Consumer Choice and Merchant Acceptance of Payment Media: A Unified Theory

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Abstract

In this article, we present a theoretical model to study the ability of banks to influence the consumer's payment instrument choice. Unlike most two-sided market models where benefits are exogenous, we explicitly consider how consumers' utility and merchants' profits increase from additional sales resulting from greater security and access to credit lines. Consumers participate in payment card networks to insure themselves from three types of shocks— income, theft, and their merchant match. Merchants choose which payment instruments to accept based on their production costs and are categorized as cash only, debit card and cash, or full acceptance. The model considers the merchants' ability to pass on payment processing costs to consumers in the form of higher goods prices. Our key results can be summarized as follows. The structure of prices, i.e. what share of the total price of the payment service is paid by consumers and merchants, is determined by the level of the bank's cost to provide payment services. Furthermore, the level of aggregate credit loss impacts the credit card price structure. In addition, we identify equilibria where the bank finds it profitable to offer one or both payment cards simultaneously. Finally, one price policies benefit the bank when it supplies both payment cards and credit card transactions are more profitable.

Key Words: Retail Financial Services, Network Effects, Multihoming, Payment Networks

JEL Codes: L11, G21, D53

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1 Introduction

Over the last two decades, consumer usage and merchant acceptance of payment cards have increased in industrialized countries while cash and check usage has declined (Amromin and Chakravorti, 2007 and Humphrey, 2004). Many observers argue that movement away from paper-based payment instruments to electronic ones such as payment cards has increased overall payment system efficiency. More recently, policymakers and academics have increased their attention on the pricing of payment card services. Chakravorti (2003), Katz (2003), Rochet and Tirole (2002), Wright (2003 and 2004) discuss key issues regarding network pricing of payment services. However, bank pricing of multiple payment media has largely been ignored in the theoretical literature. Empirical investigations of bank profit from payment services have been largely elusive due to the lack of price and cost data at the bank level.

We construct a model in the spirt of Diamond and Dybvig (1983) that analyzes the pricing decision of banks in the provision of payment instruments to maximize profits in a two-sided market. A market is said to be two-sided if two distinct set of end-users are unable to negotiate prices and the prices charged to each end-user affects the allocation of good or service (Armstrong, 2005 and Rochet and Tirole, 2006). For the most part, the recent payments literature has used a reduced form approach when considering the costs and benefits of payment cards.[1] Furthermore, most of the payments literature has not modeled the provision of multiple payment media by a single payment provider that offers payment services that use different payment networks.[2]

Our model differs from the existing literature in the following ways. All consumers are identical ex ante and must make decisions regarding which networks to participate in based on their expected utility. Consumers participate in non-cash payment networks to insure themselves from three types of shocks– income, theft, and the type of merchant that they are matched to. Consumers multihome because either all merchants do not accept their preferred payment instrument and/or they are offered price incentives to use a certain payment instrument. In other words, carrying only one instrument may result in lower expected utility. We focus on the ability of the bank and merchants to steer consumers to use a specific payment instrument given that they multihome. We derive conditions when merchants accept one, two, or three payment instruments based on their costs and ability to pass on payment processing costs to consumers. We also derive the bank's profit-maximizing consumer and merchant fees.

Our main results can be summarized as follows. The maximum bank fixed fee that consumers are willing to pay is dependent on potentially higher prices of goods they purchase with payment cards and maintain or increase their expected utility when using cash. The proportion of merchants that accept debit

[1] Chakravorti and Emmons (2003), Chakravorti and To (2007), and McAndrews and Wang (2006) are notable exceptions.

[2] Chakravorti and Roson (2006) construct a model where two different networks are operated by a single owner. We abstract from network pricing issues and instead focus on the pricing by the payment provider.

cards and those that accept credit cards are derived from the bank's profit maximization problem. The structure of prices, i.e. what share of the total price of the payment service is paid by consumers and merchants, is dependent on the probability of getting mugged, the timing of consumer income flows, and merchant revenue and cost structures. In addition, for credit cards, the level of aggregate credit loss, i.e. those that never receive income, impacts the price structure. For higher level of credit losses, merchants pay higher fees. Finally, one price policies increase bank profit when it supplies both payment instruments resulting from extracting greater merchant surplus than when merchants set different prices.

In the next section, we present a model where we consider cash-only; cash and debit card-only; and cash and credit card-only. We explore an economy where all three instruments are used in section 3. In section 4, we discuss extensions of our model. We conclude in section 5.

2 Model

2.1 The Environment

There are three types of agents– consumers, merchants, and a bank. All agents are risk neutral.[3] A continuum of ex ante identical consumers reside on a line segment from 0 to 1. A continuum of merchants reside on a line segment from 0 to 1 differentiated by the type of good and the cost that they face to serve each customer.

Consumers maximize expected utility. For computational ease, we assume a linear utility function $u(c) = c$. Consumers only have positive utility when consuming goods sold by the merchant they are matched to and from purchases made during the day. Each consumer spends all her income during the day because she receives no utility from unused income after that. Consumers are subject to three shocks. First, consumers either receive income, I, in the morning with probability, ϕ_1, or at night with probability, ϕ_2, or no income at all with probability, $1 - \phi_1 - \phi_2$, where $\phi_1 + \phi_2 \leq 1$. These probabilities are given exogenously. Second, before leaving home, each consumer is randomly matched to a merchant selling a unique good. Third, a cash-carrying consumer may also be mugged in transit to the merchant with probability $1-\rho$ resulting in complete loss of income (and consumption).[4]

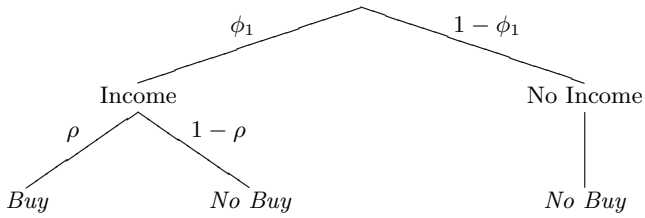
Merchant heterogeneity is based on the type of good that they sell and their cost. Each merchant faces an unique exogenously given cost, γ_i. Merchant costs are uniformly distributed on a line segment from 0 to 1.[5] Although merchants face different costs, each merchant sells its good at p_m. This price is

[3] Our qualitative results would not change if consumers and merchants were risk averse. In fact, consumers and merchants would be willing to pay more to participate in payment card networks.

[4] He, Huang, and Wright (2005) construct a search model of money and banking that endogenizes the probability of theft.

[5] We would expect our results to be robust to different distributions of merchant costs.

Figure 1: Probability tree for cash



set exogenously.[6] We make this assumption to capture that there are merchants with different markups in the economy.[7] Our main motivation is to focus on bank pricing of payment services and not merchant setting of goods prices. We also assume merchants cannot collude.

