

# The Determinants of Optimal Interchange Fees in Payment Systems

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## Abstract

A fundamental aspect of any open payment system is the interchange fee that is paid from the merchant's bank to the cardholder's bank. Using a model in which there is partial participation by heterogeneous consumers and merchants, this paper characterizes the output maximizing, profit maximizing and welfare maximizing level of such an interchange fee. It examines how the optimal level of the fee depends on costs, profits margins, pass-through coefficients, participation rates, and membership fees, as well as two different strategic effects arising from competition between merchants. It also determines the factors which drive deviations between the output maximizing, profit maximizing, and welfare maximizing interchange fees.

## 1 Introduction

Two of the most important advances in the history of payment systems have been the development of debit and credit card payment systems over the last half-century. In the United States alone, consumers charged almost one trillion U.S. dollars to payment cards in 1998 (Chang and Evans, 2000). Based on data

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from the Bank for International Settlements and the European Central Bank, Krueger (2001) calculates debit and credit cards in twelve OECD countries grew from 9.3 billion transactions in 1987 to 33.7 billion transactions in 1998.

Despite the popularity of these systems, or perhaps due to it, the rules which govern them have recently been called into question. From an economic perspective these systems are unusual in that for the most part they are run by joint ventures, with competing banks agreeing on rules and terms for their mutual operations.<sup>1</sup> Researchers, policy makers, and the courts have been particularly interested in one feature of these systems, the setting of the interchange fee. The interchange fee, which is a payment made by acquiring banks (which specialize in servicing merchants) to issuing banks (which specialize in servicing cardholders) as a percentage of each transaction, is typically set by the members of a payment system collectively.<sup>2</sup> This collective setting of the interchange fee has given rise to claims of price-fixing, although in the United States collective determination of interchange fees was found to be legitimate by the courts after National Bancard Corporation unsuccessfully sued Visa in 1984. Frankel (1998), Evans and Schmalensee (1999), and Chang and Evans (2000) present the arguments for and against the price-fixing allegation, while Small and Wright (2001) analyze what would happen with the decentralized setting of interchange fees in an open card payment network. Recently, the European Commission and the central bank of Australia have challenged the private setting of interchange

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<sup>1</sup>MasterCard and Visa are the primary examples, with the members of each joint venture consisting of the many thousands of banks and other financial institutions which compete to service cardholders and merchants. Such systems are also sometimes called open payment systems. These contrast with closed payment systems, such as those offered by American Express, Discover/Nexus and Diners Club. Closed payment systems differ in that they are proprietary systems, offering a cardholder and merchant service through a single operation.

<sup>2</sup>According to Australian Banking Association (2001), MasterCard uses a cost recovery methodology to determine its interchange fees, where specific costs of issuing are allowed to be recovered, while Visa's methodology is more demand driven, in which costs are allocated in proportion to revenues, and its interchange fees are determined by the difference between the issuing banks' actual cost and their allocated portion of network costs. Like MasterCard, these cost measures are simply the starting point before adjustments based on commercial judgement are made. Interchange fees (for electronic Visa transactions) are currently 0.8% in Australia, 1% in Hong Kong, Japan, and the U.K., 1.25% in France and Germany, and 1.38% +\$0.10 in the U.S. MasterCard interchange fees are generally similar to those set by Visa.

fees, with government authorities in Australia moving to regulate interchange fees (see Hehir, 2000 and Reserve Bank of Australia, 2001).

Despite the strong public interest in payment systems, and the important role of interchange fees in these systems, there is only a small economic literature that policy makers can use to evaluate the role of interchange fees. The purpose of this paper is to provide a framework for analyzing the privately and socially optimal level of a centrally set interchange fee, and to use the framework to explain the determinants of efficient interchange fees. In so doing we build on three existing papers.

Baxter (1983) provides the first formal analysis of the interchange fee in a payment system. Baxter notes that higher interchange fees raise the cost to acquiring banks, and thus merchants, of card services, while lowering the cost to issuing banks, and thus cardholders, of using their cards. The optimal interchange fee will not be too high, since this would lead to too few merchants, and nor should it be too low, since this would lead to too few cardholders. Because a payment system represents a joint service to cardholders and merchants, to maximize system benefits, the sum of the benefits accruing to cardholders and merchants from an additional card transaction should just equal the costs of providing an additional transaction. This could be achieved if cardholders and merchants are each charged a fee equal to the corresponding marginal benefits of card use and merchant acceptance at this point. However, with different banks providing the issuing and acquiring functions, there is no reason to expect that competing banks will cover their costs if they price in this way. By setting an interchange fee so that the money-making bank compensates the money-losing bank, the efficient pricing can be recovered, even though each bank acts independently.

Baxter works out the resulting interchange fee assuming banks compete according to perfect competition. With imperfect competition between banks, Schmalensee (2001) models the determination of the interchange fee through bargaining between issuing and acquiring banks. He derives several implications for the resulting interchange fees, including that for a non-extreme case in which the privately optimal interchange fee maximizes total system output and a Marshallian measure of social welfare. He also finds the optimal inter-

change fee depends on the differences in demand elasticities across cardholders and merchants, and the differences in costs across issuing and acquiring banks.

While Baxter and Schmalensee both consider the trade-off between cardholder and merchant demand, neither provides a model in which consumer and merchant demand for the payment system is derived from the underlying benefits they receive from the using the payment service. Rochet and Tirole (2000) develop a first-principles model of a card payment system, and in so doing, incorporate the interaction between consumers and merchants that arises from merchant competition.<sup>3</sup> By deriving consumer demand from first principles they are able to consider the full welfare effects of different interchange fees, allowing for the effects on cash paying consumers as well. However, because they assume all merchants are identical, their model cannot capture the trade-offs which the models of Baxter and Schmalensee identified. Instead, Rochet and Tirole introduce an asymmetry between issuing and acquiring banks, by assuming acquiring banks are perfectly competitive, while assuming issuing banks have market power. This framework implies privately set interchange fees will either be socially optimal (because higher interchange fees would lead to all merchants to drop out, which is bad for banks as well as society), or will lead to overprovision of card services (because issuing banks will set interchange fees up to the point where all merchants are indifferent about accepting cards or not, and the resulting low cardholder fees can lead to too much card usage).

This paper integrates the above approaches in a tractable framework. It builds on Rochet and Tirole by starting from first principles and incorporating merchant competition. However, it extends Rochet and Tirole's model by analyzing the implications of heterogeneity in merchant benefits, as well as con-

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<sup>3</sup>Rochet and Tirole model merchants as competing according to the standard Hotelling model. Wright (2001) uses Rochet and Tirole's framework to examine the cases of Bertrand competition and monopoly pricing. When merchants set monopoly prices the privately and socially optimal interchange fees are equal, and the no-surcharge rule unambiguously improves welfare. With Bertrand competition the interchange fee and the no-surcharge rule are irrelevant as merchants specialize in either accepting cards or not. Gans and King (2001a) derive the latter result in a much more general setting. Gans and King (2001b) derive the optimal interchange fee in an environment where there is a representative merchant and a representative consumer, and the consumer chooses when to use cards and when to use cash. However, customer-merchant interactions are not taken into account.

sumer benefits, so that the trade-off between consumer and merchant demand can be studied in the spirit of Baxter's and Schmalensee's work. Moreover, in deriving cardholder and merchant demand from first principles we do not have to assume, as Baxter implicitly does, that merchants can pick which individual transactions to accept. In his analysis optimality requires the joint benefit of the marginal transaction equals the joint cost. In practice, because each merchant will have to either decide to accept all card transactions or to accept none, additional structure is imposed on the problem. This makes the analysis of optimal interchange considerably richer than that implied by Baxter's approach. Inevitably some inefficient card transactions will be made and some efficient card transactions will not be made. Optimality will no longer be characterized by the joint transactional benefits equal joint costs condition. Rather, optimality also depends on the infra-marginal cardholders and merchants, and the surplus they obtain when another consumer decides to use cards or another merchant decides to accept cards. Despite this added richness, explicit expressions for the optimal interchange fee are obtained.<sup>4</sup>

Using this framework we compare the output maximizing, profit maximizing, and welfare maximizing interchange fee. The output maximizing interchange fee is determined by equating the magnitude of the card usage elasticity with respect to the interchange fee with the magnitude of the card acceptance elasticity with respect to the interchange fee. The idea is to use the interchange fee to balance card usage with merchant acceptance, as would be the case in any other two-sided network. For instance, a dating agency may set a higher fee to men than women so as to roughly balance the numbers of men and women that will be matched. The privately optimal interchange fee coincides with this output maximizing level, except to the extent acquiring banks pass-through interchange fee costs to merchants at a greater rate than issuing banks rebate

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<sup>4</sup>Following the existing literature which models interchange fees, the paper does not explicitly address the credit functionality available in some payment cards. Chakravorti and To (2000) and Chakravorti and Emmons (2001) provide models which focus on the credit aspect of payment systems, but neither paper models the interchange fee. Using a framework similar to Rochet and Tirole, Wright (2000) derives the optimal interchange fee as being characterized by a trade-off between card membership and card usage when an aspect of credit functionality is allowed for.

interchange revenue to card users. Banks, in aggregate, will sacrifice output to increase profits by increasing the interchange fee if by doing so they can increase merchant fees more than any reduction in cardholder fees (or increase in cardholder rebates).<sup>5</sup>

The welfare maximizing interchange fee balances the additional cardholder demand from a higher interchange fee, and the surplus arising from the additional card usage with existing merchants, with the decrease in merchant demand from a higher interchange fee, and the surplus lost from a decrease in card acceptance for existing card users. The difference between the socially optimal interchange fee and that which maximizes output depends only on the difference between the average transactional benefit and the marginal transactional benefit across consumers and merchants from using or accepting cards. For instance, if the average transactional benefits obtained by card users are higher than the average transactional benefits obtained by merchants that accept cards, while the marginal card user obtains lower transactional benefits from using cards compared to the marginal merchant that accepts cards, then clearly by decreasing the interchange fee below the output maximizing level, welfare can be increased. The loss in benefits from cardholders no longer using cards is small compared to the benefits inframarginal card users obtain from an additional merchant that accepts cards. In this case the social planner sacrifices some card transactions in order that externalities are better internalized.

A special case of the model is examined in which issuing and acquiring bank fees, and cardholder and merchant demand become linear in the interchange fee. In this case, where merchants do not use card acceptance to attract additional customers, and where issuing and acquiring banks pass-through costs at the same rate, the interchange fee which maximizes banks' joint profits is identical to the output and welfare maximizing interchange fee regardless of the relative benefits obtained by cardholders and merchants and regardless of the relative

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<sup>5</sup>Provided issuing and acquiring banks have pass-through coefficients equal to one, the privately optimal interchange fee will not depend on any difference in bargaining power between issuing and acquiring banks. Otherwise, if issuing banks have greater bargaining power then they will obtain an interchange fee above the output maximizing level if the pass-through coefficients are less than one, and an interchange fee below the output maximizing level if pass-through coefficients are greater than one.

costs and profitability of issuing and acquiring.

Under these assumptions the optimal interchange fee is increasing in the costs and markups of issuing banks and decreasing in the costs and markups of acquiring banks. If the costs or markups of issuing banks are higher than those of acquiring banks, the fees charged to cardholders will be correspondingly higher. Given any card transaction is a joint transaction, optimality calls for some of these fees to be shared with the other users of the card system, merchants. This is achieved by an interchange fee determined by some portion of the difference between issuing and acquiring per-transaction costs (and markups).

Similarly, the optimal interchange fee is increasing in the mean of merchants' transactional benefits from accepting cards, and decreasing in the mean of consumers' transactional benefits. When merchants receive greater transactional benefits from accepting cards than consumers receive from using them, there will be disproportionately more demand by merchants for card transactions. Given the joint nature of card transactions, optimality will require some of these benefits to be shared with cardholders, which is achieved by an interchange fee determined by some portion of the difference between merchants transactional benefits and cardholders transactional benefits.

