Spatial Competition with Online Platforms: An Empirical Analysis of the Wealth Management Product Market[*]

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Abstract

We study wealth management products (WMPs) issued by banks and find higher prices online than offline. The explanation is: banks must charge lower prices at physical branches to compensate customers for traveling costs. The online-offline price gaps decrease with the share of online-banking users, the number of incumbent banks, and a bank's branch density and clustering. WMP markets provide an ideal scenario to identify the effect of spatial competition on the online-offline spread because online and offline channels for issuing WMPs (selling financial products) do not differ in delivery, search, or waiting costs or the convenience of inspecting product quality.

Keywords: Digital economy, Digital finance, Spatial competition, Online prices, Banking

JEL Codes: G2, G5, L1, L8, R1

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1. Introduction

As the digital economy and digital finance develop rapidly, an increasing number of products and services can be purchased both online and offline. Correspondingly, an open question is whether prices are reduced by online availabilities. Previous empirical studies have examined many sectors (e.g., clothing, electronics, drugs, office products, CDs, and books) and the overall finding is that, when there is a price difference, most of the time, the online price is lower than the offline price (Cavallo, 2017; Brynjolfsson and Smith, 2000).

In this paper, we study the market of a financial product, the wealth management product (WMP) market, which is the largest component of China's shadow banking sector. WMPs are a financial innovation that was initiated in 2004 by commercial banks in China. Banks design the terms (e.g., promised yields and maturities) in the contracts of WMPs, sell WMPs to households, and then invest the raised money into underlying assets (including loans, bonds, equities, money market rates, foreign exchanges, and gold).[1] The type of underlying assets of a WMP is specified in the contract at issuance. Later, banks distribute part of the revenues generated from the underlying assets to the WMP buyers as the principal and interest payments according to the agreements. The risk of WMPs is much lower than that of other investment tools, such as stock and commercial bonds, while the return on WMPs is much higher than that on bank deposits. At the end of 2017, the total value of outstanding WMPs reached RMB 29.54 trillion (approximately USD 4.25 trillion). During 2017, banks issued 93,500 individual WMPs.

We find that prices (promised yields) of WMPs sold online are significantly higher (lower) than prices (promised yields) of WMPs sold at banks' physical branches,[2] which is opposite to

[1] WMPs issued by banks are mainly sold to households. There are other types of asset management products issued by mutual funds, trust funds, and other financial intermediaries, which mainly target institutional investors. Compared with those financial intermediaries, banks have a much larger household customer base and a more widely distributed branch network. Therefore, banks have a dominant advantage in attracting funds from households and have significantly lower issuing costs. This paper focuses on WMPs issued by banks.

[2] Prices and yields of financial products are inversely related. Holding the future payoffs of a financial product fixed, the lower the current selling price is, the higher yield (or rate of return).

previous empirical studies on nonfinancial retail industries. The explanation is that customers need to pay travel (inconvenience) costs to visit physical branches and thus banks have to charge lower prices at physical branches to attract customers from online platforms. We further find that the gap between online and offline prices decreases with the share of online banking users.

In addition, we find that the online-offline price gaps of a bank decrease with both the number of incumbent banks and the bank's branch density and clustering in the city, although the former tends to decrease a bank's market power whereas the latter tends to increase a bank's market power. As the number of competitors increases, a bank can still maintain some local market power in the offline market over residents near its physical branches but cannot do so in the online market. In contrast, a bank's branch density and clustering in a city directly increase the bank's local market power in the offline market but do not directly increase its market power in the online market.

Multiple factors tend to cause online prices lower than offline prices. First, for online products, firms usually bear lower shipping and inventory costs and do not need to pay shelf costs. Second, search costs online are usually lower than search costs offline. Third, visiting a physical store provides a consumer with more convenience to inspect a product's quality or to determine whether the product fits the consumer's preference prior to purchase. Fourth, at physical stores, consumers can immediately obtain the item after purchase, while online shopping incurs waiting costs for consumers (Loginova, 2009).

The WMP market provides an ideal scenario to identify the effect of firms' spatial competition that contributes to the gap between online and offline prices because, for WMPs, this gap is unlikely to be confounded by other reasons. First, because WMPs are a type of financial product (contract), there are no shipping costs, inventory costs, or shelf costs at all. As a result, WMPs sold online and offline do not differ in these dimensions that can affect prices. Second, customers have similar search costs for WMPs sold online and at physical branches because the information on WMPs sold at physical branches is also posted on banks' websites. Third, WMPs are essentially a type of financial contract, and customers do not need to visit a physical branch to inspect the product quality or determine whether the product characteristics fit their preference.

Investors' perception of the characteristics of a financial product through the online channel should be similar to their perception at a physical branch (see Appendix B for a sample document of a WMP provided by the issuing bank). Fourth, regardless of whether it is purchased online or offline, the financial contract becomes effective immediately after the transaction. Customers purchasing online do not need to pay additional waiting costs. Therefore, the online-offline price gap should be purely driven by firms' (banks') spatial competition behavior, which causes online prices to be higher than offline prices.

In this study, we first build stylized theoretical models of banks' spatial competition with the existence of online banking platforms for the WMP market. Following the spirit of Salop (1979), the model assumes that banks' physical branches are located on a circle, on which customers reside. In addition, the models allow heterogeneous preferences across customers for different banks. The models also allow the existence of both online banking users and customers who never use online banking because of their lack of Internet access or trust in digital finance. Next, we analyze the WMP data and provide empirical evidence that is consistent with the models' predictions.

The results in this study generate policy implications for regulators. Online markets are beneficial because they can save many costs, including consumers' travel costs. However, the saved costs do not necessarily become consumers' surplus because sellers can charge higher margins for online products. Therefore, increasing the competitiveness in online markets is important for regulators, especially when we empirically find that the competitiveness in online markets is more sensitive to an increase in the number of sellers than is the competitiveness in offline markets and that if online markets lack competitiveness, it will hurt not only online consumers' surplus but also offline consumers' surplus.

Regulators can increase the competitiveness of online markets of WMPs in two ways. The first way is deregulation of geographical restrictions on bank branching. A bank's branch entry into a city can also increase the number of competitors in the online market of the city because, unlike the U.S. banking industry, the online market of WMPs is segmented at the city level. Customers in a city cannot purchase online products of banks that do not have physical branches in the city.

The second way is to remove the geographical segmentation of online markets of WMPs and unify them into a national online market. Customers in a city should be enabled to freely purchase online products of banks that do not have physical branches in the city. Consequently, each customer will face more competing banks, which will help reduce online prices.

Our study contributes to multiple strands of literature. First, several studies have analyzed retail industries and found that online prices are mostly lower than offline prices, if there is a price difference between the two channels (e.g., Cavallo, 2017; Brynjolfsson and Smith, 2000). In contrast, we analyze WMPs, a type of financial product issued by commercial banks, and find that online prices are higher than offline prices. The WMP market provides an ideal scenario to identify the effect of firms' spatial competition that contributes to the gap between online and offline prices because, for WMPs, this gap is unlikely to be confounded by other factors.

Second, multiple studies have analyzed firms' competing behavior when both online and offline channels are available, and they focused on aspects other than the gap between online and offline prices. For example, Balasubramanian (1998) and Loginova (2009) built theoretical models for the competition between direct (online) marketers and conventional retailers. Dinlersoz and Pereira (2007) built a theoretical model for firms' decisions on the adoption of e-commerce platforms. Empirical studies have estimated the degree of substitution (or complementarity) between print and online newspapers (Gentzkow, 2007), between Walmart or Barnes & Noble and Amazon (Forman, Ghose and Wiesenfeld, 2008), between online peer-to-peer lenders and banks (Tang, 2019), between online and offline advertising (Seamans and Zhu, 2014; Goldfarb and Tucker, 2011a & 2011b), and between online and offline sales for women's clothing (Brynjolfsson, Hu, and Rahman, 2009), for niche diapers (Choi and Bell, 2011), and for personal computers (Goolsbee, 2001; Prince, 2007; Duch-Brown, Grzybowski, Romahn and Verboven, 2017). Ghili and Kumar (2020) studied the effect of rideshare platforms on geographical distortion of supply from demand. Rabello de Castro (2019) estimated the welfare value of online grocery services.

Third, several studies have analyzed the effect of e-commerce platforms on different aspects of the real economy. Brown and Goolsbee (2002) found that Internet comparison shopping sites reduce search costs and thus the price dispersion of life insurance. Krasnokutskaya, Song and Tang (2020) examined buyers' welfare gains associated with the globalization enabled by online markets. Fan, Tang, Zhu and Zou (2018) found that Alibaba's e-commerce platform increased intercity trade and alleviated spatial consumption inequality. Bhargava and Choudhary (2008), Fay and Xie (2008), and Lambrecht and Misra (2017) studied digital price discrimination enabled by e-commerce platforms. Cohen, Hahn, Hall, Levitt and Metcalfe (2016) estimated the consumer surplus brought by the UberX car service.

Fourth, this paper is also related to a broader literature on digital finance and fintech. Some studies have analyzed industries that emerged with fintech, such as online P2P lending platforms (Wei and Lin, 2017; Lin, Prabhala and Viswanathan, 2013; Tang, 2019; Li and Ching, 2019; Biancini and Verdier, 2019), fintech credit for small businesses (Hau, Huang, Shan and Sheng, 2019), mobile payment apps (Agarwal, Qian, Yeung and Zou, 2018; Buchak, Hu and Wei, 2021), and bitcoin (Cong and He, 2019; Foley, Karlsen and Putniņš, 2019; Easley, O'Hara and Basu, 2019; Makarova and Schoar, 2020). Other studies have analyzed how fintech affects traditional financial services, such as data sharing (He, Huang and Zhou, 2020) and mortgage lending (Buchak, Matvos, Piskorski and Seru, 2018; Bartlett, Morse, Stanton and Wallace, 2019; Fuster, Plosser, Schnabl and Vickery, 2019). In those financial services, banks act as lenders, and customers act as borrowers. In contrast, our study analyzes how online banking platforms affect the competition among commercial banks in selling WMPs (the largest component of China's shadow banking system), in which banks act as debtors and customers act as investors.[3]

The remainder of this paper is organized as follows. Section 2 provides the background of the WMP market in China. Section 3 builds stylized theoretical models of banks' spatial competition with the existence of online banking platforms for the WMP market. Section 4 describes the data from the multiple sources used in this study. Section 5 proposes five testable hypotheses implied by the stylized models in Section 3 and conducts empirical tests based on the data described in Section 4. Section 6 addresses several concerns. Section 7 discusses the welfare

[3] There is also a broader literature on digital economy. Goldfarb and Tucker (2017) provided a thorough literature review on this area.

and policy implications of the results. Then, we conclude in Section 8.

2. Background

WMPs are a financial innovation that was initiated in 2004 by commercial banks in China. Banks design the terms in the contracts (e.g., promised yields, maturities, types of underlying assets, preservation terms, and minimum investment requirements), sell WMPs to households, and then invest the raised money into underlying assets. Later, banks distribute part of the revenues generated from the underlying assets to the WMP buyers as the principal and interest payments according to the agreements. The realized returns of the underlying assets are not visible to the WMP buyers.

The issuing volume of a WMP is often above RMB 50 million. Buyers of the same WMP face the same price (or promised yield), which is public information (similar to purchasing a bond or a mutual fund in the primary market). The issuing period of a WMP usually ranges from several days to serval weeks.

The underlying assets of WMPs include loans, bonds, equities, money market products, foreign exchanges, and commodities (e.g., gold). In addition, banks can hedge off the risk using financial derivatives related to the underlying assets and make the WMP a structured product. The type of underlying assets of a WMP and whether the WMP is a structured product are specified in the contract at issuance.

The risk of WMPs is much lower than that of other investment tools, such as stock and commercial bonds. There are three types of preservation term: principal and interest guarantee, principal guarantee, and no guarantee. For WMPs with fixed interest rates, investors are guaranteed both the principals and the interest rates stated in the agreement. For WMPs with flexible rates, investors are given an expected interest rate (or an interest rate range with upper and lower bounds); the actual payment at the maturity date depends on the performance of the underlying assets (in principle, the actual return rate can be different from the expected rate and investors can even lose part of the principal). If the WMP principal is guaranteed, investors receive at least the principal;

if there is no guarantee, investors receive whatever is left from the market value of the underlying assets after the management fee deduction. Although a significant proportion of WMPs have flexible rates, among all WMPs issued by banks, 96.43% finally paid a realized return that was the same as the expected return or the upper bound of the expected return range specified at issuance; only 0.79% paid a realized return that was lower than the expected return or the upper bound of the expected return range specified at issuance; the remaining 2.78% paid even a higher realized return than the expected return or the upper bound of the expected return range specified at issuance. As required by the China Banking and Insurance Regulatory Commission, investors need to fill out an assessment form of risk capacity and risk tolerance. Although banks do not literally offer deposit insurance for WMPs, there are almost no default cases in the first 10 years of WMP history. In practice, WMPs are implicitly guaranteed by issuing banks, and thus investors usually consider WMPs to be a relatively safe way to invest.[4]

The returns on WMPs are much higher than bank deposit rates. Given that deposit rates in China are capped by the regulator, WMPs almost always offer much higher expected returns than time deposits with the same maturity. Table 1 shows the average rates of 3-month time deposits and the average returns of WMPs with similar maturities for each year from 2004 to 2016. For investors, WMPs are less liquid than checking accounts. Although there are a variety of terms to maturity, ranging from one day (or daily renewable) to five years, investors need to apply for early termination during business days and they receive no interest payment with early withdrawal. Moreover, to purchase a WMP, investors are usually required to transfer the money to the WMP account a few days earlier. Meanwhile, there is a minimum investment requirement for WMP buyers, usually above RMB 50,000. Appendix B displays a sample document of a WMP provided by the issuing bank.

[Insert Table 1 here]

With the significant increase in M2 growth in China since 2009, households are worried about how to preserve the value of their money. Given the limited investment choices in China,

[4] "The new regulatory rules on asset management" announced by the regulator in 2018 would alter banks' implicit guarantees for WMPs. However, our sample period is from 2004 to 2016, before the policy change.

WMPs have become an alternative to deposits. The high interest rates with implicit guarantees make WMPs quite attractive for most risk-averse households. Since the initiation of WMPs, the WMP market has experienced skyrocketing growth. The total number of WMP issuances per year by banks increased dramatically from 112 in 2004 to 93,500 in 2017. As shown in Figure 1, the outstanding WMPs at the end of 2017 reached RMB 29.54 trillion (approximately USD 4.25 trillion). The WMP market has become the largest component of China's shadow banking system.[5]

[Insert Figure 1 here]

While absorbing deposits and lending belong to banks' on-balance sheet activities, selling WMPs and investing the money raised from WMPs are categorized as banks' off-balance-sheet activities, except for WMPs whose underlying assets are loans issued by the same bank.[6] This means that WMPs, unlike deposits, do not need to meet the required reserve ratio, loan to deposit ratio, or other related regulatory requirements, which provides plenty of freedom to commercial banks. For example, some firms or projects cannot receive financing from on-balance sheet bank loans because banks need to meet multiple regulation requirements, such as risk control or loan quotas, but they can be the investment targets of banks' cash raised from WMP sales.

While on-balance sheet interest rates (for deposits and loans) are strictly regulated in China, the off-balance sheet WMPs provide a playground of interest liberalization. The expected returns specified in the contracts of WMPs at issuance are determined by the market. The issuing bank sets the expected return in the contract based on its judgment of the current WMP conditions. If the bank believes that the demand of local households for WMPs is low but the bank still wants to raise a sufficient amount of money, it will offer a higher expected return.

A WMP can either be issued nationwide (as long as the issuing bank has a local branch in

[5] Because of its importance and unique characteristics, the WMP market has been employed by economists to answer many other general-interest research questions, such as the effect of monetary policy on shadow banking (Chen, Ren and Zha, 2018), the effect of house prices on the financing costs of financial institutions (Ma and Zhang, 2019), interest rate liberalization (Wang, Wang, Wang and Zhou, 2018), liquidity regulation (Hachem and Song, 2016), bank risk (Qian, Acharya, Su and Yang, 2019), and banks' maturity mismatch and regulation evasion (Luo, Fang, Liu and Zhao, 2019).

[6] As of 2009, the regulator requires WMPs with the issuing bank's credit assets as the underlying assets to be shown on the bank's balance sheets (CBRC 2009 rules No. 111 & No. 113).

the city) or be issued exclusively in several cities or a single city. As shown in Table 2, 10% of WMPs were issued exclusively in a single city, which constitutes the main sample for our empirical study. To be able to purchase WMPs issued exclusively in a single city, regardless of whether purchasing through online or offline channels, investors need to have a local checking account with the issuing bank. To open a local checking account, customers have to physically visit a local branch of the issuing bank in the city. Customers of the same bank but with an account in a different city (which can usually be identified by certain digits of the account number) are not qualified for purchase in the current city.[7] Customers in a city cannot purchase online products of banks that do not have physical branches in the city.[8] Therefore, both the online and offline markets for these WMPs are local and the buyers are mainly residents in the city.[9] Banks set different promised yields for WMPs sold exclusively in different cities. For example, in March 2013, the average promised yields of online products sold by Industrial and Commercial Bank of China exclusively in Beijing and Guangzhou were 4.29% and 4.24%, respectively, and the average yields of its offline products sold exclusively in the two cities were 4.20% and 4.03%, respectively. When setting promised yields, issuing banks will consider the demand of households in the city and the competitiveness of the local WMP market.

[Insert Table 2 here]

3. Stylized models

In this section, we build stylized models to show that travel costs can make offline prices lower than online prices and how the price gap changes according to the number of incumbent banks,

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[7] Unlike the U.S., in China, customers of the same commercial bank but residing in different cities have different local accounts. A local account is affiliated with a city branch of a commercial bank. Many banking services require a local banking account, such as receiving direct deposits for salaries from local employers or social securities from the local government. Some bank services charge higher fees for customers with an account in another city, such as money transfer.

[8] Note that in the U.S., Customers in a city can purchase online products of banks that do not have physical branches in the city.

[9] It is possible that a few customers may have a bank account in a city other than their city of residence. However, these customers cannot comprise a significant portion of the buyers for the WMPs issued in the city.

branch densities, and branch clustering. Admittedly, multiple alternative mechanisms can cause the price gap (e.g., different price sensitivities and marginal costs between online and offline customers). We do not build these alternative mechanisms into the stylized models, but we will provide evidence that our empirical results should not be fully driven by these alternative mechanisms in Section 6.

We first derive a bank competition model in which banks have only physical branches and a model in which banks have only online platforms. Then, we derive a model in which banks have both physical branches and online platforms and all customers are omni-channel. Further, we build a model that allows the existence of customers who never use online banking either because they do not have Internet access or because they do not trust online banking. In addition, although decreases in the number of incumbent banks, increases in a bank's own branch density, increases in its branch clustering, or decreases in its competitors' branch density would increase the bank's market power, we theoretically show that the former one affects online markets more substantially than offline markets and hence enlarges the online-offline price gap whereas the latter three affect offline markets more substantially than online markets and hence narrow the price gap.

3.1. Spatial competition without online technology

Following the spirit of Salop (1979), we assume that customers uniformly reside on a circle with circumference l. Bank A and bank B are located symmetrically on each side of the circle, as shown in Figure 2.1. Neither bank has online banking platforms. Assume that the mass density of customers residing at any point on the circle is equal to 1; thus, the total mass of all customers on the circle is l. Each customer either purchases one unit of banking service from either bank A or bank B or chooses the outside option. Denote the prices of bank A and bank B as p_A and p_B, respectively. Customers have complete information about banks' prices. The marginal costs of the two banks are both zero. Customer i's utilities of choosing bank A, bank B, and the outside option are as follows:

$$u_{iA} = \alpha - p_A - \gamma d_{iA} + \varepsilon_{iA} \tag{3.1}$$

$$u_{iB} = \alpha - p_B - \gamma d_{iB} + \varepsilon_{iB} = \alpha - p_B - \gamma\left(\frac{l}{2} - d_{iA}\right) + \varepsilon_{iB} \tag{3.2}$$

$$u_{i0} = \varepsilon_{i0} \tag{3.3}$$

d_{iA} and d_{iB} are the distances for customer i to bank A and bank B, respectively. γ captures the travel cost per unit of distance. α captures the average preference of all customers for purchasing a product compared to the outside option.[10] ε_{iA}, ε_{iB}, and ε_{i0} represent customer i's idiosyncratic preferences for bank A, bank B, and the outside option, respectively. Assume that ε_{iA}, ε_{iB}, and ε_{i0} follow the type II extreme value distribution.

