A Puzzle of Card Payment Pricing: Why Are Merchants Still Accepting Card Payments?

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Abstract

This paper presents models that explain why merchants accept payment cards even when the fees they face exceed the transactional benefits they receive from a card transaction. Such merchant behaviors can be explained by competition among merchants and/or the effectiveness of the merchant's card acceptance in shifting cardholders' demand for goods upward. The prevalent assumption used in payment card literature—merchants accept cards only when their transactional benefits are higher than the fees they pay—holds only for a monopoly merchant who faces an inelastic consumer demand. A card network that wants all merchants in a given industry to accept cards sets a lower merchant fee initially and then gradually increases it to the highest possible level, which may be higher than the sum of the merchant's transactional benefit and the merchant's initial margin without cards. Such merchant fees potentially create inequality between cardholders and non-cardholders.

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1. Introduction

Credit and debit card payments are experiencing rapid growth. This rapid growth in card payments is attracting controversy and antitrust scrutiny in many countries. Recently, the European Commission and the Reserve Bank of Australia have issued their decisions on pricing of card payments.[2] Regulatory authorities in other countries, such as Mexico and the United Kingdom, are evaluating potential future regulations. At the center of those policymakers' attention are interchange fees, which are paid by the bank (called the acquirer) that processes the card transaction for the merchant to the bank (called the issuer) that has issued the payment card to the consumer. Interchange fees are typically set by the card network (or by its member financial institutions collectively) and in many instances they are considered by regulators to be too high.

Chart 1 shows the credit card interchange rates in Australia and the European Union (EU), before and after the reductions of interchange rates were forced. In these regions, the regulator's involvements on pricing of card payments lowered the credit card interchange rates significantly. The chart also includes the UK credit card interchange rates. In the United Kingdom, the antitrust authority has not decided whether it will regulate the credit card interchange rates.[3] But if it does, then some industry observers anticipate the rates will be cut to 0.7 percent or below.[4] Current U.S. credit card interchange rates are also included in the chart. As seen in the chart, the U.S. interchange rates are even higher than the rates in the three regions before the interchange rates were lowered.

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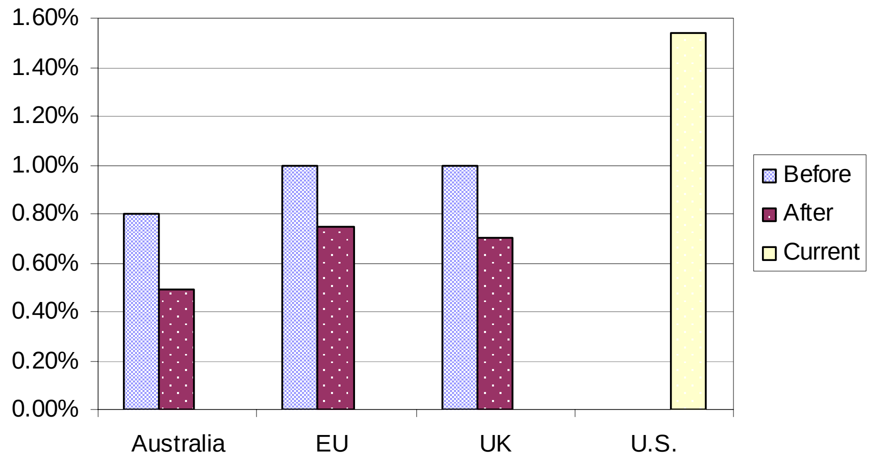
[2]While the Reserve Bank of Australia has regulated the credit card interchange rates, the European Commission has issued its decision to exempt Visa's interchange fees under European competition laws. Visa has voluntarily reduced its interchange rates for cross-boarder transactions within certain European Union countries.

[3]According to *The Herald,* November 11, 2004, a spokesman of the UK antitrust authority said "we would hope to issue a decision by the summer of next year."

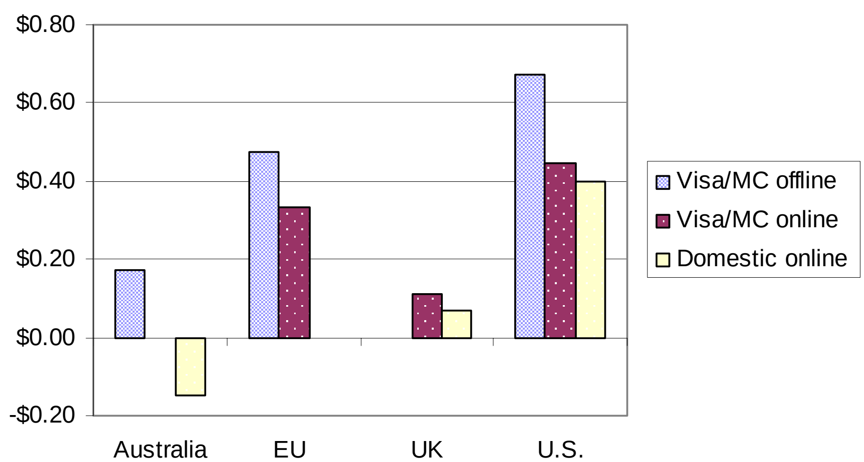
[4]Industry observers expect the interchange rates in the United Kingdom to be between 0.35 to 0.7 percent. See, for example, *The Times,* May 17, 2004 and November 11, 2004, and *Financial Times,* November 11, 2004.

Chart 1: Credit Card Interchange Rates in Selected Countries



Sources: Reserve Bank of Australia, Visa Europe, MasterCard International, and *American Banker*
Notes: "Before" = before the rate was forced to be lowered; "After" = after the rate was lowered; "Current" = as of November, 2004. In Australia, the regulation is effective for both Visa and MasterCard. The 'before' and 'after' rates are the average of Visa and MasterCard rates. In the EU, the European Commission made its decision on the Visa rate for cross-boarder transactions only. The 'before' rate is not publicly available, but the rate was estimated at about 1 percent according to the report "Credit Card Services" by the UK Monopolies and Mergers Commission and others. In the United Kingdom, the antitrust authority has not made a final decision on the credit card interchange rates as of November 2004. Therefore, the 'after' rate is an expectation by industry observers. They predict the regulated interchange rate will be between 0.35 to 0.7 percent. (See footnote 4.) The U.S. rate is the average of Visa and MasterCard rates.

Chart 2: Debit Card Interchange Fees for a $50 Transaction in Selected Countries

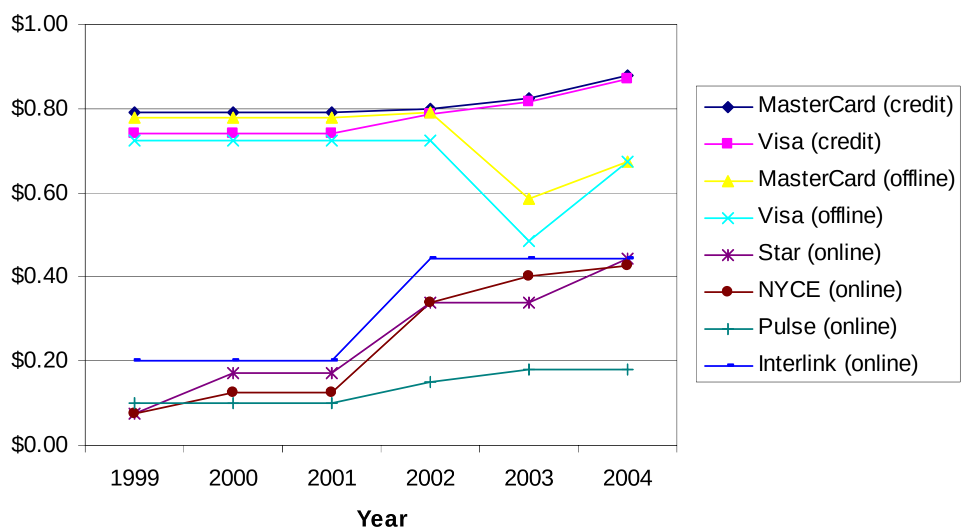


Sources: Reserve Bank of Australia, Visa Europe, MasterCard International, and ATM & Debit News
Notes: In Australia, there are no Visa/MasterCard online debit products. The domestic debit network's interchange fees are paid by issuers to acquirers. For the EU, only cross-boarder debit products are listed. In the United Kingdom, the domestic debit network and MasterCard agreed in 2002 that the domestic products will be migrated into Maestro, the MasterCard online debit product by 2007. The rates shown were the 1998 rates. In the United States, there exist more than ten domestic online debit networks. The rate shown as domestic debit network is the weighted average of the top three domestic online debit interchange fees. To convert the currencies, the average exchange rates for the first three quarters of 2004 are used.

Chart 2 shows the debit card interchange fees in selected countries. Interchange fees for offline debit are higher than those for online debit.[5] In Australia, the online debit interchange fees go in the opposite direction—paid by the issuer to the acquirer. Although the chart does not include them, many countries have domestic debit schemes with zero interchange fees.[6] Similar to credit card interchange fees, debit card interchange fees in the United States are among the highest in the world.

In the United States, interchange fees for both credit and debit card transactions are among the highest in the world. Moreover, they have been increasing very rapidly for the past several years. Chart 3 shows the various interchange fees for a $50 transaction at a retail store in the United States. Interchange fees for credit and online debit transactions have been increasing. Although the offline debit interchange rates were reduced after the settlement of a lawsuit by a group of merchants against the two offline debit networks in August 2003, they have increased since 2004.

Chart 3: Interchange Fees for a $50 Transaction at Non-Supermarket: 1999-2004



Sources: *American Banker* and *ATM & Debit News*

[5]See Hayashi, Sullivan, and Weiner (2003) for the difference between online and offline debit.
[6]Those include Belgium, Canada, Denmark, Germany, Netherlands, and Switzerland.

Since interchange fees are a component of merchant fees charged by acquirers, increases in interchange fees result in increases in merchant fees. More and more merchants have expressed their concerns with the fees and some even argue that the current fee level exceeds the benefits they receive in accepting cards. However, few merchants have stopped accepting card payments.