Let us consider an economy where only cash exists.[8] In a cash economy, consumers cannot consume if they are mugged on the way to the merchant or their income arrives at night. However, we ignore benefits of cash such as anonymity which may be valued by consumers and some types of merchants. In figure 1, the probability tree for the cash economy is diagrammed. The expected consumption of a consumer is:

$$u(c) = \rho\phi_1 I.$$

A merchant's expected profit is:

$$\Pi_m^M = \phi_1\rho(1-\gamma_i)I.$$

Next, we consider technologies that can reduce the loss associated with theft and allow consumers that receive income at night to consume during the day. Our environment is similar to a Diamond-Dybvig one. Diamond and Dybvig (1983) model liquidity demands when all consumers are endowed equally in period zero. Instead, in our model, consumers have positive utility only if they consume during the day, but their income may not arrive before they go shopping. The bank offered payment instruments provide insurance against theft and income shocks. This aspect of payment cards is largely ignored in the payments literature.[9]

The monopolist bank provides all three payment instruments– cash, debit card, and credit card.[10] Consumers that choose to participate in a debit or

[6] Alternatively, one could consider merchants facing different elasticities of demand resulting in different pricing power.

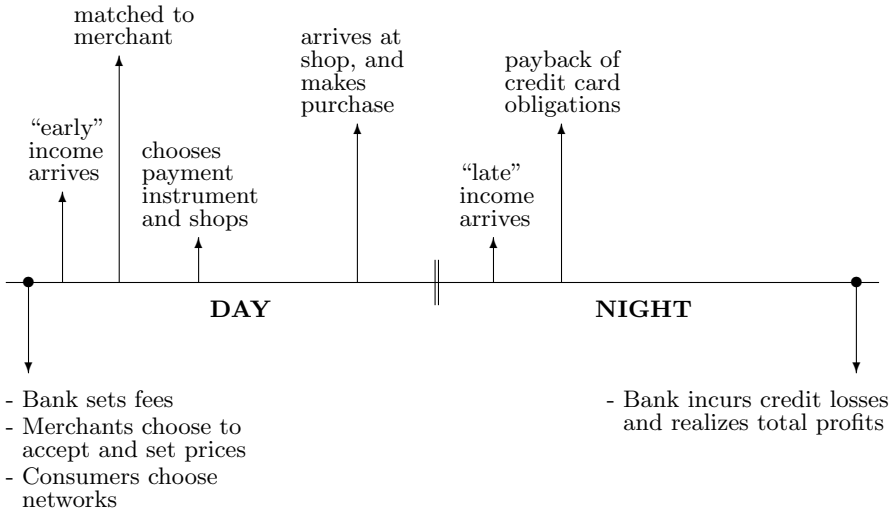
[7] Initially, general-purpose charge cards were accepted by high-margin merchants. Diners Club, the first general-purpose charge card in the United States, targeted restaurants and hotels where business men frequented, i.e. establishments with high margins.

[8] We do not model the role of a central bank in providing fiat money and the implications on price level. An alternative interpretation of cash in our model is to assume that consumers are endowed with income in the form of a good that merchants consume.

[9] Chakravorti and Emmons (2003) and Chakravorti and To (2007) are notable exceptions.

[10] On average the bank is endowed $\phi_2 I$ per consumer to lend to consumers during the day.

Figure 2: Timing of events



credit card network sign fully enforceable contracts where their incomes are directly deposited into the bank when realized.[11] The bank provides access to cash at no charge, but charges consumers membership fees to use their debit cards, F_D, and credit cards, F_C, that are deducted from their payroll deposits upon arrival.[12] We denote F_T as the total fixed fee charged to consumers for participation in both networks. It charges merchant per-transaction fees, f_d and f_c, for debit and credit card transactions, respectively.[13] In reality, different merchants face different fees for payment services. For tractability, we only consider one fee for all merchants.

The timing of events is depicted in figure 2. In the early morning, the bank posts its prices for payment services, merchants announce their acceptance of payment products and their prices, and consumers choose which payment networks to participate in. Next, some consumers realize their income and are matched with a specific merchant. Consumers decide which payment instrument to use before leaving home based on the merchant acceptance and their prices. During the day, consumers go shopping. We assume time consistency

[11]The bank is providing convenience and security of payroll deposits for businesses and employees. We ignore these benefits.

[12]Clearly, the bank can use a strategy to price cash as well. We ignore this aspect primarily because of the tractability of solving a model with six different prices for payment services. However, banks generally do not charge for cash withdrawals from their own automated teller machines in advanced economies.

[13]This fee structure 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.

Table 1: Variables in the Model

Exogenous variables:	
I	Income for consumer
ϕ_1	Probability of receiving income before shopping
ϕ_2	Probability of receiving income after shopping
ρ	Probability of not getting robbed when carrying cash
γ_i	Merchant-specific cost
p_m	Price for good if paying by cash
λ_d	Proportion of debit card merchant fee absorbed by merchants
λ_c	Proportion of credit card merchant fee absorbed by merchants
c_d	Bank's per-transaction cost to process debit card transaction
c_c	Bank's per-transaction cost to process debit card transaction

Endogenous variables:	
α	Proportion of merchants accepting debit cards
β	Proportion of merchants accepting credit cards
p_d	Price of good if paying with debit card
p_c	Price of good if paying with credit card
F_D	Fixed consumer fee for debit card
F_C	Fixed consumer fee for credit card
f_d	Per-transaction merchant fee for debit card
f_c	Per-transaction merchant fee for credit card

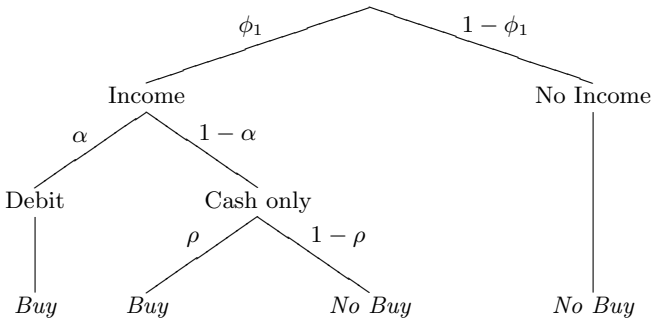
in our model. In other words, consumers know debit and credit card prices of goods when they choose to participate in payment card networks and merchants cannot change them at the time of the transaction. At night, consumers that did not receive income in the morning may receive income and pay back their credit card obligations. The bank faces losses from credit card consumers that never receive income.

Given consumer income flows, the probability of getting mugged, and merchant profit, the bank sets consumer and merchant fees which determines the proportion of merchants that accept debit and credit cards by maximizing its profit function. For reference, we list the exogenous and endogenous variables in table 1. In the following sections, we derive existence conditions for debit and credit cards and study the pricing of payment card services.

2.2 Debit Cards

In this section, we will limit our analysis to an economy with only debit cards and cash. When compared to cash, debit cards are more secure for consumers to carry than cash because cash-carrying consumers have some probability of being mugged. A proportion α merchants accepts debit cards. Because debit cards may not be accepted by all merchants, consumers must use cash for some

Figure 3: Probability tree for debit cards



purchases. In figure 3, we diagram additional states of nature when consumption occurs when debit cards exist. Consumers can consume in an additional $\alpha(1-\rho)$ states of nature.