[Insert Figure 2 here]

[Insert Figure 3 here]

Figure 3.1 displays a coordinate in which the vertical axis represents the idiosyncratic preference difference of a customer between bank A and bank B ($\varepsilon_{iA} - \varepsilon_{iB}$) and the horizontal axis represents the customer's distance to bank A. Conditional on purchasing a product, the blue area represents customers who choose bank A over bank B, while the red area represents customers who choose bank B over bank A. Consequently, the demand for bank A is

$$D_A = 2\int_0^{\frac{l}{2}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \tag{3.4}$$

The demand for bank B is

$$D_B = 2\int_0^{\frac{l}{2}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \tag{3.5}$$

Assume that the two banks play a Bertrand-Nash pricing game. Bank A solves the following profit-maximization problem w.r.t. p_A given its rival's price p_B

$$\max_{p_A | p_B} \pi_A = p_A D_A \tag{3.6}$$

Bank B solves the following profit-maximization problem w.r.t. p_B given its rival's price p_A

[10] For simplicity, we assume bank A and bank B have the same α and thus we can obtain symmetric solutions. Our results are extendable to the case in which different banks have different α. In Subsection 3.7, we will discuss such a case.

$$\max_{p_B|p_A} \pi_B = p_B\, D_B \tag{3.7}$$

Denote the equilibrium prices as (p_A^*, p_B^*). Because of the symmetry between bank A and bank B, $p_A^* = p_B^*$.

Given a small α ($\alpha = 0$), the blue curve in Figure 4.1 displays the numerical solution of the equilibrium prices (p_A^*, p_B^*), which are decreasing in l.[11] In contrast, given a large α ($\alpha = 10$), the blue curve in Figure 4.2 displays the numerical solution of the equilibrium prices (p_A^*, p_B^*), which are increasing in l.

[Insert Figure 4 here]

Two competing forces on equilibrium prices change with l. First, as l increases, more people live further away from banks' branches and find banks' products less attractive relative to the outside option due to the higher travel costs. Consequently, banks need to charge lower prices to prevent too many customers from choosing the outside option. Second, for a customer who chooses bank A, as l increases, the difference between her/his distance to bank A and that to its competitor (bank B) will become larger; bank A will become more advantaged than its competitor for this customer. Therefore, as l increases, banks will have greater local market power over their customers, which enable them to charge higher prices.

When α is small, the outside option is sufficiently attractive such that the first force on equilibrium prices dominates the second force. Therefore, the equilibrium prices are decreasing in l, as shown in Figure 4.1. In contrast, when α is large, the outside option is not very attractive. Therefore, the second force on equilibrium prices dominates the first force, and the equilibrium prices are increasing in l, as shown in Figure 4.2.

3.2. Competition with only online platforms

Suppose that banks do not have any physical branch and can sell products only through online platforms. The online prices of bank A and bank B are $p_{\tilde{A}}$ and $p_{\tilde{B}}$, respectively. Customer i's utilities of choosing bank A, bank B, and the outside option are as follows:

[11] Increasing γ is equivalent to increasing l.

$$u_{i\tilde{A}} = \alpha - p_{\tilde{A}} + \varepsilon_{iA} \tag{3.8}$$

$$u_{i\tilde{B}} = \alpha - p_{\tilde{B}} + \varepsilon_{iB} \tag{3.9}$$

$$u_{i0} = \varepsilon_{i0}$$

As shown in Figure 3.2, conditional on purchasing a product, the blue area represents customers who choose bank A over bank B, while the red area represents customers who choose bank B over bank A. Consequently, the demand for bank A is

$$D_A = l \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} \tag{3.10}$$

The demand for bank B is

$$D_B = l \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} \tag{3.11}$$

Assume that the two banks play a Bertrand-Nash pricing game. Bank A solves the following profit-maximization problem w.r.t. $p_{\tilde{A}}$ given its rival's price $p_{\tilde{B}}$

$$\max_{p_{\tilde{A}} | p_{\tilde{B}}} \pi_A = p_{\tilde{A}} \, D_A \tag{3.12}$$

Bank B solves the following profit-maximization problem w.r.t. p_B given its rival's price p_A

$$\max_{p_{\tilde{B}} | p_{\tilde{A}}} \pi_B = p_{\tilde{B}} \, D_B \tag{3.13}$$

Denote the equilibrium prices as $(p_{\tilde{A}}^*, p_{\tilde{B}}^*)$. Because of the symmetry between bank A and bank B, $p_{\tilde{A}}^* = p_{\tilde{B}}^*$.

The horizontal red lines in Figures 4.1 and 4.2 display the numerical solution of the equilibrium prices $(p_{\tilde{A}}^*, p_{\tilde{B}}^*)$ for the small-α case and the large-α case, respectively. The online prices do not change with l because purchasing online products does not involve traveling costs. The online prices in Figure 4.1 (small α) are lower than those in Figure 4.2 (large α) because when α is large, the outside option is less attractive and hence banks can charge higher prices.

Compare the equilibrium offline prices (p_A^*, p_B^*) in the case of only physical branches and no online channels (discussed in Subsection 3.1) and the equilibrium online prices $(p_{\tilde{A}}^*, p_{\tilde{B}}^*)$ in the case of only online channels and no physical branches (discussed in Subsection 3.2). As shown in Figure 4.1, when α is small (the average preference for purchasing a product relative to choosing the outside option is low), $p_A^* = p_B^* < p_{\tilde{A}}^* = p_{\tilde{B}}^*$. The reason is that customers need to pay travel costs to visit physical branches and thus banks have to charge lower prices at physical branches to prevent too many customers from choosing the outside option. In contrast, as shown in Figure 4.2, when α is large, $p_A^* = p_B^* > p_{\tilde{A}}^* = p_{\tilde{B}}^*$. The reason is as follows: given that customers' average preference for purchasing a product relative to choosing the outside option is high, banks do not need to worry too much that charging a high offline price may cause many customers to choose the outside option; moreover, banks can use their greater local market power and charge higher offline prices.

3.3. Spatial competition with both physical branches and online platforms

Now, we assume that bank A and bank B located as in Figure 2.2 can sell their products through both physical branches and online banking channels. Correspondingly, customers have five options: bank A's physical branch, bank A's online platform, bank B's physical branch, bank B's online platform, and the outside option. We assume that customers have identical idiosyncratic preferences between the online and offline products of the same bank, except for the travel costs of the offline products. Customer i's utilities of these five options are as follows:

$$u_{iA} = \alpha - p_A - \gamma d_{iA} + \varepsilon_{iA}$$

$$u_{iB} = \alpha - p_B - \gamma d_{iB} + \varepsilon_B = \alpha - p_B - \gamma\left(\frac{l}{2} - d_{iA}\right) + \varepsilon_{iB}$$

$$u_{i\tilde{A}} = \alpha - p_{\tilde{A}} + \varepsilon_{iA}$$

$$u_{i\tilde{B}} = \alpha - p_{\tilde{B}} + \varepsilon_{iB}$$

$$u_{i0} = \varepsilon_{i0}$$

Denote

$$d_1 = \frac{p_{\tilde{A}} - p_A}{\gamma} \tag{3.14}$$

$$d_2 = \frac{l}{2} - \frac{p_{\tilde{B}} - p_B}{\gamma} \tag{3.15}$$

As shown in Figure 2.2, when $d \in [0,\ d_1]$, customers reside so close to bank A's physical branch that bank A's physical branch dominates its online platform; meanwhile, they reside so far from bank B's physical branch that bank B's online platform dominates its physical branch. Consequently, these customers choose between bank A's physical branch and bank B's online platform, conditional on purchasing a product, and whether the former or the latter is chosen depends on the customers' idiosyncratic preferences (ε_{iA} and ε_{iB}) for the two banks.

When $d \in (d_1, d_2)$, customers reside so far from bank A's physical branch that bank A's online platform dominates its physical branch; meanwhile, they also reside so far from bank B's physical branch that bank B's online platform dominates its physical branch. Consequently, these customers choose between bank A's online platform and bank B's online platform, conditional on purchasing a product, and whether the former or the latter is chosen depends on the customers' idiosyncratic preferences (ε_{iA} and ε_{iB}) for the two banks.

When $d \in [d_2, \frac{l}{2}]$, customers reside so far from bank A's physical branch that bank A's online platform dominates its physical branch; meanwhile, they reside so close to bank B's physical branch that bank B's physical branch dominates its online platform. Consequently, these customers choose between bank A's online platform and bank B's physical branch, conditional on purchasing a product, and whether the former or the latter is chosen depends on the customers' idiosyncratic preferences (ε_{iA} and ε_{iB}) for the two banks.

Suppose that each bank's offline price is lower than its online price. As shown in Figure 3.3, conditional on purchasing a product, first, the blue area represents customers who choose bank A's physical branch; because bank A's offline price is lower than its online price and these customers are not far away from bank A's physical branch, they would like to choose bank A's offline products. Second, the green area represents customers who choose bank A's online platform; because they reside far away from bank A's physical branch, they would like to choose bank A's online products even though the online price is higher than the offline price. Third, the orange area represents customers who choose bank B's online platform; although they reside close to bank A's branch, their idiosyncratic preferences favor bank B substantially more than bank A, and thus they would like to choose bank B; because they reside far away from bank B's physical branch, they choose bank B's online products. Fourth, the red area represents customers who choose bank B's physical branch; their idiosyncratic preferences favor bank B substantially more than bank A and they reside close to bank B's physical branch.[12] Comparing Figure 3.3 with Figure 3.1, the existence of online platforms enhances each bank in penetrating customers residing near its competitor's physical branches.

Consequently, the profit function for bank A is

$$\begin{aligned}\pi_A = 2\Bigg[& p_A \int_0^{d_1} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\ & + p_{\tilde{A}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\ & + p_{\tilde{A}} \int_{d_2}^{\frac{l}{2}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \Bigg]\end{aligned} \tag{3.16}$$

The profit function for bank B is

$$\begin{aligned}\pi_B = 2\Bigg[& p_{\tilde{B}} \int_0^{d_1} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\ & + p_{\tilde{B}} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\ & + p_B \int_{d_2}^{\frac{l}{2}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \Bigg]\end{aligned} \tag{3.17}$$

Assume that the two banks play a Bertrand-Nash pricing game. Bank A solves the following profit-maximization problem w.r.t. p_A and $p_{\tilde{A}}$ given its rival's prices p_B and $p_{\tilde{B}}$:

$$\max_{p_A, p_{\tilde{A}} | p_B, p_{\tilde{B}}} \pi_A \tag{3.18}$$

Bank B solves the following profit-maximization problem w.r.t. p_B and $p_{\tilde{B}}$ given its rival's prices p_A and $p_{\tilde{A}}$:

$$\max_{p_B, p_{\tilde{B}} | p_A, p_{\tilde{A}}} \pi_B = p_B D_B \tag{3.19}$$

[12] For illustration purposes, in Figure 3.3, we set $p_{\tilde{A}} > p_{\tilde{B}}$. In the later part of this section, we will show that in equilibrium, $p_{\tilde{A}} = p_{\tilde{B}}$ and $p_A = p_B$ because of the symmetry between bank A and bank B.

Denote the equilibrium prices as $(p_A^{**}, p_B^{**}, p_{\tilde{A}}^{**}, p_{\tilde{B}}^{**})$.

If α is small such that $p_A^* = p_B^* < p_{\tilde{A}}^* = p_{\tilde{B}}^*$, i.e., the price when banks have only physical branches is lower than the price when banks have only online platforms, banks will set $p_A^{**} = p_B^{**} = p_{\tilde{A}}^{**} = p_{\tilde{B}}^{**} = p_{\tilde{A}}^* = p_{\tilde{B}}^*$ when both online and offline channels are available. In this case, conditional on purchasing a product, every customer will choose online platforms and no customer will use physical branches. The reason for this equilibrium is obvious: if any customer uses physical branches, banks need to charge lower prices; therefore, it is better for banks to charge identically higher prices online and offline and drive all customers to use online platforms.

If α is large such that $p_A^* = p_B^* > p_{\tilde{A}}^* = p_{\tilde{B}}^*$, i.e., the price when banks have only physical branches is higher than the price when banks have only online platforms, banks will set $p_A^{**} = p_B^{**} = p_{\tilde{A}}^{**} = p_{\tilde{B}}^{**} = p_{\tilde{A}}^* = p_{\tilde{B}}^*$ when both online and offline channels are available. In this case, conditional on purchasing a product, every customer will choose online platforms and no customer will use physical branches. First, when products are available at both physical branches and online platforms, if offline prices are higher than online prices, no customer will use physical branches, and thus the equilibrium online prices will be the same as when products are available only on online platforms. If offline prices are set to be lower than online prices, there will be some customers choosing offline products; but from the banks' perspective, this choice will be weakly dominated by setting offline prices equal to online prices, in which all customers choose online products and banks charge every customer a high price.

Second, when α is large, bank A and bank B may increase their profits if they both shut down product availability at their online platforms and maintain the same outcome as that in the equilibrium when online platforms do not exist. However, this outcome is not a Nash equilibrium when online platforms exist. Given that both banks offer products only at their physical branches, each bank has an incentive to add online availability to penetrate the locations close to its rival's physical branch.[13]

[13] We implicitly assume that given the existence of online platforms, the setup cost of online availability of WMPs is close to zero. Banks build the online banking platforms to provide many services and products, such as deposits, transfers, credit card applications, mortgage originations, auto loan originations, foreign

3.4. Existence of customers who never use online banking

In Subsection 3.3, we have shown that when each customer has identical idiosyncratic preferences between physical branches and online platforms of the same bank, except for travel costs associated with physical branches, regardless of the values of α and l, banks will set offline prices equal to online prices and all customers will end up purchasing products online. In this subsection, we further allow that there are a fraction of customers who never use online banking.

Suppose that in each location d and for each combination of ε_{iA}, ε_{iB}, and ε_{i0}, there exist two types of customer, with shares equal to θ and $1-\theta$, respectively. Customers in the first type can purchase a product either online or offline, depending on which channel provides higher utility. Customers in the second type purchase only at physical branches and do not use online banking because they do not have Internet access, are not comfortable with online operation, or simply do not trust online banking. At physical branches, banks cannot conduct price discrimination and charge the two types of customer different prices.

Then, the profit function for bank A becomes

$$\begin{aligned}\pi_A = 2\theta\Bigg[& p_A \int_0^{d_1} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\ & + p_{\tilde{A}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\ & + p_{\tilde{A}} \int_{d_2}^{\frac{l}{2}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \Bigg] \\ & + 2(1-\theta) p_A \int_0^{\frac{l}{2}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \end{aligned} \tag{3.20}$$

The profit function for bank B becomes

exchange transactions, and merchant services. Adding another product line (WMPs) to an existing online platform would not incur a large cost.

$$
\begin{aligned}
\pi_B = 2\theta \Bigg[& p_{\tilde{B}} \int_0^{d_1} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\
& + p_{\tilde{B}} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\
& + p_B \int_{d_2}^{\frac{l}{2}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \Bigg] \\
& + 2(1-\theta) p_B \int_0^{\frac{l}{2}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd
\end{aligned}
\tag{3.21}
$$

Assume that the two banks play a Bertrand-Nash pricing game and denote the equilibrium prices as $(p_A^{***}, p_B^{***}, p_{\tilde{A}}^{***}, p_{\tilde{B}}^{***})$. If α is large such that $p_A^* = p_B^* > p_{\tilde{A}}^* = p_{\tilde{B}}^*$, banks will set $p_A^{***} = p_B^{***} = p_A^* = p_B^*$ and set $p_{\tilde{A}}^{***} = p_{\tilde{B}}^{***} = p_{\tilde{A}}^* = p_{\tilde{B}}^*$. First, for customers of the first type, banks will maximize the profit from them by making all of them use online platforms, i.e., setting the online prices equal to $p_{\tilde{A}}^*$ or $p_{\tilde{B}}^*$ and setting the offline prices higher than $p_{\tilde{A}}^*$ or $p_{\tilde{B}}^*$. Second, for customers of the second type, banks will maximize the profit from them by setting $p_A^{***} = p_B^{***} = p_A^* = p_B^*$, which is higher than $p_{\tilde{A}}^*$ or $p_{\tilde{B}}^*$. Therefore, at the equilibrium prices, banks maximize the profit from the first type of customer and the profit from the second type of customer, respectively, and thus maximize the overall profit.

If α is small such that $p_A^* = p_B^* < p_{\tilde{A}}^* = p_{\tilde{B}}^*$, the numerical solution of $(p_A^{***}, p_B^{***}, p_{\tilde{A}}^{***}, p_{\tilde{B}}^{***})$, as shown in Figure 5.1, indicates that $p_A^* = p_B^* < p_A^{***} = p_B^{***} < p_{\tilde{A}}^{***} = p_{\tilde{B}}^{***} < p_{\tilde{A}}^* = p_{\tilde{B}}^*$. In this equilibrium, some of the customers in the first type use online channels and the rest in the first type use physical branches, whereas all the customers in the second type use physical branches. Although the online price that maximizes the profit from customers in the first type when physical branches are not available is $p_{\tilde{A}}^*$ or $p_{\tilde{B}}^*$ and the offline price that maximizes the profit from customers in the second type is p_A^* or p_B^*, because banks cannot conduct price discrimination and charge customers of different types different prices at physical branches, banks have to compromise and set the online and offline prices between p_A^* and $p_{\tilde{A}}^*$ (or between p_B^* and $p_{\tilde{B}}^*$) in order to maximize the total profit from both types of customer. In addition, the gap between online and offline prices increases with l. The reason is that when l is large, banks' physical branches have to charge a lower price to prevent too many remote and branch-only customers from choosing the outside option because of the distance.

[Insert Figure 5 here]

Another interesting pattern shown in Figure 5.1 is that the equilibrium online price $p_{\tilde{A}}^{***}$ or $p_{\tilde{B}}^{***}$ first decreases with l and then increases with l. The reason is that when l is small, as l increases and hence the offline price p_{A}^{***} or p_{B}^{***} decreases to prevent too many remote and branch-only customers from choosing the outside option because of the distance, it is more important to reduce the online price along with the offline price to prevent too many customers in the first type from choosing physical branches with a lower price. When l is large, physical branches are less attractive than online banking for most of the first type customers because of the long distance; as l increases, it is more important to increase the online price to extract more profits from customers who choose online banking. Moreover, as shown in Figure 5.2, when the share of customers in the first type (θ) increases, the turning point of the online price curve will move leftward. The reason is that banks' price setting has less need to compromise with the profit from the second type of customer when that type has a small share: offline prices do not need to decrease with l at a high speed, leading to a weaker force that tends to draw down online prices.

Furthermore, based on the numerical solution shown in Figure 6, given a city size l, online and offline prices increase with θ; and the gap between online and offline prices decreases with θ. The larger θ is, the closer this equilibrium will be to the equilibrium when there are no customers who never use online banking; in the latter equilibrium, the online price is equal to the offline price and every customer chooses online channels.

When θ is small, there are many customers who never use online banking, and hence banks have to charge lower offline prices. Otherwise, a great number of customers who never use online banking and meanwhile reside far away from bank branches will choose the outside option because they cannot purchase online to save the high travel costs. Given low offline prices, online prices should also be set low. Otherwise, many online buyers will switch to offline; banks can no longer earn the higher online prices from them, although banks will not lose these customers.

When θ is large, for a bank, there are many potential customers who can use online banking and meanwhile reside near the bank's competitors' branches. Consequently, banks have to set their online prices much closer to their competitors' offline prices; otherwise, they cannot penetrate the great number of online banking users residing near their competitors' physical branches.

[Insert Figure 6 here]

In the empirical industrial organization literature, most studies that estimated discrete choice models for consumer demand systems (such as the multinomial logit model and the BLP model first developed by Berry, Levinsohn and Pakes, 1995) obtained a small α. The reason is that, for most industries, the share of consumers who choose the outside option is large. Accordingly, in later analyses, we focus on the case in which α is small.

3.5. Factors affecting online markets more than offline markets

More incumbent banks in a city will make both the online and offline markets more competitive, but the magnitudes of the effect could be larger on online markets than on offline markets. As the number of incumbent banks in a city increases, each bank can still maintain some local market power in the offline market over residents near its branch but cannot do so in the online market.

Suppose there are four banks (banks A, B, C, and D) in a city, each with one branch, located as shown in Figure 2.3. The profit function of each bank (say bank A) is derived in Appendix C.1.

Because of the symmetry, in equilibrium, for online prices of the four banks, $p_{\tilde{A}} = p_{\tilde{B}} = p_{\tilde{C}} = p_{\tilde{D}}$, of which the numerical solution is plotted as the solid light green line in Figure 7.1; for offline prices, $p_A = p_B = p_C = p_D$, of which the numerical solution is plotted as the solid purple line in Figure 7.1. They are both lower than those in the cases of only two incumbent banks, including the case in which each of the two banks has one branch as displayed in Figure 5.1 and the case in which each of the two banks has two branches (to be discussed in Section 3.6). However, the increase in the number of incumbent banks makes the online price drop more than the offline price, making the online-offline price gap become narrower.