Two interesting questions arise from the experience of the U.S. payments industry. First, why have interchange fees been increasing despite the fact that the payments industry experienced technological advances and intensified competition? A variety of sources reported that technological advances have reduced the costs of processing card transactions.[7] Since one of the rationales for the interchange fee is to cover the issuer's costs for providing card services, the reduction of some of their costs may reduce the fees. Intensified competition has been observed among card networks, issuers, acquirers, and processors, although some of them have greater market power than the others.[8]

Traditional economic theories suggest that technological advances and competition will reduce prices. Since the payment industry is characterized as a two-sided market, some of the traditional theories that analyze one-sided markets are not applicable.[9] Nevertheless, previous literature on payment card networks predicts that network competition will reduce interchange fees and/or merchant fees.[10]

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[7]See, for example, Evans and Schmalensee, *Paying with Plastic*, the MIT Press, 1999, p. 130, *ATM & Debit News,* February 12, 2004, and April 22, 2004, and "Murky Future for Interchange" *European Card Review,* September/October 2004.
[8]In the ruling in the Department of Justice's antitrust case against Visa and MasterCard, the court found that these two card networks have market power in payment card markets. United States Court of Appeals for the Second Circuit, United States of America v. Visa USA, Visa International Corp, and MasterCard, August Term, 2002.
[9]See, for example, Evans (2001) for the difference between one-sided and two-sided markets.
[10]Studies that analyze competition among card networks include Manenti and Somma (2002), Bolt (2003), Guthrie and Wright (2003), and Rochet and Tirole (2003).

The second question is why merchants are accepting card payments even when merchant benefits in accepting cards are not higher than the fees they face. Merchants explain that the competitive pressure does not allow them to reject card payments and if they do so, they lose sales. Card networks, on the other hand, claimed that the benefits merchants receive today are greater than those in the past since card networks provide useful customer information that merchants can use to increase their profits. Therefore, the networks reason, merchants receive more benefits than fees (even though the fees today are higher than in the past), and if not they can drop their card acceptance. The networks also claimed that because of network externalities, payment cards generate more benefits since the number of merchants that accept payment cards has increased.

The literature on payment cards has been growing, but only a few studies have analyzed merchant card acceptance. Most studies simply assume either that merchants accept cards when their transactional benefits from cards exceed the merchant fees or that merchants accept cards regardless of the level of merchant fees.[11] Therefore, one cannot use these models to answer the second question above. Some exceptions are Rochet and Tirole (2002), Chakravorti and To (2003), and Wright (2003b). Rochet and Tirole (2002) and Wright (2003b) have found that if merchants compete against each other, they accept cards as long as the merchant fees do not exceed the sum of the merchant's transactional benefits and the cardholder's average net transactional benefits from cards. Chakravorti and To (2003) focus on the credit card's revolving function and explain that competing merchants accept credit cards because it allows them to make sales to illiquid customers today rather than to wait for uncertain sales tomorrow. Their

[11] Models with the assumption that merchants only accept cards when their transactional benefits from cards exceed the fees include Baxter (1983), Schmalensee (2002), Bolt and Tieman (2003), and Wright (2003a, 2004). In contrast, Frankel (1998), Gans and King (2002), Katz (2001), and Schwartz and Vincent (2003) assume that merchants accept cards regardless of the level of merchant fees.

model also concludes that although each merchant chooses to accept cards, since all merchants accept cards in equilibrium each merchant's profit is lower.

Chakravorti and To (2003) explain the merchants' credit card acceptance but do not explain their debit card acceptance. The models by Rochet and Tirole (2002) and Wright (2003b) explain both credit and debit card acceptance by merchants even when merchant fees are higher than their transactional benefits. In Wright (2003b), merchants can increase their profit margins by accepting cards, which contradicts what some of the merchants are saying. In contrast, in Rochet and Tirole (2002), merchants cannot increase their margins by accepting cards. Their model, however, expects that the maximum merchant fee decreases as competition among issuers intensifies, which seems contrary to the experience in the United States.[12]

Understanding merchant card acceptance behavior may be a key in answering the first question. As mentioned, no previous literature is successful in explaining that network competition raises the interchange fees. This is so, partly because most of the studies assume that merchants accept cards only when the merchant fees do not exceed their transactional benefits, and partly because most of them do not model issuers' behavior when the issuers decide which networks they will join.

This paper analyzes the merchant incentives to accept payment cards—both credit and debit cards. Four different markets that are characterized by merchant competitiveness (monopoly or a Hotelling model of competition) and by price elasticity of the market aggregate consumer demand (inelastic or elastic) are considered in turn. The results suggest that only monopoly merchants who are facing an inelastic consumer demand do not accept cards if the

[12]While the top ten credit card issuers' market share in terms of managed receivable is high and has increased from 79.4 percent in 2000 to 85.7 percent in 2003, the top ten debit card issuers' market share is low and steady. According to *EFT Data Book* (various years), both the online and offline debit issuers' market shares either in terms of number of cards issued or in terms of transaction volume have been around 30 to 35 percent since 2000.

fees exceed the merchant's transactional benefits. In the other three markets, merchants accept cards even when the fees exceed their transactional benefits. As previous studies found, competing merchants accept cards for strategic reasons. Merchants initially hope that their card acceptance can lure customers away from their rivals, but later on they accept cards to keep their current customers. Even monopoly merchants accept cards when their transactional benefits are lower than the fees they pay if they face an elastic consumer demand. They do so not because they have a strategic reason but because card acceptance shifts their cardholder customers' demand upward.

In the model, there is one card network that determines both the merchant fees and cardholder fee.[13] The network is assumed to be conservative in the sense that it sets a merchant fee so that all of the merchants in a given industry accept cards. If the merchants' price setting is completely flexible, the network will set the highest possible merchant fees from the first period in the markets with a monopoly merchant, while the network will set lower merchant fees in the first period and will raise them to the highest possible merchant fees in the second period in the markets of the Hotelling competition. In reality, however, merchants are unwilling to raise their prices by a large amount over a short period.[14] In such cases, the network will set a merchant fee lower in earlier periods of card acceptance in a given industry, and it will gradually increase the fee as more periods have passed after the industry first adopts card payments.

The paper also analyzes the welfare of cardholders, non-cardholders, and merchants separately because policymakers may want to evaluate the card pricing from both an efficiency and equity point of view. To reflect realty, the model assumes that merchants set the same price

[13]In most networks, merchant fees are determined by each individual acquirer and cardholder fees are determined by each individual issuer. However, the fees do not vary very much by acquirer or issuer.
[14]See, for example, Rotemberg (2004).

for card users and cash users.[15] Under this pricing, in comparison with an equilibrium without cards, if the network charges the highest merchant fee then cardholders are better off (or at least indifferent), non-cardholders are worse off, and merchants are either better off or indifferent. In the long run, however, the total of the consumers' and merchants' surplus will gradually decrease as the network raises the merchant fees. In particular, in markets where aggregate consumer demands are inelastic, the total of the consumers' and merchants' surplus will converge to the total of the consumers' and merchants' surplus without cards at all.

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 presents results of four different cases in turn, and section 4 concludes.

2. The model

For simplicity, only two payment instruments are available in the model. They are card and cash. Each industry is small enough so that the card acceptance by the merchants in the industry does not affect the consumer's cardholding decision and therefore a fixed (α) percent of the customers for the industry hold a card.

A card transaction brings transactional benefits to both the card users and the merchants who accept those cards. One of the transactional benefits of cards is reducing transactional costs associated with cash transactions for both consumers and merchants. When consumers pay with cash, the consumers incur some transactional costs besides the price of goods or services they purchase and the merchants also incur some transactional costs in addition to the costs of selling goods or services. Generally, transactional costs with cash for consumers include costs of obtaining cash (such as ATM fees and time to go to the bank) and risks associated with cash

[15] Due to no-surcharge rules imposed by card networks.

(such as theft); those for merchants include handling cash transactions (such as costs of labor, armed car, and bank fees).

Some transactions require more costs to consumers and merchants if they are paid by cash. Think about the transactions that require reservations, such as a hotel reservation. Although the reservation may not be impossible with cash, cash is inconvenient if a customer wants a late arrival guarantee as well as an ability to cancel the reservation without paying fees. The hotel may want some advance payments from the cash customer to keep the room until he or she arrives, but it may hesitate to do so since it needs to send the cash back on the chance that if the customer cancels before the date that a cancellation fee is assessed. So, either the cash customer cannot obtain a late arrival guarantee or the hotel may loose business should the cash customer not show up. Card payment can diminish such inconvenience or loss. At the time of reservation, a card customer gives the hotel his or her card number. If the card customer cancels the reservation earlier, the hotel does not charge anything to the customer's card account. The hotel can keep the room until he or she arrives, but in case the customer did not show up without canceling the reservation, the hotel can simply charge a cancellation fee to the account.

Although there may exist some other transactional benefits of cards, the model assumes that card transactions reduce both card users' and merchants' transactional costs to zero but create no other transactional benefits to either merchants or card users. Card transactions require per transaction fees to cardholders, f, (if rewards instead of fees, then f is negative) and to merchants, m. For consumers, the true cost of purchasing a good or service is $p+t_c$ with cash and $p+f$ with a card, where p is the product price charged by the merchant and t_c is the transactional cost for cash users. For merchants, the true cost of selling a good or service is $d+t_m$ with cash and $d+m$ with a card, where d is the cost of selling a product regardless of the payment methods used for the transaction and t_m is the merchant's transactional costs with cash.

