EUROPEAN REVIEW OF BUSINESS ECONOMICS • VOL. II, NO. 2 • JUNE 2023

Innovation and Firm Performance Across Portuguese Municipalities: The Role of Patents

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To cite this article: Oliveira, C., J. Pereira dos Santos & Tavares, J. 2023. Innovation and Firm Performance Across Portuguese Municipalities: The Role of Patents. European Review of Business Economics II(2):23-51; DOI: https://doi.org/10.26619/ERBE-2022.2.2.2.

ABSTRACT

We examine a dataset, which until now remained unused, on the requests and awards of patents and industrial designs for the universe of mainland Portuguese municipalities. We use it to assess the impact of innovation on firms' sales and value added. Using micro data firm performance by municipality for the period 2006-2012, we estimate that patents awarded impact sales and value added in the three years that follow, initially by decreasing and then by increasing financial performance indicators. The impact of innovation is most evident in value added and during crisis years. It is less evident in sales, works carried out through industrial businesses and medium and large-sized firms (measured by the number of employees). We also find that unemployment decreases, with a lag, in municipalities where the number of patents awarded increased. When we measure patents awarded with the number of patents requested and the number of tertiary education professors, we uncover a causal relation between innovation and increases in value added, and less so between innovation and sales.

Keywords: Regional Innovation; Patents; Trademarks; Portugal
JEL Codes: H11; O31; O32

I. Introduction

THE CAPACITY TO INNOVATE and assimilate new and existing knowledge has been regarded as a key factor behind the economic performance of a territory.[1] By creation or assimilation, and then adaptation to productive and commercial use, firms gain competitive advantages that translate into higher levels of performance. Not surprisingly, many innovations developed by the ideas sector

* The authors are indebted to Rita Cortesão Casemiro (INPI) and Duarte Rodrigues (ADC).

[1] See Audretsch and Feldman (1996) and Stern et al. (1999) for early efforts in understanding the determinants of a country´s innovative capacity.

are not fully exploited by firms.[2] However many economists recognize the importance of ideas, transforming ideas into value is not only an engineering task, rather the difficult combination of a large set of skills that firms put together to satisfy demand.

The positive effect of research and development (R&D) on economic growth has been the subject of several theoretical contributions, including the seminal growth models advanced by Arrow (1962), Romer (1990), and Aghion and Howitt (1992). The main theoretical prediction of endogenous growth theory predicts that the scale of an economy increases rents to be captured by successful innovators and should thus lead to a rise in innovative activity and economic growth.[3] This prediction is contradicted by the recent experience of developed OECD economies, where growth stagnated in spite of rising R&D effort. On the contrary, the positive link between innovation and growth, where more innovative regions grow faster than comparable areas, has been empirically confirmed by Grossman and Helpman (1990), Cameron et al. (2005), Coe et al. (2009), and Hasan and Tucci (2010). Empirical evidence on the effect of innovation on firm performance remains contentious. Three factors may explain the persistence of this debate: the complexity of the process of transforming innovation to value, the unevenness of the process itself as far as firm nature and context, and the nature of the data used.

Regarding the process of transforming innovation into value, one can start by thinking of economies as drawing on a set of assets that include ideas and objects, as in Romer (1993). Physical assets such as roads are objects, and the knowledge able to create value are ideas. In this paper, we use information on patents and industrial designs. While both can be seen as ideas, the latter is in principle closer to the creation of economic value for business firms. We assess how they affect firms' bottom line across regions and over time, from the advantage point that the underlying R&D effort affects both invention and the assimilation of others' discoveries. The protection of intellectual property rights in the form of patents may affect growth, as shown in Gould and Gruben (1996).[4] Colombelli et al. (2013) find that innovative firms grow faster than non-innovative ones, based on different indicators of firm growth, and these results are robust when considering different types of innovation. Artz et al. (2010) examine

[2] This may be due to many factors, including a lack of incentives for scientists and engineers to develop linkages to firms. However, as pointed out in Romer (1993), "[t]he full translation of ideas and new technologies into productive output depends on many intervening factors including the technical and human capital of the workforce, whether the economy's physical and information infrastructure are positioned to take advantage of new technologies, and whether the industrial organization of adopting sectors is conducive to taking advantage of technology development (e.g., consumers who are willing to experiment with new technologies, the existence of micro-market incentives to commercialize new technologies, and supply relationships which complement and reinforce the social value of novel technologies."

[3] See Young (1998).

[4] Gould and Gruben (1996) examine cross-country data on patent protection, trade regime, and other country characteristics and find evidence that protection of intellectual property protection fosters economic growth, more importantly so in open economies.

different innovation outcomes, both new ideas and commercially viable products or services, and find that both have effects on firm performance, measured as return on assets and sales growth.[5] Hasan and Tucci (2010), using a sample of 58 countries for the period 1980–2003, find that countries with a higher quality or higher level of patenting experience faster growth.

In our study, we address the possible asymmetry of the process of transforming innovation into value by examining how the sector of activity, firm size, innovation context, and an aggregate economic crisis may, or may not, change, the innovation to value transmission mechanism. Coe and Rao (2008) show returns on innovation are highly skewed, and Artz et al. (2010) find evidence of increasing returns on R&D spending. Evangelista and Vezzani (2010) explore the relationship between technological and non-technological innovations, finding that different modes of innovation have a differentiated impact on firms' performances, with differences between services and manufacturing firms. Finally, unlike previous studies, we use data at the local level, with sectoral and size information on the firm, and a sufficiently extended time period to cover normal times and an unprecedented recession. Overwhelmingly, empirical studies carried out in relation to innovation have focused on the country as the unit of observation. Using sub-national geographic units as the unit of analysis brings important benefits. Howells (2005) highlights the importance of a regional approach for the design of innovation policy. First, he addresses the issue that, within every nation, important regional disparities in economic performance persist, lacking appropriate explanation. The uneven geographical distribution of income suggests that some activities are a local source of competitive advantage, so that a more refined analysis of the impact of innovation should be conducted at the regional level.[6] Second, it has become widely accepted that innovation is a territorially embedded process, either because of relative immobile factors or important spillovers at the local level.[7] By measuring the output of the sum of firms in the municipality instead of looking at the individual firm, we may also be capturing the spillovers between geographically close firms, alluded to in Goetz and Han (2020). Our paper contributes to the literature by examining the specific influence of local innovation outcomes on a panel dataset, which until now remained unused, on patents and industrial designs originating in all 278 Portuguese municipalities, between 2003 and 2012. This novel dataset covers the Portuguese mainland, for which we collect data on socioeconomic and demographic variables, at the municipal level, that we used to control for the local context. Portugal is a particularly interesting case study for this purpose. Firstly, the tremendous impact of the great recession in the wake of the sovereign debt crisis, second only to the Greek

[5] The authors find a positive relationship between the development of inventions and product announcements.

