Regional Competition, Spatial Spillover Effects, and Entrepreneurship Subsidy Policies—Evidence from Incubators in Guangdong, China

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ABSTRACT: Taking the innovation performance of incubators as an example, this paper discusses the effects of regional competition and spatial spillover on regional entrepreneurship subsidy policies. Using the data of all incubators in Guangdong Province, China from 2016 to 2018, this paper reveals that at the micro level, the actual number of patents obtained per unit area of incubators is positively correlated with the intensity of local government subsidy policies and significantly negatively correlated with the intensity of policy subsidies in surrounding areas. At the macro level, urban subsidy policies have a significantly positive direct effect on the actual number of patents obtained per unit area of local incubators, while there is a significantly negative indirect effect on the actual number of patents obtained per unit area of incubators in surrounding areas. The sizes of the two effects are similar, and the total effect of the subsidy policy is almost completely offset—that is, although the intensity of the subsidy policy in a certain city is significantly positively correlated with the actual number of patents obtained per unit area of local incubators, there is basically no substantial effect on the region as a whole.

Keywords: regional competition; spatial spillover; subsidy policy; business incubators; patents obtained

1. INTRODUCTION

Although most economies worldwide currently adopt market-based systems, for a considerable number of developing countries—represented here by China—the impact of government policies on economic development is still determinative. Under the influence of the theory of market competition and fiscal federalism (Li & Zhou 2005), local governments in China are relatively independent in their formulation of industrial and economic policies, and there is therefore obvious competition between regions. With continued economic growth, economic regions have begun to interact more frequently, and whether the policies of different regions—in particular, subsidy policies—have spatial spillovers and result in heightened competition, thereby weakening the effect of local government policies, is a matter of urgent concern. As the cradle of important startups and the vehicle for technology dissemination, science and technology business incubators (hereinafter referred to as "incubators") are an indispensable part of the entrepreneurship and innovation ecosystem. In light of China's vigorous promotion of entrepreneurship and innovation, the importance of incubators has become increasingly prominent, and they have therefore become an important avenue through which many local governments in China improve the entrepreneurial environment in their regions. Due to their unique characteristics, incubators have significant externalities and thus their development cannot be overlooked by government subsidy policies (Obaji et al. 2016). To this end, this paper selects all registered business incubators in Guangdong Province, China from 2016 to 2018 as a research sample and analyzes the impact of local government policies on the innovation performance of business incubators in local and surrounding areas to reveal the spatial spillover and actual effects of government subsidy policies.

2. LITERATURE REVIEW

2.1. Incubators and Entrepreneurship

Technology incubators are institutions that support startups in their growth and development. Unlike ordinary industrial parks, incubators usually provide startup companies with entrepreneurial training, mentorship, and market development in addition to basic office space and facilities (Delmar & Shane 2003). Such support can make up for innovation teams' shortcomings in the early stages of entrepreneurship, such as insufficient operating experience or a lack of resources. Incubators can also help newly established companies build social networks, obtain resources, expand their visibility and establish their reputation in the market, which enhance their competitive advantages. Empirical findings prove that providing comprehensive support for startups can (1) improve the efficiency of information search, thereby reducing unnecessary trial and error costs and improving operational efficiency (Cohen et al.; 2019); (2) reduce rental costs by utilizing co-working spaces (Pauwels et al. 2016); (3) establish a platform that connects the industrial chain with technological innovations that may lack social resources, and provide a reliable path for the adoption of the scientific and technological achievements of startups (Woolley and MacGregor 2021); and (4) serve as a knowledge platform that provides much-needed support (Blackburne & Buckley 2019; Gao et al. 2021). Incubators enable startups, especially those that are innovation-driven, to realize their full potential by providing personalized services (Ayyash et al. 2022), which makes them more likely to succeed (Carree & Thurik 2010). Startups are also eager to join incubators (Ramiel 2017; Clayton et al. 2018). Therefore, incubators have become a key component of the innovation and R&D ecosystem and thus a driver of innovation policy in many countries (Avnimelech et al. 2007; Etzkowitz et al. 2005). For example, the Norwegian government's public policy is designed to transfer innovation from large enterprises to the public, and incubators are indispensable intermediaries in this process (Clausen & Rasmussen 2011); By encouraging the development of incubators, local governments in China have significantly improved the level of regional entrepreneurship and innovation, and the role of incubators in developing countries is more prominent than that in developed economies with a strong entrepreneurial atmosphere (Wang 2020). For example, Incubators in Spain have played a key role in helping local startups combat the outbreak of the COVID-19 pandemic (Cristina et al. 2021).

2.2. Externalities and Government Subsidies

It is worth noting that as business entities, incubators play a dual role in improving the level of social innovation and welfare. On the one hand, the positive social impact of incubators stands as evidence of their necessity and influence in modern economies; on the other hand, if incubators cannot obtain economic benefits that match the social value they create, this imbalance will result in negative externalities. Compared with other types of institutions, incubators often need to provide more complex services for high-risk customers and thus charge relatively low fees. Therefore, in most cases, their social value is more significant than their actual economic value (Sentana et al. 2016; Haugh 2020; Cavallo et al. 2020). Without external support, the externalities of incubators will result in the overall level of investment being insufficient to create social benefits. Government assistance is an important avenue through which to address this problem. In fact, government subsidies play a crucial role in the development of the incubator industry, especially in developing countries that lack sufficient venture capital resources (Chandra and Fealey 2009). Government support can take several forms. For example, government subsidies can enable incubators to obtain better physical facilities, thus making it easier for them to obtain technical support from universities and research institutions (Tang et al. 2014). They can also help incubators connect with large multinational companies and international institutions (Tang et al. 2021). The government itself can also provide a platform for knowledge acquisition (Sagath et al. 2019). If an incubator improves the success rates of entrepreneurs and is profitable on balance, it is financially feasible for the government to subsidize it. In Spain, for example, for every euro the government invests in incubators, it generates €2.8 in taxes (Sentana et al. 2017). In China, providing government subsidies to incubators has a more significant effect on regional innovation than does directly funding startups (Liang et al. 2022).