Assume that transactional costs with cash for consumers and merchants do not vary by each individual consumer or merchant but vary by industry. Thus, consumers who purchase goods from the same industry incur the same transactional costs with cash, and merchants who are in the same industry incur the same transactional costs with cash. Some empirical evidence can justify this assumption. The consumer payment study by Dove Consulting (2001) showed that the consumers' payment mix varies by the type of store. Hayashi and Klee (2003) also found that a consumer's payment choice depends on the transaction characteristics, such as average transaction value and physical characteristics at the points of purchase. Although larger merchants in a given industry may pay lower merchant fees than their smaller counterparts, typically in the U.S. merchant fees vary by a type of industries.[16] This assumption is also adopted by some of the previous studies. Wright (2004) assumes that card benefits vary by industry. Wright (2000) and Katz (2001) assume that without cards, some of the transactions extract the consumer's entire surplus. Such transactions may happen only in particular industries.

Merchants are assumed to set the same price for cash users and card users. The network imposes the no-surcharge rule, which prohibits merchants from charging a higher price to card users. Although the rule does not prohibit merchants from giving cash discounts, merchants likely choose to set the same prices since setting different prices may be costly.[17] In some

[16]Both credit card networks and debit card networks in the United States set different interchange fees according to industry types. Typically, debit card networks have two fees: one for supermarkets and the other for non-supermarkets. Visa and MasterCard credit card networks set different fees for different categories of industry, such as supermarkets, general retail markets, emerging retail markets, hotel and car rentals, automated fuel dispenser, and so on.
[17]Setting different prices may increase some administration costs or customer dissatisfaction.

countries, a surcharge has been allowed, but only a small percentage of merchants actually set different prices for card users and the rest of the consumers.[18]

Four different cases are analyzed and these four are characterized by consumer demand for goods—either elastic or inelastic—and merchant market competitiveness—either monopoly or competition according to the Hotelling model. Each industry faces either an elastic or inelastic aggregate consumer demand for goods. In the industry that faces an elastic demand, the consumer's quantity demanded depends on the consumer's true costs of purchasing goods or services rather than the price itself. Let us think about the hotel industry again. As explained above, making reservations with cash will likely be more costly for both customers and hotels than that with cards. Since cards reduce such transactional costs for customers, even when the price of the hotel stay does not change, there will either be more travelers or the current travelers will travel more. Industries that face inelastic demand, on the other hand, cannot shift industry aggregate demand by simply accepting payment cards. The consumer home appliances industry is an example of this. Each household needs at most a certain number of refrigerators or washers and dryers. Since these are large-dollar items, accepting cards reduces the consumer's risk or inconvenience associated with cash transactions. However, the consumers do not buy more refrigerators or washers and dryers because the merchants accept card payments. To simplify the analysis, each individual cardholder's and each individual non-cardholder's demand functions are assumed to be identical.[19]

In each industry, there is either a monopoly merchant or two merchants competing according to the Hotelling model. Merchants decide not only their card acceptance strategy but also their prices. Merchants are assumed to face some restrictions when they adjust their prices

[18]Those countries include Australia, Netherlands, Sweden, and the United Kingdom.

upward, since they may be afraid of antitrust scrutiny or customers' dissatisfaction toward their price increases.[20] In the model, merchants can increase their prices with at most the growth rate of i in the period. i is an industry specific and is a random draw from the range of $[0, \bar{i}]$ each period. i is realized after the network sets the merchant fee and before the merchants set their prices.

The model assumes that there exists only one card network, which sets both merchant fees and the cardholder fee.[21] The network sets a unique merchant fee in a given industry and a universal cardholder fee. Although a variety of network objectives, such as maximizing the total members' profits, balancing the profits or costs between acquirers and issuers, or maximizing the total transaction volume, are suggested, since the paper focuses on the merchant card acceptance behavior, the network is assumed to have an incentive to set merchant fees as high as possible. The network is also assumed to be conservative when it sets merchant fees. It sets a merchant fee so that all of the merchants in a given industry accept cards. When the network sets the merchant fee, however, it cannot observe the realized maximum price growth rate, so it conservatively predicts that the growth rate of the price is zero.

It is assumed that consumers are either cardholders or non-cardholders. Non-cardholders need to pay with cash all the time. On the other hand, cardholders can choose their payment method—either cash or a card. Consumers observe all the decisions the merchants made (card acceptance and new price) before they determine their payment methods, the merchants from which they make purchases, and quantities (if demand is elastic).

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[19]This assumption may not be realistic. The average income of credit card holders is higher than the average income of non-credit card holders. Thus demand functions are likely different.
[20]In the United States, the recent growth of interchange fees of credit and major debit card networks has outpaced the growth of consumer prices in some industries. For example, Consumer Price Indices (CPI) for household furnishing and apparels have declined for the last five years, and the growth rate of CPI for public transportation or for recreation is lower than the growth rate of interchange fees.

Table 1: Timing of the Game

Period	Stage	Actions
0		Neither the monopoly merchant nor the duopoly merchants accept cards. They set the product price, p^0 so as to maximize their profits.
1	1	Given p^0, the network sets the cardholder fee, f, and the industry-specific merchant fee, m.
	2	The merchant decides whether to accept cards or not, and determines the new price, p^1, if it chooses to accept cards.
	3	The consumer decides from which merchant he or she makes purchases (if duopoly), which payment method he or she uses (if a cardholder), and how much he or she purchases (if demand is elastic).
N		Given p^{N-1}, repeat the game in period 1.

The timing of the game is described in Table 1. We consider a multi-period game and in each period, there are three stages: at stage 1 the network sets a merchant fee and a cardholder fee, at stage 2 the merchants decide whether to accept cards and their prices, and at stage 3 the consumers decide from which merchant they make purchases, which payment method they use, and how much they purchase if demand is elastic.

3. Merchant acceptance and the highest possible merchant fees

3.1 Monopoly merchant

3.1.1. Inelastic demand

In period 0, for whatever reason the monopoly merchant does not accept cards. All of its customers (mass 1) pay with cash. Assume that each customer makes a fixed number of transactions, n. The merchant profit in period 0 is:

$$\pi^0 = (p^0 - d - t_m)n\,, \tag{1}$$

[21]Closed system networks as well as open system networks can influence both merchant fees and cardholder fees. See, for example, Schwartz and Vincent (2003) and Wright (2003a).

where p^0 is the product price the monopoly merchant charges in period 0. Assume that each consumer receives gross benefit by purchasing one unit of the product, υ. Since the monopoly merchant extracts the consumer's entire surplus, it sets the product price p^0 so that:

$$p^0 = \upsilon - t_c. \tag{2}$$

Starting with stage 3 of period 1, a cardholder will use a card if $t_c > f$, and if the merchant accepts cards since the merchant sets a unique product price for both cash users and card users. That is, by using a card, the cardholder can save $t_c - f > 0$ per transaction as opposed to paying with cash.

At stage 2 of period 1, given the merchant fee, m, charged by the network, the merchant decides whether to accept cards or not and determines the product price. The merchant's profit if it does not accept cards is the same as the profit in period 0. Three different levels of the merchant's profit from accepting cards are possible. One of them is the profit without changing the product price from p^0. Since the merchant has already extracted the cash users' entire surplus, raising the price from p^0 implies that the merchant losses all cash customers. Another level of the merchant's profit is that of when the merchant extracts the card users' entire surplus. By doing so, the merchant raises the price to:

$$p^1{*} = \upsilon - f = p^0 + t_c - f. \tag{3}$$

At this price, the merchant extracts the card users' entire surplus but loses the entire profit from cash users. This level of profit, however, may not be attainable because the merchant cannot raise the price by a large amount in a single period. Since the realized maximum price growth rate is i in period 1, the price in period 1, p^1, cannot be higher than $p^0(1+i)$. If

$p^0(1+i) < p^1*$, then the merchant cannot extract the card users' entire surplus. The other level of the profit, therefore, is that when the merchant sets $p^1 = p^0(1+i)$.

Given m, the merchant's maximum profit in period 1 is defined as:

$$\begin{aligned}
\pi^c &= (p^0 - d - t_m)(1-\alpha)n + (p^0 - d - m)\alpha n, && \text{if } (p^0 - d - t_m)(1-\alpha)/\alpha \geq \min\{t_c - f, ip^0\}, \\
&= (p^0(1+i) - d - m)\alpha n, && \text{if } t_c - f > ip^0 > (p^0 - d - t_m)(1-\alpha)/\alpha, \\
&= (p^0 + t_c - f - d - m)\alpha n, && \text{if } ip^0 \geq t_c - f > (p^0 - d - t_m)(1-\alpha)/\alpha.
\end{aligned} \tag{4}$$

From equations 1 and 4, $\pi^c \geq \pi^0$ always holds as long as $t_m \geq m$. This implies that at any of the three levels of the merchant's profit, the merchant accepts cards if the merchant fee is lower than the merchant transactional costs with cash. From equation 4, the merchant may accept cards even when the merchant fee exceeds the merchant transactional costs with cash, if raising the price increases the merchant's profit.

At stage 1 of period 1, the network sets a cardholder fee, f, which should be lower than the transactional costs with cash for consumers, t_c. Since, by assumption, the network conservatively predicts the industry's realized maximum price growth rate is zero, the network sets a merchant fee, m, as high as t_m. Therefore, the highest possible merchant fee in period 1,

$$\overline{m}^1 = t_m. \tag{5}$$

Proposition 1 (Price and Welfare): *Suppose the network sets $f < t_c$ and $m \leq \overline{m}^1$. A monopoly merchant who faces an inelastic consumer demand accepts cards. Compared to the equilibrium without the cards,*

a) The merchant raises the product price if the cardholder's per transaction fee is low relative to his or her transaction benefits and/or the cardholder base is high enough;

b) Non-cardholders' surplus is lower if the merchant raises the price, otherwise it is unchanged;[22]

c) Cardholders' surplus is higher (or at least the same);

d) Aggregate consumer surplus is lower if the merchant raises the price to its profit maximizing level; if the merchant raises the price to the restricted level, it is either higher or lower; if the merchant does not change the price it is higher;

e) The merchant's surplus is higher or at least the same.

