TECHNOLOGY TRANSFER IN ITALY: A QUANTITATIVE ANALYSIS

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Abstract. Literature review discusses the evolution of economic growth theories, particularly the transition from the neoclassical model to endogenous growth theories that emphasize the role of knowledge, ideas, and human capital in increasing productivity and output. Empirical research supports the positive relationship between R&D and productivity growth, with university R&D showing long-term benefits and corporate R&D yielding quicker returns.
Moreover, innovation is historically considered the main driver of economic and social development and, above all, investments in R&D are considered essential for enhancing national competitiveness and productivity.
This study investigates the impact of patent and research and development (R&D) expenditures by universities and firms on economic growth in Italy, highlighting the mechanisms of innovation propagation and diffusion and contributing to the debate on the differential role of universities versus firms in growth processes.
Utilizing a panel data technique, the analysis demonstrates a positive correlation between value added per worker and R&D expenditures per capita. The empirical findings indicate that university R&D expenditures have a higher impact on value added per worker compared to firm R&D expenditures. Gross fixed investments show an immediate but lower impact, while patents significantly influence economic growth after a five-year lag. Notably, the results reveal a time lag in the impact: university R&D investments generally exhibit an immediate effect on economic growth, whereas firms experience positive spillovers on regional growth after some years.
The findings suggest that policies supporting technology transfer should strengthen the role of universities in areas with low industrial intensity by enhancing intermediation tools (such as Technology Transfer Offices, incubators, and contamination labs).

1. Introduction

In recent years, particular attention has been given to the role of universities in the process of technology transfer to enterprises. Indeed, academic institutions are not only centres of knowledge production, but also crucial intermediaries in the transfer of scientific knowledge to the businesses.

Technology transfer in universities refers to the process through which academic research and innovations are transferred from academic institutions to the market.

This activity, which is one of the most formal activities within the so-called Third Mission of Universities[1], can assume different forms: academic entrepreneurship (spin-offs, start-ups, contamination labs, etc.); valorisation of intellectual or industrial property (e.g. patents); intermediation and technology transfer structures (e.g. technology transfer offices, incubators); cross-innovation and cross-fertilisation initiatives, enterprise-university collaborations.

The importance of technology transfer lies in its ability to bridge the gap between research and practical application, thereby accelerating innovation. By transferring cutting-edge research and technologies to businesses, universities enable companies to access novel advancements without bearing the full cost and risk of internal Research and Development (R&D). This symbiotic relationship boosts the innovative capacity of firms, leading to the development of new products, services, and processes that enhance their competitiveness in the global market (Rambe and Khaola, 2023; Padilla Bejarano *et al.*, 2023).

Through collaborations, patents and spin-offs, and all the other highlighted activities, Universities help to transform scientific discoveries into practical applications, thus generating innovation and consequently economic and social value for companies and the territories to which they propagate (Secundo *et al.,* 2017).

After all, innovation has always been the main driver of economic growth and social development (Ciccarelli, 2008). In recent decades, it has been verified that innovation is less and less the result of ‘accidental’ behaviours and more and more the result of structured activities – such as investments in research and development (R&D) – which become a crucial element in stimulating the competitiveness and productivity of territory.

In this context, it becomes crucial to know in detail how innovation spreads across the territory, and how structured research activities contribute to the growth of business productivity and output. Indeed, although the effects of investments and research and development on output have been widely discussed in the literature, this study aims to contribute to the scientific debate by providing a systematic comparison of different sources of innovation and their varying capacity for diffusion. These findings have significant policy implications, particularly concerning the design of effective technology transfer instruments aimed at maximizing the socioeconomic impact of public research in the less industrialized areas of the country.

For these reasons, this article aims to explore the impact of investments, R&D expenditure and patents on the Gross Domestic Product (GDP), highlighting how

[1] In the latest documents of ANVUR (National Agency of Evaluation), the so-called Third Mission of Universities has been given a partially different name, taking on the name of Knowledge Enhancement (Third Mission/Social Impact); see ANVUR Decree no. 8/2023 Research Quality Assessment 2020-2024.

innovation can transfer into a significant increase in production at the national level. The aim is to examine the mechanisms of propagation and diffusion of innovative activity, in order to be able to prepare adequate technology transfer policies from universities to enterprises. A comprehensive understanding of these mechanisms is essential to facilitate a two-way flow of knowledge. This process can represent a pillar fostering sustainable growth and long-term competitiveness while promoting an environment conducive to adopting technological innovations throughout the production system.