[6] As suggested by Porter (2003).

[7] For example, Rodríguez-Pose and Crescenzi (2008) compute multiple regression analyses for all regions of the group of 25 European Union countries and find that local socio-economic conditions matter for the assimilation of innovation and its transformation into economic growth.

crisis, provides a testing ground for intertemporal changes in the relevance of innovation to performance.[8] Secondly, we rely on local-level innovation data that covers all municipalities on the Portuguese mainland, providing a laboratory of variability in the innovation experience within a single national innovation system.

The novel nature of our data, its completeness and reliability in covering complementary aspects of the innovation process, and the key period under consideration, we believe, will provide new valuable empirical insights into the relevance of the innovation process at the local level.

II. Econometric approach

We assess how the frequency with which R&D outputs – patents and industrial designs, which emerge across all of the 278 mainland Portuguese municipalities, relates to local economic outcomes. The following specification is used:

$$ln(Y_{it}) = \alpha_i + \delta_t + \sum_{j=1}^{3} \theta \; Patents\ awarded_{it-j} + \sum_{j=1}^{3} \gamma \; Industrial\ designs\ awarded_{it-j} + \beta Controls_{it-1} + \varepsilon_t$$

where Yit is an economic outcome variable in municipality i and year t, α_i are municipal fixed effects, and δ_t are year dummies. To take care of possible inter-regional confounds, we include a vector of time-variant controls that will be discussed in more detail in the following section. Standard errors are clustered at the municipal level.[9] This specification is run for different sectoral and firm size subsamples, before and after the great recession took hold, and for a subsample of "innovative" municipalities, those that have demonstrated that they are a locus where patents are generated.[10]

A key concern is the possibility, put forward by modern endogenous growth theory, that innovation is endogenous to economic performance, as suggested by Aghion and Jaravel (2015). We mitigate reverse causality using lagged variables of interest and controlling for time-invariant effects using fixed effects and macro effects using year dummies. Furthermore, we develop an instrumental

[8] Carneiro et al. (2014) document the contribution of job destruction to the increase of the unemployment rate. These authors highlight large increases in the incidence of minimum wage earners and nominal wage freezes and claim that the severity of credit constraints played a significant role in the job destruction process. Carreira and Teixeira (2016) show that the crisis period is associated with a strong exit flow of firms and a substantial increase in the job destruction rate, but they do not find evidence that job reallocation is countercyclical.

[9] For robustness, we include baseline estimation tables with standard errors clustered by NUTS 3 regions in the Appendix Table I.

[10] This specification addresses the concern that about 75% of the municipalities in our sample have no patents or industrial designs awarded in the period.

variable (IV) approach as a further way to control for causality by employing lagged patent requests and the number of tertiary education professors as IVs for patents awarded. Whereas the rate of requests may depend on local conditions, namely economic growth and firm performance, the rate and rhythm at which patents are awarded depends on a central authority and is independent of local developments.

III. Data

Economic outcome variables

We use data from the Simplified Business Information database (*Informação Empresarial Simplificada – IES*), collected by Banco de Portugal, for the period between 2007 and 2012. IES is an administrative census that gathers financial information reported by firms for statistical, tax administration, business registry, and financial supervision purposes. The quality of this dataset is very high for several reasons. First, reporting is mandatory – and it is carried out in a single coherent operation with multiple automatic editing rules that ensure consistency. Penalties apply in case of non-compliance. Second, Statistics Portugal (INE) regularly monitors the quality of the data, checking and correcting the accuracy of the information with respondents. On average, about 350 thousand firms report information to the database each year.[11] Our dependent variables are the *ln(Sales)* and the *ln(Value Added)*. To construct them, we sum firm-level data at the municipal level. Our definition of firm encompasses all strictly private businesses with at least one paid employee (cases of self-employment and non-profit organizations are thereby excluded). Moreover, we restrict our sample to firms' headquarters that do not have branches somewhere else to carry out a more careful comparison between municipalities.

We also provide a more refined analysis dividing our dependent variables by sector of activity – between primary, secondary, and tertiary sector – and by size – between micro (with one or two paid employees), small (from three to ten), and medium and large firms (more than ten workers).

For robustness, we take advantage of data from *Instituto de Emprego e Formação Profissional* (IEFP) to construct the unemployment rate at the municipal level. This variable allows us to evaluate the impact of the innovation in the labor market, not restricting the analysis to the private sector. Van Roy et al. (2018), using panel data for the exact same period, and with European firms, find that innovation has an effect on employment.

Innovation variables

As is common in this type of research, the numbers of regional patents are used as a measure of the production of new knowledge (Griliches, 1990; Audretsch

[11] For more information regarding the database see Carneiro et al. (2014).

and Feldman, 1996; Acosta et al., 2009; Broekel, 2015). We use dependent variables kindly provided by *Instituto Nacional de Propriedade Industrial* (INPI) to approximate the output of innovation activities such as the number of Patents awarded, and the number of Industrial Designs awarded. These variables include outcomes from the private and the public sector (universities, institutes, and foundations), which naturally involve innovation outputs filed by the residents of each municipality, associated with innovation processes of differing intensity and characteristics. We present the geographical distribution of these variables in Figure I (for Patents awarded) and Figure II (for Industrial Designs awarded). As expected, innovation variables are more concentrated in coastal areas.

Figure I
Geographical Distribution of Patents Awarded
Mean values for the period 2003-2012.