2.3. China's Regional Competition and the Spatial Spillover Effect of Subsidies

Over the past 40 years, China has maintained relatively high rates of economic growth. As with other issues in China's economic and social development, regional competition is a factor that cannot be ignored when analyzing subsidies provided to incubators. Regional competition has intensified since China's tax reform in 1994 (Xu 2011). It is generally believed that moderate regional competition positively affects China's economic development (Jin 2005; Sun & Zhou 2014). Local governments often adopt tax incentives and government subsidies to attract high-quality enterprises (Xiao & Wu,2020; Wang 2023). Compared with tax incentives, government subsidies are more flexible and thus preferable for local governments. Subsidizing high-quality development has a positive impact on regional economic growth (Chen & Wang 2023). However, it cannot be denied that the subsidy policies of local governments are at least partly due to political considerations such as regional competition. In some cases, local governments are even willing to provide subsidies that exceed the tax revenue generated by enterprises in their localities (Hopp & Kriebel 2016). Empirical evidence shows that there are many factors that affect enterprises' willingness to invest, among which government support is one of the most important (Du et al. 2008) as it can determine the viability of relocation decisions (Haupt & Krieger 2020).

Government subsidies can improve not only the production efficiency but also the technical sophistication of enterprises (Wu et al. 2022). Attracting high-quality enterprises through subsidy policies distorts the allocation of resources to some extent (Xu et al. 2017), thereby resulting in losses in social welfare (Albornoz et al. 2009). More importantly, subsidy policies that are driven by regional competition are likely to have negative spatial spillover effects while intensifying regional competition (Emilson & Chikara 2010; Alcacer & Chung 2014; Amitrajeet et al. 2022), thereby resulting in the "Matthew effect" and aggravating economic inequality across regions (Jaumotte & Papageorgiou 2013).

2.4. Literature review and hypotheses development

On the one hand, regional innovation is a crucial source of social and economic growth; on the other hand, it is also an important performance indicator that is considered in the promotion of local government officials in China. During the 13th Five-Year Plan (2016-2020), improving regional innovation performance has been a particularly important goal of local governments at all levels in China. In the context of regional economic competition in China, the influence of subsidy policies on incubators' innovation performance and the spatial spillover effect are worthy of attention. According to the above literature review, the following hypotheses are presented:

Hypothesis 1: Government subsidies can improve the innovation performance of incubators.

Hypothesis 2: Government subsidies can be used to attract high-quality incubators.

Hypothesis 3: Since government subsidy policies can be used to recruit high-quality incubators from surrounding areas, there is a negative spillover effect by which the social benefits of the policies are reduced.

3. SAMPLE and VARIABLES

3.1 Sample Selection

Since China's reform and opening up in 1978, Guangdong has been a pioneer in various reforms in China, including by hosting three of the country's four "special economic zones" that were first opened to the outside world. Figure 1 shows the years in which the per capita GDP of Guangdong Province reached the national level according to data collected by the National Bureau of Statistics of China. It can be clearly seen from Figure 1 that the economic growth of Guangdong Province is consistent with that of the country as a whole and has been 3 to 5 years ahead of it since the 1990s. Therefore, using Guangdong Province as the research setting can provide the basis for understanding current and future development trends in China.

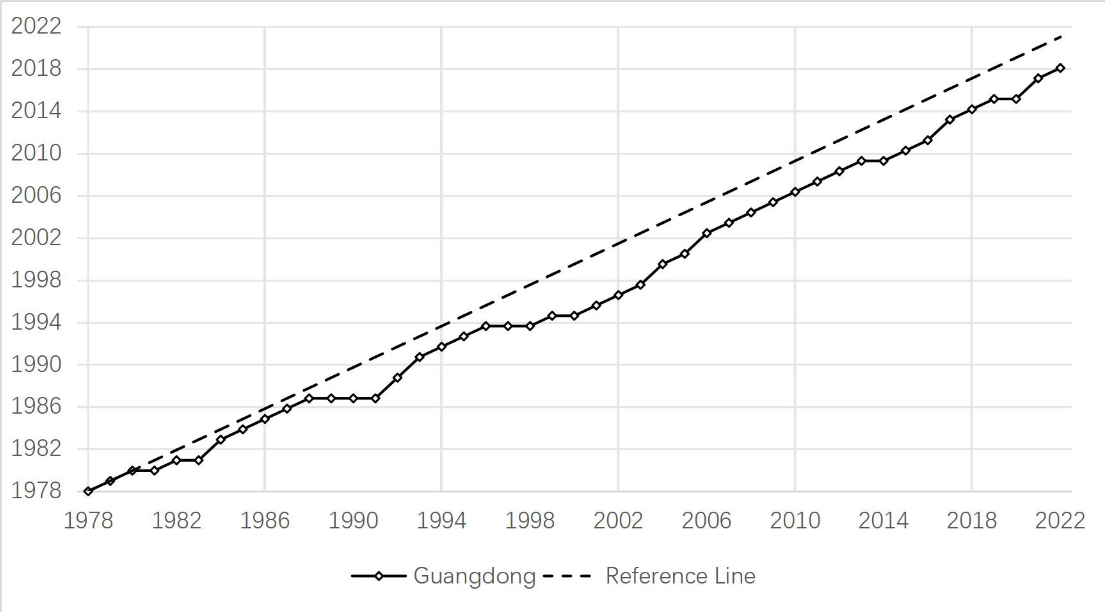

Figure 1. Per capita GDP of Guangdong Province vs. per capita GDP of China

Source: National Bureau of Statistics of China

As of 2022, Guangdong Province has the largest economy and population among all provinces in China. According to the World Bank, Guangdong's annual GDP in 2021 was 1.93 trillion USD, which was slightly higher than that of South Korea (1.81 trillion USD) in the same period. The total population of Guangdong at the end of 2021 was about 126.8 million, which was slightly higher than that of Japan (125.6 million). Given these statistics, if counted as an independent economy, it would rank as the 10th largest economy in terms of output and the 11th largest in terms of population.