The optimal interchange fee also turns out to depend on merchant competition in a fundamental way. Merchants accept cards for a number of reasons, including the transactional benefits they receive by being able to accept cards rather than alternative types of payments, the ability to attract and retain customers who desire to pay using their cards, and the ability to make sales to customers who are constrained by lack of cash or funds. In deciding whether to accept cards, merchants trade off the profits arising from these additional sales with the merchant fee charged by acquiring banks on existing and new transactions, taking account of the fact that a number of existing customers will also switch to using cards. When evaluating this trade-off, each individual merchant ignores the fact that by accepting cards to take sales from their rivals, other merchants are made worse off. This feature of equilibrium helps explain why individually some merchants will want to accept cards, even though if merchants could coordinate, some industries might not accept cards.

When merchants compete to attract card customers, we find the optimal

interchange fee is higher. This results from the fact competing merchants will internalise the average benefit their customers get from being able to use cards, while consumers do not internalise the benefits that merchants obtain. Because merchants have a high willingness to accept cards, efficiency dictates that they should incur a greater share of the costs of providing the payment system.

The rest of the paper proceeds as follows. Section 2 sets out the basic version of our model. In Section 3 we analyze the model, characterizing the output, profit, and welfare maximizing interchange fees, showing how these depend on the parameters of the model. Two extensions are considered in Section 4, where we study the impact of subscription costs and fees, and the impact of impulse purchases, on the optimal interchange fee. Finally, Section 5 briefly summarizes our results and provides suggestions for future work.

## 2 Model Set-Up

We suppose there are two types of payment systems, a card payment system run by an association of issuing and acquiring banks, and some other form of payment that is determined independently of the interchange fee in the card payment system. To be specific we take the alternative to the card payment technology to be cash, although cash can easily be interpreted as the composite of other systems, such as cash and cheques. The members of the card payment system either collectively agree on an interchange fee, or if this is not allowed, face a regulated interchange fee. In either case the interchange fee is denoted  $a$ .<sup>6</sup> This is an amount paid from a merchant's bank (acquiring bank) to a cardholder's bank (issuing bank) when a consumer uses their card to make a purchase from a merchant.

We suppose that a transaction that is done using cards costs the issuing bank  $c_I$  and the acquiring bank  $c_A$ . These are technological costs as opposed to costs that acquiring banks might face due to the interchange fee, or costs that issuing banks may face from providing reward programs, cash rebates or interest-free terms to cardholders. Given net per-transaction costs of  $c_I - a$ , the issuing banks are assumed (through competition) to set a per-transaction

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<sup>6</sup>Notation corresponding to that introduced by Rochet and Tirole (2000) is used wherever possible.

fee to cardholders of  $f$  (which can be negative to reflect the various benefits given to cardholders). Similarly, through competition acquiring banks, facing net per-transaction costs of  $c_A + a$ , set a per-transaction fee to merchants of  $m$ .<sup>7</sup>

We assume these per-transaction fees are increasing in costs per-transaction so that  $\partial f/\partial(c_I - a) \geq 0$  and  $\partial m/\partial(c_A + a) \geq 0$ .<sup>8</sup> Per-transaction markups or profits are then defined by the difference between per-transaction fees and per-transaction costs, with these being

$$\pi_I = f - (c_I - a) \tag{1}$$

and

$$\pi_A = m - (c_A + a). \tag{2}$$

We assume with a zero interchange fee banks will at least cover their marginal costs,  $\pi_I(a = 0) \geq 0$  and  $\pi_A(a = 0) \geq 0$ , and that  $\partial^2 \pi_I(a = 0)/\partial(c_I - a)^2 \leq 0$  and  $\partial^2 \pi_A(a = 0)/\partial(c_A + a)^2 \leq 0$ . According to this specification, higher interchange fees imply cardholders will face lower fees for using their cards, while merchants will face higher fees (merchant service fees) corresponding to the higher costs acquiring banks face. Our specification allows for different degrees of markups in the issuing and acquiring sides of the market, as well as the fact markups can vary with per-transaction costs and the interchange fee. For simplicity we assume away costs and fees that arise per cardholder or per merchant until Section 4.<sup>9</sup>

We assume there are a continuum (measure one) of separate industries and of consumers. Each industry is made up of two merchants, which compete according to Hotelling competition. We suppose consumers are exogenously matched with industries, and without loss of generality, that each consumer is matched with all industries. This approach captures the idea that consumers do not choose which industry to purchase from based on whether merchants in that industry accept cards or not, even though within the industry they may pick

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<sup>7</sup>In a closed card system, the network would set prices  $f$  and  $m$  directly. Thus our framework can easily be applied to an analysis of pricing in a closed card system.

<sup>8</sup>In practice banks set ad-valorem interchange fees, merchant fees and cardholder rebates. We assume per-transaction fees, consistent with the assumption consumers have unit demands.

<sup>9</sup>In most countries there are no membership or annual fees for debit cards. For credit cards, annual fees for cardholders are present in many countries, although options without such fixed fees are often available, and are widely used in the United States.

the merchant to buy from based on whether the merchant accepts cards or not. To abstract from the substitutability of goods between industries, we assume consumers wish to purchase one good from each industry they are matched to. This is consistent with consumers having Leontief preferences for goods across different industries.

Consumers are randomly located in each industry according to the standard “linear city” version of the Hotelling model, and the two merchants are located at the two extremes of the unit interval. As is usual we think of the Hotelling model as capturing the random benefits consumers associate with purchasing from each of the two firms. Thus, consumers draw an  $x$  for each industry from the  $U[0, 1]$  distribution, and incur transportation costs of  $tx$  if they purchase from firm 1 and  $t(1 - x)$  if they purchase from firm 2. All goods have a cost  $d$ .

When a merchant (seller) accepts a card for a transaction, rather than cash, they get a net convenience benefit of  $b_S$ , where  $b_S$  is drawn independently for each industry from the common distribution function  $G(b_S)$ . Thus, different industries are distinguished by the different benefits merchants obtain by accepting cards for payment versus the alternative cash. This assumption is motivated by the fact that the costs of handling cash (and the convenience of accepting cards) differs across different industries. Because the only thing which distinguishes industries in the model is the benefit merchants in the industry get from accepting cards, we refer to an industry by its type  $b_S$ . We define the critical value of  $b_S$  (when merchants in the industry are indifferent between accepting cards or not) to be  $b_S^m$ , so that for all industries with  $b_S \geq b_S^m$  merchants in these industries will also accept cards.<sup>10</sup> We define the demand by merchants to accept cards (or the supply of merchants that accept cards) to be  $S = 1 - G(b_S^m)$ , and the average transactional benefit to those merchants accepting cards to be

$$\begin{aligned} \beta_S(b_S^m) &= E[b_S \mid b_S \geq b_S^m] \\ &= \frac{\int_{b_S^m}^{\infty} b_S g(b_S) db_S}{1 - G(b_S^m)}. \end{aligned} \tag{3}$$

When a consumer (buyer) uses a card for a transaction, rather than cash, they get a net convenience benefit of  $b_B$ , where  $b_B$  is drawn for each consumer

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<sup>10</sup>A feature of equilibrium behavior turns out to be that either both merchants in an industry accept cards, or not.

from the common distribution function  $H(b_B)$ .<sup>11</sup> We also refer to consumers as being of type  $b_B$ , which means the consumer has a draw of convenience benefit equal to  $b_B$ . We define the critical value of  $b_B$  (when a consumer is indifferent between using their card or not) to be  $b_B^m$ , so that all consumers with  $b_B \geq b_B^m$  will want to use cards. We define the demand for card usage by consumers to be  $D = 1 - H(b_B^m)$ , and the average transactional benefit to those consumers using cards to be

$$\begin{aligned}\beta_B(b_B^m) &= E[b_B \mid b_B \geq b_B^m] \\ &= \frac{\int_{b_B^m}^{\infty} b_B h(b_B) db_B}{1 - H(b_B^m)}.\end{aligned}\tag{4}$$

We also denote the *net* benefits to the average cardholder from using their card for a transaction to be

$$\begin{aligned}\delta(b_B^m) &= E[b_B - f \mid b_B \geq b_B^m] \\ &= \frac{\int_{b_B^m}^{\infty} (b_B - f) h(b_B) db_B}{1 - H(b_B^m)}.\end{aligned}\tag{5}$$

We assume merchants cannot price-discriminate between the two types of payments or across consumers. The lack of surcharging for card payments could be optimal given transaction costs of charging multiple prices in the face of relatively small merchant fees. It could also result from the rules card payment systems have adopted to prevent merchants charging consumers surcharging for using their cards. We initially assume consumers always observe prices before making their choice of which merchant to purchase from; this assumption is relaxed in Section 4.2. Following Rochet and Tirole (section 6.1.a), we assume each consumer has only a probability of  $\alpha$  of observing whether merchants accept cards or not within any industry.<sup>12</sup>

The timing of the game is summarized as follows:

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<sup>11</sup>Alternatively, each consumer could face the same expected convenience benefit of using cards, but their specific draw of  $b_B$  differs with each transaction. Provided fixed fees are not too large, all consumers would obtain cards, but would only use cards when the convenience benefits exceed the fee charged per-transaction. In this case the analysis of Section 3 still holds.

<sup>12</sup>This requires that consumers cannot infer which merchants accept cards or not within an industry by observing the merchants' prices. The assumption could be motivated from bounded rationality considerations. In practice prices will depend on many factors, and so it seems unreasonable for consumers to be able to work out whether a merchant accepts cards

- (i) The payment card association or regulators set the level of the interchange fee  $a$ .
- (ii) Issuing and acquiring banks set prices to cardholders and merchants, according to (1) and (2) respectively.
- (iii) Based on these prices and their individual realizations of  $b_S$  or  $b_B$  from the distributions  $G$  and  $H$ , consumers and merchants simultaneously decide whether to join the payment network. When there is no cost to card membership we assume all consumers hold a card.
- (iv) Merchants simultaneously set retail prices.
- (v) Consumers get a particular draw of  $x$  (their location) from the uniform distribution on the unit interval for each industry. With probability  $\alpha$  in each industry, they observe whether merchants accept cards or not.
- (vi) Consumers decide which merchant to purchase from in each industry, and whether or not to use a card for the payment.

The most important differences between our model and that analyzed in Rochet and Tirole are:

- We allow for different industries, where different industries have different costs of accepting cards and cash.
- In doing so, we allow for heterogeneity across merchants, so partial participation is modelled on both sides of the market.<sup>13</sup>
- Cardholder rebates (or fees) relate to usage rather than membership.
- We do not assume perfect competition between acquiring banks.
- Bank fees on both sides of the model are explicit functions of costs, so explicit results are derived.

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or not within an industry by comparing the merchants' prices. Moreover, in equilibrium both merchants within an industry will set the same price.

<sup>13</sup>Rochet and Tirole (section 6.1.c) briefly discuss the extension of their model to allow merchants to have benefits that are drawn from a distribution, but explain how this can be done only for the special case  $\alpha = 0$ , and do not draw implications for the optimal interchange fee.

### 3 Optimal interchange fees

In this section the model developed above is used to characterize the level of the privately and socially optimal interchange fees. Before doing so, it is worth noting that the socially optimal interchange fee will not, in general, deliver the first-best solution. A central planner that could determine which card transactions occur and which do not, will dictate that cards be used for transactions if and only if  $b_B + b_S \geq c_I + c_A$ .<sup>14</sup> However, this requires far more power and information on the part of the central planner or the network operator than can be reasonably assumed. It requires that the planner can directly control which transactions are made using cards and which are not. If, more feasibly, the planner can only influence (through the control of the fees charged to cardholders and merchants) which consumers will use the payment card and which merchants will accept the payment card, it may want to pick fees that imply the condition  $b_B + b_S \geq c_I + c_A$  is violated for some transactions.