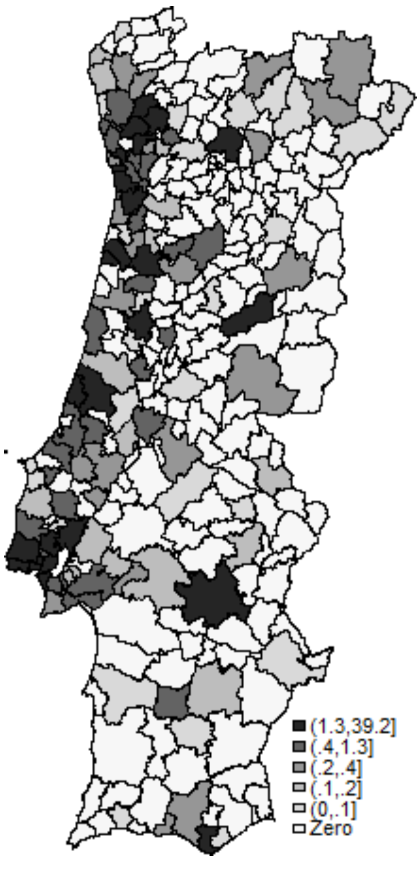
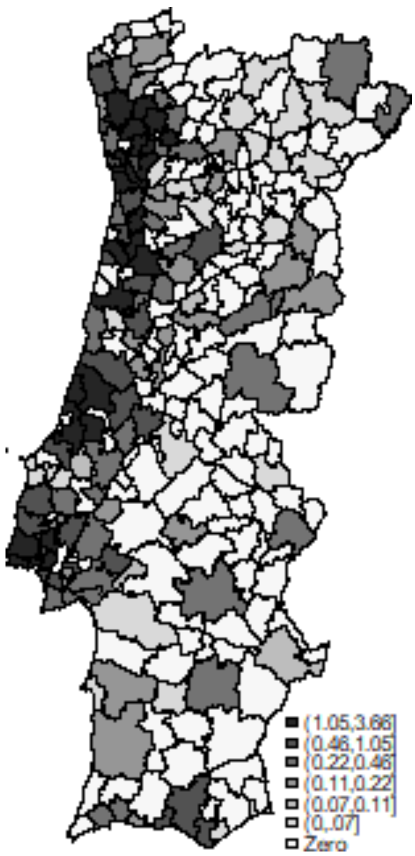


Figure II

Geographical Distribution of Industrial Designs Awarded

Mean values for the period 2003-2012.



Control variables

The literature suggests a wide range of regional characteristics that influence firm's innovation activities (Fritsch and Slavtchev, 2011). As independent variables, we have access to a rich municipal level dataset for the period 2003-2012, constructed merging several statistical sources, including Statistics Portugal (INE), and *Quadros de Pessoal* (a linked employer-employee dataset covering paid work in Portugal).[12] Among the standard controls considered in the literature on regional determinants of economic activity are measures of demographic, institutional and political differences. Following Bleakley and Lin (2012), we measure population density by the number of inhabitants per square

[12] For more information regarding this database see Tavares et al. (2015) and Audretsch et al. (2017).

kilometer. We also take into account the age structure using the age dependency ratio (number of people above 65 and below 15 divided by the active population) and the level of human capital using the tertiary education share (percentage of workers with a degree).[13] As there is no data available for Portuguese municipal GDP, we proxy income and purchasing power with the mean value of real estate and we consider the possibility that motorways increase the performance of locations close to, at least, some kind of such infrastructure with a highway dummy. For Portugal, Audretsch et al. (2017) investigate the impact of a switch from free to charged highway provision on firm numbers and private sector employment. Results from a difference-in-differences (diff-in-diff) analysis indicate a significantly negative effect in treated municipalities vis-à-vis the control group. Through the synergies of exploring an integrated location with informational spillovers, industrial areas can greatly affect the regional variation in business activity.[14] The differences in tax rates might also significantly impact on regional attractiveness (Henrekson and Sanandaji, 2011). We control for the effects of distinct political ideologies and agendas, using *derrama* tax rates (municipal tax rates on the profits of private businesses) and the fraction of leftist mandates in each Municipal Assembly.[15]

Finally, although there is a plethora of papers dealing with the impact of European structural funding in economic development (Becker et al., 2010; 2012; 2013; Giua, 2016, Barone et al., 2016), little is known about the relation between the accessibility of European funds accessibility and regional innovation.[16] With regard to Portugal, Santos and Tavares (2017), using a diff-in-diff approach, exploit an exogenous administrative increase in access to European funding to estimate its impact on small business creation in "convergence" regions. These authors find that being close to a municipality that was granted greater access leads to an increase in (net) firm creation. We use ln (European Funds) transfers to municipalities that were kindly provided by *Agência para o Desenvolvimento e Coesão* (ADC). Our data covers two EU regional policy initiatives: QCA III, 2003 to 2006, and QREN, 2007 to 2012, the latter shifting the emphasis from infrastructure to more innovation-oriented goals.

The descriptive statistics for all variables are reported in Table I.

[13] Acs and Audretsch (1988) report that the total number of innovations is positively correlated to the amount of skilled labor. Using data for European regions, Cuaresma et al. (2014) find that the population share of workers with higher (tertiary) education has a robust positive association with regional economic growth. For Portugal, Baptista and Mendonça (2010) found that regional access to knowledge and an educated workforce significantly influence firm location in specific sectors.

[14] Audretsch et al. (2004) argue that the expansion of industrial parks, science and technology incubators is one of the most effective start-up-oriented policies.

[15] Reynolds et al. (1994) argue that right-wing conservatism tends to be related with a resilient entrepreneurial culture.

[16] One exception is Broekel (2015) who measures the impact of national and European R&D subsidies in stimulating the innovation efficiency of German regions.

Table I

Descriptive Statistics

Variable	N	Mean	Stand. Dev.	Min	Max
Main dependent variables					
ln(Sales)	1668	2.239	0.706	-0.249	4.507
ln(Value Added)	1664	0.792	0.701	-1.596	3.925
ln(Sales)_sector1	1661	15.302	1.627	7.591	20.833
ln(Sales)_sector2	1668	17.919	1.83	12.237	23.155
ln(Sales)_sector3	1668	18.25	1.593	13.521	23.755
ln(Value Added)_sector1	1635	14.073	1.575	4.445	19.724
ln(Value Added)_sector2	1664	16.666	1.755	10.631	22.467
ln(Value Added)_sector3	1666	16.61	1.637	12.433	22.406
ln(Sales)_Micro	1668	16.554	1.377	12.850	21.328
ln(Sales)_Small	1668	17.763	1.391	13.628	22.843
ln(Sales)_Medium/ Large	1653	18.323	1.865	11.644	23.902
ln(Value Added)_Micro	1660	14.927	1.369	9.051	19.982
ln(Value Added)_Small	1664	16.260	1.382	12.389	20.992
ln(Value Added)_Medium/ Large	1647	16.970	1.810	10.815	22.973
Local labor market					
Unemployment Rate	1668	6.53	2.332	1.439	16.933
Innovation variables					
Patents awarded	2780	0.584	2.883	0	66
Industrial Design awarded	2780	0.974	3.695	0	87
Controls					
Population Density	2502	0.312	0.851	0.005	7.582
Tertiary Education Share	2502	0.064	0.032	0.009	0.302
Dependency Ratio	2502	58.942	12.12	38.239	108.789
Mean value of real estate	2502	5.716	4.682	0.121	63.741
Highways dummy	2502	0.535	0.499	0	1
Industrial Area	2502	0.014	0.023	0	0.15
Leftist Mandates	2502	0.55	0.254	0	1
Derrama Tax Rate	2502	0.027	0.039	0	0.1
ln(European Funds +1)	2502	6.09	2.793	0	10.637
Instruments					
University Professors	2453	82.612	510.477	0	7698
Patent requests	2742	1.256	5.722	0	125

IV. Results

In Tables II A and II B below we present the baseline results for the estimated association between the concession of patents and industrial designs and firm performance measured by the *ln(Sales)* and the *ln(Value Added)*. We use three lags of each innovation indicator to capture the dynamics of the association between innovation and performance.[17] In all specifications, we add Municipal Fixed Effects and Year Dummies, and to every second specification we add a vector of time-varying controls, as presented in the previous section. All standard errors are clustered at the municipal level to correct for heteroskedasticity and autocorrelation considerations.

