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Spatial Competition of the Bank Branch Networks in Taiwan

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This research aims to empirically analyze spatial competition of branch network in the banking industry. Theoretical prediction of the spatial competition effect is ambiguous because business-stealing effect and positive externality in this industry would have opposite impacts on a bank's profitability of opening a branch. I collect address information for all bank branches in Taiwan for a 35-year period (from 1981 to 2016). The addresses of all bank branches are geocoded to quantitatively analyze spatial competition in the choice of branch location. Controlling for observed socioeconomic variables, I estimate the effect on the number of a bank's branches in a township caused by nearby branches operated by own and rival banks. I find that the competition of rival banks' branches within the same township has a negative but diminishing effect on the profitability of opening a branch. On the other hand, there is a positive effect from branches of the same bank in nearby townships, suggesting the existence of economies of density in this industry.

Keywords: banking industry, branch network, spatial competition, economies of density, business-stealing effect
JEL classification: G21, L81, R39

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1 Introduction

This paper empirically analyzes spatial competition of branch network in the banking industry in Taiwan. As in most retailing industries, many transactions in the banking industry require face-to-face contacts with their customers. By establishing more branches, a bank can potentially reach more customers. On the other hand, opening an additional branch incurs some fixed costs. Moreover, the competition of branches opened by both own and rival banks in the nearby area can affect the profitability of a bank branch. Therefore, there is a trade-off between the benefit and the cost when a bank determines its branch network.

From a policy point of view, bank branches could promote local economic activities. Consequently, the spatial competition of bank branches could affect the development in a region. For example, Jayaratne and Strahan (1996) use the variation of branch deregulation across different states in the United States to estimate its impact on economic growth, and find the growth rates increase significantly following intrastate branch reform. Burgess and Pande (2005) find a branch expansion policy implemented in India between 1977 and 1990 significantly reduced poverty in rural areas. In a recent paper, Nguyen (2019) investigates the impact of branch closings on local economic outcomes. Using data from the United States during the period 1999–2012, she finds a prolonged negative impact on credit supply to local small businesses.

Theoretic prediction on the effect of spatial competition between different banks is ambiguous. On the one hand, business-stealing effect implies a negative impact of rival branches on a bank's profitability as in most entry game models (Berry, 1992; Bresnahan and Reiss, 1991). Increasing the number of rival branches would reduce the residual demand and hence the profit of opening a branch declines. On the other hand, there is potentially positive externality from nearby bank branches. While banks offer similar services, their services are differentiated. Each bank may specialize in some types of services. Moreover, since there is a cap in the deposit insurance, customers may want to choose more than one bank if the amount of their deposit exceeds the cap.[1] Consequently, consumers may want to do busi-

[1] The cap of the deposit insurance for each individual in one bank is 1 million Taiwan dollars before 2007, 1.5 million Taiwan dollars in 2007–2010, and 3 million Taiwan dollars after 2010.

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ness with multiple banks, and they probably prefer a location with a cluster of several banks. Anecdotal observations find that bank branches cluster in a few streets in many cities. Overall, the net effect of the spatial competition between rival bank branches is an empirical question.

As for the spatial competition within the same bank, there are also opposite effects on the profitability of a branch. Because of lower residual demand, the cannibalization effect would reduce a branch's profitability when other branches of the same bank are located nearby. On the contrary, a bank may benefit from economies of density as mentioned in Jia (2008). For example, a bank can use the same marketing or advertising strategies for all branches in the same region since the customer base is similar. It could also save management costs if several branches are close to each other. In this paper, I do not observe branch-level profits or revenues. Therefore, I cannot identify the spatial competition within the same bank for branches located in the same township. However, using the township-level data, I can estimate the net competition effect caused by a bank's branches located in nearby townships.

Previous research on the branch network in the banking industry typically focuses on the competition within a defined geographic unit. The presence of a bank is almost always measured by the number of branches within an administrative boundary. Competition from nearby geographic units is ignored. Such an approach essentially assumes that consumers do not travel across administrative boundaries for banking service. For example, Cohen and Mazzeo (2007) use small isolated labor market areas as the geographic unit in their analysis.[2]

Nonetheless, to study a densely populated country such as Taiwan, it is impossible to analyze only isolated markets. A bank's service is unlikely to be bounded by administrative boundaries. Actually, approximately 70% of bank branches in Taiwan are less than 1 KM away from a township boundary. In addition to analyzing the competition within the same township, an

[2]Similarly, in Chang, Chaudhuri, and Jayaratne (1997)'s analysis of branch location in New York City, they count the number of branches in each census tract. Greve (2000) studies the entry decision of bank branches in Tokyo City in the early 20th century at ward and county level. Okeahalam (2009) uses municipal area in South Africa to estimate the correlation between branch numbers of socioeconomic variables. Alamá and Tortosa-Ausina (2012) and Alamá et al. (2015) analyze the geographic pattern of bank branches in Spain by the branch number at the municipal level.

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important contribution of this study is to estimate the competition effect from branches located in nearby townships. Specifically, for each township I count the numbers of a bank's own and rival branches located outside but less than 2 KM away from its boundary. Then I estimate the effects of these nearby branches on profitability. Furthermore, using a method similar to Huysentruyt, Lefevere, and Menon (2013), I propose a novel measure of branch numbers to allow for the possibility of serving consumers both inside and outside an administrative boundary if a branch is located near the boundary.

I collect the address information of all bank branches in Taiwan for a 35-year period (from 1981 to 2016). The addresses are geocoded to quantitatively analyze their geographic relation. Controlling for observed socioeconomic variables, I estimate the effect of nearby branches on the profitability of operating a bank branch. My estimation indicates that the number of rival branches within the same township has a negative but diminishing effect on branch profitability. In other words, business stealing effect is the dominant force in the spatial competition of banks within the same township. On the contrary, a bank's own branches in nearby townships have a positive effect on branch profitability. This suggests the existence of economies of density within a bank's own branch network. Nevertheless, the competition effect from rival banks' branches located in nearby townships is estimated to be insignificant in most specifications.

The rest of the paper is organized as the following. In the next section, I discuss the related literature. Section 3 briefly introduces the development of the banking industry in Taiwan over the past four decades. Section 4 describes the data used in the empirical analysis and presents summary statistics of the variables. Empirical approach is introduced in Section 5, and the estimation results are presented in Section 6. In Section 7, I discuss alternative measures for branch numbers and separate the spatial competition effect by bank ownership. Concluding remarks are given in the last section.

2 Related Literature

This study is related to the literature on empirical analysis of entry games. A firm chooses to enter a market if it can obtain a non-negative profit in equilibrium. For example, the seminal work by Bresnahan and Reiss (1990, 1991) empirically analyze the entry decisions of several retail industries (such as car dealers, tire dealers, dentists, doctors, $\cdots$) in small isolated towns in

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the United States. By restricting to these isolated markets, they can simplify the entry game and ignore competition across different geographic areas. However, these isolated small towns make up only a tiny proportion of the economy. For many interesting research questions, this simplification is too restrictive to understand the overall economy.

To analyze the general economy, we have to account for spatial competition across different geographic areas. In the past decade, some research of entry games started to account for spatial interaction. For example, Jia (2008) considers a static entry game between Wal-Mart and Target in the United States discount retailing industry. In her model, each of the two retailers chooses their branch network simultaneously. Because of the spatial interaction across geographic areas, a retailer cannot make its entry decision on each location separately. In her model, a retailer has to make the entry decisions on each county in the United State at the same time and also considers the strategic interaction with the other retailer. A retailer's strategy space consists of the entry decisions in all United States counties. Nishida (2015) also estimates a structural model to investigate store networks in the retailing industry. His paper investigates the spatial competition within the same chain and across rival chains of convenience stores in Okinawa of Japan. Because he observes aggregate revenue for each 1KM $\times$ 1KM grid in Okinawa, he is able to separately identify cost function and revenue function under the structural model. Based on the estimated parameters, he finds that the net effect on profit is negative for branches of the same chain located within the same gird, but the effect is positive for branches of the same chain in nearby grids. While the above two papers model the interaction as a static game, Holmes (2011) studies the dynamic expansion of Wal-Mart. He analyzes how the spatial competition affects the branch network of Wal-Mart over the entire history of this retailer.

Both Cohen and Mazzeo (2007) and Cohen and Mazzeo (2010) use a structural game-theoretic model to account for the interaction between rival banks. Their research focuses on the entry choice among three possible types: multi-market bank, single-market bank, and thrift. They only consider the competition within the same market because their empirical sample consists of small isolated rural areas. The profit of a branch depends of the number of competing banks of each type in the market. Their empirical results indicate the importance of product differentiation in the United States banking industry. They find that product differentiation generates additional profits for banks. As a result, smaller banks survive even when

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larger banks expand their operations.

