Regional innovation and patent system effectiveness: evidence from Greece

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Abstract

Patent Libraries are a growing network of innovation hubs across the member states of the European Patent Organization that assist local inventors in using the patent system effectively. We examine whether local patent libraries affect knowledge generation and diffusion and provide the first systematic evidence using the opening and closure of three regional patent libraries in Greece as a quasi-natural experiment. Employing a difference-in-difference estimation framework, we show a mild asymmetric effect: whereas the opening of the local patent libraries had no significant contemporaneous effect, apart from one region, their closure induced a mild decrease on patent applications which varied significantly among regions. These results imply that the impact of such institutions on innovation takes time to build, but once in place, they could induce a positive effect which varies among regions.

Keywords: Patents; regional innovation; regional growth; Smart specialization; knowledge spillovers
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1. Introduction

Innovation is critical for fostering economic growth (Romer 1990), and it can be a competitive advantage for a region. On the other hand, regional characteristics are essential for knowledge generation, and successful diffusion since innovation itself is considered a territorial embedded process (Crescenzi and Rodríguez-Pose 2011). Local institutions could play an important role in shaping this two-way relationship since they facilitate Research and Development (R&D) efforts and knowledge diffusion (Furman et al. 2018). In this study, we aim to shed light on the contribution of regional patent libraries centres (henceforth, PATLIB), considering their role as research-enhancing institutions, on regional innovation utilizing the operation and the random closure of PATLIB offices in Greece.

PATLIB is a growing network of regional patent information centres in Europe. They operate as "innovation hubs", aiming to guide and support local inventors to apply for a title, through each national system, protecting their novelty successfully. The users of the patent system might face a variety of difficulties that could hinder their protection efforts. Such challenges include tackling with the complexity of the patent procedure, the establishment of a successful patent strategy, evaluating the potential of the final products in a global market and how to enforce intellectual property rights (IPRs) in other countries (Artelsmair et al. 2009). Thus, PATLIB services might be essential for small and medium-sized enterprises (SMEs), which accounted for 99.7% of all enterprises in the non-financial business sector of the OECD area in 2013 (OECD 2017), or academic researchers who might lack relevant experience.

In order to investigate the role of the PATLIB offices in innovation production, we take advantage of the Greek PATLIBs' operation and especially their quasi-random closing. Hellenic Industrial Property Organisation (HIPO), the Greek Patent Office, following the European wave of opening regional patent offices, inaugurated three new PATLIBs in a short period from the November of 1995 until the July of 1996. PATLIBs were established in Thessaloniki, the second most populated city in Greece, in Patra and Heraklion. Libraries operated until February of 2009 where the last one was closed. The reasoning behind this

decision was not sufficiently provided, and no official statement was made. Interviewing the old executives of the organization informed us that the decision was not related to any efficiency concern, and it was probably related to other bureaucratic issues[1]. Thus, we consider their closing as a quasi-natural experiment to our analysis.

Obtaining exogenous variation when institutions impact is concerned, is challenging since their operation is usually based on their efficiency and the benefits that they offer. Furthermore, the choice of location is usually a strategic decision, and mostly, they are established in areas where their impact would be greater. Thus, taking into account the quasi-randomness of this PATLIBs termination, interesting results could be drawn relating to the role of these institutions innovation. To our knowledge, an analysis from this scope takes place for the first time.

We employ a difference in differences estimation framework approach for evaluating the library's effect on innovation. Year and region fixed effects are considered to account for time trends and systematic regional differences. We also add regional characteristics as controls to gain a deeper understanding of the channels that PATLIBs affected the patent activity. The opening effect is positive but not significant in many tests, which is not surprising as it could take more years for building a substantial impact on innovation, and the policy was not random. However, our analysis indicates mildly negative effects on regional innovation due to the PATLIBs closing. Our results remain similar for several robustness checks. The rest of the paper provides a related literature review, a more detailed PATLIB system description, empirical strategy, and results followed by the conclusion drawn from the analysis.

[1] The main explanation behind the closing decision, received during the interviews, was that staff in libraries was paid as freelances but according to Greek Law when a freelancer has a contract renewed constantly in the same organization and under some other conditions, he/she can claim a permanent position in the organization. However, hiring in legal entities that belong to the greater government sector, such as the Hellenic Industrial Property Organisation, is complex and demands a lot of effort. Therefore, it was preferred to close the offices instead of hiring permanent staff for their operation. Until their closing the offices operated fully.

