table 1: Variables, definition and summary statistics

Variable	Definition	Mean	Median	Std. Dev
Firm Growth	Log difference in sales between *t* & *t-1*	0.098	0.101	0.328
Relative profitability	Profits over sales, relative to the sector mean	-0.001	-0.023	0.068
Profitability Growth	Log difference in profitability between *t* & *t-1*	-0.002	0	0.048
Sales	Total sales from industrial goods	3484.735	462.350	46641.830
Age	Number of years since the year of incorporation of firm	23.119	19	15.569
Investment Intensity	Additions to gross fixed assets/Sales	.072	.029	.118
Leverage	Borrowings/Total Assets	0.627	0.388	4.021
Cash in hand	Amount of cash available with the firm after payment of all expenses	4.261	0.400	64.079
Export Dummy	Takes value 1 if the firm exported and 0 otherwise	0.646	1	0.478
R&D Dummy	Takes value 1 if the firm invests in R&D and 0 otherwise	0.220	0	0.414

Table 2: Comparison of the summary statistics for firms investing or not investing in R&D.

	R&D		Without R&D		
Variable	Mean	Std. Dev	Mean	Std. Dev	T-test p-values
Firm Growth	0.098	0.345	0.096	0.264	0.347
Relative profitability	-0.002	0.067	-0.000	0.071	0.027
Profitability Growth	-0.002	0.048	-0.004	0.048	0.015
Size	1116.542	3870.768	10861.25	93988.87	0.000
Age	20.981	14.373	30.659	17.197	0.000
Investment Intensity	0.070	0.120	0.075	0.114	0.006
Leverage	0.693	4.527	0.394	0.873	0.000
Cash in hand	2.151	22.069	10.902	124.263	0.000
Export Dummy	0.563	0.495	0.868	0.337	0.000
Number of firms	1273		4798		

Note: The T-test refers to the null hypothesis that the two populations have the same mean.

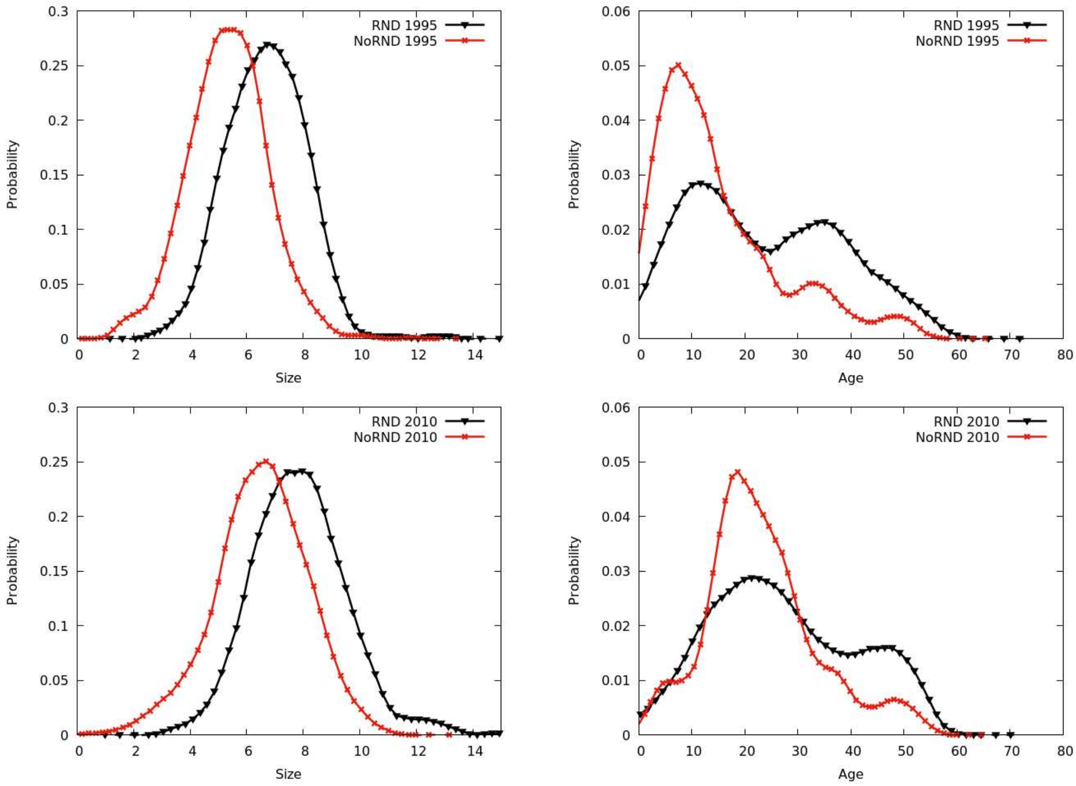
that the R&D activities are quite persistent: the values on the main diagonal are rather high.