The empirical approach in this research is close to Chang, Chaudhuri, and Jayaratne (1997). They analyze the locations of bank branches in New York City. The geographic unit in their study is census tract. They use Poisson and ordered-logit models to estimate the effect of existing branches within the same census tract on the number of hew branch openings in the subsequent year. The estimated effect is positive but diminishing when the initial branch number is less than fourteen. They interpret the positive effect of existing branches on new branch openings as an evidence of rational herding in the decision of branch locations. While my approach is similar to Chang, Chaudhuri, and Jayaratne (1997), their estimation does not consider the potential endogeneity of the initial branch number. As a result, uncontrolled tract characteristics could bias the estimated effect upward.[3] I address this issue by using instrumental variable in this study. Besides, the competition effect from branches located in nearby tracts is ignored in Chang, Chaudhuri, and Jayaratne (1997), but I am going to take this effect into account.

3 Industry Background

This section provides a brief overview of the banking industry in Taiwan in the past several decades.

3.1 The Banking Industry in Taiwan

This study focuses on the bank branch network in Taiwan during the period 1981–2016. The banking industry was highly regulated before 1990. In particular, most banks were owned by the central and local governments. Over 80% of banks branches were operated by state-owned banks in 1981. The government decided to gradually deregulate the banking industry in 1990. Among other deregulation policies, new private commercial banks were allowed to enter the industry. Consequently, 16 new privately-owned commercial banks were established in 1991–1993. In addition, some other financial institutes (such as trust and investment companies, credit cooperatives) were allowed to transform into commercial banks during the 1990s.

[3]They run an auxiliary regression on the deposit amount to provide additional support for the positive externality, but do not directly address the endogeneity on the regression of the branch number.

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The number of domestic banks increased dramatically from 23 in 1990 to 50 in 2000.

Because of the Asian financial crisis in 1998 and the burst of the dot.com bubble in 2001, many banks in Taiwan suffered from nonperformance loans and incurred substantial losses. Consequently, the government tightened the regulation in the 2000s. No new bank was allowed to establish after 2000. Moreover, the government encouraged banks to merge to benefit from economies of scale. In addition, seven insolvent banks were taken over by Resolution Trust Corporation between 2002 and 2008 and then sold to other banks. Therefore, the number of domestic banks reduced from 50 in 2000 to 36 in 2016.

3.2 Bank Branches

Establishing a branch in the banking industry is regulated by the government. In the 1980s a bank can apply to open up to three new branches every year. In 1993, the government relaxed the upper bound from three to five branches per year. Nevertheless, the regulator could restrict establishing new branches by not approving applications. Figure 1 shows the total number of domestic branches over time. During the 1990s, the regulator generally allowed banks to expand their branch network at the upper limit. The branch number almost tripled during this decade. Nonetheless, corresponding to the attitude toward stricter regulation on the banking industry, the approval rate for establishing new branches became much lower after 2001. The regulation rule on the upper bound of new branch was reduced from five to two branches per year in 2007, but the increasing rate had dropped before this rule change. After peaking at 3,485 in 2014, the total number of domestic branches slightly declined in the past few years, presumably because Internet banking and mobile banking have gradually replaced services provided in brick-and-mortar branches. In 2017, the regulator fully eliminated the regulation on the upper bound of establishing new branches.

To be more specific, the branch networks are affected by the following major events during the research period.

1. Sixteen new private commercial banks began their business between 1991 and 1993. Most of these new banks open five new branches every year during the 1990s.
2. Four trust and investment companies transformed to commercial banks

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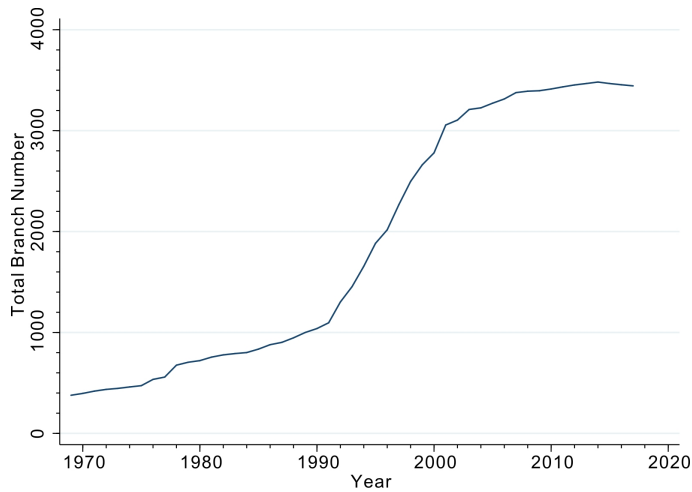


Figure 1: Total Number of Domestic Bank Branches in Taiwan, 1969–2017

between 1992 and 1998. Each already has many branches at the time of transformation.

3. Nine credit cooperatives transformed into commercial banks between 1997 and 2007. In addition, 32 credit cooperatives were merged by commercial banks since 1997. Their branches were also transformed into bank branches.
4. In 2001 and 2002, 43 local financial institutes (the credit department of farmers' associations) with poor financial status were taken over by 10 commercial banks, and became these banks' branches.

When a bank takes over branches from an insolvent bank, it is likely to reorganize its branch network. Among the 422 branches taken over by other banks during the data period, nearly half of them (203 branches) have been closed. Moreover, as Figure 2 indicates, 60% of these closures occur within one year of takeover. The closure rate becomes quite flat thereafter.

This suggests that the location of a branch obtained from a recent takeover do not represent the bank's optimization behavior. As a result, in the empirical analysis I will drop branches which are less than one year after a takeover event from the data.

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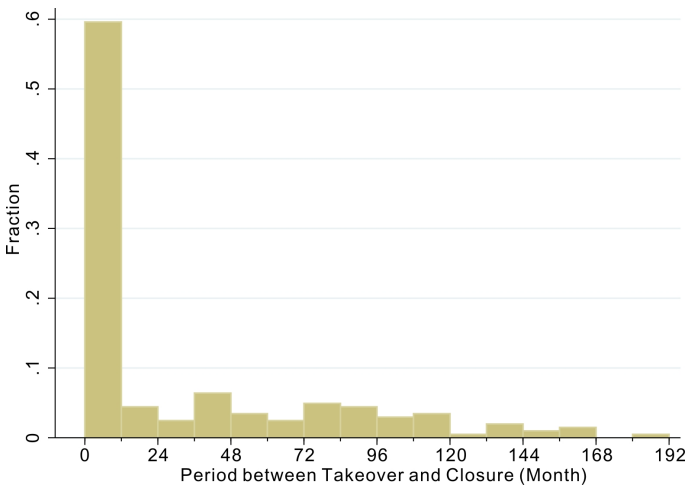


Figure 2: Duration between Takeover and Closure

3.3 Regional Variation of Bank Branches

Before 2005, some banks were licensed as regional banks. They were restricted to operate in the designated counties. In the 1980s, nine of the 23 banks were regional banks. Each operated in up to four counties. Besides, each credit cooperative was restricted to operate in only one county. When a credit cooperative was allowed to transform into a commercial bank, its geographic restriction remained the same. Nonetheless, the government began to relax the restrictions on regional banks in 1994. A regional bank was allowed to expand its operating area when its asset level was higher than a specified threshold. The restrictions on the operating area were fully eliminated in 2005, and every bank could operate throughout the country afterward.[4]

Table 1 lists the branch number by county over the past 40 years.[5] In addition to observing the increasing trend of the total branch number, we can also find that bank branches are not evenly distributed geographically. For example, in 2016, the population in Taipei City was roughly 11% of the

[4]The threshold for the expanding operation area was revised several times between 1994 and 2005, making expansion easier over time.

[5]The geographic area of the counties is based on the boundary at the end of 2016. In this paper I use "county" to refer to all county-level administrative divisions. As of 2016, there are six special municipalities, three provincial cities, and 13 counties.

