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## Do R & D activities matter for productivity? A regional spatial approach assessing the role of human and social capital<sup>☆</sup>

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## ABSTRACT

We estimate the long-run effects of Research and Development (R & D) activities on Total Factor Productivity (TFP) across the Spanish regions during 1980–2007. We use panel data cointegration methods and control for spatial externalities linked to human and social capital. Our empirical results, robust to different specifications and additional control variables, show a significant direct effect of public R & D capital on productivity. No significant results are observed for private R & D capital. In contrast, the effect of patents is highly significant but proves to be small. Furthermore, Spain has greatly benefited from importing technology from leading countries. Spatial spillovers are crucial in explaining long-run productivity for the case of Spain. Human and social capital exert direct positive impacts, however, their effects are geographically bounded and negative spatial spillovers offset direct outcomes. Overall TFP increases when neighbouring territories engage in R & D activities.

## 1. Introduction

The economic growth literature highlights how R & D activities play a central role in explaining differences in productivity across countries (Griliches, 1980; Coe and Helpman, 1995; Coe et al., 2009). Cettè et al. (2016) provide evidence that confirm that Continental European economies have been falling back relative to the U.S frontier at varying rates since the mid-1990s. In this context, the European Union Research and Innovation Program has become a central element as part of the new EU competitive strategy – named *Europe 2020*.<sup>1</sup> The program has re-established the Lisbon objective of 3% R & D spending over GDP as a policy that aims to induce innovation to promote productivity and reduce regional disparities within Europe. In 2014, the average level of R & D spending exhibited by the EU-28 was 2.03%, below the ratios of the U.S (2.81%) and Japan (3.48%). At regional level, the heterogeneity in R & D spending within European regions is quite remarkable.<sup>2</sup>

Among the EU countries that exhibit lower national and regional R & D spending ratios, Spain constitutes a particularly relevant case of study. It is the fourth major economy in the Euro Zone by real GDP and has experienced a rapid development since the 1980s. Despite the country's social and economic progress, productivity in terms of Total Factor Productivity (TFP) has decreased by an average of 0.31% per year since 1995 and the country suffers from persistent regional disparities. In terms of R & D efforts, data show an improving trend. The stock of R & D capital as a percentage of the stock of physical capital has increased from 1.5% in 1980 to 4.15% in 2007. However, the accumulation of R & D capital has not been effective enough to boost productivity levels.<sup>3</sup>

These stylized facts raise relevant economic questions in a context of productivity stagnation: (i) what is the long-run impact of R & D activities on regional productivity?, (ii) can we observe differential effects in the contribution of R & D capital depending on its source of funding – public and private?, (iii) are those effects conditioned by the

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<sup>1</sup> Approximately 9% of the total EU budget, 80 billion dollars, has been assigned to R & D spending over the period 2014–2020.

<sup>2</sup> According to the latest data available published by EUROSTAT some EU regions have R & D spending ratios above or near the target of 3% of GDP (in Sweden, Denmark, Austria, and Germany), while others exhibit ratios around or below 1% (as in Spain, Greece, Poland, and Slovakia).

<sup>3</sup> We switch attention to the stock of R & D capital as it is widely considered a critical input affecting productivity. The National Accounts estimate the capital stocks from R & D expenditure and assuming a fixed depreciation rate (see Griliches, 1980).

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accumulation of human and social capital and the existence of geographical spillovers?

These are the questions that this paper analyzes to explain differences in productivity levels across Spanish regions. In our novel approach we use a panel cointegration model to estimate the long-run relationship of R&D activities on TFP from 1980 to 2007. To fully understand its impact on productivity, we also consider the effect of factors that enhance access to knowledge. Ultimately, the effectiveness of policies based on increasing R&D spending is greatly conditioned by regional endowments and geographical factors. Hence, as an additional hypothesis, we study if productivity in Spain is affected by differences in absorptive capacities which can be geographically bounded. In this study, the absorptive capacities are associated with human and social capital. The emphasis lies on their geographical spillovers as crucial factors to explaining low productivity levels.<sup>4</sup> This paper contributes to the literature by connecting the effects of technology transfer on productivity to the spatial dimension of knowledge and of the absorptive capacities.

Wang (2007) defines R&D activities as well-organized processes that entitle the creation, production, diffusion, and application of knowledge. A growing literature identifies alternative measures and determinants of R&D effort (Cullmann et al., 2012; Franco et al., 2016). We use input and output measures of R&D activities to capture the long-run dynamics. Specifically, we use three different proxies for R&D activities. First, we focus on the role of the stock of R&D capital as an input variable, differentiating between public and private. Second, in Spain the deficit in R&D spending has been usually counterbalanced by importing technology from leading economies. Therefore, we test the effect of imports of technology from G7 countries as an alternative channel of technology transfer. Last, we employ an output measure of research effort – number of patents per researcher which aims to capture R&D output effectiveness.

