Consumer credit and payment cards

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PRELIMINARY DRAFT — PLEASE DO NOT QUOTE

Abstract

We consider two different business models of payment cards; debit and credit cards. Our contribution is to introduce the role of consumer credit into these payment networks, and to assess the way this affects equilibrium fees and competition. Whilst network fees are set monopolistically, we assume interest rates are determined by a competitive 'aftermarket' for credit. We find that credit card fees still depend on the networks' cost of funds and the probability of default. When we consider competition between the two business models, we find degrees of both competition and complementarity between debit and credit card networks. Effectively, the bank offering the debit card benefits from consumers maintaining a positive current account balance, when they use their credit instead of their debit card. As a result, the debit card fee may be increased to discourage debit card acceptance at the margin, allowing for the possibility that debit cards are driven out of the market in equilibrium.

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1 Introduction

Debit or credit? Every day, millions of consumers stand at store checkout counters and make a payment decision: whether to pay by debit or by credit card. Since the retail price at the checkout is generally the same either way, this decision looks pointless. It is not. Financial incentives, merchants' interests, and available credit facilities do play an important role for consumer payment choice. Moreover, behind the scenes, billions of dollars are at stake.

The present paper studies equilibrium pricing of payment cards and analyzes the economic consequences of payment card competition. Since payment card networks are two-sided markets, we consider the optimal fees charged by the network to the consumer and to the merchant. Unlike most payment models, where consumer credit is not considered, our model is among the first to analyze payment network fees and competition by explicitly incorporating the different ways consumer credit is offered in debit and credit card networks. Specifically, we consider overdraft facilities and credit lines.

In our framework, payment cards derive their intrinsic value from consumers' liquidity constraints and from enabling the consumer to economize on cash holdings. That is, debit and credit cards may provide additional security over cash and the ability to borrow funds allowing consumers to increase their consumption. Furthermore, merchants may be willing to partly subsidize the cost to consumers to increase sales and avoid handling cost of cash. In effect, consumers and merchants trade off these increased consumption possibilities and cost savings from reduced cash use against payment card fees and potential finance charges. Ultimately, the ability of payment networks to extract surplus from consumers and merchants determines the level of the payment card fees and overall card usage.

Debit and credit cards offer distinctly different credit possibilities for the consumer. A debit card enables its holders to make purchases and have these transactions directly and immediately charged to their current accounts. The consumer can access credit via her debit card as long as she has an overdraft facility on her current account. Typically, such credit faces immediate interest charges. By contrast, a credit card enables cardholders to make purchases up to a prearranged credit limit. Such credit is interest free for a limited 'grace' period, beyond which the consumer faces interest charges on any remaining negative balances. In short, debit and credit card networks operate different business models for supplying credit.

We show how the different models of credit affect equilibrium merchant and consumer fees, as well as the nature of competition between the two payment networks. This is despite the fact that we price credit in both networks as determined in a competitive aftermarket. Effectively, we assume both networks have to compete with alternative mechanisms for credit, such as merchants' 'store credit', at the point of purchase. Intuitively, therefore, we would expect interest rates and the credit option to become irrelevant for equilibrium merchant and consumer fees. This is not what we find. The mechanism is as follows. Higher finance charges decrease consumers' willingness to pay for cards which then translates into lower fixed fees. To offset these lower revenues on the consumer side, payment networks will have to set higher merchant fees.[1]

We explore two cases; the first in which credit and debit cards set merchant and consumer fees monopolistically, and the second in which the two networks compete for custom. First, when the credit card network behaves monopolistically, we find that default risk and funding cost are partly passed onto the merchant through the credit card merchant fee. Yet, debit card merchant fees do not share this feature as long as the only alternative to the debit card is cash. Second, when we turn to consider competition between a debit and a credit card model, we find that a degree of a complementarity exists between debit and credit cards. Greater credit card acceptance increases profit for the bank that issues the debit card as the consumer can maintain a positive balance whilst using the 'grace' period on the credit card to make purchases. Competition drives payment fees down, but the complementarity results remains. As a result, the debit card bank may increase merchant fees at the margin in order to decrease debit card acceptance in favor of credit cards; this can lead to the possibility of credit cards driving out debit cards in the payment market.

Payment card networks have received a great deal of attention from policymakers and regulators in recent years, especially regarding the pricing of debit and credit card services. Recently, the European Commission and MasterCard agreed to significantly reduce interchange fees—the fee that the merchant's bank pays the cardholder's bank—for cross-border European payment card transactions. Visa Europe has now also agreed to reduce its interchange fees, but only for cross-border debit card payments, cross-border credit card inter-

[1] Even if perfectly competitive pricing is not applicable to all instances of credit pricing in payment cards, we believe this is a useful baseline from which to consider the effects of interest rates on consumer and merchant fees.

change fees are still being debated. In December 2010, as part of the Dodd-Frank Wall Street Reform and Consumer Protection Act in the US, the Federal Reserve proposed a new rule to set interchange fees on debit and prepaid cards. Our analysis provides a useful benchmark for this policy debate. Moreover, our study may serve as a first guide for market design and policy options regarding the realization of the Single Euro Payments Area (SEPA). The broad aim of the SEPA project is to enable closer European financial integration, through enhancing harmonization in the means of payment, treating all payments in the euro area as domestic payments. With respect to payment cards, the SEPA framework has focused on the need to increase competition and efficiency between card networks. This could have significant welfare implications given that payment cards have become the most commonly used non-cash payment instrument—not only in Europe, but also in many other regions. Our paper attempts to shed new light on what competition between debit and credit cards and access to funds imply for optimal payment pricing of payment cards.

The paper contributes to the literature as it combines the growing theoretical work on payment cards with the research work in the field of consumer finance. It builds on the payment card literature that started with Baxter (1983). He argued that consumer and merchant payment fees should balance the demands of consumers and merchants for payment services to improve consumer and merchant welfare. Many other contributions in the academic literature have followed and addressed key issues surrounding card payment networks in general and payment pricing in particular (e.g., Frankel 1998; Balto 2000; Schmalensee 2002; Rochet and Tirole 2002, 2003a; Wright 2003, 2004; Chakravorti and To 2007; Guthrie and Wright 2007; Bolt and Chakravorti 2008; Bedre and Calvano 2009; Bolt and Schmiedel 2011). Many formal models have recently stressed the 'two-sidedness' of payment markets (Rochet 2007). That is, the consumption of card payment services involves two sides of a transaction—a consumer and a merchant—each of whom takes actions, enjoys benefits, and incurs costs. As a result, setting the right price structure (e.g., the ratio of the consumer fee and merchant fee) is crucial for card adoption and usage, and the resulting levels of economic efficiency.

So far, no paper has explicitly studied the impact of overdraft facilities and access to credit on the pricing decisions for card payment networks. Chakravorti and To (2007) introduce a credit line into their model of credit cards, but do not consider periods beyond the 'grace' period and therefore do not consider the relevant interest charge for credit. Moreover, their paper lacks an analysis of competition between credit and debit cards. Our paper builds on the modeling framework of Bolt and Chakravorti (2008) and Bolt and Schmiedel (2011), but extends that work to consider consumer credit. In so doing, we attempt to bridge the gap between the payment card literature and that of consumer finance.

The remainder of this paper is structures as follows. Section 2 presents a simple model of payment cards. Section 3 and 4 analyzes monopolistic debit and credit card pricing. In section 5 we study pricing arrangements in which the debit and credit card networks compete. Section 6 discusses some possible extensions, while the final section concludes.

2 Model Overview

In our model, there are three types of agents: consumers, merchants and payment network providers. Payment network providers supply payment cards as an alternative technology for cash to make purchases. All agents are risk neutral. Banks are considered to play the role of payment network providers. In our model, we have combined the issuer and acquirer into one entity, the payment network provider, so as to abstract from the interchange fee decision between issuers and acquirers.[2] In planning their payment activities, (ex ante identical) consumers need to decide whether to subscribe to a payment card and pay a fixed subscription fee, while (ex ante heterogenous) merchants need to decide whether to accept a payment card and pay a per-transaction merchant fee.[3] We will analyze both monopolistic and competitive payment pricing arrangements for debit and credit cards.

