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The Economics of Payment Card Fee Structures: What Drives Payment Card Rewards?

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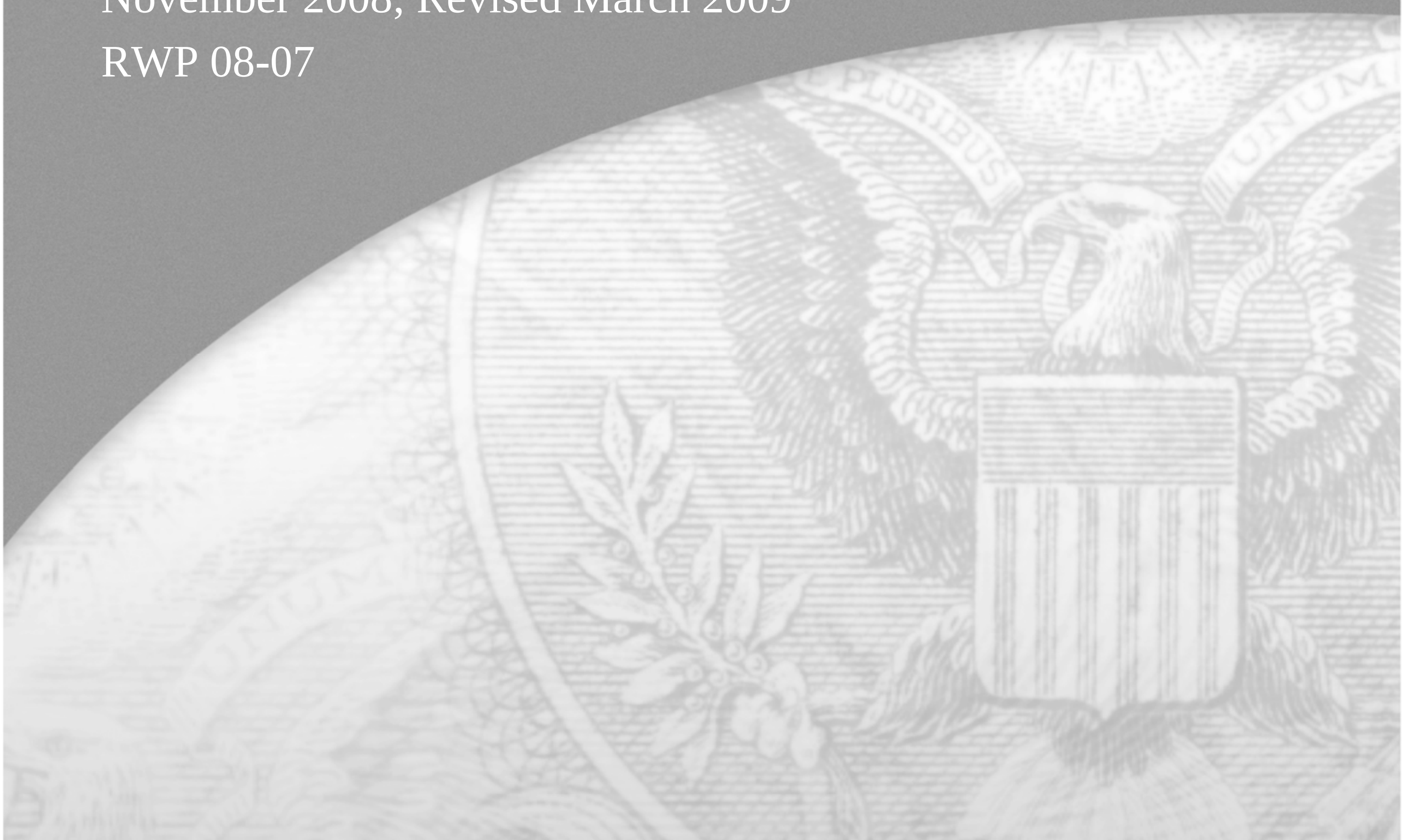

RESEARCH WORKING PAPERS

THE ECONOMICS OF PAYMENT CARD FEE STRUCTURE: WHAT DRIVES PAYMENT CARD REWARDS?

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Abstract: This paper investigates potential market forces that cause payment card rewards even when providing payment card rewards is not the most efficient. Three factors—oligopolistic merchants, output-maximizing card networks, and the merchant's *inability* to set different prices across payment methods—may potentially explain the prevalence of payment card rewards programs in the United States today. The paper also points out that competition among card networks may potentially make payment rewards too generous, and thus *deteriorate* social welfare and its distribution. The situation may potentially warrant public policy interventions.

Keywords: Payment card rewards, equilibrium fee structure, oligopolistic merchants, card network competition, no-surcharge-rules

JEL Classification: L13, L22

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1. Introduction

Payment card rewards programs have become increasingly popular in the United States. However, providing payment card rewards may not be necessarily beneficial to consumers and society as a whole. According to the theoretical literature on payment card fee structure, in most cases the most efficient cardholder fees would be the difference between the card network's costs for a card transaction and the merchant's transactional benefit from the card transaction. Available empirical evidence suggests that in the United States the merchant's transactional benefit from a card transaction may not exceed the card network's cost. This implies providing rewards would unlikely be the most efficient. What drives payment card rewards?

This paper is the second of a series of three papers. The first paper examined the optimal balance between the merchant fee and the cardholder fee from both efficiency and equity perspectives.[2] In this paper, we investigate what market forces drive payment card rewards. The results are useful for policymakers when determining whether the current situation should call for public policy interventions and if so what policies are appropriate. Policy options are considered in the third paper.

The equilibrium card fee structure is greatly influenced by many factors. This paper examines the equilibrium fee structure under various combinations of assumptions and identifies what factors potentially cause payment card rewards. We also consider the welfare consequences of equilibrium card fee structures. The results suggest three factors that together may explain the prevalence of rewards card programs in the United States today. They are oligopolistic merchants, output-maximizing card networks and the merchant's inability to set different prices according to their customers' payment methods. Whether per transaction costs and fees are fixed

[2] Hayashi (2008).

or proportional to the transaction value may also play an important role in determining the level of rewards. When per transaction costs and fees are proportional and the three factors mentioned above co-exist, competition among card networks would likely *increase* the level of rewards as well as the merchant fees. The higher merchant fees would result in the higher product prices, and as a result the equilibrium social welfare would be potentially lower than the social welfare without cards at all. Although the previous studies suggested competition in a two-sided market may not necessarily improve efficiency, the finding in this paper—competition in a two-sided market may potentially *deteriorate* efficiency—is new in the literature and has a potentially important public policy implication.

The rest of the paper is organized as follows. Section 2 constructs theoretical models. Section 3 examines the market equilibrium—fee structures and their welfare consequences for different parties that are involved in payment card markets. Section 4 concludes.

2. Models

We use the models that were constructed in the first paper (Hayashi, 2008) as the base models here. We also make additional assumptions regarding merchants and card networks, which greatly affect equilibrium fee structure. This section first recaps our base models then makes additional assumptions regarding merchants and card networks.

2.1 Recap of the Base Models

The assumptions common to all models are the following. The payment card markets are considered to be matured. All consumers hold at least one card and merchants accept cards as long as the merchant fees are lower than a certain threshold level, which is endogenously determined.

Consumers are heterogeneous in their transactional benefit from cards as opposed to the alternative payments. A consumer's transactional benefit from a card, b_B, consists of three parts. One is a gross benefit minus gross cost from using a card, B_B^C;[3] one is a gross benefit minus gross cost from using the alternative payment method, B_B^A;[4] and one is the consumer fee paid for the alternative payment method, f^A. Thus, the transactional benefit from a card is defined as: $b_B = B_B^C - B_B^A + f^A$. To simplify the model, we assume every consumer receives the same level of B_B^A, which is equal to f^A (i.e., $B_B^A = f^A$). b_B is assumed to be distributed over the interval $[\underline{b}_B, \overline{b}_B]$ with a density function of $h(b_B)$, and a cumulative distribution function of $H(b_B)$. Consumers pay the cardholder fee of f when they use a card.

Merchants are homogeneous (at least ex-ante) and their transactional benefit from cards, $\hat{b}_S$, is defined as the merchant cost for the alternative payment method, c_S^A, plus the merchant fee paid for the alternative payment method, m^A, minus the merchant cost for a card transaction, c_S^C (i.e., $\hat{b}_S = c_S^A + m^A - c_S^C$). To simplify the model, we assume $c_S^C = 0$. Merchants pay the merchant fee of m when their customers use a card. Merchants also incur a cost of selling one unit of goods, d.

The assumptions in terms of (i) per transaction costs and fees; (ii) consumer demand for goods; and (iii) merchant ability to set different prices according to the payment method can vary. Per transaction costs and fees are either flat or proportional to the transaction value. Consumer demand for goods is either inelastic (i.e., a consumer makes a fixed number of transactions) or downward-sloping (i.e., the number of transactions increases as the effective

[3] Note that gross cost does not include the fees for using a card.
[4] Again, gross cost does not include the fees for using the alternative payment method.

price of goods decreases). A merchant either sets the same price for all of its customers regardless of the payment method or sets the different prices according to the payment method its customers use.

2.2 Additional Assumptions

Merchants

Although some merchants are possibly monopolistic, many U.S. merchants are considered to be quite competitive. However, a perfectly competitive market described as the Bertrand competition unlikely reflects the reality. At equilibrium under the Bertrand competition, two types of merchants—cash-only merchants and card-accepting merchants—serve the customers separately, and because of the higher price set by card-accepting merchants, only card-using consumers make transactions at the card-accepting merchants. In reality, however, most card-accepting merchants serve both card-using customers and non-card-using consumers.