Table 3: Transition matrix of firms engaging in R&D over the whole time period (1995-2013)

t	t+1		
	0	1	Total
0	24,400	905	25,305
	(96.42)	(3.58)	(100.00)
1	265	6,974	7,239
	(3.66)	(96.34)	(100.00)
Total	24,665	7,879	32,544
	(75.79)	(24.21)	(100.00)

Note. Absolute and relative (in brackets) frequencies. 1 and 0 represent the status of engaging in R&D or not.

Figure 1: Distributions of size and age for R&D vs non-R&D firms



3 R&D and firm performance

3.1 Standard regressions

Our baseline equation will be:

$$FirmGrowth_{i,t} = \alpha + \beta 1\, Size_{i,t-1} + \beta 2\, R\&D_{i,t-1} + \beta 3\, Age_{i,t-1} + \beta 4\, PftGr_{i,t-1} + \beta 5\, Cash_{i,t-1} + \beta 6\, Invest_{i,t-1} + \beta 7\, Expdum_{i,t-1} + \beta 8\, Leverage_{i,t-1} + Controls_{i,t} + \epsilon_{i,t} \quad (1)$$

The dependent variable in equation 1 is firm growth, defined as the log difference of total sales of firm i between years t and $t-1$ (Törnqvist et al., 1985; Coad, 2009). Among the independent variables, the variable of interest is the presence of R&D in the firm. Other variables include size of the firm (measured by log sales), log of cash flow, investment intensity, leverage, export dummy and controls. Notice also that for size and age we control for a non-linear relationship by adding a quadratic term. The controls include ownership,[2] year and sector (2-digit industry) dummies. For the definition of the variables, please refer to table 1.

A variant of Equation (1) is also estimated with relative profitability as a dependent variable:

$$\begin{aligned} RelProfitability_{i,t} = \alpha + \beta 1\, Size_{i,t-1} + \beta 2\, R\&D_{i,t-1} + \beta 3\, Age_{i,t-1} + \beta 4\, PftGr_{i,t-1} + \beta 5\, Cash_{i,t-1} \\ + \beta 6\, Invest_{i,t-1} + \beta 7\, Expdum_{i,t-1} + \beta 8\, Leverage_{i,t-1} + Controls_{i,t} + \epsilon_{i,t} \end{aligned} \tag{2}$$

As a baseline test, we perform an OLS and Fixed Effect estimation and the results are presented in table 4. The first two columns present the results with firm growth as an independent variable - column I shows the results using an OLS estimation and column II shows the results using fixed effects estimation. Similar to the first two columns, the third and the fourth column presents the results with profitability as a dependent variable.

The results concerning the relationship between R&D and firm performance are, as expected from previous literature on Indian firms (Mathew, 2017), underwhelming. As seen in bold in table 4, the R&D dummy does not have any significant effect on firm growth and has significant negative effects on relative profitability.

3.2 Which firms invest in R&D?

We will now look in detail if firms that invest in R&D and those that do not are inherently different. We will see in particular how the discrete choice to invest in R&D for a firm is forecasted using a simple Probit model. We estimate the following equation:

$$\begin{aligned} P(D_{R\&D_{it}} = 1) = \phi(\beta 1\, Size_{i,t-1} + \beta 2\, Age_{i,t-1} + \beta 3\, PftGr_{i,t-1} + \beta 4\, Cash_{i,t-1} \\ + \beta 5\, Invest_{i,t-1} + \beta 6\, Expdum_{i,t-1} + \beta 7\, Leverage_{i,t-1} + \epsilon_i + d_t + e_{it}) \end{aligned} \tag{3}$$

where ϕ is the Cumulative Distribution Function (CDF) of the standard normal distribution.

The independent variables are the same as defined before. We also include robustness checks by estimating a random effects probit model as well as an OLS LPM (linear probability model) (Angrist and Pischke, 2008) which are reported in table 5. In the table, column 1 shows the results of the estimation while employing a Probit model, column 2, the results from a random effects probit estimation, and column 3 from an OLS LPM.

[2] Ownership dummies include four categories, namely, private-owned, foreign-owned, joint-owned and public-owned. The omitted baseline dummy is domestic private-owned firms.