In recent years, the economic development of Guangdong Province has shifted from focusing on quantity to focusing on quality. Therefore, entrepreneurship and innovation have become key concerns for governments at all levels in Guangdong Province. In particular, the importance of entrepreneurship and innovation has been significantly increased after the central Chinese government issued two documents on its importance in May 2015 and September 2015 and the Guangdong provincial government also issued its opinions on entrepreneurship and innovation in March 2016. Figure 2 shows the frequency of the term "entrepreneurship and innovation" in the annual government work reports of all 21 prefecture-level cities in Guangdong Province. As shown in Figure 2, the proportion of those that did soared from 28.57% in 2015 to 85.71% in 2016, and the frequency rose from 0.66 times in 2015 to 2.19 times in 2016 and remained at relatively high levels for several years before the COVID-19 pandemic period.[1]

[1] The original Chinese for "entrepreneurship and innovation" is "创业创新", which is a common collocation in Chinese usage.

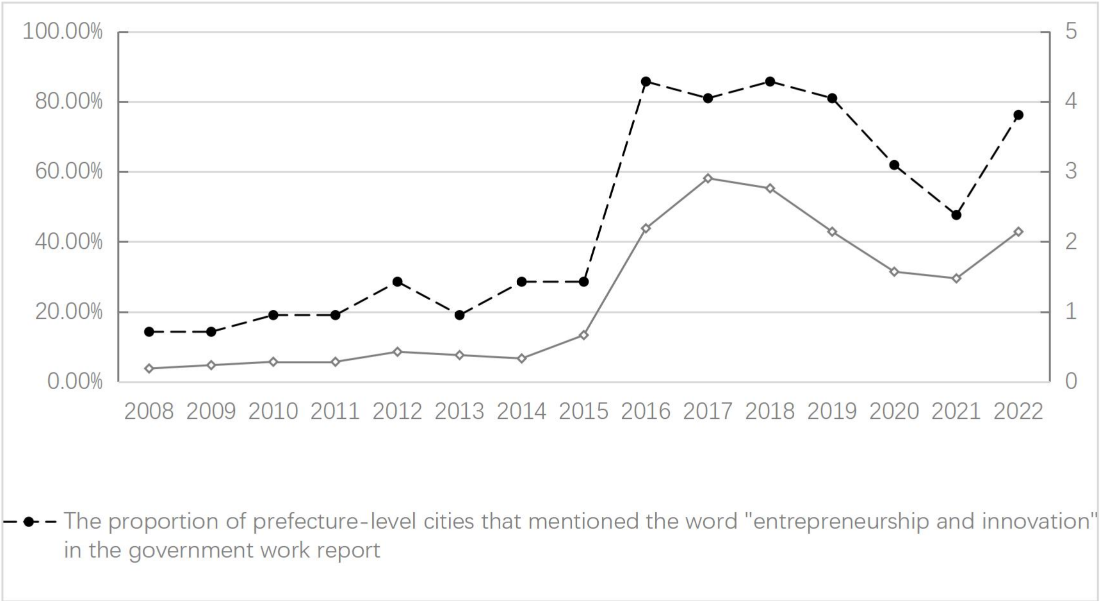

Figure 2. Frequency of the term "innovation and entrepreneurship" in the work reports of prefecture-level cities in Guangdong Province from 2008 to 2022

Source: Municipal government work reports in Guangdong

Since 2016, Guangdong Province has ranked first among provincial administrative units in terms of the number of invention patents obtained. From 2016 to 2021, the number of invention patents obtained by firms in Guangdong Province ranked in the top three in 51 (out of 54) fields among provincial administrative units in China and first in 25 of those fields. The number of invention patents granted by Guangdong reached 102,842 in 2021, which was about 2/3 of that of South Korea and 5/9 of that of Japan and equivalent to 94.5 percent of the total granted by the European Union in the same period. At present, innovation in Guangdong Province is still dominated by large enterprises and universities. However, recent entrepreneurship and innovation policies have enabled small and medium-sized enterprises, especially startups, to become more competitive in this respect. Incubators have played a key role in this transition. From 2016 to 2021, the proportion of patents obtained by incubated enterprises was between 8% and 10%, which was higher than that of the largest local technology enterprise, Huawei Technologies Co., Ltd. Taken together, it can be seen that incubators have become an indispensable part of the invention and innovation ecosystem in Guangdong Province and thus this research has important reference value for predicting future trends in innovation and development both in China and worldwide.