In period 2, can the network raise the merchant fee higher than the highest possible merchant fee in period 1? Obviously, if the merchant did not raise the price in period 1, the network cannot raise the merchant fee, because the game in period 2 is exactly the same as the game in period 1. In this case, the highest possible merchant fee in period 2, $\overline{m}^2$, is the same as $\overline{m}^1$. If, on the other hand, the merchant raised the price in period 1, the network can raise the merchant fee. Since the merchant can always go back to the original strategy (to not accept cards and to set the original price, p^0), the new merchant fee needs to guarantee at least the same profit as the merchant's profit without accepting cards. If the merchant has already extracted the card users' entire surplus in period 1, the highest possible merchant fee in period 2 is:

$$\overline{m}^2 = t_m + t_c - f - \frac{1-\alpha}{\alpha}(p^0 - d - t_m). \tag{6}$$

If the merchant did not extract the card users' entire surplus in period 1 due to the pricing restriction, $\overline{m}^2$ is lower than the level of equation 6.

[22]If a consumer has no disutility from not purchasing any goods, non-cardholders' surplus is unchanged. Otherwise it is lower.

In the long run, if the merchants chose to serve card users only, the merchant fee eventually converges to the level of equation 6 and the product price also converges to the level of equation 3. Otherwise, the merchant fee does not change from period 1 and the price does not change from the initial price, p^0. The long-run equilibrium merchant fee and price are described in equations 7 and 8.

$$
\begin{aligned}
\overline{m}^N &= t_m, && \text{if } (p^0 - d - t_m)(1-\alpha)/\alpha \geq t_c - f, \\
&= t_m + t_c - f - \frac{1-\alpha}{\alpha}(p^0 - d - t_m), && \text{otherwise.}
\end{aligned}
\tag{7}
$$

$$
\begin{aligned}
p^N &= p^0, && \text{if } (p^0 - d - t_m)(1-\alpha)/\alpha \geq t_c - f, \\
&= p^0 + t_c - f, && \text{otherwise.}
\end{aligned}
\tag{8}
$$

Notice that if the merchant's price setting is completely flexible (and the network knows that flexibility), the long-run equilibrium merchant fee will be set from the first period the merchant accepts cards even when the merchant chooses to serve card users only, and the long-run equilibrium price will be charged by the merchant from period 1.

3.1.2 Elastic demand

In period 0, the monopoly merchant does not accept cards. All of its customers (mass 1) pay with cash. Assume that each individual customer's demand function $D(p+t_c)$ is identical regardless of his or her cardholding. The merchant's profit function in period 0 is:

$$\pi^{nc}(p) = (p - d - t_m)D(p + t_c). \tag{9}$$

The monopoly merchant sets the product price so as to maximize its profit. The price in period 0 is defined as:

$$
\begin{aligned}
p^0 &= \text{argmax}\, \pi^{\text{nc}}(p) \\
&= d + t_m - \frac{D(p^0 + t_c)}{D'(p^0 + t_c)}
\end{aligned}
\tag{10}
$$

Starting with stage 3 of period 1, a cardholder will use the card if $t_c > f$ and if the merchant accepts cards. At stage 2 of period 1, the merchant decides whether to accept cards; if it decides to accept, it adjusts the product price. The merchant's profit if it does not accept cards is the same as the profit in period 0. Given a merchant fee, m, the merchant's profit function if it accepts cards is defined as:

$$
\pi^c(p; m) = (p - d - t_m)(1-\alpha)D(p + t_c) + (p - d - m)\alpha D(p + f). \tag{11}
$$

The merchant accepts cards if and only if $\pi^c(p; m) \geq \pi^{nc}(p^0)$. Although, by assumption, the product price growth rate is limited, since the merchant still has the freedom to set the product price different from p^0, $\pi^c(p; m) \geq \pi^{nc}(p^0)$ always holds if $\pi^c(p^0; m) \geq \pi^{nc}(p^0)$ holds. Given m, the merchant's profit maximizing price, p^1*, is defined as:

$$
p^1* = d + t_m - \frac{(1-\alpha)D(p^1 * + t_c) + \alpha D(p^1 * + f) - \alpha(m - t_m)D'(p^1 * + f)}{(1-\alpha)D'(p^1 * + t_c) + \alpha D'(p^1 * + f)}. \tag{12}
$$

Since the product price growth rate is limited to i, the price in period 1 will be:

$$
\begin{aligned}
p^1 &= p^1*, && \text{if } p^1 * \leq p^0(1+i), \\
&= p^0(1+i), && \text{otherwise.}
\end{aligned}
\tag{13}
$$

At stage 1 of period 1, the network sets a cardholder fee, f, which should be lower than t_c. Since the network conservatively predicts the industry's maximum price growth rate is zero, it will set the merchant fee so that the merchant's profit by accepting cards under p^0 is at least as high as the profit without cards. That is $\pi^{c}(p^{0};m) \geq \pi^{nc}(p^{0})$. The highest merchant fee in period 1 set by the network is, therefore:

$$\overline{m}^{1} = t_m + (p^{0} - d - t_m)(1 - \frac{D(p^{0} + t_c)}{D(p^{0} + f)}). \tag{14}$$

Equation 14 yields the following proposition.

Proposition 2 (Merchant fee): *The monopoly merchant who faces an elastic consumer demand accepts cards even if the merchant fee is higher than the merchant transactional benefit from cards.*

Proof: Clearly, the second term of equation 14 is positive. Thus, $\overline{m}^{1} > t_m$. ■

Wright (2003b) analyzes merchant card acceptance in the industry where aggregate consumer demand is elastic and merchants are competing according to a Cournot model. The model also assumes that each consumer buys at most one unit in the industry. In such an industry, merchants will accept cards even when the merchant fee is higher than their transactional benefit from cards. In my model, each consumer has an elastic demand and buys as many units as he or she wants from the same merchant. Although a monopoly merchant does not have to compete, the merchant will accept cards even when the merchant fee is higher than their transactional benefit. This is because the merchant can make the cardholder's demand curve shift upward by accepting cards.

Since general results are not available for the case of elastic consumer demand, the rest of this subsection restricts its attention to linear demand. Proposition 3 compares the product price with and without the cards and Proposition 4 summaries the consumers' and merchant's welfare.

Proposition 3 (Price): *A monopoly merchant who faces linear consumer demand will adjust the product price if it accepts cards.*

i) For $t_m \le m \le \overline{m}^1$*, the product price with cards is higher if* $i > 0$.

ii) For $m < t_m$*: if* $t_m < t_c - f$*, the product price with cards is higher when* $i > 0$*; if* $t_m \ge t_c - f$*, for* $m > t_m - (t_c - f)$ *the product price with cards is higher if* $i > 0$ *and for* $m < t_m - (t_c - f)$ *the product price with cards is lower.*

Proof: From equations 10 and 12,

$$p^1 * - p^0 = \frac{\alpha}{2}\{(m - t_m) + (t_c - f)\}. \tag{15}$$

By assumption $t_c > f$. Obviously, $p^1 * > p^0$ when $m \ge t_m$. When $m < t_m$, if $t_c - f$ is greater than $t_m - m$, $p^1 * > p^0$, otherwise $p^1 * \le p^0$. ■

Proposition 4 (Welfare): *Suppose the network sets* $f < t_c$ *and* $m \le \overline{m}^1$*. A monopoly merchant who faces linear demand accepts cards. Compared to the equilibrium without cards:*

a) Non-cardholders' surplus is higher (lower) if the merchant sets a lower (higher) price after accepting cards;

b) Cardholders' surplus is higher;

c) Aggregate consumer surplus is higher;

d) The merchant's surplus is higher (or at least the same).

Proof: The consumers' surplus is measured by using the Marshallian demand curve. Non-cardholders' surplus depends only on the product price. The higher the price, the lower the non-cardholders' surplus is. Therefore, if the product price with cards is higher than that without cards, non-cardholders are worse off and vise versa.

Cardholders' surplus depends on the product price, the cardholder's per transaction fee, and the consumer's transactional costs with cash. The total costs for a cardholder when he or she uses a card, $p^1 + f$, is always lower than the total costs for the cardholder when the merchant does not accept cards, $p^0 + t_c$. To show this, suppose that the network sets the highest merchant fee so that the merchant accepts cards with the good price, p^0. Suppose also that the merchant can charge the profit maximizing price in period 1, which is $p^1 *$. The profit maximizing product price is also the highest, because $\partial p^1 * / \partial m > 0$ from equation 12. At this highest price, $\overline{p}^1$, the following equation holds.

$$(\overline{p}^1 + f) - (p^0 + t_c) = \frac{1}{2}[\alpha\{1 + \frac{D(p^0 + t_c)}{D(p^0 + f)}\} - 2](t_c - f) \tag{16}$$

Since $\alpha\{1 + \frac{D(p^0 + t_c)}{D(p^0 + f)}\} < 2$, and $t_c > f$, equation 16 is negative. This implies that $p^1 + f$ is always lower than $p^0 + t_c$, and therefore cardholders are always better off.

Denote $v(\cdot)$ is a consumer's surplus. Aggregate consumers' surplus without cards, $v(p^0 + t_c)$, is lower than aggregate consumers' surplus when the merchant accepts cards and sets the product price at the highest level, $(1-\alpha)v(\overline{p}^1 + t_c) + \alpha v(\overline{p}^1 + f)$.

$$(1-\alpha)v(\overline{p}^1 + t_c) + \alpha v(\overline{p}^1 + f) - v(p^0 + t_c) =$$
$$\frac{\alpha b(t_c - f)^2\{D(p^0 + t_c) + D(p^0 + f)\}}{2D(p^0 + f)}\{\frac{\alpha\{D(p^0 + t_c) + D(p^0 + f)\}}{4D(p^0 + f)} + (1-\alpha)\} > 0$$

By assumption, the network sets the merchant fee at most as high as the level that makes the merchant's profit with cards equal to the profit without cards, under the price of p^0. Since the merchant will adjust the price after deciding to accept cards, the merchant's profit should be at least as high as the profit without cards. From equation 13, $p^1 > p^0$ when $m = \overline{m}^1$, unless $i = 0$, the merchant is better off. ■

Propositions 3 and 4 imply that the merchant's card acceptance impacts the welfare of non-cardholders, cardholders, and the merchant differently. While cardholders and the monopoly merchant are always better off, non-cardholders are likely worse off. Even when the network sets the merchant fee lower than the merchant transactional benefit, non-cardholders are likely worse off. If cardholders' net transactional benefit from cards, $t_c - f$, is greater than the merchant's transactional benefit from cards, t_m, non-cardholders are always worse off, unless $i = 0$. This result supports the findings of Schwartz and Vincent (2003). They compare the equilibrium with and without the no-surcharge rules and show that when a monopoly network charges a profit maximizing merchant fee from a monopoly merchant, cash users' (non-cardholders') surplus is lower under no-surcharge than under surcharge. Since cash users' surplus at the equilibrium without cards and that at the equilibrium with cards under surcharge are the same, my results suggest that even when the network charges a merchant fee that is lower than the profit-maximizing level, cash users' surplus is lower under no-surcharge than under surcharge.