Table 4: **R&D activities and firm performance: OLS and Fixed effects**

	(1)	(2)	(3)	(4)
	I	II	III	IV
Log Sales (t-1)	-0.0361***	-0.3915***	0.0122***	0.0203***
	(5.27)	(24.06)	(4.44)	(3.94)
Squared Log of Sales (t-1)	0.0025***	0.0121***	-0.0006***	-0.0011***
	(5.23)	(10.87)	(2.99)	(3.04)
Log Age (t-1)	-0.0610***	-0.1450***	0.0197***	0.0042
	(3.52)	(3.53)	(3.02)	(0.33)
Squared Log of Age (t-1)	0.0029	0.0352***	-0.0053***	-0.0126***
	(0.98)	(3.23)	(4.77)	(3.69)
Investment Intensity (t-1)	-0.0345***	-0.1442***	0.0132***	-0.0102***
	(15.59)	(32.86)	(15.26)	(7.17)
Profitability Growth (t-1)	0.6994***	0.4720***	0.3273***	0.2800***
	(18.12)	(13.19)	(22.90)	(26.20)
Export Dummy (t-1)	0.0279***	0.0033	0.0065***	-0.0038*
	(6.22)	(0.47)	(3.80)	(1.78)
Log Leverage (t-1)	0.0043**	0.0149***	-0.0136***	-0.0020**
	(2.25)	(5.17)	(17.92)	(2.14)
Cash Balance (t-1)	0.0024*	0.0069***	0.0000	-0.0008
	(1.93)	(3.83)	(0.03)	(1.47)
R&D Dummy (t-1)	**0.0016**	**0.0068**	**-0.0045*****	**-0.0048****
	(0.33)	**(0.87)**	**(2.58)**	**(2.03)**
Foreign-Owned	0.0098		-0.0098***	
	(1.27)		(3.31)	
Public-Private	-0.0076		0.0106	
	(0.34)		(1.22)	
Public-Owned	-0.0407***		-0.0204***	
	(3.24)		(4.01)	
Sector dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Observations	16693	16693	13137	13137
R^2	0.092	0.222	0.121	0.127
Pseudo R^2				
firm clusters		3074		2630

t statistics (in absolute values) in parentheses
Constant term included in the regression but not reported here.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Column I - OLS with firm growth, Column II - Fixed effects with firm growth, Column III - OLS with profitability, Column IV - Fixed effects with profitability

Table 5: **Determinants of R&D activities**

	(1) I	(2) II	(3) III
Log Sales (t-1)	0.3761***	0.5563***	0.0464***
	(7.31)	(3.31)	(5.71)
Squared Log of Sales (t-1)	-0.0078**	0.0136	0.0019***
	(2.19)	(1.15)	(3.22)
Log Age (t-1)	-0.3609***	-0.9329***	-0.1328***
	(3.48)	(3.00)	(4.94)
Squared Log of Age (t-1)	0.1215***	0.3308***	0.0405***
	(6.93)	(5.69)	(8.61)
Investment Intensity (t-1)	0.1284***	0.1745***	0.0331***
	(9.62)	(4.33)	(10.26)
Profitability Growth (t-1)	0.1081	0.4576	0.0477
	(0.47)	(1.09)	(0.75)
Export Dummy (t-1)	0.5605***	0.5186***	0.1277***
	(19.70)	(6.73)	(19.98)
Log Leverage (t-1)	-0.1419***	-0.1322***	-0.0404***
	(12.47)	(4.39)	(12.72)
Cash Balance (t-1)	0.0177**	0.0251	0.0079***
	(2.50)	(1.39)	(3.79)
Foreign-Owned	0.1705***	1.0098***	0.0749***
	(4.07)	(4.11)	(5.39)
Public-Private	0.1287	0.1477	0.0515
	(0.97)	(0.18)	(1.39)
Public-Owned	0.2809***	0.1770	0.0506**
	(4.01)	(0.48)	(2.31)
Sector dummies	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes
Observations	18004	18004	18004
R^2			0.268
Pseudo R^2	0.243	0.478	
firm clusters		3316	

t statistics (in absolute values) in parentheses
Constant term included in the regression but not reported here.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Column I - Probit, Column II - Random effects Probit,
Column III - Linear Probability Model

Comparing table 5 with table 4, we observe that many characteristics that are significantly related to the decision to undertake R&D activities are also significantly related to firm performance. We observe that firms performing R&D are significantly different from others in most of the firm characteristics we observe - they are bigger, younger, exporters, with high capital investments and low leverage. From such a comparison, we expect that the effects of R&D on performance could be commonly mis-specified: while firms investing in R&D often do not perform significantly better than others in many respects – or they even perform significantly worse than others – it is also conceivable that there may be reverse causality (e.g. if firms invest in R&D because of pressure from fierce competition, for example according to the failure-inducement model of R&D investment in Antonelli (1989) and Antonelli and Scellato (2011). In other words, analysis studying the effect on performance of R&D, suffer indeed from a censoring issue: no matter how far away they are from spending their first rupees on R&D, firms do not have negative amounts of R&D investment. In the following sub-section, we elucidate how to deal with such censoring.