2. Related Literature

Regions play a notable role in aggregating growth by cultivating innovation and technology development. 'Innovation is a territorially embedded process and cannot be fully understood independently of the social and institutional condition of every space' (Rodriguez-Pose and Crescenzi 2008, p. 54). Therefore, this paper illustrates further the role of institutions in regional innovation since Patent Libraries could serve as research-enhancing institutes (Furman et al. 2018). Economic institutions that aim the accumulation of knowledge, leading to innovation, using these mechanisms are the so-called research-enhancing institutions (Furman and Stern 2011).

The working paper by the Furman et al. (2018), which examines the effect of information disclosure through patents on subsequent innovation, is closer to our work. They utilize the expansion of the USPTO Patent and Trademark Depository Library system from 1975 to 1997. Using this period turns convenient for taking advantage of the pre-internet era and the regional variation in the costs of access to patent documents yielded by the opening of libraries. Main results show that after the opening of a library the local patenting increases by 17% relating to control region, local inventors tend to cite more distant and technological diverse patents and that libraries turn to be significant for young companies, local business formation, and job creation. To our knowledge, the European Patent Library system has not been studied in literature before, and this kind of exogenous closing has not been a matter of study either.

Some researchers have exploited other institutes operation for estimating their role in innovation generation. Furman et al. (2011) empirically estimated the impact of a biological resource center on knowledge production and diffusion taking advantage exogenous shifts of biomaterials across institutional setting finding that effective institutions boost the cumulative impact of individual scientific discoveries. What is more, Donges et al. (2018) investigate the effect of inclusive institutions on innovation using data for Imperial Germany. They conclude that the number of patents per capita was higher in occupied counties than in unoccupied ones and the impact of institutions on innovation is amplified when the banking sector is developed.

Our research also contributes to the general issue of the patent system effectiveness in generating innovation. Theoretically speaking, the patent effect on innovation is described by the contract and the reward theory; a patent serves as a "contract" between the inventor and the society where the inventor agrees to make his/her invention public in exchange for exclusive rights on it which play the role of the "reward". However, a great debate exists whether patent systems affect innovation generation (Williams, 2017). Arguments against them exist such as Boldrin and Levine (2013) claiming that the insufficiency of empirical evidence to support positive patent effect on innovation. On the other hand, many insist that patents facilitate the dissemination of technical information, encouraging productivity growth (Machlup and Penrose, 1950; Landes and Posner, 2003). Utilizing the exogenous variation of the Greek PATLIB offices closing, we are able to disentangle the effect of Patent Offices on innovation production.

3. Patent Libraries

Patent Information Centers or Patent Libraries (PATLIB) primary purpose is providing technological information to prospective patent applicants and support their efforts through several extra services. They operate in cooperation with the national patent offices of the member states of the European Patent Organisation (EPO). The PATLIB Network is continuously growing. During the 1995 116 Centres operated when in 2003, the network expanded in 283 centres. Today, more the 300 PATLIB centres exist across Europe working at a regional level.

PATLIB centres usual services include, apart from patent information services, technology, and competitor watches, patent statistics, patent valuation/audits, advice on patent strategy and guidance on commercialisation/technology transfer. The patent information source is national and international patent databases. Furthermore, some offices might provide additional services relating to other intellectual property rights, such as trademarks, registered designs, and utility models.

PATLIBs promote public awareness by organizing relevant events such as presentations and workshops where locals become familiar with the methods of innovation protection. Knowing the regional characteristics -economic, industrial, and social profile- of their area,

a PATLIB office is possible to work as an innovation hub that assists local inventors in producing further knowledge. Especially for small entities that they cannot afford paid counseling, such as SMEs, private inventors and students, PATLIB centres can be the catalyst in the innovation engine.

In Greece, there were three regional patent offices have been operated for approximately the same period, in Heraklion (opened at 01/11/1995 and closed at 28/02/2009), in Thessaloniki (opened at 20/02/1996 – closed at 28/02/2009) and in Patra (opened at 31/07/1996 – closed at 31/08/2008). Greek regional patent libraries offered mainly patent, utility models and designs prior art information and they supported the whole process of applying for a title by providing guidance, solving potential questions by applicants and informing about potential protection strategies.