Now, let us consider the game in period 2. Suppose in period 1 the network sets the merchant fee, $\overline{m}^1$. Can the network raise the merchant fee higher than $\overline{m}^1$, without changing the cardholder fee? If the realized maximum price growth rate in period 1 were greater than zero, the merchant raised the price to increase his profit under $\overline{m}^1$. Thus, by definition, $\pi^c(p^1;\overline{m}^1) > \pi^c(p^0;\overline{m}^1) = \pi^{nc}(p^0)$. The network can set $\overline{m}^2$, such that $\overline{m}^2 > \overline{m}^1$, to make the merchant's profit with cards equal to the maximum profit without cards:

$$\pi^c(p^1;\overline{m}^2) = \pi^{nc}(p^0). \tag{17}$$

If the realized maximum price growth rate in period 1 was zero, the product price in period 1 was the same as the price in period 0. Since $\pi^c(p^1;\overline{m}^1) = \pi^c(p^0;\overline{m}^1) = \pi^{nc}(p^0)$, the network cannot raise the merchant fee higher than $\overline{m}^1$.

The merchant will continue to accept cards and adjust the price to maximize profit with the merchant fee, $\overline{m}^2$.

$$\pi^c(p^2;\overline{m}^2) \geq \pi^c(p^1;\overline{m}^2) = \pi^{nc}(p^0) \tag{18}$$

Since $\overline{m}^2 \geq \overline{m}^1$, the merchant's profit in period 2 is equal to or lower than that in period 1:

$$\pi^c(p^2;\overline{m}^2) \leq \pi^c(p^1;\overline{m}^1) \tag{19}$$

In the long run, the highest merchant fee and the product price will gradually increase:[23]

$$\overline{m}^1 \leq \overline{m}^2 \leq \ldots \leq \overline{m}^{N-1} \leq \overline{m}^N,$$

$$p^1 \leq p^2 \leq \ldots \leq p^{N-1} \leq p^N,$$

and the merchant's profit converges to the maximum profit without cards:

$$\pi^c(p^N;\overline{m}^N) \xrightarrow{N\to\infty} \pi^{nc}(p^0). \tag{20}$$

Proposition 5 (Long-run equilibrium): *Suppose that the network will set the (conservative) highest merchant discount fee every period. Compared to the equilibrium without the cards, at the long run equilibrium:*

a) Non-cardholders are worse off;

b) Cardholders are better off;

c) Aggregate consumer surplus is higher;

d) The merchant is indifferent.

[23]Notice that if the merchant's price setting is completely flexible and the network knows that flexibility, the long-run equilibrium defined above can be reached from the first period that the merchant accepts cards.

Proof: (a) is obvious since p^N is higher than p^0. (d) is obvious from equation 20. The proof of (b) and (c) are in Appendix A. ■

In the long run, in monopoly markets with inelastic consumer demands, all participants are at most indifferent with and without cards. On the other hand, in monopoly markets with elastic consumer demands, although non-cardholders and the merchant are at most indifferent with and without cards, cardholders are better off. Moreover, cardholders' welfare gain surpasses non-cardholders' welfare loss from card acceptance, and therefore the sum of consumers' and the merchants' surplus is higher with cards than without cards.

3.2 Duopoly merchants—Hotelling competition

Additional assumptions are made for this section. There are two merchants, Merchant A and Merchant B, who are competing with each other according to the Hotelling model. Consumers (mass 1) are uniformly distributed on the interval of [0, 1], which is independent of their cardholding. Merchant A is located at point 0 and Merchant B is located at point 1. For the consumer located at point x, where $0 \le x \le 1$, the transportation cost to Merchant A is tx, and the transportation cost to Merchant B is $t(1-x)$. Only pure strategy Nash equilibria are considered in this section.

3.2.1 Inelastic demand

Before considering the equilibrium with cards, first we describe the equilibrium without cards (equilibrium in period 0). As is usual in the symmetric Hotelling model, the equilibrium prices, (p_A^0, p_B^0), are the same for both merchants and are equal to the merchant's marginal cost, $d+t_m$, plus the transportation cost, t:

$$p_A^0 = p_B^0 = p^0 = d + t_m + t\,. \tag{21}$$

Each merchant's profit is equal to the margin times the market share:

$$\pi_A^0 = \pi_B^0 = \pi^0 = \frac{t}{2}. \tag{22}$$

Now, let us consider the equilibrium in period 1. At stage 3 of period 1, a non-cardholder chooses the merchant based on the prices. If $t_c > f$, a cardholder chooses the merchant based on the merchants' card acceptance and their prices. If the cardholder chooses the merchant who does not accept cards he or she uses cash, otherwise the cardholder pays with a card. If $t_c \leq f$, the cardholder acts as if he or she is a non-cardholder.

Suppose $t_c > f$. At stage 2 of period 1 the merchants decide whether to accept cards and determine the product prices. First, let us describe the cases where both merchants take the same card acceptance strategy. Suppose that the merchants accept cards. Given the other merchant's price p_j, merchant l's profit function is defined as:

$$\pi_l^c(p_l; p_j) = (p_l - d - t_m)(1-\alpha)\left(\frac{1}{2} + \frac{p_j - p_l}{2t}\right) + (p_l - d - m)\alpha\left(\frac{1}{2} + \frac{p_j - p_l}{2t}\right), \text{ for } l\text{=A, B} \tag{23}$$

Since the merchants cannot raise the product prices by more than the price growth rate, i, in period 1, their pricing and profits are dependent on i. Merchant l's price in period 1 is:

$$\begin{aligned} p_l(l:\text{accept}; j:\text{accept}) &= d + t_m + t + \alpha(m - t_m), \quad \text{if } ip^0 \geq \alpha(m - t_m), \\ &= p^0(1+i), \quad \text{otherwise.} \end{aligned} \tag{24}$$

Merchant l's profit is:

$$\begin{aligned} \pi_l(l:\text{accept}; j:\text{accept}) &= \frac{t}{2}, \quad \text{if } ip^0 \geq \alpha(m - t_m), \\ &= \frac{t}{2} + \frac{1}{2}\{ip^0 - \alpha(m - t_m)\}, \quad \text{otherwise.} \end{aligned} \tag{25}$$

Suppose instead that the merchants do not accept cards. In this case, the equilibrium is the same as the equilibrium without cards.

Next, let us describe the cases where each merchant takes a different card acceptance strategy from its rival's. Suppose that Merchant A accepts cards and Merchant B does not. Each merchant's profit function depends on $t_c - f$ and t. If the ratio of a cardholder's net benefit from a card transaction to the transportation costs, $(t_c - f)/t$, is large, the cardholder's merchant choice does not depend on the price difference but depends on the difference of merchant card acceptance. The analysis below focuses on $(t_c - f)/t \le 2$.[24]

Merchant A's profit function is defined as:

$$\pi_A^c(p_A;\, p_B) = (p_A - d - t_m)(1-\alpha)(\frac{1}{2} + \frac{p_B - p_A}{2t}) + (p_A - d - m)\alpha(\frac{1}{2} + \frac{p_B - p_A}{2t} + \frac{t_c - f}{2t}), \quad (26)$$

and Merchant B's profit function is:

$$\pi_B^{nc}(p_B;\, p_A) = (p_B - d - t_m)\{(1-\alpha)(\frac{1}{2} + \frac{p_A - p_B}{2t}) + \alpha(\frac{1}{2} + \frac{p_A - p_B}{2t} - \frac{t_c - f}{2t})\}. \quad (27)$$

The product price and profit for each of the merchants are dependent on the industry's realized maximum price growth rate:

$$\begin{aligned} p_A(\text{accept; reject}) &= d + t_m + t + \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\}, \text{ if } ip^0 \ge \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\}, \\ &= p^0(1+i), \qquad\qquad \text{otherwise.} \end{aligned} \quad (28)$$

$$\begin{aligned} p_B(\text{reject; accept}) &= d + t_m + t - \frac{\alpha}{3}\{(t_c - f) - (m - t_m)\}, \text{ if } ip^0 \ge \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\}, \\ &= p^0 + \frac{1}{2}\{ip^0 - \alpha(t_c - f)\}, \qquad\qquad \text{otherwise.} \end{aligned} \quad (29)$$

---

[24]The other cases might be more important. In the United States, many of the card issuers give rewards to their cardholders, thus negative *f* is very popular. In addition, some of the merchant markets are very competitive, thus *t* may be very small in such markets.

$$\pi_A(\text{accept; reject}) = \frac{1}{2t}[\{t + \frac{\alpha}{3}(t_c - f) - \frac{\alpha}{3}(m - t_m)\}^2 - \alpha(1-\alpha)(t_c - f)(m - t_m)],$$

$$\text{if } ip^0 \geq \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\}, \qquad (30)$$

$$= \frac{1}{2t}[(t + ip^0)\{t - \frac{ip^0}{2} + \frac{\alpha}{2}(t_c - f)\} - \alpha(m - t_m)\{t - \frac{ip^0}{2} + (1 - \frac{\alpha}{2})(t_c - f)\}],$$

$$\text{otherwise.}$$

$$\pi_B(\text{reject; accept}) = \frac{1}{2t}\{t - \frac{\alpha}{3}(t_c - f) + \frac{\alpha}{3}(m - t_m)\}^2, \text{if } ip^0 \geq \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\},$$

$$= \frac{1}{2t}\{t + \frac{ip^0}{2} - \frac{\alpha}{2}(t_c - f)\}\{t + \frac{ip^0}{2} - (1 - \frac{\alpha}{2})(t_c - f)\}, \text{otherwise.} \qquad (31)$$