[Insert Figure 7 here]

3.6 Factors affecting offline markets more than online markets

The effect of the number of branches

Suppose that each bank has two branches instead of one and that those branches are located as shown in Figure 2.4. The profit functions of bank A and bank B are derived in Appendix C.2. It is easy to see that the effect of more branches on prices is equivalent to the effect of shorter distances (smaller l).

The numerical solutions of the equilibrium prices shown in Figure 7.1 indicate that, holding other factors constant, the gap between online and offline prices is narrower when each bank has more branches. When a bank has a lower branch density, it has to charge a lower offline price to prevent too many remote and branch-only customers from choosing the outside option or its competitors' physical branches; in contrast, the online market is not directly affected by the branch density but will be indirectly affected by the change in offline prices because online products need to compete with offline products. The direct effect on offline prices is larger in magnitude than the indirect effect on online prices, making the online-offline gap become wider as the bank's branch density increases.

The effect of the number of competitors' branches

Given the city size (l), if the branches of a bank's competitors increase, the offline market for the bank will be tougher and the bank has to offer a lower offline price, which will enlarge the gap between the bank's online and offline prices.

Now, we consider a situation in which bank A has three branches while bank B only has one branch, as displayed in Figure 2.5. The profit functions of bank A and bank B are derived in Appendix C.3.

The numerical solutions of equilibrium prices shown in Figure 7.2 indicate that the online and offline prices of bank A with more branches are, respectively, higher than the online and offline prices of bank B with fewer branches. As bank A has a higher branch share, it has greater local market power to maintain a high price at its physical branches, which also enables it to maintain a high online price accordingly. The direct effect on bank A's offline price is larger in magnitude than the indirect effect on its online price, making bank A's online-offline price gap narrower than bank B's.

The effect of clustering of physical branches of a bank

At the beginning of this subsection, we discuss a two-bank case in which the locations of each bank's two branches are scattered; they are separated by its rival's branches (as shown in Figure 2.4). Now, we analyze another two-bank case, as shown in Figure 2.6: the locations of each bank's two branches are clustered.

For customers who can purchase either online or offline, the demands of bank A and bank B on the segment between two branches of different banks are similar to those displayed in Figure 3.3. On the segment between two branches of bank A, the two banks' demands are displayed in Figure 3.4; the market is split by bank A's physical branches (blue area) and online platform (green area) and bank B's online platform (orange area). On the segment between the two branches of bank B, the two banks' demands are displayed in Figure 3.5; the market is split by bank B's physical branches (red area) and online platform (orange area) and bank A's online platform (green area).

For customers who never use online banking, the demands of bank A and bank B on the segment between two branches of different banks are similar to those displayed in Figure 3.1. On the segment between two branches of bank A, the two banks' demands are displayed in Figure 3.6. On the segment between two branches of bank B, the two banks' demands are displayed in Figure 3.7.

The profit functions of bank A and bank B are derived in Appendix C.4. The numerical solutions of equilibrium prices, as shown in Figure 7.3, indicate that clustering of branches of a bank generally will increase offline prices and hence reduce the gap between online prices and offline prices. For customers who never use online banking, as branches of a bank are clustered, the bank has larger market power over customers residing between its two branches and thus can charge higher prices at physical branches. However, for customers who can purchase either online or offline, branch clustering does not have any direct effect because a bank's clustering areas can still be penetrated by its rival's online channels; consequently, the bank does not gain greater local market power over online banking users in these areas. Online prices will still be indirectly affected by the increase in offline prices, but the indirect effect on online prices is smaller in magnitude than the direct effect on offline prices, making the online-offline price gap become narrower as the degree of branch clustering increases.

3.7. Pricing of offline-only banks

Most banks that have ever sold WMPs online started to sell both online and offline at the beginning of the sample period. A small fraction of banks (small local banks) have never sold WMPs online during the entire sample period. The WMPs sold by these banks comprise 10.18% of all the WMPs. In this subsection, we theoretically examine the pricing behavior of these offline-only banks.

Suppose that there are three banks (A, B, and E) in a city located as in Figure 2.7. Banks A and B sell WMPs both online and offline, while bank E sells WMPs only offline. Bank E is a small local bank with a small market share. The utility of purchasing one product from bank E for customer i who resides with a distance d_{iE} from bank E is

$$u_{iE} = \alpha + \Delta\alpha - p_E - \gamma d_{iE} + \varepsilon_{iE} \tag{3.22}$$

where $\Delta\alpha \leq 0$. A negative $\Delta\alpha$ means that, on average, customers have a lower preference for small banks than for large banks because small banks only offer limited services and have a higher bankruptcy risk.

Because the market share of bank E is small, when banks A and B determine their prices, they ignore bank E. Therefore, the online and offline prices of banks A and B are the same as the brown and green lines in Figure 5.1 derived in Subsection 3.4.

Given the online and offline prices of banks A and B, bank E will determine its offline price.

For simplicity, instead of analyzing the case shown in Figure 2.7, we analyze the case shown in Figure 2.8. Although in Figure 2.8, bank E has the same number of branches as bank A or bank B, the negative $\Delta\alpha$ can still make the market share of bank E ignorable to bank A and bank B. Overall, Figure 2.8 can fully capture the result pattern of the case shown in Figure 2.7. The profit function of bank E in Figure 2.8 is derived in Appendix C.5.

Given p_A, p_B, $p_{\tilde{A}}$, and $p_{\tilde{B}}$, which are determined as the solid lines in Figure 5.1, bank E will determine its offline price p_E to maximize π_E. The solid line in Figure 8.1 displays the numerical solution of p_E when $\Delta\alpha$ is set to zero. The price of bank E that only sells products offline is lower than the online and offline prices of banks A and B that sell products both online and offline. In Figure 8.2, we set $\Delta\alpha = -0.2$, and the price of bank E is even lower. Figures 8.1 and 8.2 indicate that even without the disadvantage of small size (or lower average preference by customers), the disadvantage of only offering offline channels itself can drive bank E's price lower than the online and offline prices of banks A and B that sell products both online and offline.

[Insert Figure 8 here]

As the city size (l) increases, the price of bank E first decreases and then increases. As l increases, bank E needs to decrease its price for two reasons: first, bank E should prevent too many remote and branch-only customers from choosing the outside option because of the distance; second, because bank E becomes more disadvantaged compared to banks A and B's online platforms, it has to compete more aggressively with banks A and B's online products for customers who can use both physical branches and online banking platforms. However, when l is large enough, banks A and B's online prices increase as l increases; thus, the competition faced by bank E lessens, and bank E can charge higher prices.

In contrast, the offline prices of banks A and B always decrease as the city size (l) increases. The reason is that although bank A or bank B's physical branches face competition from its rival bank's online platform, bank A or bank B's physical branches do not need to compete with its own online platform. Consequently, their offline prices have less need to move along with their online prices than bank E's offline price does. Bank A or bank B would even like more customers who can use both physical branches and online platforms to purchase at its online platform so that it can charge those customers higher prices.

4. Data

4.1 WMP data

We extract WMP data from WIND, one of the largest financial data providers in China. The data contain information on each WMP issued by commercial banks from 2004 to 2016, including the WMP's name, issuing bank, issuing date, expected return offered (or the lower and upper bounds of the expected return range), term to maturity, type of underlying assets, issuing region, guarantee type, minimum investment requirement, realized return at maturity, etc. The data also have information on whether a WMP is sold online or at physical branches. By 2004, when WMPs were initiated, most moderate-to-large banks had already built their online banking systems.

There are two possible ways that banks specify the expected returns in the contract at issuance: some WMPs (especially fixed-rate WMPs) specify an expected return; other WMPs (especially flexible-rate WMPs) specify the upper and lower bounds of an expected return range. As 96.43% of WMPs finally paid a realized return equal to the expected return or the upper bound of the expected return range, we treat the upper bound of the expected return as the expected return if the contract specifies an expected return range.

A higher expected return offered by the WMP issuing bank means a lower price of the WMP because, for financial products, returns are inversely related to prices. Holding the future cash (interest and principal payments) flows generated by the WMP to purchasers fixed, a higher expected return means customers need to pay a lower price to purchase (invest in) the WMP at issuance.

Based on the raw data, we construct additional WMP-level variables. We construct the principal coverage ratio using the information on guarantee type. The principal coverage equals 0 for flexible-rate WMPs without any guarantee; it equals 100% for flexible-rate WMPs with a principal guarantee; and it equals 100% plus the expected rate of return for fixed-rate WMPs (with principal and interest guarantees). We generate a dummy variable "trust" based on whether the WMP is issued jointly with a trust. We also generate a dummy variable "structured product" based on whether the bank designs the WMP contract using derivatives.

We mainly focus on the WMPs issued exclusively in a single city, with which city-level macroeconomic variables can be matched. As shown in Table 2, the raw data have approximately 33,000 single-city products. After deleting products with missing values, approximately 18,000 products remain.

4.2. Bank branch data

We collect bank branch data from the China Banking and Insurance Regulatory Commission. The data contain information on the street address, establishment date, and exit date for each bank branch. Using the street address, we obtain the longitude and latitude coordinates of each bank branch through Google Earth. Based on the longitude and latitude coordinates, we obtain the spherical distance between any two branches in a city. There are approximately 220,000 branches in total.

4.3. Digital financial inclusion indices

We extract the city-level annual digital financial inclusion indices from 2011 to 2018, which are constructed jointly by the Institute of Digital Finance at Peking University and Ant Financial Services Group. The Ant Financial Services Group is the parent company of Alipay, the dominant mobile and online payment platform in China. In 2019, 33% of Ant Financial Services Group's shares were owned by Alibaba Inc., the dominant online retail platform in China, which operates a B2C platform (Tmall.com) and a C2C platform (Taobao.com). The annual sales of Alibaba are larger than the sum of Amazon and eBay.

There are four indices available: the breadth index of digital finance coverage, the depth index of digital finance usage, the maturity index of digitized financial business, and the overall index of digital financial inclusion. These indices are constructed by artificial intelligence algorithms and cloud computing technologies based on data with billions of digital financial transaction records. The index construction method can be found in Guo, Wang, Wang, Cheng, Kong and Zhang (2020).[14]

4.4. Macroeconomic data

We extract multiple national-level macroeconomic variables from CEIC. The first is the Shanghai Interbank Offered Rate (SHIBOR), which is analogous to the London Interbank Offered Rate (LIBOR) in China and is commonly used as the baseline interest rate of China's Financial Market. SHIBOR has a variety of maturities, including one day, one week, two weeks, one month, three months, six months, nine months, and one year. We match SHIBOR to each WMP by the issuing date and maturity to control for the baseline interest rates. We also obtain the Shanghai Security Composite Index (SHSCI) and Shenzhen Security Composite Index (SZSCI) from CEIC to control for returns of households' alternative investment opportunities. Furthermore, we obtain the required reserve ratio (RRR) from CEIC and the M2 growth rate from the central bank of China because monetary supply can affect both WMP returns and house price appreciations.

We also extract multiple city-level macroeconomic variables from the China City Statistical Yearbook, including per capita GDP, city area, population, and the number of Internet users.

Table 3 provides the descriptive statistics for the variables constructed from the data sources discussed above. Table 4 provides the descriptive statistics of promised yields and product characteristics separately for online and offline single-city products. There is no major systematic difference in product characteristics between online and offline products that can influence the expected returns.[15]

[Insert Table 3 here]

[Insert Table 4 here]

[14] More details about the Digital Financial Inclusion Indices can be found at https://idf.pku.edu.cn/.

[15] Table A. 1 provides the descriptive statistics of promised yields and product characteristics based on all the WMPs, including not only products issued in a single city but also products issued in multiple cities or nationwide.

5. Testable hypotheses, empirical strategies, and results

In this section, we first provide empirical evidence that online prices of WMPs are higher than offline prices. Then, we empirically show that the gap between online and offline prices decreases with the share of online banking users in the city. Further, we empirically show that some factors affect the competitiveness and prices of online markets more substantially than those of offline markets (the number of incumbent banks), whereas other factors affect the competitiveness and prices of offline markets more substantially than those of online markets (the branch density and clustering of incumbent banks).

5.1. Are online prices higher than offline prices?

We first examine whether online prices are higher than offline prices for WMPs by estimating the following equation:

$$r_{ibct} = \kappa Online_{ibct} + \beta X_{ibct} + \gamma Z_{ct} + \lambda W_t + \psi_b + \mu_c + \varphi_y + \varepsilon_{ibct} \qquad (5.1)$$

The dependent variable r_{ibct} is the expected return (promised yield) specified in the contract of WMP i issued exclusively in city c in month t by bank b. A higher expected return offered by the WMP issuer means a lower price of the WMP because, for financial products, returns are inversely related to prices. Holding the future cash flows (interest and principal payments) generated by the WMP to purchasers fixed, a higher expected return means customers need to pay a lower price to purchase the WMP at issuance.

The variable of main interest is $Online_{ibct}$, which equals 1 if the product can be purchased online and equals 0 if it can only be purchased at physical branches. We control for a rich set of WMP characteristics in X_{ibct}, including principal coverage, minimum investment requirement, term to maturity, investment target categories of the money raised from the WMP (including equities, bonds, loans, the money market, foreign exchanges, and commodity markets), whether it is issued jointly with a trust, and whether the product has a derivative design. In X_{ibct}, we also include SHIBOR in month t with the same term to maturity as WMP i's to control for the baseline interest rates. In Z_{ct}, we control for city-level competitiveness measures for the local WMP markets, including the number of WMPs available in city c during month t, the number of banks issuing WMPs in city c during month t, and HHI based on product numbers; we also include city-level GDP growth rates to control for local economic conditions. In W_t, we control for RRR and M2 growth because monetary supply can affect WMP returns. We also add SHSCI growth and SZSCI growth in W_t to control for returns of households' alternative investment opportunities. In addition, we control for bank fixed effects (ψ_b), city fixed effects (μ_c), and year fixed effects (φ_y).

As shown by the model in Subsection 3.4, when α is small (customers' average preference for purchasing a product relative to choosing the outside option is small), online prices should be higher than offline prices; while when α is large, online prices should not be lower than offline prices. In the empirical industrial organization literature, most studies that estimated discrete choice models for consumer demand systems (such as the multinomial logit model and the BLP model) obtained a small α. The reason is that for most industries, the share of consumers who choose the outside option is large. Therefore, we have the following hypothesis:

Hypothesis 1: Prices of WMPs at online platforms are higher than those at physical branches. In other words, expected returns of WMPs on online platforms are lower than those at physical branches after controlling for other factors. That is, κ in equation (5.1) should be significantly negative.

The regression results of equation (5.1) are reported in Table 5. The online channel indicator is significantly negative at a level of 1% across all the specifications. This means that after controlling for other factors, the expected returns (promised yields) on the WMPs sold online are lower than those sold at physical branches. In other words, the prices of the WMPs sold online are higher than those sold at physical branches because, for financial products, prices are inversely related to expected returns.

[Insert Table 5 here]

The sample for columns 1 and 2 of Table 5 includes all the WMPs. Column 1 only controls for product characteristics; the result indicates that promised yields for online WMPs are lower than those for offline WMPs by 14.24 basis points (bps). Column 2 also controls for national-level macroeconomic variables; promised yields for online WMPs are lower than those for offline WMPs by 13.76 bps. The sample for columns 3, 4, and 5 includes WMPs issued exclusively in a single city. Column 3 only controls for product characteristics; promised yields for online WMPs are lower than those for offline WMPs by 7.02 bps. Column 4 also controls for national-level macroeconomic variables; promised yields for online WMPs are lower than those for offline WMPs by 4.17 bps. Column 5 further adds city-level variables; promised yields for online WMPs are lower than those for offline WMPs by 3.80 bps.

The magnitude of the coefficient of $Online_{ibct}$ (approximately 4 bps) has economic significance. As shown in Table 3, the standard deviation of the WMP promised yields is 107 bps. The variation of the yields mostly comes from time (see Table 1) because the baseline interest rates and correspondingly the expected returns of banks' investment targets vary substantially over time according to macroeconomic conditions. Therefore, 4 bps is a significant magnitude compared to banks' profit margin (expected returns of banks' investment targets minus promised yields of WMPs) and its variation.

The magnitude of the coefficient of $Online_{ibct}$ (approximately 4 bps) is also comparable to the effects of other factors on the WMP promised yields. Based on column 5 of Table 5, a one-month increase in term to maturity will increase the promised yields by 2.7 bps (0.0009*30=0.0270), while the average term to maturity of the data is 122 days. The promised yields of WMPs with high-risk bonds as the underlying assets are 11.19 bps higher (-0.3935-0.5054=0.1119) than those of WMPs with low-risk money market products as the underlying assets.[16]

The coefficients of the control variables are also consistent with theories or intuition. The

[16] Approximately 400 single-city WMPs are sold through third-party payment platforms. The regression results are similar if we exclude them from the sample. Starting from June 27, 2021, the China Banking and Insurance Regulatory Commission no longer allows WMPs to be sold through third-party payment platforms, with a 6-month grace period for existing WMPs.

coefficient of the baseline interest rate (SHIBOR) is significantly positive. The coefficient of RRR is significantly positive and the coefficient of M2 growth is significantly negative, which is consistent with the fact that increases in money supply will cause WMP returns to drop.[17] WMPs with longer terms to maturity and lower principal coverages have higher expected returns. The coefficients of the equity dummy variable, the loan dummy variable, and the bond dummy variable are generally higher than the coefficient of the money market product dummy variable because the former underlying assets are riskier and thus households require higher returns. Local WMP markets with higher competitiveness (more available WMPs, more issuing banks, and lower HHI in the city) tend to have higher expected returns.

5.2. The effect of shares of online banking users

As shown by the model in Subsection 3.4, if the share of customers in the city who are able to use both online and offline channels is larger and the share of customers in the city who never use online banking is smaller, both online and offline prices will be higher and the gap between online prices and offline prices will be narrower.

Empirically, we estimate the following equation:

$$\begin{aligned} r_{ibct} = {} & \kappa \cdot Online_{ibct} + \delta \cdot Online_{ibct} \cdot Share\_online\_users_{ct} \\ & + \omega \cdot Share\_online\_users_{ct} + \beta \cdot X_{ibct} + \gamma \cdot Z_{ct} + \lambda \cdot W_t + \psi_b \\ & + \mu_c + \varphi_y + \varepsilon_{ibct} \end{aligned} \tag{5.2}$$

where $Share\_online\_users_{ct}$ represents the proxy for the share of customers in city c during period t who are able to use both online and offline channels. We use five proxies for the share of this type of customer in a city. The first four proxies are the four digital financial inclusion indices at the city level constructed jointly by the Institute of Digital Finance at Peking University and Ant Financial Services Group based on data with billions of digital financial transaction records, including the overall index of digital financial inclusion, the breadth index of digital

[17] In columns 4 and 5 of Table 5, the coefficient of M2 growth is positive. The reason is that M2 growth is highly correlated with the required reserve ratio. If we drop the required reserve ratio in the regression, the coefficient of M2 growth will become significantly negative.

finance coverage, the depth index of digital finance usage, and the maturity index of digitized financial business. The last proxy is simply the number of Internet users divided by the city population based on the China City Statistical Yearbook. Accordingly, we have the following hypothesis:

Hypothesis 2: In equation (5.2), the coefficient of $Share\_online\_users_{ct}$ is significantly negative; the coefficient of the interaction term $Online_{ibct} \cdot Share\_online\_users_{ct}$ is significantly positive. That is, if the share of customers in the city who are able to use both online and offline channels is larger, both online and offline prices will be higher and the gap between online prices and offline prices will be narrower.

The regression results of equation (5.2) are reported in Table 6. Higher digital finance inclusion indices and more Internet users will lead to higher online and offline prices and a narrower gap between online and offline prices.

[Insert Table 6 here]

When there are many customers who never use online banking, banks have to charge lower offline prices. Otherwise, a great number of customers who never use online banking and meanwhile reside far away from bank branches will choose the outside option because they cannot purchase online to save the high travel costs. Given low offline prices, online prices should also be set low. Otherwise, many online buyers will switch to offline; banks can no longer earn the higher online prices from them, although banks will not lose these customers.

In contrast, when the proportion of online banking users is large, for a bank, there are many potential customers who can use online banking and meanwhile reside near the bank's competitors' branches. Consequently, banks have to set their online prices much closer to their competitors' offline prices; otherwise, they cannot penetrate the great number of online banking users residing near their competitors' physical branches.

