On the Level and Incidence of Interchange Fees Charged by Competing Payment Networks*

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Abstract

We develop a two-sided model of the payment card market, featuring novel elements, such as detailed demand, merchant competition, and competing networks with ad valorem pricing for interchange fees and rewards. The fees and rewards determine taxes, imposed by the network for credit card and cash users, which create a wedge between the price consumers pay and the price merchants receive. We are examining the effect of product market and network competition on these taxes. We highlight the "elasticity effect", related to demand subconvexity, and the "competition effect". Enhanced network competition, when networks are differentiated and so the elasticity effect dominates, leads to higher credit card taxes and merchant prices, reducing welfare. Conversely, with minimal differentiation, intense competition for cardholders, due to stronger network competition, lowers the tax and enhances welfare.

Keywords: credit cards, debit cards, two sided networks, interchange fees, antitrust

JEL codes: L13, L40, G28, E42

PRELIMINARY AND INCOMPLETE

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1 Introduction

This paper examines the level and incidence of a wholesale price-the interchange fee-typically set by a payment card network that influences the distribution of acceptance costs and benefits incurred by merchants and consumers. Interchange fees have been controversial for half a century, ever since the credit card networks, now known as Visa and MasterCard, began to dominate purchases at the point-of-sale in the early 1970s.

One of the complications in understanding the role and consequences of interchange fees is the consensus among economists that payments represent a classic example of a two-sided market that is intermediated by a platform-the payment card network. As such, the adoption and pricing decisions that affect one side of the market (cardholders) affect the comparable decisions made by participants (merchants) on the other side of the market. Competition and welfare implications in these markets can be very different than in the traditional markets studied by economists. Over the last three decades, an extensive theoretical literature on two-sided markets has emerged and many of those papers examine the implications for payment systems.[1]

In this paper, we explore the level, incidence, and welfare implications of interchange fees using a new model that accommodates varying degrees of competition among both payment networks and merchants. Why develop a new model? We believe several critical aspects of the issue are not sufficiently addressed in the existing literature. Our approach aims to fill these gaps. We will illustrate our points with several observations.

First, the literature on networks and two-sided markets has rightly focused on the chicken-and-egg problem associated with establishing a successful payment network amidst a host of adoption externalities and coordination problems. Success has often required that users on one side of the network be subsidized at the expense, at least relatively so, of users on the other side. Once widespread adoption and coordination is established, however, those same phenomenon may lock-in an equilibrium with one or a few payment networks that are both durable and difficult to displace. It is when networks are well established that concerns about antitrust, inequality, and welfare losses emerge. For example, a major theme of the current policy debate in the United States is the extent to which networks raise interchange fees paid by merchants to cover the costs of increasing rewards (e.g., cash back or air miles) paid to cardholders. This, in turn, raises questions about welfare and inequality.

The models that are well suited for studying the emergence and adoption of a network in a two-sided market are less well suited for understanding the questions policy makers face when confronting an equilibrium with established networks. This is because most of the models developed hitherto abstract away from important elements we observe in the real world payments market.

For simplicity, the prevailing literature often assumes that consumer decisions are binary: individuals

[1] See Rochet and Tirole (2006), Rysman (2009) and Jullien, Pavan, and Rysman (2021) for reviews of this literature.

either make a purchase or they do not, with the purchased quantity being predetermined. The model's extensive margin arises from less urgent consumers who buy only when prices drop sufficiently, yet they too purchase the predetermined quantity. In scenarios where demand is elastic, a constant elasticity is assumed and this assumption rules out a host of potentially empirically relevant outcomes. Moreover, there is typically no explicit connection between the product and payment markets in the literature; for instance, the prices paid by consumers are usually not influenced directly by the rewards card users gain from transactions.

At the same time, in most of the literature, the fees charged to enable payments are specific, i.e., an absolute fee. Ad valorem pricing is rarely studied even-though it is the dominant component of interchange fees and consumer rewards set by payment card networks.[2] And we know from the public economics literature that the implications of specific vs. ad valorem taxes are usually different. In addition, the implications of ad valorem pricing cannot be thoroughly examined in models of inelastic individual demand.