Consider Merchant A's card acceptance behavior. Suppose that Merchant B accepts cards. Merchant A will accept cards if and only if $\pi_A(\text{accept;accept}) \geq \pi_A(\text{reject;accept})$. This is equivalent to the merchant fee being lower than m_1, where m_1 is defined as:

$$m_1 = t_m + t_c - f, \qquad \text{if } ip^0 \geq \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\},$$

$$= \infty, \qquad \text{if } \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\} > ip^0 \geq \alpha(m - t_m), \qquad (32)$$

$$= t_m + \frac{1}{\alpha}[t + ip^0 - \{1 + \frac{ip^0}{2t} - \frac{\alpha}{2t}(t_c - f)\}\{t + \frac{ip^0}{2} - (1 - \frac{\alpha}{2})(t_c - f)\}], \quad \text{otherwise.}$$

Suppose instead that Merchant B does not accept cards. Merchant A will accept cards if and only if $\pi_A(\text{accept;reject}) \geq \pi_A(\text{reject;reject})$. This is equivalent to $m \leq m_2$, where m_2 is defined as:

$$m_2 = t_m + \frac{3}{\alpha}t + \frac{15 - 9\alpha}{2\alpha}(t_c - f) - \sqrt{\{\frac{15 - 11\alpha}{2\alpha}(t_c - f) + \frac{3}{\alpha}t\}^2 + \frac{15 - 11\alpha}{\alpha^2}(t_c - f)^2 + t_m^2},$$

$$\text{if } ip^0 \geq \frac{\alpha}{3}\{(t_c - f) + 2(m - t_m)\}, \qquad (33)$$

$$= t_m + \frac{ip^0(t - ip^0) + \alpha(t_c - f)(t + ip^0)}{\alpha\{2t - ip^0 + (2 - \alpha)(t_c - f)\}}, \qquad \text{otherwise.}$$

From equations 32 and 33, $m_1 > m_2$ always holds.

Since Merchants A and B are identical, Merchant A's card acceptance behavior described above is also applicable to Merchant B. Thus, pure strategy Nash equilibria are defined as follows: When the merchant fee is higher than m_1, there is one Nash equilibrium—both merchants do not accept cards; when the merchant fee is between m_1 and m_2, there are two Nash equilibria—both merchants do not accept cards, or both accept cards; when the merchant fee is lower than m_2, there is one Nash equilibrium—both merchants accept cards.

At stage 1 of period 1, the network sets a cardholder fee, f, such that $f < t_c$. It also sets the merchant fee, m, so that both merchants accept cards. Since the network cannot observe the industry's realized maximum price growth rate, i, when it sets the merchant fee, it predicts i to be zero. From equations 32 and 33, when $i = 0$:

$$m_1 = t_m + \frac{1}{\alpha}(t_c - f)\{1 - \frac{\alpha}{2t}(1 - \frac{\alpha}{2})(t_c - f)\}, \tag{34}$$

and

$$m_2 = t_m + \frac{(t_c - f)t}{2t + (2 - \alpha)(t_c - f)}. \tag{35}$$

In order to have both of the merchants accept cards, the network will set the merchant fee lower than either m_1 or m_2. While a unique Nash equilibrium in which both of the merchants accept cards exists when the network sets the merchant fee lower than m_2, two Nash equilibria—either both accept cards or both do not accept cards—exist when the network sets the merchant fee lower than m_1 but higher than m_2. Since neither merchant previously accepted cards, each merchant hardly believes that his rival merchant will accept cards when "both do not accept cards" can be an equilibrium. Such merchant's belief makes the conservative network set m_2 as the highest merchant fee in period 1. The highest merchant fee in period 1, $\overline{m}^1$, is therefore:

$$\overline{m}^1 = t_m + \frac{(t_c - f)t}{2t + (2-\alpha)(t_c - f)}. \tag{36}$$

Proposition 6 (Merchant fee): *In the industry whose aggregate consumer demand is inelastic, the duopoly merchants competing according to the Hotelling model accept cards even if the merchant fee is higher than the merchant transactional benefit from cards.*

Proposition 6 implies that the merchants' strategic motive to accept cards enables the network to raise the merchant fee higher than the fee for a monopoly merchant. While the network charges the merchant fee to a monopoly merchant who faces an inelastic demand as high as t_m in period 1, the fee it charges duopoly merchants who face the same aggregate consumer demand as the monopoly merchant is higher than t_m in period 1.

Since both merchants accept cards for any $m \le \overline{m}^1$, the new product prices (p_A^1, p_B^1) are given in equation 24. Clearly, if $m > t_m$, the merchants raise the product prices unless $i = 0$, and if $m < t_m$ the merchants lower the prices even when $i > 0$.

Proposition 7 (Welfare): *Suppose the network sets $f < t_c$ and $m \le \overline{m}^1$. In the industry whose aggregate consumer demand is inelastic, the duopoly merchants who are competing in the Hotelling model accept cards. Compared to the equilibrium without cards:*

a) Non-cardholders' surplus is lower (higher) if the merchants set higher (lower) product prices;

b) Cardholders' surplus is higher;

c) Aggregate consumers' surplus is higher;

d) The merchants' surplus is lower or at most the same.

Proof: Since consumer demand is elastic, assume that each consumer receives gross benefit by purchasing one unit of the product, υ. The net utility is, therefore, $\upsilon - p - t_c$ for a cash transaction and $\upsilon - p - f$ for a card transaction.

From equation 24, if $i > 0$, the new prices are higher (lower) when the merchant fee is higher (lower) than the transactional costs with cash. Since the non-cardholders' surplus depends only on the product price, if the product price with cards is higher than that without cards, non-cardholders are worse off and vise versa.

The total cost for a cardholder when he or she uses a card, $p^1 + f$, is always lower than the total cost for the cardholder when the merchants do not accept cards, $p^0 + t_c$. The merchant will set the price to at most $\overline{p}^1 = d + t_m + t + \dfrac{\alpha(t_c - f)t}{2t + (2-\alpha)(t_c - f)}$, under the highest merchant fee, $\overline{m}^1$.

$$(\overline{p}^1 + f) - (p^0 + t_c) = -\frac{(2-\alpha)(t + t_c - f)(t_c - f)}{2t + (2-\alpha)(t_c - f)} < 0$$

Aggregate consumers' surplus without cards is $\upsilon - p^0 - t_c$, and that with cards and product price $\overline{p}^1$ is $(1-\alpha)(\upsilon - \overline{p}^1 - t_c) + \alpha(\upsilon - \overline{p}^1 - f)$.

$$\{(1-\alpha)(\upsilon - \overline{p}^1 - t_c) + \alpha(\upsilon - \overline{p}^1 - f)\} - (\upsilon - p^0 - t_c) = \frac{\alpha(t_c - f)\{t + (2-\alpha)(t_c - f)\}}{2t + (2-\alpha)(t_c - f)} > 0.$$

From equations 22 and 25, if the merchants can adjust their prices to their profit maximizing level (either $m \le t_m$, or $m > t_m$ and $ip^0 \ge \alpha(m - t_m)$), the merchants' profits are unchanged, otherwise their profits are lower. ■

Let us turn to the game in period 2. Can the card network raise the merchant fee higher than the highest merchant fee in period 1? In contrast to monopoly merchants, duopoly merchants cannot go back to the original strategy easily. Given the fact that the other merchant is now accepting cards, "continue to accept cards" is the better strategy than "reject cards," as long as the merchant fee is lower than the level detailed below.

Suppose that both merchants accepted cards and raised their prices in period 1. Consider the case where one of the merchants rejects cards and the other continues to accept cards in period 2. The profit for the merchant who continues to accept cards is given as:

$$
\begin{aligned}
\pi_l(\text{accept; reject}) &= \frac{1}{2t}[\{t+\frac{\alpha}{3}(t_c - f)-\frac{\alpha}{3}(m-t_m)\}^2 - \alpha(1-\alpha)(t_c - f)(m-t_m)], \\
&\qquad \text{if } p^1(1+i) \geq p^0 + \frac{\alpha}{3}\{(t_c - f)+2(m-t_m)\}, \\
&= \frac{1}{2t}[(t+p^1(1+i)-p^0)\{t+\frac{p^0}{2}-\frac{p^1(1+i)}{2}+\frac{\alpha}{2}(t_c - f)\} \\
&\qquad -\alpha(m-t_m)\{t+\frac{p^0}{2}-\frac{p^1(1+i)}{2}+(1-\frac{\alpha}{2})(t_c - f)\}], \qquad \text{otherwise.}
\end{aligned}
\tag{37}
$$

Even if the realized maximum price growth rate in period 2 is zero, as long as the merchant fee in period 2 is lower that m_3, where m_3 is defined as:

$$
m_3 = t_m + \frac{(t_c - f)t + \{t+\alpha(t_c - f)-(p^1 - p^0)\}(p^1 - p^0)/\alpha}{2t+(2-\alpha)(t_c - f)-(p^1 - p^0)}, \tag{38}
$$

$\pi_l(\text{accept; reject}) \geq \pi_l(\text{reject; reject}) = \frac{t}{2}$. This implies that when the network sets the merchant fee lower than m_3, both merchants continue to accept cards. Since $p^1 > p^0$, m_3 is higher than the highest merchant fee in period 1. If the network wants to have a unique Nash equilibrium where both merchants accept cards, then the highest merchant fee the network can charge is m_3. Thus, if both of the merchants raised their prices in period 1, the network can raise the merchant fee in period 2.