Thus, oligopolistic merchants are more realistic. This paper assumes ologopolistic merchants compete according to the Hotelling model. Although the other models, such as the Cournot model, can be used to describe oligopolistic merchants, the Hotelling model is more flexible.[5]

The basic framework of the Hotelling model is the following: There are two merchants, Merchant A and Merchant B. Consumers are uniformly distributed on the interval of [0, 1], which is independent of their transactional benefit from cards. Merchant A is located at point 0 and Merchant B is located at point 1. For the consumers located at point x, where $0 \leq x \leq 1$, the transportation cost to Merchant A is tx, and the transportation cost to Merchant B is $t(1-x)$. A

[5] For example, the Cournot model requires downward-sloping consumer demand for goods to obtain equilibrium price.

consumer located at point x with transactional benefit from cards b_B chooses a merchant and a payment method, which gives the consumer the lower effective price plus transportation costs. For example, suppose a monopoly card network provides the card services, only Merchant A accepts the cards, and Merchant A sets an identical price p_A for both card-using consumers and non-card-using consumers. Merchant B sets price p_B for their customers. Then, the consumer's effective price plus transportation cost is $p_A + f - b_B + tx$, when he purchases goods at Merchant A with a card, $p_A + tx$, when he purchases goods at Merchant A with an alternative payment method, and $p_B + t(1-x)$, when he purchases goods at Merchant B. Suppose $b_B \geq f$. The consumer chooses a card at Merchant A, and therefore, he compares $p_A + f - b_B + tx$ and $p_B + t(1-x)$. If $p_A + f - b_B + tx > p_B + t(1-x)$, then he purchases goods at Merchant B with an alternative payment method, otherwise he purchases goods at Merchant A with a card.

<u>Card networks</u>

This paper assumes the card network sets both cardholder fees (rewards) and merchant fees. Although, in reality, four-party scheme card networks do not directly set merchant fees, assuming a card network sets its merchant fees is not too far from the reality because a major part of the merchant fee (70-80 percent) is an interchange fee, almost all acquirers entirely pass through the interchange fee to merchants, and the acquirers' charges to merchants in addition to the interchange fees seem not to vary very much within an industry. In contrast, assuming a card network (four-party scheme) sets its cardholder fees may appear to be unrealistic. Cardholder fees, especially credit card rewards, vary by card issuers: Large card issuers tend to provide more generous rewards than their smaller counterparts. However, about 80 percent of the total four-party scheme credit cards are issued by the top 10 card issuers. Although it is difficult to compare the level of rewards among the top 10 issuers, if, as card networks and their issuers claim, they compete vigorously in the consumer-side of the payment card market, then the level of rewards should be very close to the difference between the interchange fees and the issuer's costs of processing a card transaction. Again, card issuers' costs of processing a card transaction vary. But if the top 10 issuers' costs of processing a card transaction are similar, then the interchange fees set by a card network greatly influence the level of rewards on the cards issued by the top 10 issuers.

There is a variety of assumptions about the objective of payment card networks, but the objective can be abstracted as either profit- or output-maximization. Profit-maximization is obvious, but output-maximization may not be. When card networks compete, each card network may reduce its markup to undercut its' rival card networks until the markup reaches the reservation markup. And the reservation markup may potentially be very close to zero. In such a case, card networks likely aim to increase their market share as much as possible. Even when card networks are monopolistic (potentially collude), their objective can be output-maximization. In a four-party scheme card network, it is possible that each acquirer and issuer gets a small fixed markup. Typically, an acquirer's markup is small, and because of the intensified competition among issuers, each issuer may get a small markup even when the card network they join is monopolistic.

Competitive card networks' behavior is likely affected by their cardholders' homing behavior. When a cardholder holds only a single-branded card or has a strong preference among cards (singlehoming), then each card network can set monopolistic merchant fees. In contrast, if all cardholders hold multiple cards and they are indifferent among those cards (multihoming), then card networks cannot set monopolistic merchant fees, because merchants may influence their customers' choice of payment methods. In the model, we assume that singlehoming cardholders are not sensitive to rewards when deciding which card to use, while multihoming cardholders are very sensitive to rewards and they always choose a card with the highest level of rewards among the cards the merchant accepts.

In this paper, three types of card networks are considered: (i) profit-maximizing monopoly, (ii) output-maximizing monopoly, and (iii) output-maximizing competing networks with cardholders who are all multihoming. Although we do not explicitly consider the case of output-maximizing competing networks with some singlehoming cardholders, the results would be somewhere between those of an output-maximizing monopoly network and those of output-maximizing duopoly networks with cardholders who are all multihoming.[6]

3. Market Equilibrium

Hayashi (2008) examined the most efficient fee structure under various combinations of the assumptions. In most cases, the most efficient cardholder fee is the difference between the card network's costs for a payment card transaction and the merchant transactional benefit from the card transaction. This implies that unless the merchant transactional benefit from a card exceeds the card network's costs of processing a card transaction, providing payment card rewards to consumers is less efficient. According to the available cost studies in the United States, the merchant transactional benefit from a card may not be higher than the card network's costs.[7] Nevertheless, payment card rewards programs are prevalent in the United States.

This section examines the equilibrium fee structures and their influence on the welfare of different parties, such as card-using consumers, non-card-using consumers, merchants, and

[6] Output-maximizing networks may have a positive reservation markup per transaction; however, this section assumes the markup is zero (i.e., the profit of output-maximizing network is zero) for simplicity.
[7] These cost studies are Garcia-Swartz et. al. (2006), Food Marketing Institute (1998), and Star Network (2006, 2007). See also Hayashi (2008) for more detailed discussion.

payment card networks (and their member financial institutions). The main purpose of this exercise is to find out what market forces may potentially drive payment card rewards. The results may also be useful for public policy consideration: For example, does encouraging competition among card networks reduce the level of payment card rewards? Does regulatory intervention that abolishes the no-surcharge rules improve social welfare?

This section looks at four factors that may significantly affect the equilibrium fee structures. The first factor is competition among card networks and their objectives. As mentioned above three types of card networks are considered.

The second factor is consumer demand for goods. Consumer demand for goods is assumed to be either inelastic or downward-sloping. When a consumer's demand for good is inelastic, the consumer would make a fixed number of transactions regardless of the price of goods or fees charged for each transaction. When a consumer's demand for goods increases as the effective price of goods (i.e., sum of the price of goods and the cardholder fee per transaction) decreases, the consumer would make more transactions as the effective price of goods decreases.

The third factor relates to per transaction costs and fees for given payment methods. Per transaction costs and fees are assumed to be either fixed regardless of the transaction value or proportional to the transaction value. Many previous studies assumed that per transaction costs and fees are fixed. In reality, however, especially in the United States, merchants pay proportional fees for card transactions and consumers receive rewards that are proportional to the purchase value. According to the available cost studies, costs of handling a cash transaction and a credit card transaction increase as the transaction value increases.

Finally, the fourth factor is about the merchant's ability to set different prices according to their customers' payment methods. Currently in the United States, most merchants set the same price for all of their customers regardless of their payment methods. But in the other countries, such as Australia and Netherlands, many merchants set different prices according to their customers' payment methods. The difference between these countries and the United States is caused by card networks' rules. In the United States, major card networks have a rule that does not allow merchants to (or makes merchants difficult) set different prices according to payment methods, while in Australia or Netherlands they do not. Especially in Australia, the Reserve Bank of Australia prohibits the card networks from imposing such a rule.

This section first considers the case where merchants set the same price for all of their customers regardless of their payment methods (no-discriminatory pricing). There are four possible scenarios depending on the assumptions regarding consumer demand and per transaction costs and fees. The first scenario is where consumer demand is fixed and per transaction costs and fees are fixed (Scenario I). The second scenario is where consumer demand is fixed but per transaction costs and fees are proportional to the transaction value (Scenario II). The third scenario is where a consumer demand function is downward-sloping and per transaction costs and fees are fixed (Scenario III). And the fourth scenario is where a consumer demand function is downward-sloping and per transaction costs and fees are proportional to the transaction value (Scenario IV). Except for Scenario I, analytical solutions for equilibrium fee structure cannot be obtained. For Scenarios II and III, numerical examples can be used to characterize the equilibrium fee structure. Therefore, this section only considers Scenarios I, II and III. In each scenario, three types of card networks—(i) profit-maximizing monopoly, (ii) output-maximizing monopoly, and (iii) output-maximizing competing networks with cardholders who are all multihoming—are considered.

This section then considers the case where merchants set the different prices according to their customers' payment methods (discriminatory pricing). Similar to the case of non-discriminatory pricing, analytical solution is obtainable only for Scenario I. Numerical examples can be used for Scenario II. Thus, only two scenarios are considered in this case.

Because tedious calculations are required to obtain market equilibrium fee structures under various combinations of assumptions, the below summarizes the results. Detailed calculations are in the Appendix.

3.1 Market Equilibrium under No-discriminatory Pricing

Tables 1 and 2 summarize the equilibrium fee structure and the welfare consequences, respectively, when merchants set the same price for card-using consumers and consumers who use an alternative payment method. There are several key observations.

First, in all three scenarios, a profit-maximizing monopoly network would set the most efficient cardholder fees. This implies that if providing rewards to card-using consumers is not the most efficient, then the profit-maximizing monopoly network would not provide rewards. However, this does not necessarily imply that social welfare is maximized under a profit-maximizing card network. Except for Scenario I, social welfare is also affected by the product price, which is affected by the merchant fee. The merchant fee set by the profit-maximizing monopoly network is higher than the merchant's transactional benefit from cards, which implies the merchant fee is not necessarily at the most efficient level. As a result, with profit-maximizing monopoly network(s), social welfare may not be reached at the maximum level (except for Scenario I).

Second, in all three scenarios, an output-maximizing monopoly network would set cardholder fees lower than the most efficient cardholder fees. This implies that even when providing rewards is not the most efficient, the output-maximizing monopoly network would likely provide rewards to card-using consumers. Because the highest merchant fee the monopoly network can set increases as the cardholder fee decreases (or the level of rewards increases), the merchant fee set by the output-maximizing monopoly network is higher than that set by the profit-maximizing monopoly network. As a result, the equilibrium product prices set under the output-maximizing monopoly network are higher than those set under the profit-maximizing monopoly network. Social welfare under the output-maximizing monopoly network is also lower than that under the profit-maximizing monopoly network.