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Table 1: Branch Numbers by County and by Year

County	1971	1976	1981	1986	1991	1996	2001	2006	2011	2016
Chaiyi City	9	11	13	17	19	36	52	54	48	44
Chaiyi County	2	2	6	9	10	15	18	19	18	18
Changhua County	17	20	30	33	42	73	98	116	106	103
Hsinchu City	8	9	14	15	22	45	73	85	86	85
Hsinchu County	6	9	15	16	18	20	33	42	54	53
Hualien County	7	8	15	16	18	23	25	27	21	22
Ilan County	11	15	20	20	22	26	35	40	40	41
Kaoshiung City	47	67	97	109	144	299	384	403	408	390
Keelung City	13	16	17	17	18	20	28	29	26	26
Kinmen County	2	2	2	2	2	2	2	5	5	6
Lienchiang County	1	1	1	1	1	1	1	1	1	1
Miaoli County	14	16	22	24	25	32	45	46	48	45
Nantou County	14	17	26	26	27	32	37	44	37	36
New Taipei City	28	40	67	84	123	278	455	520	555	577
Penghu County	4	4	5	5	6	6	6	6	5	5
Pingtung County	13	17	23	23	27	45	70	85	63	56
Taichung City	34	45	66	79	103	201	321	378	380	392
Tainan City	33	42	55	62	77	145	213	232	234	234
Taipei City	119	149	189	218	289	530	775	870	977	992
Taitung County	6	7	14	17	19	19	19	24	13	14
Taoyuan County	16	21	34	42	57	137	210	237	259	268
Yunlin County	15	17	25	26	27	32	51	51	49	47
Total	419	535	756	861	1,096	2,017	2,951	3,314	3,433	3,455

national total, but over one fourth of bank branches in Taiwan were located in Taipei City. This table suggests that the branch number is positively correlated with population and business activities. Consequently, my empirical analysis of spatial competition will control for these socioeconomic factors.

4 Data

This section describes the data used in the analysis. I first explain how the branch location data were collected. Then I describe other data used in my empirical analysis.

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Since the focus of this study is on the banking service for the general public, I do not include foreign banks in the data. Most foreign banks do not target the general public and have only one or two branches in Taiwan. However, five of the foreign banks had become much more active in the local market by merging domestic banks since 2007. They also established subsidiary banks for domestic business after mergers. As a result, these banks (Citi Bank, Standard Chartered, DBS, HSBC, and ABN AMRO) are included in the analysis after their respective mergers.[6] Besides, Export-Import Bank of the Republic of China (中國輸出入銀行) and two industrial banks (工業銀行) are also excluded from my analysis because their service does not target the general public and they have very few branches.

In this study, I use township (鄉鎮市區) as the geographic unit in the analysis. Township is the second level of the administrative hierarchy in Taiwan. Currently, there are 368 townships in Taiwan. During the sample period, the township-level administrative organization is quite stable. There were only very few changes in township boundaries.[7] Branch location data are combined with GIS information to measure the number of branches in each township. In addition, I also collect socioeconomic variables at the township level to control for heterogeneities across townships and over time.

4.1 Branch Location

I combine several data sources to manually construct a complete history of the address of each bank branch in Taiwan since 1969. First, I use information from "Organizational Change of Financial Institutes" (金融機構組織動態), which has been published monthly in the journal *Reference Materials of Financial Business* (金融業務參考資料) by the Central Bank of Taiwan. This monthly published document lists status changes of all financial institutes

[6]The operation of ABN AMRO in Taiwan was sold to ANZ in 2010. It was in turn sold to DBS in 2017.

[7]Except for some minor boundary adjustments, changes in the township organization since 1981 are listed below: The 16 township-level districts in Taipei City were reorganized into 12 districts in March 1990 with substantial changes in their boundaries. Hsinchu City merged Xiangshan Township to become a provincial city in July 1982, and it was subdivided from a single administrative region into three township-level districts in October 1990. Chaiyi City was subdivided from a single administrative region into two districts in October 1990. West District and Central District in Tainan City merged into a single district in April 2004.

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in Taiwan. In particular, when a new bank branch opens, the document would report its branch name, address, and opening date. When a branch moves, it would report its new location and new branch name (if it is also changed). When a branch closes, it would report its closing date. In addition to the branch-level records, it also describes bank-level changes, such as mergers, takeovers, or name changes. In theory, I can use the monthly reports on the status changes to trace out the complete location history of all bank branches opened after 1969. However, some records appear to be missing in the monthly report. I use supplemental data sources to check the complete history of all bank branches, including annual financial statements of banks listed on the Taiwan Stock Exchange, anniversary books on bank history, *Financial Institutions Business Operations Annual Reports* published by the Central Bank. Moreover, the address information for bank branches opened before 1969 began to appear on "Organizational Change of Financial Institutes" only after such a branch has moved its location after 1969. Consequently, I also use the aforementioned supplementary documents to look for the complete history of their address. Finally, I check the address of all current branches with the information provided on the website of Bank Bureau of Financial Supervisory Commission.

To analyze spatial competition, the address data are geocoded into the TWD97 (Taiwan Datum 1997) coordinate system using the online service of Taiwan Geospatial One-Stop Portal (`https://www.tgos.tw/`).[8]

4.2 Socioeconomic Variables

To control for variation in observed socioeconomic factors, township-level variables are collected from the following two sources.

1. *Monthly Bulletin of Interior Statistics* (內政統計月報): Township-level population is measured as the registered population reported in this monthly bulletin, which is published by the Ministry of the Interior.
2. Industry and service census: It is conducted every five years by the Directorate General of Budget, Accounting and Statistics. Most of

[8] Because house numbers and street names obtained from the historical address information may have changed, the historical addresses are transformed into the current ones before geocoding by using the web services provided by the Department of Household Registration, Ministry of Interior (`https://www.ris.gov.tw/doorplateX/`) and by the Department of Civil Affairs, Taipei City Government (`http://houseno.civil.taipei/`.

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the township-level variables used in my analysis are from the period 1981–2016. I use the census data to obtain township-level information on the number of establishment, the average worker number in an establishment, and average payroll per worker.[9] The payroll values are deflated by the consumer price index to 2011 Taiwan dollars. In addition, the number for each category of establishments (independent units, managing units, and branches) in a township is reported since the 1991 census.

4.3 Summary Statistics

In my empirical analysis, the geographic unit is township, there are between 368 and 370 townships in Taiwan during the sample period. Because industry and service census is conducted every five years, the empirical analysis uses data from the following years: 1981, 1986, 1991, 1996, 2001, 2006, 2011, and 2016.

The unit of observation is the combination of bank, township, and time. For regional banks, I only include the townships located within its designated counties. Table 2 lists the variables used in the regression analysis and their summary statistics. The top panel in the table shows the dependent variable and explanatory variables in the regression. The dependent variable, BranchNumber, measures the number of branches in a township for a bank at the end of a given year. On average, a bank has 0.2 branches in a township, but the distribution is highly skewed. The maximum branch number, 16, occurs for Taipei Fubon Bank in Zhongshan District of Taipei City in 2011 and for Taiwan Cooperative Bank in Da-an District of Taipei City in 2006. On the other extreme, many rural townships have no branch of any bank. The branch number is zero for 87% of the observations. In fact, among the 368 townships in Taiwan, 141 do not have any branch from any bank in 2016.

Three variables measure the intensity of spatial competition. The variable RivalBranches is the number of branches of all other banks in the same township. It is also highly skewed with mean 6.95 and median 1. The maximum occurs for COTA Bank (三信商銀) in Zhongshan District, Taipei City in 2016. OwnNearby counts the number of a bank's own branches

[9] I cannot compute average payroll per worker in 2016 because the relevant information has not been publicly released.

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Table 2: Descriptive Statistics

	Mean	Std. Dev.	Min.	Max.
BranchNumber	0.2037	0.6883	0.0000	16.0000
RivalBranch	6.9505	16.9563	0.0000	181.0000
OwnNearby	0.5611	1.9852	0.0000	40.0000
RivalNearby	19.2198	53.9714	0.0000	493.0000
Population (million)	0.0602	0.0757	0.0001	0.5553
Establishments (1000)	2.8038	4.4316	0.0040	33.4970
Indep Units (1000)	2.8025	4.2981	0.0030	30.0910
Managing Units (1000)	0.0410	0.1070	0.0000	1.5030
Branches (1000)	0.1313	0.2374	0.0000	2.2130
AvgWorkers (1000)	0.0055	0.0045	0.0010	0.0956
AvgPayroll (million TWD)	0.3815	0.1238	0.0142	0.9732
HQ Distance (1000 KM)	0.1574	0.0975	0.0001	0.4158
BanksAllowed	34.3262	9.8419	14.0000	47.0000
RivalHQ (1000 KM)	0.1574	0.0772	0.0017	0.3399
NearbyAllowed	33.3531	11.2508	14.0000	47.0000
Boundary (KM)	47.8656	34.7672	0.0000	228.5190

Note: The number of observations is 87,690 (except 76,743 for Indep Units, Managing Units, Branches and 74,478 for AvgPayroll). Please refer to the main text for the data sources.

located outside but less than 2 KM away from the boundary of the township. On average, a bank has 0.56 own branches in this 2KM-wide band for a given township. Similarly, I define RivalNearby by counting the number of branches operated by rival banks in this 2KM-wide band outside a township. The average number of rival branches in this band is 19.2.[10]

Several socioeconomic variables are included in the analysis to capture the variation across townships. Population is the number of residents in a township. Establishment is the number of establishments in the manufacturing and service industries in a township. For observations in 1991–2016, we can also separate the establishments into three categories: independent units, managing units, and branches. AvgWorkers is the average number

[10] I consider different widths of the band in the empirical analysis as robustness checks.