2.1 Consumers

Consumers are homogenous and try to maximize (linear) utility through their usage of payment instruments. Consumers obtain utility from buying one unit of a good from the merchant with whom they are matched. A consumer receives utility $v_0 = v - p$ from purchasing the good at price p, where $v_0 \geq 0$. Without loss of generality, we normalize $p = 1$.

The model operates over two periods, period 1 ('day') and period 2 ('night'). At the

[2] A four-party network is mathematically equivalent to a three-party network when issuing or acquiring is perfectly competitive. Under these conditions, the optimal interchange fee is directly derived from the optimal consumer and merchant fee (see Bolt 2006).

[3] This imposed fee structure makes the model less complex and captures what we observe in many countries. Generally, consumers do not pay per-transaction fees when using their payment cards, but merchants generally do pay the bulk of their payment service fees on a per-transaction basis.

beginning of period 1, day time, the following events occur: the consumer chooses whether to subscribe to a given payment card, she receives an initial period-1 income shock (either zero or positive income) and then is matched with a merchant. The consumer will only be able to purchase the good if she has sufficient payment facilities. In particular, to use a specific payment card, the consumer must have sufficient available funds and must be matched with a merchant who accepts such a card. She must also pay a fixed fee in order to use the card. By default, the consumer can always use cash to make the purchase. However, we assume there is a cost to using cash.[4] Specifically, we assume the consumer will be mugged with positive probability, $1 - \rho$, on her way to make the purchase; in that case, she will be unable to purchase and consume the good. Safe transit occurs with probability $\rho > 0$.[5]

During period 2, night time, the consumer receives a second income shock. Income may arrive early at the beginning of period 2, or late at the end of period 2, or not at all. Consumption can only occur during the day; any unused funds during the night render no consumer utility. Yet, period-2 income can be used to pay back potential debt obligations that arose during the day. If income does not arrive during the night at all, the consumer will default on her debt. Before describing the credit options offered by each network, we consider the specific income shocks in more detail.

2.1.1 Income shocks and default

Period-1 income is given by x_1 and period-2 income by x_2. We assume that period-1 income is insufficient to cover the purchase, whilst period 2 income is greater than the price of the good. In other words,

$$x_1 < 1 < x_2.$$

At the beginning of period 1, the probability the consumer receives income x_1 is given by δ; otherwise she receives zero. In period 2, the probability she receives income early is given by γ_E and the probability she receives income late is given by γ_L. With the remaining probability she receives no income in period 2: $1 - \gamma_E - \gamma_L$. Note that the probability she

[4] Naturally, cash usage also carries benefits such as anonymity and convenience. We abstract from these benefits as they are difficult to measure.

[5] Both theoretical and empirical models of money demand use theft to model, as a reduced form, the cost of carrying cash. He, Huang, and Wright (2005) construct a theoretical search model of money and banking that endogenizes the probability of theft. Alvarez and Lippi (2009) estimate the probability of cash theft around 2 percent in Italy in 2004.

Table 1: Income streams: timing and shocks

Probabilities		Income			Total Income Received
Period 1	Period 2	1	2_{early}	2_{late}	
δ	γ_E	x_1	x_2		$x_1 + x_2$
	γ_L	x_1		x_2	$x_1 + x_2$
	$1 - \gamma_E - \gamma_L$	x_1			x_1
$1 - \delta$	γ_E	0	x_2		x_2
	γ_L	0		x_2	x_2
	$1 - \gamma_E - \gamma_L$	0			0

receives income in period 2 is completely independent of the period-1 income shock.

Given the independence between period-1 and period-2 income shocks, there are six possible outcomes in the game as a whole. We can summarize this by considering the total amount of income received by the end of period 2, gross of any outgoing payments. Income shocks and timing are captured by the following table; the upper panel depicts the case of positive period-1 income shock, the lower panel a zero period-1 income shock.

Regardless of period-1 income, the consumer must use credit for the purchase (since $x_1 < 1$). From Table 1, the consumer will default in two states, conditional on having purchased the good. Therefore, the ex ante probability of default, conditional on the consumer making a purchase, is given by $1 - \gamma_E - \gamma_L$.

Given the probabilities and income shocks described above, ex ante expected income is equal to:

$$E(I) = \delta x_1 + (\gamma_E + \gamma_L)x_2.$$

Since we assume consumers are ex ante solvent, this implies that $E(I) > 1$, or rearranging

$$1 - \delta x_1 < (\gamma_E + \gamma_L)x_2.$$

There are two distinct differences between credit and debit cards in our model. Both relate to the nature of credit offered in association with the two systems. Firstly, we assume that the consumer always has access to an overdraft associated with her current account, while the credit card offers a credit line to the consumer. If she holds a debit card, the consumer can use her overdraft facility to make payments via this card. Whilst this debt will immediately accrue interest charges, the credit line of the credit card offers the consumer a free 'grace' period. In effect, the credit line associated with the credit card will not accrue interest charges until after the first period.

Secondly, we assume the credit line is larger than the overdraft facility, thus enabling the consumer to make payments in more states of the world. Specifically, we assume the overdraft limit is sufficient to cover the purchase if the consumer received period-1 income, but insufficient if there was no income received; as a result she will be unable to purchase the good. By contrast, the credit limit on the credit card is sufficient to cover the purchase, even if the consumer received no period-1 income. This captures the fact that both credit and debit cards are used alongside credit facilities, but the credit card enables payment in extra states, relative to the debit card.

2.2 Merchants

Merchants try to maximize their profit margin by optimally accepting payment cards. In our model, merchant heterogeneity is based on the type of good that they sell and their profit margin.

Each merchant i realizes a unique exogenously given profit margin $\pi(i)$. We assume that merchant profit margins on a sold unit of good are uniformly distributed on a line segment from 0 to p (with p normalized to 1). That is, merchants have different profit margins due to different underlying production costs. We make this assumption to capture merchant pricing power heterogeneity in the economy in a tractable model. Extraction of consumer surplus through merchant pricing is measured by v_0. Local monopolists will not leave any consumer surplus and set $v = p$, so that $v_0 = 0$. More competitive market structures are characterized by $v_0 > 0$. When accepting a card payment, the merchant avoids a (per-transaction) cash handling cost, but incurs a per-transaction merchant fee (or so-called merchant service charge) charged by the payment network. In a cash economy, without payment cards, merchants can only make sales to consumers that receive initial income in period 1 and arrive at their stores without being mugged.

Throughout we assume that merchants receive their payment immediately after the sale. While this is obvious for cash payments, it implies an immediate credit transfer from the payment network to the merchant resulting in a credit position that needs to be funded.[6]

[6]In practice, the actual moment of payment after the sale has occurred is a bargaining issue between the

2.3 Payment networks

The payment network either provides a debit card or a credit card as an alternative payment technology for cash. Debit cards offer consumers protection from theft while credit cards also allow consumption even when initial income did not arrive.[7] Hence, the supply of debit and credit card services by the networks increases the states of the world where consumption occurs.

2.3.1 Payment fees and cost

Payment networks maximize profit by optimally setting payment card fees. It is throughout assumed that cash services are supplied (by a central bank) at zero cost and that access to cash is without direct charges for consumers. Payment networks incur a processing cost $c_j \geq 0$, $j = d, c$. Credit cards carry (more) default risk than debit cards—modeled through the probability of late income arrival γ_L.

For convenience, we assume that the card network can only charge non-negative merchant fees, but consumer fees may turn negative.[8] Each card network charges consumers membership fees to use payment cards, F_j, $j = c, d$, and sets merchant per-transaction fees, $f_j \geq 0$, $j = d, c$, for card transactions. Consumers that choose to participate in a card network pay their fixed fee up-front no matter what state of the world realizes. Contractually, when income arrives late, they pay ex-post for card usage.