Consumers are willing to participate in a debit card network if the fixed fee, F_D, is less than or equal to the expected utility from additional consumption. The upper bound of F_D, $\bar{F}_D$, is derived from the following consumer debit card network participation constraint:

$$\rho\phi_1 I \leq \phi_1 \left((1-\alpha)\rho(I-F_D) + \alpha((I-F_D)/p_d)\right). \tag{1}$$

Solving for F_D, yields:

$$F_D \leq \bar{F}_D(p_d, I, \alpha, \rho) = \frac{\alpha(1-p_d\rho)}{\alpha(1-p_d\rho)+p_d\rho} I. \tag{2}$$

Equation (2) expresses the highest fixed fee that consumers are willing to pay given the probability of getting mugged, the potentially higher goods prices and the proportion of merchants accepting debit cards. We will solve for α and F_D as part of the bank's profit maximization problem given a pricing rule for merchants. In other words, equation (2) is the consumer's participation constraint for the bank's optimization problem.

There are several interesting features of the merchant participation problem. First, we assume that all merchants will post the same price for their goods given the payment instrument used to make the purchase. In other words, each merchant is unable to fully endogenize the cost of payment processing in terms of its goods prices. In reality, merchants would set prices based on the fee it faces and demand elasticity of consumers. However, given our focus to derive payment service fees in a tractable model, we introduce a merchant pricing rule that captures the ability of merchants to pass on payment processing costs to consumers, albeit imperfectly. Second, we assume that each merchant faces the same bank fee. In reality, merchant fees are generally negotiated bilaterally. Again, for tractability, we do not consider different fees for each merchant.

To capture the ability of merchants to pass on payment costs, we consider the following pricing rule. Let us consider two polar cases– the merchant is unable to pass any costs to consumers, $p_d = p_m = 1$, or is able to pass on all of its cost to consumers, $p_d = 1/(1 - f_d)$. The level of pass through is determined exogenously by $\lambda_d \in [0, 1]$. Thus, p_d is given by:

$$p_d(f_d, \lambda_d) = \frac{1}{1 - f_d(1 - \lambda_d)}. \tag{3}$$

When $\lambda_d = 1$, merchants cannot pass on any payment processing costs in the form of higher prices to consumers. When $\lambda_d = 0$, merchants are able to pass on all payment processing costs to consumers.

Merchants must make at least as much profit from accepting debit cards than only accepting cash.[14] The merchant's profit from accepting cash, Π_m^M, or accepting debit cards also, Π_d^M, are, respectively:

$$\Pi_m^M = \phi_1 \rho (1 - \gamma_i)(I - F_D),$$
$$\Pi_d^M = \phi_1 \left[(1 - f_d) - \frac{\gamma_i}{p_d} \right] (I - F_D).$$

Note that consumers have less disposable income to spend at merchants than in the cash-only economy. Given our assumption of atomistic merchants and no collusion, merchants are unable to internalize the loss in disposable income from the consumer's fixed fee. If merchants could do so, their participation threshold would occur at a lower fee. The proportion of merchants willing to accept debit cards when $\Pi_m^M \leq \Pi_d^M$, is:

$$\alpha(f_d, p_d, \rho) = \gamma_d = \frac{1 - f_d - \rho}{\frac{1}{p_d} - \rho}.$$

There is a threshold cost, γ_d, below which merchants will accept debit cards.

Substituting our pricing rule $p_d(f_d, \lambda_d)$ in merchant acceptance, we find:

$$\alpha(f_d, \rho, \lambda_d) = \frac{1 - f_d - \rho}{1 - f_d(1 - \lambda_d) - \rho}. \tag{4}$$

Merchants with the highest costs may not be able to accept payment cards unless they are able to pass on this cost to consumers. We observe that $\alpha(f_d, \rho, \lambda_d) \in [0, 1]$ if and only if $f_d \in [0, 1 - \rho]$ and $\lambda_d > 0$. When $\lambda_d = 0$, $\alpha(f_d, \rho, \lambda_d) = 1$.

Lemma 1 *The maximum fixed debit card fee $\bar{F}_D(f_d, I, \rho)$, is:*[15]

$$\bar{F}_D(f_d, I, \rho) = \left(1 - \frac{\rho}{1 - f_d} \right) I. \tag{5}$$

[14] Our model does not capture business stealing incentives as a driver for card acceptance. See Chakravorti and To (2007), Rochet and Tirole (2003), and Wirght (2003 and 2004).

[15] All proofs of lemmas and propositions are in the appendix.

Note that our pricing rule, $\bar{F}_D(f_d, I, \rho) = 0$ when $f_d = 1 - \rho$. Given that consumers must commit to the membership fee before being matched to a merchant, all consumers purchasing from stores that accept debit cards will always use their debit cards and never carry cash because they face a potential loss of income if they are mugged. To maintain time consistency, merchants cannot charge higher prices than what they posted when consumers made their decision to join the debit card network.

Now, we will derive which set of consumer and merchant fees the bank chooses based on its profit maximization problem. The bank maximizes its expected per-consumer profit:

$$\Pi_D^B = \phi_1 \left(\alpha(f_d - c_d)(I - F_D)\right) + (\phi_1 + \phi_2)F_D. \tag{6}$$

Substituting $\alpha = \alpha(f_d, \rho, \lambda_d)$, and $F_D = \bar{F}_D(f_d, I, \rho)$ into bank profits—for convenience, suppressing the dependence on all exogenous parameters in the functional notation—yields:

$$\Pi_D^B(f_d) = \frac{(1 - f_d - \rho)((1 - (1 + c_d)\rho - f_d(1 - \lambda_d - \rho))\phi_1 + (1 - f_d(1 - \lambda_d) - \rho)\phi_2)}{(1 - f_d)(1 - f_d(1 - \lambda_d) - \rho)} I. \tag{7}$$

Generally, the profit function (7) is valid when $f_d \in [0, 1 - \rho]$.[16] In particular, for $f_d > 1 - \rho$, it is not profitable for any merchant to accept debit cards, so $\alpha = 0$ and hence bank profit is zero. On the other hand, for $f_d < 0$, all merchants will accept debit cards, i.e. $\alpha = 1$. Hence, for $f_d < 0$, bank's profit is determined by substituting $p_d(f_d, \lambda_d)$, $\alpha = 1$, and $\bar{F}_D(p_d(f_d, \lambda_d), I, 1, \rho)$ into equation (6). Bank profit from debit cards when $\lambda_d > 0$ is given by:

$$\Pi_D^B(f_d) = \begin{cases} \left(1 - \frac{\rho(1-\phi_1(f_d - c_d))}{1 - f_d(1-\lambda_d)}\right) I, & f_d < 0, \\ \left(\frac{(1-f_d-\rho)((1-(1+c_d)\rho - f_d(1-\lambda_d-\rho))\phi_1 + (1-f_d(1-\lambda_d)-\rho)\phi_2)}{(1-f_d)(1-f_d(1-\lambda_d)-\rho)}\right) I, & f_d \in [0, 1-\rho], \\ 0, & f_d > 1 - \rho. \end{cases}$$

As we observed with the consumer fixed fee, when $f_d = 1 - \rho$, merchants are not willing to pay for debit card acceptance. The function $\Pi_D^B(f_d)$ is continuous in f_d. Furthermore,

$$\Pi_D^B(f_d) \geq 0 \text{ iff } f_d \in [l_d, 1 - \rho],$$

where

$$l_d = \frac{1 - \rho(1 + c_d\phi_1) + (1 - \rho)\phi_2}{1 - \lambda_d - \rho\phi_1 + (1 - \lambda_d)\phi_2}.$$

[16] When λ_d is close to or equal to 0, f_d may be less than zero. We will discuss this case in greater detail below.