5.3. Factors affecting online markets more than offline markets

As shown by the model in Subsection 3.5, if the number of incumbent banks in a city increases, both online and offline prices will drop. However, the online price drops more than the offline price, making the online-offline gap narrower (see Figure 7.1). The reason is that as the number of incumbent banks in a city increases, each bank can still maintain some local market power in the offline market over residents near its branch but cannot do so in the online market.

Empirically, we estimate the following equation:

$$\begin{aligned} r_{ibct} = \kappa \cdot Online_{ibct} + \delta \cdot Online_{ibct} \cdot Bank\_num_{ct} + \omega \cdot Bank\_num_{ct} \\ + \beta \cdot X_{ibct} + \gamma \cdot Z_{ct} + \lambda \cdot W_t + \psi_b + \mu_c + \varphi_y + \varepsilon_{ibct} \end{aligned} \tag{5.3}$$

where $Bank\_num_{ct}$ is the number of incumbent banks in city c during period t that issue WMPs. Accordingly, we have the following hypothesis:

Hypothesis 3: In equation (5.3), the coefficient of $Bank\_num_{ct}$ is significantly positive; and the coefficient of the interaction term $Online_{ibct} \cdot Bank\_num_{ct}$ is also significantly positive. That is, if the number of incumbent banks in a city increases, both online and offline prices will drop and the online-offline gap will become narrower.

The regression results of equation (5.3) are reported in column 1 of Table 7. The coefficient of $Bank\_num_{ct}$ is 0.0218, significantly positive at a level of 1%. The coefficient of the interaction term $Online_{ibct} \cdot Bank\_num_{ct}$ is 0.0054, significantly positive at a level of 1%.

[Insert Table 7 here]

5.4. Factors affecting offline markets more than online markets

The effect of branch density (or city size)

As shown by the model in Subsection 3.4, given the number of branches, as the city size increases, the offline price will decrease and the gap between the online and offline prices will become wider (see Figure 5.2). Similarly, given the city size, as the number of a bank's own branches decreases, the offline price will decrease and the gap between the online and offline prices will become wider.

When a bank has a lower branch density, it has to charge a lower offline price to prevent too many remote and branch-only customers from choosing the outside option or its competitors' physical branches; in contrast, the online market is not directly affected by the branch density but will be indirectly affected by the change in offline prices because online products need to compete with offline products. The direct effect on offline prices is larger in magnitude than the indirect effect on online prices, making the online-offline gap become wider as the bank's branch density increases. As shown in Figure 7.1 in Subsection 3.6, in the case of two incumbent banks, given the city size (l) fixed, the offline price when each bank has one branch is lower than that when each bank has two branches.

In contrast, based on the second model in Subsection 3.6, given the city size, as the number of branches of a bank's competitors decreases, the bank's offline price will increase and the gap between the online and offline prices will become narrower. The reason is that the bank will face less competition in the offline market, whereas the competition it faces in the online market will not be directly affected. As shown in Figure 7.2, bank B's competitor has three branches in the case where bank A has three branches and bank B has one branch, and bank B's offline price is lower than those in the cases where its competitor has one or two branches.

Empirically, we estimate the following equation:

$$\begin{aligned} r_{ibct} = \kappa \cdot Online_{ibct} &+ \delta_1 \cdot Online_{ibct} \cdot Own\_branch\_density_{bct} \\ &+ \omega_1 \cdot Own\_branch\_density_{bct} \\ &+ \delta_2 \cdot Online_{ibct} \cdot Competitor\_branch\_density_{bct} \\ &+ \omega_2 \cdot Competitor\_branch\_density_{bct} + \beta \cdot X_{ibct} + \gamma \cdot Z_{ct} \\ &+ \lambda \cdot W_t + \psi_b + \mu_c + \varphi_y + \varepsilon_{ibct} \end{aligned} \tag{5.4}$$

where $Own\_branch\_density_{bct}$ is the number of bank b's own branches in city c during month t divided by the city area, and $Competitor\_branch\_density_{bct}$ is the number of branches of bank b's competitors that issue WMPs in city c during month t divided by the city area. Accordingly, we have the following hypothesis:

Hypothesis 4: In equation (5.4), the coefficient of $Own\_branch\_density_{bct}$ is significantly negative; the coefficient of $Online_{ibct}Own\_branch\_density_{bct}$ is significantly positive. In contrast, the coefficient of $Competitor\_branch\_density_{bct}$ is significantly positive;

the coefficient of $Online_{ibct}Competitor\_branch\_density_{bct}$ is significantly negative. That is, as the number of a bank's own branches decreases, the offline price will decrease and the gap between the online and offline prices will become wider; as the number of branches of a bank's competitors decreases, the bank's offline price will increase and the gap between the online and offline prices will become narrower.

The regression results of equation (5.4) are reported in columns 2-4 of Table 7, which is consistent with Hypothesis 4.

The effect of branch clustering

As shown by the third model in Subsection 3.6, if branches of the same bank are clustered rather than scattered, the gap between the bank's online and offline prices will be narrower (see Figure 7.3). For customers who never use online banking, as branches of a bank are clustered, the bank has greater market power over customers residing between its two branches and thus can charge higher prices at physical branches. However, for customers who can purchase either online or offline, branch clustering does not have any direct effect because a bank's clustering areas can still be penetrated by its rival's online channels; consequently, the bank does not gain greater local market power over online banking users in these areas. Online prices will still be indirectly affected by the increase in offline prices, but the indirect effect on online prices is smaller in magnitude than the direct effect on offline prices, making the online-offline price gap become narrower as the degree of branch clustering increases.

Empirically, we construct a measure for the degree of clustering of a bank's branches in a city. Suppressing the subscripts for city and time, denote the set of all banks in a city as $\mathcal{G}$, the set of all branches in the city as $\mathcal{F}$, and the set of all branches of bank b in the city as $\mathcal{F}_b$. Consequently,

$$\bigcup_{b\in\mathcal{G}} \mathcal{F}_b = \mathcal{F}$$

The measure for the clustering degree of bank b's branches in a city during a period is

$$cluster_b = \frac{\frac{\sum_{k \in \mathcal{F}_b} \frac{\sum_{j \in \mathcal{F}/\mathcal{F}_b} d_{kj}}{\|\mathcal{F}/\mathcal{F}_b\|}}{\|\mathcal{F}_b\|}}{\frac{\frac{1}{2}\sum_{k \in \mathcal{F}_b} \frac{\sum_{j \in \mathcal{F}_b/\{k\}} d_{kj}}{\|\mathcal{F}_b\| - 1}}{\|\mathcal{F}_b\|}} \tag{5.5}$$

where the $\|\cdot\|$ operator computes the number of elements of a set. The denominator in equation (5.5) is the average distance between any two branches of bank b in the city. The numerator in equation (5.5) is the average distance between any branch of bank b and any branch of a bank other than bank b. If a bank's branches are more clustered, its branches should be closer to its own branches than to other banks' branches, and this clustering measure will be higher. For the branch distribution displayed in Figure 2.4, this measure equals $\frac{1}{2}$. For the branch distribution displayed in Figure 2.6, this measure equals $\frac{3}{2}$.

Empirically, we estimate the following equation:

$$\begin{aligned} r_{ibct} = \kappa \cdot Online_{ibct} + \delta \cdot Online_{ibct} \cdot Cluster_{bct} + \omega \cdot Cluster_{bct} + \beta \cdot X_{ibct} \\ + \gamma \cdot Z_{ct} + \lambda \cdot W_t + \psi_b + \mu_c + \varphi_y + \varepsilon_{ibct} \end{aligned} \tag{5.6}$$

Accordingly, we have the following hypothesis:

Hypothesis 5: In equation (5.6), the coefficient $Cluster_{bct}$ is significantly negative; the coefficient of $Online_{ibct} \cdot Cluster_{bct}$ is significantly positive. That is, if branches of the same bank are clustered rather than scattered, the bank's online price and offline price will be higher, and the online-offline price gap will be narrower.

Columns 1 and 2 of Table 8 report the regression results of equation (5.6) based on the WMPs issued in the city-year combinations with the digital finance inclusion indices above the average and those below the average, respectively. First, the coefficients of $Cluster_{bct}$ in the two columns are both significantly negative, which indicates that banks with greater branch clustering offer higher offline prices (or lower offline returns) because of the greater local market power and also charge higher online prices accordingly. Second, the coefficients of $Online_{ibct} \cdot Cluster_{bct}$ in the two columns are both significantly positive, which indicates that branch clustering will reduce the gap between online and offline prices. Third, the coefficient of $Cluster_{bct}$ in column 1 of Table 8 (the high digital finance inclusion index group) is larger in magnitude than that in column 2 of Table 8 (the low digital finance inclusion index group). A possible explanation is that, when the proportion of customers who never use online banking is larger, although branch clustering can provide a bank with greater local market power in the offline market, the bank still cannot substantially increase its offline price because a higher offline price will cause a great number of branch-only users residing far away from the bank's branch to choose the outside option or the bank's competitors' branches.

[Insert Table 8 here]

Based on the results in Tables 7 and 8, while increases in a bank's own branch density, increases in the bank's branch clustering, decreases in the branch density of the bank's competitors, and decreases in the number of incumbent banks all would increase the bank's market power, the effects of the former three and the latter one on the online-offline price gap are opposite: the former three decrease the gap whereas the latter one increases the gap. The former three directly affect the bank's local market power in the offline market but do not directly affect the bank's market power in the online market. The online prices are influenced indirectly through the changes in offline prices. In contrast, changes in the number of incumbent banks directly affect each bank's market power in both the online and offline markets; the effect on the online market is larger than that on the offline market because, as the number of competitors increases, a bank can still maintain some local market power in the offline market over residents near its physical branches but cannot do so in the online market.

5.5. Offline-only banks

A small proportion of banks, which are in small sizes and usually operating in a single city, had never sell online WMPs in our sample period. As shown by the model in Subsection 3.7 (see Figure 8), the prices of banks that only sell products offline should be lower than the online and offline prices of banks that sell products both online and offline. Accordingly, we run the following regression:

$$r_{ibct} = \kappa_1 \cdot Online_{ibct} + \kappa_2 \cdot Offline_{ibct} + \beta \cdot X_{ibct} + \gamma \cdot Z_{ct} + \lambda \cdot W_t + \psi_b + \mu_c + \varphi_y + \varepsilon_{ibct} \quad (5.7)$$

$Online_{ibct} = 1$ if the product is an online product; and $Online_{ibct} = 0$ otherwise. $Offline_{ibct} = 1$ if the product is an offline product of a bank that sells products both online and offline; and $Offline_{ibct} = 0$ otherwise. The omitted group is the products of banks that only sell offline (offline-only banks). The three groups comprise 46%, 44%, and 10% of the sample, respectively.

The regression results of equation (5.7) are reported in Table 9. The coefficients of $Online_{ibct}$ and $Offline_{ibct}$ are both significantly negative, which indicates that the prices (promised yields) offered by offline-only banks are lower (higher) than the online and offline prices (promised yields) offered by the banks that sell products both online and offline.

[Insert Table 9 here]

6. Concerns

6.1. Fundamental difference between online and offline WMPs

One concern is the possible endogeneity of the online indicator. If banks select WMPs with lower risk to sell through online channels versus through offline channels, it is natural that WMPs sold online have lower promised yields than WMPs sold offline. However, first, we have already controlled for all the risk-related product characteristics that are specified in the contracts. In addition, according to Table 4 and Table A.1 in Appendix A, while there is some difference between online and offline products in each dimension on average, the differences are not always in the same direction. For example, online WMPs have shorter terms to maturity and lower minimum investment requirement, which would cause higher online prices (lower online returns), whereas online WMPs also have lower principle coverage ratios and a greater proportion with equities as the underlying assets, which would cause lower online prices (higher online returns). Therefore, there is no systematic difference in product characteristics between online and offline products that would cause online prices higher than offline prices. Moreover, the unconditional mean of promised yields (prices) is even higher (lower) for online products than offline products.

Second, employing propensity score matching (see Tables A.2 in Appendix A for the logit regressions of the online indicator), we match each online product with an offline product with similar characteristics and re-estimate equation (5.1) using the matched sample. The coefficient of the online indicator is still significantly negative and has a similar magnitude (see Tables A.3 in Appendix A for regression results), while the characteristics of online and offline products in the matched sample are closer to each other (see Table A.4 in Appendix A for descriptive statistics).

Third, one may argue that banks may select WMPs with lower risk based on characteristics unobserved by researchers to sell through online channels. However, the rich set of observed characteristics in the data includes all the product characteristics that can be seen by customers at purchase. If there are risk-related product characteristics that are unobserved by researchers, they are also unobservable to customers. Therefore, banks do not need to price based on those unobserved characteristics. Moreover, banks have no reason to sell online and offline products with systematic differences in the dimensions unobservable to customers. In practice, WMPs are all implicitly guaranteed by the issuing banks; thus, there is effectively not much difference in risks across different WMPs. Investors usually consider WMPs to be a relatively safe way to invest. There have been almost no default cases in the first ten years of WMP history.

Fourth, if the online-offline spread were purely driven by the fundamental difference in product characteristics between online and offline products, in Subsection 5.4, we should not have found that the spread changes according to branch density and branch clustering, which directly affect customers' travel costs to physical branches rather than product characteristics.

6.2. Difference in searching costs

One may argue that the information of some offline products may not be listed on banks' websites in a timely manner, which could lead customers to effectively face higher search costs for offline products than for online products.

Another concern is that although banks' websites post information on their offline products, customers who never use online banking may not search banks' websites; they search only offline and hence have higher search costs.

However, these arguments tend to push online prices lower than offline prices, whereas our empirical results show that online prices are higher than offline prices. Therefore, the actual effect of traveling costs on the gap between online and offline prices could be even larger than our estimates.

6.3. Difference in customers' price sensitivities

One concern is that customers who can use online banking may be less price-sensitive than customers who never use online banking, driving online prices higher than offline prices.

However, first, it is more likely that online banking users are more price-sensitive because of their better access to alternative investment tools and lower search costs (as discussed in Subsection 6.2). Second, even if online banking users are less price-sensitive, it is unlikely that the higher online prices are purely driven by this instead of saving on travel costs. Otherwise, we should not find that the online-offline price gap changes according to branch density and branch clustering, which affect customers' travel costs to physical branches rather than customers' price sensitivities.

6.4. Are the higher online prices (lower online returns) caused by convenience fees?

No. To purchase a WMP issued by a bank, customers need to use their deposits in the bank, regardless of whether they purchase at the bank's online banking system or physical branches. If they do not have (enough) deposits in the bank, they need to transfer enough money to their checking accounts in that bank several days in advance (usually one week, as required by issuing banks). Therefore, the money goes through the same payment channel within the bank regardless of whether the purchase is made online or offline, which is different from purchasing a movie ticket.

Moreover, the regulator requires commercial banks to strictly distinguish between fees and interest rates or yields in their pricing structures. Banks are not allowed to hide fees in interest rates or yields.[18]

6.5. Bundling

One concern is whether banks bundle WMPs with other products or services. During the sample period, banks seldom conducted bundling for WMPs. In later years, bundling could occur occasionally; for example, some banks offer interest discounts for mortgage borrowers if they also purchase WMPs from the same banks.

However, first, bundling can occur not only among offline products during customers' branch visits but also among online products during customers' online shopping because nowadays most financial products or services are available through online banking systems. Thus, bundling should not drive the online-offline price gap.

Second, bundling often affects the price of the other bundled products instead of WMPs because WMP prices are product-specific rather than individual-specific. A WMP has an enormous issuing volume (often higher than RMB 50 million), is sold to many customers, and has a standardized contract document for all the customers. Banks have to charge buyers of the same WMP the same price (offer buyers of the same WMP the same return) regardless of whether the buyers also purchase other products or services; each individual buyer is a price taker and cannot negotiate with banks on the price of a specific WMP (similar to purchasing a bond or a mutual fund in the primary market). In contrast, mortgage contracts are more personalized and can be negotiated between banks and customers. Therefore, in the above example, bundling can affect mortgage prices but not WMP prices. A similar case is that a customer purchasing treasury bills at a bank will pay the same price for treasury bills regardless of whether the customer simultaneously originates a mortgage at the bank.

[18] See *Document No. 3 [2012] of the China Banking Regulatory Commission*.

On the other hand, because visiting a physical branch is costly, a customer may conduct multiple transactions with a bank during one visit instead of only purchasing a WMP. However, this tends to increase offline prices because it reduces the portion of the customer's travel cost that should be allocated to the offline WMP. Given this possibility, our empirical analyses still find that online prices are higher than offline prices.

6.6. Difference in operating costs

One concern is that operating costs online could be higher than those at physical branches, which can cause higher online prices. However, in fact, operating costs are lower online than offline. First, banks build their online banking systems to provide many services and products; adding another product line (WMPs) to an existing online platform would not incur a substantial marginal cost. Second, the setup and maintenance costs of a bank's online platform are much lower than those of a bank's physical branches. Banks charge low fees online than at physical branches for the money transfer service, which is a consequence of lower online operating costs.

Another question is why fees for money transfer services are lower online than offline, whereas WMP prices are higher online than offline. The reason is that the demand of a customer for money transfer services is relatively inelastic. When the customer needs to transfer a certain amount of money, usually she/he has to do it; the customer also has to use the banks in which she/he currently has an adequate amount of deposit, which is a fairly limited choice set compared to the set of all the existing banks. Consequently, a bank's offline transfer services do not face intensive competition from other banks' online services and the outside option. Moreover, money transfer services are standard, and fees across different banks are similar.

6.7. Endogeneity of branch locations

One concern is that the locations of bank branches might be endogenously determined. However, first, banks make their branch location decisions based on their entire businesses, such as deposits, lending (e.g., mortgages, credit cards, and business loans), merchant services, and other intermediary businesses, whereas WMPs are only part of their businesses.[19] Second, branch location decisions are made for the long run, whereas the terms to maturity of WMPs are relatively shorter. The office rental contracts of branches are usually for from 5 to 20 years; there is a fixed cost for establishing a physical branch; and it takes time to build up local customer bases for a physical branch. In 2016, among 191,880 existing branches, only 1,153 branches exited (the exit rate was 0.60%). Among the 1,153 exiting branches, 78.14% existed for more than 5 years. Among the branches alive in 2016, 83.29% of them were established before 2011.

7. Welfare and policy implications

We use WMPs, a financial-product sector, to tease out the effect of travel costs or spatial competition on online-offline price gaps. The effect should also exist in nonfinancial-product sectors, although it is difficult to be teased out because, in those sectors, other price-driving factors are substantially different between online and offline and usually making online prices tend to be lower online than offline. Therefore, the results in our study can generate implications not only for financial-product sectors but also for nonfinancial-product sectors.

Online markets are beneficial because they can save many costs, including consumers' travel costs. However, the saved costs do not necessarily become consumers' surplus because sellers can charge higher margins for online products. Therefore, increasing the competitiveness in online markets is important for regulators, especially when we find the following two phenomena both theoretically and empirically:

First, the competitiveness in online markets is more sensitive to an increase in the number of sellers than is the competitiveness in offline markets. As the number of sellers increases, each seller can still maintain some local market power in the offline market over residents near its physical branches but cannot do so in the online market.

[19] The banking literature has documented the effects of branch location distribution on the local mortgage lending markets (Tewari, 2014), small-firm finance and small-business growth (Rice and Strahan, 2010; Krishnamurthy, 2015), entrepreneurship (Cetorelli and Strahan, 2006), and deposit rates (Calem and Nakamura, 1998).

Second, when online prices are high, offline prices also tend to be high because online and offline prices are interlocked. Therefore, if online markets lack competitiveness, it will hurt not only online consumers' surplus but also offline consumers' surplus.

Regulators can increase the competitiveness of online markets of WMPs in two ways. The first way is deregulation of geographical restrictions on bank branching.[20] A bank's branch entry into a city can also increase the number of competitors in the online market of the city because, unlike the U.S. banking industry and many nonfinancial industries in China that have a national online market, the online market of WMPs is segmented at the city level. To be able to purchase WMPs issued in a city, regardless of whether purchasing through online or offline channels, customers need to have a local checking account with the issuing bank. To open a local checking account, customers have to physically visit a local branch of the issuing bank in the city. The affiliated city of an account can be identified by certain digits of the account number. Customers in a city cannot purchase online products of banks that do not have physical branches in the city.

The second way of increasing the competitiveness of online markets of WMPs is to remove the geographical segmentation of online markets of WMPs and unify them into a national online market. Customers in a city should be enabled to freely purchase online products of banks that do not have physical branches in the city. Consequently, each customer will face more competing banks online, which will help reduce online prices.