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of people working in an establishment in the township. This variable captures the average firm size in the township. AvgPayroll is the average payroll per worker in the township. It captures the average wage income in the township. As Table 2 shows, townships vary substantially in their size and development level.

Finally, as Jia (2008) and Holmes (2011) suggest, the distance of a market to the firm's headquarter could affect its profitability because of management cost. I use HQ Distance to denote the straight line distance between the headquarter of a bank and the population weighted centroid of a township. The average distance is 157 KM.

5 Empirical Approach

This section introduces the model used in my empirical analysis and the econometric tools to estimate the model.

5.1 Empirical Model

Suppose that bank i's incremental profit from its n-th branch in township k in year t can be expressed as

$$\pi(n, \text{RivalBranch}_{ikt}, \text{OwnNearby}_{ikt}, \text{RivalNearby}_{ikt}, \mathbf{w}_{ikt}) \quad \text{for} \quad n \in \mathbb{N}, \tag{1}$$

where $\mathbf{w}_{ikt}$ includes all the socioeconomic variables introduced in Subsection 4.3. Consequently, to maximize the profit of operating N branches in this township, bank i solves the following problem.

$$\max_{N \in \{0\} \cup \mathbb{N}} \sum_{n=1}^{N} \pi(n, \text{RivalBranch}_{ikt}, \text{OwnNearby}_{ikt}, \text{RivalNearby}_{ikt}, \mathbf{w}_{ikt}). \tag{2}$$

Let $\text{BranchNumber}_{ikt}$ denote the profit-maximizing choice of the branch number.

Assumption 1. The solution to the maximization problem stated in (2) exists.

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This assumption rules out the situation that intra-township positive externality among branches of the same bank is very strong so that the optimal $\text{BranchNumber}_{ikt}$ goes to infinity. A sufficient condition for Assumption 1 to hold is the following monotonicity assumption.

Assumption 2. π strictly decreases in n, and $\lim_{n\to\infty}\pi < 0$.

When there is no intra-township externality among branches of the same bank, Assumption 2 is very reasonable because the marginal benefit from opening an additional branch is likely to decline while the marginal cost is likely to rise when the bank has more branches in this township. Although I cannot explicitly analyze intra-township positive externality among branches of the same bank in the current research due to data limitation, I will discuss its potential impacts on these assumptions and on the estimation results after introducing the regression equation.

Under Assumption 2, the optimal choice of the branch number can be expressed as

$$\begin{aligned}\text{BranchNumber}_{ikt} = \min_{n\in\mathbb{N}}\{\pi(n,\ \text{RivalBranch}_{ikt},\ \text{OwnNearby}_{ikt},\\ \text{RivalNearby}_{ikt},\ \mathbf{w}_{ikt}) < 0\} - 1. \qquad (3)\end{aligned}$$

Similar to the literature on the empirical analysis of entry games, I do not observe profit directly and use the observed branch numbers to infer the incremental profit π.

Proposition 1. Suppose that the condition stated in Assumption 1 holds. For each $x\epsilon\{\text{RivalBranch}_{ikt}, \text{OwnNearby}_{ikt}, \text{RivalNearby}_{ikt}, \mathbf{w}_{ikt}\}$, if π is an increasing (decreasing) function of x, then $\text{BranchNumber}_{ikt}$ also increases (decreases) in x.

proof. As Eq. (2) shows, bank i's total profit from operating N branches in township k can be written as $\Pi_{ikt}(N, x) = \sum_{n=1}^{N}\pi(n, \text{RivalBranch}_{ikt}, \text{OwnNearby}_{ikt}, \text{RivalNearby}_{ikt}, \mathbf{w}_{ikt})$. $\Pi_{ikt}(N, x)$ is a supermodular (submodular) function of N and x if the incremental profit function π increases (decreases) in x. Therefore, Topkis's theorem implies that the profit-maximizing choice of N, $\text{BranchNumber}_{ikt}$, increases (decreases) in x. □

In other words, if a variable x has a positive (negative) impact on the incremental profit π, it would also increase (decrease) the bank's optimal

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branch number. Therefore, we can use $\text{BranchNumber}_{ikt}$ as a proxy for bank i's profitability π in township k.

The regression equation in my empirical analysis is a linear equation with quadratic terms of the numbers of competing branches. In the baseline model, the branch number of bank i in township k at the end of year t is specified as the following.

$$\begin{aligned}\text{BranchNumber}_{ikt} = {} & \beta_1 \text{RivalBranch}_{ikt} + \beta_2 \text{RivalBranch}_{ikt}^2 \\ & + \beta_3 \text{OwnNearby}_{ikt} + \beta_4 \text{OwnNearby}_{ikt}^2 \\ & + \beta_5 \text{RivalNearby}_{ikt} + \beta_6 \text{RivalNearby}_{ikt}^2 \\ & + \mathbf{w}_{ikt}' \boldsymbol{\gamma} + \alpha_i + \delta_k + \tau_t + \varepsilon_{ikt}, \end{aligned} \tag{4}$$

where α_i, δ_k, and τ_t are bank fixed effect, township fixed effect, and year fixed effect, respectively. Unobserved factors are captured by the error term ε_{ikt}.[11] We are mainly interested in the coefficients $(\beta_1, \beta_2, \cdots, \beta_6)$. The first line in Eq. (4) captures the spatial competition effect from branches of rival banks in the same township. The second and third lines measure the effects from own and rival branches located in the 2KM band outside the township. The last line controls for the observed and unobserved socioeconomic factors.

While the research focuses on the effects of RivalBranch_{ikt}, OwnNearby_{ikt}, and RivalNearby_{ikt}, one potential concern is the impact of intra-township positive externality among branches of the same bank on the estimated coefficients. When such externality exists, it would shift the incremental profit function π upward. This effect is captured by the error term ε_{ikt} in the regression equation (4). As long as I can use instrumental variables discussed in the next subsection to deal with the endogeneity problem, intra-township positive externality within the same bank would not bias the estimated parameters. Besides, when the intra-township positive externality within the same bank is strong, Assumption 2 may be violated. Nonetheless, in the proof of Proposition 1, we only require Assumption 1 but not Assumption 2. Therefore, as long as the observed branch number does not go to infinity, using the branch number $\text{BranchNumber}_{ikt}$ as a proxy for profitability π remains a valid approach.

[11] It is quite difficult to obtain township-level socioeconomic variables in Taiwan, especially those in the 1980s and 1990s. I have tried my best to include many important variables in the vector $\mathbf{w}_{ikt}$ and used township fixed effects δ_j to control for time-invariant factors. If there are still some missing variables, their impacts are captured only by the error terms ε_{ikt}.

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5.2 Endogeneity

The aim of this study is to estimate the causal effect of spatial competition from nearby branches. If the decision on branch number is indeed affected by rival banks' decisions on their branches in the same township (i.e. $\beta_1 \neq 0$ or $\beta_2 \neq 0$), the variable RivalBranch_{ikt} and its squared terms are endogenous. This is because when the error term ε_{ikt} affects $\text{BranchNumber}_{ikt}$ of bank i, it also affects RivalBranch_{ikt} through the interaction with other banks. Therefore, ε_{ikt} and RivalBranch_{ikt} are correlated. To find the direct causal effect of RivalBranch_{ikt} on $\text{BranchNumber}_{ikt}$, it is necessary to take into account the reverse causality. I need instrumental variables which are correlated with RivalBranch_{ikt}, but not ε_{ikt}.

By the same logic, the numbers of competing branches in nearby townships (OwnNearby_{ikt} and RivalNearby_{ikt}) are also likely to be endogenous. When the branch number can affect the choice in the nearby townships, the error term ε_{ikt} in township k could have an indirect effect on the branch number in the nearby township through $\text{BranchNumber}_{ikt}$. As a result, I need instrumental variables which exclusively affect the number of nearby own and rival branches, but are not correlated with ε_{ikt}.