Based on discussions with the executives of the Hellenic Industrial Property Organisation, informed us that the reasoning for the closure of the local offices of their closing was not connected to either with their efficiency or their performance. Given that there was no official explanation provided and that behind this decision. Furthermore, as their closing dates indicate, they stopped their operation before the beginning of the financial Greek economic crisis, expands. For these reasons, we assume that their closing was quasi-random, and use considered it as a quasi-natural experiment to our analysis.

4. Empirical strategy and datasets

We use a newly collected and cleaned patent dataset from the HIPO, along with Cambridge Econometrics European Regional Database to control for regional characteristics. As controls, we employed Gross Fixed Capital Formation (GFCF) (used as a proxy for local investment), employment and population data from the Cambridge Econometrics European Regional Database for the 1991-2014 period. Table 1 provides the descriptive statistics for all variables utilizes in our analysis. For the 2015 and 2016 years we use data extracted from Eurostat database (access 16/05/2019). We employ a difference in differences estimation framework for evaluating the library's effect on innovation, taking into account a seven-year window from opening (1996) and closing (2009). Year and region fixed effects are considered to account for time trends and systematic regional differences. We

also add regional characteristics as time-varying controls that would help to gain a deeper understanding of the channels that PATLIBs affected the patent activity and region-specific time trends are employed to allow treatment and control regions to follow different trends.

Table 1 Descriptive statistics of variables

	Total	Peloponnese	Central Macedonia	Crete
	1989-2003	1989-2003	1989-2003	1989-2003
Patent applications	31.29 (65.57)	21.13 (7.78)	55.72 (18.83)	23.48 (11.70)
Industrial investment	363,608,125.73 (466,047,703.06)	559,860,968.53 (141,639,245.59)	528,189,666.13 (76,969,254.62)	94,071,333.33 (26,087,795.62)
Employment	348,309.62 (394,444.15)	421,613.47 (17,966.52)	698,027.33 (20,683.90)	243,882.93 (22,808.73)
Number of observations	180.00	15.00	15.00	15.00
	2002-2016	2002-2016	2002-2016	2002-2016
Patent applications	52.93 (94.59)	38.41 (11.47)	103.47 (23.07)	35.44 (6.71)
Industrial investment	286,936,805.38 (360,104,199.36)	284,358,739.20 (107,486,121.20)	521,530,267.73 (99,974,632.34)	108,587,998.93 (45,179,348.02)
Employment	369,050.26 (436,779.98)	432,375.00 (34,885.17)	724,187.67 (63,649.11)	262,177.87 (18,423.32)
Number of observations	180	15.00	15.00	15.00
	1996	1996	1996	1996
Patent applications	32.00	24.00	49.00	23.00
Industrial investment	366,951,410.00	482,754,336.00	571,702,976.00	65,806,000.00
Employment	344,388.25	419,107.00	688,557.00	244,567.00
	2009	2009	2009	2009
Patent applications	58.17	42.00	107.00	45.08
Industrial investment	398,743,497.33	282,660,384.00	497,535,008.00	119,665,000.00
Employment	402,416.67	472,896.00	789,886.00	282,431.00

Notes: This table shows the averages of key variables in our analysis of regions with a patent library and control regions. Standard deviations are reported in parenthesis below the relevant average figures.

To investigate the role of the PATLIB offices on innovation production, we take advantage of the Greek PATLIBs' operation and their quasi-random closing. In the first place, we

employ two econometric specifications that allow us to evaluate the average effect of PATLIBs opening and closing on regional innovation:

$$\ln Patents100_{rt} = a_1 + \beta_1 treat + \beta_2 post96 + \beta_3 DiD96 + D'_{rt}\gamma_1 + \rho_{rt} + d_t + d_r + \varepsilon_{rt} \quad (1)$$

$$\ln Patents100_{rt} = a_2 + \delta_1 treat + \delta_2 post09 + \delta_3 DiD09 + D'_{rt}\zeta_1 + \rho_{rt} + d_t + d_r + e_{rt} \quad (2)$$