8. Conclusion

As the digital economy and digital finance develop rapidly, an increasing number of products and services can be purchased both online and offline. Correspondingly, an open question is whether online prices are lower than offline prices. Previous empirical studies have analyzed multiple sectors and found that most of the time, online prices are lower than offline prices if there is a price

[20] The bank deregulation in 2009 by the China Banking Regulatory Commission has already removed some restrictions: a joint-stock bank can freely set up branches in any city in a province as long as the bank already has branches in the capital city of the province; a city commercial bank can freely set up branches in any city in the province where the legal person of the bank locates. However, the deregulation has not been as thorough as in the U.S.

difference.

In this paper, we study the market of a financial product, the WMP market, which is the largest component of China's shadow banking sector (the total value of outstanding WMPs reached RMB 29.54 trillion at the end of 2017, approximately USD 4.25 trillion).

We find that prices (promised yields) of WMPs sold online are significantly higher (lower) than prices (promised yields) of WMPs sold at banks' physical branches. We provide empirical evidence supporting a possible explanation that customers need to pay travel (inconvenience) costs to visit physical branches and thus banks have to charge lower prices at physical branches to attract customers from online platforms. We further find that the gap between online and offline prices decreases with the share of online banking users in the city.

The WMP market provides an ideal scenario to identify the effect of firms' spatial competition on the gap between online and offline prices. The reason is that online and offline channels for issuing WMPs (selling a financial product) do not differ in other dimensions that could affect prices, including delivery costs, search costs, the convenience of inspecting product quality, and waiting costs.

Although decreases in the number of incumbent banks, increases in a bank's own branch density, increases in its branch clustering, or decreases in its competitors' branch density would increase the bank's market power, we find that the effects of the former one and the latter three on the online-offline price gap are opposing: the former one increases the gap whereas the latter three decrease the gap. Changes in the number of incumbent banks affect each bank's market power in both the online and offline markets; the effect on the online market is larger than that on the offline market because, as the number of competitors increases, a bank can still maintain some local market power in the offline market over residents near its physical branches but cannot do so in the online market. In contrast, the latter three directly affect the bank's local market power in the offline market but not in the online market. Online prices are influenced indirectly through the changes in offline prices.

The results in our study generate implications not only for financial-product sectors but also for nonfinancial-product sectors. Online markets are beneficial because they can save many costs, including consumers' travel costs. However, the saved costs do not necessarily become consumers' surplus because sellers can charge higher margins for online products. Therefore, increasing the competitiveness in online markets is important, especially when we find the following two phenomena both theoretically and empirically: First, the competitiveness in online markets is more sensitive to an increase in the number of sellers than is the competitiveness in offline markets; second, because of the interlocking between online and offline prices, if online markets lack competitiveness, it will hurt not only online consumers' surplus but also offline consumers' surplus.

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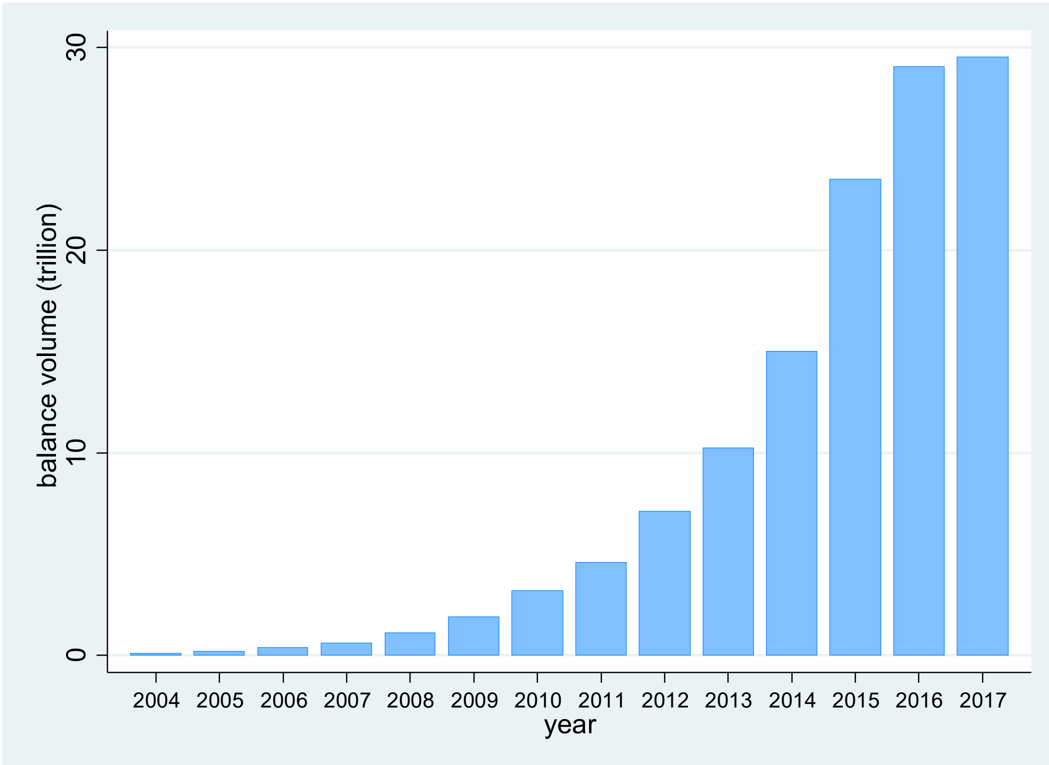
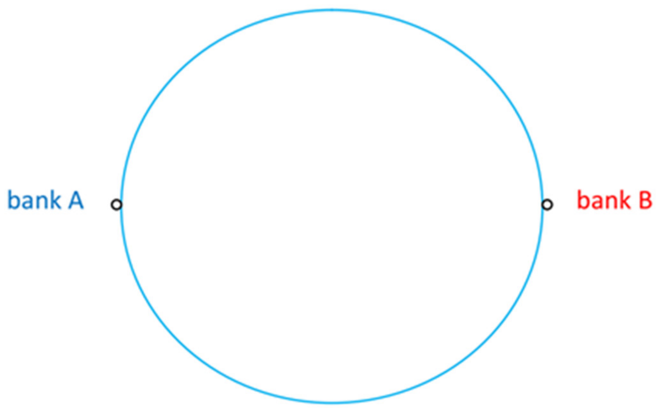


Figure 1. Outstanding balance of WMPs



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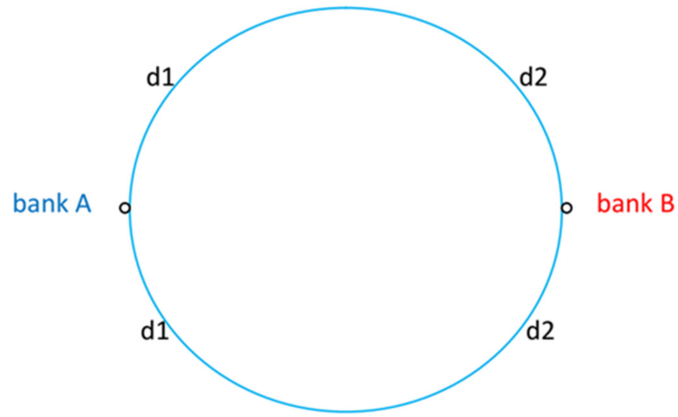

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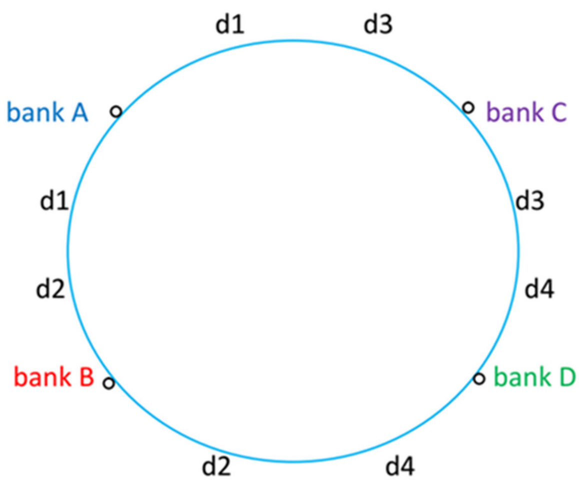

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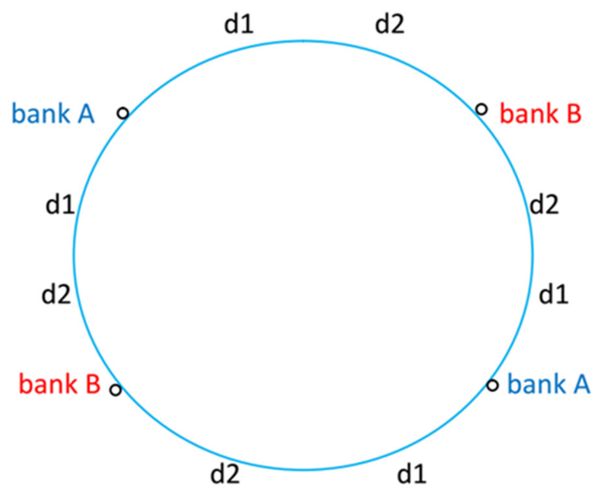

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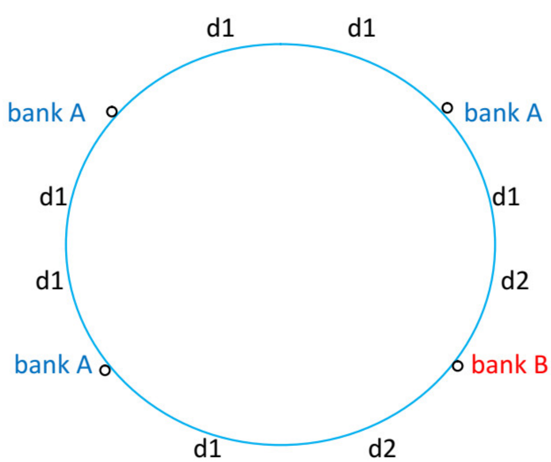

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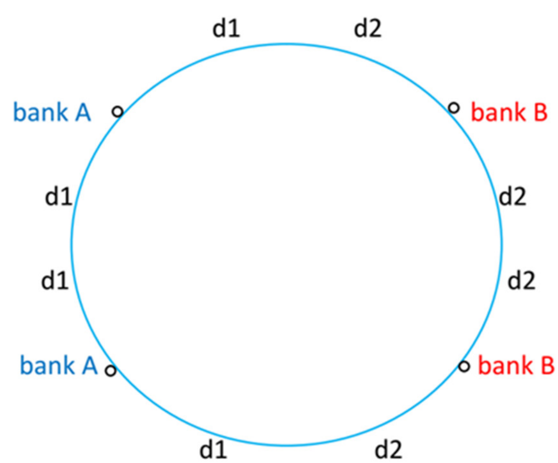

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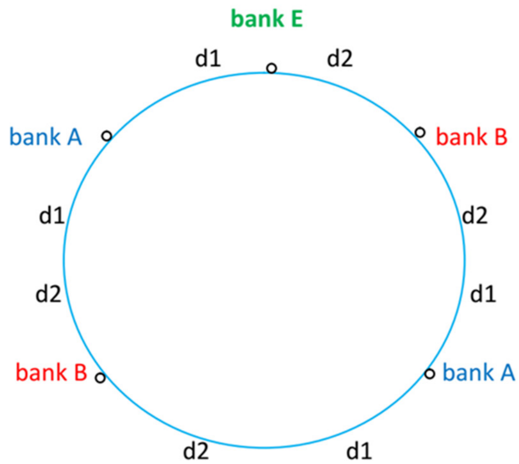


Figure 2.7

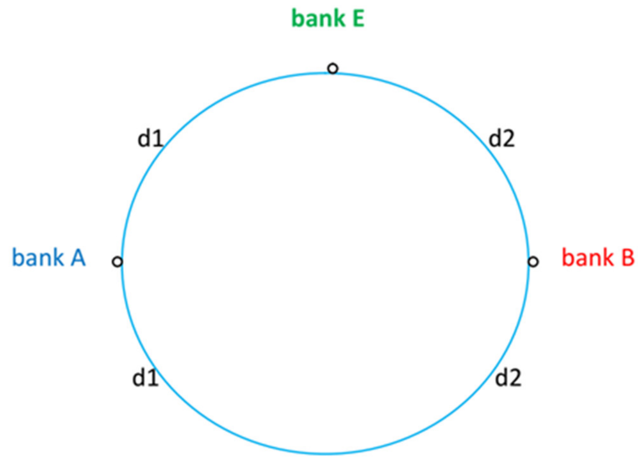


Figure 2.8

Figure 2. Bank branch location. A city is represented by a circle and customers uniformly reside on the circle. d_1 or d_2 is the distance between a customer and the nearest branch of bank A to the customer. d_3 or d_4 is the distance between a customer and the nearest branch of bank D to the customer.

In Figures 2.1 and 2.2, there are two banks in the city, each with only one physical branch. A customer residing at point d_1 (d_2) who chooses bank A (B) can obtain the same utility regardless of whether she/he chooses bank A's (B's) online or offline products.

In Figure 2.3, there are four incumbent banks instead of only two.

In Figures 2.4 and 2.6, each of the two banks has two branches: the two branches of the same bank are scattered in Figure 2.4, whereas they are clustered in Figure 2.6.

In Figure 2.5, there are two incumbent banks, one with three branches and the other with one branch.

In Figures 2.7 and 2.8, there are two large banks (bank A and bank B) with both online platforms and physical branches and one small bank (bank E) with only a physical branch and no online platforms.

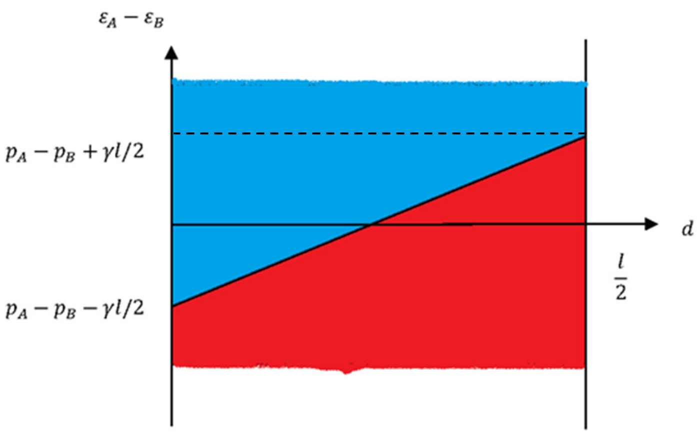
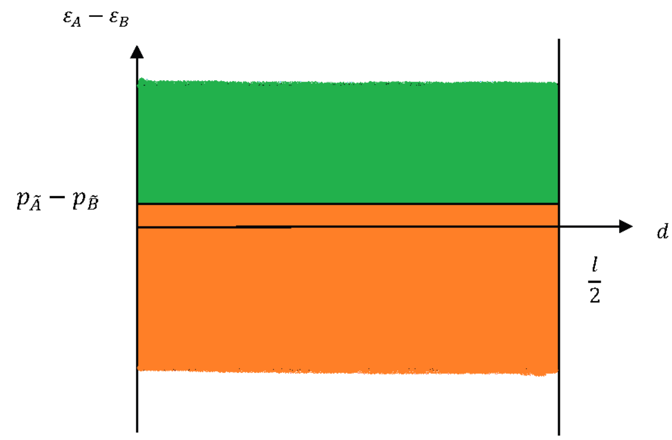


Figure 3.1



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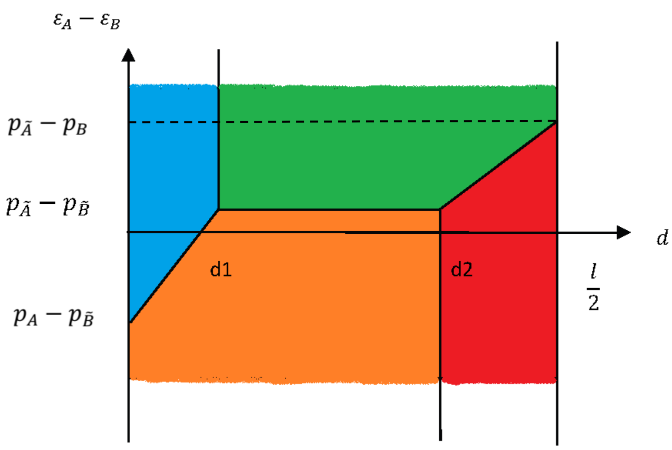

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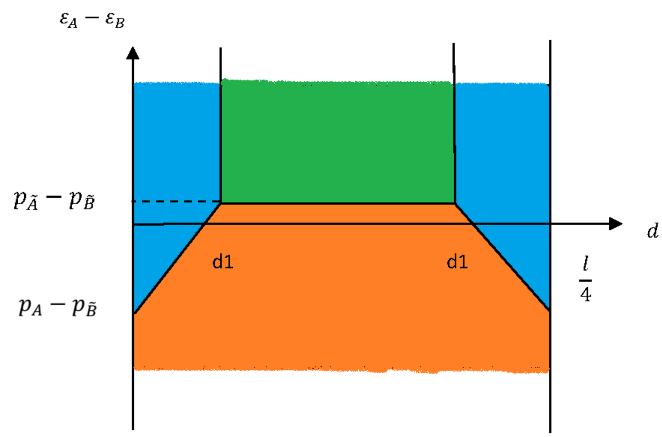

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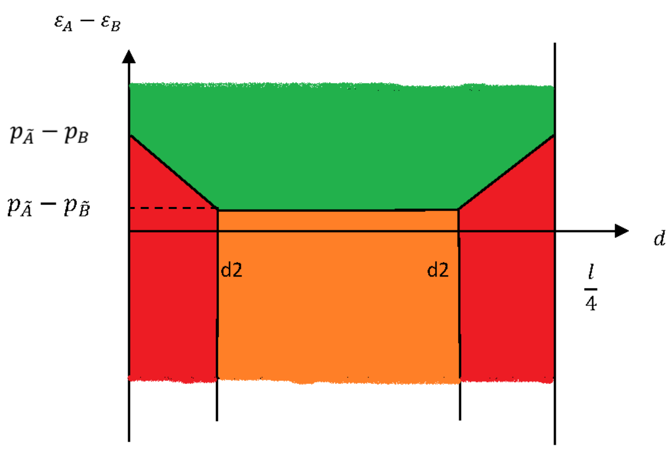

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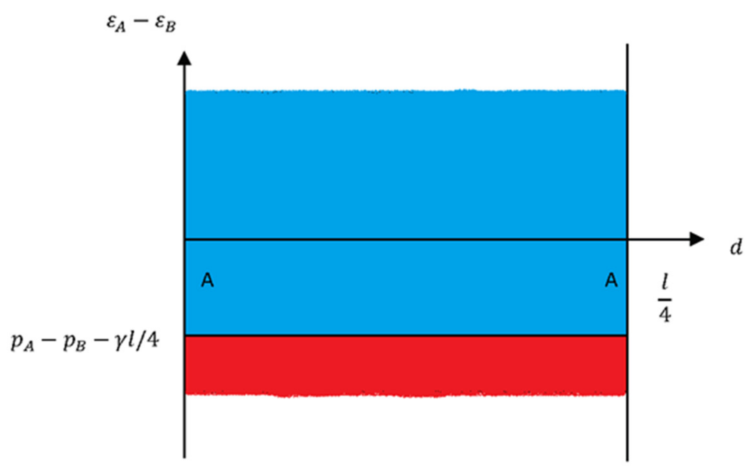

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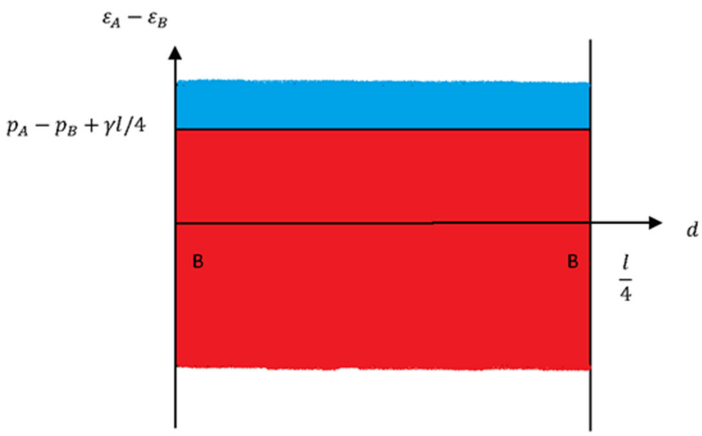
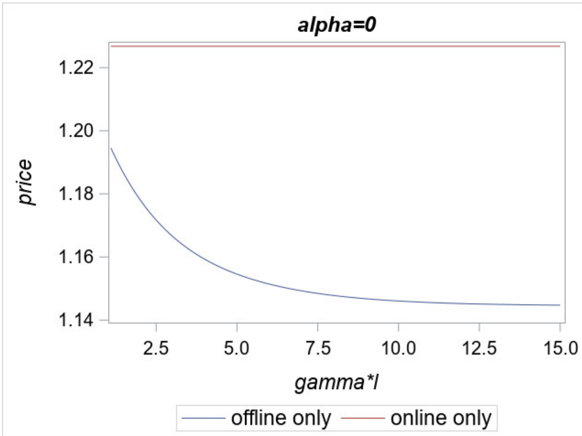


Figure 3.7

Figure 3. Market shares. Given two incumbent banks (bank A and bank B) in a city, the diagrams above display their market shares over consumers who purchase a product. The vertical axis represents the difference between a customer's idiosyncratic preference for bank A and that for bank B. The horizontal axis represents the distance between a customer and the closest branch of bank A. The **blue** and **red** areas represent customers who purchase the offline products of bank A and bank B, respectively. The **green** and **orange** areas represent customers who purchase the online products of bank A and bank B, respectively.