The first instrumental variable, BanksAllowed, is the number of banks allowed to operate in the given township. Before 2005, some banks were licensed as regional banks and could open branches only in the designated counties. As the regulation relaxed, all banks become national banks in 2005 and can open a branch in any county. Intuitively, when more rival banks are allowed to operate in a township, more rival branches are likely to exist in this township.[12] The second instrumental variable, RivalHQ, is defined as the average of the distances from the township to the headquarters of each of the rival banks which are allowed to operate in the township in the given year. The intuition for this instrument is that the distance to headquarter only affects a bank's own branching decision, but there is no direct effect on other banks. To allow for more flexible functional form, I also include the cross term, BanksAllowed $\times$ RivalHQ, and the squared term, BanksAllowed^2, as two additional instruments.

One potential instrument to control for the potential endogeneity of the

[12] If the data set contains an observation from bank i, township k, and year t, it means that bank i is allowed to operate in this township in year t. In other words, conditional on being included in the data set, $BankAllowed_{ikt}$ essentially measures the number of i's rival banks allowed to operate in township k in year t.

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branch numbers located in the 2KM-wide band outside a township is the boundary length of the township (Boundary). Other things being equal, a township with a longer boundary is likely to observe more branches in its 2KM band surrounding its boundary. On the other hand, after using township fixed effect to control for the size of a township, its boundary length should have no direct impact on the number of branches within its boundary. However, I cannot use Boundary directly as an instrumental variable because it is time-invariant. When I include township fixed effects in the regression, using Boundary would cause collinearity problem. Instead, I use Boundary $\times$ RivalHQ to form an instrumental variable so that the marginal effect of RivalHQ on the number of nearby rival branches could be heterogeneous, depending on the boundary length. Furthermore, the number of banks allowed to operate in the neighboring townships is likely to correlate with the nearby branch numbers. Therefore, two instruments, NearbyAllowed and NearbyAllowedSq, are defined as the weighted average of the number (and its squared value) of banks allowed to operate in each of the adjacent townships, where the weight is the boundary length with the adjacent township.

The seven instrumental variables introduced in this subsection are used to construct moment conditions in the estimation. Summary statistics for these variables are shown in the bottom panel of Table 2.

5.3 Estimation Method

The model parameters are estimated by the generalized method of moments (GMM). The moment conditions in the estimation are

$$E\left[\varepsilon_{ikt}\mathbf{z}_{ikt}\right] = 0, \tag{5}$$

where the vector $\mathbf{z}_{ikt}$ includes all the socioeconomic variables in $\mathbf{w}_{ikt}$, bank dummy variables α_i, township dummy variables δ_k, year dummy variables τ_t, and the seven instrumental variables introduced in the previous subsection. The identification assumption is that the error term ε_{ikt} is orthogonal to the variables in $\mathbf{z}_{ikt}$. This assumption allows for potential correlation between the error term ε_{ikt} and the numbers of competing branches: RivalBranch_{ikt}, OwnNearby_{ikt}, and RivalNearby_{ikt}.

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6 Estimation Results

I first estimate spatial competition within a township, without accounting for the potential impact from branches in nearby townships. Then, I estimate the complete model to allow for possible competition effect from nearby townships.

6.1 Spatial Competition within a Township

In this subsection, I focus on the effect from branches of rival banks located in the same township and ignore the impact of branches in nearby townships. Table 3 presents the regression results on a bank's branch number in a township. Column (A) is the preferred one. The remaining columns compare it with alternative specifications. The number of rival branches, RivalBranch, appears to have a nonlinear effect. Therefore, its squared term is included as a regressor. Indeed, the squared term has a significantly positive effect on the branch number. Adding the cubic term of RivalBranch does not change the estimation results and the coefficient for the cubic term is small and insignificant. Therefore, I do not report it.

The estimated coefficients in Column (A) indicate that spatial competition from rival branches generally has a negative effect on the profitability of opening a branch. The business-stealing effect is the dominant effect in most markets. When the number of rival branches increases from zero to one, the marginal effect is to reduce the branch number by 0.029, which is approximately 14 percent of the average branch number. A positive coefficient on the squared term RivalBranch^2 indicates that the marginal effect is diminishing in the number of rival branches. The estimated coefficients imply that the competition effect is negative as long as the number of rival branches is less than 51, which accounts for the vast majority (97%) of the observations. Furthermore, all the estimated coefficients on the township-level socioeconomic variables have the expected signs. A township with larger population attracts more bank branches. More establishments in the manufacturing and service industries also make opening branches more profitable. The average size of an establishment has a positive effect on the branch number as well. Lastly, as previous literature in the retailing markets indicates, the distance to headquarter is an important negative factor to profit (Holmes, 2011). Specifically, the effect of increasing the distance by 1 KM on the branch number is equal to the effect of reducing the township population by 251.

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Table 3: Spatial Competition within a Township

	(A)	(B)	(C)	(D)	OLS
RivalBranch	−0.0291***	−0.0262***	−0.0296***	−0.0255***	−0.0111***
	(0.0049)	(0.0080)	(0.0047)	(0.0062)	(0.0020)
RivalBranch^2	0.00029***	0.00027***	0.00030***	0.00026***	0.00006***
	(0.00004)	(0.00007)	(0.00004)	(0.00005)	(0.00002)
Population	4.8714***	7.2918***	4.9380***	5.3893***	−0.9793*
	(0.7250)	(1.7336)	(0.7101)	(1.2332)	(0.5218)
Establishments	0.0662***		0.0667***	0.0669***	0.1258***
	(0.0107)		(0.0107)	(0.0114)	(0.0072)
Indep Units		0.0265			
		(0.0186)			
Managing Units		1.3358**			
		(0.5308)			
Branches		−0.0058			
		(0.2884)			
AvgWorkers	4.8486***	4.9450***	4.8907***	7.1823***	5.8172***
	(0.7960)	(1.3527)	(0.7934)	(1.3301)	(0.7329)
AvgPayroll		0.1112***			
		(0.0403)			
HQ Distance	−1.2234***	−1.2501***	−1.1222***	−1.2740***	−1.1971***
	(0.0455)	(0.0487)	(0.0470)	(0.0463)	(0.0426)
Township dummy	Y	Y	Y	Y	Y
Year dummy	Y	Y	N	Y	Y
Bank dummy	Y	Y	N	Y	Y
Bank×Year dummy	N	N	Y	N	N
Time period	1981–2016	1991–2011	1981–2016	1991–2016	1981–2016
Observations	87,690	63,531	87,690	76,743	87,690
R^2	0.4817	0.4741	0.4885	0.4942	0.5053
p value in over-id test	0.2066	0.1688	0.0254	0.1501	n.a.

Notes: Robust standard errors are given in parentheses. Superscripts ***, **, and * represent significance at 1%, 5%, and 10%, respectively.

Column (B) separates establishments in a township into three categories and includes an additional explanatory variable, AvgPayroll. Because data for these variables are available only for 1991–2011, the sample size is smaller. Among the three types of establishments, only the number of managing units has a significantly positive effect while the other two do not. This seems reasonable. Independent units tend to be smaller firms, and their existence only has a small impact on the banking industry. On the other hand, the managing units are generally headquarters of larger firms. They rely more on the banking service, such as doing foreign trades or direct deposit

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of employee salaries. Besides, the average payroll of a worker has a positive effect on branch profitability. Other coefficients are very similar to Column (A). Because of the data limitation, I am going to use the aggregate number of establishments and drop AvgPayroll for the remaining of the paper.

Column (C) uses the interactive terms of year dummies and bank dummies in the regression equation. Because of the regulation on the number of new branches a bank can open in a year, each bank faces a year-specific constraint on the decision of branch locations. By using the interactive terms of these dummy variables, I can control for this constraint. All the estimated coefficients are very similar to the preferred specification in Column (A), suggesting that the regulation of the number of new branches does not have a significant impact in determining the branch network.

Column (D) uses the subsample from the period of deregulation (1991–2016) to estimate the model. The results are similar but the coefficient on RivalBranch is slightly smaller.

Instead of GMM, I use the OLS regression to estimate Eq. (4) in the last column, ignoring the endogeneity problem. Comparing to Column (A), the magnitude of the marginal effect of RivalBranches becomes much smaller. This indicates the unobserved factor ε_{ikt} is probably positively correlated with the number of rival branches, consistent with the discussion on endogeneity in Subsection 5.2.

6.2 Spatial Competition from Nearby Townships

Next, I account for spatial competition arising outside township boundaries by adding OwnNearby and RivalNearby into the regression equation. The estimation results are shown in Table 4. Column (A) replicates the preferred specification in Table 3 for comparison. The remaining columns show the estimated competition effects from own and rival branches located in nearby townships. As defined in Subsection 4.3, these additional variables count the numbers of own and rival branches located within a 2KM-wide band outside a township respectively.