where the r and t index region and time accordingly. The dependent variable $Patents\ 100_{rt}$is the patent applications per capita (100,000 citizens), treat indicates the regions that a PATLIB operated, post96 and post09 are the dummies for treated periods 1996 and 2009 respectively, which take the value 1 for the years following the opening and the closing of libraries, $DiD96$ and $DiD09$ are the interaction terms between treated areas and treated years, D'_{rt} are the time-varying regional characteristics such as employment, and gross fixed capital formation. The variable ρ_{rt} is the region-specific time trends which is a region-specific trend coefficient multiplying the time-trend variable, t. Finally, d_r and d_t are the binary regressors for region and time respectively for our fixed effects model in order to account for time trends and systematic differences among regions.

The coefficients β_3 and δ_3 are those of interest and they measure the average yearly change in the number of patents around a PATLIB after their opening/closing relative to the period before it was opened controlling for the logarithmic values of the regional characteristics as mentioned above. This specification allows us to use as controls the rest of the regions of Greece which is an important part of our mission. In late 2009 a deep economic crisis started in Greece which affected the majority of country's figures, this specification combined with region and year fixed effects permits us to account for the crisis impact and investigate the PATLIBs effect on regional innovation. In order to account for different trends among regions, we also add region-specific time trends.

The previous specification examines the average effect on regional patenting for all the areas that were treated simultaneously. To investigate the effect that each library stimulated to the region that it operated we separate the effect as follows:

$$\ln Patents100_{rt} = h_1 + k_1 Central\ Macedonia + k_2 Crete + k_3 Peloponnese + k_4 post09 + k_5 DiD\ of\ Central\ Macedonia + k_5 DiD\ of\ Crete + k_6 DiD\ of\ Peloponnese + D'_{rt}\lambda_1 + \rho_{rt} + d_t + d_r + u_{rt} \quad (3)$$

$$\ln Patents100_{rt} = h_2 + \kappa_1 Central\ Macedonia + \kappa_2 Crete + \kappa_3 Peloponnese + \kappa_4 post09 + \kappa_5 DiD\ of\ Central\ Macedonia + \kappa_5 DiD\ of\ Crete + \kappa_6 DiD\ of\ Peloponnese + D'_{rt}\mu_1 + \rho_{rt} + d_t + d_r + \eta_{rt} \quad (4)$$

The difference in these specifications is that instead of one aggregate treat and interaction variable that equal one when we encounter regions that libraries were operated, we employ three different treat and interaction binary regressors. For example, $Central\ Macedonia$ equals one when the region of Central Macedonia is considered and $DiD\ of\ Central\ Macedonia$ is the interaction variable between $Central\ Macedonia$ and $post09$. Similar definitions apply for Heraklion and Patra PATLIB office. In this model, we control for the rest of the regions, in order to assess the effect of each PATLIB in the region that it was closed. Similarly, to average impact approach region, year fixed effects are also employed accompanied with region-specific time trends.

5. Results

The estimation of the main specifications indicates a mildly negative effect from after the closure of local offices took place, whereas opening does not appear to be significant for most of the test. Table 2 shows the results of the first specification. Column 1 is the specification without the utilization of time-varying controls. Their addition does not

Table 2 Difference-in-Differences estimates of the average impact of the PATLIBs opening in 1996

	(1) lnpatent100	(2) lnpatent100	(3) lnpatent100	(4) lnpatent100	(5) lnpatent100	(6) lnpatent100
DiD96	0.234	0.227	0.124	0.147	0.142	0.103
	(0.201)	(0.190)	(0.147)	(0.249)	(0.231)	(0.223)
Ln of industry investment		0.196	0.241		-0.015	0.052
		(0.199)	(0.174)		(0.207)	(0.200)
Ln of employment			2.161**			3.397
			(0.955)			(1.896)
Constant	0.585***	-3.085	-30.639**	0.300**	0.588	-42.434
	(0.162)	(3.730)	(12.954)	(0.101)	(4.012)	(24.852)
Observations	180	180	180	180	180	180
Region-specific time trends	NO	NO	NO	YES	YES	YES

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the logarithmic value of patent applications per 100,000 citizens. DiD96 is the Difference-in-Differences estimator. Control regions are the rest of the Greek regions. Treatment and post variables were omitted during calculations. For all the specifications we control for region and year fixed effects, and their coefficients are not reported. Region-specific time trends coefficients are not reported.

change the results of the regression since the opening of the PATLIBs did not affect the regional innovation activity on average. Controlling for region-specific time trends delivers the same results. On the other hand, there is a mildly negative effect on average patenting, as Table 3 presents. Controlling for industrial investment and employment delivers a coefficient significant at the 10% level but adopting strictest specifications indicate an absence of significant impact.