Table II A
Baseline results: Sales

	ln (Sales)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Patents Awarded t-1	-0.003**	-0.004*			-0.004**	-0.005**
	(0.001)	(0.002)			(0.002)	(0.002)
Patents Awarded t-2	0.005**	0.005**			0.006***	0.006**
	(0.002)	(0.002)			(0.002)	(0.002)
Patents Awarded t-3	0.005**	0.005**			0.007**	0.007***
	(0.002)	(0.002)			(0.003)	(0.003)
Industrial Designs Awarded t-1			-0.002	-0.001	-0.003**	-0.002*
			(0.002)	(0.002)	(0.001)	(0.001)
Industrial Designs Awarded t-2			-0.001	-0.001	-0.001	-0.002
			(0.001)	(0.002)	(0.001)	(0.002)
Industrial Designs Awarded t-3			0.000	0.001	-0.001	-0.000
			(0.001)	(0.001)	(0.001)	(0.001)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
Number of observations	1 668	1 668	1 668	1 668	1 668	1 668
Adjusted R2	0.027	0.037	0.025	0.035	0.027	0.037

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

In the first two columns of Table II A, we find that there is a decrease in average firm sales one year after an increase in patents conceded, and a stronger

[17] We present results with one and two lags in Table I in the Appendix.

increase two and three years afterward. Columns three and four show no statistically significant association between awarded industrial designs and firm sales. Moreover, when both patents and industrial designs conceded are included as regressors, patents awarded again show an initial decrease in sales, followed by stronger increases in the second and third years. To have a clear idea of the magnitude of our results, one additional patent is associated with a decrease of 0.5% in sales in the following year and is compensated for by an increase of 0.6% and 0.7% in the second and third years, respectively. We can interpret this pattern as suggestive of an initial "investment" period where the use of the patent may actually cause sales to fall, but this is then compensated for by the rebound in the two following years.

Table II B

Baseline results: Value Added

	ln (Value Added)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Patents Awarded t-1	0.003	0.002			0.000	0.000
	(0.003)	(0.003)			(0.003)	(0.003)
Patents Awarded t-2	0.007***	0.007***			0.008***	0.008***
	(0.002)	(0.002)			(0.002)	(0.002)
Patents Awarded t-3	0.010***	0.011***			0.013***	0.013***
	(0.003)	(0.002)			(0.003)	(0.003)
Industrial Designs Awarded t-1			-0.003**	-0.002	-0.005***	-0.003**
			(0.002)	(0.002)	(0.001)	(0.002)
Industrial Designs Awarded t-2			0.001	0.001	-0.001	-0.000
			(0.002)	(0.002)	(0.002)	(0.002)
Industrial Designs Awarded t-3			-0.002	-0.000	-0.002	-0.001
			(0.002)	(0.002)	(0.002)	(0.002)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
Number of observations	1 664	1 664	1 664	1 664	1 664	1 664
Adjusted R2	0.064	0.077	0.062	0.074	0.065	0.076

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Examination of Table II B, where value added is the dependent variable, presents us with a similar pattern of association. While initially there is no impact on value added, more patents boost value added in the second and third years after being awarded, and this rebound is even more pronounced than in the case of sales. In the third year after a patent is awarded, its association with an increase in value added is about twice as strong as with sales. To have an idea of the magnitude, one additional patent is associated with an increase of 0.7% and 1.3% in value added in the second and third years, respectively.

In both Tables IIA and II B, adopting an additional industrial design seems to have an initial negative impact on sales and value added, while there is no statistically significant evidence of a later rebound in terms of firm performance.

We undertake robustness tests of three kinds. First, we run our baseline results using standard errors clustered at the NUTS 3 regions rather than municipalities to test for possible autocorrelation concerns. The results for this specification are reported in Appendix II A and II B, and are in line with those in Tables II A and II B. Second, Tables III through to VI inspect and confirm results in the benchmark specification in Tables II A and II B by estimating them for subsamples of interest. Third, we substitute our financial dependent variables by the unemployment rate to measure the impact on the local economy as a whole.

In Table III, we study subsamples of interest dividing our dependent variables by the three economic sectors of activity – between sector 1 (agriculture and fisheries), sector 2 (manufacturing), and sector 3 (services) – to find that it is through sector 2 that innovation is associated to both higher sales and value added some years after it is undertaken. The association with sales is about two times stronger for the manufacturing industry than for the whole sample. In the case of value added, one more patent is associated with an average increase of 1.8% in the first year, and of 2.4% after two and three years. The nature of patents suggests that these benefits on production and performance are likely to be seen in industry. In contrast, there is no statistical association whatsoever between innovation measured by patents awarded in the municipality and firm performance in the agricultural and the service sectors. The award of industrial designs has no clear patterns of association with firm performance in any of the sectors. Again, if anything, there is only evidence of some decrease in performance in the year after innovation has commenced.

Table III
By Sector

	ln (Sales)			ln (Value Added)		
	Sector 1	**Sector 2**	**Sector 3**	**Sector 1**	**Sector 2**	**Sector 3**
Patents Awarded t-1	0.006	-0.006	-0.003*	-0.010	0.018***	0.000
	(0.012)	(0.005)	(0.002)	(0.011)	(0.004)	(0.002)
Patents Awarded t-2	-0.020	0.017**	-0.002	-0.036**	0.024***	0.000
	(0.015)	(0.006)	(0.003)	(0.015)	(0.005)	(0.002)
Patents Awarded t-3	-0.011	0.011**	0.002	-0.011	0.024***	0.001
	(0.015)	(0.004)	(0.002)	(0.015)	(0.006)	(0.002)
Industrial Designs Awarded t-1	-0.002	-0.005*	-0.001	-0.002	-0.009***	-0.001
	(0.008)	(0.003)	(0.001)	(0.007)	(0.002)	(0.001)
Industrial Designs Awarded t-2	0.002	0.002	-0.001	0.005	0.002	-0.001
	(0.008)	(0.003)	(0.001)	(0.008)	(0.004)	(0.002)
Industrial Designs Awarded t-3	0.011*	0.003	-0.001	-0.003	-0.002	0.002
	(0.007)	(0.003)	(0.001)	(0.010)	(0.004)	(0.002)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	1 661	1 668	1 668	1 635	1 664	1 666
Adjusted R2	0.068	0.030	0.039	0.031	0.103	0.155

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table IV examines the association of innovation and firm performance by size – between micro (with one or two paid employees), small (from three to ten), and medium and large firms (more than ten workers), – and uncovers the exact same pattern for medium and large companies as for the whole sample, in Tables II above. Even quantitatively the effects are similar, although there is no evidence of the initial cost of the implementation of patents leading to a decrease in sales and value added. The sales and value added of micro and small firms have no association with innovation as measured by patent counts.