The effect of own branches in nearby townships (OwnNearby) is positive and significant, and its squared term indicates a diminishing marginal effect in both Column (B) and (D). As for the effect of rival branches in nearby townships, the estimated effect is positive, but it is small and insignificant in both Column (C) and (D). The estimated coefficients of socioeconomic variables are qualitatively similar to what we found in the previous

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Table 4: Spatial Competition from Nearby Townships

	(A)	(B)	(C)	(D)
RivalBranch	−0.0291***	−0.0242***	−0.0504**	−0.0471**
	(0.0049)	(0.0060)	(0.0228)	(0.0203)
RivalBranch^2	0.00029***	0.00028***	0.00044***	0.00044***
	(0.00004)	(0.00005)	(0.00015)	(0.00013)
OwnNearby		0.2821**		0.2410*
		(0.1397)		(0.1260)
OwnNearby^2		−0.0169*		−0.0078
		(0.0095)		(0.0104)
RivalNearby			0.0068	0.0100
			(0.0069)	(0.0067)
RivalNearby^2			−0.00002	−0.00003
			(0.00002)	(0.00002)
Population	4.8714***	2.1654	5.1491**	2.7632**
	(0.7250)	(1.5680)	(0.9017)	(1.4105)
Establishments	0.0662***	0.0581***	0.0740***	0.0528***
	(0.0107)	(0.0135)	(0.0153)	(0.0200)
AvgWorkers	4.8486***	3.5432***	6.0552***	5.3500***
	(0.7960)	(1.1377)	(1.8377)	(1.7912)
HQ Distance	−1.2234***	−0.8909***	−1.2147***	−0.6955***
	(0.0455)	(0.1891)	(0.0466)	(0.2317)
Township dummy	Y	Y	Y	Y
Year dummy	Y	Y	Y	Y
Bank dummy	Y	Y	Y	Y
Observations	87,690	87,690	87,690	87,690
R^2	0.4817	0.2233	0.4724	0.5266
p value in over-id test	0.2066	0.3490	0.1068	0.1775

Notes: Robust standard errors are given in parentheses. Superscripts ***, **, and * represent significance at 1%, 5%, and 10%, respectively.

subsection. The effect of the distance to headquarter on profitability is also significantly negative.

Based on the most complete specification in Column (D), the marginal effect of adding the first own branch in the 2-KM band is 0.24, which is significant at 10% level. This magnitude is slightly larger than the mean

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of the dependent variable. The estimated coefficient on the squared term implies that the marginal effect of OwnNearby is positive as long as it is less than 16. As a result, for over 99% of the observations in the data, this marginal effect is positive. Therefore, the estimation result provides evidence of positive externality among own branches in the nearby area. This implies the benefit from economies of density outweighs cannibalization effect for a bank's own branches in nearby townships.

I compare several alternative model specifications in Table 5 for robustness checks. The first column replicates the complete model in Column (D) of Table 4. Because AvgPayroll is not available in 2016, I add this additional explanatory variable in the second column but use only data in 1981–2011. The estimated result is similar to that of the first column, but the effects from own and rival branches in nearby townships become smaller and insignificant. Furthermore, the third column uses only the period after the deregulation in 1990. The standard errors are much larger under this specification, and most coefficients become insignificant. Given the low explanatory power in this specification, I cannot say much on the estimated coefficients in Column (C), but the estimated coefficient on OwnNearby is significantly positive at 5% level.

As mentioned in the previous subsection, each bank faces a year-specific constraint on the decision of branch locations because of the regulation on the number of new branches. To account for this constraint, I use the interactive terms of bank dummies and year dummies in the last column of Table 5. All the estimated coefficients are qualitatively similar to the first column. Similar to the finding in Table 3, it appears that the regulation on the number of new branches does not have a strong effect. Overall, the estimated results in Table 5 support a positive effect from OwnMearby and a small effect from RivalNearby.

Table 6 considers alternative widths of the band for defining the nearby region. When I increase the bandwidth from 0.5 KM to 5 KM, the competition effects from own and rival branches in the nearby band both become much smaller. This is what we should have expected. A branch farther away has a smaller impact on the profit. When the band is wider, the average competition effect from a branch in the band becomes smaller. Despite of the differences in the estimated magnitude, Table 6 also supports a positive effect from OwnMearby and a small effect from RivalNearby. Nonetheless, the over-identification test of the moment conditions in the GMM is rejected when the bandwidth is either 0.5 KM or 5 KM. As a consequence,

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Table 5: Spatial Competition from Nearby Townships: Various Specifications

	(A)	(B)	(C)	(D)
RivalBranch	−0.0471**	−0.0424**	−0.0141	−0.0584***
	(0.0203)	(0.0187)	(0.0226)	(0.0214)
RivalBranch^2	0.00044***	0.00039***	0.00022	0.00050***
	(0.00013)	(0.00012)	(0.00017)	(0.00014)
OwnNearby	0.2410*	0.1549	0.3644**	0.2866*
	(0.1260)	(0.1182)	(0.1670)	(0.1537)
OwnNearby^2	−0.0078	−0.0029	−0.0166	−0.0122
	(0.0104)	(0.0096)	(0.0110)	(0.0141)
RivalNearby	0.0100	0.0070	0.0003	0.0127*
	(0.0067)	(0.0052)	(0.0140)	(0.0072)
RivalNearby^2	−0.00003	−0.00002	0.00001	−0.00003*
	(0.00002)	(0.00001)	(0.00004)	(0.00002)
Population	2.7632**	3.3312**	1.2033	2.8719*
	(1.4105)	(1.5664)	(2.3520)	(1.5881)
Establishments	0.0528***	0.0642**	0.0433	0.0608***
	(0.0200)	(0.0305)	(0.0398)	(0.0199)
AvgWorkers	5.3500***	3.9257***	5.3575	6.1615***
	(1.7912)	(1.4464)	(3.8924)	(2.0125)
AvgPayroll		0.1198*		
		(0.0712)		
HQ Distance	−0.6955***	−0.7900***	−0.6364	−0.6553***
	(0.2317)	(0.2125)	(0.6837)	(0.1837)
Township dummy	Y	Y	Y	Y
Year dummy	Y	Y	Y	N
Bank dummy	Y	Y	Y	N
Bank×Year dummy	N	N	N	Y
Time period	1981–2016	1981–2011	1991–2016	1981–2016
Observations	87,690	74,478	76,743	87,690
R^2	0.5266	0.5659	0.3555	0.4279
p value in over-id test	0.1775	0.2566	0.1002	0.8379

Notes: Robust standard errors are given in parentheses. Superscripts ***, **, and * represent significance at 1%, 5%, and 10%, respectively.

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Table 6: Spatial Competition from Nearby Townships: Alternative Bandwidths

Bandwidth of Nearby Area	0.5 KM	2 KM	5 KM
RivalBranch	−0.0426	−0.0471**	−0.0390**
	(0.0215)	(0.0203)	(0.0209)
RivalBranch^2	0.00022	0.00044***	0.00037***
	(0.00030)	(0.00013)	(0.00012)
OwnNearby	1.5544	0.2410*	0.0930*
	(2.2487)	(0.1260)	(0.0526)
OwnNearby^2	−0.0131	−0.0078	−0.0012
	(0.6087)	(0.0104)	(0.0013)
RivalNearby	−0.0020	0.0100	0.0018
	(0.0550)	(0.0067)	(0.0016)
RivalNearby^2	0.00008	−0.00003	−0.00000
	(0.00010)	(0.00002)	(0.00000)
Population	4.4680*	2.7632**	4.0808***
	(2.6218)	(1.4105)	(1.1027)
Establishments	0.0015	0.0528***	0.0537*
	(0.0530)	(0.0200)	(0.0311)
AvgWorkers	5.0261	5.3500***	8.5917***
	(3.4060)	(1.7912)	(2.6019)
HQ Distance	−0.1845	−0.6955***	−0.5611
	(0.7979)	(0.2317)	(0.4022)
Township dummy	Y	Y	Y
Year dummy	Y	Y	Y
Bank dummy	Y	Y	Y
Observations	87,690	87,690	87,690
R^2	0.2193	0.5266	0.5591
p value in over-id test	0.0626	0.1775	0.0363

Notes: Robust standard errors are given in parentheses. Superscripts ***, **, and * represent significance at 1%, 5%, and 10%, respectively.

the preferred choice of the bandwidth is 2 KM.

Because most of the rural townships have no branch at all, I also estimate the model using only observations in more densely populated townships as a robustness check. Table 7 compares the estimated coefficients with various

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density criteria. The first column is the benchmark case with the full sample. The second column uses observations in townships with population density higher than the median in 1991. The estimated coefficients are qualitatively the same as the benchmark although several coefficients become insignificant. On the contrary, the third column shows that estimated coefficients using observations in township with density lower than the median are all insignificant. This is not surprising because 98.6% of these observations have zero bank branches. Lastly, the fourth column changes the criterion to include observations located in townships with population density higher than 300 per square KM in 1991.[13] The estimated coefficients are also qualitatively similar to the benchmark. While we observe bank branches concentrating in the urban area from the raw data, Table 7 indicates that the main findings on the effects of spatial competition are robust when I restrict the sample to more densely populated townships.