Given that bank profit is increasing in f_d when fees are negative, this implies that the profit maximizing fee f_d^* always lies between 0 and $1-\rho$ when λ_d is sufficiently large. Let us denote $f_d^*(c_d, \rho, \phi_1, \phi_2, \lambda_d)$ as the fee that maximizes the bank's profit maximization problem (7) and satisfies the second order conditions (see appendix). The following proposition characterizes the equilibrium.

Proposition 1 *The debit card fee f_d^* that maximizes $\Pi_D^B(f_d)$ is given by:*

$$f_d^* = \begin{cases} f_d^*(c_d, \rho, \phi_1, \phi_2, \lambda_d) & \text{iff } \underline{c}_d \leq c_d \leq \bar{c}_d, \\ 0 & \text{iff } 0 \leq c_d < \underline{c}_d, \end{cases}$$

where

$$\underline{c}_d = \frac{(1-\rho)\phi_2}{(\lambda_d + \rho - 1)\phi_1} \text{ and } \bar{c}_d = \frac{(1-\rho)(\lambda_d(\phi_1+\phi_2)+\rho\phi_1)}{\rho\phi_1}.$$

Depending on the bank's per-transaction cost, the optimal fee f_d^* results in a debit card price, $p_d^* = p_d^*(f_d^*, \lambda_d)$, and an optimal merchant acceptance, $\alpha^* = \alpha^*(f_d^*, \rho, \lambda_d)$. In turn, the consumer's fixed debit card fee follows from $\bar{F}_D^* = \bar{F}_D(f_d^*, \rho, I)$.

Figure 4 shows the two different cases. The left panel shows that $f_d^* = 0$ for low bank costs, which then induces full merchant acceptance $\alpha^* = 1$ and a fixed debit card fee of $\bar{F}_D^* = (1-\rho)I$. For a higher bank cost, the optimal debit card fee is an interior solution inducing incomplete merchant acceptance and a debit card goods price larger than 1.

Our model identifies three ranges of fees. When the cost of providing payment services is sufficiently low, consumers pay all of the payment processing costs. As the bank cost rises and consumers are unable to bear the full cost, merchants pay a positive fee. However, if the bank cost is too high, neither consumers nor merchants are willing to pay for debit cards.

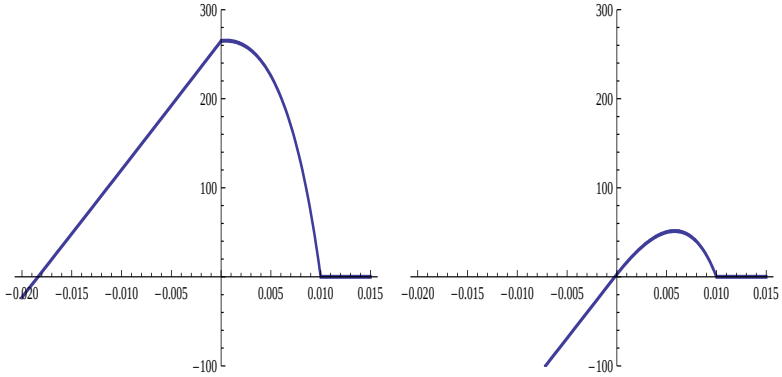
2.2.1 Equilibria

First, let us consider when $\lambda_d > 0$. In equilibrium, parameter values determine the proportion of what the bank charges merchants and consumers. The maximum f_d is bounded from above by $1-\rho$. Consumers' willingness to pay increases as more merchants accept cards resulting from a lower f_d. Given the two-sided nature of our model, the network effect results in asymmetric price structure in the sense that the bank looks to extract surplus first from consumers and then from merchants.

The ability of merchants to pass on costs to consumers affects bank profits.

Proposition 2 *As λ_d approaches 1, the bank is able to set a higher F_T because of an increase in the consumer's purchasing power from a lower p_d. However, α decreases even though f_d decreases resulting from the merchant's absorption of f_d^* rising faster than the reduction in f_d^*.*

Figure 4: Bank debit card profits



Note: In left panel, $0 \leq c_d \leq \underline{c}_d$ and $f_d^* = 0$; in right panel, $\underline{c}_d < c_d \leq \bar{c}_d$ and $f_d^* \in (0, 1-\rho]$. Other parameter values: $\rho = 0.99$, $\phi_1 = 0.98$, $\phi_2 = 0$, $\lambda_d = 0.5$, and $I = 30000$. These values yield: $\underline{c}_d = 0$ and $\bar{c}_d = 0.015$.

Now, let's consider the special case of full pass through. Given our pricing rule, full pass through induces $\alpha = 1$. In other words, the bank is unable to extract any surplus from merchants. Consumers bear the full cost of the debit card network. When $\lambda_d = 0$ resulting in $p_d = 1/(1 - f_d)$, the bank's optimal fee may be significantly less than zero.[17] At first glance, one might conclude that bank profits are not dependent on the price structure. However, this is not the case. The bank faces a real resource cost only when transactions are processed and this cost is based on the transaction size. As F_D increases, consumers are left with less disposable income but higher purchasing power resulting in a lower transaction cost while maintaining their cash-only consumption level. Additionally, the bank collects fees from consumers that receive income at night and are unable to consume during the day.

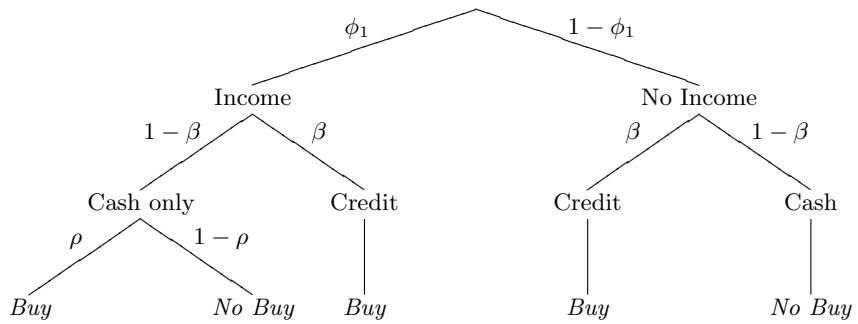
2.3 Credit Cards

In addition to being as secure as debit cards, credit cards allow consumption when consumers have not received income before they go shopping if merchants accept them.[18] Merchants benefit from making sales to those without funds. A proportion of β merchants accepts credit cards that is determined by the bank's profit maximization problem. Figure 5 shows the probability tree corresponding to an economy with credit card consumption. Consumers are able to consume

[17] There is a limit how negative f_d can be given that it has to be financed by what is extracted from the consumer.

[18] While it is common for consumers to access overdraft facilities with their debit cards in some countries, we ignore this aspect of debit cards to distinguish them from credit cards.

Figure 5: Probability tree for credit cards



in $\beta(1-\rho)+\beta(1-\phi_1)$ additional states of nature when participating in a credit card network than when only making cash purchases.