Table IV

By Firm Size

	ln (Sales)			ln (Value Added)		
	Micro	**Small**	**Medium/ Large**	**Micro**	**Small**	**Medium/ Large**
Patents Awarded t-1	-0.003	0.003	-0.006*	-0.002	-0.003	0.004
	(0.002)	(0.004)	(0.004)	(0.002)	(0.004)	(0.003)
Patents Awarded t-2	-0.000	0.001	0.006**	0.004	0.008	0.008**
	(0.002)	(0.004)	(0.003)	(0.003)	(0.006)	(0.003)
Patents Awarded t-3	0.001	-0.005	0.008**	0.004*	0.008	0.011***
	(0.002)	(0.004)	(0.003)	(0.002)	(0.006)	(0.003)
Industrial Designs Awarded t-1	-0.003*	-0.004**	-0.003**	0.000	-0.009***	-0.002*
	(0.002)	(0.002)	(0.001)	(0.002)	(0.003)	(0.001)
Industrial Designs Awarded t-2	0.001	0.006	-0.003	0.001	-0.001	0.001
	(0.002)	(0.004)	(0.002)	(0.002)	(0.003)	(0.002)
Industrial Designs Awarded t-3	0.001	-0.002	-0.001	0.003	0.001	-0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	1 664	1 668	1 653	1 668	1 660	1 647
Adjusted R2	0.140	0.007	0.017	0.070	0.040	0.101

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

In Table V, we take a closer look at the crisis years to assess whether the association between patents and performance disappears in the crisis years. We find otherwise: not only is the number of patents awarded, by municipality, positively associated with both sales and value added, but that association is present for the whole sample, for manufacturing, and medium to large-sized firms. Furthermore, the quantitative effect of innovation on firm performance is not quantitatively weaker in the crisis years.

Table V
The Crisis (2009-2012)

	ln (Sales)			l	In (Value Added)	
	Total	**Sector 2**	**Medium/ Large**	**Total**	**Sector 2**	**Medium/ Large**
Patents Awarded t-1	-0.009*	-0.011	-0.012*	-0.005	0.018**	0.004
	-0.005	-0.007	(0.007)	-0.007	-0.007	(0.006)
Patents Awarded t-2	0.007*	0.021***	0.008	0.007**	0.028***	0.004
	-0.004	-0.006	(0.005)	-0.004	-0.006	(0.005)
Patents Awarded t-3	0.008**	0.013***	0.011***	0.015***	0.031***	0.014***
	-0.003	-0.004	(0.004)	-0.004	-0.008	(0.004)
Industrial Designs Awarded t-1	-0.003**	-0.003	-0.004*	-0.006**	-0.009***	-0.005***
	-0.002	-0.003	(0.002)	-0.002	-0.003	(0.002)
Industrial Designs Awarded t-2	-0.002	0.004	-0.004	-0.001	0.002	-0.001
	-0.002	-0.004	(0.003)	-0.002	-0.005	(0.003)
Industrial Designs Awarded t-3	-0.002	0.003	-0.002	-0.003	-0.002	-0.001
	-0.002	-0.004	(0.003)	-0.004	-0.005	(0.003)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	No	Yes	Yes
Number of observations	1 112	1 112	1 111	1 111	1 108	1 098
Adjusted R2	0.041	0.042	0.018	0.097	0.166	0.126

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

We compare the magnitude of coefficients related to Patents awarded for firms in sector 2 and medium to large firms in Figure III and Figure IV, respectively.

Figure III

The Impact of One Extra Patent Count for Firms in Sector 2

Full Period (2007-2012) And Crisis Period (2009-2012).