Similarly, while the market structure and nature of competition among banks and networks are modeled with detail and variation in the literature, the nature of competition and the extent of market power in the retail sector is relatively undeveloped. The combination of these assumptions in much of the literature limits the kinds of welfare statements that can be made about interchange fees using these models. To address these limitations, we propose a different approach that follows from the literature on tax incidence. We can establish several general results. However, because we move away from several of the simplifying assumptions described above, some of the additional results are established using examples and numerical simulations. We believe those results can be generalized with additional work.

We parameterize the retail sector in three dimensions: the number of firms (n), the elasticity of demand (ε), and the conjectural variation (λ) retailers use when interpreting how their competitors will respond to their pricing decisions. The number of retailers and the conjectural variation combined determine the conduct parameter (γ) that describes the amount of competition in the final goods market; on the one extreme $\gamma = 0$ means perfect competition (Bertrand), while on the other extreme $\gamma = 1$ implies a monopoly or a perfect cartel. This set-up permits us to understand more generally how consumer preferences (as captured by the shape of the demand function) and merchant competition endogenously determine retail prices. Interchange fees and the consumer response to rewards affect consumer demand which, in turn, affects retail prices.

The baseline model establishes an equilibrium where aggregate demand and merchant profits are influenced by what we term "credit card taxes." These taxes create a wedge between the price consumers pay-depending on whether they use cash or credit-and the price merchants receive for each unit

[2] Shy and Wang (2011), along with Wang and Wright (2017) and Wang and Wright (2018), consider models with ad valorem pricing. However, they either assume demand with constant elasticity or model merchant competition as Bertrand. These assumptions result in perfect tax pass-through to consumers, potentially limiting the applicability of any derived policy insights.

of the final good. The difference between these two prices represents the network revenue per dollar of transactions. The amount of credit card taxes is positively correlated with the interchange fee paid by merchants and the tax credit card users pay is negatively correlated with the relative generosity of cardholder rewards. These taxes emerge naturally when we link the product market with network fees and rewards.

A standard result follows from demand and taxation theory: if there is perfect competition in the retail market or demand is of the constant elasticity form, then there is perfect pass through of any credit card tax to cardholders. In other words, the incidence of any markup resulting from using payment cards is borne entirely by consumers. Further, the more intense the competition in the retail sector (lower γ), the higher will be consumer surplus and the profits earned by the payment network. This follows from (1) the greater aggregate consumption that occurs when the goods market is more competitive and (2) the use of ad valorem pricing by the network. In addition, reliance on ad valorem pricing for interchange and rewards makes the network sensitive to the effects of the credit card tax on aggregate demand. This is an important element of the implications that follow.

If the price elasticity is not constant, then merchants do not raise prices one-for-one as the credit card taxes rise-so long as competition is not perfect (i.e., $\gamma > 0$). The tax incidence depends on the sign of the derivative of the demand elasticity with respect to aggregate output, which affects what we term *the elasticity effect*. If the sign is positive, i.e., market demand becomes more elastic when aggregate output falls (equivalently, subconvex demand, e.g., Mrázová and Neary (2017), Mrázová and Neary (2019)), then the incidence of any credit card tax is borne by merchants and consumers. More intense competition in the product market increases the credit card tax and the fraction of the tax that is borne by consumers. If, on the other hand, the sign is negative, i.e., market demand becomes less elastic when aggregate output falls (equivalently, superconvex demand, e.g., Mrázová and Neary (2017), Mrázová and Neary (2019)), then there is credit card tax over-shifting: consumers may pay more than 100% of the tax. More intense competition in the product market decreases the credit card tax and the fraction of the tax that is borne by consumers.

Next, we allow for competition between two differentiated payment networks. This permits us to explore the complicated question of whether network competition raises costs by competing for cardholders via more generous rewards, (see Guthrie and Wright (2007) for an example; for a general discussion, see Hayashi et al. (2009)). First, consider the case of a second payment network establishing a "toehold" in the market. This has the effect of reducing the aggregate demand of consumers that use the incumbent card brand. If market demand becomes more elastic when aggregate output decreases (subconvex demand), then the incumbent network responds by increasing its credit card tax. This is the elasticity effect and it can be understood in more detail as follows. A higher tax reduces aggregate output, and if market demand becomes more elastic merchants lower the price they charge resulting in losses for the network, due to lower total value of transactions. When the incumbent network has a lower market share, due to entry of a second network, the effect of the incumbent's higher tax on aggregate output is smaller and this, in turn, diminishes the negative impact of the elasticity effect. Hence, the incumbent is less reluctant to increase its tax, which leads to a higher tax.