Third, whether competing card networks would set their cardholder fees at the most efficient level depends on two factors. One is cardholders' homing behavior and the other is the nature of per transaction costs and fees. When all cardholders are singlehoming (either they have only one card or they have a strong preference and cardholder fees do not affect their card choice), competing card networks can act like an output-maximizing monopoly network. When all cardholders are multihoming (i.e., they have multiple networks' cards and are indifferent among cards as long as the cardholder fees are the same), the equilibrium cardholder fee depends on whether per transaction costs and fees are fixed (Scenario I) or proportional to the transaction value (Scenario II). If the former is the case, the competing card networks would set their cardholder fee at the most efficient level and their merchant fee at the merchant's transactional benefit. This is because oligopolistically competing merchants would only accept the cards with the lower merchant fee. If the latter is the case, the competing card networks would set their cardholder fees as low as possible. As a result, the merchant fees can be higher than the fees set by monopoly card networks. In this case, two types of merchants would co-exist ex-post: One type of merchants would accept the cards with the lower merchant fee only, while the other type of merchants would accept both networks' cards. In fact, the card network with the higher merchant fee (thus the lower cardholder fees) would have more transactions than its rival card network. Knowing at least some merchants would accept both cards, card networks would not lower their merchant fees. Rather, they would raise merchant fees and lower cardholder fees in order to increase their card transactions.[8] Thus, competition among card networks would likely *increase* the equilibrium merchant fee and the level of payment card rewards.

Fourth, related to the previous observations, whether per transaction costs and fees are fixed (Scenario I and III) or proportional to the transaction value (Scenario II) would significantly affect social welfare. If the former is the case, social welfare with cards is always at least the same as social welfare without cards. While merchant profits are not affected by competition among card networks and their objectives, the surplus of consumers as a whole is higher when card networks are competing (Scenario I). In contrast, if the latter is the case (Scenario II), social welfare with cards is not always higher than or the same as social welfare without cards. Social welfare under profit-maximizing monopoly network is always higher than social welfare without cards, while social welfare under output-maximizing monopoly or competitive card networks could be higher or lower than social welfare without cards. It depends on factors, such as card networks' costs of processing a card transaction, merchants' transactional benefit from cards, and consumers' transactional benefits from cards. Consumer surplus could be higher under output-maximizing card networks than under profit-maximizing card networks. Network competition may improve merchant surplus but it does not improve consumer surplus; rather in some cases it deteriorates consumer surplus.

[8] The card network can increase its merchant fee until one type of merchants would become more profitable by rejecting both cards than rejecting the cards with the higher merchant fees, given the other type of merchants would accept both networks' cards.

3.2 Market Equilibrium under Discriminatory Pricing

Tables 3 and 4 summarize the equilibrium fee structure and the welfare consequences, respectively, when merchants set different prices for card-using consumers and consumers who use an alternative payment method. There are four key observations.

First, under Scenario I, where per transaction costs and fees are fixed regardless of the transaction value, a card fee structure has no effect on the number of card transactions, rather the sum of the two fees—the merchant fee and cardholder fee—affects the number of card transaction. [9] In this case, the card networks would not have an incentive to provide rewards. In contrast, under Scenario II, where per transaction costs and fees are proportional to the transaction value, a card fee structure still affects the number of card transactions. It is likely that the *lower* the merchant fees the more the number of card transactions. Thus, a card network that maximizes its output would increase the cardholder fee rather than providing rewards to card users. Even a card network that maximizes its profit would increase the cardholder fee if more transactions are profitable than higher markups per transaction.

Second, competition among card networks would unlikely influence the equilibrium fee structure. Under Scenario I, since the sum of the two fees determines the number of card transactions, a card network that maximizes its output sets the sum of the two fees at the card network's costs of processing a transaction, regardless of whether it is monopoly or competing. Competition would unlikely influence the equilibrium fee structure under Scenario II, either. Competing card networks would not set their merchant fees lower than the fee set by the output-maximizing monopoly network because it would set its merchant fee as low as possible in the realistic range of the merchant fees.[10]

[9] This is consistent with the neutrality of interchange fees found in Gans and Small (2000).
[10] See Appendix B.

Third, in contrast to the case where merchants set the same prices for all their customers, the fee structure set by a profit-maximizing monopoly network would not lead to the most efficient number of card transactions; rather, it leads to a fewer number of card transactions. The fee structure set by an output-maximizing card network would lead to the most efficient number of card transactions under Scenario I and it would lead the number of card transactions that is more efficient than that the number of card transactions with a profit-maximizing card network under Scenario II.

Fourth, related to the third observation, social welfare is higher with output-maximizing networks than with a profit-maximizing monopoly network. Nevertheless, even a profit-maximizing monopoly network improves social welfare from that without cards at all. This implies social welfare with cards is always higher than social welfare without cards.

3.3 Factors that Drives Payment Card Rewards

The observations in the previous subsections suggest three potential market forces that together may drive payment card rewards. The first is oligopolistic merchants, the second is the merchant's *inability* to set different prices across payment methods, and the third is output-maximizing card network(s).

As mentioned, merchants are unlikely perfectly competitive, but some merchants may be monopolistic at least locally. Having rewards at equilibrium with monopolistic merchants is possible but in rather limited circumstances.[11] In contrast, rewards can exist with oligopolistic merchants in much broader circumstances, as has been shown in the subsection 3.1.

[11] It is easy to show that providing rewards is unlikely to be at equilibrium when merchants are monopolistic *and* consumers make a fixed number of transactions. In this case, monopolistic merchants would not accept cards if the merchant fee exceeds their transactional benefit, and thus card networks cannot provide rewards without incurring losses. When a consumer's demand function for goods is downward-sloping, the equilibrium cardholder fee may potentially be negative. In this case, monopolistic merchants would accept the cards even when the merchant fee exceeds their transactional benefit because accepting the cards may induce a consumer demand curve shift upwards.

As has been shown in the subsection 3.2, when merchants set different prices according to their customers' payment methods, card networks do not have an incentive to provide rewards (Scenario I) or card networks have an incentive to set their merchant fees as low as possible and thus, they set their cardholder fees higher (Scenario II). Therefore, if merchants are allowed to set different prices across payment methods and they actually do, then payment card rewards are less likely to exist at equilibrium.

Output-maximizing card networks are more likely to provide rewards than profit-maximizing card networks. When merchants are oligopolistic and set the same price regardless of their customers' payment methods, a profit-maximizing monopoly card network would not set rewards level that is higher than the most efficient level, while an output-maximizing monopoly network or output-maximizing competing network would set rewards level that is higher than the most efficient level.

The observations also suggest that the rewards level could be higher under competitive card networks and as a result, efficiency could be deteriorated in some circumstances. The previous literature on two-sided markets suggests that competition in a two-sided market does not necessarily improve efficiency but few studies suggested that competition in a two-sided market may *deteriorate* efficiency. In the context of the payment card market, Guthrie and Wright (2007) found that competition among payment card networks would not improve efficiency when all cardholders are singlehoming, while it would improve efficiency as more cardholders become multihoming. The results in this paper are consistent with their results because Guthrie and Wright assumed per transaction costs and fees are fixed. However, when per transaction costs and fees are proportional to the transaction value, competition among card networks would not improve efficiency even if all cardholders are multihoming; rather, it would potentially deteriorate efficiency. In this sense, the paper makes a contribution to the literature by showing a potential negative effect of competition on efficiency in a two-sided market.

4. Conclusion

This paper investigated what market forces drive payment card rewards, when providing rewards may not be the most efficient. The paper identified three factors that together may explain the prevalence of rewards programs in the United States today. They are output-maximizing card networks, oligopolistic merchants and the merchant's inability to set different prices across payment methods. Existence of these three factors in the U.S. payment card market is quite plausible. Although whether per transaction costs and fees are proportional to the transaction value is an empirical question, the theoretical models suggest that when per transaction costs and fees are proportional to the transaction value, the equilibrium social welfare would potentially be lower than the social welfare without cards at all. Consumers as a whole and merchants would be worse off, compared with the economy without cards at all. This may warrant public policy interventions. In this case, enhancing competition among card networks would not improve efficiency but would potentially deteriorate efficiency. The equilibrium fee structures and their welfare consequences may be useful for policymakers when they consider policy options.