Next, we estimate the separate influence of each office opening and closing on regional innovation Table 4 and Table 5 report the results, respectively. The opening of Cretan PATLIB induced a positive effect with a range from 74,5 % to 78,4% in the innovative activity in the more relaxed models and considering region-specific time trends, the range

Table 3 Difference-in-Differences estimates of the average impact of the PATLIBs closing in 2009

	(1) lnpatent100	(2) lnpatent100	(3) lnpatent100	(4) lnpatent100	(5) lnpatent100	(6) lnpatent100
DiD09	-0.177	-0.200	-0.223*	-0.513	-0.527	-0.161
	(0.117)	(0.115)	(0.110)	(0.938)	(0.951)	(0.225)
Ln of industry investment		0.111*	0.112		0.135	0.068
		(0.060)	(0.063)		(0.238)	(0.081)
Ln of employment			-1.046			-0.312
			(0.687)			(1.282)
Constant	1.183***	-0.916	11.927	2.470***	-0.041	4.451
	(0.147)	(1.057)	(8.873)	(0.329)	(4.299)	(16.431)
Observations	180	180	180	180	180	180
Region-specific time trendss	NO	NO	NO	YES	YES	YES

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the logarithmic value of patent applications per 100,000 citizens. DiD09 is the Difference-in-Differences estimator. Treatment and post variables were omitted during calculations. Control regions are the rest of the Greek regions. For all the specifications we control for region and year fixed effects, and their coefficients are not reported. Region-specific time trends coefficients are not reported.

for the same region is around 56,1% to 58,6%. The rest of the areas did not deliver a statistically significant result.

On the other hand, the closing impact was strong and negative in the Cretan region with and without time-varying controls, and the drop to innovation level varies from -32% to -30,2%. Also, Central Macedonia library appears to have affected the regional patent activity slightly. When region-specific time trends are not included in the econometric specification, we have a negative impact, which tends to be stronger with the addition of time-varying controls. The termination of Thessaloniki PATLIB seems to generate a drop to patent activity from -20,1% to -13,5%. However, when region-specific time trends are added in the estimated model, the previously mentioned effects fade away. When

Peloponnese library is considered in columns four to six of Table 5, a strong negative effect significant at the 1% level is suggested, which ranges from -42,7% to -41,6%.

Table 4 Difference-in-Differences estimates of the separate impact of the PATLIBs opening in 1996

	(1) lnpatent100	(2) lnpatent100	(3) lnpatent100	(4) lnpatent100	(5) lnpatent100	(6) lnpatent100
DiD of Central Macedonia, 1996	0.146	0.113	0.110	-0.008	-0.005	0.053
	(0.115)	(0.125)	(0.117)	(0.205)	(0.196)	(0.181)
DiD of Peloponnese, 1996	-0.022	0.015	-0.022	0.003	0.005	-0.066
	(0.115)	(0.116)	(0.108)	(0.205)	(0.201)	(0.200)
DiD of Crete, 1996	0.579***	0.557***	0.314	0.445*	0.461**	0.350
	(0.115)	(0.119)	(0.180)	(0.205)	(0.197)	(0.227)
Ln of industry investment		0.164	0.211		0.023	0.081
		(0.215)	(0.194)		(0.208)	(0.202)
Ln of employment			1.983*			3.348
			(0.982)			(1.947)
Constant	0.585***	-2.476	-27.897*	0.300**	-0.144	-42.399
	(0.156)	(4.040)	(13.756)	(0.105)	(4.032)	(25.279)
Observations	180	180	180	180	180	180
Region-specific time trends	NO	NO	NO	YES	YES	YES

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the logarithmic value of patent applications per 100,000 citizens. DiD of Central Macedonia, 1996, DiD of Peloponnese, 1996, DiD of Crete, 1996 are the Difference-in-Differences estimators for libraries in the respective regions. Control regions are the rest of the Greek regions. Treatment and post variables were omitted during calculations. For all the specifications we control for region and year fixed effects, and their coefficients are not reported. Region-specific time trends coefficients are not reported.