Consumers are willing to hold a credit card if their expected consumption from participating in a credit card network is greater than not participating. Their credit card participation constraint is:

$$\rho\phi_1 I \leq \phi_1(1-\beta)\rho(I-F_C)+\beta((I-F_C)/p_c) \tag{8}$$

Solving for F_C, yields:

$$F_C \leq \bar{F}_C(p_c, I, \beta, \rho, \phi_1) = \frac{\beta(1-p_c\rho)+p_c\rho(1-\phi_1)}{\beta(1-p_c\rho)+p_c\rho} I. \tag{9}$$

Similar to the debit card problem, equation (9) is the consumer's participation constraint that is used in the bank's profit maximization problem.

Merchants must make at least as much profit from accepting credit cards as accepting only cash.[19] While all merchants set the same price, if they accept credit cards, their cost varies. Furthermore, given that consumers must commit to paying membership fees before being matched to merchants, all consumers purchasing from stores that accept credit cards will always use their credit cards to reduce their probability of being mugged. Merchant profit from accepting cash, Π_m^M, and accepting credit cards , Π_c^M, are given, respectively, by:

$$\Pi_m^M = \phi_1\rho(1-\gamma_i)(I-F_C),$$
$$\Pi_c^M = \left[(1-f_c)-\frac{\gamma_i}{p_c}\right](I-F_C).$$

[19] As in the debit card case, consumers have less disposable income to spend at merchants than in the cash-only economy. Given our assumption of atomistic merchants and no collusion, merchants are unable to internalize the loss in disposable income from the consumer's fixed fee in an economy with credit cards. If merchants could do so, their participation threshold would occur at a lower fee.

These conditions imply a threshold value of merchant cost, γ_c, below which merchants will accept credit cards. Setting $\Pi_m^M = \Pi_c^M$ and solving γ_i yields:

$$\beta(f_c, p_c, \rho, \phi_1) = \gamma_c = \frac{1 - f_c - \rho\phi_1}{\frac{1}{p_c} - \rho\phi_1}.$$

We also develop a merchant pricing rule for credit card purchases. As before, there are two polar cases– the merchant is unable to pass any costs to consumers, $p_c = p_m = 1$, or is able to pass all of its cost to consumers, $p_c = 1/(1 - f_c)$. The level of pass through is determined exogenously by $\lambda_c \in [0, 1]$. Thus, p_c is given by:

$$p_c(f_c, \lambda_c) = \frac{1}{1 - f_c(1 - \lambda_c)}. \tag{10}$$

Substituting our pricing rule, $p_c(f_c, \lambda_c)$, into the above equation, we find:

$$\beta(f_c, \rho, \phi_1, \lambda_c) = \frac{1 - f_c - \rho\phi_1}{1 - f_c(1 - \lambda_c) - \rho\phi_1}. \tag{11}$$

We observe that $\beta(f_c, \rho, \phi_1, \lambda_c) \in [0, 1]$ if and only if $f_c \in [0, 1 - \rho\phi_1]$ when λ_c is sufficiently larger than 0.

Lemma 2 *The maximum fixed credit card fee, $\bar{F}_C(p_c, I, \beta, \rho, \phi_1)$, is:*

$$\bar{F}_C(f_c, I, \rho, \phi_1) = \left(1 - \frac{\rho\phi_1}{1 - f_c}\right) I. \tag{12}$$

Note that $\bar{F}_C(f_c, I, \phi_1, \rho) = 0$ when $f_c = 1 - \rho\phi_1$. Furthermore, a consumer is willing to pay more for a credit card than a debit card, all else equal, because credit cards offer more benefits, namely consumption in no income states when matched with a credit card accepting merchant.

The bank maximizes its profits:

$$\Pi_C^B = \beta f_c(I - F_C) + (\phi_1 + \phi_2)F_C - (c_c + (1 - \phi_1 - \phi_2))\beta(I - F_C).$$

When issuing credit cards, the bank faces a certain aggregate loss from consumers that never receive income. Note if $\phi_2 = 1 - \phi_1$, there is no credit loss.

Substituting $\beta = \beta(f_c, \rho, \phi_1, \lambda_c)$ and $F_C = \bar{F}_C(f_c, I, \rho, \phi_1)$ into the bank profit function, yields:

$$\Pi_C^B(f_c) = \frac{(1 - f_c - \rho\phi_1)((1 - (1 + c_c)\rho - f_c(1 - \lambda_c - \rho))\phi_1 + (1 - f_c(1 - \lambda_c))\phi_2)}{(1 - f_c)(1 - f_c(1 - \lambda_c) - \rho\phi_1)} I. \tag{13}$$

Generally, the bank profit function (13) is valid when $f_c \in [0, 1 - \rho\phi_1]$.[20] Similar to debit cards, bank profit from credit cards is given by:

[20] When λ_c is close to or equal to zero, f_c may be less than zero.

$$\Pi_C^B(f_c) =$$

$$\begin{cases} \left(\left(1 - \frac{\rho(1-(f_c-c_c))}{1-f_c(1-\lambda_c)}\right)\phi_1 + \phi_2\right) I, & f_c < 0, \\ \left(\frac{(1-f_c-\rho\phi_1)((1-(1+c_c)\rho - f_c(1-\lambda_c-\rho))\phi_1 + (1-f_c(1-\lambda_c))\phi_2)}{(1-f_c)(1-f_c(1-\lambda_c)-\rho\phi_1)}\right) I, & f_c \in [0, 1-\rho\phi_1], \\ 0, & f_c > 1-\rho\phi_1. \end{cases}$$

The function $\Pi_C^B(f_c)$ is continuous in f_c. Furthermore,

$$\Pi_C^B(f_c) \geq 0 \text{ iff } f_c \in [l_c, 1-\rho\phi_1],$$

where

$$l_c = \frac{(1-\rho(1+c_c))\phi_1 + \phi_2}{(1-\lambda_c-\rho)\phi_1 + (1-\lambda_c)\phi_2}.$$

We observe that the profit maximizing credit card fee, f_c^*, lies between 0 and $1-\rho\phi_1$, and maximizes the bank profit function (13) when $\lambda_c > 0$. Denote this fee by $f_c^*(c_c, \rho, \phi_1, \phi_2, \lambda_c)$, satisfying the second order conditions (see appendix). The following proposition characterizes maximum credit card fee.

Proposition 3 *The credit card fee f_c^* that maximizes $\Pi_C^B(f_c)$ is given by:*

$$f_c^* = \begin{cases} f_c^*(c_c, \rho, \phi_1, \phi_2, \lambda_c) & \textit{iff } \underline{c}_c \leq c_c \leq \bar{c}_c, \\ 0 & \textit{iff } 0 \leq c_c < \underline{c}_c, \end{cases}$$

where

$$\underline{c}_c = \frac{-\lambda_c(1-\phi_1-\phi_2)}{\lambda_c + \rho\phi_1 - 1} \text{ and } \bar{c}_c = \frac{(1-\rho)\lambda_c(\phi_1+\phi_2) + \rho\phi_1((1-\rho)\phi_1 + \phi_2)}{\rho\phi_1}.$$

Note proposition 3 states that for sufficiently large ϕ_1, we have $\underline{c}_c < 0$, and therefore, the optimal f_c^* will be the interior solution to bank profit problem (13) for all $c_c \in [0, \bar{c}_c]$.