3.2 Variables and Data

As all entrepreneurial activities are dependent on the external environment, this paper, based on the studies of Duranton et al. (2001) and Qian （2017), defines an incubator as a startup being incubated and nurtured or an organization that discovers technology-based entrepreneurial opportunities, mobilizes entrepreneurial resources, and generates technological knowledge. This paper selected all registered incubators in Guangdong Province from 2016 to 2018 from the survey conducted by the Guangdong Science and Technology Business Incubation Association and Foshan Science and Technology Business

Incubation Association as the research sample. The data can be assessed from the enterprise inspection website (https://www.qcc.com/). Even though the incubators in Guangdong Province are relatively new, the number of emerging incubators began to soar after government support was increased at all levels in 2016. However, considering the unstable nature of incubator development, the number of incubators fluctuated widely during these years. Therefore, the data used in this paper are unbalanced panel data. The subsidy policies for incubators in Guangdong Province are generally divided into two categories: advance subsidies and deferred subsidies. Advance subsidies are generally only provided for newly established incubators, where local governments will provide targeted subsidies based on the potential of the incubator's leadership team. Deferred subsidies generally only apply to existing incubators, where local governments will provide incentive subsidies based on their performance in the previous year. As it takes a long time to analyze and assess the operating performance of incubators, the operating performance of incubators in the current year will not directly determine the subsidies they receive in the current year. Figure 3 shows the distribution of the subsidized status of the sample incubators. The figure on the left depicts the distribution of raw data, and the figure on the right shows the distribution of data after panel balancing.

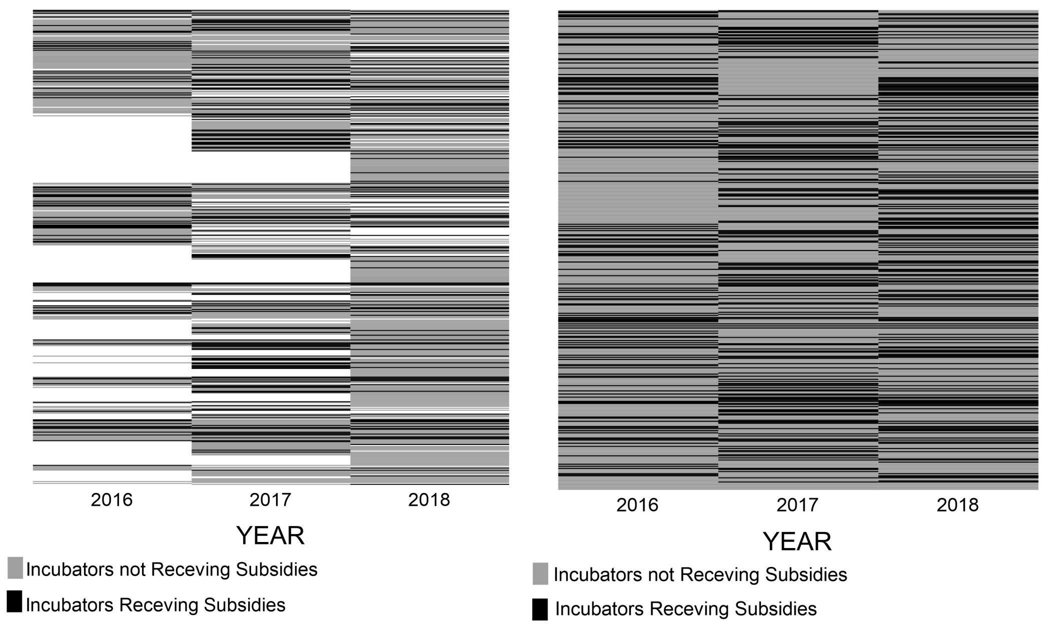

Figure 3. Distribution of subsidy status of the sampled incubators

On the one hand, a major focus of Guangdong Province is to improve regional innovation capacity, where the number of invention patents obtained is an important indicator for measuring innovation ability. On the other hand, the number of patents obtained by startups operating within an incubator is also an important indicator for measuring its operating performance. Therefore, this paper uses the number of invention patents in an incubator as an indicator to measure the performance of incubators. Specifically, the number of invention patents obtained per unit of incubator area is used as a dependent variable; the actual amount of subsidies received by the incubator is used as an independent variable; the difference in subsidies between the region where the incubator is located and the surrounding area (hereinafter referred to as the "regional subsidy difference") is used as an independent variable; and the ratio of the region where the incubator is located to the average subsidy level in Guangdong Province (hereinafter referred to as the "regional subsidy strength") is introduced as an independent variable. The number of incubators managed by the incubator and the number of personnel are introduced as a covariate to measure incubator size; the number of mentors the incubator employs is introduced as a covariate to measure the incubator's external resources; the covariate for measuring the incubator's management team's experience; and the proportion of incubator investment revenue, whether the incubator is located within China's national high-tech zone, and whether the incubator is a professional incubator are introduced as covariates to measure the incubator type. To more intuitively reflect the impact of policies on regional development and eliminate imbalances in the microdata, this paper macroscopically processes microdata—that is, it analyzes the average value of all microscopic samples in the same region as a macro-indicator of regional development. What needs to be emphasized here is that since the sample used in this article includes all registered incubators in Guangdong Province, there is no theoretical randomness bias. Specific usage indicators include the average number of invention patents obtained per unit area of incubators as a dependent variable, the average subsidy amount obtained by incubators as an independent variable, and the city's GDP per unit area, the proportion of high-tech industries in the city's manufacturing industry, R&D investment, and the city's fixed assets as covariates. See Table 1 for a specific description of the indicators.