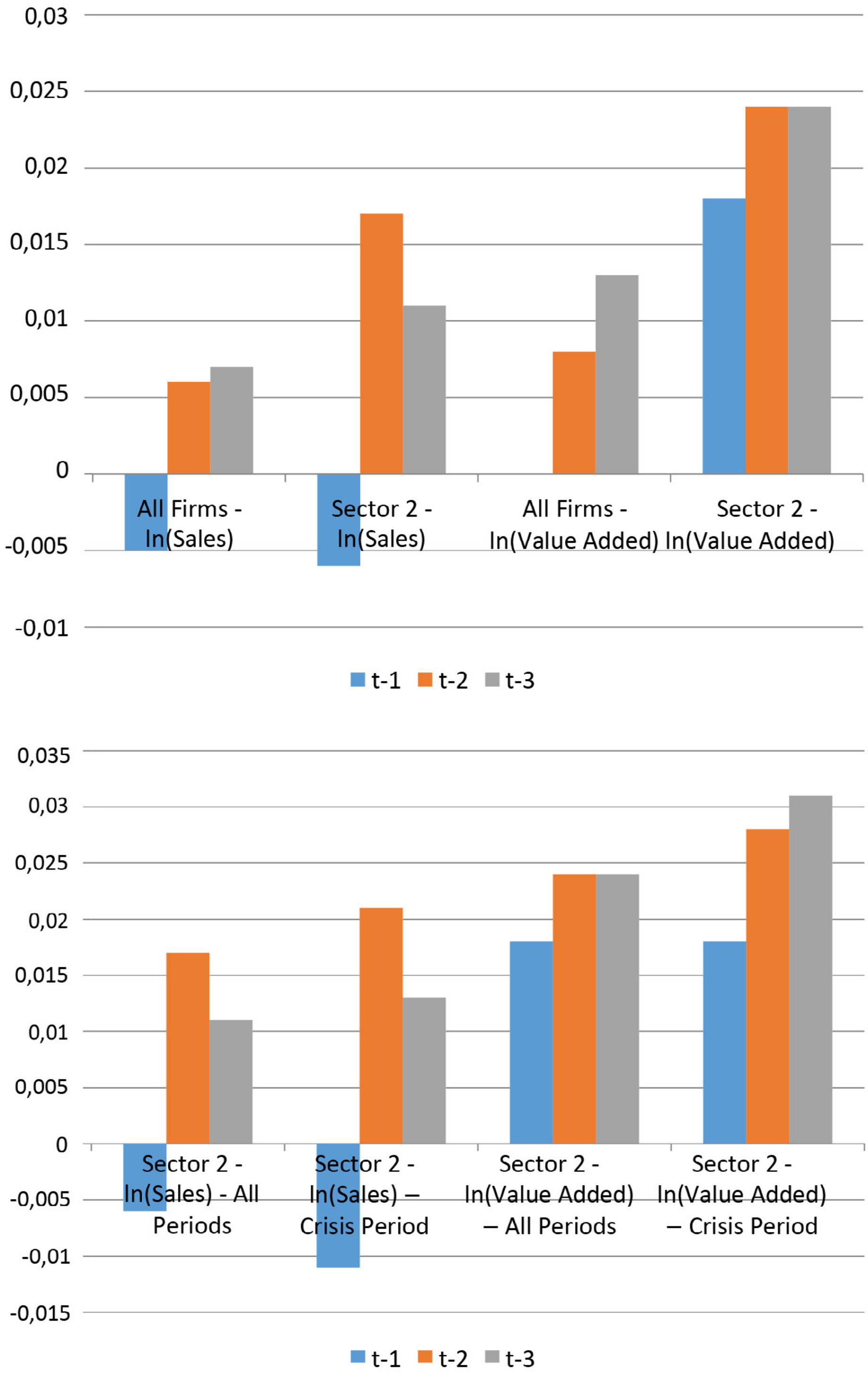
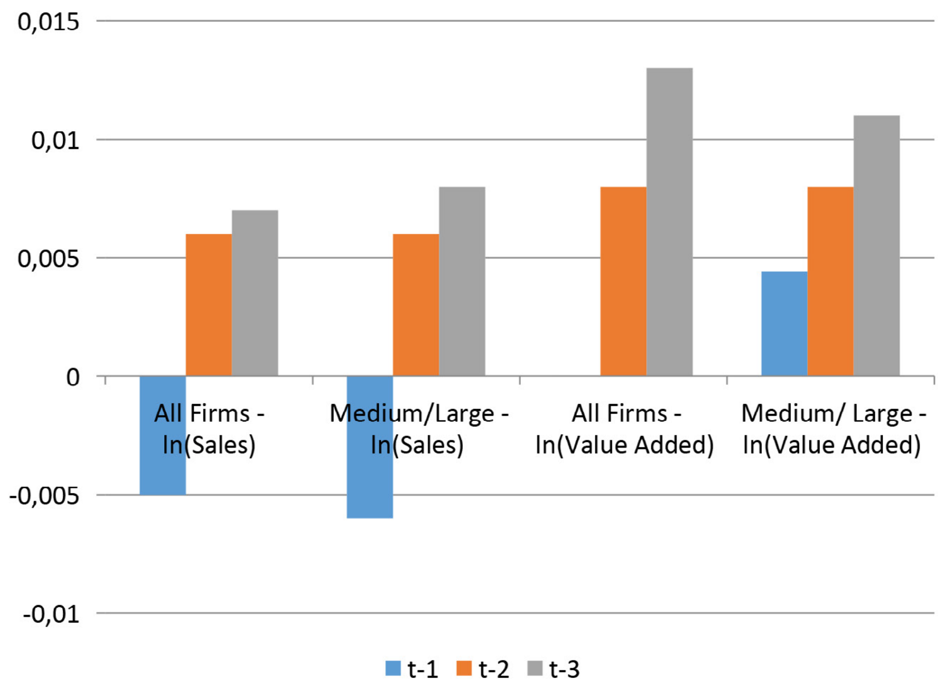
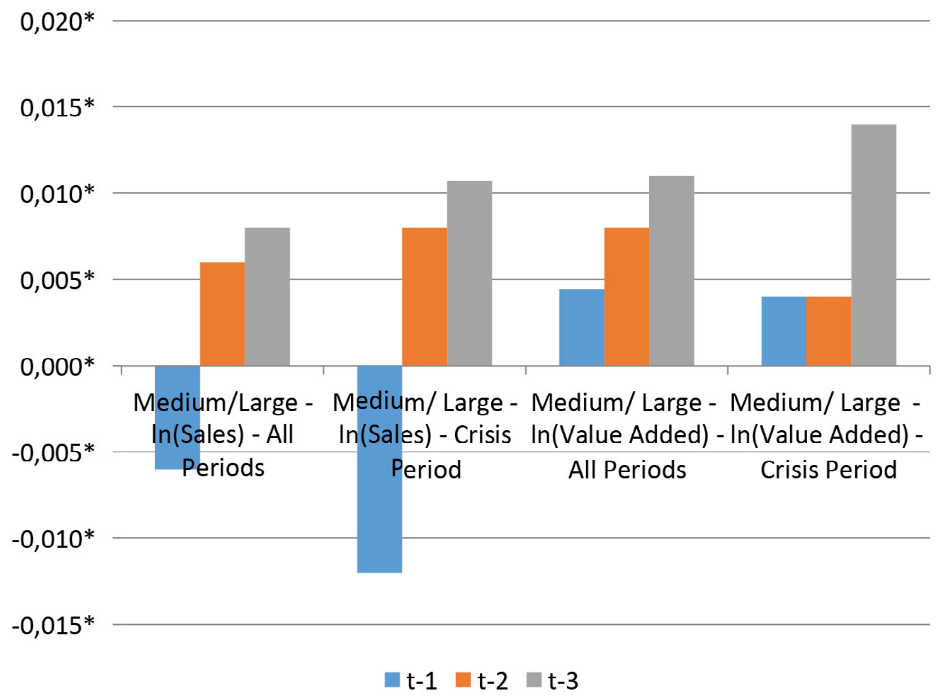


Figure IV

The Impact of One Extra Patent Count for Medium and Large-Sized Firms

Full Period (2007-2012) And Crisis Period (2009-2012).





In Table VI, we restrict our sample to those municipalities that had at least one patent awarded in the three years before firm performance is measured. The goal is to certify that our results do not stem from the differences between "innovative municipalities", where firms have demonstrated an ability to have patent requests awarded, and "non-innovative municipalities". Concerning the subsample of innovative municipalities, we assess whether more patents awarded translate into yet higher sales and value added. The estimates remain significant, displaying a similar qualitative pattern and quantitative strength. If anything, the benefits of additional innovation on firm performance are visible earlier on, after one year.