3.3 Dealing with censored data

The standard way of dealing with this kind of econometric issue is the Heckman's treatment effect. We estimate at the same time, through Full Information Maximum Likelihood (FIML), two equations: i) the probability that a firm engages in R&D activities, and, ii) the effect of R&D on performance. In this way, we remove the censoring issue and obtain an unbiased estimate of the correlation between performance and R&D. The coefficient represents an unbiased effect of R&D on performance for a random firm.[3]

We need an exclusion restriction (Puhani, 2000), a variable which affects the selection equation but does not affect performance if not through R&D. A commonly used exclusion restriction (Campa and Kedia, 2002) in the empirical literature is the status of firms in the same sector: if other firms in the same sector invest in R&D, it is more likely that the firm under analysis will invest in R&D too, since there may be common routines, processes, knowledge bases and technological opportunities for firms in the same sector (Malerba, 2002).

However, for a variable to be considered as a candidate to be an exclusion restriction, it should not directly affect the dependent variable - firm performance. In our case, if we consider the R&D status of other firms in the same sector as the exclusion variable, it obviously affects firm performance through competition. If, for example, firms invest in R&D when they are forced to, due to fierce competition in the sector, other firms in the same sector investing in R&D would be signaling the same. Therefore we use as our exclusion restriction the share of firms investing in R&D among the firms in the same 4 digit sector (to ensure some common technical routines) but in a different 5 digit sector (to ensure that there is no direct competition). In the following, we call this variable NOFRND.

[3]While a causal interpretation to the results of Heckman estimates is sometimes ventured, we are uneasy with this (e.g. in case there are unobserved confounding variables), and prefer to be cautious in attributing a causal interpretation to our regression estimates.

The results are shown in table 6. The first two columns are related to the firm growth equations and the last two columns to firm profitability. The first and the third column shows the results from the performance equations, while the second and the fourth columns are the results from the selection equations. Our variable of interest, the R&D dummy, is presented in bold. Here, we observe different results with respect to table 4: the effect of R&D on relative profitability that was previously negative is now not significant, while the effect on firm growth that was not significant is now significantly positive.

3.4 Endogenous Switching Regression

Heckman's treatment effect gives the unbiased average effect of investing in R&D for a randomly-selected firm. If, however, our narrative involves endogeneity, i.e. if we are assuming that firms investing in R&D are not randomly-selected firms, we cannot consider that the effect of investing in R&D is the same for all firms. Indeed, although table 6 shows that the choice to invest in R&D does not have an effect on a randomly-selected firm's relative profitability on average, there may well be positive effects for the subset of R&D-investing firms. Indeed, if we assume that firms' choices are better than random, this should be not only possible, but even expected: the firms that invest in R&D are the firms that will gain more out of it. Firms' choice of investing in R&D should be related to the different effect of R&D investment on firm performance in different contexts. The average effect on a random firm is not informative in this case of the effect of investing in R&D for a specific firm. We therefore apply Endogenous Switching Regression (Maddala et al., 1986; Lokshin and Sajaia, 2004), which features a latent variable to determine which firms invest in R&D, as well as 2 equations representing different regimes for R&D investors vs non-R&D firms.

$$RD_{it} = \begin{cases} 1 & \text{if} \quad \gamma Z_{it} + \mu_{it} > 0, \\ 0 & \text{if} \quad \gamma Z_{it} + \mu_{it} \leq 0. \end{cases} \tag{4}$$

$$Regime \quad 1: \quad y_{1it} = \beta_1 X_{1it} + \epsilon_{1it}, \quad if \quad RD_{it} = 1 \tag{5}$$

$$Regime \quad 2: \quad y_{2it} = \beta_2 X_{2it} + \epsilon_{2it}, \quad if \quad RD_{it} = 0 \tag{6}$$