For convenience, we consider one merchant fee for all merchants, although, in reality, different merchants face different fees for payment services. Following the so-called 'No Surcharge Rule', we assume that merchants are prohibited from surcharging consumers who pay by card. This precludes merchants from charging a different price to consumers making payments with cards compared with those making payments in cash.

merchant and his acquiring bank. It can be immediate but it can also be at the end of the month when the consumer repays its debt. Effective funding cost for the payment network varies accordingly.

[7]Monnet and Roberts (2008) specify a dynamic environment that incorporates frictions such as trade mismatches between agents, private information and limited enforcement that give rise to the use of payment cards.

[8]Our model is able to consider negative merchant fees in a straightforward way. However, allowing negative fees makes the analysis more complex without gaining additional insight. In our model merchant acceptance will not increase any further by lowering merchant fees below zero, acceptance is already complete.

2.3.2 Interest rates

As described above, regardless of period-1 income, the consumer must use credit to purchase the good. We assume the overdraft limit on the debit card (and by extension if the consumer pays by cash) is sufficient to cover the purchase if the consumer received period-1 income, but insufficient if there was no income received. If the consumer uses her overdraft, then she will be in debt by an amount $m_d \equiv 1 - x_1$. This debt will accrue interest at rate r_d from period 1, until she repays using period-2 income.

By contrast, we assume the credit limit on the credit card is sufficient to cover the purchase, even if the consumer received no period-1 income. Her expected debt amounts to $m_c \equiv 1 - \delta x_1$, and note that $m_c > m_d$. If the consumer uses her credit card, she will not face any interest accrual for period 1. This is known as the 'grace' period. However, if she is unable to repay the debt using period-2 early income, she will face interest charges over period 2 at rate r_c.

In order to pin down both r_d and r_c we assume the bank and the credit card network operate perfectly competitively in providing credit. Even though the payment card itself is priced monopolistically, the credit part can be thought of as a competitive 'after market'. This implies that consumers could substitute other loans at the point of purchase, such as 'store credit', for overdrafts or credit lines. Given this assumption, both r_d and r_c can be found by equating the expected payoff of the loan (conditional on the purchase) to the expected cost of funds. That is, the net present value (NPV) of the loans are zero. As a result, r_d and r_c will be functions of the risk free interest rate r (the 'cost of funds') and the probabilities of second period income γ_E and γ_L.

For the bank providing the overdraft, the expected cost, per unit of funds, is

$$r + (1 - \gamma_E)r + (1 - \gamma_E - \gamma_L).$$

Note that this includes the probability of default. The per period simple interest rate r_d must therefore solve[9]:

$$r_d(\gamma_E + 2\gamma_L) = r + (1 - \gamma_E)r + (1 - \gamma_E - \gamma_L).$$

[9] We model interest revenue as simple interest so that the lender receives revenue of $2r$ if the capital is left untouched over two periods. This keeps the notation simpler without changing the qualitative results.

This gives r_d as follows:

$$r_d = r_d(r, \gamma_E, \gamma_L) = \frac{(2-\gamma_E)r + (1-\gamma_E-\gamma_L)}{\gamma_E + 2\gamma_L}. \tag{1}$$

We can easily show that equilibrium r_d decreases with γ_E and γ_L and increases with r.

For the credit card network provider, the first period credit will be free for the consumer. However, this will mean the second period interest rate cost must be high in order to compensate. Following the same logic as above, the interest rate r_c will be given by

$$r_c\gamma_L = r + (1-\gamma_E)r + (1-\gamma_E-\gamma_L).$$

This gives r_c as follows:

$$r_c = r_c(r, \gamma_E, \gamma_L) = \frac{(2-\gamma_E)r + (1-\gamma_E-\gamma_L)}{\gamma_L}. \tag{2}$$

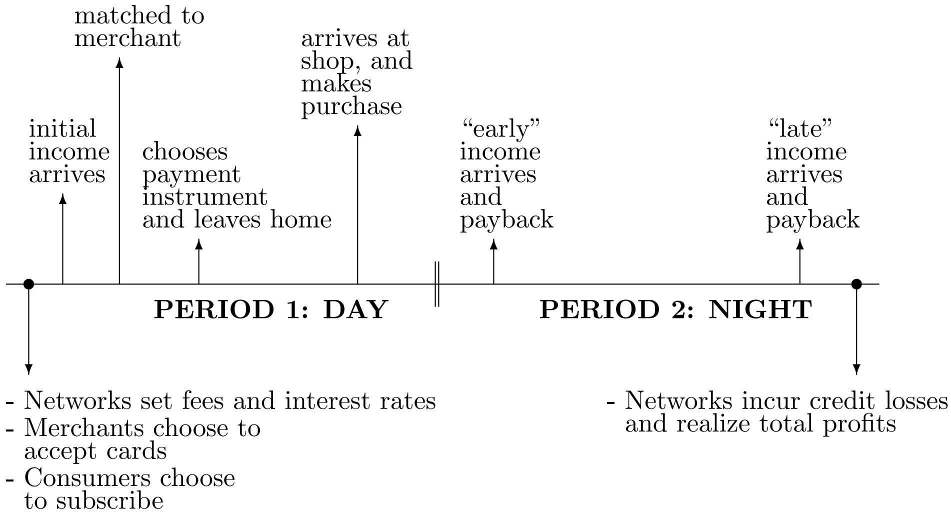
Similarly, equilibrium r_c decreases with γ_E and γ_L, and increases with r. Note that r_c explodes when γ_L approaches zero. With credit cards, consumers that receive late income carry all the funding and default cost. When γ_L is small, only a few consumers carry this burden and so pay very high interest rates. In the extreme, if $\gamma_L = 0$, no consumer pays interest on its credit card loan (they receive grace or they default) and therefore the loan cannot be made NPV-zero. In this case, to recover cost, the burden must be shifted to merchants and consumers through higher payment fees.[10]

2.4 Timeline

The timing of events is depicted in Figure 1. In the early morning, payment networks post their fees for payment services and set interest rates for overdraft and credit, merchants announce their acceptance of card services, and consumers choose whether to subscribe to the payment network. Next, consumers are matched with a specific merchant. Consumers decide which payment instrument to use before leaving home based on merchant acceptance and income availability. Note that cash-carrying consumers might get mugged before reaching

[10]To avoid this exploding characteristic, we will mainly focus on distributions (γ_E, γ_L) that are not too 'skewed'. We ignore direct burden sharing mechanisms between merchants and credit card debtors. Naturally, the parameters that determine the interest rates will influence optimal merchant fees.

Figure 1: Timing of events



the store. At night, consumers who did not receive income in period 1 may receive income in period 2—early or late—and repay (potential) card obligations.

3 Debit Card Only Model

In this section, the consumer can either rely solely on cash to make a purchase, or decide to hold a debit card. The overdraft facility works similarly for cash as for the debit card. Therefore, the only benefit to holding a debit card comes from the risk of getting mugged, and losing cash.

3.1 Consumer's problem

The probability of getting mugged is $(1-\rho)$. We denote by α^D the proportion of merchants who accept the debit card and F^D is the consumer's debit card fee. Recall that if debit cards and cash are the only payment instruments available to the consumer, she can only make a purchase if she receives a positive level of initial income; this occurs with probability δ. With probability $(1-\delta)$, there is no buy, no consumption, but also no default loss. Observe that $m_d \equiv 1 - x_1$ denotes the amount of debt when using the overdraft facility associated with the checking account.

The consumer will want to hold a debit card as long as:

$$\delta\rho v_0 - \delta(\gamma_E + 2\gamma_L)r_d m_d \ \leq \ \delta\left(\alpha^D + \rho(1-\alpha^D)\right)v_o - \delta(\gamma_E + 2\gamma_L)r_d m_d - F^D.$$

The left-hand side is the payoff from just holding cash; in this case, the consumer can purchase the good only if she receives high initial income and is not mugged. If she makes a payment (which occurs with probability $\delta\rho$), then she will have to pay interest on his overdraft of size m_d. Note, however, if she gets mugged he will still have gone into his overdraft, having withdrawn 1, and thus will have to pay interest. In other words, we assume the consumer has no insurance against cash theft.