Suppose, instead, that both merchants accepted cards but did not raise their prices in period 1 (i.e., the realized maximum price growth rate in period 1 was zero). In this case, if the network wants to have a unique equilibrium where both merchants accept cards, then the highest merchant fee the network can charge is the same as $\overline{m}^1$. Nevertheless, the network may raise the merchant fee in period 2 because the network may not want to have such a unique equilibrium. In period 1, since neither merchant had previously accepted cards, each merchant hardly believed that his rival merchant would accept cards when "both do not accept cards" can be an equilibrium. In period 2, however, since both merchants have accepted cards in period 1, each merchant may believe that his rival will continue to accept cards when "both merchants continue to accept cards" can be an equilibrium. The merchants' change in perception enables the network to charge a merchant fee as high as m_1, which is defined in equation 34. Notice that $m_1 > \overline{m}^1$. Thus, even when the merchants did not raise their product prices, if each of the merchants strongly believes that its rival will accept cards in period 2, the network can raise the merchant fee in period 2.

In period 2, both merchants will continue to accept cards and raise their prices according to the merchant fee increase unless the realized maximum price growth rate in the period is zero. The increase in product prices enables the network to raise the merchant fee further in the succeeding periods. In this way, the merchant fee and product prices gradually increase. In the long run, both the merchant fee and product prices converge to the point where they cannot increase anymore. The long run equilibrium merchant fee and product prices are defined as:

$$\overline{m}^N = t_m + t_c - f \,, \tag{39}$$

and

$$p_A^N = p_A^N = p^N = d + t_m + t + \alpha(t_c - f)\,. \tag{40}$$

In the long run, each of the merchants believes more strongly that its rival will continue to accept cards when "both continue to accept cards" can be an equilibrium. Therefore, the network can set the merchant fee in the range where there exist multiple Nash equilibria that include an equilibrium in which both merchants accept cards. In addition, in the long run, as the product prices increase, the merchants' price restrictions become less restrictive so that the merchants can set their profit maximizing prices.

Notice that the long-run equilibrium merchant fee is the same as what Rochet and Tirole (2002) found. In their model, the merchants' price setting is completely flexible. In my model, however, even if the merchants' price setting is completely flexible, the network may not set the long-run equilibrium merchant fee in the first period. This is because the conservative network wants to make sure that both of the merchants accept cards in period 1, and by doing so it avoids setting a merchant fee which may lead to the equilibrium where both do not accept cards.

Proposition 8 (Long-run equilibrium): *Suppose that the network will set the (conservative) highest merchant fee in every period. Compared to the equilibrium without cards, at the long run equilibrium:*

a) Non-cardholders are worse off;

b) Cardholders are better off;

c) Aggregate consumers' surplus is the same;

d) The merchant is indifferent.

Proof: (a) It is obvious since $p^N > p^0$. (b) From equations 21 and 40, $p^N + f < p^0 + t_c$. (c) $\{(1-\alpha)(\upsilon - p^N - t_c) + \alpha(\upsilon - p^N - f)\} - (\upsilon - p^0 - t_c) = \alpha\{(\overline{m}^N - t_m) + (t_c - f)\} = 0$. (d) It is obvious from equations 22 and 25. ■

Merchant competition allows the network to set merchant fees higher. In industries whose aggregate consumer demand is inelastic, the network can charge monopoly merchants the merchant fees as high as the merchants' transactional benefits from cards or in some circumstances it can charge the fees higher than the merchants' transactional benefits. If the same industries are more competitive, the network can always charge the merchant fees higher than the merchants' transactional benefits. And in the long run it charges the fees that are equal to the merchants' transactional benefits plus card users' net transactional benefits. Moreover, in a competitive market where each merchant's initial profit margin, t, is smaller than the card user's net benefit, $t_c - f$, the long-run merchant fee exceeds the sum of the merchants' transactional benefit *and* the merchants' initial margin. In either monopoly or competitive markets, in the long run, the sum of consumers' and merchants' surpluses with cards converges to the sum of their surpluses without cards.

3.2.2 Elastic demand

In order to make the model analytically solvable, we modify the Hotelling model in the following way. We assume that a consumer buys at least one unit of product per trip. The consumer chooses a merchant based on the total cost—the sum of the product price, the transactional cost with the payment instrument he or she uses, and transportation cost. After the consumer decides from which merchant to purchase the products, the consumer determines the quantity based on the product price and the transactional cost.

Before considering the equilibrium with cards, first we describe the equilibrium without cards. This modified Hotelling model gives the equilibrium prices, (p_A^0, p_B^0), which are the same for both merchants.

$$p_A^0 = p_B^0 = p^0 = d + t_m + \frac{tD(p^0 + t_c)}{D(p^0 + t_c) - tD'(p^0 + t_c)}. \tag{41}$$

Each merchant's profit is:

$$\pi_A^0 = \pi_B^0 = \pi^0 = \frac{1}{2} \frac{tD(p^0 + t_c)}{\{D(p^0 + t_c) - tD'(p^0 + t_c)\}}. \tag{42}$$

Now consider equilibrium with cards. In order to make the model analytically solvable, the merchant's decision-making is broken into two steps. First, the merchants decide whether to accept cards before determining their prices. Second, after observing each other's card acceptance strategy, they determine their prices. This assumption may make the highest merchant fee the network will charge slightly lower in each period, compared with the model where the merchants decide their card acceptance and prices at the same time.

Suppose $t_c > f$. At stage 3 of period 1, a cardholder chooses the merchant based on the merchants' card acceptance and prices. If the cardholder chooses the merchant who does not accept card, he or she pays with cash, otherwise he or she pays with a card. Similar to the case where consumer demand is inelastic, merchant card acceptance and pricing behavior depend on the parameter values. Here, we analyze equilibrium only for $(t_c - f)/t \leq 1$.

At stage 2 of period 1, first let us suppose both merchants take the same card acceptance strategy. Given m, each merchant's profit when both merchants accept cards under price p^0 is:

$$\pi_l(\text{accept; accept}) = (p^0 - d - t_m)(\frac{1-\alpha}{2})D(p^0 + t_c) + (p^0 - d - m)\frac{\alpha}{2}D(p^0 + f), \text{ for } l = \text{A, B}, \tag{43}$$

and when both merchants reject the cards under price p^0 is:

$$\pi_l(\text{reject; reject}) = \frac{1}{2}(p^0 - d - t_m)D(p^0 + t_c). \tag{44}$$

Suppose instead a merchant takes a different card acceptance strategy from its rival's. Consider the case where Merchant A accepts cards and Merchant B does not. Merchant A's profit is:

$$\pi_A(\text{accept; reject}) = (p^0 - d - t_m)(\frac{1-\alpha}{2})D(p^0 + t_c) + (p^0 - d - m)\alpha(\frac{1}{2} + \frac{t_c - f}{2t})D(p^0 + f), \quad (45)$$

and Merchant B's profit is:

$$\pi_B(\text{reject; accept}) = (p^0 - d - t_m)(\frac{1}{2} - \frac{\alpha(t_c - f)}{2t})D(p^0 + t_c). \quad (46)$$

Suppose that Merchant B accepts cards. Merchant A accepts cards if and only if:

$$t_m + (p^0 - d - t_m)\{1 - \frac{t - (t_c - f)}{t}\frac{D(p^0 + t_c)}{D(p^0 + f)}\} \geq m. \quad (47)$$

Suppose instead Merchant B does not accept cards. Merchant A accepts cards if and only if:

$$t_m + (p^0 - d - t_m)\{1 - \frac{t}{t + t_c - f}\frac{D(p^0 + t_c)}{D(p^0 + f)}\} \geq m. \quad (48)$$

Define m_1 and m_2 that satisfy the equality in equations 47 and 48. Clearly, m_1 is greater than m_2. When the merchant fee is higher than m_1, there is one Nash equilibrium; both merchants do not accept cards. When the merchant fee is between m_1 and m_2, there are two Nash equilibria; both merchants do not accept cards, or both accept cards. When the merchant fee is lower than m_2 there is one Nash equilibrium; both merchants accept cards.

Since the network wants as many merchants to accept cards as possible, it will set a merchant fee lower than m_2. The highest merchant fee in period 1, $\overline{m}^1$, is therefore:

$$\overline{m}^1 = t_m + (p^0 - d - t_m)\{1 - \frac{t}{t + t_c - f}\frac{D(p^0 + t_c)}{D(p^0 + f)}\}.$$

Proposition 9 (Merchant fee): *In the industry whose aggregate consumer demand is elastic, the duopoly merchants competing in the (modified) Hotelling model accept cards even if the* *merchant fee is higher than the merchant transactional benefit from cards. If all parameter values are the same (t, t_c, t_m, f, and the demand function), the ratio of the first-period highest merchant fee to the initial equilibrium price, $\overline{m}^1 / p^0$, in the duopoly market with elastic consumer demand is higher than that in the monopoly market with elastic consumer demand or in the duopoly market with inelastic consumer demand.*

For many of the card transactions, merchant fees are set as a rate of the transaction value, which is equivalent to some percentage of the price. Proposition 9 implies that in the market whose aggregate demand is elastic, the more competitive the market, the higher the merchant fee rate is and that in the competitive market, the more elastic the consumer demand, the higher the merchant fee rate is.