Results indicate that the regions treated were not affected in a similar pattern. The Cretan region was significantly affected by the operation of the local office, but the impact on the Central Macedonia region did not appear significant for all tests. Peloponnese region in the

strictest estimation delivered a significant negative effect on innovative local activity due to the regional PATLIB closure.

Table 5 Difference-in-Differences estimates of the separate impact of the PATLIBs closing in 2009

	(1) lnpatent100	(2) lnpatent100	(3) lnpatent100	(4) lnpatent100	(5) lnpatent100	(6) lnpatent100
DiD of Central Macedonia, 2009	-0.145*	-0.187**	-0.224**	-0.058	-0.062	-0.064
	(0.075)	(0.080)	(0.085)	(0.133)	(0.128)	(0.129)
DiD of Peloponnese, 2009	-0.026	-0.040	-0.058	-0.538***	-0.557***	-0.551***
	(0.075)	(0.069)	(0.070)	(0.133)	(0.132)	(0.161)
DiD of Crete, 2009	-0.359***	-0.372***	-0.386***	0.118	0.119	0.120
	(0.075)	(0.069)	(0.069)	(0.133)	(0.127)	(0.128)
Ln of industry investment		0.110*	0.112		0.071	0.071
		(0.061)	(0.064)		(0.084)	(0.082)
Ln of employment			-1.032			-0.091
			(0.710)			(1.296)
Constant	1.183***	-0.905	11.763	0.790***	-0.536	0.585
	(0.151)	(1.071)	(9.127)	(0.131)	(1.467)	(16.527)
Observations	180	180	180	180	180	180
Region-specific time trends	NO	NO	NO	YES	YES	YES

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the logarithmic value of patent applications per 100,000 citizens. DiD of Central Macedonia, 1996, DiD of Peloponnese, 1996, DiD of Crete, 1996 are the Difference-in-Differences estimators for libraries in the respective regions. Treatment and post variables were omitted during calculations. Control regions are the rest of the Greek regions. For all the specifications we control for region and year fixed effects, and their coefficients are not reported. Region-specific time trends coefficients are not reported.

6. Dynamic effects

The effect of research-enhancing institutes on innovation might not be instantaneous since it could take more time for a significant impact to be built. PATLIBs in Greece offered information services relating to the patent process and access to patent databases providing necessary technological knowledge for potential patentees. Assisting the local innovation ecosystem, the PATLIBs could encourage the development of an innovation culture which would be more evident in the long run. To account for short and long-run effects, we also employ a dynamic specification which is defined as follows for opening and closing respectively:

$$\begin{aligned}\ln Patents100_{rt} &= o_1 + \mu_1 treat + \varphi_1 y93 + \cdots + \varphi_6 y98 + \omega_1 Dopen^{T-3} + \cdots \\ &+ \omega_6 Dopen^{T+3} + D'_{rt}\iota\xi_1 + \rho_{rt} + d_t + d_r \\ &+ \varepsilon_{rt} \qquad (6)\end{aligned}$$

$$\begin{aligned}\ln Patents100_{rt} &= \pi_1 + \rho_1 treat + \sigma_1 y06 + \cdots + \sigma_6 y12 + \tau_1 Dclose^{T-3} + \cdots \\ &+ \tau_6 Dclose^{T+3} + D'_{rt}q_1 + \rho_{rt} + d_t + d_r \\ &+ \varepsilon_{rt} \qquad (7)\end{aligned}$$

Where $Dopen^{T-3}$ equals to one in third the year before the opening of PATLIBs, $Dopen^{T-2}$ is one in the second year before the opening and similarly for the rest of the years except the $Dopen^{T+3}$ which equals one in the third year after the opening of the PATLIBs and in all subsequent years. Each binary regressor equals zero in all other years than those specified. This specification permits to capture the short run effect ($Dopen^{T}$ to $Dopen^{T+2}$) and long run effects ($Dopen^{T+3}$). The same procedure is employed in the specification (7) where the dynamic effect of PATLIB closing is examined.