A welfare maximizing social planner would pick fees  $f$  and  $m$  so as to maximize total welfare

$$W = \int_{b_B^m}^{\infty} \int_{b_S^m}^{\infty} (b_B + b_S - c_I - c_A) g(b_S) h(b_B) db_S db_B. \quad (6)$$

which in general implies  $b_B^m + b_S^m \neq c_I + c_A$ .<sup>15</sup> Note that total welfare does not depend on merchants' retail prices since any transfer between cash paying customers, card paying customers, merchants or banks washes out due to the assumption of unit demands (each consumer buys only one item from each merchant regardless of the price). The effects of allowing for downward sloping demand are likely to be subtle since the impact of a change in the interchange fee on the demand of card paying and cash paying customers will largely cancel out. As is shown in (17), it is not necessarily the case that cash paying customers pay more as a result of merchants' acceptance of cards. Whether overall demand would increase or decrease if elastic demand was allowed for also depends on whether consumers who pay by credit card tend to be more or less price elastic.

<sup>14</sup>This is essentially the approach taken in Baxter's model. Note, even this is only a second-best solution if the alternatives to using cards, cash and cheques, are themselves inefficiently provided.

<sup>15</sup>A sophisticated planner may be able to pick more complex fee structures so as to price discriminate among users and get closer to the first-best solution.

Because of the positive network externalities between cardholders and merchants, optimality will generally occur when  $b_B^m + b_S^m < c_I + c_A$ , which suggests a subsidy to the payment system will be needed if banks are going to cover their costs. Similarly, a closed card system picks cardholder and merchant fees directly to maximize profit

$$\Pi = \int_{b_B^m}^{\infty} \int_{b_S^m}^{\infty} (\pi_I + \pi_A) g(b_S) h(b_B) db_S db_B,$$

thereby setting fees which are above the socially optimal fees, even if they are effectively constrained by effective inter-system competition. A non-unitary closed card system (that has separate issuing and acquiring agents) will set wholesale fees to downstream issuing and acquiring banks, who will in turn set retail fees to cardholders and merchants. The resulting double-marginalization problem suggests retail fees will be even higher for this organizational form.

In an open payment system, the card association does not get to pick the cardholder and merchant fees directly. Instead, it sets the level of the interchange fee. Whether the overall level of retail fees set by the members of an open card system are higher or lower than those set by a closed system will be determined in the first instance by the extent of inter-system versus intra-system competition, rather than the level of the interchange fee. When an interchange fee is used to try to optimize the size of the network it can have at best only a limited effect. Because an interchange fee is a transfer from one side of the system to the other, it cannot be used to change the overall number of transactions other than by altering the balance between cardholder and merchant demand. Put differentially, in an open payment system where retail fees are set in a decentralized way, a single interchange fee cannot simultaneously achieve the optimal level of retail fees to be set to cardholders and merchants. Rather, the optimal interchange fee will inevitably involve a trade-off between promoting cardholder demand and promoting merchant demand.<sup>16</sup> This trade-off is examined at a general level in Section 3.1, with subsequent sections dealing with a number of special cases.

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<sup>16</sup>Welfare may be able to be increased if different interchange fees can be used for different industries. Both MasterCard and Visa use lower interchange fees for card transactions with supermarkets. In this paper the analysis is restricted to the identification of the optimal level of a single interchange fee.

### 3.1 The fundamental balancing conditions

The interchange fee which maximizes the total number of card transactions is denoted  $a^T$ , where the total number of card transactions is

$$T = \int_{b_B^m}^{\infty} \int_{b_S^m}^{\infty} g(b_S)h(b_B)db_Sdb_B. \quad (7)$$

The first order condition is<sup>17</sup>

$$\begin{aligned} \frac{\partial T}{\partial a} &= S \frac{\partial D}{\partial a} + D \frac{\partial S}{\partial a} \\ &= 0, \end{aligned} \quad (8)$$

where

$$\frac{\partial D}{\partial a} = -h(b_B^m) \frac{\partial b_B^m}{\partial a} \quad (9)$$

is how the demand for using cards changes as the interchange fee increases, while

$$\frac{\partial S}{\partial a} = -g(b_S^m) \frac{\partial b_S^m}{\partial a} \quad (10)$$

is how the acceptance of cards by merchants changes as the interchange fee increases. At the margin, the output maximizing interchange fee balances the increase in cardholder demand resulting from lower cardholder fees (this depends on the number of merchants who accept cards) with the decrease in merchant demand resulting from higher merchant fees (this depends on the number of times consumers use cards for transactions).

Output maximization can be characterized by the equalization of the card usage elasticity with the card acceptance elasticity. Multiplying (8) everywhere by  $a$  and dividing by  $DS$ , the expression simplifies to

$$\varepsilon_D = -\varepsilon_S,$$

where  $\varepsilon_D = (\partial D/\partial a)(a/D)$  and  $\varepsilon_S = (\partial S/\partial a)(a/S)$ .

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<sup>17</sup>Appropriate concavity conditions are assumed to hold throughout the paper so that the solution to the relevant first order condition represents the unique solution to the associated maximization problem. For instance, for output maximization a sufficient condition is that the demand functions  $D$  and  $S$  are log-concave with respect to the interchange fee. In Proposition 3 we check second order conditions hold at the optimal interchange fee for the special case of perfect symmetry. We have also checked second order conditions hold for all other results using a numerical example based on Section 3.3.

The interchange fee which maximizes total welfare in (6) is denoted  $a^W$ . The first-order condition for maximizing (6) with respect to  $a$  is

$$\begin{aligned} \frac{\partial W}{\partial a} &= \frac{\partial D}{\partial a} \left[ \int_{b_S^m}^{\infty} (b_B^m + b_S - c_I - c_A)g(b_S) db_S \right] \\ &\quad + \frac{\partial S}{\partial a} \left[ \int_{b_B^m}^{\infty} (b_B + b_S^m - c_I - c_A)h(b_B) db_B \right] \\ &= 0, \end{aligned} \quad (11)$$

To interpret the welfare maximizing interchange fee, note that as a result of lower cardholder fees there will be some consumers who will now want to use cards for transactions whereas previously they did not (this is  $\partial D/\partial a$ , which will be positive). The additional consumers who use cards will provide benefits that depend on how many merchants accept cards. Each additional card usage by the marginal cardholder with a merchant of type  $b_S$  will create a social surplus of  $b_B^m + b_S - c_I - c_A$ , so the total surplus created by the decrease in cardholder fees is equal to the first line in (11). On the other hand, as a result of higher merchant service fees there will be some industries where merchants no longer want to accept cards even though previously they did (this is  $\partial S/\partial a$ , which will normally be negative). The decrease in surplus arising from this fall in merchant acceptance depends on the amount of card usage. Since  $(b_B + b_S^m - c_I - c_A)$  is the social surplus which was created by the marginal merchant who accepted cards from a consumer of type  $b_B$ , the total surplus lost by the increase in merchant fees is equal to the second line in (11).

At the welfare maximizing interchange fee a small increase in the interchange fee increases surplus through additional card users by the same amount that surplus is lost through a reduction in merchants that accept cards. Thus, equation (11) illustrates the fundamental balancing role of the welfare maximizing interchange fee, and the reason cost-based or zero interchange fees will only be welfare maximizing in very special cases. To compare the welfare maximizing and the output maximizing interchange fee, note (11) can be rewritten as

$$(b_B^m + \beta_S - c_I - c_A) \frac{\partial D}{\partial a} S + (b_S^m + \beta_B - c_I - c_A) \frac{\partial S}{\partial a} D = 0 \quad (12)$$

Clearly if  $b_B^m + \beta_S = b_S^m + \beta_B$  at the output maximizing interchange fee, then (12) coincides with (8) and the welfare maximizing and output maximizing

interchange fees are identical. Assuming the normal case in which  $\partial D/\partial a$  is positive,  $\partial S/\partial a$  is negative, and  $\partial^2 W/\partial a^2 < 0$  over the relevant range of the interchange fee (between  $a^T$  and  $a^W$ ), this leads to the following result:

**Proposition 1** *The welfare maximizing interchange fee is higher than the output maximizing interchange fee if and only if  $\beta_S - b_S^m > \beta_B - b_B^m$  at  $a = a^T$ .*

The result has a natural interpretation. If the condition  $\beta_S - b_S^m > \beta_B - b_B^m$  holds at the output maximizing interchange fee, by increasing the interchange fee above the level which maximizes output there will be fewer card transactions, but the loss in surplus from the decrease in merchants that accept cards will be less than the gain to the inframarginal merchants from additional card users. It is an asymmetry in the difference between the benefits received by inframarginal and marginal users across cardholders and merchants that drives any divergence between the output and welfare maximizing interchange fee. In this case the social planner sacrifices some card transactions in order that externalities are better internalized.

If, instead of a social planner, a bank association sets the interchange fee, it will do so to maximize the joint profits of its members. In doing so, it is possible that either issuing or acquiring banks will have greater control in setting the interchange fee. To allow for the possibility of asymmetric bargaining power we weight the profit of acquiring banks with  $\lambda$ , which can be more or less than one. The ‘joint’ profit is then

$$\Pi = \int_{b_B^m}^{\infty} \int_{b_S^m}^{\infty} (\pi_I + \lambda\pi_A) g(b_S)h(b_B)db_Sdb_B, \quad (13)$$

and the interchange fee which maximizes (13) is denoted  $a^\Pi$ , the (weighted) profit maximizing interchange fee.

The first-order condition from maximizing (13) with respect to  $a$  is

$$\begin{aligned} \frac{\partial \Pi}{\partial a} &= (\pi_I + \lambda\pi_A) \left[ S \frac{\partial D}{\partial a} + D \frac{\partial S}{\partial a} \right] \\ &\quad + \left( \frac{\partial \pi_I}{\partial a} + \lambda \frac{\partial \pi_A}{\partial a} \right) DS \\ &= 0. \end{aligned} \quad (14)$$

The profit maximizing interchange fee is also closely related to the output maximizing interchange fee. Ignoring for a moment the second line in (14), the

profit maximizing interchange fee maximizes the total number of card transactions  $DS$ .

The second line of (14) represents an additional determinant of a banking association's optimal interchange fee. Consider first the case  $\lambda = 1$ , so the profits of issuing and acquiring banks are weighted equally. Whenever higher interchange fees increase per-transaction profits to issuing banks more than they decrease per-transaction profits to acquiring banks, the expression in the second line of (14) will be positive. The optimal interchange fee will not maximize output, with some transactions being sacrificed in order to transfer per-transaction profits to the side of the market where they will be competed away less.

When the profits of acquiring banks are given less weight than the profits of issuing banks ( $\lambda < 1$ ), the expression in the second line of (14) can be non-zero even if costs are passed through into retail fees at the same rate by issuing and acquiring banks. In this case the bank association's optimal interchange fee will be higher than the output maximizing level if the pass-through of costs is less than one, and will be lower than the output maximizing level if the pass-through of costs is greater than one. Only if banks pass through costs one-for-one, so that their markups do not depend on the interchange fee, will the weight given to acquiring banks profits not affect results. In general we get:

**Proposition 2** *The privately optimal interchange fee is higher than the output maximizing interchange fee if and only if  $\partial\pi_I/\partial a > -\lambda\partial\pi_A/\partial a$  at  $a = a^T$ .*

Combining Propositions 1 and 2, it is clear that whether the privately optimal interchange fee exceeds the socially optimal interchange fee can depend both on whether  $\beta_S - b_S^m < \beta_B - b_B^m$  and whether  $\partial\pi_I/\partial a > -\lambda\partial\pi_A/\partial a$ .