Table 1. Indicators and their corresponding descriptions

Variable Type	Variable Symbol	Definition and Description
Micro index	$patents$	The number of invention patents obtained per unit area, calculated as the ratio of the number of invention patents obtained per year to the area of the incubator.
	$subsidy$	The actual amount of subsidies received by the incubator in each year.
	equ_sur	Regional subsidy difference, calculated as the difference between the annual average amount of government subsidies received by each incubator in the region and the annual average amount of government subsidies received by incubators in neighboring regions.[2]
	equ_pro	Regional subsidy level, calculated as the difference between the annual average amount of government subsidies received by each incubator in the region and the annual average amount of government subsidies received by incubators in neighboring regions.
	$number$	Number of incubated enterprises, calculated as the number

[2] In order to avoid the possible collinearity of the variables "Incubator's Actual Subsidy Amount Received" and "Regional Subsidy Difference", this paper excludes the incubator's own data when calculating the average subsidy level in the region where an incubator is located

		of incubated enterprises within the incubator in the current year.
	$size$	The area of the incubator.
	$team$	Number of managers, calculated as the number of incubator management team members.
	$tutor$	The number of business mentors retained by incubators.
	$time$	The establishment dates of the incubator and its affiliated company. Note that due to the possibility of relocation, the establishment time of the incubator's affiliated company is not the same as that of the incubator, as shown below.[3]
	$prof$	The proportion of professional managers, calculated as the proportion of people who have received professional training in the incubator management team.
	$invest$	The proportion of investment income, calculated as the proportion of investment income in the total incubator income.
	$area$	Whether the incubator is in China's national high-tech development zone.
	$type$	Whether it is a professional incubator, and whether the incubator is dedicated to serving startups in a single industry.
Macro index	$PATENTS$	The average number of incubator invention patents obtained per unit area, calculated as the ratio of the total number of incubator invention patents obtained in the city to the actual total area of incubators in the city.
	$SUBSIDY$	The average amount of subsidies for incubators, calculated as the ratio of the total amount of subsidies provided to incubators in the city to the actual number of incubators in the city.
	S_GDP	GDP per unit area, calculated as the ratio of the city's GDP to the city's area.
	$HIGH\_TECH$	The proportion of high and new industries, calculated as the ratio of the added value of the city's high and new industries to the added value of the manufacturing industry.
	R_D	R&D investment in the city.
	$CAPITAL$	Fixed assets stock of the whole city.

4. EMPIRICAL RESULTS

4.1 Results of the micro-model

To evaluate the impact of regional subsidy intensity on incubator performance, a benchmark measurement model was established as follows:

[3] The period of existence starts when it is actually established. Since the incubator operator does not need to re-apply for registration even if the actual business address of the incubator changes, the length of time it has operated in a particular region cannot be determined based on this indicator.

$$patents_{i,t} = \delta + \beta_{1_i} subsidy_{i,t} + \beta_{2_i} reg\_sur_{i,t} + \beta_{3_i} id_i + \beta_{4_i} year_t + \sum_{j=4}^{m} \beta_{j_i} x_{j_{i,t}} + \varepsilon_{i,t} \cdots\cdots (1)$$

$$patents_{i,t} = \delta + \beta_{1_i} subsidy_{i,t} + \beta_{2_i} reg\_pro_{i,t} + \beta_{3_i} id_i + \beta_{4_i} year_t + \sum_{j=4}^{m} \beta_{j_i} x_{j_{i,t}} + \varepsilon_{i,t} \cdots\cdots (2)$$

where $Patents_{i,t}$ is the number of effective invention patents generated per unit area of incubators to measure the actual performance of incubators; $Subsidy_{i,t}$ is the amount of government subsidies received by the incubator; $reg\_sur_{i,t}$ is the regional subsidy difference and $reg\_pro_{i,t}$ is the local subsidy intensity. $Subsidy_{i,t}$ is introduced to observe the direct effect of government subsidies on incubators, and $reg\_sur_{i,t}$ is introduced to observe whether the difference in subsidy intensity across regions will affect the operation of incubators. $reg\_sur_{i,t}$ observes the difference between the general level of subsidies and local subsidies and whether this gap will affect the incubators in the region. The model estimation results are shown in Table 2, corresponding Equation (1) in columns 1 to 5 and Equation (2) in columns 6 to 10. The results in Table 2 are in line with the expectations of Hypotheses 1 and 2—that is, that there is a significantly positive correlation between the subsidies received by an incubator and its operating performance. Meanwhile, although the influence of the level of subsidies on the incubator itself has been excluded from the data processing, the greater the subsidies in the area where the incubator is located compared with the surrounding area, the stronger the operating performance of the incubator is.

Table 2. Effects of government subsidies on incubator performance

VARIABLES	*patents*	*patents*	*patents*	*patents*	*patents*	*patents*	*patents*	*patents*	*patents*	*patents*
subsidy	0.220***	0.159***	0.159***	0.143***	0.143***	0.219***	0.158***	0.158***	0.141***	0.141***
	(0.0176)	(0.0268)	(0.0250)	(0.0205)	(0.0253)	(0.0176)	(0.0271)	(0.0251)	(0.0207)	(0.0254)
equ_sur	0.121***	0.181**	0.181**	0.193**	0.193**					
	(0.0409)	(0.0746)	(0.0766)	(0.0697)	(0.0777)					
equ_pro						0.211***	0.320**	0.320**	0.333**	0.333**
						(0.0692)	(0.147)	(0.157)	(0.126)	(0.156)
i.year	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
i.ID		✓	✓	✓	✓		✓	✓	✓	✓
Covariates				✓	✓				✓	✓
Cluster		*City*	*ID*	*City*	*ID*		*City*	*ID*	*City*	*ID*
Constant	-15.92***	-16.84***	-16.84***	13.48	13.48	-15.80***	-16.67***	-16.67***	-0.660	-0.660
	(0.509)	(0.639)	(0.602)	(14.23)	(14.02)	(0.509)	(0.640)	(0.609)	(14.33)	(14.45)
Observations	2,323	1,954	1,954	1,954	1,954	2,323	1,954	1,954	1,954	1,954
R-squared	0.134	0.498	0.498	0.505	0.505	0.134	0.497	0.497	0.512	0.512

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Considering the different impacts that policies may have on existing and new incubators, after excluding the samples that closed in 2017 and 2018 and the abnormal samples (Note 3) the incubators were divided into existing incubators and new incubators according to whether they initiated operations in 2016 or before and the operational performance of the two samples was evaluated in 2017 to 2018 . The regression results are shown in Table 3, where columns 1–3 correspond to Equation (1) and columns 4–6 correspond to Equation (2).