Figures 3.1 through 3.3 display the cases in which each bank has only one branch (as shown in Figure 2.2). Figure 3.1 displays the case in which bank A and bank B only have offline channels and not online channels. Figure 3.2 displays the case in which bank A and bank B only have online channels and not offline channels. When bank A and bank B offer both online and offline channels, Figure 3.3 displays their market shares over customers who can use online banking; their market shares over customers who never use online banking are similar to those in Figure 3.1.

When each bank has two branches clustered as shown in Figure 2.6, for customers who can use online banking, Figures 3.4 and 3.5 display the market shares of the two banks in the segment between the two branches of bank A and in the segment between the two branches of bank B, respectively; the market shares in the segment between two branches of different banks are similar to those in Figure 3.3. For customers who never use online banking, Figures 3.6 and 3.7 display the market shares of the two banks in the segment between the two branches of bank A and in the segment between the two branches of bank B, respectively; the market shares in the segment between two branches of different banks are similar to those in Figure 3.1.



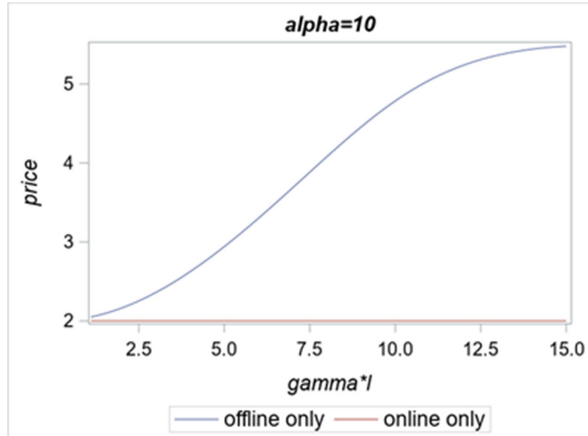
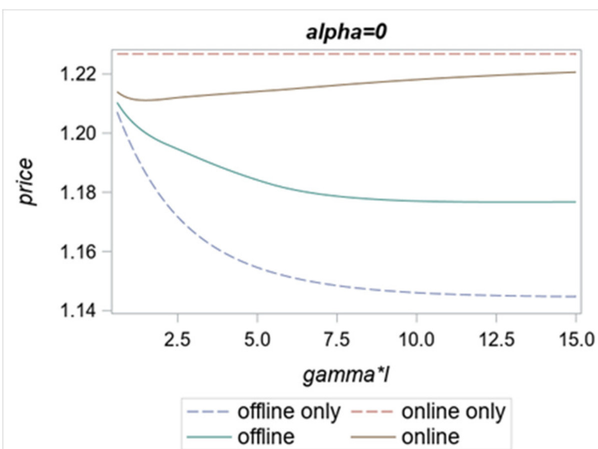


Figure 4.1 **Figure 4.2**

Figure 4. Offline-only city market vs. online-only city market. The blue line represents the price when banks only have physical branches and do not have online platforms. The red line represents the price when banks only have online platforms and do not have physical branches. Figures 4.1 and 4.2 display the cases with small α and large α, respectively, where α represents customers' average preference toward purchasing a product instead of choosing the outside option.



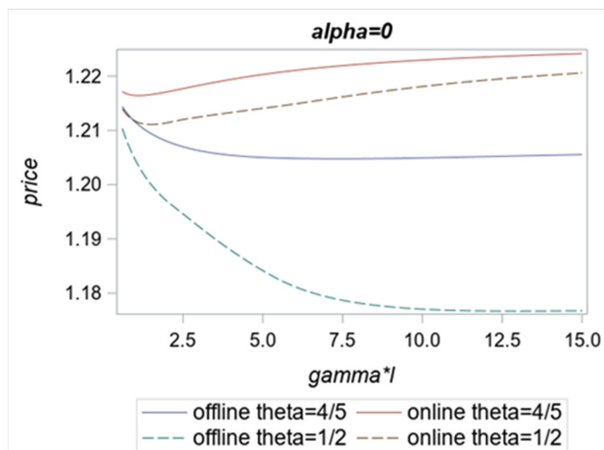


Figure 5.1 **Figure 5.2**

Figure 5. City market with both offline and online channels. In Figure 5.1, the offline and online prices in a city with both physical branches and online platforms are shown by the green line and brown line, respectively, compared with the price in an offline-only city (the blue dashed line) and the price in an online-only city (the red dashed line); the share of customers who can use online banking (θ) is set to 0.5. Two reasons for the lower offline prices compared to the online prices: First, if offline prices are too high, offline-only customers residing far away from bank physical branches will choose the outside option because they do not have the online option to save the high travel costs, and then banks will lose these customers; second, each bank need to set lower offline prices to compete with other banks' online products.

Figure 5.2 displays the online and offline prices in a city with both physical branches and online platforms for a large-θ case and a small-θ case, respectively.

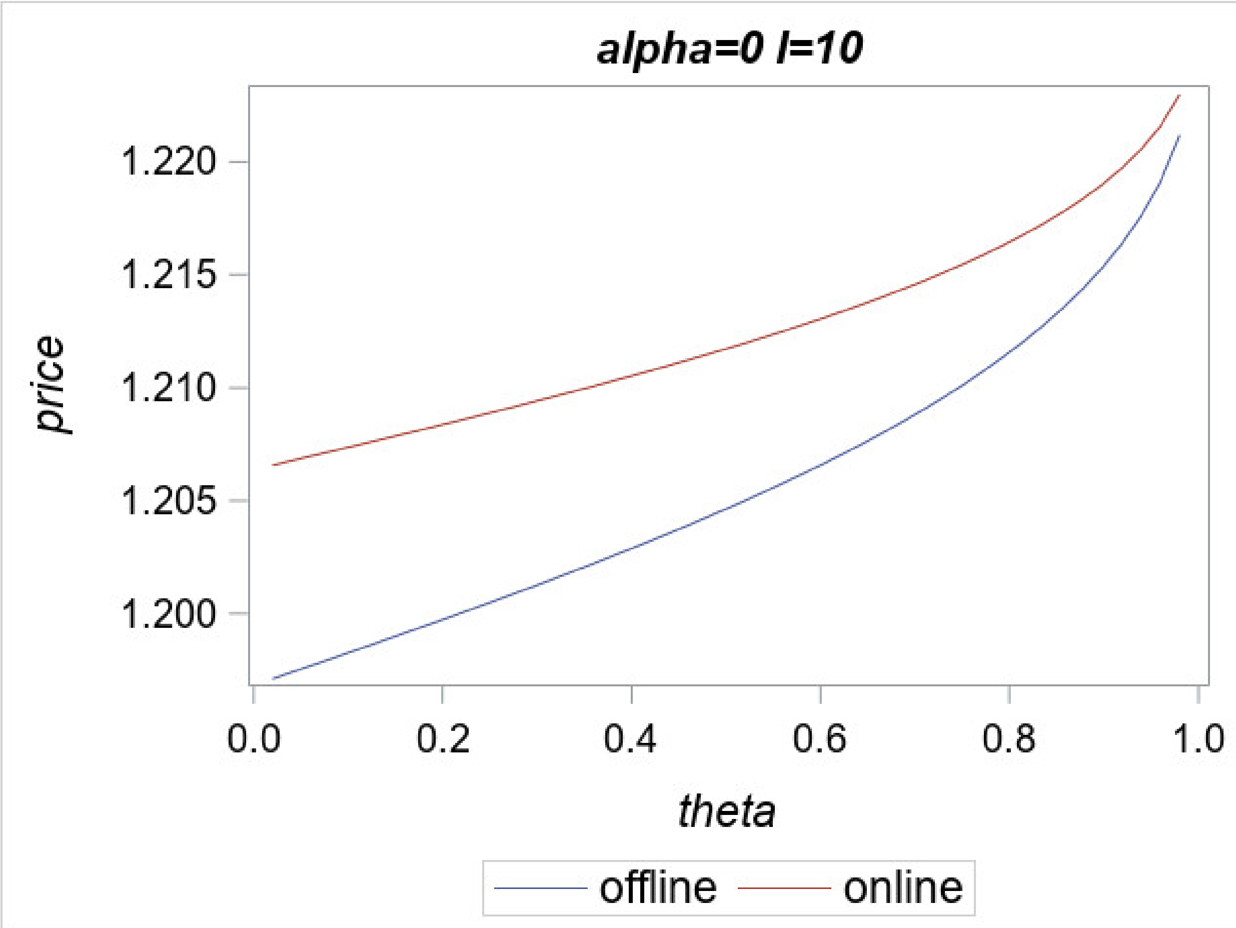


Figure 6. Online-offline price gap and the share of online banking users. In a city with both physical branches and online platforms, given a city size (l is set to 10), the online prices (red line) and offline prices (blue line) both increase with the share of customers who can use online banking (θ). The online prices increase faster with θ than the offline prices, which leads the online-offline price gap to be decreasing in θ.

When θ is small, there are many customers who never use online banking, and hence banks have to charge lower offline prices. Otherwise, a great number of customers who never use online banking and meanwhile reside far away from bank branches will choose the outside option because they cannot purchase online to save the high travel costs. Given low offline prices, online prices should also be set low. Otherwise, many online buyers will switch to offline; banks can no longer earn the higher online prices from them, although banks will not lose these customers.

When θ is large, for a bank, there are many potential customers who can use online banking and meanwhile reside near the bank's competitors' branches. Consequently, banks have to set their online prices much closer to their competitors' offline prices; otherwise, they cannot penetrate the great number of online banking users residing near their competitors' physical branches.

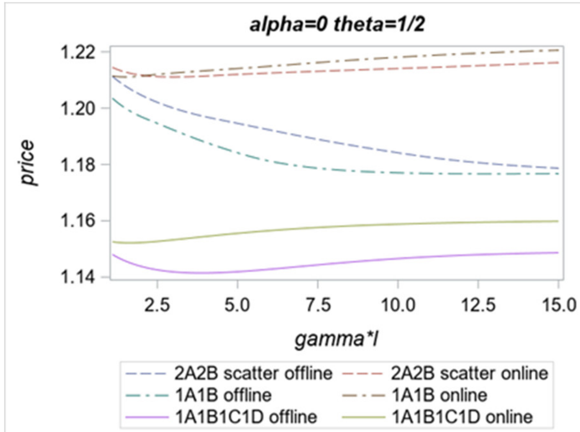


Figure 7.1

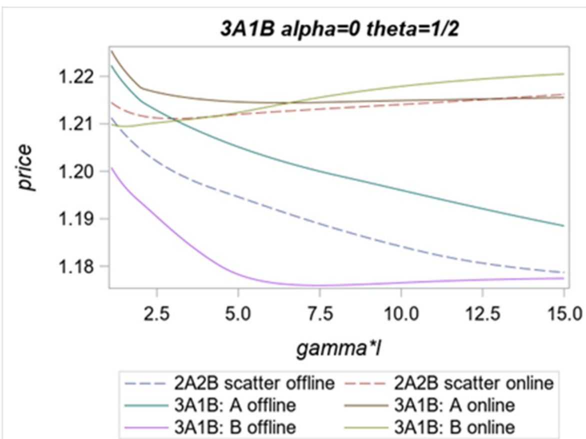


Figure 7.2

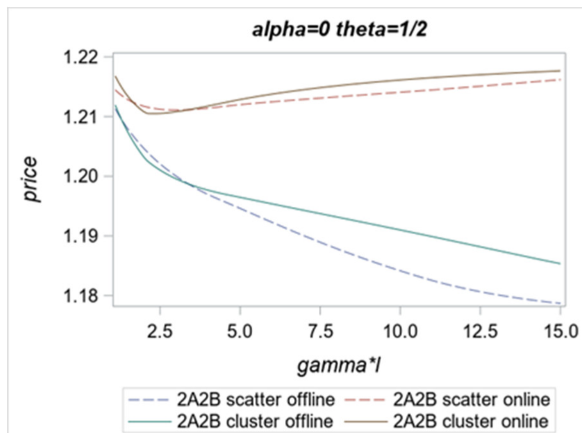


Figure 7.3

Figure 7. Effects of incumbent bank numbers, branch densities, and branch clustering. Figure 7.1 compares a two-bank case in which each bank has only one branch (as shown by Figure 2.2), another two-bank case in which each bank has two branches (as shown by Figure 2.4), and a four-bank case (as shown by Figure 2.3).

Figure 7.2 displays the case in which bank A has three branches and bank B has only one branch (as shown by Figure 2.5).

Figure 7.3 compares the case in which the two branches of each bank are clustered (as shown by Figure 2.6) with the case in which the two branches of each bank are scattered (as shown by Figure 2.4).

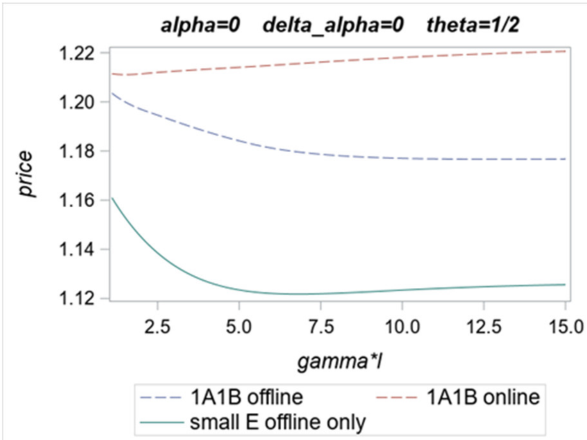


Figure 8.1

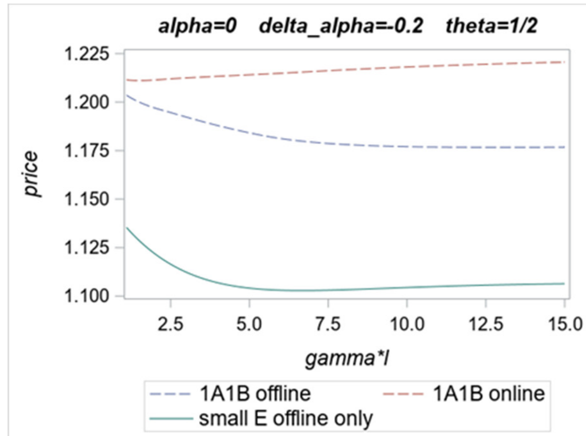


Figure 8.2

Figure 8. Existence of small banks with physical branches and no online platforms. The price of bank E that only offers offline products is represented by the green line; it is compared with the online price (the dashed red line) and the offline price (the dashed blue line) of bank A and bank B that offer both online and offline products.

In Figure 8.1, bank E has the same α (=0) as bank A or bank B.

In Figure 8.2, bank E has a smaller α (=-0.2) than bank A or bank B; that is, due to its small size, on average, bank E is less favored by customers than are bank A and bank B.

Figures 8.1 and 8.2 indicate that even without the disadvantage of small size (or lower average preference by customers), the disadvantage of only offering offline channels itself can drive bank E's price lower than the online and offline prices of banks A and B that sell products both online and offline.

Table 1. Average expected returns on WMPs

Year	3-month time deposit rate	Expected return of WMP with maturity between 87-93 days			
		State-owned banks	Joint-stock banks	City commercial banks	Overall
2004	1.71	2.23	4.08	---	3.34
2005	1.71	3.26	2.98	3.34	3.09
2006	1.74	4.04	4.15	4.58	4.23
2007	2.31	4.29	4.21	4.14	4.22
2008	3.15	4.48	4.39	4.17	4.36
2009	1.71	1.85	2.18	1.80	1.98
2010	1.76	2.42	2.50	2.35	2.43
2011	2.87	3.73	4.20	4.38	4.06
2012	2.84	3.63	4.30	4.71	4.22
2013	2.60	4.33	4.63	4.89	4.64
2014	2.57	5.02	5.36	5.38	5.28
2015	1.72	4.63	4.84	5.09	4.92
2016	1.10	3.67	3.94	4.05	3.94

Table 2. Locally issued WMPs

	Number of products	proportion
Products sold in 1 city	33924	0.096479
Products sold in <= 2 cities	39381	0.111998
Products sold in <= 3 cities	43746	0.124412
Products sold in <= 4 cities	49542	0.140896
Products sold in <= 5 cities	56718	0.161304
Products sold in 1 province	51416	0.146226
Products sold in <=10 cities	95334	0.271127
All the products	351,621	1
Products sold in all the cities with the issuing banks' branches (nationwide)	279,488	0.794856

Table 3. Variable definitions and descriptive statistics

Variable	Definition	Mean	Standard deviation
Key dependent variable			
WMP interest rate (%)		4.6664	1.0662
WMP characteristics			
Term to maturity (days)		122.1	220.1
Principal coverage (%)		28.84	45.52
Min investment requirement (RMB)	Minimum purchase amount required	3103644	2.83×10^7
Trust	=1 if issued jointly with a trust; =0 otherwise	0.580	0.494
Structure	=1 if with derivative designs in the contract; =0 otherwise;	0.0116	0.107
Underlying asset categories:			
Loans	=1 if the underlying assets are loans; =0 otherwise	0.0927	0.290
Equities	=1 if the underlying assets are equities; =0 otherwise	0.0343	0.182
Bonds	=1 if the underlying assets are commercial or local gov bonds; =0 otherwise	0.583	0.493
Money market products	=1 if the underlying assets are money market products; =0 otherwise	0.136	0.342
Other or unknown underlying assets		0.155	0.362
Key independent variable			
Online	=1 if the WMP is sold online; =0 otherwise	0.465	0.499
Overall digital index	The overall index of digital financial inclusion	177.5	48.18
Coverage breadth	The breadth index of digital finance coverage	184.1	47.26
Usage depth	The depth index of digital finance usage	165.8	47.26
Digitization maturity	The maturity index of digitized financial business	176.7	68.96
Internet users/city population		0.575	0.523
Num of issuing banks	Number of banks issuing WMPs in the city during the month	21.30	6.671
Num of own branches / city area	Number of branches of the bank in the city during the month / city area	0.0179	0.0225
Num of competitors' branches / city area	Number other issuing banks' branches in the city during the month / city area	0.179	0.151
Branch clustering measure	Defined in equation (5.5)	1.914	20.72

	Macroeconomic variables		
City-level			
GDP growth (%)		9.268	2.661
City area (square kilometer)		12274	15840
Num of available WMPs	Number of WMPs issued in the city during the month	1801	1017
HHI		0.193	0.161
National-level			
SHIBOR	Shanghai Interbank Offered Rate matched by term to maturity	3.853	1.221
RRR	Required reserve ratio (%)	18.17	1.832
M2 growth	Broad money growth	0.146	0.0420
SHSCI growth	Shanghai Security Composite Index growth	0.00347	0.0858
SZSCI growth	Shenzhen Security Composite Index growth	0.00953	0.106

The descriptive statistics of product-level variables in this table are for the sample of all the single-city WMPs. The descriptive statistics for all the WMPs are reported in Table A.1 in Appendix A.