To interpret these results further, we need to determine how consumers decide whether to use cards, and how merchants decide whether to accept cards. Consumers will use cards whenever the transactional benefits of doing so  $b_B$  exceed the fee  $f$ , which can be negative because of interest-free benefits and other rebates. This follows because merchants are assumed not to surcharge for card usage and because at this stage there are no membership fees. Thus, consumers use cards whenever

$$b_B \geq b_B^m = f. \tag{15}$$

Merchants, in deciding whether to accept cards or not, will compare the transactional benefits  $b_S$  with the merchant service fee  $m$ . In addition, they will consider the fact that by accepting cards they are offering those consumers who want to use cards an additional surplus, which allows them to attract more such customers. Although the additional surplus for the average card customer equals  $\delta(f)$ , because consumers are only aware of these benefits before they choose the merchant to shop from a fraction  $\alpha$  of the time, an individual merchant will do better by accepting cards rather than not, given the other merchant in the same industry accepts cards, whenever

$$b_S \geq b_S^m = m - \alpha\delta(f). \quad (16)$$

Thus, both merchants accepting cards is an equilibrium in each industry provided  $b_S \geq b_S^m$ , while when  $b_S < b_S^m$  both merchants will not accept cards.<sup>18</sup>

Merchants trade-off two types of customers when deciding whether or not to accept cards. If a merchant accepts cards it will steal some sales from its rival, thereby increasing its profits. This gain is proportional to the number of consumers who are informed of the merchant's acceptance policy. For the remaining customers, it will only do better by accepting cards if the convenience benefits  $b_S$  exceed the merchant service fee it is charged  $m$ , since if it did not accept cards, all of these customers would still frequent its store, but would pay using cash.

Appendix A shows the equilibrium retail price set by two merchants in an industry of type  $b_S$  is  $d + t + (1 - H(f))(m - b_S)$  if they accept cards and  $d + t$  if they do not. Contrary to the case with homogeneous merchants, the effect of card acceptance on merchant's retail prices is ambiguous. The average retail price across merchants that accept cards is

$$\bar{p} = \frac{\int_{m-\alpha\delta(f)}^{\infty} (d + t + (1 - H(f))(m - b_S)) g(b_S) db_S}{\int_{m-\alpha\delta(f)}^{\infty} g(b_S) db_S}. \quad (17)$$

With  $\alpha = 0$ , because  $b_S \geq m$ , merchants that accept cards will have lower retail prices than those that do not. Cash paying customers unambiguously benefit from the existence of card paying customers. In this case, merchants only accept cards where doing so provides them with cost savings and transactional benefits which exceed the merchant service fees levied on them.

<sup>18</sup>The proof is contained in Appendix A.

Where merchants accept cards for other reasons ( $\alpha > 0$ ), there will be some merchants that accept cards even though the transactional benefits they obtain are less than the merchant service fees they pay. For these merchants, retail prices will be higher than if they did not accept cards. Equation (17) implies that averaged across all card accepting merchants, retail prices can be higher or lower than for those merchants that do not accept cards. There can be no presumption that card paying customers are being subsidized by cash paying customers.

When the usage conditions (15) and (16) are combined with the optimality conditions (11) and (14) the determinants of the optimal interchange fee can be characterized further. To do this the assumption of symmetry is initially used, and then specific deviations from symmetry are considered.

### 3.2 Symmetric card systems

An important form of asymmetry between consumers and merchants is that merchants accept cards for strategic reasons — so as to attract additional customers from rival merchants. In order to study the implications of symmetry we initially assume away the strategic motive that merchants face to accept cards. To do this we assume that  $\alpha = 0$  throughout this section, so that consumers are never informed about whether merchants accept cards or not. This has the effect of making the role of the interchange fee much the same as balancing demand in a generic two sided network, such as for Adobe reader and writer, or between men and women in a dating agency. The additional effects that arise when merchant competition matters ( $\alpha > 0$ ) are discussed in Section 3.3.

We start by looking at the case of perfect symmetry, showing that in this case the optimal interchange fee is equal to zero. This provides a useful benchmark for interpreting deviations from symmetry.

**Proposition 3** *If consumers and merchants are symmetric, and issuing and acquiring banks are symmetric, then the output maximizing, profit maximizing, and welfare maximizing interchange fees are all zero.*

**Proof.** If issuing and acquiring banks are symmetric then among other things, issuing and acquiring banks will have the same bargaining power in

determining the interchange fee, issuing and acquiring banks' costs and profits will be equal when the interchange fee is set at zero, and the profit of issuing banks will be increasing in the interchange fee at the same rate as the profit of acquiring banks is decreasing. This implies  $\lambda = 1$ ,  $c_I = c_A$ ,  $\pi_I = \pi_A$ , and  $\partial\pi_I/\partial a = -\partial\pi_A/\partial a$  when  $a = 0$ . If in addition consumers and merchants are symmetric, then it follows that  $b_B^m = b_S^m$ ,  $D = S$ ,  $\partial D/\partial a = -\partial S/\partial a$ , and  $\partial^2 D/\partial a^2 = -\partial^2 S/\partial a^2$  when  $a = 0$ , and  $g(b) = h(b)$  for all  $b$ . Substituting these conditions into (8), (11), and (14) implies

$$\frac{\partial T(0)}{\partial a} = 0,$$

$$\frac{\partial W(0)}{\partial a} = 0$$

and

$$\frac{\partial \Pi(0)}{\partial a} = 0.$$

Taking second derivatives of (6), (7), and (13) and evaluating using the above conditions implies

$$\begin{aligned} \frac{\partial^2 T(0)}{\partial a^2} &= 2 \frac{\partial D}{\partial a} \frac{\partial S}{\partial a} < 0, \\ \frac{\partial^2 W(0)}{\partial a^2} &= \frac{\partial D}{\partial a} \int_{b_S^m}^{\infty} \frac{\partial b_B^m}{\partial a} g(b_S) db_S + \frac{\partial S}{\partial a} \int_{b_B^m}^{\infty} \frac{\partial b_S^m}{\partial a} h(b_B) db_B < 0 \end{aligned}$$

and

$$\frac{\partial^2 \Pi(0)}{\partial a^2} = 2(\pi_I + \pi_A) \frac{\partial D}{\partial a} \frac{\partial S}{\partial a} + \left( \frac{\partial^2 \pi_I}{\partial a^2} + \frac{\partial^2 \pi_A}{\partial a^2} \right) DS \leq 0,$$

since  $\partial b_B^m/\partial a < 0$ ,  $\partial b_S^m/\partial a > 0$ ,  $\partial D/\partial a > 0$ ,  $\partial S/\partial a < 0$ ,  $\pi_I \geq 0$ ,  $\pi_A \geq 0$ ,  $b_B^m = b_S^m > 0$ ,  $\partial^2 \pi_I/\partial a^2 \leq 0$ , and  $\partial^2 \pi_A/\partial a^2 \leq 0$ . Thus, when the two sides of the card payment system are symmetric, output, industry profits and total welfare are all (locally) maximized when the interchange fee is set at zero.<sup>19</sup> ■

The proposition shows that under some very special symmetry conditions, the optimal interchange fee is zero. Generally, however, the optimal interchange fee will deviate from zero, and in what follows we seek to understand the determinants of these deviations. Broadly speaking, there are two fundamental types of asymmetry — one arising from differences in participation rates or demand

<sup>19</sup>When there is perfect competition in the banking sector,  $\pi_I + \pi_A = 0$  and  $\partial^2 \pi_I/\partial a^2 = \partial^2 \pi_A/\partial a^2 = 0$ . In this case the profit maximizing interchange fee is undefined, as banks are indifferent over the level of the interchange fee.

(so  $D \neq S$ ), and one arising from a difference in the responsiveness of demand to interchange fees (so  $\partial D/\partial a \neq -\partial S/\partial a$ ). Equations (11) and (14) show either of these asymmetries will affect the optimal level of the interchange fee. However, unless the densities  $g$  and  $h$  are constant, the two types of asymmetry are not generally independent. For this reason Section 3.3 considers the special case in which cardholder and merchant benefits  $b_B$  and  $b_S$  are drawn from the uniform distribution, so each type of asymmetry can be separately identified. Provided both effects work in the same direction we get the following proposition.

**Proposition 4** *If for a zero interchange fee more merchants join than consumers (formally,  $b_S^m < b_B^m$ ) and merchant demand is no more sensitive to the interchange fee than cardholder demand (formally,  $|\partial S/\partial a| \leq \partial D/\partial a$ ), then provided issuing and acquiring banks have the same pass-through of costs and the same bargaining power, and consumers and merchants have the same distribution of benefits, the output maximizing, profit maximizing, and welfare maximizing interchange fees will be positive.*

**Proof.** From the symmetry assumptions on banks we get that  $\lambda = 1$ , and  $\partial\pi_I/\partial a = -\partial\pi_A/\partial a$  when  $a = 0$ . From the symmetry assumption on consumers and merchants we get that  $g(b) = h(b)$  for all  $b$ . For  $a = 0$ ,

$$\int_{b_S^m}^{\infty} (b_B^m + b_S - c_I - c_A)g(b_S)db_S > \int_{b_B^m}^{\infty} (b_B + b_S^m - c_I - c_A)h(b_B)db_B$$

since  $b_S^m < b_B^m$ ,  $b_S^m = c_A + \pi_A \geq c_A > 0$  and  $b_B^m + b_S^m = c_I + c_A + \pi_I + \pi_A \geq c_I + c_A$  at  $a = 0$ . This result, together with the result  $|\partial S/\partial a| \leq \partial D/\partial a$ , imply  $\partial W/\partial a > 0$  at  $a = 0$  from (11). Thus, the welfare maximizing interchange fee is above zero. Similarly,  $S > D$  and  $|\partial S/\partial a| \leq \partial D/\partial a$  imply  $\partial T/\partial a > 0$  at  $a = 0$  from (8), and this plus the fact  $\lambda = 1$  and  $\partial\pi_I/\partial a = -\partial\pi_A/\partial a$  imply  $\partial\Pi/\partial a > 0$  at  $a = 0$  from (14). Thus, the output maximizing and profit maximizing interchange fees are also above zero. ■

Proposition 4 follows from the fact, if merchants are more likely to accept cards than consumers (so the marginal merchant requires a smaller transactional convenience from cards than the marginal consumer), then a higher interchange fee will help balance demand by making it relatively cheaper for consumers to use cards. This balancing of demand is optimal given the surplus (or profit) generated by additional card usage is greater at the margin than that generated by

additional merchant acceptance. Similarly, inelastic merchant demand, other things equal, means it is optimal to charge merchants a higher fee than consumers. This can be achieved by setting a positive interchange fee. An increase in the interchange fee above zero has a smaller negative effect on merchants' demand than the positive response it elicits from consumers, thereby expanding total demand, profits and welfare.

Proposition 4 has implications for the effect of a number of variables on the optimal interchange fee. For instance, if issuing costs exceed acquiring costs, consumers will bear a greater proportion of the joint cost of the service, even though their benefits may be the same as merchants. With less cardholders or more merchants, Proposition 4 implies the privately and socially optimal interchange fees will be positive, so as to help rebalance the costs and benefits faced by consumers relative to merchants. Along the same lines, if markups of issuing banks are higher than markups of acquiring banks then, other things equal, there will be too few consumers relative to merchants. Proposition 4 implies from a profit and welfare maximizing point of view, a positive interchange fee is needed to address this asymmetry.<sup>20</sup>

From (9) and (10) consumer demand is more responsive to the interchange fee than merchant demand the greater the pass-through of interchange fee revenues by issuing banks back to cardholders, relative to the pass-through of the costs of interchange fees by acquiring banks to merchants. Given (15) and (16), this is equivalent to assuming  $\partial f/\partial c_I > \partial m/\partial c_A$ . With this assumption, Proposition 4 implies the welfare maximizing interchange fee will be positive, since the assumption that  $\partial \pi_I/\partial a = -\partial \pi_A/\partial a$  was only used in deriving that the banks' profit maximizing interchange fee is positive. As Proposition 2 shows, the condition  $\partial f/\partial c_I > \partial m/\partial c_A$  will make banks want to shift revenues onto the acquiring side, thus offsetting any incentive to set positive interchange fees.