Firms therefore face two regimes, depending on their values of RD (i.e. whether or not they invest in R&D). Endogenous switching regressions allow for a correlation between the decision to invest in R&D and the performance effects of R&D, which might arise if firms have time-varying innovative capabilities that influence their ability to benefit from R&D investment (Cohen and Klepper, 1992). Furthermore, firms may endogenously switch between regimes over time, depending on the set of explanatory variables Z. In the special case where the performance equation for regime 2 (when RD_i=0) were unobserved, we would be in the context of a classic Heckman (1979) selection equation. Different sets of explanatory variables can be entered into X_1 and X_2 for the two regimes. Furthermore, the sets of explanatory variables X and Z are allowed to overlap (Maddala et al.,

Table 6: **R&D activities and firm performance: Heckman Treatment Effect**

	Firm Growth	Selection	Rel. Profitability	Selection
Log Sales (t-1)	-0.017	0.322*	-0.007	0.243
	(0.74)	(1.84)	(0.56)	(1.25)
Squared Log of Sales (t-1)	-0.000	-0.003	0.000	0.002
	(0.13)	(0.22)	(0.24)	(0.14)
Log Age (t-1)	-0.045	-0.352	0.026	-0.282
	(0.92)	(1.16)	(1.31)	(0.79)
Squared Log of Age (t-1)	-0.007	0.126**	-0.009**	0.121*
	(0.77)	(2.33)	(2.32)	(1.90)
Investment Intensity (t-1)	-0.042***	0.042	0.011***	0.092*
	(6.04)	(1.03)	(3.31)	(1.74)
Profitability Growth (t-1)	0.714***	1.003**	0.001	2.336*
	(6.07)	(2.10)	(0.00)	(1.88)
Export Dummy (t-1)	0.017	0.457***	-0.002	0.427***
	(1.08)	(5.31)	(0.29)	(4.67)
Log Leverage (t-1)	0.016***	-0.156***	-0.003	-0.208***
	(2.67)	(3.85)	(1.10)	(3.97)
Cash Balance (t-1)	0.004	0.014	-0.002	0.028
	(1.26)	(0.58)	(0.92)	(1.04)
Foreign-Owned	0.001	-0.046	-0.016	0.138
	(0.04)	(0.28)	(1.54)	(0.77)
Public-Private	-0.053	0.144	0.019	0.092
	(1.00)	(0.38)	(1.04)	(0.24)
Public-Owned	-0.018	-0.299	0.030	-0.296
	(0.62)	(1.39)	(1.38)	(1.02)
R&D Dummy (t-1)	0.245***		0.101***	
	(5.60)		(3.36)	
NOFRND		1.083***		1.280**
		(2.59)		(2.57)
Rho	-0.550***		-0.655***	
	(6.707)		(4.612)	
Sector Dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

t statistics (in absolute values) in parentheses

1986), even if the exclusion restriction requires that there is at least one variable in Z that is not in X_1 and X_2 (Puhani, 2000).

The dependent variables y_{ji} ($j = 1, 2$) correspond to firm performance (either sales growth or relative profitability) in the two regimes. β_1, β_2 and γ are vectors of parameters, that are jointly estimated (instead of being estimated via a two-step procedure) using a Full Information Maximum Likelihood (FIML) method. This provides us with an efficient method to compute the counterfactuals in order to calculate the effect of investing in R&D for firms that actually did R&D (i.e. the Average Treatment effect on the Treated, the ATT), and the effects of R&D investment for those that did not (i.e. the Average Treatment effect on the Untreated, the ATU).

Our endogenous switching regression assumes that the residuals from the three models, μ_i, ϵ_{1i} and ϵ_{2i} follow a trivariate normal distribution, with the mean vector zero, and the following covariance matrix (Lokshin and Sajaia, 2004):

$$\Omega = \begin{bmatrix} \sigma_\mu^2 & \sigma_{1\mu} & \sigma_{2\mu} \\ \sigma_{1\mu} & \sigma_1^2 & . \\ \sigma_{2\mu} & . & \sigma_2^2 \end{bmatrix}$$

Where σ_μ^2, σ_1^2 and σ_2^2 are the variances of the error terms coming from the selection equation and the two regime equations, respectively. Note that the covariance between ϵ_{1i} and ϵ_{2i} is not defined, because y_{1i} and y_{2i} are never simultaneously observed (i.e. a firm cannot simultaneously be an R&D-investing firm and a non-R&D firm). If $\sigma_{1\mu}$ and $\sigma_{2\mu}$ are equal to zero, then the relationship between a firm's decision to invest in R&D and the firm's performance due to R&D are exogenous. However, if $\sigma_{1\mu}$ and $\sigma_{2\mu}$ are different from zero, then we have an endogenous switching model (Maddala et al., 1986, p1635) whereby the decision to invest in R&D is endogenous to the performance effects of R&D investment.