However, when we endogenize payment network competition for cardholders the results can change. We do this using a Hotelling model, which allows us to parameterize the extent of network differentiation. Because we assume there are no fixed costs of adoption for retailers, so long as merchants cannot price discriminate (i.e. steer) with respect to the brand of payment card presented, in equilibrium merchants will multi-home in card acceptance. Consumers, in turn, have no incentive to multi-home.[3]

Relative to a monopoly network, we find that in the case of constant elasticity demand or Bertrand competition in the product market the presence of a second network lowers the credit card tax, increases merchant profits, raises consumer surplus and reduces the incidence of the tax paid by consumers. The effect of network competition for cardholders (what we call *the competition effect*) is at work since the elasticity effect is absent when the elasticity is constant or competition is Bertrand. However, when competition in the product market is imperfect and the elasticity of demand is not constant, the elasticity effect appears. As the payment networks become more differentiated, the competition effect is attenuated, reducing the extent of competition for cardholders. With sufficient network differentiation, the elasticity effect dominates, so entry of a second network increases the credit card tax and the product price consumers pay and reduces welfare. The elasticity effect can be easily overlooked, as it has been the case in the two-sided market literature, if the analysis is based on oversimplified assumptions regarding the product market and consumer demand.

This finding has important policy implications regarding the effect of network competition and its interaction with product market competition on prices and welfare. Consider, for instance, the recent proposed merger between Capital One and Discover. This is a case of two banks who use different networks to clear and settle credit card transactions that might combine and use one network. This, in turn, would alter the market shares of the dominant credit card networks. What is the effect of such a merger on the credit card tax and hence on prices consumers pay? Our theory suggests that, even in the absence of economies of scale, the credit card tax and hence merchant prices can go up or down as a result of changes in network competition. Key factors are how differentiated will networks be in the new equilibrium and the shape of product demand.

The remainder of this paper is organized as follows. Section 2 provides a brief overview of the literature; it is not intended to be comprehensive. Section 3 lays out the fundamental structure of the model, while Section 4 analyzes merchant competition and equilibrium with a monopoly network and a fixed number of cardholders and cash users. Section 5 extends the previous section by endogenizing the number of cardholders and cash users. Section 6 extends section 5 by allowing a second network to enter the market to examine the effect of network competition. Section 7 concludes and presents a number of policy implications.

[3] In the text we discuss the implications for merchant surcharging - a form of steering - on equilibrium outcomes.

2 Literature review

The literature on two-sided markets, especially as applied to payment systems is voluminous, spanning over four decades. Our purpose here is simply to sketch the main findings and highlight our contributions.

Baxter (1983) developed the first formal model of interchange fees in a payment scheme. In that paper, Baxter makes three key assumptions: i) Issuers and acquirers make no profit (perfect competition), ii) Merchants do not use card acceptance strategically, i.e., to attract consumers from rival merchants who do not accept a card and iii) there is no merchant heterogeneity in the benefit of accepting cards. Schmalensee (2002) develops a model that explores the double marginalization problem that emerges when networks set an interchange fee that is paid to card issuers and the acquiring bank for the merchant separately sets a merchant discount for processing transactions.

Rochet and Tirole (2006) offers a definition of a two-sided market: *A two-sided market is one in which the volume of transactions between end-users depends on the structure and not only on the overall level of the fees charged.* This can be contrasted with Rysman (2009), where he draws a parallel to the literature on network effects in which demand for a given good depends on the supply of a complementary good.

In Rochet and Tirole (2002), the consumers receive a different benefit from transacting using cards rather than paying cash. There is a single payment network that sets an interchange fee, but it is not ad valorem. The retail market is a Hotelling model, but consumers face the choice of purchasing a fixed quantity of their preferred good. Rochet and Tirole (2011) develop a similar model, but here there is competition between networks modelled using the Hotelling framework. Wright (2004) uses a model similar to Rochet and Tirole (2002) and relaxes all three assumptions of Baxter (1983). Bedre-Defolie and Calvano (2013) show that networks oversubsidize card usage and overtax merchants.