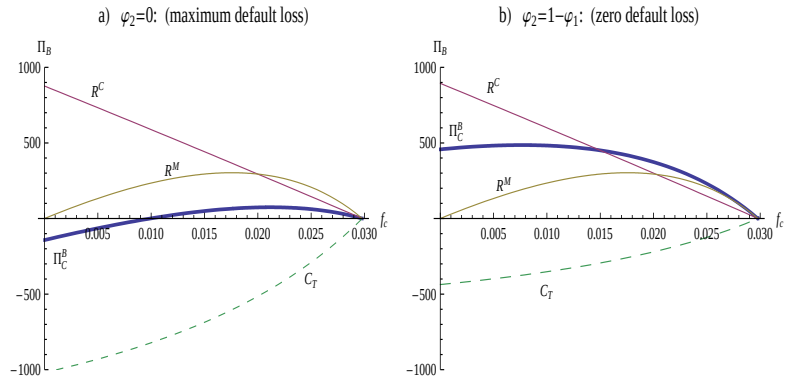
Unlike the debit card case, the bank has two types of costs– per-transaction cost to operate the system and credit losses from consumers who make credit card purchases but do not receive income. Once the bank has fully extracted surplus from consumers, it tries to capture surplus from merchants to fund the loss if possible to do so.

2.3.1 Equilibria

Three sources contribute to credit card bank profits: merchant revenue (R^M), consumer revenue (R^C), and total costs (C_T) which is the sum of total processing costs and default losses. The bank's profit function can be described as:

$$\Pi_C^B = R^C + R^M + C_T,$$

Figure 6: Bank credit card profits and default probability



Note: Given parameter values $\rho = 0.99$, $\phi_1 = 0.98$, $c_c = 0.015$, $\lambda_c = 0.5$, and $I = 30000$, in panel a) we calculate $f_c^* = 0.021$ for $\phi_2 = 0$, and in panel b) $f_c^* = 0.007$ for $\phi_2 = 0.02$. The cut off value is $\bar{\phi}_2 = 0.008$.

where

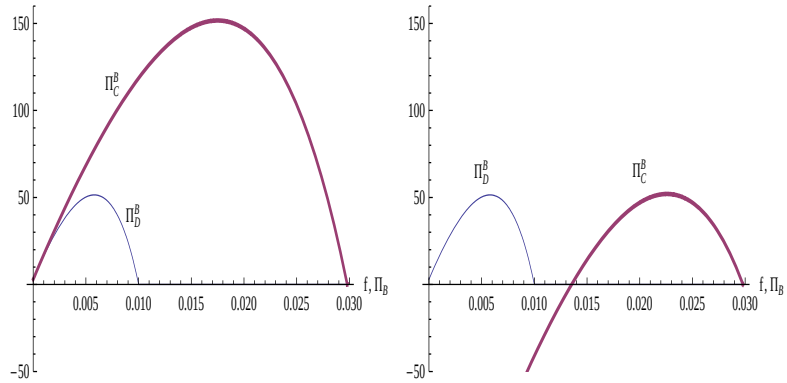
$$
\begin{aligned}
R^M &= \beta(f_c)(I - \bar{F}_C), \\
R^C &= (\phi_1 + \phi_2)\bar{F}_C, \\
C_T &= -\beta(c_c + (1 - \phi_1 - \phi_2))(I - \bar{F}_C).
\end{aligned}
$$

Figure 6 shows the bank profit and its components for the two polar cases: $\phi_2 = 0 < \bar{\phi}_2$ and $\phi_2 = 1 - \phi_1 > \bar{\phi}_2$. Given a sufficiently large c_c, merchant share of payment costs increases as credit risk goes up. As a result, we conclude that merchants pay a greater share of the total price when default losses can no longer be extracted from consumers. In other words, as additional benefits to merchants increase and the ability of consumers to pay decreases, merchants carry a larger share of the cost.

Proposition 4 *For sufficiently large c_c, there exists $\bar{\phi}_2 \in [0, 1 - \phi_1]$ such that $f_c^* = c_c$ for $\phi_2 = \bar{\phi}_2$. If and only if $\phi_2 < \bar{\phi}_2$, then $f_c^* > c_c$.*

Regarding comparative statics, if $\phi_2 < \bar{\phi}_2$ then lowering fees to the cost level, $f_c = c_c$, increases merchant acceptance and reduces goods prices p_c. This allows a higher fixed credit card fee for consumers. But the bank loses on the merchant side by lowering merchant fees, and suffers more default losses as credit card acceptance gets more widespread. These latter effects dominate resulting in lower bank profit. The reverse case, when $\phi_2 > \bar{\phi}_2$, raising fees to $f_c = c_c$ induces lower merchant acceptance and higher goods prices. This leads to lower fixed fees, but also to lower default losses. On net, the bank's profit decreases.

Figure 7: Bank credit card and debit card profits



Note: Parameter values set equal to $\rho = 0.99$, $\phi_1 = 0.98$, $\phi_2 = 0$, $\lambda_c = \lambda_d = 0.5$, and $I = 30000$. In panel a) we set $c_d = c_c = 0.010$, in panel b) $c_c = 0.017$ and $c_d = 0.010$.

Similar to the debit card case, when $\lambda_c = 1$ ($p_c = p_m = 1$) bank profits are higher. The inability of merchants to pass any processing costs to consumers results in lower merchant acceptance and lower goods prices. This induces higher fixed fees and lower default losses, yielding higher bank profits. In other words, banks extract rents from both consumers and merchants.

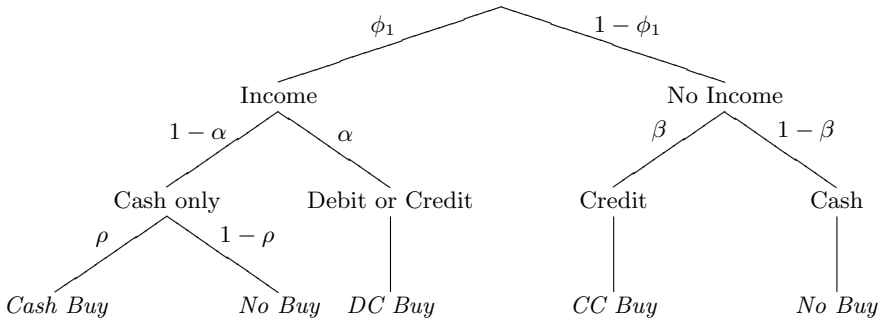
Full pass through, on the other hand, with $\lambda_c = 0$ and $p_c = 1/(1 - f_c)$ corresponds to a corner solution with $f_c^* < 0$. As in the debit card case, this perverse effect results from the bank transferring rents from the consumer to the merchant so that transaction dollar volume decreases.

2.4 Comparison

The extra functionality of credit cards, insurance against negative income shocks, becomes obsolete if all consumers receive income in the morning. However, when $\phi_1 < 1$, credit cards become useful for consumers and merchants, and banks may make a profit supplying credit cards. Possible cost differentials (c_c vs. c_d) and/or cost absorption differentials (λ_c vs. λ_d) will determine whether banks prefer to supply credit cards or debit cards.