This work aims to explore how R&D expenditure not only stimulates output but also facilitates knowledge transfer within business networks or through partnerships between the public and private sectors. We believe that this contribution would be relevant especially for policymakers seeking to encourage sustainable economic growth.

The paper is organized as follow: section 2 we highlight the literature review; section 3 we show data and methodology description; section 4 we discuss the empirical results; section 5 conclusion.

2. Literature review

Economic growth theories have evolved significantly over time, reflecting changing understandings of what drives increases in a nation's output and living standards.

The concept of endogenous growth emerged as a response to the limitations of the neoclassical growth model, particularly the Solow-Swan model, which treated technological progress as an exogenous factor. In the 1980s a group of growth economists led by Paul Romer started a paradigm shift in the economic growth theory. By now the key determinant of growth were endogenous.

Romer (1986) introduced the idea that knowledges, ideas and human capital are not rival-goods, meaning that their use by one individual does not affect the possibility of another to use it too. This characteristic can lead the economic system to a sustainable economic growth, due to the increasing return to scale.

The importance of the human capital is an extension of the endogenous economic growth argued by Lucas (1988), who highlighted the positive contribution of education and training in order to enhance the productivity.

Jones, in his paper “R&D-Based Models of Economic Growth” (1995), provided a critical assessment of R&D-based endogenous growth models. He pointed out that these models often predicted scale effects—that larger economies should grow faster—which were not always supported by empirical evidence. Studying the total factor productivity growth and the number of engineers and scientists in developed countries as United States, Germany, France and Japan he finds no proof that there is a relationship between these two variables.

However, Aghion and Howitt (1998) tried to explain Jones' results i) distinguishing scale effects and growth drivers; ii) introducing more realistic assumptions about market structures and knowledge spillovers; iii) demonstrating that endogenous technological change could lead to balanced growth paths, iv) providing a framework where growth is driven by the quality of inputs rather than their quantity; v) introducing some variables about the real world, showing that these elements could explain differences in growth rates across countries without relying on scale effects.

Empirical research has played a crucial role in validating and refining endogenous growth models.

In this field we can include Mankiw, Romer and Weil (1992) with their empirical analysis which demonstrated that the differences in human capital accumulation could explain a significant part of the growth rates variations across countries, confirming the previous endogenous growth models.

Important contributors are also Coe and Helpman (1995), who found that R&D not only enhances domestic productivity but also has significant spillover effects for other countries.

In the main literature we can find different studies which argue that there is a positive relationship between countries' R&D and productivity growth using international panel data: it is the case of Frantzen (2000) and Griffith, Redding and Reenen (2004).

Despite their contribution, endogenous growth models have faced several criticism and challenges: for instance, the empirical validity which not always is supported by data; their complexity; about the policy, implementing effective policy in the real world can be harder than in the model.

Overall, endogenous growth theory offers valuable insights into the mechanisms that sustain economic growth and provides a foundation for designing policies that foster innovation, education, and long-term prosperity.

For this reason, we chose to investigate the impact of innovation using the R&D expenditure as a proxy in an endogenous growth model.

Notably, many researchers provide insights into the temporal impact of R&D activities conducted by universities and firms on economic growth, highlighting how the benefits derived from university R&D tend to manifest in the long term, while those from corporate R&D emerge more quickly (e.g. Hall *et al.*, 1986; Jaffe, 1986; Boskin and Lau, 1992; Henderson and Cockburn, 1996; Griliches, 1998; Jaffe and Trajtenberg, 2002; Aghion *et al.*, 2009). Otherwise, Siegel *et al.* (2003) demonstrate that linkages between universities and firms conducted by the technology transfer offices can accelerate the impact of the university R&D expenditures.

Abramovsky and Simpson (2011) studied the impact of geographic proximity between firms and universities, focusing specifically on pharmaceutical companies. The results of their research show that spatial closeness promotes collaboration, thereby facilitating knowledge transfer.

A very interesting study on the impact of research and development on economic growth was conducted by Minviel and Bouheni (2022), who employed the kernel-based regularized least squares (KRLS) to analyze this aspect. This advanced machine learning method allows researchers to move beyond single-point estimates. This technique could represent a further step forward in our research by calculating pointwise marginal effects at the regional level, offering a more detailed analysis than linear methods. In fact, this paper could serve as the starting point for more advanced research that will certainly be implemented in the future. The paper is organized as follows: section 2 we show the model; section 3 data and methodology description; section 4 statistical analysis; section 5 Results and conclusion.