Perhaps the most important source of asymmetry between consumers and merchants is the strategic motive merchants have to accept cards. As equation

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<sup>20</sup>These results require that  $h(b_B^m) \geq g(b_S^m)$  when  $b_B^m < b_S^m$  so that merchant demand is less sensitive than consumer demand. This will be true provided the common density function ( $g = h$ ) is non-decreasing over the relevant range. For instance, this will be satisfied by a uniform distribution of benefits, or by a bell-shaped distribution when the marginal card user and marginal merchant lie in the lower tail.

(16) shows, this motive for accepting cards leads to greater participation by merchants. Whether Proposition 4 necessarily applies in this case depends on whether this motive for accepting cards also leads to merchant demand becoming less sensitive to the interchange fee. The responsiveness of merchant demand to interchange fees varies with  $\alpha$  according to

$$\begin{aligned}\frac{\partial^2 S}{\partial \alpha \partial a} &= -\frac{\partial^2 b_S^m}{\partial a \partial \alpha} g(b_S^m) - \frac{\partial b_S^m}{\partial a} \frac{\partial g}{\partial b_S^m} \frac{\partial b_S^m}{\partial \alpha} \\ &= -\frac{\partial f}{\partial c_I} \frac{\partial \delta}{\partial f} g(b_S^m) + \left( \frac{\partial m}{\partial c_A} + \alpha \frac{\partial \delta}{\partial f} \frac{\partial f}{\partial c_I} \right) \frac{\partial g}{\partial b_S^m} \delta(f).\end{aligned}\quad (18)$$

In the following section, by assuming consumer and merchant benefits  $b_B$  and  $b_S$  are uniformly distributed, not only can this derivative be signed, but the separate effects of differences in demand levels and demand elasticities can be identified.

### 3.3 A specific functional form

Further results can be obtained by assuming specific forms for the functions and distributions above. Specifically, we assume the consumer and merchant benefits  $b_B$  and  $b_S$  are uniformly distributed. This distribution represents a benchmark case in which the density of consumer and merchant benefits are neither increasing or decreasing as the interchange fee is varied, thus enabling us to obtain explicit results. We define the mean transactional benefits to consumers and merchants from using cards to be  $\mu_B$  and  $\mu_S$ , with ranges  $2\sigma_B$  and  $2\sigma_S$  respectively. Thus,

$$\begin{aligned}b_B &\sim U[\mu_B - \sigma_B, \mu_B + \sigma_B] \\ b_S &\sim U[\mu_S - \sigma_S, \mu_S + \sigma_S].\end{aligned}$$

Using this distribution it is straightforward to show that demand and average benefit functions are linear in fees, so for instance

$$D(f) = \frac{\mu_B + \sigma_B - f}{2\sigma_B}$$

and

$$\delta(f) = \frac{\mu_B + \sigma_B - f}{2}.$$

From (18) this implies

$$\frac{\partial^2 S}{\partial a \partial \alpha} = \frac{1}{4\sigma_S} \frac{\partial f}{\partial c_I} \geq 0 \quad (19)$$

with the derivative being strictly positive whenever there is some pass through of costs by card issuing banks. Thus, for the uniform distribution it follows that the merchants' responsiveness to the interchange fee decreases as more consumers become aware of which merchant types accept cards and which do not. This, combined with the fact that when  $\alpha$  increases there are more merchants who accept cards, implies from Proposition 4 a positive interchange fee is privately and socially optimal, other things equal.

Moreover, from (11)

$$\frac{da^W}{d\alpha} = \frac{-\frac{\partial^2 W}{\partial a \partial \alpha}}{\frac{\partial^2 W}{\partial a^2}}. \quad (20)$$

Provided  $\partial^2 W / \partial a^2$  is negative, it is straightforward to show that a sufficient condition for  $da^W / d\alpha$  to be positive is that  $\partial^2 S / \partial a \partial \alpha \geq 0$ . Thus, the more consumers pick merchants based on whether they accept cards or not, the higher is the welfare maximizing interchange fee.

Explicit results for the optimal interchange fee can be obtained if we assume the per-transaction fees set by issuing and acquiring banks can be written in linear form. Specifically, we assume

$$f = \bar{\pi}_I + r_I(c_I - a) \quad (21)$$

and

$$m = \bar{\pi}_A + r_A(c_A + a), \quad (22)$$

where, from our earlier assumptions the pass-through coefficients satisfy  $r_I \geq 0$  and  $r_A \geq 0$ . If the pass-through coefficients are equal to one ( $r_I = r_A = 1$ ) then banks pass costs on one-for-one to end users, and issuing and acquiring banks' retain constant per-transaction profits of  $\bar{\pi}_I$  and  $\bar{\pi}_A$  respectively. If the pass-through coefficients are zero ( $r_I = r_A = 0$ ), banks keep fees to end users constant, and retain or absorb any changes in costs or interchange payments.

Substituting (21) and (22) into (15) and (16) implies

$$b_B^m = f = \bar{\pi}_I + r_I(c_I - a) \quad (23)$$

and

$$\begin{aligned} b_S^m &= m - \alpha \delta(f) \\ &= \bar{\pi}_A + r_A(c_A + a) - \frac{\alpha}{2}(\mu_B + \sigma_B - f). \end{aligned} \quad (24)$$

Substituting these expressions into (11) and rearranging terms implies the welfare maximizing interchange fee satisfies

$$\begin{aligned} & r_I \int_{m - \frac{\alpha}{2}(\mu_B + \sigma_B - f)}^{\mu_S + \sigma_S} (b_S + f - c_I - c_A) db_S \\ &= \left(r_A - \frac{\alpha}{2}r_I\right) \int_f^{\mu_B + \sigma_B} ((1 - \alpha)b_B + \alpha f + m - c_I - c_A) db_B. \end{aligned} \quad (25)$$

Similarly, substituting (23) and (24) into (14) and rearranging terms implies the banks' profit maximizing interchange fee satisfies

$$\begin{aligned} & (\pi_I + \lambda\pi_A) \left[ \begin{array}{c} r_I (\mu_S + \sigma_S - m + \frac{\alpha}{2}(\mu_B + \sigma_B - f)) \\ - (r_A - \frac{\alpha}{2}r_I) (\mu_B + \sigma_B - f) \end{array} \right] \\ & + (\lambda r_A - r_I + 1 - \lambda) \left[ \begin{array}{c} \mu_S + \sigma_S - m \\ + \frac{\alpha}{2}(\mu_B + \sigma_B - f) \end{array} \right] (\mu_B + \sigma_B - f) \\ &= 0. \end{aligned} \quad (26)$$

Both (25) and (26) imply that the optimal interchange fee is the solution to a quadratic.

### 3.3.1 A linear solution

The quadratics implied by (25) and (26) become linear expressions in the case where  $\alpha = 0$ ,  $\lambda = 1$  and  $r = r_I = r_A$ , which, after some laborious algebra, simplifies to

$$a^W = a^\Pi = a^T = \frac{c_I - c_A}{2} + \frac{(\bar{\pi}_I - \bar{\pi}_A) + (\mu_S - \mu_B) + (\sigma_S - \sigma_B)}{2r}. \quad (27)$$

When merchants do not decide whether to accept cards or not for strategic purposes ( $\alpha = 0$ ), and when the pass-through of costs is the same for both issuing and acquiring banks ( $r_I = r_A$ ), there is no particular reason for banks in aggregate to set interchange fees that differ from the output maximizing level (Proposition 2).<sup>21</sup> Moreover, in the particular case of uniformly distributed

<sup>21</sup>Provided  $r = 1$ , the same result applies for any value of  $\lambda$ , including the case  $\lambda = 0$ . Thus, even if acquiring banks have no say over the setting of the interchange fee, this does not necessarily imply an issuer controlled bank association will set the interchange fee too high. When  $r = 1$  even an issuer controlled association will want to maximize the total number of card transactions in order to maximize its profit, as its per-transaction profits will not depend on the interchange fee.

consumer and merchant benefits, equation (27) shows the socially optimal interchange fee also coincides with the output maximizing interchange fee. In this case both a bank association and a social planner will want to set the interchange fee to maximize the total number of card transactions.

Equation (27) illustrates our earlier propositions, and shows for the uniform distribution, Propositions 3 and 4 extend to a multivariate setting. When there is perfect symmetry, (27) implies the optimal interchange fee will be zero, as Proposition 3 predicts. The higher are the average benefits from accepting cards, and the lower are the costs of (and profits from) servicing merchants, the more merchants will accept cards. Other things equal, this implies to obtain the optimal balance in the network, one needs more cardholders and less merchants, which can be achieved via a higher interchange fee, as Proposition 4 predicts. With a uniform distribution, a greater range of cardholder and merchant benefits implies a lower density of consumer and merchant types. With an increase in the variability of merchant benefits there will be less merchants on the margin of accepting cards or not, and thus a smaller drop in merchant demand for any increase in interchange fees. As Proposition 4 suggests, this implies the optimal interchange fee will be higher.

Equation (27) implies that when banks do not pass on costs at all to consumers or merchants ( $r = 0$ ), the optimal interchange fee will be undefined. With no pass-through of interchange fees, the level of the interchange fee does not affect the fees consumers or merchants face. Rather, the interchange fee simply distributes funds from the acquiring bank to the issuing bank. Thus, for banks in aggregate to care about the interchange fee, it must be that there is some pass-through of costs.

### 3.3.2 Cost-based interchange fees

There is a natural tendency to argue that efficient interchange fees should be equal to cost, since in the telecommunications literature cost-based access prices and interconnection fees have sometimes been shown to maximize social welfare.<sup>22</sup> This tendency is misguided when applied to payment systems. Instead,

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<sup>22</sup>See Armstrong (2000) and Laffont and Tirole (2000) for a discussion of optimal access prices and interconnection fees. Models of interconnection typically assume networks are sym-

what matters is the difference in costs across issuing and acquiring banks. More generally, the results highlight that there are several determinants of optimal interchange fees, and that it is the differences in these variables across the two sides of the market, not their average level, that determines optimal interchange fees.

There is one special case where a cost-based interchange fee turns out to be optimal. If  $r_I = 0$  and  $\lambda = 1$ , (25) and (26) imply

$$a^W = \frac{1}{r_A} \left[ c_I + (1 - r_A)c_A - \alpha\bar{\pi}_I - \bar{\pi}_A - \frac{(1 - \alpha)}{2}(\mu_B + \sigma_B + \bar{\pi}_I) \right] \quad (28)$$

and

$$a^\Pi = \frac{1}{2r_A} \left[ c_I + 2(1 - r_A)c_A - \bar{\pi}_I - \bar{\pi}_A + \frac{\alpha}{2}(\mu_B + \sigma_B - \bar{\pi}_I) + (\mu_S + \sigma_S - c_A - \bar{\pi}_A) \right]. \quad (29)$$

Clearly if  $\alpha = 1$ ,  $r_A = 1$ ,  $\bar{\pi}_I = 0$ , and  $\bar{\pi}_A = 0$  then  $a^W = c_I$ . In the special case in which acquiring banks pass on all their costs to merchants while issuing banks do not rebate any of the interchange revenue back to cardholders, cost-based interchange fees can be justified as a cap on the interchange fee which should be charged. Under this extreme assumption, the interchange fee is like a one-way access fee, since it is not competed away at all by issuing banks.<sup>23</sup> The profit maximizing interchange fee, which is given by (29), will generally diverge from the welfare maximizing and output maximizing interchange fee as predicted in Proposition 2. When acquiring banks pass on all their costs, but issuing banks retain all interchange revenue, the banking industry has an incentive to tax the competitive merchant services side of its business (where the tax will be passed on to the merchant) and use the tax to subsidize the less competitive cardholding side of the business (where the subsidy will not be competed away).