Tables 6 and 7 show the dynamic effects of opening and closing of PATLIBs. Opening affected the patenting activity positively in the short run which significance fades away as strictest versions of the specification are adopted. On the other hand, closing the negative impact on innovation in the short run remains statistically significant for all the specification examined. Specifically, during the second year after the closing, there is a

decrease in patenting activity ranging between 30% - 32% among the tested specifications due to the libraries closing.

Table 6 Dynamic effects of opening in 1996

	(1) lnpatent100	(2) lnpatent100	(3) lnpatent100	(4) lnpatent100	(5) lnpatent100	(6) lnpatent100
$Dopen^{T-3}$	0.299	0.286	0.237	0.207	0.206	0.136
	(0.218)	(0.223)	(0.228)	(0.273)	(0.266)	(0.268)
$Dopen^{T-2}$	0.131	0.114	0.047	0.002	0.000	-0.096
	(0.163)	(0.166)	(0.187)	(0.291)	(0.284)	(0.307)
$Dopen^{T-1}$	0.051	0.055	-0.025	-0.115	-0.119	-0.235
	(0.149)	(0.136)	(0.172)	(0.285)	(0.263)	(0.320)
$Dopen^{T}$	0.328	0.358	0.266	0.126	0.118	-0.016
	(0.266)	(0.276)	(0.289)	(0.393)	(0.332)	(0.337)
$Dopen^{T+1}$	0.530*	0.550*	0.438	0.291	0.283	0.121
	(0.282)	(0.286)	(0.271)	(0.277)	(0.246)	(0.302)
$Dopen^{T+2}$	0.107	0.133	0.007	-0.169	-0.178	-0.362
	(0.367)	(0.364)	(0.352)	(0.458)	(0.371)	(0.365)
$Dopen^{T+3}$	0.292	0.259	0.114	-0.095	-0.102	-0.302
	(0.189)	(0.168)	(0.114)	(0.484)	(0.434)	(0.450)
Ln of industry investment		0.203	0.254		-0.017	0.043
		(0.201)	(0.176)		(0.211)	(0.206)
Ln of employment			2.177*			3.438
			(0.994)			(1.924)
Constant	0.571***	-3.215	-31.090**	0.266**	0.590	-42.805
	(0.165)	(3.785)	(13.330)	(0.115)	(4.113)	(24.921)
Observations	180	180	180	180	180	180
Region-specific time trends	NO	NO	NO	YES	YES	YES

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the logarithmic value of patent applications per 100,000 citizens. $Dopen^{T-3}$ to $Dopen^{T+3}$ are the binary regressors that capture the dynamic effects. Control regions are the rest of the Greek regions. For all the specifications we control for region and year fixed effects, and their coefficients are not reported. Region-specific time trends coefficients are not reported.

Table 7 Dynamic effects of closing in 2009

	(1) lnpatent100	(2) lnpatent100	(3) lnpatent100	(4) lnpatent100	(5) lnpatent100	(6) lnpatent100
$Dclose^{T-3}$	-0.148	-0.141	-0.135	-0.171	-0.185	-0.182
	(0.256)	(0.257)	(0.262)	(0.336)	(0.317)	(0.328)
$Dclose^{T-2}$	-0.280	-0.261	-0.261	-0.312	-0.327	-0.324
	(0.299)	(0.301)	(0.305)	(0.308)	(0.304)	(0.309)
$Dclose^{T-1}$	-0.273	-0.261	-0.282	-0.315	-0.340	-0.338
	(0.209)	(0.216)	(0.223)	(0.303)	(0.296)	(0.296)
$Dclose^{T}$	-0.256	-0.223	-0.229	-0.306	-0.329	-0.324
	(0.148)	(0.147)	(0.140)	(0.323)	(0.315)	(0.319)
$Dclose^{T+1}$	-0.406	-0.414	-0.427	-0.465	-0.514	-0.510
	(0.303)	(0.305)	(0.311)	(0.469)	(0.444)	(0.441)
$Dclose^{T+2}$	-0.550***	-0.520***	-0.528***	-0.619	-0.657	-0.650
	(0.140)	(0.116)	(0.113)	(0.507)	(0.494)	(0.486)
$Dclose^{T+3}$	-0.201	-0.235	-0.270	-0.297	-0.387	-0.381
	(0.224)	(0.226)	(0.221)	(0.576)	(0.539)	(0.529)
Ln of industry investment		0.096	0.099		0.046	0.047
		(0.064)	(0.065)		(0.092)	(0.091)
Ln of employment			-1.027			-0.131
			(0.733)			(1.441)
Constant	1.189***	-0.625	11.960	0.781***	-0.090	1.516
	(0.139)	(1.130)	(9.473)	(0.147)	(1.633)	(18.063)
Observations	180	180	180	180	180	180
Region-specific time trends	NO	NO	NO	YES	YES	YES