Treatment effects of the R&D status of the firm are estimated using the regression output, by looking at the counterfactual cases in which an R&D-investing 'goose' is compared to other geese, and a non-R&D 'gander' is compared to other ganders. This allows to have two different effects, separately: i) the average change in performance of a firm performing R&D with respect to the hypothetical case where the firm does not invest in R&D (Average Treatment Effect on the Treated, ATT); ii) the performance of a firm which do not invest in R&D with respect to the hypothetical case in which it had performed R&D (Average Treatment Effect on the Untreated, ATU). Although the standard approach in the literature has been to implicitly assume that ATT=ATU, we challenge this assumption. The Average Treatment effects for the Treated (ATT) and Untreated (ATU) do not appear as standard 'movestay' regression output (Lokshin and Sajaia, 2004), although we compute them in a similar way to Crowley and McCann (2017).

Our endogenous switching results, which are our main results and our preferred specifications, are reported in table 7. The first three columns relate to firm growth, while the last three to firm profitability. Columns three and six gives the results from the selection equation (eq 4); columns 1 and 2 present results for the estimation of equations 5 and 6 for firm growth; similarly columns

Table 7: **R&D activities and firm performance: Endogenous Switching Regression**

	F.Growth Without R&D	F.Growth With R&D	Selection	Rel. Profit Without R&D	Rel. Profit With R&D	Selection
Log Sales (t-1)	-0.012	0.008	0.413**	0.016	-0.036**	0.182
	(0.34)	(0.29)	(2.41)	(0.91)	(1.96)	(0.92)
Squared Log of Sales (t-1)	-0.001	-0.000	-0.009	-0.002	0.002**	0.007
	(0.34)	(0.26)	(0.75)	(1.24)	(2.03)	(0.46)
Log Age (t-1)	-0.057	0.017	-0.418	0.027	0.011	-0.261
	(1.01)	(0.30)	(1.40)	(1.10)	(0.28)	(0.79)
Squared Log of Age (t-1)	-0.005	-0.010	0.131**	-0.009**	-0.005	0.118**
	(0.50)	(1.01)	(2.46)	(2.07)	(0.81)	(2.00)
Investment Intensity (t-1)	-0.047***	-0.041***	0.079**	0.009***	0.009*	0.052
	(5.61)	(4.69)	(1.96)	(2.60)	(1.73)	(1.03)
Profitability Growth (t-1)	0.638***	0.910***	1.082**	-0.112	0.275***	2.161**
	(4.22)	(5.59)	(2.27)	(0.66)	(4.99)	(1.97)
Export Dummy (t-1)	0.022	0.030	0.431***	-0.010	0.014	0.391***
	(1.29)	(1.56)	(5.13)	(1.27)	(1.60)	(4.47)
Log Leverage (t-1)	0.009	0.014**	-0.157***	0.001	-0.006**	-0.175***
	(1.22)	(2.00)	(3.88)	(0.27)	(2.01)	(3.60)
Cash Balance (t-1)	0.004	0.006**	0.017	-0.004*	0.002	0.026
	(0.83)	(2.30)	(0.73)	(1.73)	(1.11)	(0.97)
Foreign-Owned	-0.020	0.020	0.020	-0.019	-0.012	0.142
	(0.69)	(1.30)	(0.12)	(1.23)	(1.10)	(0.80)
Public-Private	-0.174	-0.002	0.349	0.002	0.032	0.322
	(1.09)	(0.09)	(0.72)	(0.08)	(1.38)	(0.75)
Public-Owned	-0.064	-0.014	-0.096	-0.001	0.068	-0.343
	(1.45)	(0.63)	(0.40)	(0.08)	(1.59)	(1.31)
NOFRND (t-1)			1.221***			0.817*
			(3.06)			(1.71)
Rho	-0.608***	0.019		-0.876***	-0.150	
	(8.000)	(0.377)		(17.52)	(1.562)	
Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
ATT		0.289***			0.146***	
		(5.254)			(3.476)	
ATU	-0.005			0.020		
	(0.100)			(0.444)		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

t statistics (in absolute values) in parentheses

4 and 5 for profitability. Notice how the shocks related to the performance equation for firms not investing in R&D and to the selection equation are significantly negatively correlated (value of Rho in column 1 and 4), justifying the usage of this econometric technique. Results show that indeed the effect of R&D on firm performance are different according to the context in which the choice is taken: the effect on a random firm is not informative. If a firm that did not invest in R&D, had instead invested in R&D, it would not have had any effect. However, firms that decided to invest in R&D achieved both higher firm growth (around 29% more) and a higher profit margin (around 15% more) by doing so. We also perform robustness analysis using time lags for two and three years and obtain similar results (see Appendix A).