According to the results in Table 2, with incubators actually operating from 2017 to 2018 as samples and 2017–2018 as the period, the regression results are similar to those in Table 1—that is, the amount of subsidies received by the incubator itself and the level of subsidies in the region where the incubator is located are significantly positively correlated with the operational performance of the incubator. This statistical result proves the robustness of the regression results in Table 2 to some extent. Similarly, the regression results of the operational performance of new incubators were similar. By contrast, the operational performance of existing incubators had no significant correlation with that of the surrounding area, although it was significantly positively correlated with the amount of subsidies received by the incubator itself. In addition to the impact of the subsidies received by incubators on their operational performance, the higher the average subsidy amount, the easier it was to attract high-quality incubator teams to the region, and the higher the average subsidy amount, the stronger the performance of new incubators was. If some existing incubators move due to regional differences in subsidy intensity, those incubators will be treated as new incubators in their new location. Therefore, the difference in regional subsidies is not significantly correlated with the operational performance of existing incubators, which is in line with the expectations of Hypotheses 1 and 2.

Table 3. Results of a heterogeneity analysis

VARIABLES	*patents*	*patents*	*patents*	*patents*	*patents*	*patents*
All Incubators in Operation from 2017 to 2018						
subsidy	0.256***	0.224***	0.200***	0.254***	0.217***	0.194***
	(0.0205)	(0.0324)	(0.0332)	(0.0205)	(0.0325)	(0.0331)
equ_sur	0.194***	0.320***	0.324***			
	(0.0537)	(0.112)	(0.117)			
equ_pro				0.318***	0.606***	0.599***
				(0.0845)	(0.176)	(0.176)
i.year	✓	✓	✓	✓	✓	✓
i.ID		✓	✓		✓	✓
Covariates			✓			✓
Cluster		*ID*	*ID*		*ID*	*ID*
Constant	-17.00***	-17.25***	33.63	-16.88***	-17.06***	32.19
	(0.589)	(0.752)	(26.22)	(0.589)	(0.750)	(26.07)
Observations	1,388	1,388	1,384	1,388	1,388	1,388
R-squared	0.093	0.546	0.565	0.094	0.548	0.567
Existing incubators in Operation from 2017 to 2018						
subsidy	0.253***	0.211***	0.186***	0.252***	0.207***	0.182***
	(0.0265)	(0.0379)	(0.0398)	(0.0266)	(0.0381)	(0.0398)
equ_sur	0.117	0.214	0.202			
	(0.0774)	(0.149)	(0.159)			
equ_pro				0.184	0.408*	0.373
				(0.127)	(0.226)	(0.233)
i.year	✓	✓	✓	✓	✓	✓

$i.ID$		✓	✓		✓	✓
Covariates			✓			✓
Cluster		ID	ID		ID	ID
Constant	-16.34***	-17.20***	33.83	-16.29***	-17.09***	33.84
	(0.722)	(0.844)	(37.75)	(0.723)	(0.846)	(37.43)
Observations	922	922	922	922	922	922
R-squared	0.111	0.562	0.581	0.110	0.563	0.582
New Incubators in Operation from 2017 to 2018						
$subsidy$	0.208***	0.185***	0.167***	0.208***	0.179***	0.163**
	(0.0368)	(0.0635)	(0.0641)	(0.0368)	(0.0633)	(0.0638)
equ_sur	0.273***	0.478***	0.544***			
	(0.0753)	(0.138)	(0.165)			
equ_pro				0.430***	0.855***	0.945***
				(0.114)	(0.237)	(0.276)
$i.year$	✓	✓	✓	✓	✓	✓
$i.ID$		✓	✓		✓	✓
Covariates			✓			✓
Cluster		ID	ID		ID	ID
Constant	-19.00***	-18.81***	36.91	-18.77***	-18.43***	31.62
	(1.124)	(1.596)	(42.31)	(1.124)	(1.573)	(42.02)
Observations	466	466	466	466	466	466
R-squared	0.081	0.532	0.550	0.083	0.553	0.553

Standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

Note 3: Some incubators reported annual data in 2016 and 2018, but were missing data in 2017, which does not rule out the possibility of statistical errors or special conditions in their operations. Such samples were taken as abnormal samples and removed. The resulting number of observations is 694. There are significant differences in the levels of development within Guangdong Province. Shenzhen is the prefecture-level city with the largest economy. Its GDP and total industrial output in 2021 were 26.9 times and 32.9 times those of Yunfu City and the smallest comparable prefecture-level city, respectively. Considering the possible impact of such regional differences on policy analysis, a regression analysis is carried out using the following econometric model:

$$z_{i,t}^{j} = \delta'''' + \alpha_1 GDP_{i,t} + \alpha_2 year_t + \alpha_3 id_i + \sum_{j=4}^{m} \alpha_i^l X_{i,t}^l + \varepsilon''''_{i,t} \cdots\cdots(3)$$

where $z_{i,t}^{j}$ represents three dependent variables, namely, the total amount of regional subsidies $SUBS \times NUM$, the number of regional incubators NUM, and the average amount of subsidies received by regional incubators $SUBS$. GDP is the main independent variable used to measure the level of regional economic development. In addition, the contributions of secondary industries and new products are added as covariables. The regression results are shown in Table 4, where columns 1–2 are the regression results of the total subsidies to incubators on the GDP of prefecture-level cities; columns 3–4 are the regression results of the number of incubators on the GDP of prefecture-level cities; and columns 5–6 are the regression results of the average amount of subsidies to incubators on the GDP of prefecture-level cities. According to the results in Table 4, regional GDP is significantly positively correlated with the total subsidies provided to incubators by the local government, but the number of incubators in regions with larger GDPs is also higher. Finally, the average amount of subsidies received by each incubator is not significantly correlated with the GDP of the region. Considering that the intensity of the subsidy policy analyzed in this paper is measured at the regional level, the impact caused by regional economic differences can be excluded from our analysis.