A paper that employs assumptions closer to ours is Shy and Wang (2011). They adopt a constant elasticity demand and compare "proportional" versus "fixed" transaction fees in a model where both merchants and a monopoly payment network enjoy market power. Consumers and networks fare better under proportional fees, while merchants fare worse. The less competitive the retail market, the greater the benefit to the network of charging proportional rather than fixed fees. Our paper introduces the following novelties relative to Shy and Wang (2011): (i) cash as an alternative mode of payment, (ii) product demands that deviate from constant elasticity and iii) competition between two networks. These innovations introduce more realistic and less restrictive elements into the model, allowing us to derive new and more plausible predictions.

Guthrie and Wright (2007) show that network competition can increase the interchange fees. This result is reminiscent of our result, where entry of a network can increase the credit card tax. However, the two results are qualitatively different and result from different underlying factors. In Guthrie and Wright (2007) network entry can induce networks to compete more vigorously on the rewards they offer to users and to compensate their profits they also increase the interchange fees. To put differently, while entry can increase the interchange fee it need not increase the overall credit card tax. In contrast, in our model network competition can increase the credit card tax.

The prevailing methodology in the majority of the above papers is twofold: (1) it posits that consumer choice is binary–either purchasing a single unit or none at all, and (2) it considers fees that are specific rather than ad valorem. While these simplifications are made to facilitate analysis, they diverge significantly from real-world observations. Furthermore, there is a common presumption that the benefits and costs experienced by both parties-merchants and consumers-due to card usage are independent of each other and of the product price.

Our study seeks to bridge this gap by offering a more generalized approach, albeit at the expense of some analytical simplicity.

In related work, Wang and Wright (2017, 2018) assume Bertrand competition among sellers in a market with many different goods that vary widely in their costs and values. By assumption there is perfect pass through of any taxes to buyers. The authors show that ad valorem fees and taxes represent an efficient form of price discrimination relative to uniform fees that disadvantage low-cost, low-value goods. Wang (2023) develops a structural approach to a two-sided market of payments. He finds that interchange fee caps increase welfare by reducing rewards, retail prices, and credit card use. In the absence of regulation, because consumers are reward-sensitive, but merchants are fee-insensitive, entry of private credit card network raises rewards without cutting fees, lowering welfare.

Edelman and Wright (2015) shows that an intermediary always chooses to impose price coherence if it has the ability to do so. Doing so increases its profit even though it leads to excessive intermediation, excessive investment in buyer-side benefits, and indeed harms buyers, making them worse off in aggregate compared to the case without any intermediation. They show these effects persist and even grow when multiple intermediaries compete. Such outcomes can be overcome if merchants have a means of steering consumers to a preferred network or form of payment (e.g. surcharging). An important qualification is that the fees examined are not ad valorem.

There is a growing body of literature that employs two-sided market models to study competition in digital markets, such as Jeon and Rey (2022) and Bisceglia and Tirole (2023). A significant concern in these markets is the high commissions charged by platforms, like Apple's App Store and Google's Play Store, to app developers. Jeon and Rey (2022) demonstrate that competition between platforms exacerbates rather than alleviates high commission fees. While this result is similar to ours in its implications, the underlying mechanism and model differ significantly.

Our elasticity effect is related to the shape of the demand function and in particular whether it is superconvex or subconvex. Mrázová and Neary (2019) define a demand function as superconvex if $\log p$ is convex in $\log x$. This is equivalent to the demand function being more convex than a constant elasticity CES demand function, and to one whose (absolute) elasticity of demand is increasing in output. Subconvexity is equivalent to the demand becoming less elastic as output increases. Super- or subconvexity determine competition effects and relative pass-through. We quote from Mrázová and Neary (2017) on page 3840: "Hence, if globalization reduces incumbent firms' sales in their home markets, it is associated with a higher elasticity and so a lower markup if and only if demand is subconvex." Rephrasing the quote: entry in the product market increases mark-ups if and only if demand is superconvex. Superconvexity also implies a more than 100% pass-through, which has implications in our analysis for the credit card tax incidence. Subconvexity (which encompasses the linear demand) is sometimes called "Marshall's Second Law of Demand", but superconvexity cannot be ruled out either theoretically or empirically (for more details see the discussion in footnote 10 in Mrázová and Neary (2017)).