She will only have to pay interest in one period, if she receives an early second income shock (which occurs with probability γ_E). However, if she has to wait for positive income until period 2, she will have to pay twice the amount of interest; this occurs with probability γ_L.

On the right-hand side is the payoff from holding a debit card. The consumer can make a purchase with a debit card if he receives high initial income, and the merchant accepts the card. She can also rely on cash for the payment if the merchant does not accept the card (with probability $(1-\alpha^D)$), providing she is not mugged. Either way, the consumer must pay the debit card fee f^D.[11]

We continue to make the same assumptions about mugging. If a consumer is aware that she cannot pay by debit card, she will withdraw cash equal to 1. At this point, she faces a risk of being mugged, in which case she loses the money, and thus must pay interest on the overdraft until she can repay. The participation constraint can be simplified as follows:

$$F^D \leq \delta\alpha^D(1-\rho)v_0.$$

Note that the debit card allows the consumer to pay in one extra state, which occurs with probability $\delta\alpha^D(1-\rho)$. For this reason, the surplus from buying the good v_0, is multiplied by this term.

[11] There is a chance that period-2 income does not arrive at all so that the consumer cannot pay for the fixed fee. Hence, the default probability 'artificially' increases the consumer willingness-to-pay for the card. However, the payment network would discount the high fixed fee with the same probability. Mathematically, this effect cancels out.

3.2 Merchant's problem

The merchant i receives profit $\pi(i)$ from a sale, where $\pi(i)$ is uniformly distributed between 0 and 1. His cost of handling cash is h whilst f^D is the merchant fee for accepting the debit card. His expected payoff from accepting cash is:

$$Z_{cash}(i) = \delta\rho[\pi(i) - h],$$

and his expected payoff from accepting the debit card is:

$$Z_D(i) = \delta[\pi(i) - f^D].$$

Merchants accept debit cards only when

$$Z_{cash}(i) \leq Z_D(i).$$

Since there is a level of profits $\bar{\pi}$ above which merchants will accept debit cards, we can write the proportion of accepting merchants as follows:

$$\alpha^D(f^D) \;=\; \Pr[\pi(i) \geq \bar{\pi}] \;=\; 1 - \bar{\pi} \;=\; 1 - \frac{(f^D - \rho h)}{1 - \rho}.$$

3.3 Maximum consumer fee for debit cards

Using the function $\alpha^D(f^D)$, we can derive the maximum possible consumer fee as a function of f^D. This is obtained by finding the fee such that the consumer is indifferent between holding a debit card or solely relying on cash. It is given by:

$$F^D_{\max}(f^D) = \delta\left(1 - f^D - \rho(1 - h)\right)v_0.$$

3.4 Debit card network

We make the standard assumption that the same bank operating the debit card network is the one to provide the consumer with a current account and associated overdraft facility. The Debit Card Bank (DCB) faces processing cost c^D per debit card transaction. The DCB is also able to earn interest on a positive balance in the customer account; we assume the bank takes this interest rate r as given. In addition, the bank charges interest rate r_d on any overdraft.

The DCB's payoff from issuing a debit card is:

$$\pi^{DCB} = F^D + \delta\alpha^D(f^D - c^D) + r[(1-\delta)\gamma_E x_2 + \delta\gamma_E(x_2 - m_d)].$$

The DCB receives the consumer fee regardless debit card usage. With probability $\delta\alpha^D$ the consumer will make a payment using the debit card, so the bank will receive the net per transaction payoff, which is a function of the merchant fee f^D.

In addition to the per transaction fee, the bank earns interest on a positive balance in the customer account. A positive balance may exist for two reasons. If she did not make a purchase, but receives early income in period 2, the balance will be x_2 throughout that period. Alternatively, if she *did* make a purchase (or was mugged), and receives early income in period 2, the balance will be $x_2 - m_d = x_1 + x_2 - 1$ throughout that period. These two cases correspond to the third and fourth terms in the DCB's profit function.

Since the credit offered via the overdraft is priced perfectly competitively, the loan is zero NPV for the DCB. As a result, neither the revenues nor the costs from this loan show up in the profit function.

The DCB sets the optimal merchant fee by maximizing its payoff with respect to f^D, subject to

$$F^D = F^D_{\max}(f^D) \text{ and } \alpha^D = \alpha^D(f^D).$$

The optimal merchant fee is therefore:

$$f^*_D = \frac{1}{2}[c^D + 1 - \rho(1-h)] - \frac{1}{2}(1-\rho)v_0. \tag{3}$$

The merchant fee increases with the transaction cost faced by the bank and decreases with consumer surplus, v_0. When merchant extraction of consumer surplus is low, the debit card bank will set low merchant fees; this way, the acceptance rate will rise, thus increasing the value of the card to the consumer. As a result, the network can charge higher consumer fees. Note that the term v_0 is multiplied by $(1-\rho)$, the probability of the state in which debit cards enable payment when cash cannot.[12]

4 Credit Card Only Model

We now consider the case in which only a credit card is available to the consumer. We do, however, assume the consumer still has access to a current account, with an associated overdraft facility. The size of the overdraft facility is, once again, only sufficient to cover the desired overdraft in the high income case. However, the credit line associated with the credit card enables the consumer to take out a larger loan. In this way, the credit card can enable payment in the low period-1 income case. Moreover, as with debit cards, credit cards insure against theft.

4.1 Consumer's problem

We denote by α^C the proportion of merchants who accepts the credit card and F^C is the consumer's credit card fee. Given merchant acceptance, recall that credit cards can be used in all states of the world regardless of period-1 income. Observe that $m_c \equiv 1 - \delta x_1$ denotes the average amount of debt when using the credit line associated with the credit card.

The consumer will want to hold a credit card as long as:

$$\begin{aligned} \delta\rho v_0 - \delta(\gamma_E + 2\gamma_L) r_d m_d \quad &\leq \quad \left(\alpha^C + \delta\rho(1-\alpha^C)\right) v_o - \alpha^C \gamma_L r_c m_c \\ &\quad -\delta(1-\alpha^C)(\gamma_E + 2\gamma_L) r_d m_d - F^C. \end{aligned}$$

If the consumer makes a payment with a credit card, she will have to pay interest on this credit line only if she needs to extend the credit for an extra period, having received no income at the end of period 1. If the merchant does not accept the card, and the consumer has to pay cash, she will then face the interest charges from the overdraft in each period, as previously discussed. This condition can be rearranged as follows:

$$F^C \leq \alpha^C(1-\delta\rho)v_o - \alpha^C \gamma_L r_c m_c + \delta\alpha^C(\gamma_E + 2\gamma_L) r_d m_d.$$

[12]Observe that the optimal debit merchant fee in (3) is the same as in the model of Bolt and Schmiedel (2011) without overdraft facility. This holds because the overdraft facility works similarly for cash as for debit cards and so presents no value added.

The consumer will never leave the house with cash if the merchant accepts a credit card. Indeed, given how credit is priced in the two models, the expected costs of servicing a credit line are the same as the equivalent costs associated with an overdraft, if the consumer has high initial income (it is only in this state where the consumer could use cash). This is because both are priced competitively. In other words,

$$(\gamma_E + 2\gamma_L)r_d = \gamma_L r_c,$$

given, see (1)-(2),

$$r + (1 - \gamma_E)r + (1 - \gamma_E - \gamma_L) = (2 - \gamma_E)r + (1 - \gamma_E - \gamma_L).$$

Hence, since the consumer is indifferent regarding use of funds, she will certainly use her credit card so as to avoid mugging on her way to the store.