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the logarithmic value of patent applications per 100,000 citizens. $Dclose^{T-3}$ to $Dclose^{T+3}$ are the binary regressors that capture the dynamic effects. Control regions are the rest of the Greek regions. For all the specifications we control for region and year fixed effects, and their coefficients are not reported. Region-specific time trends coefficients are not reported.

7. Conclusion

Our results are critically important for future policy-making in the patent system area. The mild negative effects of the Greek PATLIB offices closure could be attributed to insufficient supporting mechanisms rather than institutional ineffectiveness. Greek PATLIB offices were operating mainly as information centers; however, in order to boost innovation, they should include other mechanisms that enhance the innovation ecosystem such as patent attorney services or raising relative awareness events. Mere access to patent databases in the era of internet and immediate access to information, as results indicate, do not affect significantly and contemporaneously the innovation produced regionally. However, local stakeholders need further guidance and support as the negative effect suggests. Policy makers should consider including other supporting services that encourage local investors and SMEs to create and protect their inventions.

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Appendix

Data transformation

In this paper, we use the first time newly collected and processed data from the HIPO, along with other data on regional characteristics. Patent data utilized are annual data on patent filings made in Greece from 1988-2014, and at least one of the owners was based in Greece. Greek patent evidence base is a HIPO project that aims to foster strategic industrial and innovation policy. The existing database included data that were in an inappropriate condition for conducting statistical analysis. Data cleaning and harmonization processed took place correcting issues such as misspellings, entry errors, matching the owner address correctly with the owner country or region entry and inadvertent designation of the legal entity.

To deal with timeliness issues, we utilize patent applications instead of patent grants since it demonstrates the innovative output in a year. Patent grants rate may vary every year since it is affected by other factors such as the number of patent examiners (Schmookler, 1966). What is more, when a patent application had more than one owner, we created equal shares among the owners, and the share was distributed to the region that each owner declared. The HIPO database did not include any details about the real shares among owners. Thus, we hypothesize that the share among them is equal.

Greek NUTS2 classification follows the current official administrative regional subdivisions which differ from the historical and geographical traditional one. Greece until 1987 administrative reform was divided into nine official administrative regions (ΦΕΚ, 1987), today called geographical regions of Greece, since they are consistent with the historical and geographical borders. Administratively, today Greece consists of thirteen regions, but geographical division seems to be also extensively referred.

For evaluating the PATLIB closing effect on innovation, it is crucial to consider the regional dimension as perceived by the local stakeholders and not as it is divided for administrative purposes. Patra city is the largest economic, commercial and cultural center of the Peloponnese as defined geographically. Therefore, for our analysis, it is necessary to control for Peloponnese region using the traditionally historical – geographical

definition. The geographical region of Peloponnese is the peninsula next to the mainland of Greece when the administrative region of Peloponnese is the peninsula except for Achaia and Ileia counties. The counties above and Aitoloakarnania constitute the Western Greece administrative region. Western Greece was first established in the 1987 reform and had no previous correspondent. The geographical region that Aitolokarnania belongs to is the Central Greece region.

In this spirit, NUTS2 classification is used in our analysis, but instead of thirteen regions, we employ twelve. Western Greece it is not used Aitoloakarnania is added to Central Greece region and Achaia, Ileia counties are added to Peloponnese. Thessaloniki and Heraklion belong to regions of Central Macedonia and Crete respectively, which belong to their traditional geographical regions.