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Table 1: Equilibrium Fee Structure: No Discriminatory Pricing

Scenario	Scenario I		
Type of network	Monopoly Network		Competitive Networks
Objective	Profit-max	Output-max	Output-max
Consumer homing	Single	Single	All multihoming
Cardholder fee(f)	$c-\hat{b}_S$	$c-\hat{b}_S-(\overline{b}_B+\hat{b}_S-c)$ or $\underline{b}_B$	$c-\hat{b}_S$
Merchant fee (m)	$\hat{b}_S+(\overline{b}_B+\hat{b}_S-c)/2$	$\hat{b}_S+(\overline{b}_B+\hat{b}_S-c)$ or $\hat{b}_S+(\overline{b}_B-\underline{b}_B)/2$	$\hat{b}_S$
Card transactions	Efficient	More	Efficient

Scenario	Scenario II		
Type of network	Monopoly Network		Competitive Networks
Objective	Profit-max	Output-max	Output-max
Consumer homing	Single	Single	Multihoming
Cardholder fee(f)	$c-\hat{b}_S$	$c-\hat{b}_S-(\overline{b}_B+\hat{b}_S-c)+\varepsilon$ or $\underline{b}_B$	$\underline{b}_B$ or higher
Merchant fee (m)	$\hat{b}_S+(\overline{b}_B+\hat{b}_S-c)/2$	$\hat{b}_S+(\overline{b}_B+\hat{b}_S-c)-\varepsilon$ or $\hat{b}_S+(\overline{b}_B-\underline{b}_B)/2$	$\hat{b}_S+(\overline{b}_B-\underline{b}_B)/2$ or lower
Card transactions	Efficient*	More	More

Scenario	Scenario III		
Type of network	Monopoly Network		Competitive Networks
Objective	Profit-max	Output-max	Output-max
Consumer homing	Single	Single	All multihoming
Cardholder fee(f)	$c-\hat{b}_S$	$c-\hat{b}_S-(\overline{b}_B+\hat{b}_S-c)+\varepsilon$ or $\underline{b}_B$	Not available
Merchant fee (m)	$\hat{b}_S+(\overline{b}_B+\hat{b}_S-c)/2$	$\hat{b}_S+(\overline{b}_B+\hat{b}_S-c)-\varepsilon$ or $\hat{b}_S+(\overline{b}_B-\underline{b}_B)/2$	
Card transactions	Efficient**	More	

Notes: *: The number of card transactions is at the most efficient level; however, due to a higher merchant fee, the equilibrium product price is higher than the most efficient product price. Thus, the social welfare is not maximized at equilibrium.
**: The equilibrium fee structure results in the most efficient marginal card users; however, due to a higher merchant fee, the equilibrium product price is higher than the most efficient product price. Thus, the social welfare is not maximized at equilibrium.

Table 2: Consumer, Merchant, and Network Surplus: No Discriminatory Pricing

Scenario	Scenario I			
Type of network	Monopoly Network		Competitive Networks	No-Card
Objective	Profit-max	Output-max	Output-max	
Consumer homing	Singlehoming	Singlehoming	Multihoming	
Social Welfare	$\tilde{\upsilon} + (\bar{b}_B + \hat{b}_S - c)^2 h/2$	$\tilde{\upsilon}$ or $\tilde{\upsilon} + (\bar{b}_B + \underline{b}_B)/2 + \hat{b}_S - c$	$\tilde{\upsilon} + (\bar{b}_B + \hat{b}_S - c)^2 h/2$	$\tilde{\upsilon}$
Consumer Total	$\tilde{\upsilon} - t$	$\tilde{\upsilon} - t$	$\tilde{\upsilon} - t + (\bar{b}_B + \hat{b}_S - c)^2 h/2$	$\tilde{\upsilon} - t$
Cash user/ Marginal card user	$\tilde{\upsilon} - t - (\bar{b}_B + \hat{b}_S - c)^2 h/2$	$\tilde{\upsilon} - t - 2\{\bar{b}_B - (c - \hat{b}_S)\}^2 h$ or $\tilde{\upsilon} - t - (\bar{b}_B - \underline{b}_B)/2$	$\tilde{\upsilon} - t$	$\tilde{\upsilon} - t$
Card user w/ b_B	$\tilde{\upsilon} - t - (\bar{b}_B + \hat{b}_S - c)^2 h/2$ $+ (b_B + \hat{b}_S - c)$	$\tilde{\upsilon} - t + b_B - 2(c - \hat{b}_S) + \bar{b}_B$ $+ 2\{\bar{b}_B - (c - \hat{b}_S)\}^2 h$ or $\tilde{\upsilon} - t + b_B - (\bar{b}_B + \underline{b}_B)/2$	$\tilde{\upsilon} - t + b_B + \hat{b}_S - c$	Not applicable
Merchant Total	t	t	t	t
Network Total	$(\bar{b}_B + \hat{b}_S - c)^2 h/2$	0 or $(\bar{b}_B + \underline{b}_B)/2 + \hat{b}_S - c$	0	0

Notes: $h = 1/(\bar{b}_B - \underline{b}_B)$. $\tilde{\upsilon} = \upsilon - d - \hat{b}_S$.

Table 2: Consumer, Merchant, and Network Surplus: No Discriminatory Pricing (Cont.)

Scenario	Scenario II			
Type of network	Monopoly Network		Competitive Networks	No-Card
Objective	Profit-max	Output-max	Output-max	
Consumer homing	Singlehoming	Singlehoming	Multihoming	
Social Welfare	Higher "No-card"	Lower than "Monopoly, Profit-Max"; Higher or same as "No-card"	Lower than or same as "Monopoly, Output-Max"; Higher or lower than "No-card"	$\upsilon + \frac{\hat{b}_S t - d}{1-\hat{b}_S}$
Consumer Total	Same as "No-card"	Higher than or same as "Monopoly, Profit-Max"	Lower than or same as "Monopoly, Output-Max"; Higher or lower than "No-card"	$\upsilon - t - \frac{d}{1-\hat{b}_S}$
Cash user/ Marginal card user	Lower than "No-card"	Lower or higher than "Monopoly, Profit-Max"; Lower than "No-card"	Not applicable or Lower than "Monopoly, Output-Max"; Lower than "No-card"	$\upsilon - t - \frac{d}{1-\hat{b}_S}$
Card user w/ b_B	Lower or higher than "No-card" cash user	Lower or higher than "Monopoly, Profit-Max"	Lower or higher than "Monopoly, Output-Max"	Not applicable
Merchant Total	Same as or lower than "No-card"	Higher or lower than "Monopoly, Profit-Max"; Higher or lower than "No-card"	Lower than or same as "Monopoly, Output-Max"; Higher or lower than "No-card"	$(1-\hat{b}_S)t$
Network Total	Higher than "No-card"	Lower than "Monopoly, Profit-Max"; Same as or higher than "No-card"	Same as "No-card"	0

Table 2: Consumer, Merchant, and Network Surplus: No Discriminatory Pricing (Cont.)

Scenario	Scenario III			
Type of network	Monopoly Network		Competitive Networks	No-Card
Objective	Profit-max	Output-max	Output-max	
Consumer homing	Singlehoming	Singlehoming	Multihoming	
Social Welfare	Higher than “No-card”	Higher than “No-card” but lower than “Monopoly Profit-Max”	Not available	$b\{\tilde{a}^2 - 2t\tilde{a} - 2t^2 + \tilde{a}\sqrt{4t^2 + \tilde{a}^2}\}$
Consumer Total	Slightly higher than “No-card”	Slightly higher than “Monopoly, Profit-Max”		$b\{\tilde{a}^2 - 2t\tilde{a} + 2t^2 + (\tilde{a} - 2t)\sqrt{4t^2 + \tilde{a}^2}\}$
Cash user/ Marginal card user	Lower than “No-card”	Lower than “Monopoly, Profit-Max”		$b\{\tilde{a}^2 - 2t\tilde{a} + 2t^2 + (\tilde{a} - 2t)\sqrt{4t^2 + \tilde{a}^2}\}$
Card user w/ b_B	Lower or higher than “No-card” cash user	Lower or higher than “Monopoly, Profit-Max”		Not applicable
Merchant Total	Slightly lower than “No-card”	About the same as “Monopoly, Profit-Max”		$2bt\{\sqrt{4t^2 + \tilde{a}^2} - 2t\}$
Network Total	Higher than “No-card”	Same as “No-card”		0

Note: $\tilde{a} = a/b - d - \hat{b}_S$.

Table 3: Equilibrium Fee Structure: Discriminatory Pricing

Scenario	Scenario I		
Type of network	Monopoly Network		Competitive Networks
Objective	Profit-max	Output-max	Output-max
Consumer homing	Single	Single	All multihoming
Marginal card user (b_B^m)	$c-\hat{b}_S+\{1-H(b_B^m)\}/h(b_B^m)$	$c-\hat{b}_S$	
Cardholder fee (f)	$c+\{1-H(b_B^m)\}/h(b_B^m)$	c	
Merchant fee (m)			
Card transactions	Fewer	Efficient	

Scenario	Scenario II	
Type of network	Monopoly Network	
Objective	Profit-max	Output-max
Consumer homing	Single	Single
Marginal card user (b_B^m)	$b_B^m > c-\hat{b}_S$	Higher or lower than $c-\hat{b}_S$
Cardholder fee (f)	can be higher than $\overline{b}_B$ or lower than $\underline{b}_B$	as high as possible
Merchant fee (m)	Either as high as or as low as possible	as low as possible (likely a negative fee)
Card transactions	Fewer†	More or fewer†

Notes: †: The number of card transactions is compared with the most efficient number of card transactions when product prices for card-using consumers and non-card-using consumers are the *same*. Thus, the number of card transactions is not necessarily the most efficient when merchants are allowed to set different prices for these two groups of consumers.
Equilibrium fee structure under Scenario III is not available.

Table 4: Consumer, Merchant, and Network Surplus: Discriminatory Pricing

Type of merchants	Scenario I			
Type of network	Monopoly Network		Competitive Networks	No-Card
Objective	Profit-max	Output-max	Output-max	
Consumer homing	Singlehoming	Singlehoming	Multihoming	
Social Welfare	$\tilde{\upsilon} + 3(\bar{b}_B + \hat{b}_S - c)^2 h/8$	$\tilde{\upsilon} + (\bar{b}_B + \hat{b}_S - c)^2 h/2$		$\tilde{\upsilon}$
Consumer Total	$\tilde{\upsilon} - t + (\bar{b}_B + \hat{b}_S - c)^2 h/8$	$\tilde{\upsilon} - t + (\bar{b}_B + \hat{b}_S - c)^2 h/2$		$\tilde{\upsilon} - t$
Cash user/ Marginal card user	$\tilde{\upsilon} - t$	$\tilde{\upsilon} - t$		$\tilde{\upsilon} - t$
Card user w/ b_B	$\tilde{\upsilon} - t + b_B + \hat{b}_S$ $-\{(c - \hat{b}_S) + \bar{b}_B\}/2$	$\tilde{\upsilon} - t + b_B + \hat{b}_S - c$		Not applicable
Merchant Total	t	t		t
Network Total	$(\bar{b}_B + \hat{b}_S - c)^2 h/4$	0		0

Notes: $h = 1/(\bar{b}_B - \underline{b}_B)$. $\tilde{\upsilon} = \upsilon - d - \hat{b}_S$.