The evidence we find tells a sharp narrative: firms investing in R&D would have had less growth and less relative profitability if they had not done so. However, firms that did not invest in R&D would not have had better performance if they had done so. Indeed, this is what we might expect, if firms have access to detailed information about their circumstances that remains unobserved to the econometrician.

4 Conclusions and Implications

We investigated the relationship between R&D spending of Indian firms and its effects on sales growth and profitability. We employed a refined econometric method to study such relationship, thereby taking into consideration the inherent differences between firms that invest in R&D and those that do not. We find that firms that invest in R&D and others differ significantly in terms of several observed firm characteristics. Once we control for such self-selection bias, i.e. self-selection of a group of firms into R&D investment, we are able to begin a causal interpretation of the results: firms investing in R&D would have had less growth and less relative profitability if they had not. However, an interesting finding is that firms that did not invest in R&D would not have had better performance if they had done so. Some broad implications of our findings can be mentioned. First, we provide an explanation why previous work has encountered difficulties in finding performance benefits of innovative activity. Second, we show that, even if policymakers observe performance benefits of innovative activity among innovative firms, nevertheless this should not be taken to imply that there might be any benefits from encouraging non-innovative firms to invest in R&D. R&D investment is not for everyone. Third, we observe that firms investing in R&D are making a rational decision (because the ATT is positive), and that firms that are not investing in R&D are also making a rational decision (because the ATU =0). This should remind the econometrician that firms are not as irrational as we might sometimes think, and that their decisions are based on much more information than is included in standard econometric specifications.

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A Time lags and long run effects

The time lags between R&D investment and the associated economic benefits are worth investigating (Kafouros and Wang, 2008). The effects of R&D on firm performance could well unfold over a longer time scale than we have thus far investigated, although it is also plausible that initial gains could be lost by a reversion to the mean in the years after R&D investment. Of course each further year reduces the sample, and hence, we are limited in our analysis: we will only look at the effects of R&D activities after two or three years. For each lag, we will perform Endogenous Switching Models, to ensure the robustness of the results.[4] The effect of investing in R&D seems to be still significant and positive two and three years later, even if the statistical significance slowly fades. There is clearly not a reversion to the mean: firms investing in R&D grow more the next year and also the following years. The overall long-run effect on growth of investing in R&D is therefore likely underestimated in the current analysis. This is however only a very preliminary analysis of longer-term effects. A more refined identification strategy, able to address the high statistical persistence of time series data on R&D levels, would be necessary if one wished to make claims on long run effects of R&D. Such an investigation is beyond the scope of this paper.

[4]We also performed Heckman's treatment effect model and the results are as expected: the coefficient of R&D lies in between ATT and ATU (reported in tables 8 and 9) in each case.

Table 8: **R&D activities and firm performance: Endogenous Switching Regression - Time lag of 2 years**