Table VI

Innovative Municipality Sample

	ln (Sales)			ln (Value Added)		
	Total	**Sector 2**	**Medium/ Large**	**Total**	**Sector 2**	**Medium/ Large**
Patents Awarded t-1	-0.001	-0.002	-0.002	0.006***	0.023***	0.009***
	(0.002)	(0.004)	(0.002)	(0.002)	(0.004)	(0.003)
Patents Awarded t-2	0.003**	0.013**	0.003	0.007**	0.021***	0.009**
	(0.001)	(0.005)	(0.003)	(0.003)	(0.005)	(0.004)
Patents Awarded t-3	0.004**	0.011**	0.005*	0.009**	0.023***	0.011**
	(0.002)	(0.005)	(0.003)	(0.003)	(0.008)	(0.004)
Industrial Designs Awarded t-1	0.001	-0.002	-0.001	0.000	-0.005**	-0.001
	(0.001)	(0.004)	(0.001)	(0.001)	(0.002)	(0.001)
Industrial Designs Awarded t-2	0.000	0.000	-0.002	0.001	0.001	0.000
	(0.002)	(0.004)	(0.003)	(0.002)	(0.005)	(0.003)
Industrial Designs Awarded t-3	0.001	0.001	0.000	0.001	-0.005	-0.001
	(0.001)	(0.003)	(0.001)	(0.001)	(0.004)	(0.001)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	No	Yes	Yes
Number of observations	253	253	253	253	253	253
Adjusted R2	0.420	0.399	0.588	0.563	0.588	0.378

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

One possibility is that innovation is associated not only with improved firm performance but has a strong enough impact on the local economy that aggregate indicators such as the rate of unemployment also change. This is examined in Table VII. We find robust evidence that, for the whole sample and for the crisis years, there is a statistically significant decrease in the rate of unemployment, three years after a new patent has been awarded.

Table VII
Unemployment Rate

	Unemployment Rate	
	2006-2012	**Crisis (2009-2012)**
Patents Awarded t-1	-0,003	0,015
	-0,017	-0,018
Patents Awarded t-2	-0,009	-0,005
	-0,020	-0,022
Patents Awarded t-3	-0,024**	-0,024*
	-0,010	-0,013
Industrial Designs Awarded t-1	0,003	-0,005
	-0,008	-0,011
Industrial Designs Awarded t-2	0,008	-0,009
	-0,011	-0,012
Industrial Designs Awarded t-3	-0,013	-0,009
	-0,014	-0,016
Municipal Fixed Effects	Yes	Yes
Year dummies	Yes	Yes
Controls	Yes	Yes
Number of observations	1946	1 112
Adjusted R2	0,657	0,757

Note: Standard errors are clustered at the NUTS 3 level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

As mentioned in the presentation of the econometrics approach, modern growth theories suggest that innovation is endogenous to economic performance. Our first approach is to lag innovation indicators in the specification of firm performance. We have seen above that the robust and consistent complex pattern of signs and significance of the lagged coefficients suggests the estimates are not just a spurious association. We now adopt an IV approach to deal with the remaining questions on endogeneity. We measure the three lags of the patent counts awarded using two vectors of instruments, also lagged for the three periods. The first instrument is the number of patents requested, as reported in the INPI dataset. The number of patents requested is different from those of patents awarded, but all requests have to be formalized before they can be awarded. It is clear that patent requests are associated with patents awarded, but not directly with firm performance, not after the effect of the patents awarded has been taken into account. The other instrumental variable is the number of tertiary degree professors, from all scientific areas, as reported in *Direção-Geral de Estatísticas da Educação e Ciência* (DGEEC). The more university professors in a jurisdiction, the higher is the probability that an innovative system at the highest level, capable of generating patents, is in place. The two instrumental variables are obviously partially correlated with the number of patents awarded. We believe that the exclusion restriction is also satisfied for two main reasons. First, for patents to be awarded, they must be requested. Whereas the rate of requests may depend on local conditions, namely economic growth and firm performance, the rate and rhythm at which patents are awarded depends on a central authority, and is independent of local developments. Requests imply significant early investment costs that, due to the risk that the patent might not be awarded (and even if it is awarded it might take some time), may not necessarily have implications for production and therefore to sales. Second, tertiary degree scholars constitute a residual part of the population, so they consume a small portion of the sales. However, universities and research institutes generate important environments to induce growth – not only through partnerships with the private sector but also by creating and shaping local human capital.[18]

In Table VIII we present the results for our two economic outcomes, sales and value added. All specifications include municipal fixed effects, year dummies, and the vector of time-varying controls previously described. We restrict our analysis to the sample of "more innovative municipalities". In this way we are relying on the variation between more and less innovative – in terms of patents an industrial designs, as the source of variability to identify our coefficients, and not at all in the variability between municipalities with positive innovation outcomes and those that never demonstrated innovative capacity. In the case of sales, we do not find statistically significant effects of the innovation counts, except for medium and large firms. In this subsample, one additional patent seems to cause an initial reduction in sales of about 0,8%, that is compensated by an increase of more than 1% two years after. In the case of value added, one extra patent seems to cause an average increase of 1,4% in average value added for firms in the municipality. These effects are not evenly distributed. Manufacturing firms, as before, seem to gain more – on average, 3,6%, and medium and large firms also reap more of the benefits of innovation. All in all, our results suggest that causality is already mostly taken care of in the benchmark and associated specifications.

[18] We present a correlation table between our dependent variables, innovation outcomes, and our instruments in the Appendix Table III.

Table VIII
2nd Stage IV Results

	ln (Sales)			ln (Value Added)		
	Total	**Sector 2**	**Medium/ Large**	**Total**	**Sector 2**	**Medium/ Large**
Patents Awarded t-1	-0.005	-0.009	-0.008**	-0.001	0.017***	0.001
	(0.004)	(0.007)	(0.004)	(0.006)	(0.006)	(0.006)
Patents Awarded t-2	-0.000	0.010	-0.001	0.001	0.013	0.004
	(0.004)	(0.007)	(0.007)	(0.008)	(0.012)	(0.008)
Patents Awarded t-3	0.007	0.016	0.011**	0.014**	0.036***	0.018***
	(0.005)	(0.011)	(0.006)	(0.006)	(0.008)	(0.006)
Industrial Designs Awarded t-1	0.001	-0.002	-0.001	0.000	-0.005**	-0.001
	(0.002)	(0.004)	(0.001)	(0.002)	(0.003)	(0.002)
Industrial Designs Awarded t-2	-0.000	-0.000	-0.002	-0.001	-0.002	-0.001
	(0.002)	(0.004)	(0.003)	(0.002)	(0.005)	(0.003)
Industrial Designs Awarded t-3	-0.000	-0.002	-0.002	-0.001	-0.009**	-0.003*
	(0.001)	(0.004)	(0.001)	(0.001)	(0.004)	(0.002)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	240	240	240	240	240	240
Adjusted R2	0.070	0.087	0.100	0.237	0.385	0.023

Note: Results are computed using xtivreg2 command in STATA (for more information see Schaffer, 2015). Our instruments are the number of patents requested and the number of university professors. First stage endogenous regressors are substantially partially correlated with the endogenous variables. First stage F-statistics are above 10. Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

V. Concluding remarks

In this study, we combine information from a novel dataset on patents and industrial designs awarded to estimate their impact on firm sales and value added. Our information covers all 278 Portuguese mainland municipalities during the 10 years between 2003 and 2012, which enables us to control for local context, innovation dynamics, and properly address the issue of causality.