Commensurate with Bronzini and Piselli (2009) and Costantini and Destefanis (2009) evidence for the Italian regions, we demonstrate that across the 17 Spanish regions long-run productivity depends, mainly, on public R&D capital. Our measure of research effort, patents by researcher, captures significantly better the effectiveness of private R&D capital. The evidence favors direct positive impacts of human and social capital within regions. The positive impacts are offset by the existence of negative spatial externalities from the absorptive capacities. We additionally observe that Spain suffers from a mismatch in spatial patterns that can run these results. This is, the distribution of human and social capital is spatially concentrated, while our results show geographical dispersion in the accumulation of R&D capital. Ertur and Koch (2007) findings suggest that R&D activities are more productive if located close to other technology centers – with direct access to human capital and networks for information sharing-, as they favor positive spillovers. Conversely, if R&D activities are spread then productivity diminishes, which can explain unequal regional development.

Our findings raise reflective points for policymakers: regions that are unable to attract talent and develop social capital to feed R&D activities will not achieve levels of productivity to close the gap with the leading European regions. We empirically assess how important and differential these effects are in Spain.

The rest of the paper is organized as follows. Section 2 presents a review of the literature. Section 3 briefly describes the evolution of TFP and technological inputs by region. Section 4 explains the econometric specification. Section 5 states the main results of the estimations, and Section 6 concludes and offers economic policy recommendations.

<sup>4</sup> The absorptive capacity represents the ability to assimilate and apply new knowledge. It has a strong influence on the effectiveness of R&D as a way to enhance technology transfer. The literature about the role of absorptive capacities dates back to Gerschenkron (1952) and Abramovitz (1986).

## 2. Literature review

Our paper relates to two branches of literature. The first one focuses on the impact of R&D activities and other determinants of productivity, such as human and social capital. The second one analyses the role of geographical dependence and spatial externalities (Papalia and Bertarelli, 2010). Coe and Helpman (1995) and Coe et al. (2009) were pioneers in estimating the long-run relationship between foreign and domestic R&D stocks of capital and TFP for a sample of G7 economies. They empirically measured how differences in innovation capacities can explain persistent differences in productivity even when controlling for absorptive capacities linked to human capital and institutional variables. The seminal work by Griffiths et al. (2004) provides the theoretical framework to consider R&D not only as a vehicle to stimulate innovation but also as a factor that enhances technology transfer. They empirically test the effect of R&D as a source of innovation and catching-up in a panel of twelve OECD economies. Their results confirm that both faces of R&D play a major role in productivity growth even when controlling for human capital and trade. Silaghi et al. (2014) results indicate that the contribution of private R&D declines when controlling for human capital but it remains significant in explaining long-run economic growth for Central and Eastern European Countries. At regional level, Castellani and Pieri (2013) empirically find a large and positive correlation between the extent to which R&D activities are transferred abroad and regional productivity in Europe. The ability of a country/region to assimilate knowledge from public and externally conducted R&D seems to be conditioned by its absorptive capacities (Roper and Love, 2006).

Absorptive capacities can be measured using a broad range of economic indicators.<sup>5</sup> Human capital is identified among one of the most relevant. It is viewed as a crucial factor affecting knowledge transmission and regional development (Lucas, 1988; Miller and Upadhyay, 2000; De Lucio et al., 2002; De la Fuente and Doménech, 2006; Jones, 2011; Mellander and Florida, 2014; and Haugh and Westmore, 2014). However, the influence of human capital spatial spillovers on growth and productivity levels still remains an open empirical question subject to further analysis. Fingleton and Lopez-Bazo (2006) find positive spatial spillovers of human capital on growth for the EU regions. Shapiro (2006) and Bronzini and Piselli (2009) report similar results for the Italian regions. The latest empirical work by Benos and Karagiannis (2016) demonstrates that tertiary education spillovers exerted a significant and positive effect on productivity in Greece for the period 1971–2011. In contrast, the studies by Olejnik (2008) and Ramos et al. (2010) report negative externalities for the European and Spanish regions, respectively.<sup>6</sup>

In addition to other traditional economic variables, social capital is considered an important factor in explaining economic growth and productivity. Temple and Johnson (1998) and Putnam (1995) define social capital as connections among individuals in form of social networks and the norms of reciprocity and trustworthiness that arise from them. The underlying idea is that social capital and spatial proximity can reinforce the deep bonds of trust that facilitate exchange of tacit knowledge. Beugelsdijk and Van Schaik (2005) demonstrate that social capital, in the form of generalized trust and associational activity, is related to regional differences in economic growth in Europe. Agrawal et al. (2008) highlight how the quality of inter-organizations and social networks act as relevant factors for knowledge

<sup>5</sup> The literature identifies among the most relevant absorptive capacities: human capital, easiness in doing businesses, ITC penetration, technological capital, infrastructures, social capital, or labour market aspects. Social capital is considered as an intangible asset that accounts for greater information capacity, trust and the existence of labour networks (Coleman, 1990).

<sup>6</sup> Results are sensitive to the territory object of analysis, the econometric techniques employed and to different proxies of human capital.

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