More generally, even if the pass-through coefficient for issuing banks is less than for acquiring banks, issuing banks will still pass-through costs and rebate metric and all consumers participate. Once consumers differ and there is partial participation for at least one type of consumer, cost-based interconnection fees are no longer generally optimal. Wright (2001) demonstrates this result in the context of fixed-to-mobile termination charges.

<sup>23</sup>Note even a monopolist issuing bank would choose to pass back some of the interchange fee to customers. For instance, the pass-through coefficient for a monopolist firm facing linear demand and constant marginal costs is one-half.

interchange revenues to some extent. A linear solution arises under the more general condition that  $r_A = (1 + \frac{\alpha}{2})r_I$  and  $\lambda = 1$ , in which case the socially optimal interchange fee is

$$a^W = \frac{2(\mu_S + \sigma_S - \bar{\pi}_A - r_A c_A) - (2 - \alpha)(\mu_B + \sigma_B - \bar{\pi}_I - r_I c_I)}{4r_I}.$$

The result implies the socially optimal interchange fee is increasing in the overall level and range of benefits ( $\mu$  and  $\sigma$ ) and decreasing in the overall level of costs and markups ( $c$  and  $\bar{\pi}$ ). For instance, if  $\alpha = 1$ ,  $r_A = 1$  and  $c = c_A = c_I$ , then  $da^W/dc = -1/2$ . Thus, the model suggests not only is the principle of cost-based interchange fees wrong in general, but that at least for the special case examined here it is exactly the opposite of what is required for socially optimal outcomes.

### 3.3.3 Effects of merchant competition

Perhaps the most important determinant of interchange fees is the strategic motive for merchants to accept cards. The strategic motive for merchants to accept cards implies more merchants will accept cards, and merchant demand will become more inelastic. As (20) shows, both these factors cause the socially optimal interchange fee to increase. To see what exactly these factors imply for optimal interchange fees, we assume  $r = r_I = r_A$  and  $\lambda = 1$ , and consider several special cases.

In general, the privately optimal interchange fee is

$$a^\Pi = \frac{(\mu_S + \sigma_S - r c_A - \bar{\pi}_A) - (1 - \alpha)(\mu_B + \sigma_B - r c_I - \bar{\pi}_I)}{(2 - \alpha)r} \quad (30)$$

so that

$$\frac{da^\Pi}{d\alpha} = \frac{2\delta}{(2 - \alpha)r}. \quad (31)$$

Because  $\delta > 0$  the derivative in (31) will be positive and the banks' preferred interchange fee is increasing in  $\alpha$ .

The corresponding derivative for the socially optimal interchange fee can be obtained by totally differentiating (25) with respect to  $a$  and  $\alpha$ . After considerable simplification this derivative can be written as

$$\frac{da^W}{d\alpha} = \frac{2\delta [\pi_I + \pi_A + \frac{3}{2}(1 - \alpha)\delta]}{r [(2 - \alpha)(\pi_I + \pi_A) + \mu_S + \sigma_S - m + 2\gamma\delta]}, \quad (32)$$

where

$$\gamma = 1 - \frac{3\alpha}{2} \left(1 - \frac{\alpha}{2}\right) > 0.$$

Equation (32) shows that the socially optimal interchange fee also increases in  $\alpha$ .<sup>24</sup>

An explicit result for the socially optimal interchange fee can also be obtained by looking at the special case  $\alpha = 1$ ,  $r_I = r_A = 1$  and setting per-transaction profits ( $\bar{\pi}_I$  and  $\bar{\pi}_A$ ) equal to zero in (25). This implies,

$$a^W = \frac{2(\mu_S + \sigma_S - c_A) - (\mu_B + \sigma_B - c_I)}{3}, \quad (33)$$

and the optimal interchange fee will generally be positive.

Comparing (33) with (27) in the case profits are negligible, the socially optimal interchange fee increases by

$$\frac{(\mu_S + \sigma_S - c_A) + (\mu_B + \sigma_B - c_I)}{6}$$

as a result of moving from the case in which no consumers are aware of which merchants accept cards ( $\alpha = 0$ ), to a case in which all consumers are aware of which merchants accept cards ( $\alpha = 1$ ).

Although with zero profits and equal pass-through coefficients banks will be indifferent over the level of the interchange fee, the privately set interchange fee is still determined for any positive per-transaction profits, no matter how small. Thus, by taking the limit as per-transaction profits tend to zero, the corresponding privately optimal interchange fee is

$$a^\Pi = \mu_S + \sigma_S - c_A, \quad (34)$$

which is an increase of

$$\frac{\mu_S + \sigma_S - c_A}{2} + \frac{\mu_B + \sigma_B - c_I}{2}$$

compared to the case with  $\alpha = 0$ .

Comparing (33) with (34) it is clear that the profit maximizing interchange fee exceeds the welfare maximizing interchange fee by

$$\frac{\mu_S + \sigma_S - c_A}{3} + \frac{\mu_B + \sigma_B - c_I}{3}$$

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<sup>24</sup>A sufficient condition for the derivative to be positive is that  $\pi_I + \pi_A \geq 0$  (so banks' combined per-transaction profit is non-negative), and  $\mu_S + \sigma_S - m + \frac{\delta}{2} > 0$  (so some merchants would accept cards if half the consumers were informed of whether merchants accept cards or not).

for this case. Given Proposition 1 it is not clear whether this result generalises to other distributions of cardholder and merchant benefits.

These results show that a fundamental determinant of the optimal interchange fee is the extent to which consumers know in advance whether merchants will accept cards or not. Where consumers are well informed, card acceptance becomes an important strategic instrument for merchants to increase their market share. Without a correspondingly higher interchange fee, there will be a net positive externality running from card usage to merchant benefits (as merchants internalise the average cardholder benefits while consumers do not internalise merchant benefits), and too much merchant acceptance relative to cardholder use. In addition, when consumers choose merchants based on whether they accept cards or not, merchant card acceptance becomes more inelastic, again implying a higher interchange fee is preferred.

## 4 Extensions

In this section two extensions to the model above are considered. First, the impact of fixed costs and membership fees on the optimal interchange fee is analyzed. Second, using a model in which consumers face membership fees, an additional strategic reason why merchants accept cards is considered.

### 4.1 Membership Fees and Costs

In some cases consumers are charged annual fees for having a credit card. Moreover, some of the costs of running a card system (such as customer service) could relate to the number of cardholders or merchants served, rather than the number of transactions completed. With costs to issuing banks of  $C_I$  per cardholder and  $C_A$  per merchant, the first-order conditions from welfare and profit maximization are

$$\begin{aligned} \frac{\partial W}{\partial a} &= \frac{\partial D}{\partial a} \left[ \int_{b_S^m}^{\infty} (b_B^m + b_S - c_I - c_A) g(b_S) db_S - C_I \right] \\ &\quad + \frac{\partial S}{\partial a} \left[ \int_{b_B^m}^{\infty} (b_B + b_S^m - c_I - c_A) h(b_B) db_B - C_A \right] \\ &= 0 \end{aligned} \quad (35)$$

and

$$\begin{aligned}
\frac{\partial \Pi}{\partial a} &= (\pi_I + \lambda \pi_A) \left[ S \frac{\partial D}{\partial a} + D \frac{\partial S}{\partial a} \right] \\
&\quad - C_I \frac{\partial D}{\partial a} - \lambda C_A \frac{\partial S}{\partial a} \\
&\quad + \left( \frac{\partial \pi_I}{\partial a} + \lambda \frac{\partial \pi_A}{\partial a} \right) DS \\
&= 0.
\end{aligned} \tag{36}$$

Optimality (both for the banks and the social planner) implies the interchange fee is decreasing in the cost per cardholder and increasing in the cost per merchant. Specifically

$$\frac{da^W}{dC_I} = \frac{\frac{\partial D}{\partial a}}{\frac{\partial^2 W}{\partial a^2}} < 0 \text{ and } \frac{da^\Pi}{dC_I} = \frac{\frac{\partial D}{\partial a}}{\frac{\partial^2 \Pi}{\partial a^2}} < 0$$

and

$$\frac{da^W}{dC_A} = \frac{\frac{\partial S}{\partial a}}{\frac{\partial^2 W}{\partial a^2}} > 0 \text{ and } \frac{da^\Pi}{dC_A} = \frac{\lambda \frac{\partial S}{\partial a}}{\frac{\partial^2 \Pi}{\partial a^2}} > 0,$$

provided  $\partial^2 W / \partial a^2 < 0$  and  $\partial^2 \Pi / \partial a^2 < 0$ .

Where banks pass on these costs to cardholders and merchants, the effect on the optimal interchange fee is more complex. Even with the simplification that  $\alpha = 0$ , Appendix B shows there will be a range of  $b_S$  between

$$b_S^r = m + \frac{3t}{1 - H(b_B^m)} \left( \sqrt{1 + \frac{2M}{t}} - 1 \right) \tag{37}$$

and

$$b_S^m = m + \frac{3t}{1 - H(b_B^m)} \left( 1 - \sqrt{1 - \frac{2M}{t}} \right) \tag{38}$$

for which hybrid equilibria exists — so that one merchant will accept cards and one will reject in each such industry. For  $b_S \leq b_S^r$  it is a unique equilibrium for both merchants to reject cards and for  $b_S \geq b_S^m$  it is a unique equilibrium for both merchants to accept cards. Adding to this complexity is the possibility of self-fulfilling beliefs in which consumers will not pay anything to hold cards if they do not expect their cards to be honoured by merchants, while merchants will not pay a fee to accept cards if they anticipate no cardholders.

One solution to the problem of self-fulfilling beliefs is for banks to charge fixed fees on only one side of the market. Possibly for this reason, a number of card payment systems involve annual fees for cardholders but not for merchants.

To examine the implications of such pricing for interchange fees, we assume positive costs of handling additional cardholders and merchants ( $C_I > 0$  and  $C_A > 0$ ), while assuming only cardholders face these additional costs ( $F = C_I$  and  $M = 0$ ). We continue to assume  $\alpha = 0$ . The marginal cardholder is then defined by

$$b_B^m = f + \frac{F}{1 - G(b_S^m)}, \quad (39)$$

so that all consumers with benefits  $b_B$  greater than  $b_B^m$  will obtain and use cards, while  $b_S^m = m$ . The first order condition for welfare maximization simplifies to

$$\begin{aligned} \frac{\partial W}{\partial a} &= \frac{\partial D}{\partial a} \left[ \int_{b_S^m}^{\infty} (f + b_S - c_I - c_A) g(b_S) db_S \right] \\ &\quad + \frac{\partial S}{\partial a} \left[ \int_{b_B^m}^{\infty} (b_B + m - c_I - c_A) h(b_B) db_B - C_A \right] \\ &= 0 \end{aligned} \quad (40)$$

where

$$\frac{\partial D}{\partial a} = \left( r_I - r_A \frac{g(m)F}{1 - G(m)} \right) h(b_B^m)$$

and

$$\frac{\partial S}{\partial a} = -r_A g(m).$$

Note  $b_B^m$  is higher than when  $F = 0$ , which suggests a higher interchange fee is optimal. A higher interchange fee is also preferred, to the extent that the fixed costs per cardholder is passed onto consumers but not shared by merchants, while the fixed costs per merchant are not passed on at all. However, offsetting these effects is the fact that demand for cards is less responsive to interchange fees when there are membership fees. Any increase in the interchange fee decreases the number of merchants accepting cards, which means the fixed costs of card membership will be spread over fewer card transactions, thus reducing the extent to which an increase in interchange fees expands consumers' demand for card usage. Thus, without further specification of cardholder and merchant benefits, the effect of fixed costs and membership fees on the optimal interchange fee is ambiguous.<sup>25</sup>

<sup>25</sup>The analysis becomes even more complex once the strategic motive for accepting cards is allowed for ( $\alpha > 0$ ). In this case merchants' joining decision depends on the average cardholder benefit, which in turn depends on how many merchants decide to join.