Table 4 Descriptive statistics for offline and online products

Single-city products	**Online products**		**Offline products**	
Variable	**Mean**	**Std Dev**	**Mean**	**Std Dev**
WMP interest rate (%)	4.985	0.746	4.792	0.937
Term to maturity (days)	112.5	107.9	122.7	301.3
Principal coverage (%)	13.67	34.55	42.82	49.73
Min investment requirement (RMB)	1.687e+06	1.540e+07	4.679e+06	3.890e+07
Trust	0.682	0.466	0.449	0.497
Structure	0.00480	0.0692	0.0216	0.145
Underlying asset categories:				
Loans	0.001	0.0323	0.0118	0.108
Equities	0.0217	0.146	0.0456	0.209
Bonds	0.854	0.354	0.491	0.500
Money market products	0.0664	0.249	0.251	0.433
Other or unknown underlying assets	0.0573	0.232	0.200	0.400

Table 5. Baseline results

	Column 1	Column 2	Column 3	Column 4	Column 5
	All WMPs	All WMPs	Single-city WMPs	Single-city WMPs	Single-city WMPs
Online	**-0.1424*** **	**-0.1376*** **	**-0.0702*** **	**-0.0417*** **	**-0.0380*** **
	(0.0038)	**(0.0034)**	**(0.0115)**	**(0.0098)**	**(0.0098)**
Num of issuing banks					0.0336***
					(0.0007)
Num of available WMPs (1000)					0.0249***
					(0.0040)
HHI					-0.1276***
					(0.0402)
City-level GDP growth					-0.0204***
					(0.0032)
SHIBOR		0.2531***		0.2277***	0.2242***
		(0.0027)		(0.0081)	(0.0081)
Required reserve ratio		0.2277***		0.2902***	0.3002***
		(0.0043)		(0.0110)	(0.0110)
M2 growth		-0.2354**		2.4155***	2.9424***
		(0.1074)		(0.3107)	(0.3169)
SHSCI growth		-0.5734***		-0.5631***	-0.5850***
		(0.0317)		(0.0860)	(0.0871)
SZSCI growth		0.2019***		0.1894***	0.2051***
		(0.0246)		(0.0674)	(0.0676)
Term to maturity	0.0000	0.0001***	0.0010***	0.0009***	0.0009***
	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0001)
Principal coverage	-0.0082***	-0.0080***	-0.0071***	-0.0068***	-0.0068***
	(0.0000)	(0.0000)	(0.0002)	(0.0001)	(0.0001)
Min investment requirement	0.0086***	0.0150***	-0.0211***	-0.0138***	-0.0151***
	(0.0012)	(0.0010)	(0.0043)	(0.0038)	(0.0039)
Trust	0.1154***	0.1124***	0.0668***	0.0483***	0.0428***
	(0.0040)	(0.0035)	(0.0144)	(0.0121)	(0.0121)
Structure	0.8193***	0.8499***	-0.0707	0.0203	0.0120
	(0.0142)	(0.0136)	(0.0683)	(0.0617)	(0.0618)
Underlying asset categories:					
Loans	-0.1643***	-0.0845***	-0.3934***	-0.3111***	-0.3049***
	(0.0314)	(0.0267)	(0.0662)	(0.0533)	(0.0541)
Equities	-0.0722***	-0.0243	0.0440	0.0575	0.0642
	(0.0169)	(0.0159)	(0.0573)	(0.0507)	(0.0515)

Bonds	-0.2392***	-0.1853***	-0.5398***	-0.4014***	-0.3935***
	(0.0152)	(0.0141)	(0.0436)	(0.0369)	(0.0379)
Money market products	-0.2085***	-0.2278***	-0.5906***	-0.5114***	-0.5054***
	(0.0161)	(0.0149)	(0.0461)	(0.0391)	(0.0402)
City fixed effects					Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
R^2	0.59	0.68	0.69	0.77	0.77
N	177,970	177,969	18,320	18,320	18,115

The sample for columns 1 and 2 includes all the WMPs; the sample for columns 3-5 includes the WMPs issued exclusively in a single city. To be able to purchase WMPs issued exclusively in a single city, regardless of whether purchasing through online or offline channels, customers need to have a local checking account with the issuing bank. Customers in a city cannot purchase online products of banks that do not have physical branches in the city. There are five underlying asset categories: loans, equities, bonds, money market products, and other or unknown underlying assets. The category of other or unknown underlying assets is omitted. The standard errors are reported in parentheses. * denotes significance at a 10% level. ** denotes significance at a 5% level. *** denotes significance at a 1% level.

Table 6. Effects of online banking user shares

	Column 1	Column 2	Column 3	Column 4	Column 5
Online	-0.5776***	-0.6590***	-0.4227***	-0.4301***	-0.1656***
	(0.0411)	(0.0441)	(0.0379)	(0.0274)	(0.0198)
Overall digital index	**-0.0079*** **				
	(0.0014)				
Online × Overall digital index	**0.0028*** **				
	(0.0002)				
Coverage breadth		**-0.0015**			
		(0.0010)			
Online × Coverage breadth		**0.0031*** **			
		(0.0002)			
Usage depth			**-0.0063*** **		
			(0.0008)		
Online × Usage depth			**0.0021*** **		
			(0.0002)		
Digitization maturity				**-0.0033*** **	
				(0.0004)	
Online ×Digitization maturity				**0.0021*** **	
				(0.0001)	
Internet users/city population					**-0.0440**
					(0.0336)
Online×Internet users/city population					**0.1993*** **
					(0.0267)
Num of issuing banks	0.0221***	0.0210***	0.0259***	0.0242***	0.0357***
	(0.0039)	(0.0039)	(0.0040)	(0.0040)	(0.0055)
Num of available WMPs (1000)	0.0340***	0.0323***	0.0330***	0.0349***	-0.0066
	(0.0067)	(0.0067)	(0.0067)	(0.0067)	(0.0069)
HHI	-0.1480***	-0.1205***	-0.1449***	-0.1548***	0.1576***
	(0.0388)	(0.0390)	(0.0385)	(0.0386)	(0.0462)
City-level GDP growth	-0.0187***	-0.0204***	-0.0245***	-0.0212***	-0.0106***
	(0.0032)	(0.0032)	(0.0032)	(0.0033)	(0.0039)
SHIBOR	0.2271***	0.2274***	0.2254***	0.2260***	0.2435***
	(0.0080)	(0.0081)	(0.0080)	(0.0080)	(0.0102)
Required reserve ratio	0.2971***	0.2977***	0.2991***	0.2976***	0.3728***
	(0.0109)	(0.0109)	(0.0109)	(0.0109)	(0.0288)
M2 growth	2.8743***	2.8158***	2.8291***	2.8785***	6.0912***

	(0.3039)	(0.3034)	(0.3054)	(0.3028)	(0.4441)
SHSCI growth	-0.6223***	-0.6409***	-0.6271***	-0.6160***	-0.1502
	(0.0858)	(0.0859)	(0.0861)	(0.0857)	(0.1184)
SZSCI growth	0.2360***	0.2482***	0.2364***	0.2361***	-0.2217**
	(0.0665)	(0.0666)	(0.0669)	(0.0665)	(0.1030)
Term to maturity	0.0009***	0.0009***	0.0009***	0.0009***	0.0008***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Principal coverage	-0.0068***	-0.0068***	-0.0068***	-0.0068***	-0.0067***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
Min investment requirement	-0.0117***	-0.0115***	-0.0112***	-0.0114***	-0.0154***
	(0.0039)	(0.0039)	(0.0039)	(0.0039)	(0.0050)
Trust	0.0368***	0.0404***	0.0383***	0.0346***	0.0398***
	(0.0117)	(0.0117)	(0.0119)	(0.0118)	(0.0137)
Structure	-0.0052	-0.0063	-0.0071	-0.0119	0.1232*
	(0.0629)	(0.0627)	(0.0629)	(0.0633)	(0.0676)
Underlying asset categories:					
Loans	-0.3315***	-0.3508***	-0.3066***	-0.3072***	0.0500
	(0.0543)	(0.0546)	(0.0551)	(0.0544)	(0.0952)
Equities	0.1576***	0.1563***	0.1305**	0.1544***	0.1054
	(0.0508)	(0.0510)	(0.0510)	(0.0509)	(0.0725)
Bonds	-0.3227***	-0.3265***	-0.3444***	-0.3207***	-0.2013***
	(0.0389)	(0.0392)	(0.0390)	(0.0391)	(0.0577)
Money market products	-0.4425***	-0.4407***	-0.4625***	-0.4300***	-0.2667***
	(0.0412)	(0.0417)	(0.0412)	(0.0414)	(0.0603)
City fixed effects	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
R^2	0.77	0.77	0.77	0.77	0.85
N	17,950	17,950	17,950	17,950	10,850

The sample includes the WMPs issued exclusively in a single city. The proxies for online banking user shares at the city level in columns 1-4 are the overall index of digital financial inclusion, the breadth index of digital finance coverage, the depth index of digital finance usage, and the maturity index of digitized financial business, respectively, which are constructed jointly by the Institute of Digital Finance at Peking University and Ant Financial Services Group based on data with billions of digital financial transaction records. The proxy in column 5 is simply the number of Internet users divided by the population in the city based on the China City Statistical Yearbook. There are five underlying asset categories: loans, equities, bonds, money market products, and other or unknown underlying assets. The category of other or unknown underlying assets is omitted. The standard errors are reported in parentheses. * denotes significance at a 10% level. ** denotes significance at a 5% level. *** denotes significance at a 1% level.

Table 7. Effects of incumbent bank numbers and branch densities

	Column 1	Column 2	Column 3	Column 4
Online	-0.1648***	-0.1648***	-0.1648***	-0.1648***
	(0.0371)	(0.0371)	(0.0371)	(0.0371)
Num of issuing banks	**0.0218*** **			
	(0.0041)			
Online × Num of issuing banks	**0.0054*** **			
	(0.0015)			
Num of own branches / city area		**-2.1094*** **		**-1.5944*** **
		(0.5644)		**(0.6073)**
Online × Num of own branches / city area		**2.3824*** **		**2.2565*** **
		(0.4013)		**(0.5294)**
Num of competitors' branches / city area			**1.2467*** **	**1.2455*** **
			(0.1991)	**(0.1982)**
Online × Num of competitors' branches / city area			**0.0522**	**-0.1392** **
			(0.0566)	**(0.0698)**
Num of available WMPs (1000)	0.0327***	0.0417***	0.0397***	0.0410***
	(0.0067)	(0.0071)	(0.0071)	(0.0071)
HHI	-0.1319***	-0.0815**	-0.0706*	-0.0720*
	(0.0401)	(0.0413)	(0.0410)	(0.0412)
City-level GDP growth	-0.0210***	-0.0200***	-0.0229***	-0.0234***
	(0.0032)	(0.0035)	(0.0035)	(0.0035)
SHIBOR	0.2242***	0.2263***	0.2261***	0.2268***
	(0.0081)	(0.0090)	(0.0090)	(0.0090)
Required reserve ratio	0.3008***	0.3074***	0.3128***	0.3126***
	(0.0110)	(0.0122)	(0.0122)	(0.0122)
M2 growth	2.9583***	3.0546***	3.2042***	3.1527***
	(0.3166)	(0.3492)	(0.3488)	(0.3494)
SHSCI growth	-0.5854***	-0.5857***	-0.6053***	-0.6123***
	(0.0871)	(0.0954)	(0.0954)	(0.0954)
SZSCI growth	0.2085***	0.2127***	0.2292***	0.2356***
	(0.0676)	(0.0746)	(0.0745)	(0.0746)
Term to maturity	0.0009***	0.0009***	0.0009***	0.0009***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Principal coverage	-0.0068***	-0.0067***	-0.0067***	-0.0067***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Min investment requirement	-0.0146***	-0.0230***	-0.0234***	-0.0237***

	(0.0039)	(0.0043)	(0.0043)	(0.0043)
Trust	0.0459***	0.0447***	0.0435***	0.0510***
	(0.0121)	(0.0141)	(0.0138)	(0.0141)
Structure	0.0185	-0.0129	0.0050	-0.0043
	(0.0618)	(0.0618)	(0.0620)	(0.0623)
Underlying asset categories:				
Loans	-0.3105***	-0.3587***	-0.3790***	-0.3648***
	(0.0541)	(0.0547)	(0.0547)	(0.0548)
Equities	0.0689	-0.0107	-0.0066	-0.0141
	(0.0514)	(0.0528)	(0.0523)	(0.0527)
Bonds	-0.3862***	-0.4741***	-0.4685***	-0.4686***
	(0.0379)	(0.0394)	(0.0393)	(0.0394)
Money market products	-0.5015***	-0.5611***	-0.5549***	-0.5544***
	(0.0402)	(0.0419)	(0.0418)	(0.0419)
City fixed effects	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
R^2	0.77	0.78	0.78	0.78
N	18,115	15,518	15,518	15,518

The sample includes the WMPs issued exclusively in a single city. There are five underlying asset categories: loans, equities, bonds, money market products, and other or unknown underlying assets. The category of other or unknown underlying assets is omitted. The standard errors are reported in parentheses. * denotes significance at a 10% level. ** denotes significance at a 5% level. *** denotes significance at a 1% level.

Table 8. Effects of branch clustering

	Column 1 High digital index	Column 2 Low digital index
Online	-0.1074***	-0.0251
	(0.0135)	(0.0279)
Clustering	**-0.0516*** **	**-0.0007*** **
	(0.0063)	**(0.0001)**
Online × Clustering	**0.0229*** **	**0.0260*** **
	(0.0069)	**(0.0101)**
Num of issuing banks	-0.0074	0.0268***
	(0.0065)	(0.0076)
Num of available WMPs (1000)	0.0183***	0.1249***
	(0.0065)	(0.0205)
HHI	0.1851***	-0.5084***
	(0.0414)	(0.1437)
Log per capita GDP	-0.0253***	-0.0145**
	(0.0085)	(0.0059)
SHIBOR	0.2322***	0.2198***
	(0.0112)	(0.0107)
Required reserve ratio	0.4167***	0.6544***
	(0.0086)	(0.0170)
M2 growth	2.5286***	1.8129***
	(0.3907)	(0.4586)
SHSCI growth	-0.3682***	-0.7686***
	(0.1017)	(0.1748)
SZSCI growth	0.0398	0.2804*
	(0.0792)	(0.1473)
Term to maturity	0.0002**	0.0024***
	(0.0001)	(0.0001)
Principal coverage	-0.0070***	-0.0045***
	(0.0002)	(0.0003)
Min investment requirement	-0.0068	-0.0072
	(0.0056)	(0.0067)
Trust	-0.0353*	0.0437**
	(0.0188)	(0.0213)
Structure	0.5806***	-0.3127***
	(0.1453)	(0.0484)

Underlying asset categories:		
Loans	0.4575***	-0.3134***
	(0.1391)	(0.0619)
Equities	0.3495***	-0.0783
	(0.1224)	(0.0582)
Bonds	-0.0931	-0.4135***
	(0.0974)	(0.0460)
Money market products	-0.3444***	-0.4990***
	(0.0996)	(0.0489)
City fixed effects	Yes	Yes
Bank fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
R^2	0.83	0.74
N	9,871	5,414

The measure for the degree of branch clustering of a bank in a city is defined in equation (5.5). The samples in columns 1 and 2 include the single-city WMPs issued in city-year combinations with the overall index of digital financial inclusion above and below its average, respectively. There are five underlying asset categories: loans, equities, bonds, money market products, and other or unknown underlying assets. The category of other or unknown underlying assets is omitted. The standard errors are reported in parentheses. * denotes significance at a 10% level. ** denotes significance at a 5% level. *** denotes significance at a 1% level.

Table 9. Prices of offline-only banks

	Single-city WMPs
Online products of online-offline banks	**-0.2788***** **(0.0399)**
Offline products of online-offline banks	**-0.2409***** **(0.0401)**
Num of issuing banks	0.0249*** (0.0040)
Num of available WMPs (1000)	0.0336*** (0.0068)
HHI	-0.1276*** (0.0402)
City-level GDP growth	-0.0204*** (0.0032)
SHIBOR	0.2242*** (0.0081)
Required reserve ratio	0.3002*** (0.0110)
M2 growth	2.9424*** (0.3169)
SHSCI growth	-0.5850*** (0.0871)
SZSCI growth	0.2051*** (0.0676)
Term to maturity	0.0009*** (0.0001)
Principal coverage	-0.0068*** (0.0001)
Min investment requirement	-0.0151*** (0.0039)
Trust	0.0428*** (0.0121)
Structure	0.0120 (0.0618)
Underlying asset categories:	
Loans	-0.3049*** (0.0541)

Equities	0.0642
	(0.0515)
Bonds	-0.3935***
	(0.0379)
Money market products	-0.5054***
	(0.0402)
City fixed effects	Yes
Bank fixed effects	Yes
Year fixed effects	Yes
R^2	0.77
N	18,115

The sample includes the WMPs issued exclusively in a single city. Observations are categorized into three groups: online products of banks selling both online and offline products (46%); offline products of banks selling both online and offline products (44%); and products of banks selling offline products only (10%). The last group is omitted. There are five underlying asset categories: loans, equities, bonds, money market products, and other or unknown underlying assets. The category of other or unknown underlying assets is omitted. The standard errors are reported in parentheses. * denotes significance at a 10% level. ** denotes significance at a 5% level. *** denotes significance at a 1% level.

Appendix A

Table A.1. Descriptive statistics for all products

All products	All		Online products		Offline products	
Variable	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
WMP interest rate (%)	4.551	0.952	4.655	0.862	4.614	0.871
Term to maturity (days)	140.3	5013	126.4	978.0	151.3	7003
Principal coverage (%)	34.42	47.94	23.60	42.84	43.51	50.08
Min investment requirement (RMB)	961365	1.280e+07	642079	8.084e+06	1.264e+06	1.650e+07
Trust	0.368	0.482	0.503	0.500	0.228	0.420
Structure	0.0352	0.184	0.0476	0.213	0.0234	0.151
Underlying asset categories:						
Loans	0.0243	0.154	0.0010	0.0320	0.0045	0.0671
Equities	0.0493	0.217	0.0765	0.266	0.0273	0.163
Bonds	0.509	0.500	0.683	0.465	0.378	0.485
Money market products	0.0752	0.264	0.0395	0.195	0.114	0.318
Other or unknown underlying assets	0.342	0.474	0.200	0.400	0.476	0.499

Table A.2. Logit regressions of the online indicator

Dependent variable:The online indicator	Column 1: All WMPs		Column 2: Single-city WMPs	
	coefficient	Marginal effect	coefficient	Marginal effect
Term to maturity	0.0000	3.07e-7	-0.0010***	-0.0001***
	(0.0000)	(4.3e-7)	(0.0002)	(0.00002)
Principal coverage	-0.0094***	-0.0011***	-0.0148***	-0.0019***
	(0.0002)	(0.00001)	(0.0008)	(0.0001)
Min investment requirement	-0.3666***	-0.0433***	-0.2441***	-0.0313***
	(0.0055)	(0.0006)	(0.0188)	(0.0026)
Trust	-0.1048***	-0.0124***	-0.6021***	-0.0772***
	(0.0196)	(0.0023)	(0.0716)	(0.0091)
Structure	0.4050***	0.0478***	-1.0463***	-0.1341***
	(0.0481)	(0.0057)	(0.2551)	(0.0326)
Underlying asset categories:				
Loans	-0.6880***	-0.0812***	-0.8989**	-0.1152**
	(0.1186)	(0.0140)	(0.4270)	(0.0547)
Equities	1.8343***	0.2165***	0.9315***	0.1194***
	(0.0599)	(0.0070)	(0.2836)	(0.0363)
Bonds	0.5819***	0.0687***	1.4345***	0.1839***
	(0.0529)	(0.0062)	(0.2439)	(0.0312)
Money market products	-0.1342**	-0.0158**	2.5833***	0.3312***
	(0.0564)	(0.0066)	(0.2552)	(0.0324)
City fixed effects	N		Y	
Bank fixed effects	Y		Y	
Year fixed effects	Y		Y	
N	173,618		16,369	

This table reports the logit regressions of the online indicator on product characteristics. Column 1 includes all WMPs, while column 2 includes only single-city WMPs. The dependent variable equals 1 if the product was sold through the online channel; equals 0 if not. If the regressor is a continuous variable, the marginal effect is computed by scaling the probability density evaluated at the sample mean. If the regressor is a dummy variable, the marginal effect is computed as the difference in the fitted probability with the dummy variable equal to one, then zero. Standard errors are reported in parentheses. * denotes significance at a 10% level. ** denotes significance at a 5% level. *** denotes significance at a 1% level.