Our analysis uses the concepts of subconvexity and superconvexity to examine how changes in competition at the network level, and its interaction with the product market structure, affect the credit card tax and its incidence. We show that more intense network competition can *increase* the credit card tax when demand is subconvex, whereas under subconvexity any potential strengthening of competition in the product market *lowers* merchant mark-ups. This difference underscores the nuanced impact of the structure of preferences and demand on competition in two-sided and vertically related markets.

3 Structure of the market

We consider an industry consisting of n firms (merchants), $j = 1, ..., n$, producing a single homogeneous product. The output of firm j is denoted by x_j and the industry output by $X = \sum_{j=1}^{n} x_j$. All the merchants have the same cost structure $C(x) = cx$, where $c > 0$ is a constant marginal cost. The consumer price is given by an inverse demand function $P(X)$, with derivative $P_X(X) < 0$ and elasticity $\varepsilon \equiv \frac{P}{XP_X} < 0$.

Consumers, when purchasing goods, use either cash or a credit card. There are two competing credit card networks, indexed by $l = 1, 2$.

More specifically, in a given network, there are $N_A < n$ acquiring and $N_I < n$ issuing banks, that are homogeneous and compete à la Bertrand for merchants and cardholders. We assume that networks do not compete to attract banks; the assignment of banks to networks is exogenously determined. In Figure 1, we present the payment flows in one network. Each acquiring bank α in network l chooses its merchant discount m_l^{α} to attract merchants and each issuing bank ι in network l chooses the reward $R_l^{\iota} \in [\underline{r}, 1]$ to attract users/consumers and to influence the value of consumer transactions. If $R_i^{\iota} < 0$, then the reward becomes a fee. A network chooses the interchange fee, $i_l \in [0, \bar{i}]$, which becomes each acquirer's marginal cost. We assume that $\underline{r} < 0$ and $\bar{i} > 0$ are exogenous bounds or caps imposed by regulation that these fees cannot exceed. Part of i_l, denoted by r_l, goes to the issuing banks to fund the rewards and the rest is kept by the network. For simplicity, all other costs to process a transaction are assumed to be zero.

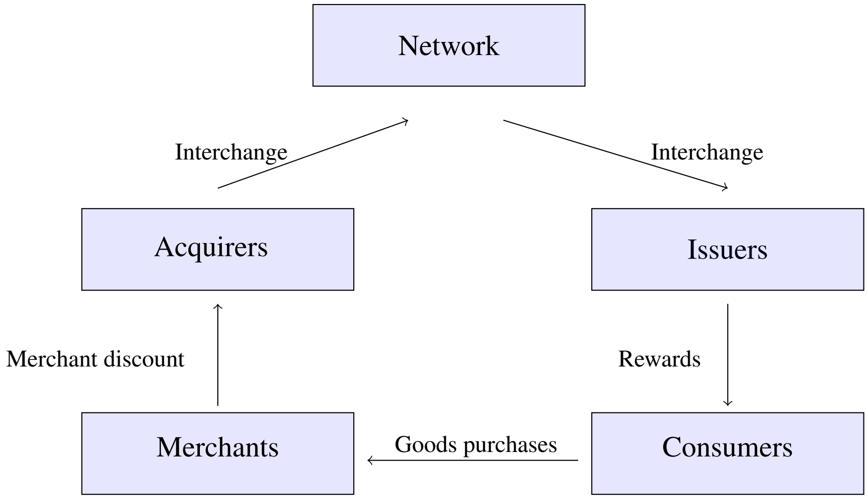

Figure 1: Payment flows in a Network

The reward for credit card l is a percent of the value of the transaction that a consumer who uses credit card l receives as a cash back from the issuing bank. The acquiring bank charges a merchant discount fee which is a percent of the value of the transaction that is paid by the merchant to the acquiring bank when a consumer uses credit card l. We assume that a network cannot price discriminate across banks, i.e., all acquirers pay the same interchange fee to the network and all issuers receive the same fraction of the interchange fee from the network.

Consumers have horizontal preferences between cash and the two credit cards (more details on this later). Network fees influence the value of transactions within a network and can attract users from the rival network or cash. Each onsumer incurs a small cost, ϵ, if he multi-homes, i.e., holds a second credit card. We assume that merchants cannot surcharge, meaning they cannot price discriminate based on the mode of payment.