3. Data Description and Methodology

This work stems from the Vitality project, an Innovation Ecosystem funded by the Ministry of University and Research as part of the National Recovery and Resilience Plan (PNRR, Mission 4, Component 2, Investment 1.5). The goal is to facilitate technology transfer and accelerate the digital transformation of business production processes with a focus on economic and environmental sustainability and social impact. Consequently, this article aims to investigate how the growth of the Italian economy is influenced by R&D investments made by both universities and businesses.

The chosen data to investigate the impact of innovation on economic growth consists of universities and firms' research and development expenditures, as well as the number of patents. The dataset includes annual data for Italian regions and was constructed using information available on the Istat platform and from the Ministry of Enterprise and Made in Italy. This dataset covers the period from 1995 to 2021.

The analysis aims to understand the impact of innovation (here measured by R&D expenditure and patents) on value added per worker.

We built our empirical model starting from Romer's work (1990), which considers three assumptions: i) technological changes drive growth; ii) technological changes are the result of people's intentional actions; iii) designs used in the production are not rival goods.

Emphasizing the role of knowledge and technological progress, and starting from the Romer's model we have

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \quad (1)$$

where A_t is the technological efficiency of the economic system, K_t and L_t are respectively the capital and the labour at time t, Y_t is the production, α the production elasticity parameter.

The following equation:

$$y_t = \alpha h_t + \gamma i_t + (1 - \alpha - \gamma)\chi_t + \varepsilon_t \quad (2)$$

represents a simplified formulation of how various factors (h_t is the human capital computed as number of employed in the tech sector, i_t the gross fixed investment normalized to the population and γ its elasticity parameter, χ_t is compounded by the firms and universities R&D expenditures and the patent stock) contribute to the value added per worker y_t, with ε_t as the stochastic error.

Table 1 – *Descriptive Statistics*,

Variables	Obs	Mean	Std. dev.	Min	Max.
Real value added per worker	540	60649.55	8495.186	42500.85	80136.78
Employees in tech sector (%)	418	.4537105	.5463865	.016	2.763
Gross fixed investment per capita	500	5680.484	1869.193	2417.651	11538.46
Universities R&D expenditure	500	88.27814	38.293	0	184.185
Firms R&D expenditure	500	137.9373	124.5743	.2490398	564.2839
Patents stock per capita	497	389.3996	435.3726	2.422626	1730.341

Employing a fixed effects panel regression (confirmed by the Hausman test; Greene, 2011), we used proxy variables for innovation including research and development expenditure by universities and firms, and patent stock. Additionally, following Ulku (2004)'s suggestion, we included the number of employees in the tech sector and gross fixed capital investments per capita in the model. In order to understand the impact over time of the dependent variables that characterize innovation, we apply the same panel regression but with time lags of 1, 3, and 5 years.

The results are reported in the following table:

Table 2 – *Panel regression analysis of value added (per worker) – Italy.*

Variable	Coefficient	Standard error	P>|t|
Constant	54824.18	1057.449	0.000
Employees in tech sector (%)	633.0554	851.4921	0.458
Gross fixed investment per capita	.5219398	.1238106	0.000
Universities R&D expenditure	20.70495	5.35528	0.000
Firms R&D expenditure	6.009479	1.888272	0.002
Patents stock per capita	-.8330457	.803345	0.300

Table 3 – *Panel regression analysis of value added (per worker) after 1 year – Italy.*

Variable	Coefficient	Standard error	P>|t|
Constant	54008.14	1050.229	0.000
Employees in tech sector (%)	1134.209	842.9605	0.179
Gross fixed investment per capita	.4650178	.1225857	0.000
Universities R&D expenditure	27.27929	5.373695	0.000
Firms R&D expenditure	6.45043	1.869041	0.001
Patents stock per capita	-.568667	.7956456	0.475

Table 4 – *Panel regression analysis of value added (per worker) after 3 years – Italy.*

Variable	Coefficient	Standard error	P>|t|
Constant	54092.58	1149.271	0.000
Employees in tech sector (%)	132.1862	920.8986	0.886
Gross fixed investment per capita	.2987241	.1339868	0.026
Universities R&D expenditure	28.19763	5.903485	0.000
Firms R&D expenditure	8.235437	2.041895	0.000
Patents stock per capita	1.109338	.8696172	0.203

Table 5 – *Panel regression analysis of value added (per worker) after 5 years – Italy.*

Variable	Coefficient	Standard error	P>|t|
Constant	56547.26	1264.341	0.000
Employees in tech sector (%)	387.2865	976.066	0.692
Gross fixed investment per capita	-.0017003	.1417273	0.990
Universities R&D expenditure	10.22335	6.427954	0.113
Firms R&D expenditure	7.732536	2.269384	0.001
Patents stock per capita	2.819818	.9158537	0.002