Table 4: Consumer, Merchant, and Network Surplus: Discriminatory Pricing (Cont.)

Type of merchants	Scenario II		
Type of network	Monopoly Network		No-Card
Objective	Profit-max	Output-max	
Consumer homing	Singlehoming	Singlehoming	
Social Welfare	Higher than “No-Card”	Higher than “Monopoly, Profit-Max”	$\upsilon - \hat{b}_S t - d/(1-\hat{b}_S)$
Consumer Total	Higher than “No-Card”	Higher than “Monopoly, Profit-Max”	$\upsilon - t - d/(1-\hat{b}_S)$
Cash user/ Marginal card user	Same as “No-card”	Same as “No-card”	$\upsilon - t - d/(1-\hat{b}_S)$
Card user w/ b_B	Higher than “No-Card” cash user	Higher than “No-Card” cash user and “Monopoly, Profit-Max”	Not applicable
Merchant Total	Higher than “No-Card”	Higher than “Monopoly, Profit-Max”	$(1-\hat{b}_S)t$
Network Total	Higher than “No-Card”	0	0

Appendix A: Equilibrium Fee Structure

1: No-Discriminatory Pricing

Scenario I: Fixed Demand and Flat Costs and Fees

When both Merchants A and B accept the cards, they earn the same profit of $t/2$. Furthermore, as long as each merchant takes the same strategy as its rival's, each earns the same profit of $t/2$.

Consider the highest merchant fee the monopoly card network can charge to the merchants. Suppose Merchant A accepts the cards but Merchant B does not. Each merchant's profit is:

$$\pi_A = \frac{1}{2t}[\{t + \frac{1-H(b_B^m)}{3}(\hat{b}_B - f + \hat{b}_S - m)\}^2 - H(b_B^m)(1-H(b_B^m))(\hat{b}_B - f)(m - \hat{b}_S)],$$

$$\pi_B = \frac{1}{2t}\{t - \frac{1-H(f)}{3}(\hat{b}_B - f + \hat{b}_S - m)\}^2,$$

where $\hat{b}_B$ is the average transactional benefit from cards among card-using consumers. When merchant fee is $m > \hat{b}_S + \hat{b}_B - f$, Merchant B rejects the cards, given Merchant A accepts the cards. Given Merchant B rejects the cards, Merchant A rejects cards, too. When merchant fee is $m \le \hat{b}_S + \hat{b}_B - f$, Merchant B does not reject cards, given Merchant A accepts the cards. Thus, the highest merchant fee the monopoly card network can charge is:

$$m = \hat{b}_S + \hat{b}_B - f.$$

<u>Profit-maximizing monopoly network</u>

The profit-maximizing monopoly network solves the following problem:

Max $\Pi = (f + m - c)(1 - H(f))$, s.t. $m \le \hat{b}_S + \hat{b}_B - f$.

The equilibrium fee structure is:

$$m = \hat{b}_S + \hat{b}_B - f = \hat{b}_S + \frac{\overline{b}_B - (c - \hat{b}_S)}{2}, \text{ and}$$

$$f = c - \hat{b}_S .$$

<u>Output-maximizing monopoly network</u>

The output-maximizing monopoly network solves the following problem:

Max $1 - H(f)$, s.t. $f + m - c \geq 0$ and $m \leq \hat{b}_S + \hat{b}_B - f$.

When $c - \hat{b}_S$ is large enough (i.e., $c - \hat{b}_S \geq (\overline{b}_B + \underline{b}_B)/2$), both constraints bind. The equilibrium fee structure is:

$$m = \hat{b}_S + (\overline{b}_B + \hat{b}_S - c), \text{ and}$$

$$f = (c - \hat{b}_S) - (\overline{b}_B + \hat{b}_S - c) .$$

However, if $c - \hat{b}_S$ is small (i.e., $c - \hat{b}_S < (\overline{b}_B + \underline{b}_B)/2$), then the cardholder fee reaches the consumers' lowest transactional benefit from cards before the budget constraint binds. The equilibrium fee structure in this case is:

$$m = \hat{b}_S + \frac{\overline{b}_B - \underline{b}_B}{2}, \text{ and}$$

$$f = \underline{b}_B .$$

<u>Output-maximizing competitive networks with all multihoming cardholders</u>

Suppose two competing card networks, Network 1 and Network 2, are symmetric in terms of their costs of processing card transactions and cardholder bases. The number of card transactions increases as the cardholder fee decreases. Both networks reduce their markups to lower their card holder fees, which means their total fee revenues per transaction is reduced to their costs per transaction: $f_1 + m_1 = f_2 + m_2 = c$. Suppose Network 1 sets the higher cardholder fee than Network 2 ($f_1 > f_2$). If both merchants accept Network 2's card (Card 2), then consumers whose transactional benefit from cards exceeds f_2 use Card 2 only. Merchants A and B earn the same profit of $t/2$. If Merchant A accepts both Cards 1 and 2 and Merchant B accepts Card 1 only, then their profits are:

$$\pi_A = \frac{1}{2t}[\{t + \frac{H_1 - H_2}{3}(\tilde{b}_B + \hat{b}_S - f_2 - m_2) + \frac{1-H_1}{3}(f_1 + m_1 - f_2 - m_2)\}^2$$
$$- H_2(m_2 - \hat{b}_S)\{(H_1 - H_2)(\tilde{b}_B - f_2) + (1-H_1)(f_1 - f_2)\}],$$

$$\pi_B = \frac{1}{2t}[\{t - \frac{H_1 - H_2}{3}(\tilde{b}_B + \hat{b}_S - f_2 - m_2) - \frac{1-H_1}{3}(f_1 + m_1 - f_2 - m_2)\}^2$$
$$+ (1-H_1)(m_1 - \hat{b}_S)\{(H_1 - H_2)(f_1 - \tilde{b}_B) + H_2(f_1 - f_2)\}],$$

where $H_1 = H(f_1)$, $H_2 = H(f_2)$, and $\tilde{b}_B = \int_{f_2}^{f_1} b_B h(b_B) db_B /(H(f_1) - H(f_2))$. By definition, $f_1 > \tilde{b}_B > f_2$. If Network 2 sets $m_2 = \hat{b}_S$ and $f_2 = c - \hat{b}_S$, rejecting Card 2 makes a merchant worse off, given the other merchant accepts Card 2. It is also true that if Network 1 sets $m_1 = \hat{b}_S$ and $f_1 = c - \hat{b}_S$, accepting Card 2 makes a merchant worse off, given the other merchant rejects Card 2. The equilibrium fee structure is:

$$m_1 = m_2 = \hat{b}_S,$$

$$f_1 = f_2 = c - \hat{b}_S.$$

Scenario II: Fixed Demand and Proportional Costs and Fees

In contrast to the case where per transaction costs and fees are fixed, the Hotelling merchant's profits are affected by the card fee structure and transactional benefit from cards, even when each merchant takes the same strategy as its rival's. When both merchants reject cards, each of them sets its price at:

$$p = t + \frac{d}{1 - b_S},$$

And each earns profit π^0:

$$2t\pi^0 = (1 - \hat{b}_S)t^2.$$

When both merchants accept cards, each sets its price at:

$$p = \frac{\{(1-\hat{b}_S)H + (1-m)(1-H)\}t + \{H + (1+f-\hat{b}_B)(1-H)\}d}{(1-\hat{b}_S)H + (1+f-\hat{b}_B)(1-m)(1-H)},$$

and each earns profit π^C:

$$2t\pi^C = \frac{\{(1-\hat{b}_S) - (m-\hat{b}_S)(1-H)\}^2 t^2 - (m-\hat{b}_S)(\hat{b}_B - f)(1-H)Htd}{(1-\hat{b}_S) - (m-\hat{b}_S)(1-H) - (1-m)(\hat{b}_B - f)(1-H)},$$

where $H = H(f)$.

Consider the highest merchant fee the monopoly card network can charge to the merchants. Suppose Merchant A accepts the cards but Merchant B does not. Each merchant sets its price at:

$$p_A = \frac{1}{A}[\{3(1-\hat{b}_S) - 3(m-\hat{b}_S)(1-H)\}t$$

$$+\{3(1-\hat{b}_S) - (m-\hat{b}_S)(1-H) - 2(1-\hat{b}_S)(\hat{b}_B - f)(1-H)\}d/(1-\hat{b}_S)]$$

$$p_B = \frac{1}{A}[\{3(1-\hat{b}_S) - 3(m-\hat{b}_S)(1-H) - (3-2m-\hat{b}_S)(\hat{b}_B - f)(1-H) + (m-\hat{b}_S)(\hat{b}_B - f)(1-H)^2\}t$$

$$+\{3(1-\hat{b}_S) - 2(m-\hat{b}_S)(1-H) - (4-2m-2\hat{b}_S)(\hat{b}_B - f)(1-H) + (1-\hat{b}_S)(\hat{b}_B - f)^2(1-H)^2\}$$

$$\times d/(1-\hat{b}_S)]$$

where $A = 3\{(1-\hat{b}_S) - (m-\hat{b}_S)(1-H)\} - \{(3-4m+\hat{b}_S) + (m-\hat{b}_S)(1-H)\}(\hat{b}_B - f)(1-H)$. And each merchant earns the following profit, respectively,:

$$2t\pi_A = \{(1-\hat{b}_S)p_A - d\}(p_B - p_A + t)H + \{(1-m)p_A - d\}\{p_B - p_A + t + (\hat{b}_B - f)p_A\}(1-H)$$

$$2t\pi_B = \{(1-\hat{b}_S)p_B - d\}(p_A - p_B + t)H + \{(1-\hat{b}_S)p_B - d\}\{p_A - p_B + t - (\hat{b}_B - f)p_B\}(1-H)$$

It is difficult (if not impossible) to analytically obtain the highest merchant fee that monopoly card networks can charge. However, numerical examples suggest that the highest merchant fee is slightly less than the sum of the merchant's transactional benefit and the average consumer's net transactional benefit, i.e., $\overline{m} \cong \hat{b}_S + \hat{b}_B - f$.