The above model could be used to address the trade-off which can arise between the optimal number of cardholders and the optimal usage by cardholders. The trade-off arises because consumers do not internalize the benefits that merchants obtain when they decide whether to hold cards, and because merchants and acquiring banks are not willing to help share the fixed costs of getting consumers to hold cards in the first place. Each individual merchant and acquiring bank takes as given the number of cardholders because each individual merchant and acquiring bank can only expect to recover a small fraction of benefits arising from any additional cardholder. This suggests a transfer to encourage consumers to hold cards, by way of a higher interchange fee, is welfare enhancing. However, because a higher interchange fee results in a higher rebate for card usage, some inframarginal cardholders will then use cards too much. In setting the interchange fee a payment system will have to consider not only the trade-off between card usage and merchant acceptance, but also the trade-off between card membership and card usage, as in Wright (2000).

An alternative way to promote card membership without leading to excessive card usage would be for banks to receive a payment (or make a payment) based on the difference between the number of cardholders and merchants a bank brings to the system. However, arrangements not based on usage are vulnerable to abuse, with consumers obtaining multiple cards simply to earn rebates for signing up. In contrast, an ad-valorem interchange fee ensures that any rebates to cardholders are only proportional to how much the consumer spends.

## 4.2 Impulse purchases

In this section another reason why merchants accept payment cards is investigated. If payment cards allow consumers instant access to cash or funds which they would not otherwise have, they ensure consumers will be able to make instantaneous purchase decisions. Sometimes, consumers may delay purchases if they do not have cash in their pocket, or funds in their chequing account. While consumers may not lose much by delaying their purchase, sometimes they will end up making their purchase from a different merchant. Thus, merchants will accept cards in order to capture the margins on such sales, rather than risk losing these margins to their rivals. Because merchants do not internalize the

margins of their rivals, this motive for accepting cards tends to lead to too many merchants accepting cards. A higher interchange fee helps re-balance the network, leading to fewer merchants that accept cards and more cardholders.

To show how this effect arises in our model, an extension of the basic model in which merchants compete in each industry according to the Hotelling model is considered. We suppose that each time a consumer is matched with an industry, the consumer wants to make an impulse purchase with probability  $q$  and a normal purchase with probability  $1 - q$ . A normal purchase is treated in the same way as in our standard model where consumers are uninformed of which merchants accept cards ( $\alpha = 0$ ).

For an impulse purchase, the consumer does not observe the merchant price or acceptance policy before deciding which merchant to frequent. Rather each consumer goes to the nearest merchant based on their random location  $x$ . This captures the notion that for some purchases, consumers ‘stumble’ across things they wish to buy, rather than knowing in advance which merchant they wish to purchase from. If consumers do not hold a card they are assumed to hold cash for such occasions. However, if they do carry a card, we assume they do not have cash available to make the purchase, and so can only make the impulse purchase if the merchant accepts their card.<sup>26</sup> Where consumers cannot complete their purchase because merchants do not accept cards and they lack cash, we assume the consumer obtains cash and a new draw of their location  $x$ , and makes a normal purchase decision (observing both merchants’ prices). In doing so, because they may go to a different location to obtain their cash, there is a risk they will end up purchasing the same item from a rival firm. To distinguish this effect from the previous strategic motive for accepting cards in which merchants accepted cards to attract cardholders to their stores, we maintain the assumption that consumers do not take into account merchants’ acceptance policy when choosing between the two merchants.<sup>27</sup>

Suppose in all industries with  $b_S$  greater than some  $b_S^m$  all merchants ac-

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<sup>26</sup>A richer model could endogenize the choice of cash holding, which will depend on the benefits as well as opportunity costs of holding cash. Presumably those who choose to carry cards will optimally want to hold less cash.

<sup>27</sup>This would be true if consumers assume that where one merchant in an industry rejects cards, so will the other.

cept cards, while with  $b_S$  less than  $b_S^m$  no merchants accept cards. Given this assumption the critical level of transactional benefits consumers require before joining the card network is equal to

$$b_B^m = f + \frac{F}{1 - G(b_S^m)},$$

where we retain the fixed membership fee  $F$  for cardholders from the previous section. Because  $b_B^m > f$ , consumers who subscribe to card networks will always use their cards whenever possible.

Consider the case both merchants of type  $b_S$  accept cards. Each merchant will earn profits of

$$\max_{p_i} \left[ (p_i - (d + (1 - H)(m - b_S))) \left( s_i(1 - q) + \frac{1}{2}q \right) \right],$$

where

$$s_i = \frac{1}{2} + \frac{p_j - p_i}{2t}. \quad (41)$$

With probability  $1 - q$ , consumers make normal purchase decisions and merchants' profit is simply their market share multiplied by their margin between price and cost. With probability  $q$ , consumers frequent the merchant closest to their draw of  $x$  on  $U[0, 1]$ . Thus, with probability  $q$ , half the time consumers will go to firm  $i$  and half the time they will go to firm  $j$ . Solving the maximization problems for each merchant simultaneously implies prices for a merchant in industry of type  $b_S$  of

$$p_i = p_j = d + t + (1 - H)(m - b_S) + \frac{q}{1 - q}t$$

and profits of all merchants that accept cards of

$$\Pi_i = \frac{t}{2(1 - q)}. \quad (42)$$

Alternatively, if merchant  $i$  rejects cards while merchant  $j$  accepts, merchant  $i$  will only make cash sales. With probability  $1 - q$  of the time, consumers will make their normal purchase decisions. With probability  $q$ , consumers frequent the merchant closest to their draw of  $x$  on  $U[0, 1]$ . In this case, half the time consumers will go to firm  $i$ . A proportion  $H$  of these consumers hold cash and will buy from merchant  $i$ . The remaining  $1 - H$  will not hold cash, and so will get a new draw of  $x$  on  $U[0, 1]$  and make their purchase decision according to the

share function (41). Thus, the proportion of such consumers which merchant  $i$  obtains is  $\frac{1}{2}q(1-H)s_i$ .

Firm  $i$ 's profit function is thus

$$\max_{p_i} \left[ (p_i - d) \left( s_i \left( 1 - q + \frac{1}{2}q(1-H) \right) + \frac{qH}{2} \right) \right].$$

Because merchant  $j$  accept cards, it obtains all its own customers, plus a share  $1 - s_i$  of those who delay their purchase because of lack of funds. Its profit is

$$\max_{p_j} \left[ \begin{aligned} &(p_j - d) \left( 1 - s_i \left( 1 - q + \frac{1}{2}q(1-H) \right) - \frac{qH}{2} \right) \\ &- (1 - s_i + \frac{1}{2}qs_i) (1-H)(m - b_S) \end{aligned} \right].$$

Solving the first order conditions simultaneously the equilibrium prices are

$$p_i = d + \frac{(6 - q + qH)t}{3(2 - q - qH)} + \frac{(2 - q)(1 - H)(m - b_S)}{3(2 - q - qH)}$$

and

$$p_j = d + \frac{(6 + q - qH)t}{3(2 - q - qH)} + \frac{2(2 - q)(1 - H)(m - b_S)}{3(2 - q - qH)}.$$

Substituting these prices into firm  $i$ 's profit function above it follows that

$$\Pi_i = \frac{t}{2 - q - qH} \left( 1 - (1 - H) \frac{qt + (b_S - m)(2 - q)}{6t} \right)^2. \quad (43)$$

Comparing (43) with (42), both merchants accepting cards is an equilibrium if

$$b_S \geq b_S^m = m - \frac{qt}{2 - q} - \frac{6t}{(2 - q)(1 - H)} \left( \sqrt{1 + \frac{q(1 - H)}{2(1 - q)}} - 1 \right). \quad (44)$$

If both merchants reject cards, it is straightforward to show they each charge

$$p_j = d + \frac{t}{(1 - qH)}$$

and earn a profit of

$$\Pi_j = \frac{t}{2(1 - qH)}.$$

When this profit is compared to the profit of accepting cards when the rival merchant rejects, it can be shown that provided the proportion of impulse purchases is not too much, and there are sufficient cardholders, both merchants will want to reject cards whenever  $b_S < b_S^m$ .<sup>28</sup> We assume that where multiple equilibria exist, an equilibrium in which both merchants have the same acceptance

<sup>28</sup>A sufficient condition is that  $q < 0.5$  and  $H < 0.6$ .

policy is picked over an equilibrium where one accepts and one rejects, and an equilibrium in which both merchants accept cards is picked over an equilibrium where both reject cards. Thus, with  $b_S^m$  defined in (44), all merchants with  $b_S < b_S^m$  will reject cards and all merchants with  $b_S > b_S^m$  will accept cards.

Equation (44) shows that merchants will accept cards in part because they want to capture sales from impulse buyers. If  $q = 0$  in (44) our earlier solution that  $b_S^m = m$  is obtained. For impulse sales,  $q > 0$  and  $b_S^m < m$ . As with the other strategic motive for accepting cards, this suggests the privately and socially optimal interchange fee will be higher, so as to reduce merchant demand and increase cardholder usage. Whether interchange fees should be increased as a result of impulse purchases also depends on what happens to the responsiveness of merchant demand to the interchange fee.

Totally differentiating (44) implies

$$\frac{db_S^m}{da} = \frac{r_A + \frac{6ht}{(2-q)(1-H)^2} r_I \phi}{1 + \frac{6ghtF}{(1-G)^2(2-q)(1-H)^2} \phi},$$

where

$$\phi = \sqrt{1 + \frac{q(1-H)}{2(1-q)}} - 1 - \frac{q(1-H)}{2\sqrt{1 + \frac{q(1-H)}{2(1-q)}}}.$$

Provided the proportion of impulse purchases is not too large ( $q < 0.45$  is a sufficient condition),  $\phi \leq 0$ . With  $\phi \leq 0$  it is straightforward to show  $\partial b_S^m / \partial a \leq r_A$  whenever

$$F < \frac{r_I(1-G)^2}{gr_A}. \quad (45)$$

Thus, as long as annual fees for cardholders are not too large, merchant demand becomes less responsive to interchange fee as a result of impulse purchases, and the privately and socially optimal level of the interchange fee should increase.

## 5 Conclusions

This paper has provided a simple framework to analyze open payment systems, which builds on the existing work of Baxter (1983), Rochet and Tirole (2000), and Schmalensee (2001) by taking account of heterogeneity of both consumers and merchants, and by relating cardholders' rebates to usage rather than membership. Our framework characterizes the fundamental role of the interchange

fee, which is to achieve the best possible trade-off between promoting cardholder and merchant demand. Social optimality occurs when the interchange fee balances the additional cardholder demand from a higher interchange fee, and the surplus arising from the additional card usage with participating merchants, with the decrease in merchant demand from a higher interchange fee, and the surplus lost from a decrease in card acceptance for existing card users. Optimality will no longer be characterized by the joint transactional benefits equal joint costs condition that Baxter emphasized. Rather, optimality also depends on the infra-marginal cardholders and merchants, and the surplus they obtain when another card user or merchant joins the system. Thus, we find that the social planner may want to sacrifice some card transactions by setting an interchange fee above or below the output maximizing level, if by doing so the loss in benefits to the marginal users are outweighed by the gain in benefits from inframarginal users. The card association may also want to set an interchange fee that does not maximize the total number of card transactions if by doing so they can shift revenues to the side of the market where they are competed away less, or if one type of bank has more say in setting the interchange fee.