	F.Growth Without R&D	F.Growth With R&D	Selection	Rel. Profit Without R&D	Rel. Profit With R&D	Selection
Log Sales (t-1)	0.024	0.003	0.285	0.005	-0.033*	0.093
	(0.88)	(0.10)	(1.62)	(0.32)	(1.66)	(0.45)
Squared Log of Sales (t-1)	-0.002	0.000	-0.001	-0.001	0.002*	0.013
	(0.94)	(0.21)	(0.05)	(0.63)	(1.79)	(0.86)
Log Age (t-1)	-0.034	0.060	-0.616*	0.024	0.015	-0.142
	(0.72)	(0.98)	(1.83)	(1.07)	(0.41)	(0.40)
Squared Log of Age (t-1)	-0.004	-0.014	0.167***	-0.008*	-0.006	0.094
	(0.49)	(1.41)	(2.83)	(1.85)	(0.90)	(1.50)
Investment Intensity (t-1)	0.022***	0.024***	0.108**	0.006	0.011*	0.076
	(2.99)	(2.82)	(2.50)	(1.59)	(1.82)	(1.29)
Profitability Growth (t-1)	0.228*	0.412*	0.941**	0.006	0.211***	1.615**
	(1.76)	(1.94)	(2.13)	(0.11)	(3.41)	(2.56)
Export Dummy (t-1)	0.010	-0.000	0.385***	-0.005	0.010	0.400***
	(0.68)	(0.00)	(4.54)	(0.69)	(1.02)	(4.19)
Log Leverage (t-1)	0.003	0.004	-0.161***	-0.000	-0.007**	-0.170***
	(0.32)	(0.63)	(3.62)	(0.07)	(2.13)	(3.31)
Cash Balance (t-1)	-0.001	-0.002	0.016	-0.003	0.002	0.013
	(0.29)	(0.80)	(0.65)	(1.55)	(0.93)	(0.47)
Foreign-Owned	-0.010	0.014	0.022	-0.016	-0.020*	0.137
	(0.38)	(0.82)	(0.12)	(1.16)	(1.83)	(0.77)
Public-Private	-0.110***	-0.053	0.492	0.011	-0.002	0.008
	(2.85)	(1.17)	(0.88)	(0.53)	(0.12)	(0.01)
Public-Owned	0.017	-0.015	-0.120	-0.013	0.065	-0.093
	(0.53)	(0.55)	(0.48)	(0.62)	(1.19)	(0.30)
NOFRND (t-1)			1.529***			1.222***
			(3.84)			(2.64)
Rho	-0.283***	-0.043		-0.766***	-0.275**	
	(2.596)	(0.671)		(10.078)	(2.27)	
Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
ATT		0.120***			0.110***	
		(3.243)			(3.055)	
ATU	0.114***			0.035		
	(3.257)			(1.060)		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, t statistics (in absolute values) in parentheses

Table 9: **R&D activities and firm performance: Endogenous Switching Regression - Time lag of 3 years**

	F.Growth Without R&D	F.Growth With R&D	Selection	Rel. Profit Without R&D	Rel. Profit With R&D	Selection
Log Sales (t-1)	0.057*	-0.010	0.285	0.021	0.031	-0.084
	(1.88)	(0.35)	(1.51)	(0.96)	(1.18)	(0.39)
Squared Log of Sales (t-1)	-0.005**	0.001	-0.001	-0.002	-0.001	0.024
	(2.31)	(0.68)	(0.06)	(1.34)	(0.39)	(1.52)
Log Age (t-1)	-0.010	-0.043	-0.621*	-0.002	-0.016	0.072
	(0.18)	(0.52)	(1.82)	(0.09)	(0.33)	(0.20)
Squared Log of Age (t-1)	-0.008	0.004	0.171***	-0.003	0.004	0.048
	(0.78)	(0.30)	(2.85)	(0.69)	(0.54)	(0.75)
Investment Intensity (t-1)	0.003	0.006	0.114**	0.003	0.019**	0.122**
	(0.37)	(0.59)	(2.54)	(0.57)	(2.53)	(2.07)
Profitability Growth (t-1)	-0.147	-0.158	1.335***	-0.008	0.151	1.117
	(0.98)	(1.26)	(2.67)	(0.12)	(1.45)	(1.55)
Export Dummy (t-1)	0.009	0.075***	0.393***	-0.006	0.033***	0.328***
	(0.57)	(3.01)	(4.28)	(0.73)	(2.67)	(3.51)
Log Leverage (t-1)	-0.005	-0.001	-0.166***	0.001	-0.021***	-0.158***
	(0.59)	(0.23)	(3.40)	(0.23)	(4.11)	(3.24)
Cash Balance (t-1)	-0.007	0.002	0.020	-0.004*	0.004	0.027
	(1.64)	(0.52)	(0.76)	(1.65)	(1.62)	(0.98)
Foreign-Owned	0.036	0.024	0.022	-0.011	-0.011	0.161
	(1.45)	(1.43)	(0.12)	(0.69)	(0.80)	(1.00)
Public-Private	-0.025	-0.040	0.530	-0.092**	0.049	0.294
	(0.41)	(0.99)	(0.92)	(2.51)	(1.24)	(0.55)
Public-Owned	-0.028	0.019	-0.152	-0.027	0.028	0.167
	(0.75)	(0.69)	(0.59)	(0.84)	(0.48)	(0.45)
NOFRND (t-1)			1.478***			0.958***
			(3.45)			(2.68)
Rho	-0.475***	0.100		-0.886***	0.905***	
	(5.219)	(0.909)		(25.314)	(22.625)	
Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
ATT		0.222*			0.143***	
		(1.656)			(4.205)	
ATU	-0.059			-0.184***		
	(1.017)			(5.411)		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

t statistics (in absolute values) in parentheses