<u>Profit-maximizing monopoly network</u>

The profit-maximizing monopoly network solves the following problem:

Max $\Pi = p(f + m - c)(1 - H(f))$,

s.t. $m \le \overline{m}$ and

$$p = \frac{\{(1-\hat{b}_S)H + (1-m)(1-H)\}t + \{H + (1 + f - \hat{b}_B)(1-H)\}d}{(1-\hat{b}_S)H + (1 + f - \hat{b}_B)(1-m)(1-H)}.$$

It is difficult to analytically solve the equilibrium fee structure; however, the numerical examples suggest that the equilibrium fee structure is:

$$m = \overline{m} \cong \hat{b}_S + \hat{b}_B - f = \hat{b}_S + \frac{\overline{b}_B - (c - \hat{b}_S)}{2}, \text{ and}$$

$$f \cong c - \hat{b}_S .$$

<u>Output-maximizing monopoly network</u>

The output-maximizing monopoly network solves the following problem:

Max $1 - H(f)$, s.t. $f + m - c \ge 0$ and $m = \overline{m}$.

If $c - \hat{b}_S$ is large enough (i.e., $c - \hat{b}_S \ge (\overline{b}_B + \underline{b}_B)/2$), then two constraints bind. The equilibrium fee structure is:

$$m = \overline{m} \cong \hat{b}_S + (\overline{b}_B + \hat{b}_S - c), \text{ and}$$

$$f = c - \hat{b}_S - (\overline{b}_B + \hat{b}_S - c).$$

If $c - \hat{b}_S$ is small (i.e., $c - \hat{b}_S < (\overline{b}_B + \underline{b}_B)/2$), then the cardholder fee reaches the consumers' lowest transactional benefit from cards before the budget constraint binds. The equilibrium fee structure in this case is:

$$m = \hat{b}_S + \frac{\overline{b}_B - \underline{b}_B}{2} \text{, and}$$

$$f = \underline{b}_B.$$

Output-maximizing competitive networks with all multihoming cardholders

As discussed in Scenario I , two competing symmetric card networks reduce their markup to zero, i.e., $f_1 + m_1 = f_2 + m_2 = c$. Suppose Network 1 sets the higher cardholder fee than Network 2 ($f_1 > f_2$), and Merchant A accepts both Cards 1 and 2 and Merchant B accepts Card 1 only. The equilibrium product prices in this case are:

$$p_A = \frac{1}{4K_1L_1 - K_2L_2}\{(K_2L_3 + 2K_3L_1)t + (K_2L_4 + 2K_4L_1)d\},$$

$$p_B = \frac{1}{4K_1L_1 - K_2L_2}\{(2K_1L_3 + K_3L_2)t + (2K_1L_4 + K_4L_2)d\},$$

where

$$K_1 = (1 - m_2)(1 + f_2)(1 - H_2) + (1 - \hat{b}_S)H_2 - (1 - m_2)\int_{f_2}^{\overline{b}_B} b_B h(b_B)db_B;$$

$$K_2 = (1 - m_2)(1 - H_2) + (1 - m_2)f_1(1 - H_1) + (1 - \hat{b}_S)H_2 - (1 - m_2)\int_{f_1}^{\overline{b}_B} b_B h(b_B)db_B;$$

$$K_3 = (1 - m_2)(1 - H_2) + (1 - \hat{b}_S)H_2;$$

$$K_4 = (1 + f_2)(1 - H_2) + H_2 - \int_{f_2}^{\overline{b}_B} b_B h(b_B)db_B;$$

$$L_1 = (1-m_1)(1+f_1)(1-H_1) + (1-\hat{b}_S)H_1 - (1-m_1)\int_{f_1}^{\bar{b}_B} b_B h(b_B)db_B;$$

$$L_2 = (1-m_1)(1+f_2)(1-H_2) + (1-\hat{b}_S)f_2(H_1-H_2) + (1-\hat{b}_S)H_1 - (1-m_1)\int_{f_1}^{\bar{b}_B} b_B h(b_B)db_B$$
$$-(1-\hat{b}_S)\int_{f_2}^{f_1} b_B h(b_B)db_B;$$

$L_3 = (1-m_1)(1-H_1) + (1-\hat{b}_S)H_1$; and

$$L_4 = (1+f_1)(1-H_1) + H_1 - \int_{f_1}^{\bar{b}_B} b_B h(b_B)db_B.$$

Since analytical solutions are difficult to obtain, we use numerical examples to examine the equilibrium. Suppose Network 2 sets its cardholder fee at $f_2 = c - \hat{b}_S$ and Network 1 sets its cardholder fee slightly higher, i.e., $f_1 = c - \hat{b}_S + \varepsilon$, where $\varepsilon > 0$. Merchant B's profit is likely higher than the profit it would have accepted Card 2 and the profit it would have rejected both cards. Thus, given the rival merchant accepts Card 2, accepting Card 1 only is the most profitable than any other strategies, such as accepting Card 2 and rejecting both Cards 1 and 2. In contrast to Scenario I, Merchant A's profit is also likely higher than that when both merchants accept Card 2. Thus, given the rival merchant accepts Card 1 only, accepting Card 2 is the most profitable strategy.

In fact, Network 2's number of card transactions is greater than Network 1's. Knowing one of the two merchants accept Card 2, Network 2 has no incentive to reduce its merchant fee; rather, it would lower its cardholder fee further by raising its merchant fee. Although Network 1 would be able to make at least one merchant accept Card 1 only by reducing its merchant fee, it would have a smaller number of transactions than that when it sets the same merchant fee (thus cardholder fee) as Network 2's. As a result, both networks have an incentive to reduce their cardholder fees and raise their merchant fees. When the lowest transactional benefit for consumers is relatively high, both networks set their cardholder fees at the lowest transactional benefit. Thus, the equilibrium fee structure is:

$$m_1 = m_2 = \hat{b}_S + \frac{\overline{b}_B - \underline{b}_B}{2}, \text{ and}$$

$$f_1 = f_2 = \underline{b}_B .$$

However, when the lowest transactional benefit for consumers is relatively low, the above would not be equilibrium fee structure. When both networks set their merchant fees high enough, Merchant B's most profitable strategy changes from accepting Card 1 only to rejecting both cards. At those merchant fees, given Merchant B rejects both cards, Merchant A's most profitable strategy is rejecting both cards. Thus, both networks may not set their merchant fees at such a high level. The threshold level of the merchant fees depends on other variables, but it is higher than the equilibrium merchant fee set by output-maximizing monopoly network.

$$m = \overline{\overline{m}} > \hat{b}_S + (\overline{b}_B + \hat{b}_S - c), \text{ and}$$

$$f < c - \hat{b}_S - (\overline{b}_B + \hat{b}_S - c).$$

Scenario III: Downward-Sloping Demand Curve and Flat Costs and Fees

In contrast to the previous two scenarios, where consumers make a fixed number of purchases and thus transactions, it is difficult to obtain analytical solution when each consumer's demand function is downward-sloping. Even equilibrium product prices are difficult to obtain when two merchants take different strategies. We are able to predict what the equilibrium fee structure looks like by making an additional assumption when cards are provided by monopoly networks; however, in order to predict the equilibrium fee structure when cards are provided by competing networks, we need to use more sophisticated simulation methods than just numerical examples used in this paper. Therefore, here we only examine the equilibrium fee structure when cards are provided by monopoly networks.

We assume that if one of the two merchants rejects the cards, the card-rejecting merchant changes its product price, but the card-accepting merchant keeps its price at the same price level where both merchants accept the cards. The card-rejecting merchant's profit derived under this assumption is likely higher than the profit when both merchants change their product price. Thus, the highest merchant fee the monopoly networks charge ($\overline{\overline{m}}$) is likely lower than the highest merchant fee they charge ($\overline{m}$) when both merchants adjust their product prices. As long as monopoly card networks set the merchant fee at $\overline{\overline{m}}$, both merchants accept the cards. The product price they set is:

$$p^C = d + \hat{b}_S + \frac{t\{D(p^C) + b(\hat{b}_B - f)(1-H)\} + (m - \hat{b}_S)(1-H)\{D(p^C) + b(\hat{b}_B - f) + tb\}}{D(p^C) + b(\hat{b}_B - f)(1-H) + tb},$$

where $D(p^C) = a - bp^C$.

<u>Profit-maximizing monopoly network</u>

$$\text{Max } \Pi = (f + m - c)\int_f^{\bar{b}_B} \{a - bp^C - bf + bb_B\} h(b_B) db_B$$

s.t. $m \le \overline{\overline{m}}$ and

$$p^C = d + \hat{b}_S + \frac{t\{D(p^C) + b(\hat{b}_B - f)(1-H)\} + (m - \hat{b}_S)(1-H)\{D(p^C) + b(\hat{b}_B - f) + tb\}}{D(p^C) + b(\hat{b}_B - f)(1-H) + tb}.$$

Numerical examples suggest that the equilibrium fee structure is:

$$m = \overline{\overline{m}} \approx \hat{b}_S + \hat{b}_B - f = \hat{b}_S + \frac{\bar{b}_B - (c - \hat{b}_S)}{2}, \text{ and}$$

$$f \cong c - \hat{b}_S.$$

Output-maximizing monopoly network

$$\text{Max } Q = \int_f^{\bar{b}_B} \{a - bp^C - bf + bb_B\} h(b_B) db_B \ ,$$

s.t. $m \le \overline{\overline{m}}$, $f + m \ge c$, and

$$p^C = d + \hat{b}_S + \frac{t\{D(p^C) + b(\hat{b}_B - f)(1-H)\} + (m - \hat{b}_S)(1-H)\{D(p^C) + b(\hat{b}_B - f) + tb\}}{D(p^C) + b(\hat{b}_B - f)(1-H) + tb}.$$

Numerical examples suggest that it is quite likely to have corner solutions for this problem. When $m = \overline{\overline{m}}$ and $f + m = c$, $\hat{b}_B \cong c - \hat{b}_S$. By definition, $f < \hat{b}_B$, and thus the equilibrium cardholder fee is likely lower than the efficient cardholder fee. The merchant fee is higher than the efficient one, so is the product price.