We further assume that if the credit line is taken down, the overdraft on the current account cannot be used to 'pay off' the credit line at the end of the period 1. For instance, we assume the bank does not allow the overdraft to be used to pay off alternative debt; or at the very least, there exists a significant fixed cost to substituting overdraft debt for credit card debt.[13]

4.2 Merchant's problem

The merchant i receives profit $\pi(i)$ from a sale, where $\pi(i)$ is uniformly distributed between 0 and 1. His cost of handling cash is h whilst f^C is the merchant fee for accepting the debit card. His expected payoff from accepting cash is:

$$Z_{cash}(i) = \delta\rho[\pi(i) - h],$$

[13] In some European countries, the overdraft is 'automatically' used to pay off outstanding credit card obligations at the end of the month. Hence, these consumers do not face a credit card interest rate but rather an interest rate on overdraft. However, consumers in the U.S. do not typically use overdrafts to pay off credit card debt, even if there are significantly lower interest rates on the former. This is sometimes called the 'credit card puzzle', and may be attributed to a specific behavioral trait or economic friction, but that discussion is beyond the scope of this paper (see e.g., Gross and Souleles 2002; Telyukova and Wright 2008).

and his expected payoff from accepting the credit card is:

$$Z_c(i) = [\pi(i) - f^C].$$

Merchants accept debit cards only when

$$Z_{cash}(i) \leq Z_c(i).$$

Since there is a level of profits $\bar{\pi}$ above which merchants will accept credit cards, we can write the proportion of accepting merchants as follows:

$$\alpha^C(f^C) \;=\; \Pr[\pi(i) \geq \bar{\pi}] \;=\; 1 - \bar{\pi} \;=\; 1 - \frac{(f^C - \delta\rho h)}{1 - \delta\rho}.$$

This is different to the proportion associated with debit cards; the ρ here is multiplied by δ. This reflects the fact that the credit card allows for payment in both the high and low initial income states, unlike cash.

4.3 Maximum consumer fee for credit cards

Using the consumer's participation constraint, as well as α^C, we obtain the maximum consumer fee:

$$\begin{aligned} F^C_{\max}(f^C) \;=\; & [1 - f^C - \delta\rho(1-h)]v_0 - \\ & \frac{[1 - f^C - \delta\rho(1-h)]}{(1-\rho\delta)}[\gamma_L r_c m_c - \delta(\gamma_E + 2\gamma_L) r_d m_d]. \end{aligned}$$

Unlike the debit fee, the probability of high initial income δ does not premultiply both terms; unlike the debit card, the credit card does not restrict the consumer to trade only in the high income state.[14]

The second term above captures the expected costs of credit; however, it is a function of both the credit line *and* the overdraft on the current account. In states where the credit card

[14] Notice that the maximum consumer fee becomes negative if $v_0 = 0$. Whilst the debit consumer fee is zero in this case, the credit consumer fee is negative since consumers would be paying higher expected interest costs under the credit card, than they would under the overdraft.

enables payment that would be impossible with cash, the relevant term for the expected cost of credit is simply $\gamma_L r_c m_c$. However, in the case of high period-1 income (which occurs with probability δ), the consumer *could* still use cash if she wished.[15] In this case, the relevant term is the *difference* between the cost of the credit line and the cost of the overdraft. It is this difference that captures the benefits (or otherwise) offered by the credit card.

Notice that this difference is positive:

$$\gamma_L r_c m_c - \delta(\gamma_E + 2\gamma_L) r_d m_d = [(2 - \gamma_E)r + (1 - \gamma_E - \gamma_L)](1 - \delta) > 0.$$

Moreover, it is not a function of period-1 income x_1. This is important; it means the difference is not a function of the relative amounts of credit in the two cases.

It might seem initially counterintuitive that this difference is non-zero; after all, the credit in the two cases is priced as a zero NPV loan. However, the loan is priced, conditional on the consumer requiring the loan in each case. Yet, when the consumer, ex ante, considers the value of a credit card she takes into account expected costs of the overdraft and the credit line; these are unconditional expected costs, before she knows the value of initial income. Since the credit card enables payment in one extra state of the world, the unconditional expected costs of credit via the credit card are higher than via the overdraft facility. Notice that the difference is decreasing in δ. As the probability of period-1 income increases, so does the probability of being able to pay using the cash and the overdraft facility. This increases the expected cost of the overdraft relative to that of the credit line on the credit card.

4.4 Credit card network's problem

The Credit Card Network's (CCN) payoff from issuing a credit card is:

$$\pi^C = F^C + \alpha^C (f^C - c^C).$$

Note that the consumer still has a current account, and overdraft facility, but neither of these show up in the credit card network's profit function. Once again, the loan via the credit card is a zero NPV loan for the network.

[15] Note of course that, if the consumer attempts to pay by cash, she will be mugged with probability $(1 - \rho)$. In this case, she still enters her overdraft, even though she has not successfully made a purchase.

The network sets the optimal merchant fee by maximizing its payoff with respect to f^C, subject to

$$F^C_{\max} = F^C(f^C) \text{ and } \alpha^C = \alpha^C(f^C).$$

The optimal merchant fee for credit cards is therefore:

$$f_C^* = \frac{1}{2}[c^C + 1 - \delta\rho(1-h)] + \frac{1}{2}\gamma_L r_c m_c - \frac{1}{2}\delta(\gamma_E + 2\gamma_L) r_d m_d - \frac{1}{2}(1-\delta\rho)v_0. \tag{4a}$$

The fee is decreasing in the consumer's expected costs of servicing the overdraft. The intuition is straightforward. The overdraft, even in the absence of a debit card, offers an outside option to consumers in one state. By choosing to pay by credit card, not cash, the consumer avoids the expected costs of servicing an overdraft; if these are high, then the benefit of holding a credit card is high. In this case, the network can extract a large fee from the consumer, and is therefore able to reduce the merchant fee. However, this effect is mitigated when credit card interest rates are high. In turn, high credit card interest rates dampen the consumer maximum fixed fee resulting in a higher merchant fee to restore the balance. This has interesting implications. Effectively, the credit card competes with the overdraft facility in the state where cash could be used. It shows that the interest rate charged can impact the acceptance ratio of credit cards. An increase in the costs of an overdraft can lead to higher acceptance of credit cards.

The 'total' interest rate effect on merchant fees is derived when we substitute $r_d = r_d(r, \gamma_E, \gamma_L)$, $r_c = r_c(r, \gamma_E, \gamma_L)$, $m_d = 1 - x_1$, and $m_c = 1 - \delta x_1$ in the optimal merchant fee f_C^*. This yields:

$$f_C^* = \frac{1}{2}[c^C + 1 - \delta\rho(1-h)] + \frac{1}{2}[(2-\gamma_E)r + (1-\gamma_E-\gamma_L)](1-\delta) - \frac{1}{2}(1-\delta\rho)v_0. \tag{4b}$$

As with the consumer fee, the merchant fee is a function of the difference between the unconditional expected costs of servicing the credit line and the overdraft. Crucially, however, it is not a function of the size of the credit facility. This equation also shows that higher funding rates r lead to higher merchant fees f_C^*. Higher defaults $(1-\gamma_E-\gamma_L)$ increases merchant fees as well. These effects make clear how merchants share the cost burden of credit card loans with consumers.

4.5 Comparison and comparative statics

In our model, the optimal debit card merchant fee f_D^* is not influenced by the funding cost or default risk. This derives from the fact that debit cards have no value added over cash regarding the use of the overdraft facility on the checking account. Debit cards only hedge against theft and that is why the probability of theft ρ plays an important role for the optimal merchant fee, as well as processing cost c_d.