Our results uncover clear patterns whereby patents and industrial designs initially have a neutral or negative impact on sales and value added, more in the former than in the latter. This initial "cost of innovation" is more than compensated for, in the case of value added, by statistically significant and quantitatively robust increases in sales and in value added, more so in the later than the former. Several robustness checks, namely alternative clustering of errors, confirm these results.

By examining specific subsamples, we are able to identify large firms in the industrial sector as the main vehicles to transform innovation into palpable performance results. The relevance of value added is confirmed. Furthermore, restricting the sample to municipalities that have demonstrated local capacity to our overall results, including the relevance of industry and of firm size.

As patents are awarded by a national independent authority, their rate and rhythm of attribution are impervious to local economic conditions. Moreover, our lagged independent variable setup, delivers robust and consistent estimates, unlikely to be produced by spurious correlations. Both facts indicate that our results are suggestive of a causal relationship between patents awarded and certain dynamics of firm performance. We complement our investigation of causality by implementing an IV approach where we instrument for patents awarded with the number of patents requested, and the number of tertiary education professors present in the municipality. Our IV estimates are consistent with the other results, confirming an initial cost to innovation, in terms of firm performance, that is compensated by later increases in sales and, most significantly, in value added. Again, the manufacturing sector and medium to large firms (measured by the number of employees) seem the vehicles for the innovation to results process.

Our results suggest further avenues for research. The most relevant, in our view, is the analysis of cross-municipality spillover effects of innovation, as well as estimates to the distance decay of innovation. We believe such analysis would rightly complement the novel results on the local effects of innovation we uncovered here, with the probable impact of such effects on proximate or similar neighboring geographies.

Appendix

Table IA

Baseline Results: Sales

Innovation variables lagged one or two periods.

	ln (Sales)			
	Total		Sector2	
Patents Awarded t-1	-0.005**	-0.005**	-0.008	-0.005**
	(0.002)	-0.002	(0.005)	-0.002
Patents Awarded t-2		0.004		0.004
		-0.002		-0.002
Industrial Designs Awarded t-1	-0.002	-0.002	-0.002	-0.002
	(0.002)	-0.001	(0.004)	-0.001
Industrial Designs Awarded t-2		-0.001		-0.001
		-0.002		-0.002
Municipal Fixed Effects	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Controls	Yes	Yes	No	Yes
Number of observations	1 668	1 668	1 668	1 668
Adjusted R2	0.036	0.036	0.028	0.036

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table IB

Baseline Results: Value Added

Innovation variables lagged one or two periods.

	ln (Value Added)			
	Total		Sector2	
Patents Awarded t-1	0.000	0.001	0.018***	0.020***
	(0.004)	-0.004	(0.005)	-0.006
Patents Awarded t-2		0.005**		0.019***
		-0.002		-0.005
Industrial Designs Awarded t-1	-0.001	-0.002	-0.004	-0.006**
	(0.002)	-0.002	(0.003)	-0.003
Industrial Designs Awarded t-2		0.001		0.005
		-0.002		-0.004
Municipal Fixed Effects	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Controls	Yes	Yes	No	Yes
Number of observations	1 664	1 664	1 664	1 664
Adjusted R2	0.074	0.074	0.097	0.099

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table II A

Baseline Results: Sales

Standard errors clustered at the NUTS 3 level.

	ln (Sales)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Patents Awarded t-1	-0.003	-0.004			-0.004**	-0.005**
	(0.002)	(0.002)			(0.002)	(0.002)
Patents Awarded t-2	0.005**	0.005*			0.006**	0.006**
	(0.002)	(0.002)			(0.003)	(0.002)
Patents Awarded t-3	0.005*	0.005**			0.007**	0.007**
	(0.002)	(0.002)			(0.003)	(0.003)
Industrial Designs Awarded t-1			-0.002*	-0.001	-0.003**	-0.002**
			(0.001)	(0.001)	(0.001)	(0.001)
Industrial Designs Awarded t-2			-0.001	-0.001	-0.001	-0.002
			(0.002)	(0.002)	(0.002)	(0.002)
Industrial Designs Awarded t-3			0.000	0.001	-0.001	-0.000
			(0.001)	(0.001)	(0.001)	(0.001)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
Number of observations	1 668	1 668	1 668	1 668	1 668	1 668
Adjusted R2	0.027	0.037	0.025	0.035	0.027	0.037

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table II B

Baseline Results: Values Added

Standard errors clustered at the NUTS 3 level.

	ln (Value Added)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Patents Awarded t-1	0.003	0.002			0.000	0.000
	(0.003)	(0.004)			(0.003)	(0.004)
Patents Awarded t-2	0.007***	0.007***			0.008***	0.008***
	(0.002)	(0.002)			(0.002)	(0.002)
Patents Awarded t-3	0.010***	0.011***			0.013***	0.013***
	(0.003)	(0.002)			(0.004)	(0.004)
Industrial Designs Awarded t-1			-0.003**	-0.002	-0.005**	-0.003*
			(0.001)	(0.002)	(0.002)	(0.002)
Industrial Designs Awarded t-2			0.001	0.001	-0.001	-0.000
			(0.002)	(0.001)	(0.002)	(0.002)
Industrial Designs Awarded t-3			-0.002	-0.000	-0.002	-0.001
			(0.002)	(0.002)	(0.002)	(0.002)
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
Number of observations	1 664	1 664	1 664	1 664	1 664	1 664
Adjusted R2	0.064	0.077	0.062	0.074	0.065	0.076

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table III
Correlation Tables

ln (Sales)	1					
ln (Value Added)	0.931	1				
Patents Awarded	0.231	0.246	1			
Industrial Designs Awarded	0.314	0.326	0.686	1		
Patent Requests	0.269	0.286	0.838	0.795	1	
Industrial Design Requests	0.328	0.343	0.756	0.923	0.766	1
Tertiary Degree Professors	0.195	0.210	0.859	0.714	0.874	0.728

Note: Standard errors are clustered at the municipal level. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

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