Table A.3. Baseline results using the matched samples

	Column 1 All WMPs	Column 2 All WMPs	Column 3 Single-city WMPs	Column 4 Single-city WMPs
Online	**-0.1451***** **(0.0042)**	**-0.1547***** **(0.0046)**	**-0.0725***** **(0.0230)**	**-0.0690***** **(0.0254)**
Num of issuing banks			0.0043 (0.0111)	0.0293** (0.0128)
Num of available WMPs (1000)			0.0000 (0.0000)	-0.0000 (0.0000)
HHI			0.2166* (0.1176)	-0.2985** (0.1368)
City-level GDP growth			-0.0933*** (0.0114)	-0.0863*** (0.0129)
SHIBOR	0.2214*** (0.0046)	0.2269*** (0.0048)	0.1800*** (0.0150)	0.2074*** (0.0168)
Required reserve ratio	0.2570*** (0.0074)	0.2553*** (0.0078)	0.4683*** (0.0271)	0.4220*** (0.0322)
M2 growth	0.1179 (0.1847)	-0.3551* (0.2130)	2.7440*** (0.8652)	1.2921 (1.0070)
SHSCI growth	-0.4725*** (0.0559)	-0.4182*** (0.0625)	-1.0850*** (0.2675)	-0.7400** (0.3297)
SZSCI growth	0.1667*** (0.0444)	0.0394 (0.0490)	0.6750*** (0.2052)	0.3986 (0.2470)
Term to maturity	0.0001 (0.0001)	0.0001 (0.0001)	0.0004*** (0.0001)	0.0005*** (0.0001)
Principal coverage	-0.0070*** (0.0001)	-0.0076*** (0.0001)	-0.0067*** (0.0004)	-0.0061*** (0.0004)
Min investment requirement	0.0090*** (0.0016)	0.0249*** (0.0017)	0.0469*** (0.0087)	0.0279*** (0.0101)
Trust	-0.0016 (0.0060)	0.0229*** (0.0063)	-0.0401 (0.0333)	-0.0882** (0.0401)
Structure	0.4921*** (0.0366)	0.4731*** (0.0328)	1.6146*** (0.1156)	1.7283*** (0.1404)
Underlying asset categories:				
Loans	0.1976*** (0.0601)	-0.1808*** (0.0530)	-0.2122 (0.2005)	-0.3754** (0.1491)
Equities	0.0524 (0.0320)	-0.1811*** (0.0325)	-0.0423 (0.1089)	0.2008 (0.1234)

	(1)	(2)	(3)	(4)
Bonds	-0.0030	-0.2904***	-0.4607***	-0.3110***
	(0.0295)	(0.0294)	(0.0899)	(0.1074)
Money market products	0.0134	-0.2805***	-0.8127***	-0.7304***
	(0.0304)	(0.0304)	(0.1011)	(0.1211)
City fixed effects			Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
R^2	0.67	0.69	0.81	0.81
N	55,306	47,876	2,108	1,630

This table reports the regression results of equation (5.1) using matched samples. We first run a logit regression of whether the product is an online product on other covariates in equation (5.1). Then, we obtain each product's propensity score to be an online product. In columns 1 and 3, without replacement, we match each online product with the offline product with the closest propensity score; meanwhile, the caliper requirement is set to be 0.25 (a standard commonly used in the literature), i.e., for a match to be made, the difference in the logits of the propensity scores of the two products in a pair must be less than or equal to 0.25 times the standard deviation of the logits of the propensity scores in the entire sample. In columns 2 and 4, we further require that the online product and the offline product in a matched pair be issued by the same bank. Columns 1 and 2 use the sample of all the WMPs, which are analogs of column 2 of Table 5; columns 3 and 4 use the sample of single-city WMPs, which are analogs of column 5 of Table 5. The standard errors are reported in parentheses. * denotes significance at a 10% level. ** denotes significance at a 5% level. *** denotes significance at a 1% level.

Table A.4. Descriptive statistics for the matched samples

	Online WMPs			Offline WMPs		
Variable	N	Mean	Std.Dev.	N	Mean	Std.Dev.
Panel A: The matched sample for column 1 of Table A.2						
WMP interest rate (%)	27,653	4.627	0.791	27,653	4.748	0.838
Term to maturity (days)	27,653	116.3	143.5	27,653	122.0	358.3
Principal coverage (%)	27,653	36.11	48.73	27,653	33.91	48.26
Min investment requirement (RMB)	27,653	1.756e+06	1.760e+07	27,653	2.232e+06	1.690e+07
Trust	27,653	0.545	0.498	27,653	0.577	0.494
Structure	27,653	0.0191	0.137	27,653	0.0199	0.140
Underlying asset categories:						
Loans	27,653	0.00499	0.0705	27,653	0.00235	0.0484
Equities	27,653	0.114	0.318	27,653	0.0883	0.284
Bonds	27,653	0.786	0.410	27,653	0.797	0.403
Money market products	27,653	0.0727	0.260	27,653	0.100	0.301
Panel B: The matched sample for column 2 of Table A.2						
WMP interest rate (%)	23,938	4.570	0.855	23,938	4.757	0.867
Term to maturity (days)	23,938	107.9	139.5	23,938	132.7	379.0
Principal coverage (%)	23,938	38.26	49.34	23,938	30.43	46.73
Min investment requirement (RMB)	23,938	1.961e+06	1.940e+07	23,938	3.121e+06	2.880e+07
Trust	23,938	0.588	0.492	23,938	0.599	0.490
Structure	23,938	0.0195	0.138	23,938	0.0236	0.152
Underlying asset categories:						
Loans	23,938	0.00551	0.0741	23,938	0.00560	0.0746
Equities	23,938	0.0835	0.277	23,938	0.107	0.309
Bonds	23,938	0.798	0.401	23,938	0.796	0.403
Money market products	23,938	0.0908	0.287	23,938	0.0807	0.272
Panel C: The matched sample for column 3 of Table A.2						
WMP interest rate (%)	1,054	4.749	0.910	1,054	4.728	0.869
Term to maturity (days)	1,054	145.5	220.1	1,054	127.1	123.2
Principal coverage (%)	1,054	32.10	47.17	1,054	27.59	44.91
Min investment requirement (RMB)	1,054	1.060e+07	4.070e+07	1,054	6.897e+06	2.660e+07
Trust	1,054	0.767	0.423	1,054	0.695	0.460
Structure	1,054	0.0133	0.115	1,054	0.00474	0.0687
Underlying asset categories:						
Loans	1,054	0.00949	0.0970	1,054	0	0
Equities	1,054	0.0977	0.297	1,054	0.0228	0.149
Bonds	1,054	0.826	0.379	1,054	0.863	0.344

Money market products	1,054	0.0474	0.213	1,054	0.0873	0.282

Panel D: The matched sample for column 4 of Table A.2

WMP interest rate (%)	815	4.723	0.980	815	4.694	0.864
Term to maturity (days)	815	145.2	242.1	815	110.1	102.7
Principal coverage (%)	815	31.32	46.93	815	26.53	44.71
Min investment requirement (RMB)	815	1.320e+07	4.570e+07	815	1.290e+07	6.570e+07
Trust	815	0.728	0.445	815	0.796	0.403
Structure	815	0.0135	0.115	815	0.00123	0.0351
Underlying asset categories:						
Loans	815	0.00490	0.0698	815	0.0295	0.169
Equities	815	0.109	0.312	815	0.0590	0.236
Bonds	815	0.808	0.394	815	0.804	0.397
Money market products	815	0.0600	0.238	815	0.0972	0.296

Appendix B

A sample document of a WMP provided by the issuing bank

浦发银行——2008年第51期个人专项理财产品票据赢计划1个月

人民币理财产品

基本属性

发行人	浦发银行	币种	人民币
收益类型	保本浮动型	业务模式	信托
投资品种	债券	挂钩标的	-

收益指标

预期年收益率	0%~3.8%	付息方式	到期支付
保本比例	100.00%	封顶收益率	-
实际收益率	3.8000%	实际年化收益率	3.80%

委托期指标

收益起始日	2008-08-15	收益到期日	2008-09-15
委托期	1个月	委托天数	31
剩余委托天数	-	实际收益到期日	2008-09-15
实际委托期（天）	31		

发行指标

发行对象	个人	发行地区	天津,重庆,苏州,合肥,武汉,深圳,哈尔滨
销售起止日期	2008-08-07~2008-08-14	委托起始资金	50000人民币
计划募资金额（亿）	-		

Translation into English

Basic characteristics			
Issuer	Shanghai Pudong Development Bank	**Currency**	RMB
Return type	Floating rate with Principal guarantee	**Business mode**	Trust
Underlying assets	Bonds	**Target**	Pegging
Return			
Expected return	0~3.8%%	**Interest payment mode**	At maturity
Principal guarantee	100.00%	**Return cap**	—
Realized return	3.8000%	**Annualized realized return**	3.8%
Duration			
Effective date	2008-08-15	**Maturity date**	2008-09-15
Term	1 month	**Term in days**	31
Remaining days	—	**Actual maturity date**	2008-09-15
Actual term	1 month		
Issuance			
Buyer type	Individuals	**Issuing areas**	Tianjin, Chongqing, Suzhou, Hefei, Wuhan, Shenzhen, Harbin
Selling period	2008.08.07~2008.08.14	**Minimum investment requirement**	RMB 50,000
Planned selling volume	—		

Appendix C

C.1. The effect of the number of incumbent banks

Suppose there are four banks (banks A, B, C, and D) in a city, each with one branch, located as shown in Figure 2.3. The profit function of each bank (say bank A) is:

$$
\begin{aligned}
\pi_A
&= \theta\Bigg[2p_A\int_0^{d_1}\frac{\exp\{\alpha-p_A-\gamma d\}}{1+\exp\{\alpha-p_A-\gamma d\}+\exp\{\alpha-p_{\tilde{B}}\}+\exp\{\alpha-p_{\tilde{C}}\}+\exp\{\alpha-p_{\tilde{D}}\}}dd \\
&+ p_{\tilde{A}}\frac{\exp\{\alpha-p_{\tilde{A}}\}}{1+\exp\{\alpha-p_{\tilde{A}}\}+\exp\{\alpha-p_{\tilde{B}}\}+\exp\{\alpha-p_{\tilde{C}}\}+\exp\{\alpha-p_{\tilde{D}}\}}(d_2-d_1) \\
&+ p_{\tilde{A}}\frac{\exp\{\alpha-p_{\tilde{A}}\}}{1+\exp\{\alpha-p_{\tilde{A}}\}+\exp\{\alpha-p_{\tilde{B}}\}+\exp\{\alpha-p_{\tilde{C}}\}+\exp\{\alpha-p_{\tilde{D}}\}}(d_3-d_1) \\
&+ p_{\tilde{A}}\frac{\exp\{\alpha-p_{\tilde{A}}\}}{1+\exp\{\alpha-p_{\tilde{A}}\}+\exp\{\alpha-p_{\tilde{B}}\}+\exp\{\alpha-p_{\tilde{C}}\}+\exp\{\alpha-p_{\tilde{D}}\}}(d_2-d_4) \\
&+ p_{\tilde{A}}\frac{\exp\{\alpha-p_{\tilde{A}}\}}{1+\exp\{\alpha-p_{\tilde{A}}\}+\exp\{\alpha-p_{\tilde{B}}\}+\exp\{\alpha-p_{\tilde{C}}\}+\exp\{\alpha-p_{\tilde{D}}\}}(d_3-d_4) \\
&+ 2p_{\tilde{A}}\int_{d_2}^{\frac{l}{4}}\frac{\exp\{\alpha-p_{\tilde{A}}\}}{1+\exp\{\alpha-p_{\tilde{A}}\}+\exp\left\{\alpha-p_B-\gamma\left(\frac{l}{4}-d\right)\right\}+\exp\{\alpha-p_{\tilde{C}}\}+\exp\{\alpha-p_{\tilde{D}}\}}dd \\
&+ 2p_{\tilde{A}}\int_{d_3}^{\frac{l}{4}}\frac{\exp\{\alpha-p_{\tilde{A}}\}}{1+\exp\{\alpha-p_{\tilde{A}}\}+\exp\left\{\alpha-p_C-\gamma\left(\frac{l}{4}-d\right)\right\}+\exp\{\alpha-p_{\tilde{B}}\}+\exp\{\alpha-p_{\tilde{D}}\}}dd \\
&+ 2p_{\tilde{A}}\int_0^{d_4}\frac{\exp\{\alpha-p_{\tilde{A}}\}}{1+\exp\{\alpha-p_{\tilde{A}}\}+\exp\{\alpha-p_D-\gamma d\}+\exp\{\alpha-p_{\tilde{B}}\}+\exp\{\alpha-p_{\tilde{C}}\}}dd\Bigg] \\
&+ (1-\theta)p_A \\
&\times\Bigg[\int_0^{\frac{l}{4}}\frac{\exp\{\alpha-p_A-\gamma d\}}{1+\exp\{\alpha-p_A-\gamma d\}+\exp\left\{\alpha-p_B-\gamma\left(\frac{l}{4}-d\right)\right\}+\exp\left\{\alpha-p_C-\gamma\left(\frac{l}{4}+d\right)\right\}+\exp\left\{\alpha-p_D-\gamma\left(\frac{l}{2}-d\right)\right\}}dd \\
&+ \int_0^{\frac{l}{4}}\frac{\exp\{\alpha-p_A-\gamma d\}}{1+\exp\{\alpha-p_A-\gamma d\}+\exp\left\{\alpha-p_B-\gamma\left(\frac{l}{4}+d\right)\right\}+\exp\left\{\alpha-p_C-\gamma\left(\frac{l}{4}-d\right)\right\}+\exp\left\{\alpha-p_D-\gamma\left(\frac{l}{2}-d\right)\right\}}dd \\
&+ \int_{\frac{l}{4}}^{\frac{l}{2}}\frac{\exp\{\alpha-p_A-\gamma d\}}{1+\exp\{\alpha-p_A-\gamma d\}+\exp\left\{\alpha-p_B-\gamma\left(d-\frac{l}{4}\right)\right\}+\exp\left\{\alpha-p_C-\gamma\left(\frac{3l}{4}-d\right)\right\}+\exp\left\{\alpha-p_D-\gamma\left(\frac{l}{2}-d\right)\right\}}dd \\
&+ \int_{\frac{l}{4}}^{\frac{l}{2}}\frac{\exp\{\alpha-p_A-\gamma d\}}{1+\exp\{\alpha-p_A-\gamma d\}+\exp\left\{\alpha-p_B-\gamma\left(\frac{3l}{4}-d\right)\right\}+\exp\left\{\alpha-p_C-\gamma\left(d-\frac{l}{4}\right)\right\}+\exp\left\{\alpha-p_D-\gamma\left(\frac{l}{2}-d\right)\right\}}dd\Bigg]
\end{aligned}
\tag{C.1}
$$

where $d_1=\frac{p_{\tilde{A}}-p_A}{\gamma}$, $d_2=\frac{l}{4}-\frac{p_{\tilde{B}}-p_B}{\gamma}$, $d_3=\frac{l}{4}-\frac{p_{\tilde{C}}-p_C}{\gamma}$, $d_4=\frac{p_{\tilde{D}}-p_D}{\gamma}$.

C.2. The effect of the number of branches

Suppose that each bank has two branches instead of one and that those branches are located as shown in Figure 2.4. Then, d_1 and d_2 become

$$d_1 = \frac{p_{\tilde{A}} - p_A}{\gamma} \tag{C.2}$$

$$d_2 = \frac{l}{4} - \frac{p_{\tilde{B}} - p_B}{\gamma} \tag{C.3}$$

Then, the profit function for bank A becomes

$$\begin{aligned}
\pi_A = 4\theta \Bigg[& p_A \int_0^{d_1} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\
& + p_{\tilde{A}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\
& + p_{\tilde{A}} \int_{d_2}^{\frac{l}{4}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \Bigg] \\
& + 4(1-\theta) p_A \int_0^{\frac{l}{4}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd
\end{aligned} \tag{C.4}$$

The profit function for bank B becomes

$$\begin{aligned}
\pi_B = 4\theta \Bigg[& p_{\tilde{B}} \int_0^{d_1} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\
& + p_{\tilde{B}} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\
& + p_B \int_{d_2}^{\frac{l}{4}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \Bigg] \\
& + 4(1-\theta) p_B \int_0^{\frac{l}{4}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd
\end{aligned} \tag{C.5}$$

C.3. The effect of the number of competitors' branches

We consider a situation in which bank A has three branches while bank B only has one branch, as displayed in Figure 2.5. Then, the profit function for bank A becomes

$$
\begin{aligned}
\pi_A = \theta \Bigg[& 6p_A \int_0^{d_1} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\
& + 2p_{\tilde{A}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\
& + 2p_{\tilde{A}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} \left(\frac{l}{4} - 2d_1\right) \\
& + 2p_{\tilde{A}} \int_{d_2}^{\frac{l}{4}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \Bigg] \\
& + (1-\theta) p_A \Bigg[2 \int_0^{\frac{l}{4}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \\
& + 2 \int_0^{\frac{l}{8}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} + d\right)\right\}} dd \\
& + 2 \int_0^{\frac{l}{8}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \Bigg]
\end{aligned} \tag{C.6}
$$

The profit function for bank B becomes

$$
\begin{aligned}
\pi_B = \theta \Bigg[& 6p_{\tilde{B}} \int_0^{d_1} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\
& + 2p_{\tilde{B}} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\
& + 2p_{\tilde{B}} \frac{\exp\{\alpha - p_{\tilde{B}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} \left(\frac{l}{4} - 2d_1\right) \\
& + 2p_B \int_{d_2}^{\frac{l}{4}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \Bigg] \\
& + (1-\theta) p_B \Bigg[2 \int_0^{\frac{l}{4}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \\
& + 2 \int_0^{\frac{l}{8}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} + d\right)\right\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} + d\right)\right\}} dd \\
& + 2 \int_0^{\frac{l}{8}} \frac{\exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{2} - d\right)\right\}} dd \Bigg]
\end{aligned} \tag{C.7}
$$

C.4. The effect of clustering of physical branches of a bank

Suppose that, in a two-bank case, each bank has two branches, and the locations of a bank's two branches are clustered, as shown in Figure 2.6.

The profit function for bank A becomes

$$\begin{aligned}\pi_A = \theta \Bigg[& 4p_A \int_0^{d_1} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\{\alpha - p_{\tilde{B}}\}} dd \\ & + 2 \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} (d_2 - d_1) \\ & + p_{\tilde{A}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} \left(\frac{l}{4} - 2d_1\right) \\ & + p_{\tilde{A}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\{\alpha - p_{\tilde{B}}\}} \left(2d_2 - \frac{l}{4}\right) \\ & + 4p_{\tilde{A}} \int_{d_2}^{\frac{l}{4}} \frac{\exp\{\alpha - p_{\tilde{A}}\}}{1 + \exp\{\alpha - p_{\tilde{A}}\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \Bigg] \\ & + (1-\theta) p_A \Bigg[2 \int_0^{\frac{l}{4}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} - d\right)\right\}} dd \\ & + 2 \int_0^{\frac{l}{8}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(\frac{l}{4} + d\right)\right\}} dd \\ & + 2 \int_{\frac{l}{4}}^{\frac{3l}{8}} \frac{\exp\{\alpha - p_A - \gamma d\}}{1 + \exp\{\alpha - p_A - \gamma d\} + \exp\left\{\alpha - p_B - \gamma\left(d - \frac{l}{4}\right)\right\}} dd \Bigg]\end{aligned} \tag{C.8}$$

The profit function for bank B is symmetric to that for bank A.

C.5. Pricing of offline-only banks

In Figure 2.8, the profit function of bank E is

$$
\begin{aligned}
&\pi_E \\
&= 2\theta p_E \left[\int_0^{d_5} \frac{\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}}{1+\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}+\exp\{\alpha-p_{\tilde{A}}\}+\exp\{\alpha-p_{\tilde{B}}\}} dd\right. \\
&+\int_{d_5}^{\frac{l}{4}} \frac{\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}}{1+\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}+\exp\left\{\alpha-p_A-\gamma\left(\frac{l}{4}-d\right)\right\}+\exp\{\alpha-p_{\tilde{B}}\}} dd \\
&+\int_{\frac{l}{2}-d_5}^{\frac{l}{2}} \frac{\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}}{1+\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}+\exp\{\alpha-p_{\tilde{A}}\}+\exp\{\alpha-p_{\tilde{B}}\}} dd \\
&\left.+\int_{\frac{l}{4}}^{\frac{l}{2}-d_5} \frac{\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}}{1+\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}+\exp\left\{\alpha-p_A-\gamma\left(d-\frac{l}{4}\right)\right\}+\exp\{\alpha-p_{\tilde{B}}\}} dd\right] \\
&+2(1-\theta)p_E\left[\int_0^{\frac{l}{4}} \frac{\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}}{1+\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}+\exp\left\{\alpha-p_A-\gamma\left(\frac{l}{4}-d\right)\right\}+\exp\left\{\alpha-p_B-\gamma\left(\frac{l}{4}+d\right)\right\}} dd\right. \\
&\left.+\int_{\frac{l}{4}}^{\frac{l}{2}} \frac{\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}}{1+\exp\{\alpha+\Delta\alpha-p_E-\gamma d\}+\exp\left\{\alpha-p_A-\gamma\left(d-\frac{l}{4}\right)\right\}+\exp\left\{\alpha-p_B-\gamma\left(\frac{3l}{4}-d\right)\right\}} dd\right]
\end{aligned} \tag{C.9}
$$

where $d_5 = \frac{l}{4} - \frac{p_{\tilde{A}}-p_A}{\gamma} = \frac{l}{4} - \frac{p_{\tilde{B}}-p_B}{\gamma}$.