In contrast, funding cost and default risk do affect the merchant fee on credit cards. In effect, merchants pay their 'fair' share with respect to credit card debt. If the network can extract lower surplus from consumers through a lower consumer fee, they will require merchants to pay a higher fee to compensate. An increase in r leads to an overall increase of f_C^*. In principle two effects are at play. One is because an increase in r leads to an increase in r_d, and as discussed above, this increases the saving the consumer can make from avoiding the costs of servicing the overdraft. This has a negative effect on the merchant fee as the credit card network tries to increase acceptance (a^C) to benefit from the higher extraction of surplus via the fixed consumer fee. The other is an opposing effect due to a lower consumer willingness-to-pay when credit card interest rates rise, making the credit card less acceptable to consumers and dampening the amount that the network can extract from consumers. This latter effect dominates and therefore the CCN must increase the merchant fee when the funding cost rises. As a result, due to these opposing forces, the change is not one-for-one.

$$\frac{\partial f_D^*}{\partial r} = 0 \quad \text{and} \quad 0 < \frac{\partial f_C^*}{\partial r} = \frac{1}{2}(2 - \gamma_E)(1 - \delta) < 1.$$

A higher probability of early period-2 income γ_E increases the value of a credit card to consumers because it makes enjoying the grace period more likely. This allows a lower merchant fee, i.e.:

$$\frac{\partial f_D^*}{\partial \gamma_E} = 0 \quad \text{and} \quad \frac{\partial f_C^*}{\partial \gamma_E} = -\frac{1}{2}(1 - \delta)(1 + r) < 0.$$

Defining default $D = 1 - \gamma_E - \gamma_L$, and keeping γ_E constant, it is easy to show that

Table 2: Comparison between debit and credit cards

	funding cost r		default D		early income γ_E		initial income δ	
	1%	3%	5%	10%	50%	55%	95%	99%
f_D^*	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
α_D^*	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
f_C^*	0.0314	0.0321	0.0314	0.0326	0.0314	0.0301	0.0314	0.0103
α_C^*	0.4726	0.4601	0.4726	0.4517	0.4726	0.4939	0.4726	0.4837
r_d	0.0464	0.0679	0.0464	0.0885	0.0464	0.0100	0.0464	0.0464
r_c	0.1444	0.2111	0.1444	0.2885	0.1444	0.0322	0.1444	0.1444

Note: We set: $c_d = c_c = 0.00$, $h = 0.00$, $v_0 = 0$, and $\rho = 0.99$. Baseline parameters: $r = 0.01$, $\gamma_E = 0.50$, $\gamma_L = 0.45$, and $\delta = 0.95$.

$$\frac{\partial f_D^*}{\partial D} = 0 \quad \text{and} \quad \frac{\partial f_C^*}{\partial D} = -\frac{\partial f_C^*}{\partial \gamma_L} = \frac{1}{2}(1-\delta) > 0.$$

That is, higher defaults lead to higher merchant fees. Once again, with higher default rates, the required interest rate on the credit line is higher; this reduces the maximum fee the network can charge consumers and so requires a higher fee from merchants. This effect is mitigated by a high probability of receiving period-1 income, i.e. δ large. When δ is large, the unconditional expected cost to the consumer of a credit line is not so much greater than an overdraft. In effect, the probability is low of being of being able to use a credit line in an extra state of the world.

For similar reasons, when the probability of receiving initial income rises then merchant fees go down

$$\frac{\partial f_D^*}{\partial \delta} = 0 \quad \text{and} \quad \frac{\partial f_C^*}{\partial \delta} = -\frac{1}{2}\left((2-\gamma_E)r + (1-\gamma_E-\gamma_L) + \rho(1-h-v_0)\right) < 0,$$

for sufficiently small v_0 and h. As δ increases, the unconditional expected cost of the credit line decreases relative to the overdraft (since there is an increase in the probability of being able to use the overdraft). Effectively, then, the credit card becomes more valuable to consumers. Since the network can extract a high fee from consumers, it will set a low merchant fee in order to maximize the network size. If the merchant fee is low, more merchants will accept the card and thus the card will become attractive to more consumers.

Table 2 illustrates the results. As we can see from the table, the debit merchant fee and merchant acceptance does not depend on funding costs r, on the probability of default D or on the probability of different income shocks, γ_E or δ. However, the credit merchant fee increases with a higher cost of funding and a higher probability of default. We also see how the credit merchant fee decreases with a higher probability of period-1 income δ: in this case, the unconditional expected cost of servicing an overdraft increases, as the probability of using it increases. This decreases the relative cost to the consumer of using the credit card. Finally we see how the debit and the credit interest rates increase with the probability of default, and the funding cost, given they are priced in a competitive aftermarket.

5 Competition between Debit and Credit Cards

In this section, we examine competition between debit and credit cards. We analyze the case in which the consumer multihomes and the merchant singlehomes.[16] We also follow the preceding model and assume that the overdraft cannot be used to pay off the credit line in period 2. In other words, the consumer is committed to using the credit facility associated with the card he used for payment.

5.1 Consumers' participation

In what follows, α^i is the proportion of merchants who accept card i, where $i = C, D$. In addition, α denotes the proportion of merchants who hold *either* a debit or a credit card. Under the assumption of singlehoming merchants, this implies $\alpha = \alpha^D + \alpha^C$.

The consumer will hold both cards if:

$$\begin{aligned}\delta\rho v_0 - \delta(\gamma_E + 2\gamma_L)r_d m_d \quad &\leq \quad \left(\delta[(1-\alpha)\rho + \alpha] + (1-\delta)\alpha^C\right) v_o - \alpha^C \gamma_L r_c m_c \\ &\quad -\delta(1-\alpha)(\gamma_E + 2\gamma_L)r_d m_d - \delta\alpha^D(\gamma_E + 2\gamma_L)r_d m_d - F_T.\end{aligned}$$

where F_T denotes the maximum total fee that the consumer is prepared to pay to hold both

[16] In payments, multihoming on both the consumer and merchant side is often observed. This case is very difficult to analyze without imposing further restrictions on users' behavior. In our framework, competition favors singlehoming merchants so that our price predictions serve as a lower bound on merchant fees. Multihoming merchants are likely to show less resistance to higher merchant fees. It is also noted that merchants can always strategically opt out from a card network when all consumers hold both types of cards in their wallet. These endogenous multihoming decisions have been studied by Hermalin and Katz (2006) in the context of optimal routing rules between networks (see also Rochet and Tirole 2003b).

a debit and a credit card.

As we showed earlier, expected costs of using the credit line, conditional on positive period-1 income, are the same as that of the overdraft. We continue to assume therefore that the indifferent consumer will use a credit card, rather than use the overdraft. In the context of competition between the cards, this means the only reason the consumer would ever use a debit card in place of a credit card is if the merchant only accepts the former.

We can rearrange to find the maximum total consumer fee, as a function of merchant acceptance:

$$
\begin{aligned}
F_T &= [(1-\rho)\alpha + (1-\delta)\alpha^C]v_o + \delta\alpha^C(\gamma_E + 2\gamma_L)r_d m_d - \alpha^C \gamma_L r_c m_c. \\
&= [(1-\rho)\alpha + (1-\delta)\alpha^C]v_o - \alpha^C(1-\delta)[(2-\gamma_E)r + (1-\gamma_E-\gamma_L)].
\end{aligned}
$$

Note that individual contributions to the total fee will satisfy[17]

$$F_T = F_D^T + F_C^T,$$

where

$$F_T^D = \delta\alpha^D(1-\rho)v_o,$$

and

$$F_T^C = \delta\alpha^C(1-\delta\rho)v_o - \alpha^C(1-\delta)[(2-\gamma_E)r + (1-\gamma_E-\gamma_L)].$$

5.2 Merchants' acceptance

We assume that merchants singlehome; if they accept a card at all, it is *either* a debit *or* a credit card. Only merchants with high profit margins accept credit cards, intermediate merchants accept debit cards, and low-end merchants accept cash. Using the expected payoffs above, we can find the profit level above which merchants are prepared to accept debit cards $\bar{\pi}_d$ and likewise the profit level above which they will accept credit cards $\bar{\pi}_{dc}$;

[17]This breakout is derived by observing that merchants only accept one type of payment card.

$$\bar{\pi}_d(f_d) = \frac{f^D - \rho h}{1-\rho} \quad \text{and} \quad \bar{\pi}_{dc}(f_d, f_c) = \frac{f^C - \delta f^D}{1-\delta}.$$

This gives us the following acceptances:

$$\alpha(f_d) = 1 - \bar{\pi}_d(f^D) \quad \text{and} \quad \alpha^C(f_d, f_c) = 1 - \bar{\pi}_{dc}(f^D, f^C),$$

where debit card acceptance is:

$$\alpha^D = \alpha(f^D) - \alpha^C(f^D, f^C).$$

5.3 Networks' optimization

The CCN and the DCB engage in Bertrand competition.