7 Discussion

Many bank branches are located near a township boundary. When measuring the profitability in a township by counting the number of branches located within the township boundary, we essentially assume that each township is a separate market. In this section, I discuss alternative measures for branch numbers. Furthermore, when using branch number as a proxy for profitability, I implicitly assume that a bank seeks to maximize its profit through its branch network. While this is likely to be true for private banks, the objective function of state-owned banks might be more complicated. I will also address bank ownership in this section.

7.1 Alternative Measures for Branch Numbers

In the baseline analysis, I measure a bank's profitability in a township by the number of branches within the township boundary and control for township-level socioeconomic variables. Each township is treated as a separate market. This approach essentially assumes that consumers do not travel

[13] Out of the 368 townships, 258 are included in the estimation. The Directorate-General of Budget, Accounting and Statistics in Taiwan used to have an official definition of "urbanized area": a settlement with more than 20,000 inhabitants and a population density higher than 300 per square KM. I use this definition as my criterion in the fourth column. Nonetheless this official definition has been scrapped in 2010.

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Table 7: Spatial Competition from Nearby Townships: Various Population Density

Township Population Density	Full Sample	≥ Median	< Median	> 300
RivalBranch	−0.0471**	−0.0151	−0.0158	−0.0250
	(0.0203)	(0.0265)	(0.0447)	(0.0206)
RivalBranch^2	0.00044***	0.00027	0.00683	0.00031**
	(0.00013)	(0.00017)	(0.01277)	(0.00013)
OwnNearby	0.2410*	0.1433	0.2434	0.2085
	(0.1260)	(0.1426)	(0.7838)	(0.1275)
OwnNearby^2	−0.0078	0.0031	0.1117	−0.0028
	(0.0104)	(0.0094)	(0.5738)	(0.0090)
RivalNearby	0.0100	0.0053	0.0205	0.0063
	(0.0067)	(0.0063)	(0.0149)	(0.0063)
RivalNearby^2	−0.00003	−0.00003*	−0.00081	−0.00002
	(0.00002)	(0.00001)	(0.00081)	(0.00001)
Population	2.7632**	3.2019**	−0.7666	2.4463**
	(1.4105)	(1.3668)	(2.1837)	(1.2262)
Establishments	0.0528***	0.0062	−0.0381	0.0304
	(0.0200)	(0.0239)	(0.0713)	(0.0197)
AvgWorkers	5.3500***	6.7541	−0.2627	9.0419**
	(1.7912)	(8.1321)	(1.1490)	(4.5659)
HQ Distance	−0.6955***	−0.9640***	−0.0662	−0.7990***
	(0.2317)	(0.3254)	(0.0541)	(0.2741)
Township dummy	Y	Y	Y	Y
Year dummy	Y	Y	Y	Y
Bank dummy	Y	Y	Y	Y
Observations	87,690	43,888	43,802	61,541
R^2	0.5266	0.6375		0.6127
p value in over-id test	0.1775	0.0038	0.3160	0.0500

Notes: Robust standard errors are given in parentheses. Superscripts ***, **, and * represent significance at 1%, 5%, and 10%, respectively.

across township boundaries for bank service. This assumption is unrealistic if bank branches are close to township boundary. However, township boundaries in urban area often go through a business area. As a result, it is not rare to observe a bank branch located very close to a boundary. In

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Table 8: Share of Bank Branches near a Township Boundary

Year	Total Branch Number	Share of Branches near a Boundary
1981	756	63.10%
1986	861	64.81%
1991	1,096	70.26%
1996	2,017	72.78%
2001	2,951	72.08%
2006	3,314	71.21%
2011	3,433	72.36%
2016	3,455	72.36%

Note: The share means the percentage of all bank branches less than 1 KM away from a township boundary.

fact, Table 8 shows that approximately 70% of bank branches in Taiwan are less than 1 KM away from a township boundary over the sample period.[14] To be more specific, Figure 3 uses dots to illustrate the locations of all bank branches in central Taipei City in 2016. Township boundaries are represented by solid lines in the graph. It is clear from this graph that many bank branches in Taipei City are close to a boundary.

To deal with the problem mentioned in the previous paragraph, I construct an alternative measure on the branch number. This method is conceptually similar to Huysentruyt, Lefevere, and Menon (2013). When a branch is near a township boundary, I count this branch as serving both sides of the boundary. Specifically, I define the *serving area* of a branch to be a circle with a 1KM radius. This distance roughly corresponds to one-way walking time of 15 minutes.[15] If the 1KM radius circle of a branch lies entirely within a township, it is counted as one branch exclusively for this township. On the contrary, when the 1KM radius circle of a branch covers more than one township, I count this branch as serving all of these covered townships. The *effective* number of this branch in a township is only a fraction of one. It is defined as the share of land area of the township within the 1KM radius

[14] As a reference, the median size of a township in Taiwan is 53.58 KM^2, and the smallest township is only 0.88 KM^2.

[15] I also compare the estimation results with other choices of the radius.

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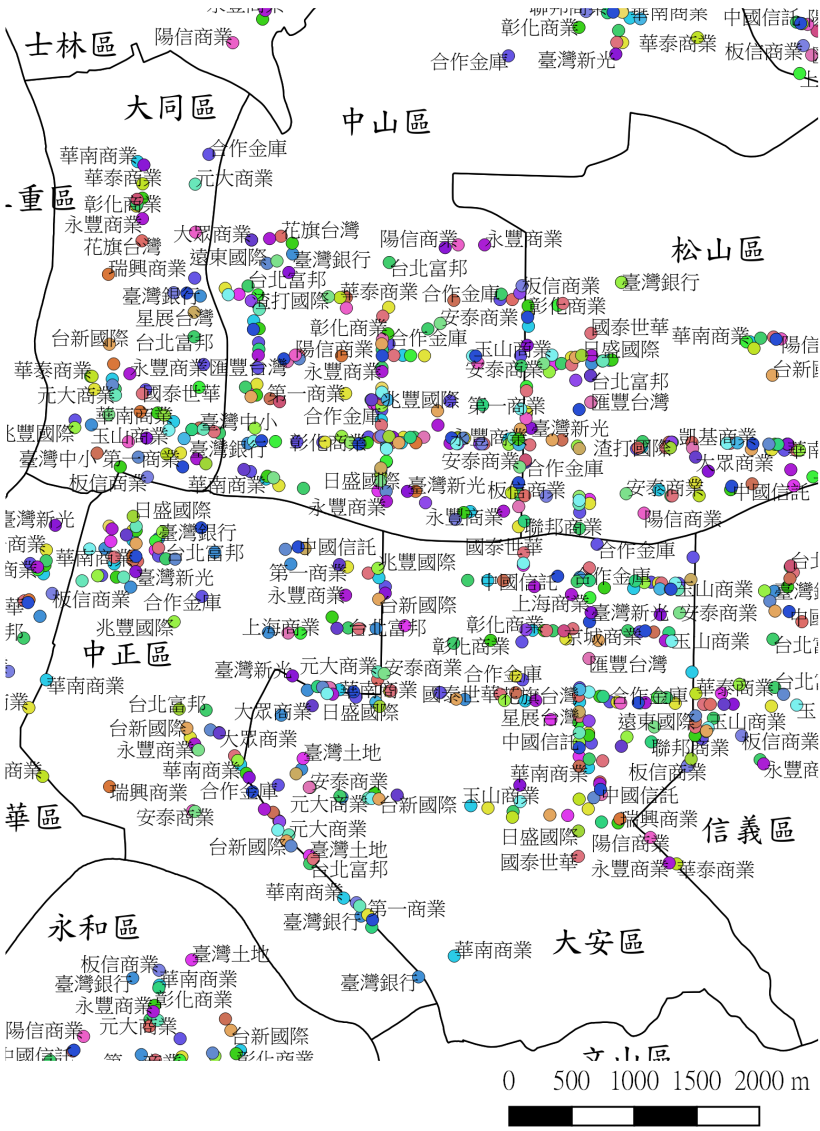


Figure 3: Bank branch locations in central Taipei City in 2016

circle.[16] For example, if a branch is located exactly on the boundary between

[16]When the 1KM radius circle covers sea, I compute the share based on the total land area

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Township A and Township B and the boundary is a straight line, I count it as 0.5 branch in both Township A and Township B.