After deciding card acceptance, both merchants set their prices. The profit maximizing prices are defined as:

$$p_A^1* = p_B^1* = p^1* = d + t_m + \frac{t\{(1-\alpha)D(t_c) + \alpha D(f)\} + \alpha(m - t_m)\{D(f) - tD'(f)\}}{(1-\alpha)\{D(t_c) - tD'(t_c)\} + \alpha\{D(f) - tD'(f)\}}, \quad (49)$$

where $D(x) = D(p^1 * + x)$ and $D'(x) = D'(p^1 * + x)$. Since the product price growth rate is limited to i, the price in period 1 will be:

$$\begin{aligned} p^1 &= p^1*, \qquad \text{if } p^1* < p^0(1+i), \\ &= p^0(1+i), \text{otherwise.} \end{aligned}$$

Since general results are not available for the case of elastic consumer demand, the rest of the subsection restricts its attention to linear demand. From equations 41 and 49, we obtain equation 50.

$$(1 + \frac{t^2 b^2}{AB})(p^1 * - p^0) = t^2 b^2 \frac{\alpha(t_c - f)}{AB} + (m - t_m)\frac{\alpha\{D(p^1 * + f) + tb\}}{A}, \quad (50)$$

where $D(p) = a - bp$, $A = (1-\alpha)\{D(p^1 * + t_c) - tD'(p^1 * + t_c)\} + \alpha\{D(p^1 * + f) - tD'(p^1 * + f)\}$,

and $B = D(p^0 + t_c) - tD'(p^0 + t_c)$. This provides the following proposition.

Proposition 10 (Price): *In the industry whose aggregate consumer demand is elastic, the duopoly merchants competing in the (modified) Hotelling model will adjust the product prices according to the merchant fee, if they accept cards.*

i) For $t_m \le m \le \overline{m}^1$, the good price with cards is higher if $i > 0$.

ii) For $m < t_m$, if $t_m < (t_c - f)\delta$, where $\delta = \dfrac{b^2 t^2}{\{D(p^0 + t_c) + bt\}\{D(p^1 + f) + bt\}}$, and if $i > 0$ the good price with cards is higher; if $t_m \ge (t_c - f)\delta$, for $m > t_m - (t_c - f)\delta$ the good price with cards is higher if $i > 0$ and for $m < t_m - (t_c - f)\delta$ the good price with cards is lower.

Similar to the monopoly merchant, the duopoly merchants will set product prices higher than the equilibrium prices without cards even when the merchant fee is lower than their transactional benefits. However, competition narrows the range of merchant fees that allows merchants to set the higher product prices. A monopoly merchant will set a higher product price when the merchant fee is higher than $t_m - (t_c - f)$. On the other hand, duopoly merchants will set higher product prices when the merchant fee is higher than $t_m - (t_c - f)\delta$, which is higher than $t_m - (t_c - f)$.

Proposition 11 (Welfare): *Suppose the network sets $f < t_c$ and $m \le \overline{m}^1$. In the industry whose aggregate consumer demand is elastic, the duopoly merchants who are competing in the Hotelling model accept cards. Compared to the equilibrium without cards:*

a) Non-cardholders' surplus is higher (lower) if the merchant sets a lower (higher) price after accepting cards;

b) Cardholders' surplus is higher;

c) Aggregate consumers' surplus is higher;

d) The merchants' surplus is higher.

Proof: See appendix A.

From the results of 3.1.2 and 3.2.1, it is not hard to imagine that the network will raise the merchant fee in the periods after both merchants accept cards. In the long run, the merchant fee will converge to the highest possible merchant fee and the product prices will also converge accordingly. Under such merchant fee and product prices, the merchant's profit with cards becomes the same as the equilibrium profit without cards.

4. Conclusion

A large group of merchants accept cards even when their transactional benefit from cards is lower than the fee they pay, as long as a card user's net transactional benefits are positive. Only monopoly merchants who are facing an inelastic consumer demand may deny cards when the fee exceeds its transactional benefit. Typically, card users are not charged a per transaction fee for credit card transactions, rather many of them receive rewards from their card issuers. For debit card transactions, some issuers charge a per transaction fee to their cardholders, but at least in the United States, such issuers are in the minority.[25] Thus, it is likely that cardholder's net transactional benefits are positive even when their gross transactional benefits are zero or even negative. This suggests that the analyses based on the assumption that merchants accept cards only when their transactional benefits from cards surpass their fees are potentially misleading.

[25] According to the Board of Governors of the Federal Reserve System's report to the Congress on the disclosure of point-of-sale debit fees, 14 percent of depository institutions charge PIN fees for some of their customers. According to the same report, 13 percent of households reported that their depository institutions charge PIN fees.

Although whether the network has an incentive to charge the highest possible merchant fee or not is in question, if it does, it will charge the fee as high as the sum of the merchant's transactional benefit and the cardholder's net transactional benefits including rewards. The network may not charge the highest fees in earlier periods of card acceptance in a given industry but it will gradually increase the fee to the highest possible level.

Merchant competition allows the network to set higher merchant fees. The network can always set higher merchant fees in more competitive markets. Moreover, in competitive markets the merchant fees in the long run may exceed the sum of the merchant's initial margin and the merchant's transactional benefit.

The highest possible merchant fees may be more efficient than the case without cards, if the real cost of processing card transactions is lower than the sum of the merchant's and the consumer's transactional costs with the other payment instruments. However, these fees potentially create inequality among consumers. While debit cards are more accessible to all consumers, credit cards are not.[26] In the United States, about 75 percent of families are estimated to hold at least one credit card.[27] In order to have a credit card, a consumer needs to meet various criteria, such as income, credit history, and so on. These criteria are necessary for banks as well as for society to have safe and sound payment systems. However, sometimes credit cards are used simply as a transactional means rather than as a tool for borrowing.[28] If higher credit card merchant fees imply higher product prices, those who cannot have a credit card need to pay higher prices. Cardholders also pay higher prices but they are compensated for that by receiving rewards.

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[26]According to the Survey of Consumer Finance (SCF) conducted by the Federal Reserve System in 2001, about 13 percent of US families did not have a checking account. About 20 percent of such families did not have enough money or have credit problems.

[27]According to the SCF (2001).

The results obtained in this paper may depend on the assumption of a monopoly card network. The network does not have to compete for merchants, for consumers, and/or for issuers. Does competition among networks lower merchant fees? The answer requires a formal analysis; however, a pessimistic speculation would be that network competition does not reduce merchant fees. One study reported that consumers are beginning to hold fewer cards, given universal acceptance of credit/debit cards by merchants.[29] Since typical merchant fees consist of per transaction fees and negligible fixed fees, merchants accept as many networks' cards as they can. Merchants are generally hesitant to reject customers' payment choices. Although they may steer customers from one payment instrument to another, in the case that their customers are not willing to use the merchant's preferred method of payment, they accept other payments to satisfy their customers. This sort of merchant behavior may have little effect on a network's pricing decision. As long as the merchant fee does not exceed the level that gives merchants negative profits, merchants may have no choice but to continue accepting cards.

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[28]According to the SCF (2001), about 40 percent of cardholding families did not borrow on credit cards.
[29]The 2004 Preferred Card Study conducted by Edger, Dunn & Company. See *www.edgardunn.com/eletter/2004-02/*.

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Appendix A:

(1) Proof of Proposition 5 (b) and (c)

Given merchant fee, $\overline{m}^N$

$$p^N = \frac{1}{2b}\{a + b(d + t_m - t_c) + \alpha b(\overline{m}^N - t_m + t_c - f)\}. \tag{A1}$$

By assumption, $\pi^c(p^N;\overline{m}^N) = \pi^{nc}(p^0)$, and this gives

$$\overline{m}^N - t_m = t_c - f - \varepsilon, \tag{A2}$$

for $\varepsilon > 0$. From equations 12 and A2,

$$p^N = p^0 + \alpha(t_c - f) - \frac{\alpha\varepsilon}{2}. \tag{A3}$$

From equation A3,

$$(p^N + f) - (p^0 + t_c) = -(1-\alpha)(t_c - f) - \frac{\alpha\varepsilon}{2} < 0,$$

and

$$\{(1-\alpha)v(p^N + t_c) + \alpha v(p^N + f)\} - v(p^0 + t_c) = \frac{\alpha}{2}\{\varepsilon D(p^0 + t_c) + \frac{\alpha b\varepsilon}{4} + (1-\alpha)b(t_c - f)^2\} > 0.$$

■

(2) Proof of Proposition 11

(a) is obvious from proposition 10. (b) It is equivalent to show $p^1 + f < p^0 + t_c$ at $m = \overline{m}^1$.

$$(1 + \frac{t^2b^2}{AB})\{(p^1 + f) - (p^0 - t_c)\} = -\frac{t_c - f}{AB}[(1-\alpha)t^2b^2 + \frac{D(p^0 + t_c) + tb}{(t + t_c - f)D(p^0 + f)}$$
$$\{(1-\alpha)tD(p^0 + t_c)(D(p^1 + f) + tb) + (t_c - f)D(p^0 + f)D(p^1 + t_c)$$
$$+ \alpha b(t_c - f)(t + t_c - f)D(p^0 + f) + tb(t_c - f)D(p^1 + f) + t^2b^2(t_c - f)\}] < 0$$

(c) To show this, first we show that aggregate quantities demand has increased at $m=\overline{m}^1$.

$$\{(1-\alpha)D(p^1+t_c)+\alpha D(p^1+f)\}-D(p^0+t_c)=\frac{\alpha b(t_c-f)^2\{D(p^0+t_c)+tb\}}{(AB+t^2b^2)(t+t_c-f)D(p^0+f)}$$

$$\{D(p^0+f)D(p^1+t_c)+tbD(p^1+f)+b(t+t_c-f)D(p^0+f)+t^2b^2\}>0$$

The difference of aggregate consumers' surplus with and without cards is:

$$(1-\alpha)v(p^1+t_c)+\alpha v(p^1+f)-v(p^0+t_c)$$

$$=\frac{1}{2b}\{(1-\alpha)D(p^1+t_c)^2+\alpha D(p^1+f)^2-D(p^0+t_c)^2\}$$

$$=\frac{1}{2b}[\{D(p^1+f)^2-D(p^0+t_c)^2\}-(1-\alpha)\{D(p^1+f)^2-D(p^1+t_c)^2\}]$$

$$>\frac{1}{2b}\{D(p^1+f)+D(p^0+t_c)\}\{(1-\alpha)D(p^1+t_c)+\alpha D(p^1+f)-D(p^0+t_c)\}>0$$

since $D(p^1+t_c)<D(p^0+t_c)<D(p^1+f)$.

(d) From the results of 3.1.2 and 3.2.1, this is likely. ■