We analyze a four-stage game with simultaneous and independent moves in each stage. In stage 1, networks set their interchange fees, i_l, and choose how much of the interchange fee, r_l, will be given to each issuing bank. In stage 2, each acquiring bank sets the merchant discount m_l^α and each issuing bank sets the reward, R_l^ι. In stage 3, each merchant chooses whether to accept both credit cards or only one and its product quantity. All merchants accept cash. In stage 4, each consumer chooses whether to hold one or both credit cards and makes purchases. We will look for a subgame-perfect Nash equilibrium in pure strategies.

4 Analysis with a monopoly network and a fixed number of users

To better grasp the forces of network competition, we begin the analysis by assuming the existence of a monopoly network, denoted by 1 and a fixed fraction of cardholders and cash users. More precisely, suppose a fixed fraction μ of (a unit mass) consumers uses the credit card and the remaining fraction, $1-\mu$, uses cash. Since the number of users in this section are fixed, the results we derive are preliminary. Nevertheless, they allows us to disentangle the various effects of competition when we later, in Section 5, endogenize the number of users. In Section 6, we introduce a second network and an endogenous number of cardholders and cash users.

Acquiring banks compete in merchant fees m_1^α. The network interchange fee i_1 is each acquiring bank's marginal cost. Given that acquiring banks are homogeneous and compete for merchants à la Bertrand each acquiring bank sets the same merchant discount $m_1^\alpha = i_1$, for all α. Acquiring banks earn zero profits in equilibrium.

Issuing banks compete in rewards R_1^ι. Each issuing bank receives from the network part of the interchange fee $r_1 < i_1$. This is the maximum amount, per dollar of transactions, that each issuing bank can give to users as a reward. (If $r_1 < 0$ then issuing banks pay the network a fee.) Given that issuing banks are homogeneous and compete à la Bertrand for users each issuing bank sets the same reward $R_1^\iota = r_1$, for all ι. Issuing banks earn zero profits in equilibrium.

Therefore, in the unique equilibrium, for credit card transactions each merchant pays a merchant discount i_1 and each consumer receives a reward r_1.

4.1 Merchant competition

Let x_1 be the individual consumer consumption using the credit card and x_{ch} the individual consumer consumption using cash. Aggregate output consists of the output purchased with credit, $X_1 = \mu x_1$ and output purchased with cash, $X_{ch} = (1-\mu)x_{ch}$, with $X = X_1 + X_{ch}$. We assume no surcharging, so consumers pay the same price (before applying any rewards) regardless of the payment mode. If P is the price merchants charge, consumers who make purchases with the credit card pay $P \cdot (1-r_1)$, while consumers who use cash pay P.[4] Thus, the inverse demand is also a function of the reward, $P(X, r_1, \mu)$.[5]

We assume that for each merchant j, a fraction μ of its sales are paid with a credit card, while a

[4] We use $\cdot$ to distinguish between multiplication, i.e., $P \cdot (1-i)$, and a function $P(X)$, when the two are not immediately distinguishable from the context.

[5] Consider the following two examples. There are two goods, x and a numeraire good y whose price is normalized to one. If each consumer has the following quasi-linear utility $U = \frac{kx(1/x)^{1/k}}{k-1} + y$, with $k > 1$, then the inverse aggregate demand is of the constant elasticity type and is given by

$$P(X, r_1, \mu) = \left(\frac{1}{X}\right)^{1/k} \left(\frac{\mu}{(1-r_1)^k} + 1 - \mu\right)^{1/k}. \tag{4.1}$$

fraction $1-\mu$ are paid with cash. In equilibrium, all merchants accept the credit card. If a merchant deviates by accepting only cash, it will lose all consumers who prefer to pay with a credit card, given that merchants sell homogeneous products. Clearly, such a deviation is unprofitable.