Figure 7 compares credit card and debit card profits when $\phi_1 < 1$ and $\phi_2 = 0$. In panel (a) all other parameters are equal, and naturally, maximum credit card profits are higher than maximum debit card profits. When credit card cost increase relative to debit card cost, credit card profits will go down, and for large enough cost differentials, banks would opt for supplying debit cards. This is depicted in panel (b) where the cost differential is large enough to yield equal bank profits, although credit card fees for the retailer are higher.

Figure 8: Probability tree for multihoming ($p_d < p_c$)



3 Full Multihoming

In this section, we will consider the case when the bank provides both debit and credit cards simultaneously. Unlike the previous two cases, when cards always dominated cash, consumers may not choose the same payment instrument in all income states when all payment instruments are accepted. If consumers are multihoming, they consider the benefits of each card before going to the store including any price differences based on the payment instrument used. By differentiating debit card and credit card purchase prices, merchants may be able to steer some consumers to the low-cost payment instrument. However, when merchants are unable to price differentiate and post one price, consumers do not face any price inducements in the store, and are assumed to opt for the instrument with the greatest functionality, regardless they have income or not.

3.1 Price differentiation

Let us now consider the case when consumers hold both debit and credit cards, and merchants are able to price differentiate between cash, debit and credit cards. Note that all merchants post the same prices based on the payment instrument used. First, we analyze the case when $p_d < p_c$. The different possibilities are shown in Figure 8. The following inequality must be satisfied for consumers already holding debit cards, to hold credit cards:

$$\begin{aligned}&\phi_1\left[(1-\alpha)\rho(I-F_D)\ +\ \alpha(I-F_D)/p_d\right]\ \leq\\&\phi_1\left[(1-\alpha)\rho(I-F_D-F_C)+\alpha(I-F_D-F_C)/p_d\right]+\\&(1-\phi_1)\beta(I-F_D-F_C)/p_c,\end{aligned}\tag{14}$$

Because consumers pay a lower price when using their debit cards, they will use credit cards only when they have not yet received their income.

Consumers will multihome when each payment product yields benefits greater than the cost to participate. The maximum total card fee $\bar{F}_T$ under full multihoming is given by:

$$\bar{F}_T = \bar{F}_D + \bar{F}_C(\bar{F}_D) = \frac{\beta(1-\phi_1)p_d + (p_c/p_d)\phi_1\alpha(1-p_d\rho)}{\beta(1-\phi_1)p_d + (p_c/p_d)\phi_1(\alpha(1-p_d\rho)+p_d\rho)} I, \quad (15)$$

When consumers multihome, only the total fixed fee matters and not the fee attributed to each card. Consumers are willing to spend up to $\bar{F}_T$ in return for participating in both the debit and credit card networks.

Merchant's acceptance of cards is determined by threshold costs γ_d for debit cards and γ_c for credit cards. On the margin, the merchant has to tradeoff the benefits of accepting debit and credit cards to accepting cash only. As shown in sections 2.2 and 2.3, the proportion of merchants willing to accept debit cards is:

$$\alpha(f_d, \rho, \lambda_d) = \frac{1 - f_d - \rho}{1 - f_d(1-\lambda_d) - \rho}, \quad (16)$$

and to accept credit cards is:

$$\beta(f_c, \rho, \phi_1, \lambda_c) = \frac{1 - f_c - \rho\phi_1}{1 - f_c(1-\lambda_c) - \rho\phi_1}. \quad (17)$$

Substituting price rules (3) and (10), and acceptance rules (16) and (17) in fixed total fee (15) yields the maximum total card fee as a function of only the merchant card fees and other exogenous variables.

Lemma 3 *The maximum total card fee*

$$\bar{F}_T(f_d, f_c, I, \rho, \phi_1, \lambda_c) = \kappa I, \quad (18)$$

where $\kappa =$

$$\frac{{\phi_1}^2\rho^2 + \phi_1(f_d\phi_1 + f_c(\phi_1-2)(\lambda_c-1)-2)\rho + (f_c(\phi_1-1) - f_d\phi_1 + 1)(f_c(\lambda_c-1)+1)}{(f_c(\phi_1-1) - f_d\phi_1 + 1)(f_c(\lambda_c-1)+1) + \phi_1(f_d\phi_1 + f_c(\phi_1-1)(\lambda_c-1)-1)\rho}.$$

As in the previous cases, note that the maximum card fee does not depend on ϕ_2 and the pass through parameter for debit λ_d. The bank's problem is to maximize profits by setting fees for debit and credit cards. When merchants charge more for goods that are purchased by credit cards than debit cards, the bank's profit function is:

$$\Pi^B_{MH} = (\phi_1\alpha(f_d - c_d) + (1-\phi_1)\beta(f_c - c_c))(I - F_T) + \\ (\phi_1 + \phi_2)\, F_T - (1 - \phi_1 - \phi_2)\beta(I - F_T).$$

Under multihoming the bank can always replicate the debit card equilibrium by setting high credit card fees to drive these cards out. In particular, setting $f_c = 1 - \rho\phi_1$, $f_d = f^*_d$, $F_T = \bar{F}^*_D$, yields $\Pi^B_{MH} = \Pi^B_D$. Hence, given the exogenous parameters, in a multihoming equilibrium, the bank can never be worse off than in a debit card equilibrium.

Table 2: Comparison of outcomes

	high cost: $c_c = 0.017 > c_c^*$			low cost: $c_c = 0.015 < c_c^*$		
	Debit only	Credit only	Multi-homing	Debit only	Credit only	Multi-homing
f_d^*	0.006		0.006	0.006		0.006
f_c^*		0.023	0.024		0.021	0.023
α^*	0.592		0.592	0.592		0.592
β^*		0.390	0.325		0.449	0.392
p_d^*	1.003		1.003	1.003		1.003
p_c^*		1.011	1.012		1.011	1.011
Bank profits	51.46	52.00	52.13	51.46	74.51	52.51
Consumer revenue	124.24	217.09	315.84	124.24	259.38	355.12
Merchant revenue	100.44	262.23	104.42	100.44	282.79	104.89
Default loss	0.00	-232.24	-192.81	0.00	-267.24	-232.17
Processing cost	-173.22	-195.08	-175.32	-173.22	-200.43	-175.33

Note: Parameter values set to $c_d = 0.01$, $\rho = 0.99$, $\phi_1 = 0.98$, $\phi_2 = 0$, $\lambda_c = \lambda_d = 0.5$, and $I = 30000$.