Other than these cases, the output maximizing, profit maximizing, and welfare maximizing interchange fee will coincide. The Frankel (1998) argument that bank associations will choose interchange fees that ‘tax’ cash customers (through merchants) and use the tax to bribe card customers to use their cards too much does not generally apply once merchants’ decision of card acceptance is incorporated.

Using special cases of our model explicit results were obtained for the privately and socially optimal levels of the interchange fee. Under various simplifying assumptions we found that the privately and socially optimal interchange fees are increasing in the issuers’ costs and profitability, and decreasing in the acquirers’ costs and profitability. Similarly, optimal fees are increasing in the average transactional benefits to merchants, and decreasing in the average transactional benefits to cardholders. Differences in demand responsiveness across cardholders and merchants are also important. If merchant demand is less responsive to fees than cardholder demand, the optimal interchange fee will be higher as it is more efficient to cover the costs of providing the joint service from

the less elastic side of the market. In our model, a larger range of merchant transactional benefits and a smaller range of cardholder transactional benefits will lower the responsiveness of merchant demand compared to cardholder demand. When transactional benefits are more spread out, fewer users will change their behavior for a given change in fees. Thus optimal interchange fees are increasing in the variance of transactional benefits to merchants and decreasing in the variance of transactional benefits to cardholders.

The optimal interchange fee was also found to be increasing in the extent to which merchants accept cards to attract additional customers to their stores. This strategic motive for accepting cards implies merchants internalise the average benefit their customers get from being able to use cards. Because consumers do not internalise the benefits that merchants obtain, an interchange fee will optimally lead to merchants covering more of the cost of providing the payment system so that network externalities are better internalised. Absent such an interchange fee, there will be an imbalance in demand, with too many merchants accepting cards relative to cardholders. These effects are reinforced by the fact the strategic motive for accepting cards makes merchant demand less responsive to the interchange fee than cardholder demand. Both of these factors imply a higher interchange fee is justified.

One potentially important determinant of optimal interchange fees which we have not examined is the extent of competition between payment systems. By comparing a single card system with given alternatives (say cash and cheques), we are abstracting from any competition existing between the two open card systems (MasterCard and Visa), as well as between these systems and closed card systems (American Express, Diners Club, and Discover). The degree of inter-system competition may affect the nature of cardholder and merchant demand, and thus the optimal interchange fee.

In analyzing inter-system competition, research should analysis the effects of changing the interchange fee set by open card systems on the retail fees set by closed card systems. If regulation requires open systems to set a level of the interchange fee which is lower than that which maximizes the total number of card transactions, it is not clear why competing closed schemes would want to lower merchant service fees and reduce cardholder rebates in response. To

the extent closed schemes will not match a change in the structure of the fees in open schemes, the regulation of interchange fees in open schemes will not be competitively neutral. Along these lines, more work is needed analyzing the advantages and disadvantages of different organizational forms for payment systems (joint venture, proprietary, and franchise), so that the consequences of any policy bias against one type of system can be better understood.

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## 7 Appendix A

In this appendix the equilibrium for merchant acceptance in each industry is derived when there are no per-cardholder or per-merchant fees. The derivation is a straightforward modification of the results of Rochet and Tirole who deal with the case of a single industry where both merchants have the same level of  $b_S$ . Their derivations are modified to allow consumers to know which merchants accept cards only a fraction  $\alpha$  of the time, and for the fact the benefit to consumers from card usage in our model is  $b_B - f$  per-transaction, rather than just  $b_B$ . Suppose in all industries with  $b_S$  greater than some  $b_S^m$  merchants accept cards, while with  $b_S$  less than  $b_S^m$  merchants do not accept cards. Given this assumption, consumers will use cards whenever  $b_B > f$ .

Consider first the case where both merchants accept cards in an industry of type  $b_S$ . We consider when this will be an equilibrium. When both merchants

accept cards the merchants average cost is

$$d + (1 - H(f))(m - b_S).$$

Given merchant  $i$ 's market share

$$s_i = \frac{1}{2} + \frac{p_j - p_i}{2t}$$

the merchant solves

$$\max_{p_i} (p_i - (d + (1 - H(f))(m - b_S)))s_i.$$

This implies prices for a merchant in industry of type  $b_S$  of

$$p_i = p_j = d + t + (1 - H(f))(m - b_S)$$

and equilibrium profits of all merchants that accept cards of

$$\Pi_i = \frac{t}{2}. \quad (46)$$

Now suppose merchant  $i$  deviates by not accepting cards. Consumers of type  $b_B < f$  will not want to use cards, so for such consumers the fraction that purchase from firm  $i$  is

$$x_i = \frac{1}{2} + \frac{p_j - p_i}{2t}.$$

The same share function applies for those consumers who do want to use cards but do not know whether merchants accept cards or not. For the remaining consumers (a fraction  $\alpha$  of those with  $b_B > f$ ), the share that purchase from firm  $i$  is

$$x_i = \frac{1}{2} + \frac{p_j - p_i - (b_B - f)}{2t}.$$

Aggregating over all customers,

$$s_i = \frac{1}{2} + \frac{p_j - p_i - \alpha \int_f^\infty (b_B - f)h(b_B)db_B}{2t}$$

and merchant  $i$  solves

$$\max_{p_i} (p_i - d)s_i$$

implying prices of

$$p_i = \frac{1}{2} \left[ p_j + t + d - \alpha \int_f^\infty (b_B - f)h(b_B)db_B \right]. \quad (47)$$

Similarly, merchant  $j$  solves

$$\max_{p_j} \left[ \begin{array}{c} H(f)(p_j - d) \left( \frac{1}{2} + \frac{p_i - p_j}{2t} \right) \\ + (1 - H(f))(p_j - d - m + b_S) \left( \frac{1}{2} + \frac{p_i - p_j + \alpha\delta(f)}{2t} \right) \end{array} \right] \quad (48)$$

which implies

$$p_j = \frac{1}{2} \left[ p_i + t + d + \alpha \int_f^\infty (b_B - f) h(b_B) db_B + (1 - H(f))(m - b_S) \right]. \quad (49)$$

Solving (47) and (49) simultaneously implies

$$p_i = t + d + \frac{1}{3}(1 - H(f))(m - b_S - \alpha\delta(f)) \quad (50)$$

and

$$p_j = t + d + \frac{1}{3}(1 - H(f))(2(m - b_S) + \alpha\delta(f)) \quad (51)$$

Substituting (50) into firm  $i$ 's profit function implies

$$\Pi_i = \frac{t}{2} \left[ 1 - (1 - H(f)) \frac{\alpha\delta(f) + b_S - m}{3t} \right]^2. \quad (52)$$

Comparing (52) with (46), it is clear that merchant  $i$  will want to accept cards if

$$b_S \geq m - \alpha\delta(f) \equiv b_S^m$$

which verifies the result in (16).

Next consider the possible equilibrium where both firms reject cards. In this case prices are trivially found by

$$\max_{p_j} (p_j - d) \left( \frac{1}{2} + \frac{p_i - p_j}{2t} \right)$$

and so

$$\Pi_j = \frac{t}{2}. \quad (53)$$

If firm  $j$  deviates and accepts cards, while firm  $i$  still rejects cards, prices will be given by (50) and (51). Substituting these prices into firm  $j$ 's profit given by (48) implies

$$\begin{aligned} \Pi_j &= \frac{t}{2} \left[ 1 - (1 - H(f)) \frac{m - b_S - \alpha\delta(f)}{3t} \right]^2 \\ &\quad - \frac{1}{2t} (m - b_S) H(f) (1 - H(f)) \alpha\delta(f). \end{aligned} \quad (54)$$

In an industry of type  $b_S \leq b_S^m = m - \alpha\delta(f)$ , merchant  $j$  will not want to deviate and accept cards as (54) is strictly less than (53). In this case there is

a unique equilibrium where both merchants reject cards. For some  $b_S > b_S^m$ , but sufficiently close to  $b_S^m$ , it will also be an equilibrium for both merchant to reject cards. Following Rochet and Tirole, where there are multiple equilibria (such that merchant profits are identical across the equilibrium) we assume merchants or the card association (which prefers the equilibrium with more merchant acceptance), are able to pick the equilibrium where both merchants accept cards.

The final possibility to consider is of a hybrid equilibrium where merchant  $j$  accepts cards while merchant  $i$  does not. For this to be an equilibrium requires that the profit in (52) be at least as high as that in (46) and that the profit in (54) be at least as high as that in (53). If  $b_S \leq m - \alpha\delta(f)$  then  $\Pi_j < \frac{t}{2}$  so firm  $j$  will not want to accept cards, while if  $b_S > m - \alpha\delta(f)$  then  $\Pi_i < \frac{t}{2}$  so firm  $i$  will not want to reject cards. Thus, there is no hybrid equilibrium where one merchant accepts and one rejects cards.<sup>29</sup>

## 8 Appendix B

In this appendix we derive the equilibrium for merchant acceptance in each industry where merchant incur membership or annual fees ( $M$ ), assuming all cardholders with  $b_B \geq b_B^m$  hold and use cards, and  $\alpha = 0$ .

Consider the case where both merchants of type  $b_S$  accept cards. Following the same argument as in Appendix A, the resulting profit will be

$$\Pi_i = \frac{t}{2} - M. \quad (55)$$

If merchant  $i$  rejects cards while merchant  $j$  continues to accept cards, it is straightforward to show (following the derivation in Appendix A), that

$$\Pi_i = \frac{t}{2} \left[ 1 - (1 - H(b_B^m)) \left( \frac{b_S - m}{3t} \right) \right]^2 \quad (56)$$

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<sup>29</sup>We assume in these derivations that  $t$  is not so small that  $(1 - H(f)) \frac{|m - \bar{b}_S - \alpha\beta(f)|}{3t}$  exceeds 2, where  $\bar{b}_S$  is the highest value of  $b_S$  with a positive value of  $g(b_S)$ . If this condition is not satisfied it is straightforward to show there exists some industries with high enough values of  $b_S$  with a hybrid equilibrium. Moreover, with very low values of  $t$  (little product differentiation between merchants), the constraints that market shares for each type of customer are between 0 and 1 may become binding in this case. Wright (2001) analyzes a model with perfect competition between merchants and shows only a hybrid equilibrium exists.

and

$$\Pi_j = \frac{t}{2} \left[ 1 - (1 - H(b_B^m)) \left( \frac{m - b_S}{3t} \right) \right]^2 - M. \quad (57)$$

Finally, if both merchants reject cards, their profits equal

$$\Pi_j = \frac{t}{2}. \quad (58)$$

Both merchants accepting cards is an equilibrium provided (55) is at least as high as (56). This is true if  $b_S \geq b_S^m$ , where  $b_S^m$  is defined by equation (38). Note that provided equilibrium profits in (55) are positive,  $\Pi_i = \frac{t}{2} - M > 0$  and  $\frac{2M}{t} < 1$ . This ensures  $b_S^m$  is well defined.

For it to be an equilibrium for both merchants to reject cards it must be that (58) exceeds (57) which requires  $b_S \leq b_S^r$ , where  $b_S^r$  is defined by equation (37). Finally, a hybrid equilibrium in which firm  $i$  rejects cards and firm  $j$  accepts cards occurs whenever  $b_S < b_S^m$  and  $b_S > b_S^r$ . It is straightforward to show that provided  $M > 0$ ,  $b_S^m > b_S^r$ . Thus, for  $b_S \leq b_S^r$  it is a unique equilibrium for both merchants to reject cards, for  $b_S \geq b_S^m$  it is a unique equilibrium for both merchants to accept cards, and for  $b_S$  between  $b_S^r$  and  $b_S^m$  it is a unique equilibrium for one merchant to accept cards and for one merchant to reject cards.