Each merchant takes the rewards and the interchange fees as given and chooses its output x_j to maximize (average) profits given by

$$\begin{aligned}\pi_j &= (\mu\cdot(1-i_1)P(X,r_1,\mu)+(1-\mu)P(X,r_1,\mu))x_j - cx_j \\ &= (1-\mu i_1)P(X,r_1,\mu)x_j - cx_j.\end{aligned}$$

In selecting its output each merchant j conjectures that other merchants' responses will be such that $\frac{dX}{dx_j}=\lambda$, the conjectural variation λ being taken as a fixed constant throughout. The case $\lambda=1$ corresponds to the Cournot conjecture. When $\lambda=0$, conjectures are 'competitive' and we obtain the Bertrand outcome. When $\lambda=n$, each firm believes that all other active firms will behave exactly as it does; tacit collusion among incumbent firms then being perfect (in the sense that aggregate profits are maximized conditional on the number of firms). It will be assumed throughout that $\lambda\in[0,n]$.[6]

The first order condition of the representative merchant is (omitting arguments)

$$\frac{\partial\pi_j}{\partial x_j}=(1-\mu i_1)\left(P_X\frac{dX}{dx_j}x_j+P\right)-c=0. \tag{4.3}$$

Restricting attention to symmetric equilibria, this becomes

$$\begin{aligned}(1-\mu i_1)\left(P_X X\gamma+P\right)=c \quad &\Rightarrow \quad P\cdot\left(1+\frac{\gamma}{\varepsilon}\right)=\frac{1}{(1-\mu i_1)} \\ &\Rightarrow \quad P=\frac{c}{\left(1+\frac{\gamma}{\varepsilon}\right)}\frac{1}{(1-\mu i_1)},\end{aligned} \tag{4.4}$$

where $\gamma\equiv\frac{\lambda}{n}\in[0,1]$.[7] As $\frac{\gamma}{\varepsilon}<0$ increases, the merchant market becomes more competitive (either because the conduct parameter γ decreases, or because the market demand becomes more elastic) and price approaches marginal cost c (adjusted by the $1-\mu i_1$). A lower interchange fee has the same effect on price as a reduction in a merchant's marginal cost.

Or, when $U=x-x^2/2$, the inverse aggregate demand is linear is given by

$$P(X,r_1,\mu)=\begin{cases}\frac{\mu-X}{\mu(1-r_1)}, & \text{if } P\in\left[1,\frac{1}{1-r_1}\right) \\ \frac{1-X}{\mu(1-r_1)+1-\mu}, & \text{if } P<1.\end{cases} \tag{4.2}$$

[6]See Seade (1980), Bresnahan (1981) and Delipalla and Keen (1992) for similar modeling frameworks.
[7]Note that γ is similar to the conduct parameter θ in Weyl and Fabinger (2013).

Let

$$E \equiv -\frac{P_{XX}X}{P_X} \tag{4.5}$$

denote the elasticity of the slope of inverse demand. In addition, ε' is the derivative of ε with respect to X. The second order condition is $2 - \gamma E > 0$. The stability condition requires that $1 + \gamma \cdot (1 - E) > 0$ (see, for example, Seade (1980) and Delipalla and Keen (1992)). Since $2 - \gamma E > 1 + \gamma \cdot (1 - E)$, the stability condition (which we assume is satisfied) is stronger than the second order condition. From the first-order condition (4.4), a non-negative price-cost margin implies that the elasticity must satisfy $\gamma + \varepsilon < 0$. Therefore, ε and E must fall in the admissible region $\varepsilon < -\gamma$ and $E < \frac{2}{\gamma}$, see also Figure 1 in Mrázová and Neary (2017).[8]

From (4.4), it follows that the (average) price merchants receive, P^m, is $(1 - \mu i_1)P$. It is instructive at this juncture to introduce the expressions for the tax consumers pay due to the credit card. The tax credit card users pay is $z_1 = \frac{1-r_1}{1-\mu i_1}$, making the price they pay $P^{b_1} = z_1 P^m$. The tax cash users pay is $z_{ch} = \frac{1}{1-\mu i_1}$, making the price they pay $P^{b_{ch}} = z_{ch} P^m$. A higher interchange fee increases the tax for all consumers, while a higher reward lowers it for the consumers who use the credit card.

As it will become more apparent soon, the reward and interchange fee affect aggregate output X and hence the merchants' first order conditions, (4.4). More specifically, X appears both on the LHS of (4.4) and on the RHS through the elasticity ε. It then follows that the (average) price merchants receive, $P \cdot (1 - \mu i_1)$, is not a function of aggregate output if competition in the product market is Bertrand, $\gamma = 0$, or the elasticity is constant. The credit card tax in these cases is passed on 100% to consumers. In all other cases, the price merchants receive is affected by the interchange fee and the reward.