Proposition 5 *All else being equal, optimal multihoming profits dominate optimal bank profits in the debit card equilibrium. That is,*

$$\Pi_{MH}(f_d^{**}, f_c^{**}) \geq \Pi_D^B(f_d^*).$$

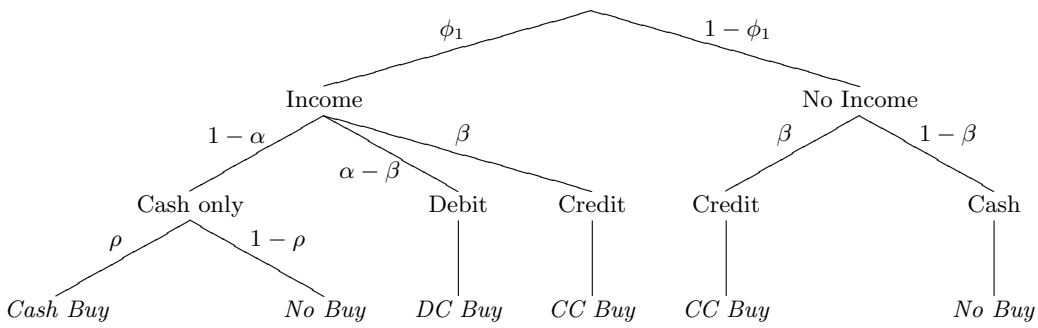
Note that credit card equilibria are not always dominated by multihoming ones. In other words, while "debit card only" equilibria are nested within the multihoming environment, "credit card only" equilibria are not.

There exists a $c_c' > c_d$ where optimal bank profits across debit cards and credit cards are the same, that is $\Pi_C^B(f_c^*) = \Pi_D^B(f_d^*)$ for $c_c = c_c'$. For $c_c \geq c_c'$, the debit card equilibrium yields higher bank profits. Since optimal multihoming profits are higher than optimal debit card profits, there must exist a $c_d \leq c_c^* \leq c_c'$ such that optimal multihoming bank profits just dominate both debit card only and credit card only profits. Hence, for $c_c \geq c_c^*$, the bank maximizes profits by issuing credit cards in addition to debit cards. On the other hand, for credit card processing cost c_c sufficiently close to c_d, a credit card only environment would be preferred by the bank, because the relatively high markup on credit cards would be profitable in all income states. The next proposition summarizes these findings. Table 2 illustrates both situations.

Proposition 6 *All else being equal, there exists a $c_c^* > c_d$ such that for $c_c > c_c^*$ optimal multihoming profits dominate optimal debit card and credit card profits when only one type of card exists. That is,*

$$\Pi_{MH}(f_d^{**}, f_c^{**}) \geq \max\left\{\Pi_D^B(f_d^*),\ \Pi_C^B(f_c^*)\right\}.$$

Figure 9: Probability tree for multihoming ($p_d = p_c$)



3.2 One-price

Now, let us consider merchants than can post only one price. Unlike before, prices for goods were uniform across merchants for a given payment instrument. When merchants post one price, we assume that their new one price is the average of the prices weighted by the probability that consumers would use each instrument that they accept. For example, if there is equal probability of a consumer using a debit card or a credit card, the uniform price would be:

$$p_u = .5p_d + .5p_c$$

In this economy, all credit card accepting merchants post the same price which is different from the uniform price of debit card accepting merchants. Cash-only merchants post price, p_m.

Let's assume that credit cards are preferred to debit cards when $p_d = p_c$ at merchants accepting both debit and credit cards.[21] In this case, $p_u = p_c$ for merchants that accept credit cards since all consumers would use their credit cards even though all consumers would be better off if consumers receiving income the morning used their debit cards because p_u would be lower. The corresponding event tree is shown in Figure 9. The consumer's participation constraint becomes:

$$\begin{aligned}&\phi_1\left[(1-\alpha)\rho(I-F_D) \;+\; \alpha(I-F_D)/p_d\right] \;\leq \\ &\phi_1\left[(1-\alpha)\rho(I-F_D-F_C)+(\alpha-\beta)(I-F_D-F_C)/p_d\right]+ \\ &\beta(I-F_D-F_C)/p_c]+(1-\phi_1)\beta(I-F_D-F_C)/p_c.\end{aligned} \tag{19}$$

If $p_d = p_c$ and all merchants accepting debit cards also accept credit cards, consumers would never choose to participate in both networks and not multihome. If there is a sufficient mass of merchants that do not accept credit cards, there may be an incentive to hold debit cards.

[21] We rule out the possiblity that $p_d > p_c$. However, there are examples of payment card prices being lower than cash, see Benoit (2002) and National Public Radio (2006).

The maximum total fee $\bar{F}_T$ under full multihoming when $p_d = p_c$ at merchants that accept debit and credit cards is given by:

$$\bar{F}_T = \frac{\beta(1-(p_c/p_d)\phi_1) + (p_c/p_d)\phi_1\alpha(1-p_d\rho)}{\beta(1-(p_c/p_d)\phi_1) + (p_c/p_d)\phi_1(\alpha(1-p_d\rho)+p_d\rho)} I. \tag{20}$$

Similar to the cases when merchants issued only one card, merchants choose to accept payment cards if by doing so their profits increase. A key feature of our model is the ability to set different prices based on the payment instrument used to purchase goods. However, there may be regulatory, contractual, and other reasons why we seldom see a menu of prices.[22] Now, we consider the two extreme cases where merchants can charge different prices and where they cannot. If merchants charge the same price regardless of the type of payment instrument used, bank profits become:

$$\begin{aligned}\Pi^B_{MH_{OP}} = &(\phi_1(\alpha-\beta)(f_d-c_d)+\beta(f_c-c_c))(I-F_T)+\\ &(\phi_1+\phi_2)\,F_T-(1-\phi_1-\phi_2)\beta(I-F_T).\end{aligned}$$

Proposition 7 *When merchants set one price regardless of the type of instrument used, the bank earns greater profits if revenue from credit cards are higher than debit cards and the default risk is sufficiently low than when merchants steer consumers through price incentives.*

4 Extensions

Given the current complexity of the model, we have left out key features of the payment card market. First, we have not considered long-term credit. Such an extension would require a multi-period model. Second, competition among banks in the provision of services could put downward pressure on prices. Others have found that competition would occur on the consumer side and put upward pressure on merchant fees. Third, we assume that all consumers multihome. In reality, not all consumers multihome and the uniform price may not be equal to the price of the most expensive instrument for the merchant to accept. We leave these extensions for future research.

5 Conclusion

We construct a model of payment instruments where consumers and merchants benefit from greater consumption and sales that arise from transactions that would not occur in a cash-only economy. We incorporate insurance motives into the payments context that are well established in the banking literature for why financial institutions play a critical role in the economy. We derive the

[22] See Chakravorti and Shah (2003), Barron, Staten, and Umbeck (1992), IMA Market Development (2000), and Katz (2001) for more discussion about merchant pricing based on payment instrument.

equilibrium fees from parameter values that support debit and credit cards. In our model, the bank will fully extract from consumers before capturing surplus from merchants assuming they are not able to fully pass on payment processing costs in terms of higher prices to consumers. In other words, merchants pay for payment services when the bank cost to operate the system is sufficiently high, merchants are unable to pass on all costs, or consumer credit risk is too high.

Furthermore, we study consumer and merchant multihoming where consumers and merchants participate in multiple payment networks. Differences in merchant acceptance across payment instruments and prices along with insurance against theft and no income states determine when consumers carry multiple payment instruments. When both types of payment instruments are available, merchants would prefer the ability to separate liquid consumers from illiquid ones whereas the bank may have incentives to entice all consumers to use their credit cards in stores that accept both types of cards.

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