2. Discriminatory Pricing

Scenario I: Fixed Demand and Flat Costs and Fees

When both Merchants A and B accept the cards, they set the price for cash users at $p^{cash} = t + d + \hat{b}_S$ and the price for card users at $p^{card} = t + d + m$. The marginal card user is, therefore:

$$b_B^m = f + m - \hat{b}_S .$$

Notice that marginal card user is determined by the total fee, not by the fee structure. It is easy to show that rejecting the cards always makes a merchant worse off, given the other merchant accepts the cards.

Profit-maximizing monopoly network

$$\text{Max } \Pi = (b_B^m + \hat{b}_S - c)(1 - H(b_B^m)) .$$

The equilibrium marginal card user and total fee are:

$$b_B^m = c - \hat{b}_S + \frac{1 - H(b_B^m)}{h(b_B^m)} \text{ , and}$$

$$f + m = c + \frac{1 - H(b_B^m)}{h(b_B^m)}.$$

<u>Output-maximizing monopoly and output-maximizing competing networks</u>

Since the total fee determines the marginal card user, the problems of output-maximizing networks become the same for monopoly and competing networks.

Max $1 - H(f)$, s.t. $f + m - c \geq 0$.

The equilibrium marginal card user and total card fee are:

$$b_B^m = c - \hat{b}_S \text{ , and}$$

$$f + m = c \text{ .}$$

Scenario II: Fixed Demand and Proportional Costs and Fees

When both Merchants A and B accept the cards, they set the price for cash users at $p^{cash} = t + \frac{d}{1 - \hat{b}_S}$ and the price for card users at $p^{card} = \frac{t}{1 + f - \hat{b}_B} + \frac{d}{1 - m}$. The average card user's transactional benefit from cards is defined as $\hat{b}_B = \frac{\int_{b_B^m}^{\bar{b}_B} b_B h(b_B) db_B}{1 - H(b_B^m)}$. The marginal card user is, therefore:

$$b_B^m = 1 + f - \frac{(1 + f - \hat{b}_B)(1 - m)\{t + d/(1 - \hat{b}_S)\}}{(1 - m)t + (1 + f - \hat{b}_B)d}.$$

Notice that, unlike in the case of flat per transaction costs and fees, the card fee structure still affects the marginal card user.

If Merchant A accepts the cards but Merchant B does not, then the marginal card user is determined by Merchant A's product prices. While Merchant B has one price, p_B for cash users, Merchant A has two prices: one for cash users: p_A^{cash} , and one for card users: p_A^{card} . These prices are:

$$p_A^{cash} = t + \frac{d}{6}\{\frac{5+H}{1-\hat{b}_S} + \frac{(1+f-\hat{b}_B)(1-H)}{1-m}\},$$

$$p_A^{card} = [t + \frac{d}{6}\{\frac{2+H}{1-\hat{b}_S} + \frac{(1+f-\hat{b}_B)(4-H)}{1-m}\}]/(1+f-\hat{b}_B), \text{ and}$$

$$p_B = t + \frac{d}{3}\{\frac{2+H}{1-\hat{b}_S} + \frac{(1+f-\hat{b}_B)(1-H)}{1-m}\},$$

where $H = H(b_B^m)$. The marginal card user is, therefore, defined as:

$$b_B^m = 1 + f - (1+f-\hat{b}_B)\frac{6(1-\hat{b}_S)(1-m)t + d\{(1-m)(5+H) + (1+f-\hat{b}_B)(1-\hat{b}_S)(1-H)\}}{6(1-\hat{b}_S)(1-m)t + d\{(1-m)(2+H) + (1+f-\hat{b}_B)(1-\hat{b}_S)(4-H)\}}.$$

It is difficult to obtain the highest merchant fee that monopoly card networks can charge. Numerical examples suggest that the highest merchant fee is unlikely to exist. A merchant's best strategy is likely to accepting the card regardless of its' rival's strategy and the merchant fee. In fact, as long as a merchant's transactional benefit from a card is positive, the lower the merchant fees, the greater the output (i.e., more consumers use cards instead of using cash). Therefore, output-maximizing monopoly network(s) would *lower* the merchant fee and *raise* the cardholder fee. The *lowest* merchant fee the output-maximizing monopoly network could charge is the fee that makes all consumers use cards. Depending on the other factors, such as merchant transactional benefit from a card, card network's costs of processing a transaction, consumers' transactional benefits from a card, this lowest merchant fee could be unrealistically low. (For example, when $\hat{b}_S$ =0.5%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; and d =90, m =-541%, or the merchant receives 541 percent of rewards on its product price for card using customers).

Whether a profit-maximizing monopoly network would raise or lower the merchant fee depends on the factors mentioned above. According to numerical examples, for a reasonable range of the merchant fee (say from -10 percent to 10 percent), in some cases, the card network's profit monotonically increases; in some cases, it monotonically decreases; and in other cases, it first decreases and then increases as the merchant fee increases. Generally, the higher the merchant fee, the lower the cardholder fee. Thus, the merchant fee set by a profit-maximizing monopoly network is either the highest or the lowest in the range.

Scenario III: Downward-Sloping Demand Curve and Flat Costs and Fees

Since it is extremely difficult to obtain analytical solution in this case, we will leave it for future research.

Appendix B: Numerical Examples

Scenario II: Fixed Demand and Proportional Costs and Fees

1. No-Discriminatory Pricing

The following parameter values are assumed: c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90, unless they are specifically mentioned.

The maximum merchant fees that monopoly card networks can charge

$\hat{b}_S$	0.5%				
f	-2%	-1%	0%	1%	2%
$\overline{m}$	2.49%	1.99%	1.49%	0.99%	0.5%
$\hat{b}_S + \hat{b}_B - f$	2.5%	2%	1.5%	1%	0.5%

$\hat{b}_S$	1%				
f	-2%	-1%	0%	1%	2%
$\overline{m}$	2.98%	2.48%	1.99%	1.49%	1%
$\hat{b}_S + \hat{b}_B - f$	3%	2.5%	2%	1.5%	1%

$\hat{b}_S$	1.5%				
f	-2%	-1%	0%	1%	2%
$\overline{m}$	3.47%	2.98%	2.48%	1.99%	1.5%
$\hat{b}_S + \hat{b}_B - f$	3.5%	3%	2.5%	2%	1.5%

Fee Structure

Profit-maximizing monopoly network

$\hat{b}_S$	0.5%			1.5%		
f	0.49%	**0.5%**	0.51%	-0.51%	**-0.5%**	-0.49%
$\overline{m}$	1.252%	**1.247%**	1.242%	2.738%	**2.734%**	2.728%
p	100.738	**100.735**	100.731	102.173	**102.167**	102.160
$1-H$	0.3775	**0.375**	0.3725	0.6275	**0.625**	0.6225
Π	0.28217	**0.28218**	0.28217	0.7873	**0.7880**	0.7873

Output-maximizing monopoly network

$\hat{b}_S$	0.5%		1%		1.5%
f	-1%	**-0.99%**	-1.97%	**-1.96%**	**-2%**
$\overline{m}$	2%	**1.99%**	2.965%	**2.96%**	**3%**
p	101.593	**101.585**	102.937	**102.926**	**102.988**
$1-H$	0.75	**0.7475**	0.9925	**0.99**	**1**
Π	-0.0038	**0**	-0.0051	**0**	**0**

Output-maximizing competing networks

$\hat{b}_S$		0.5%				
		monopoly		**Equilibrium**		
f_1		-0.99%	-0.99%	-1.29%	-1.30%	-1.30%
f_2		-0.99%	-1.00%	-1.30%	-1.30%	-1.31%
Both merchants accept Card 2	π_B	**4.973**	**4.973**	**4.966**	**4.966**	**4.966**
	S_1	0.374	0	0	0.412	0
	S_2	0.374	0.75	0.824	0.412	0.828
	p	101.585	101.596	101.956	101.956	101.969
Merchant A accepts Card 2 Merchant B accepts Card 1 only	π_B	**4.973**	**5.017**	**5.011**	**4.966**	**5.011**
	S_1	0.374	0.371	0.408	0.412	0.409
	S_2	0.374	0.378	0.416	0.412	0.417
	$\hat{p}$	101.585	101.721	102.081	101.956	102.094
Merchant A accepts Card 2 Merchant B rejects both cards	π_B	**4.973**	**4.974**	**5.011**	**5.011**	**5.013**
	S_1	0	0	0	0	0
	S_2	0.748	0.75	0.824	0.824	0.828
	$\hat{p}$	101.017	101.022	101.196	101.196	101.205

$\hat{b}_S$		1.0%		
		monopoly		**Equilibrium**
f_1		-1.96%	-1.96%	**-1.998%**
f_2		-1.96%	-1.97%	**-2.00%**
Both merchants accept Card 2	π_B	**4.950**	**4.950**	**4.949**
	S_1	0.495	0	0
	S_2	0.495	0.993	1
	p	102.926	102.941	102.988
Merchant A accepts Card 2 Merchant B accepts Card 1 only	π_B	**4.950**	**4.995**	**4.958**
	S_1	0.495	0.491	0.499
	S_2	0.495	0.500	0.501
	$\hat{p}$	102.926	103.067	103.113
Merchant A accepts Card 2 Merchant B rejects both cards	π_B	**4.950**	**4.951**	**4.956**
	S_1	0	0	0
	S_2	0.99	0.993	1
	$\hat{p}$	101.917	101.925	101.948

Equilibrium Fees and Welfares

In the following table, the price, consumer surplus, merchant surplus, and social welfare in an economy without payment cards are used to calculate the percent change in price, consumer surplus, merchant surplus, and social welfare.

