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## EXTENDED ABSTRACT

**Title: Does investment in R&D have long-run effects on productivity? An analysis of the Spanish regions.**

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**Abstract:** For more than 2500 years innovation was understood as something “evil”. This concept, whose origin dates to Ancient Greece, was strongly influenced by the opinion of some philosophers of the time who considered it as something malicious that wanted to break with the established order (Castro y Fernández, 2013). At the present, the concept of innovation has radically changed. It is synonymous of novelty, advancement, discovery, all of them words that have a great positive connotation. There is a consensus that “*innovative performance is a crucial factor in determining competitiveness and national progress.*” (OECD, 2007). Actually, it is understood as a magic word that seems to be the solution for all socioeconomic problems (Godin, 2015).

During the history, classical and neoclassical economists had discussed which role plays innovation or technological change in the economic development. For the majority, it was understood as a key factor for economic growth, but it was not until the 1950s when the interest of understanding the role of innovation in the economy increased. In 1957, the

macroeconomist Robert Solow manages to show that economic development is not only due to the growth of the productive factors, capital, and labor. He showed that there is a part of growth that was unexplained and corresponds to technical progress (Solow, 1957). He considered at first this variable as exogenous but, at the present “*economic growth is an endogenous outcome of an economic system, not the result of forces that impinge from outside*” (Romer, 1994). Considering technological change as an endogenous variable represents a turning point in innovation studies. In this moment, actions of the economic agents start to be relevant since they are able to promote innovation, and consequently economic development by doing innovative activities, like for instance, investing in Research and Development (R&D).

In this context, has predominated macroeconomic analysis aiming to demonstrate that investment in R&D is a significant variable for explaining territories economic growth. Most of them find this variable as one of the determinants of economic growth. However, there are not many studies aiming to find out which impact generates R&D investments in the medium or long-term. Considering that economic resources are limited, it is important to quantify which are the effects of R&D investment, when they materialize in terms of economic growth, and how persistent they are over time. Specifically, we ask ourselves: When a concrete investment began to be significant for explaining economic development in the context of the Spanish regions? It is not only important to know when the investment in R&D start to be significant, but also to find out how evolve this effect through the time. Particularly, does it have long-run effects on the productivity? Does this effect depend on the source of investment? Is this effect the same for the most and least developed regions?

In summary, in this analysis we want to combine three perspectives, “region, time and sector of investment” for which the effects of the investment in R&D on the productivity may vary. Based on an analysis of the effects of investment in R&D in the long term, first, as our “region” perspective, we want to analyze if the impact of the investment in R&D vary if we take in to account the kind of region, that is, if the region is poor or is rich. We will consider also control variables related to the socioeconomic and demographic characteristics of the regions to consider this possible source of variability in the results. Second, we include a “time” perspective; performing an analysis for a long period of time, will allow us to observe if there are long run effects of each investment. Also, analyzing the effect of each investment, considering different periods independently, will allow us to observe if the impact of the investment in R&D vary through the time and thereby which kind of marginal returns exist. Third, and finally, the perspective related to the “sector of investment”, we will account for the possible divergence in the effect of the investment in R&D by considering if it was made by the private sector or by the public sector. We will bring together all these three perspectives as possible source of variability on the results in a single analysis which main goal is to model the effects of investment in R&D in the long term, as we will detail later.

For the construction of our database, we obtain different variables from several sources. Specifically, data was obtained for the period 1990 to 2018 since it is the largest period for which we have data for all variables considered. The resulting panel data is

disaggregated at the regional level (NUTS2) which correspond to the Autonomous Communities level of spatial disaggregation in Spain, since it is the most disaggregated scale for which we have information related to investment in R&D. The methodology selected for developing our empirical analysis is a “Fix Effects Panel Model” in which we have included, on the one hand, regional dummies to control for time invariant unobservable region’s heterogeneity, and on the other hand, yearly dummies to control for time variant effects common for all regions. Errors have been clustered by regions to control for a possible spatial dependence. In addition to controlling for socioeconomic and demographic factors we include an interaction term which will be our focus of interest for answering our research question. Specifically, this term interacts the investment made in a specific period with yearly dummies, which represents the post-investment periods. Thanks to this interaction term we will shape the effect of initial investment in R&D through time, being able to observe if R&D investments has long run effect on region’s productivity.