5.3.1 Debit card network

The DCB, issuing the debit card, maximizes its profit function, with respect to to f^D, subject to:

$$F_T^D = F_{T\max}^D(f^D) \ \text{ and } \ \alpha^C = \alpha^C(f^D, f^C).$$

However, its profit function is slightly altered from that of the debit-only world:

$$\begin{aligned}
\pi^{DCB} \quad = \quad & F^D + \delta\alpha^D(f^D - c^D) \\
& +(1-\alpha^C)r[(1-\delta)\gamma_E x_2 + \delta\gamma_E(x_2 - m_d)] \\
& +\alpha^C r[\delta x_1 + \gamma_E(x_2 - m_c) + (1-\gamma_E)\delta x_1].
\end{aligned}$$

As in the no competition case, the bank can earn interest on positive balances, even in the absence of a credit card. However, the presence of the credit card affects both the frequency and size of the consumer's positive balance. This has positive and negative effects on the DCB's profit function. When the consumer pays by credit card, the DCB benefits from the delayed deduction of funds from the current account. Any funds remain in the current account for the duration of period 1, until the end of the 'grace' credit period. During this time, the DCB can earn interest on any positive balance, at market interest rate r. However, the credit card also enables the consumer to make a purchase in more states of the world. As a result, the size of the positive balance following early income will be smaller in period 2, relative to the no credit card case. This can be seen by rearranging the above profit function:

$$\begin{aligned}\pi^{DCB} &= F^D + \delta\alpha^D(f^D - c^D) + r[(1-\delta)\gamma_E x_2 + \delta\gamma_E(x_2 - m_d)] \\ &\quad + \alpha^C r[(2-\gamma_E)\delta x_1 - (1-\delta)\gamma_E].\end{aligned}$$

The last line captures this trade-off. It reflects an interesting case: if expected period-1 income δx_1 is sufficiently large, the DCB's profit function will increase with any increase in the proportion of merchants accepting the *credit* card. This is important. Although the credit and debit networks are in competition, there is also this element of complementarity between the debit card and the credit card. However, if the reverse holds, this complementarity will not exist.

The tradeoff continues to play a role when we solve for the optimal debit card merchant fee.

$$\begin{aligned}f^D(f^C) = &\frac{1}{2}\frac{c^D(1-\delta\rho) + (1-\delta)\rho h + (1-\rho)f^C}{1-\rho\delta} - \\ &\frac{1}{2}(1-\rho)v_0 + \frac{1}{2}\frac{(1-\rho)}{1-\delta\rho}r[(2-\gamma_E)\delta x_1 - (1-\delta)\gamma_E]. \qquad (5)\end{aligned}$$

For a given f^C, the optimal merchant fee in the debit network is *increasing* in market interest rate, as long as δ is sufficiently high such that $\delta x_1 > (1-\delta)\gamma_E/(2-\gamma_E)$. At the margin, if the DCB expects to earn a large amount on positive balances in period 1, it will set a high merchant fee to *discourage* debit acceptance in favor of credit cards. This allows for the possibility that, in equilibrium, we may observe higher debit merchant fees compared with credit merchant fees.

5.3.2 Credit card network

The profit function of the CCN remains unchanged, relative to the no competition case. That is:

$$\pi^{CCN} = F^C + \alpha^C(f^C - c^C).$$

It now maximizes this profit function, with respect to f_d, subject to

$$F_T^C = F_{T\max}^C(f^C, f^D) \text{ and } \alpha^C = \alpha^C(f^D, f^C).$$

The optimal merchant fee for credit cards is therefore:

$$f^C(f^D) = \frac{1}{2}[c^C + 1 - \delta(1 - f^D)] - \frac{1}{2}(1 - \delta\rho)v_0 + \frac{1}{2}(1 - \delta)[(2 - \gamma_E)r + (1 - \gamma_E - \gamma_L)]. \quad (6)$$

This is similar to the merchant fee in the credit-only model. The major difference is that the fee is a function of the debit merchant fee f^D, rather than the merchant's cost of cash, h.

The unique equilibrium merchant fees (f_D^{**}, f_C^{**}) are found from the intersection of the two best response functions, $f^D(f^C)$ and $f^C(f^D)$ (see appendix).

5.4 Comparison and comparative statics

Table 3 compares competitive and monopolistic card fees for two different default levels ($D = 5\%$ vs. $D = 10\%$) and funding cost levels ($r = 1\%$ vs. $r = 3\%$).

First observe how an increase in default risk affects interest rates on debit and credit cards. Monopolistic debit card fees are not affected by default risk changes. The value of debit cards is driven solely by security concerns as they generate no advantage over cash with respect to the use of the overdraft facility. By contrast, credit card merchant fees move with changes in default risk. Higher default leads to higher merchant fees.

Second, all else being equal, competition drives down payment card fees and increases merchant acceptance for both cards. However, competitive debit card merchant fees are now also affected by default risk movements. Notice that in this example, higher default leads to higher debit card merchant fees but to higher debit card acceptance as well. Total card

Table 3: Comparison between debit and credit cards: default and funding cost

Default ($r = 1\%$)	Monopoly				Competition			
	debit		credit		debit		credit	
	$D = 5\%$	$D = 10\%$	$D = 5\%$	$D = 10\%$	$D = 5\%$	$D = 10\%$	$D = 5\%$	$D = 10\%$
f^*	0.0050	0.0050	0.0314	0.0326	0.0029	0.0030	0.0280	0.0293
α^*	0.5000	0.5000	0.4726	0.4517	0.2114	0.2244	0.4954	0.4714
r_d	0.0464	0.0885	0.0464	0.0885	0.0464	0.0885	0.0464	0.0885
r_c	0.1444	0.2885	0.1444	0.2885	0.1444	0.2885	0.1444	0.2885
Funding cost ($D = 5\%$)	Monopoly				Competition			
	debit		credit		debit		credit	
	$r = 1\%$	$r = 3\%$	$r = 1\%$	$r = 3\%$	$r = 1\%$	$r = 3\%$	$r = 1\%$	$r = 3\%$
f^*	0.0050	0.0050	0.0314	0.0312	0.0029	0.0043	0.0280	0.0294
α^*	0.5000	0.5000	0.4726	0.4601	0.2114	0.0875	0.4954	0.4924
r_d	0.0464	0.0679	0.0464	0.0679	0.0464	0.0679	0.0464	0.0679
r_c	0.1444	0.2111	0.1444	0.2111	0.1444	0.2111	0.1444	0.2111

Note: We set: $c_d = c_c = 0.00$, $h = 0.00$, $v_0 = 0$, $\rho = 0.99$, $\gamma_E = 0.50$, $\delta = 0.95$, and $x_1 = 0.5$. Baseline parameters: $r = 0.01$ and 0.03, $\gamma_L = 0.45$ ($D = 5\%$) and 0.40 ($D = 10\%$).

acceptance decreases however. Intuitively, higher default increases the credit card merchant fee, allowing the competing debit merchant fee to rise as well. Although this has a negative effect on merchant acceptance of debit cards, this effect is smaller than the reduction in acceptance of credit cards. Since the merchants who no longer accept credit cards will switch to debit cards, this results in an overall increase in debit card acceptance.