Table 4. Influence of local economic development on government subsidies

VARIABLES	$SUBS \times NUM$	$SUBS \times NUM$	NUM	NUM	$SUBS$	$SUBS$
GDP	0.138***	0.203***	0.0200***	0.0322***	0.262	1.264
	(0.0252)	(0.0671)	(0.00307)	(0.00696)	(0.620)	(1.827)
$i.year$	✓	✓	✓	✓	✓	✓
$i.ID$	✓	✓	✓	✓	✓	✓
Covariates		✓		✓		✓
Constant	-480.2***	-564.0***	-52.84***	-26.62	779.3	4,218
	(113.4)	(56.43)	(13.82)	(58.50)	(2,789)	(15,360)
Observations	63	63	63	63	63	63
R-squared	0.955	0.964	0.982	0.989	0.777	0.784

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figure 4 shows the GDP in 2017 as well as the total and average amount of subsidies to incubators for each city in Guangdong. The darker the color, the greater the value is.

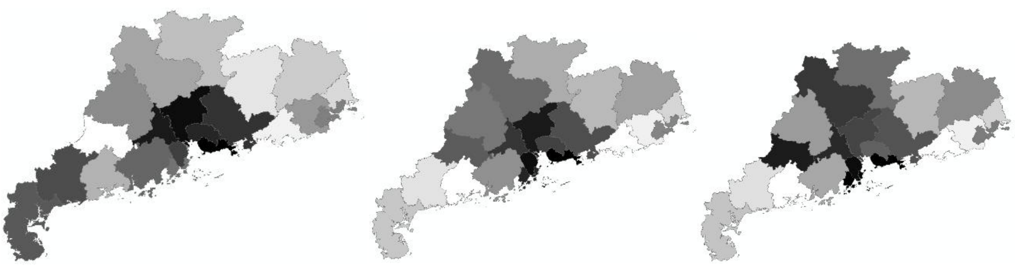

Figure 4. Distribution of GDP & subsidies to incubators in Guangdong in 2017

4.2 Results of the Macro-model

To further analyze the spatial spillover effect of government funding, macro-data are used to conduct spatial econometric analysis. Geographical conditions vary greatly across Guangdong, and its overall economic growth is still rapid. The six cities in the Pearl River Delta comprise most of the population and industry of Guangdong Province, as their GDP per capita is 2.57 times that of other regions in Guangdong Province. Considering the gaps between administrative areas and cities, this paper uses the inverse distance matrix as the spatial matrix of reference and introduces the population and economic gravity matrices as the spatial matrices of reference to improve the robustness of the model. The Moran's I values of the dependent and the main independent variables are shown in Table 5. According to the results in Table 5, the average innovation performance of regional incubators does not exhibit significant spatial agglomeration, but the intensity of regional funding and the regional capital stock do. Therefore, the spatial spillover effect of the independent variable cannot be ignored.[4]

Table 5. Moran's I for major variables

year	*PATENTS*	*SUBSIDY*	*S_GDP*	*HIGH_TECH*	*CAPITAL*	*R_D*
2016	-0.041	0.254***	0.037	0.072	0.396***	0.043
	(0.106)	(0.114)	(0.078)	(0.124)	(0.118)	(0.080)
2017	0.064	0.236***	0.033	0.191**	0.368***	0.033
	(0.117)	(0.113)	(0.077)	(0.124)	(0.120)	(0.078)
2018	-0.014	0.283***	0.033	0.032	0.350***	0.035
	(0.185)	(0.115)	(0.077)	(0.654)	(0.121)	(0.079)

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6 shows the results of the spatial characteristics of the samples. The results of the LM Test, Wald Test and LR Test all show that SDM cannot be directly streamlined into SEM. In analyzing the robust standard errors, the results of the three tests also reject the original hypothesis that SDM can be degraded to SAR.

Table 6. Spatial characteristics of the samples

		Statistic	P-value
Spatial error	LM Test	3.550	0.060
	Robust LM Test	9.547	0.002
	Wald Test	17.440	0.000
	LR Test	16.850	0.002
Spatial lag	LM Test	0.123	0.726
	Robust LM Test	6.120	0.013
	Wald Test	12.040	0.001
	LR Test	12.220	0.019

SDM is used as the benchmark model in this paper, and the model is specified as follows.

$$PATENTS_{i,t} = \delta'''' + \rho\omega \times PATENTS_{i,t} + \sigma_1 SUBSIDY_{i,t} + \sigma_2 year_t + \sigma_3 id_i + \sum_{j=4}^{m} \sigma_{j_i} X_{j_{i,t}} + \varphi_1 \omega \times SUBSIDY_{i,t} + \sum_{j=4}^{m} \varphi_{j_i} \omega \times X_{j_{i,t}} + \varepsilon''''_{i,t} \cdots\cdots (4)$$

Table 7 shows the regression results of SDM. Models 0–1 and 0–2 are fixed effects models, and Models A-1 and A-2 are SDM models. The regression results indicate that the spatial autoregressive coefficient on the average incubator performance was not significant,

[4] The micro-sample used in this paper is all registered incubators in Guangdong Province, so there is no theoretical sample selection problem. Therefore, the macro data integrated from these micro data is theoretically reliable.

which is consistent with the results of the Moran's I test. The average innovation performance of incubators is significantly positively correlated level of with the local government funding and significantly negatively correlated with that of surrounding areas. The two coefficients have similar magnitudes, but the variance of the coefficient on surrounding areas is larger and the significance is slightly weaker, which is basically consistent with the micro regression results and as expected in Hypotheses 1 and 3.