Expression 1 reflects synthetically the proposed model:

$$Y_{it} = \gamma + \sum_{t=2}^x \beta_t \left\{ \left( \frac{\text{initial R\&D}}{GDP} \right) * 100 \right\}_i * Year_t + \theta_1 X_{it} + \alpha_i + \delta_t + u_{it}$$

Where  $Y_{it}$  represents the labor productivity in each region  $i$  and period  $t$ . Given that 5 panels will be created,  $t$  will represent a value between 1990 and 2018, 1995 and 2018, 2000 and 2018, 2005 and 2018, 2010 and 2018, in each case.  $\gamma$  is a constant.  $\alpha_i$  represents region fix effects and  $\delta_t$ , time fix effects.  $X_{it}$  denotes all socioeconomic and demographic variables included in the analysis in region  $i$  and time  $t$ , also, contemporary investment in R&D is included. Finally,  $\sum_{t=2}^x \beta_t \left\{ \left( \frac{\text{initial R\&D}}{GDP} \right) * 100 \right\}_i * Year_t$  represents the interaction term between initial investment in R&D in all regions and yearly dummies corresponding to the post-investment periods.

Results have been obtained from 45 different estimates. Several important conclusions have been obtained by analyzing estimates corresponding to the effect on productivity of the total investment in R&D made in 1990, 1995, 2000, 2005 and 2010 on whole regions, less developed regions, and most developed regions. First, we observe that initial investment in R&D, specifically, that from 1990, has had significant and positive effects on regions productivity in the post-investment periods, regardless the kind of region or source of investment. Second, when we include a temporal dimension, that is, when we observe estimates corresponding to the effect on productivity of investment in R&D made in later periods, 1995, 2000, 2005 and 2010, results differ. We observe that recent investment in R&D have generated less effect on productivity, and it tends to accumulate less effect through the time. We justify this fact in two different ways.

On the one hand, Spain in the 90’s was a society with a reduced scientific and technologic development. For that reason, we consider that initial investments, has had a key role for obtaining a first progress in regions scientific and technologic systems, and that is why R&D investment could have impacted on productivity in a greater extent. Also, literature

specialized in innovation observed that “radical” innovations, that is, ones that introduce a new product or a new process in the markets, use to have a higher impact on productivity. But this kind of innovations that impact on a greater way on productivity needs higher investments to be developed. It is very probable that due to the reduced scientific and technologic development in Spain in the 90’s, innovations probably were more radical or disruptive in that time. This arguments support that is very necessary to invest continuously, not only in concrete periods, and also, to invest more through the time. On the other hand, we consider that the less importance of later investments in R&D could be justified in the fact that we need to wait a long period to observe the potential positive effect that investment in R&D generates on territories productivity.

Third, our results suggest that, through the time, R&D impact in a different way across the space. Specifically, we observe that most developed regions have had a slightly greater ability to maintain the effect on productivity of later investments. We conclude that the effect of R&D investment on regions productivity is not homogeneous through the space. There is a clear justification. Some researchers observed that less developed regions have less capacity to absorb invested resources due to their worst socioeconomic conditions, so that in turn affect their capacity to use invested resources efficiently.

Four, we distinguish between the effects of the public and private investment on regions productivity. In this context, we observe that public investment in R&D had a higher effect on less developed regions productivity. It is an expected conclusion. Less developed regions have a smaller number of firms with technologic capacities. For that reason, is not estrange that the key to support a first scientific and technologic advance rest on public R&D investment. The contrary is observed considering private investment. This spending favor in a greater quantity to most developed regions, losing all significance if we consider less developed regions.