Third, we observe higher competitive merchant fees when the funding cost increases. Note that debit card merchant fees, which were not affected in the monopolistic case, may rise considerably. They may even reach monopolistic levels. However, this is not primarily due to the rise in credit merchant fees—in fact, the latter rises by a small amount compared with the debit merchant fee. The effect is coming from the complementarity between debit and credit cards. The bank can benefit from a positive balance in the current account while the consumer enjoys the 'grace period'; the returns on the positive balance increase with r and so the bank substantially increases the debit merchant fee, to discourage debit card usage. As a result, debit card acceptance α^D strongly decreases. Effectively, due to the complementarity between debit and credit cards, debit cards may be driven out of the market in equilibrium.

6 Possible extensions and discussion

Our model differs from other models in the literature that consider consumer heterogeneity prior to the consumer adoption decision. In our model, there is consumer heterogeneity after a shock such as theft or late income arrival. This implies that ex ante the willingness-to-pay for a payment card is equal for every consumer. As a consequence, depending on the fixed fee, every consumer signs up for the card, or no consumer signs up. In real life, we do not observe this 'cornered' behavior—some consumers do have a payment card in their wallets, others do not. Introducing consumer heterogeneity (e.g., regarding theft or income availability) would not qualitatively change these results as long as a positive fraction of consumers adopts payment cards. Lower card adoption reduces extraction from consumers and would increase merchant fees. But lost sales would still occur for merchants that do not accept payments cards, leaving some of their consumers being mugged on the street during transit or being unable to purchase if income did not arrive at the beginning of the day.

European consumers differ from US consumers regarding their credit card use. In Europe, consumers generally use the card as a payment vehicle and not so much as a credit facility. Often, checking account balances are used to pay back outstanding credit card payments. Instead of revolving the credit card debt and paying interest rate r_c, consumers may now draw upon their overdraft facility for repayment and pay interest rate r_d. Although the interest effects in our model will somewhat be mitigated, the credit line channel will still affect payment fees, since $m_c - m_d > 0$. Related to this observation is the fact that few European consumers pay interest on their credit card debt. Those loans are repaid at the end of the 'grace' period, or not at all, that is, consumers default. This implies that credit card loans cannot be made of zero NPV. In this case the cost of funds burden must be shifted explicitly towards merchants and consumers in the form of higher payment fees.

The welfare consequences of a cash-only economy are significant. Consumers cannot consume if they are mugged on the way to the merchant or if their income arrives in the night. Moreover, merchants' cash handling cost may also be considerable. These costs can (partly) be avoided when payment cards are introduced, but their benefits must also be weighed against increased processing cost and default risk. In a two-sided market where participation externalities play a role, it is likely that a social planner would make different tradeoffs than monopolistic payment networks. Even in a competitive situation, it is not immediately clear whether competitive payment prices are equal to socially optimal prices.

7 Conclusions

In this model we examine the role of consumer credit in both debit and credit card networks. We allow for the fact that the consumer will always have access to a current account, with an associated overdraft facility. This account is provided by the bank which would issue an associated debit card.

In the 'credit card only' world, the credit card effectively competes with the overdraft facility in the state where cash could be used. As a result, higher expected costs of servicing an overdraft will allow the credit card network to increase the consumer fee and lower the merchant fixed fee; this will increase the acceptance ratio of credit cards among merchants.

In the case of competition between the credit card and the debit card networks, we find that there can be degrees of complementarity, as well as competition, between the two networks. The bank providing the debit card and current account actually benefits from consumers using credit cards, if they have positive initial income. In effect the bank benefits from the 'free credit' period offered to the consumer by the credit card network, as the bank can earn interest on the balance that remains in the current account during this period. If the probability of initial income is high, therefore, this complementarity incentivizes the bank to increase the merchant debit card fee. Effectively, at the margin, the bank tries to discourage debit card acceptance in favor of credit cards. This may lead to higher debit merchant fees compared with credit card merchant fees, despite the higher probability of default inherent in the credit card model.

Our model also shows that cost of funds and default risk affect debit cards and credit cards in a different way. Specifically, in a 'debit card only' world, these factors have no effect on the merchant fee, while they do affect credit card merchant fees. In a competitive situation, these cost factors drive both cards, but credit card merchant fees are more affected than debit card merchant fees. However, as a result, the debit card fee may be increased to discourage debit card acceptance at the margin, allowing for the possibility that debit cards are completely driven out of the market in equilibrium.

These results help to inform current debates about the pricing of debit and credit card fees. Recent discussion has focused on whether there should be differential interchange fees for debit and credit cards. Although we do not explicitly model the interchange fee, we shed new light on how to understand the different drivers at work in affecting debit and credit card fees.

Appendix

Note: All algebraic expressions and numerical results in our paper are derived using Mathematica, version 8, and program files are available upon request.

Derivation of competitive merchant fees:
The intersection of (upward-sloping) reaction functions $f^C(f^D)$ and $f^D(f^C)$ yields (f_D^{**}, f_C^{**}), where

$$\begin{aligned} f_D^{**} &= \frac{1}{4-3\rho\delta-\delta}\left(ab[1-\gamma_E-\gamma_L]+[ab(2-3\gamma_E)+2b(2-\gamma_E)\delta x_1]r+\right.\\ &\quad \left.[bc^C+2cc^D+2a\rho h+ab]-3bcv_0\right), \\ f_C^{**} &= \frac{1}{4-3\rho\delta-\delta}\left(2ac[1-\gamma_E-\gamma_L]+[2ac(2-\gamma_E)-ab\delta\gamma_E+b\delta(2-\gamma_E)\delta x_1]r+\right.\\ &\quad \left.[c(2c^C+\delta c^D)+2a\rho\delta h+2ac]-c(b\delta+2c)v_0\right), \end{aligned}$$

where:
$a = 1-\delta$, $b = 1-\rho$, and $c = 1-\rho\delta$. Note that $4-3\rho\delta-\delta = 4c-b\delta > 0$.
For the partial derivative wrt default D, we find:

$$\begin{aligned} \frac{\partial f_D^{**}}{\partial D} &= -\frac{\partial f_D^{**}}{\partial \gamma_L} = \frac{ab}{4-3\rho\delta-\delta} > 0, \\ \frac{\partial f_C^{**}}{\partial D} &= -\frac{\partial f_C^{**}}{\partial \gamma_L} = \frac{2ac}{4-3\rho\delta-\delta} > 0. \end{aligned}$$

It easy to show that $\partial f_C^{**}/\partial D > \partial f_D^{**}/\partial D$. For funding cost r we find:

$$\frac{\partial f_D^{**}}{\partial r} = \frac{ab(2-3\gamma_E)+2b(2-\gamma_E)\delta x_1}{4-3\rho\delta-\delta} > 0,$$

for sufficiently large average period-1 income δx_1 if $\gamma_E \geq 2/3$, and:

$$\frac{\partial f_C^{**}}{\partial r} = \frac{2ac(2-\gamma_E)-ab\delta\gamma_E+b\delta(2-\gamma_E)\delta x_1}{4-3\rho\delta-\delta} > 0,$$

since $c > b$ and $2-\gamma_E > 1$. For the probability of early period-2 income γ_E, we find:

$$\begin{aligned} \frac{\partial f_D^{**}}{\partial \gamma_E} &= -\frac{ab(1+r)+2b(a+\delta x_1)r}{4-3\rho\delta-\delta} < 0, \\ \frac{\partial f_C^{**}}{\partial \gamma_E} &= -\frac{2ac(1+r)+b\delta(a+\delta x_1)r}{4-3\rho\delta-\delta} < 0. \end{aligned}$$

Finally, defining $x^e = \delta x_1$, we find (keeping δ constant):

$$\frac{\partial f_D^{**}}{\partial x^e} = \frac{2b(2-\gamma_E)r}{4-3\rho\delta-\delta} > 0 \quad \text{and} \quad \frac{\partial f_C^{**}}{\partial x^e} = \frac{b\delta(2-\gamma_E)r}{4-3\rho\delta-\delta} > 0,$$

and hence $\partial f_D^{**}/\partial x^e > \partial f_C^{**}/\partial x^e$.

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