Table 7. Regression results of the SDM model

	Model 0-1	Model 0-2	Model A-1	Model A-2
VARIABLES	$PATENTS$	$PATENTS$	$PATENTS$	$PATENTS$
$SUBSIDY$	0.0632***	0.0636***	0.0584***	0.0567***
	(0.0165)	(0.0177)	(0.0125)	(0.0120)
$\omega \times SUBSIDY$			-0.0667**	-0.0555**
			(0.0269)	(0.0264)
rho			-0.216	-0.194
			(0.216)	(0.216)
sigma2_e			0.384***	0.330***
			(0.0687)	(0.0590)
Constant	-6.686***	-6.987		
	(0.204)	(19.06)		
Covariates		✓		✓
$\omega \times Covariates$				✓
Individual fixed effects	✓	✓	✓	✓
Time fixed effects	✓	✓	✓	✓
Observations	63	63	63	63
R-squared	0.341	0.343	0.374	0.033
Number of id	21	21	21	21

Standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

To improve the robustness of the results, this paper utilizes spatial matrices to conduct SDM regression. The results after the replacement of the spatial matrices are shown in Table 8, where Models B-1 and B-2 use the population gravity matrix as the spatial matrix. Models C-1 and C-2 use the economic gravity matrix as the spatial matrix. After replacing the spatial weight matrices, the regression results are basically consistent with the original results, thus indicating its robustness.

Table 8. Regression results of SDM model after replacing the spatial matrices

	Model B-1	Model B-2	Model C-1	Model C-2
VARIABLES	$PATENTS$	$PATENTS$	$PATENTS$	$PATENTS$
$SUBSIDY$	0.0574***	0.0509***	0.0578***	0.0500***
	(0.0128)	(0.0119)	(0.0128)	(0.0119)
$\omega \times SUBSIDY$	-0.0503**	-0.0455**	-0.0501**	-0.0447**
	(0.0242)	(0.0232)	(0.0220)	(0.0208)

rho	-0.163	-0.331	-0.087	-0.194
	(0.188)	(0.194)	(0.172)	(0.176)
sigma2_e	0.400***	0.214***	0.398***	0.310***
	(0.0716)	(0.0566)	(0.0710)	(0.0555)
Covariant		✓		✓
$\omega \times Covariates$		✓		✓
Individual fixed effects	✓	✓	✓	✓
Time fixed effects	✓	✓	✓	✓
Observations	63	63	63	63
R-squared	0.347	0.019	0.392	0.034
Number of id	21	21	21	21

Standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

Table 9 shows the direct, indirect, and total effects of $SUBSIDY$ in the SDM regression above. We should witness a positive direct effect, a negative indirect effect, and a nonsignificant total effect with an absolute value of the direct effect that is slightly higher than that of the indirect effect. The results in Table 9 show that while government subsidies are indeed conducive to improving the performance of local incubators, they have a significantly negative impact on the performance of incubators in the surrounding areas. Although local government subsidies improve the performance of local incubators, no substantive impact on the whole region is identified.

Table 9. Direct, indirect and total effects of SUBSIDY

	LR_Direct	LR_Indirect	LR_Total
Model A-1	0.0620***	-0.0699***	-0.00786
	(0.0128)	(0.0235)	(0.0257)
Model A-2	0.0600***	-0.0590***	0.00106
	(0.0121)	(0.0249)	(0.0279)
Model B-1	0.0602***	-0.0541**	0.00606
	(0.0131)	(0.0218)	(0.0256)
Model B-2	0.0566***	-0.0524***	0.00424
	(0.0125)	(0.0201)	(0.0235)
Model C-1	0.0594***	-0.0525***	0.00694
	(0.0130)	(0.0206)	(0.0251)
Model C-2	0.0536***	-0.0490***	0.00455
	(0.0121)	(0.0191)	(0.0234)

Standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

5. Conclusions

This paper takes incubator subsidy policies as the research object and all incubators in Guangdong Province as samples to analyze the impact of incubator subsidy policies on incubators' innovation performance. The main conclusions are as follows. 1. Although the amount of subsidies received by incubators is in theory not related to their operating performance in the same year, the results show that government subsidies can improve incubators' innovation performance. 2. The average amount of subsidies in a region where incubators are located is positively correlated to incubators' innovation performance. The greater the regional subsidies are, the easier it is to attract high-quality incubators to relocate. 3. Incubator subsidy policies have a significantly negative spatial spillover effect given their role in attracting high-quality resources from surrounding areas. Therefore, regional subsidy policies lead to a zero-sum game between neighboring cities. As a result, increasing policy subsidies is of no benefit to the entire region in terms of economic development.

There are three possible impacts of this negative spatial spillover effect on developing countries. 1. Policy pilots are not reliable. In developing countries such as China, the administrative and legal systems are not yet mature, and a significant number of policies are implemented through trial and error. The benefits of subsidy policies in different regions are determined by regional financing capacities. 2. Financial resources are not being fully used. Since there is a significantly negative spatial spillover effect of subsidy policies, the impact of subsidies on individual cities is significantly higher than that on the region as a whole. Subsidizing specific industries typically creates negative economic externalities. Therefore, local governments tend to overinvest in subsidies, which in turn causes vicious competition among regions and nullifies the desired overall policy effects. 3. The development gap between regions is further widened. Developing countries typically have development gaps and thus subsidy gaps between regions. In the presence of negative policy spatial spillovers, such subsidy policies will induce more resources to flow to developed regions, thereby further widening the existing development gaps between regions.

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