A bank's *effective branch number* in a particular township is the sum of the effective numbers over all of its branches located inside the boundary and less than 1 KM away outside the boundary. By using this measure of branch number, I do not restrict a consumer to visit only bank branches located within his/her township.

Overall, the effective branch number is highly correlated with the actual branch number with a correlation coefficient of 0.975 for the entire sample. At the county level, the correlation coefficients are almost always above 0.9. The only exception occurs in Keelung City, which has a correlation coefficient of 0.785. Clearly, this is caused by the fact that most bank branches in Keelung City locate very close to a township boundary.

Table 9 shows the estimated coefficients with various radiuses of the serving area. The first column, labeled as "0KM", is replicated from Column (A) in Table 3, using the exact location to count the branch number. The remaining columns increase the radius of the serving area to 1 KM, 2 KM, and 5 KM, respectively. The estimated coefficients do not change qualitatively from 0 KM to 2 KM. As expected, when the serving area is wider, all the estimated coefficients become smaller in the absolute value. But for the radius of 5 KM, some of the estimated signs reverse. It is probably because 5 KM is too large for defining the serving area in the banking industry.

Table 9 indicates that using these alternative measures of branch numbers to estimate the competition effect from rival branches within the same township does not affect my main findings in Subsection 6.1. Nonetheless, it is problematic to estimate the complete model with branch competition from nearby townships presented in Subsection 6.2 using these alternative measures. Because a branch near a township boundary is counted as a fraction of a branch in both sides of the boundary, there is a positive correlation on the *effective branch numbers* between these adjacent townships even if there is no causal effect among them. The instrumental variables introduced in this study cannot control for this spurious positive effect.

7.2 Bank Ownership

In the benchmark model, I assume that banks make their branch decision

within the circle.

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Table 9: Spatial Competition within a Township: Alternative Measures of Branch Number

Radius of Serving Area	0 KM	1 KM	2 KM	5 KM
RivalBranch	−0.0291***	−0.0265***	−0.0216***	−0.0144***
	(0.0049)	(0.0045)	(0.0041)	(0.0036)
RivalBranch^2	0.00029***	0.00027***	0.00025***	0.00028***
	(0.00004)	(0.00003)	(0.00003)	(0.00004)
Population	4.8714***	4.6384***	4.2828***	3.9891***
	(0.7250)	(0.6768)	(0.6452)	(0.5088)
Establishments	0.0662***	0.0622***	0.0518***	0.0184***
	(0.0107)	(0.0100)	(0.0092)	(0.0065)
AvgWorkers	4.8486***	4.4389***	3.2603***	−1.6047**
	(0.7960)	(0.7294)	(0.6741)	(0.7286)
HQ Distance	−1.2234***	−1.2225***	−1.2209***	−1.2178***
	(0.0455)	(0.0431)	(0.0410)	(0.0354)
Township dummy	Y	Y	Y	Y
Year dummy	Y	Y	Y	Y
Bank dummy	Y	Y	Y	Y
Observations	87,690	87,690	87,690	87,690
R^2	0.4817	0.5208	0.5467	0.5814
p value in over-id test	0.2066	0.0586	0.0013	0.0000

Notes: Robust standard errors are given in parentheses. Superscripts ***, **, and * represent significance at 1%, 5%, and 10%, respectively.

in order to maximize its own profit. While this assumption is likely to be true for private banks, state-owned banks may have different objectives. For example, since these banks have a common owner (the government), they probably care about the profit of other state-owned banks as well. Furthermore, they may also consider other policy objectives, such as universal service to the rural area. Table 10 shows the number and the fraction of branches operated by state-owned banks. Although the fraction drops from 83% in 1981 to 38% in 2016, they still comprise a substantial proportion of branches as of now.

Table 11 shows the estimation results by separating the sample according to bank ownership. Although most of estimated coefficients have the same sign for these two types of banks, there are some variations in the mag-

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Table 10: Number and Share of State-Owned Banks' Branches

Year	Number	Share
1981	630	83.33%
1986	692	80.37%
1991	813	74.18%
1996	1,103	54.69%
2001	1,295	43.88%
2006	1,303	39.32%
2011	1,324	38.57%
2016	1,306	37.80%

nitudes. The effect of rival branches within the same township is much stronger for state-owned banks. This suggests that the objective of state-owned banks is more likely to be affected by rival banks. Joint ownership among the state-owned banks probably makes them partially internalize the profit of rival banks. This result is consistent with the findings in Crawford et al. (2018). They empirically analyze vertical integration in the television markets. They find that firms internalize a substantial fraction (79%) of the profits of other integrated units when making decisions. On the contrary, the marginal effect from own branches in nearby townships is smaller for state-owned banks. Benefits from economies of density seem more important for private banks.

8 Concluding Remarks

This paper empirically analyzes spatial competition of the branch network in the banking industry in Taiwan. While business-stealing effect would imply a negative impact on profitability from rival branches, positive externality between banks would imply an opposite effect. Consequently, theoretical prediction on the net effect of spatial competition in the banking industry is ambiguous.

Using 5-year interval panel data between 1981 and 2016 from Taiwan, I find a significantly negative impact of rival branches within the same township on branch profitability for more than 97% of the observations. This effect is particularly strong in smaller market because the magnitude of the

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Table 11: Spatial Competition from Nearby Townships: State-Owned versus Private Banks

	All Banks	State-Owned	Private
RivalBranch	−0.0471**	−0.0771*	−0.0157
	(0.0203)	(0.0422)	(0.0290)
RivalBranch^2	0.00044***	0.00064***	0.00031
	(0.00013)	(0.00024)	(0.00021)
OwnNearby	0.2410*	0.1953	0.4634***
	(0.1260)	(0.2667)	(0.1147)
OwnNearby^2	−0.0078	−0.0036	−0.0098
	(0.0104)	(0.0174)	(0.0105)
RivalNearby	0.0100	0.0203**	0.0051
	(0.0067)	(0.0101)	(0.0123)
RivalNearby^2	−0.00003	−0.00005*	−0.00003
	(0.00002)	(0.00003)	(0.00003)
Population	2.7632**	0.9892	0.2878
	(1.4105)	(1.4796)	(1.3468)
Establishments	0.0528***	0.1252*	−0.0017
	(0.0200)	(0.0806)	(0.0291)
AvgWorkers	5.3500***	5.7459**	3.2320
	(1.7912)	(3.4075)	(3.3083)
HQ Distance	−0.6955***	−0.5678	−0.0201
	(0.2317)	(0.4157)	(0.4760)
Township dummy	Y	Y	Y
Year dummy	Y	Y	Y
Bank dummy	Y	Y	Y
Observations	87,690	30,569	57,121
R^2	0.5266	0.6577	0.5163
p value in over-id test	0.1775	0.6249	0.4837

Notes: Robust standard errors are given in parentheses. Superscripts ***, **, and * represent significance at 1%, 5%, and 10%, respectively.

negative impact declines in the number of rival branches. As for the spatial competition across townships, the evidence is relatively weaker. The number of a bank's branches in nearby townships has a positive effect on branch profitability, suggestion the benefit from the economies of density

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in the branch network. Nonetheless, the effect of rival banks' branches in nearby townships is insignificant in most specifications. Because Taiwan is a densely populated country, approximately 70% of bank branches locate near a township boundary. They are likely to serve customers on both sides of the boundary. I propose a novel measure of branch numbers to account for the boundary problem, but the estimation result under this alternative measure changes very little from the benchmark result estimated under the traditional measure of branch numbers.

In this paper, I do not explicitly consider the restrictions imposed by the regulation rules. For instance, opening a new branch needs to be approved by the regulator, and there is an upper bound on the number of a bank's new branches in a year. To fully analyze these regulations and evaluate the policy implications, it is probably necessary to apply a dynamic structural model to explicitly take the restrictions into account. This is left for future research.

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台灣銀行業分行網路之空間競爭

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本研究針對銀行業的分行網路之空間競爭效果, 進行實證分析。由於產業內的正外部性與偷生意效應對於分行獲利會造成相反的影響, 因此空間競爭效果的理論預測方向模稜兩可。我收集 1981 到 2016 年間台灣各銀行所有分行的地址, 結合地理資訊座標, 對於分行位置的選擇進行量化分析。在控制社經變數之後, 估計銀行在各鄉鎮市區的分行數, 如何受鄰近其它分行的影響。我發現在同一鄉鎮市區內, 對手銀行的分行數會對於獲利有負向影響。然而, 周邊鄉鎮市區的自家分行對於獲利則有正向效果, 意味著密度經濟的效應可能存在於本產業。

關鍵詞: 銀行業, 分行網路, 空間競爭, 密度經濟, 偷生意效應
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