$\hat{b}_S$ =0.5%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	0.5	0.5	-0.99	-1.30
Merchant fee rate (%)	0.5	1.25	1.99	2.30
Network profit margin	0	0.75	0	0
% change in Price	0.03	0.28	1.13	1.61
% change in Consumer Surplus	0.25	0.00	0.00	-0.24
% change in Merchant Surplus	0.28	-0.01	-0.05	1.11
% change in Social Welfare	0.31	0.31	0.00	-0.14
$\hat{b}_S$ =1%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	0	0	-1.96	-2.00
Merchant fee rate (%)	1.0	1.99	2.96	3.00
Network profit margin	0	0.99	0	0
% change in Price	0.05	0.50	2.00	2.18
% change in Consumer Surplus	0.45	0.00	0.00	-0.15
% change in Merchant Surplus	0.50	0.00	0.00	1.29
% change in Social Welfare	0.55	0.55	0.00	-0.02
$\hat{b}_S$ =1.5%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	-0.5	-0.5	-2.00	-2.00
Merchant fee rate (%)	1.50	2.73	3.00	3.00
Network profit margin	0	1.23	0	0
% change in Price	0.08	0.79	1.60	1.60
% change in Consumer Surplus	0.70	0.00	0.44	0.44
% change in Merchant Surplus	0.79	-0.04	0.49	0.49
% change in Social Welfare	0.86	0.86	0.54	0.54

$\hat{b}_S$ =0.5%; c =0.5%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	0	0	-1.98	-2.00
Merchant fee rate (%)	0.5	1.50	2.48	2.50
Network profit margin	0	1.00	0	0
% change in Price	0.05	0.5	2.02	2.17
% change in Consumer Surplus	0.45	0.00	0.00	-0.14
% change in Merchant Surplus	0.50	-0.03	0.00	1.29
% change in Social Welfare	0.55	0.55	0.00	-0.01
$\hat{b}_S$ =1%; c =0.5%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	-0.5	-0.5	-2.00	-2.00
Merchant fee rate (%)	1.0	2.24	2.50	2.50
Network profit margin	0	1.24	0	0
% change in Price	0.08	0.79	1.59	1.59
% change in Consumer Surplus	0.70	0.00	0.44	0.44
% change in Merchant Surplus	0.79	-0.04	0.49	0.49
% change in Social Welfare	0.87	0.86	0.55	0.55
$\hat{b}_S$ =1.5%; c =0.5%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	-1.00	-1.00	-2.00	-2.00
Merchant fee rate (%)	1.50	1.98	2.50	2.50
Network profit margin	0	1.48	0	0
% change in Price	0.11	1.14	1.13	1.13
% change in Consumer Surplus	1.01	0.00	0.90	0.90
% change in Merchant Surplus	1.14	-0.05	1.00	1.00
% change in Social Welfare	1.25	1.24	1.10	1.10

$\hat{b}_S$ =0.5%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-1%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	0.50	0.50	-0.98	-1.00
Merchant fee rate (%)	0.50	1.25	1.98	2.00
Network profit margin	0	0.75	0	0
% change in Price	0.04	0.38	1.50	1.70
% change in Consumer Surplus	0.34	0.00	0.00	-0.18
% change in Merchant Surplus	0.38	-0.01	0.00	1.72
% change in Social Welfare	0.42	0.42	0.00	-0.01
$\hat{b}_S$ =1%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-1%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	0.00	0.00	-1.00	-1.00
Merchant fee rate (%)	1.00	1.99	2.00	2.00
Network profit margin	0	0.99	0	0
% change in Price	0.07	0.67	1.07	1.07
% change in Consumer Surplus	0.60	0.00	0.45	0.45
% change in Merchant Surplus	0.67	-0.02	0.50	0.50
% change in Social Welfare	0.74	0.74	0.55	0.55
$\hat{b}_S$ =1.5%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-1%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	-0.50	-0.50	-1.00	-1.00
Merchant fee rate (%)	1.50	2.73	2.00	2.00
Network profit margin	0	1.23	0	0
% change in Price	0.10	1.05	0.61	0.61
% change in Consumer Surplus	0.94	0.00	0.90	0.90
% change in Merchant Surplus	1.05	-0.02	1.01	1.01
% change in Social Welfare	1.15	1.15	1.10	1.10

$\hat{b}_S$ =0.5%; c =0.5%; $\overline{b}_B$ =1%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	0.50	0.50	0.00	-0.59
Merchant fee rate (%)	0.50	0.74	1.00	1.59
Network profit margin	0	0.24	0	0
% change in Price	0.00	0.04	0.17	0.73
% change in Consumer Surplus	0.04	0.00	0.00	-0.31
% change in Merchant Surplus	0.04	0.00	-0.01	1.50
% change in Social Welfare	0.05	0.05	0.00	-0.18
$\hat{b}_S$ =1%; c =0.5%; $\overline{b}_B$ =1%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	0	0	-0.98	-1.38
Merchant fee rate (%)	1.00	1.50	1.98	2.38
Network profit margin	0	0.50	0	0
% change in Price	0.02	0.17	0.66	1.26
% change in Consumer Surplus	0.15	0.00	0.00	-0.31
% change in Merchant Surplus	0.17	-0.01	-0.02	1.51
% change in Social Welfare	0.18	0.18	0.00	-0.18
$\hat{b}_S$ =1.5%; c =0.5%; $\overline{b}_B$ =1%; $\underline{b}_B$ =-2%; t =10; d =90				
Card network market structure	Most efficient	Profit-max monopoly	Output-max monopoly	Output-max oligopolies
Cardholder fee rate (%)	-0.50	-0.50	-1.96	-2.00
Merchant fee rate (%)	1.50	2.24	2.96	3.00
Network profit margin	0	0.74	0	0
% change in Price	0.04	0.38	1.48	1.71
% change in Consumer Surplus	0.34	0.00	0.00	-0.19
% change in Merchant Surplus	0.38	-0.02	0.00	1.70
% change in Social Welfare	0.41	0.41	0.00	-0.03

2. Discriminatory Pricing

We assume the following parameter values: c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90. We also assume that card networks choose the merchant fee rate between -10% and 10%.

Fee structure

Profit-maximizing monopoly network

$\hat{b}_S$	0.5%				
m	-10%	-1%	0%	1%	**10%**
f	11.78%	2.75%	1.75%	0.75%	**-8.27%**
p^{card}	90.897	98.999	99.989	101.000	**111.102**
$1-H$	0.184	0.179	0.178	0.177	**0.172**
Π	0.130	0.133	0.134	0.134	**0.139**

$\hat{b}_S$	1%				
m	**-10%**	-1%	0%	1%	10%
f	**12.06%**	3.01%	2.00%	1.00%	-8.05%
p^{card}	**90.863**	98.962	99.952	100.962	111.061
$1-H$	**0.249**	0.239	0.239	0.237	0.227
Π	**0.2398**	0.239	0.239	0.239	0.2397

$\hat{b}_S$	1.5%				
m	**-10%**	-1%	0%	1%	10%
f	**12.34%**	3.27%	2.26%	1.25%	-7.81%
p^{card}	**90.830**	98.925	99.915	100.924	111.019
$1-H$	**0.317**	0.300	0.299	0.297	0.280
Π	**0.385**	0.377	0.377	0.376	0.370

Output-maximizing monopoly network

$\hat{b}_S$	0.5%			
m	-541%	**-10%**	0%	10%
f	542%	**11%**	1%	-9%
p^{card}	15.598	**90.931**	100.029	111.150
$1-H$	1.000	**0.368**	0.356	0.344

$\hat{b}_S$	1%			
m	-218.9%	**-10%**	0%	10%
f	219.9%	**11%**	1%	-9%
p^{card}	31.348	**90.909**	100.005	111.123
$1-H$	1.000	**0.500**	0.476	0.452

$\hat{b}_S$	1.5%			
m	-111.5%	**-10%**	0%	10%
f	112.5%	**11%**	1%	-9%
p^{card}	47.259	**90.887**	99.981	111.096
$1-H$	1.000	**0.634**	0.598	0.561

Welfares

$\hat{b}_S$ =0.5%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90		
Card network market structure	Profit-max monopoly	Output-max monopoly
Cardholder fee rate (%)	-8.27	11
Merchant fee rate (%)	10	-10
Network profit margin	0.73	0
% change in Price	10.60	-9.48
% change in Consumer Surplus	0.07	0.24
% change in Merchant Surplus	0.07	0.27
% change in Social Welfare	0.23	0.30
$\hat{b}_S$ =1%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90		
Card network market structure	Profit-max monopoly	Output-max monopoly
Cardholder fee rate (%)	12.06	11
Merchant fee rate (%)	-10	-10
Network profit margin	1.06	0
% change in Price	-9.96	-9.91
% change in Consumer Surplus	0.11	0.45
% change in Merchant Surplus	0.12	0.51
% change in Social Welfare	0.40	0.55
$\hat{b}_S$ =1.5%; c =1%; $\overline{b}_B$ =2%; $\underline{b}_B$ =-2%; t =10; d =90		
Card network market structure	Profit-max monopoly	Output-max monopoly
Cardholder fee rate (%)	12.34	11
Merchant fee rate (%)	-10	-10
Network profit margin	1.34	0
% change in Price	-10.40	-10.34
% change in Consumer Surplus	0.18	0.72
% change in Merchant Surplus	0.20	0.81
% change in Social Welfare	0.64	0.88