4. Assessing Empirical Results

The empirical analysis shows that structured activities preparatory to innovation (investments, R&D and patents) generally have a positive impact on value added per worker. However, large differences can be found in both the impact itself and the propagation pattern. Research and development expenditure by Universities generally has a higher impact, while R&D expenditure by companies tends to have a more modest impact. In essence, it would appear that university expenditure by its nature has a greater capacity to propagate to a large number of enterprises and throughout the territory, improving the capabilities of a large part of the economic system; business expenditure, on the other hand, would have a more circumscribed impact, since it tends to remain within the enterprise itself and the diffusion effect appears much more limited[2].

Gross fixed investments also seem to show their strength from the earliest years, but the impact they generate on GDP appears lower, perhaps because these investments are more generalist[3] and do not always succeed in influencing the production model.

Patents, on the other hand, do not seem to have a significant impact if we look at the model with time lags of 1 and 3 years, while the impact becomes significant only after 5 years; this element does not seem anomalous, since clearly a patent implemented by a company needs time to penetrate the market and consequently

[2] It should not be forgotten, then, that by their very nature these expenditures tend to be made mainly by medium and large-sized companies, which make up only a fraction of the total, accentuating this lesser capacity for disseminating innovations throughout the entrepreneurial system.

[3] Gross fixed capital formation is defined as the purchase of tangible durable goods by an enterprise, and includes (non-exhaustively) the purchase of machinery, plant, equipment, furniture, means of transport, construction and buildings, land, etc. These investments are, as can be seen, extremely heterogeneous and may not always have a direct impact on increasing the productivity of enterprises.

generate a positive impact at a macro-economic level (Garcia Vega and Vicente-Chirivella, 2020a e 2024; Hu and Zhang, 2021).

The positive and broader impact of university R&D could suggest an optimization of public policies, advising policymakers to promote increased investments in university research and development, while fostering partnerships between businesses and universities. This is particularly important in those areas characterised by small companies that, on their own, would not be able to affordably access R&D and innovation (Apa *et al.*, 2021; Colombelli *et al.*, 2021; Di Marco and Cavaggioli, 2024).

5. Some concluding remarks

Although our research activity is still in its early stages, we can already draw some preliminary indications on the way innovation and research and development activities can activate and increase the productivity of the economic system.

First of all, one of the elements that appears to emerge concerns the dichotomy between the public and private sectors, and the way in which investments in the public sector (universities) have the capacity to influence the results in productive terms by producing a greater impact than private ones, and thus showing a far greater capacity for dissemination than the latter; the reason probably lies in the fact that the public sector's objectives are evidently to carry out research for the benefit of the community, and in any case for a more or less broader set of entrepreneurial realities, thus being more incisive in determining the results in terms of the product obtained; private research activity, carried out within the individual company, evidently has the objective of creating a competitive advantage within the company itself and thus has a lesser capacity to spread across the territory.

Of course, the model tested at the national level could conceal differences in behaviour – even very large ones – between the different regions; from some initial estimates, in fact, it would seem that in regions with a greater presence of large-scale industry, the impact of research at company level is higher than at the average; on the contrary, in smaller regions, the diffusion effect of public research seems to be able to guarantee better impacts on the aggregate product.

Returning to the main objectives of our work, this aspect assumes contours of considerable relevance: it becomes essential to provide universities with effective and efficient intermediation and technology transfer structures, especially in those areas with low industrial intensity, where the entrepreneurial fabric is often fragmented and less structured, which find it very difficult to carry out structured research activities and which, therefore, need to be monitored and directed in order to improve their levels of competitiveness in the markets.

In such contexts, universities can act as catalysts for widespread innovation due to their capacity to generate knowledge and connect diverse actors. It is therefore essential to enhance intermediation tools—such as Technology Transfer Offices (TTOs), university incubators, and cross-contamination initiatives between academia and industry—to facilitate the circulation of skills and the adoption of innovation.

For the future, in order to investigate in even greater detail the impact that innovative activities can have on production at the micro and macro-economic level, it will be necessary to proceed with further verification in the specification of the model, testing possible different production functions or including some confounders in the analysis (although, as we have seen, we have tested variables such as the presence of employees in technology-intensive sectors and this does not seem to have a significant impact on the product obtained); in addition, it will be necessary to investigate databases at the firm level (such as those derived from enterprises micro-data such as the Community Innovation Survey) in order to conveniently test the micro economic issues.

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