Efficiency dictates that $P = c$. We can have $P > c$ either because $\frac{\gamma}{\varepsilon} < 0$, or $i_1 > 0$, or both. The first source of inefficiency arises when competition in the merchant market is imperfect ($\gamma > 0$). Also note that the effect of the elasticity on P becomes stronger as the merchant market becomes less competitive, i.e., γ increases. The second source of inefficiency is due to the credit card tax levied by the payment network. Since $i_1 > 0$ (otherwise network profit cannot be positive), there is a double-marginalization: the first mark-up is from the merchants when they have market power and the second mark-up is from the payment network (that have market power). A key issue we address with our analysis is how the distortions from the network side of the market interact with the distortions from the merchant side of the market.

The credit card taxes z_1 and z_{ch} are ad valorem taxes that create a wedge between the prices consumers pay and the price merchants receive. Hence, some of the results we derive, in particular the ones regarding credit card tax pass-through and incidence, are well-known in the public economics literature, e.g., Delipalla and Keen (1992) and Auerbach and Hines Jr (2002).

[8]In Mrázová and Neary (2017) the elasticity of the slope of the inverse demand is denoted by ρ and the elasticity ε is a positive number.

4.2 Network's decisions

The network profit consists of the interchange fee minus the rewards to consumers (both in percentages) times the total value of transactions in the market from consumers who make purchases with the credit card, $(i_1 - r_1)PX_1(i_1, r_1)$, where $X_1 = \mu x_1(i_1, r_1)$. Using (4.4), the network profit can be expressed as follows

$$\pi_1(i_1, r_1) = \frac{c\mu \cdot (i_1 - r_1)}{\left(1 + \frac{\gamma}{\varepsilon(\mu x_1(i_1,r_1)+(1-\mu)x_{ch}(i_1,r_1))}\right)(1 - \mu i_1)} x_1(i_1, r_1). \tag{4.6}$$

It will be more revealing if, using the credit card taxes $z_1 = \frac{1-r_1}{1-\mu i_1}$ and $z_{ch} = \frac{1}{1-\mu i_1}$, we express (4.6) as an explicit function of these taxes

$$\pi_1(z_1, z_{ch}) = \frac{c \cdot (\mu z_1 + (1 - \mu)z_{ch}) - 1)}{\left(1 + \frac{\gamma}{\varepsilon(\mu x_1(z_1)+(1-\mu)x_{ch}(z_{ch}))}\right)} x_1(z_1). \tag{4.7}$$

The network chooses z_1 and z_{ch} to maximize $\pi_1(z_1, z_{ch})$. For example, network can increase z_{ch} by increasing the interchange fee i_1 and it can keep z_1 fixed by simultaneously increasing the reward r_1. Note that the weighted average tax affects network profits and if $z_{ch} > 1$ (because $i_1 > 0$) the network can subsidize credit card users by choosing $z_1 < 1$ and still make positive profits $(\mu z_1 + (1-\mu)z_{ch} > 1)$.

The effect of the credit card tax for cash users on network profits is given by

$$\frac{\partial \pi_1}{\partial z_{ch}} = \frac{((\mu z_1 + (1 - \mu)z_{ch} - 1)\gamma\varepsilon' \frac{\partial X_{ch}}{\partial z_{ch}} + \varepsilon(\varepsilon + \gamma)(1 - \mu))c\mu x_1}{(\varepsilon + \gamma)^2}. \tag{4.8}$$

Given that $\frac{\partial X_{ch}}{\partial z_{ch}} < 0$ (see A.1), if $\varepsilon' < 0$ then $\frac{\partial \pi_1}{\partial z_{ch}} > 0$. In this case the network finds it profitable to increase the tax to cash users 'as much as possible'. The optimal interchange fee in this case is corner $i_1^* = \bar{i}$. A higher z_{ch} has two effects on network profits. A direct effect that is due to the fact that a higher z_{ch} induces merchants to increase the price they charge which, given the ad valorem nature of the taxes, also increases the network's revenue. An indirect effect that works through the demand elasticity: a higher z_{ch} lowers the output purchased with cash and decreases the elasticity of demand, if $\varepsilon' < 0$. This induces merchants to increase the price they charge, which increases the profit of the network (again, due to the ad valorem nature of the tax). If $\varepsilon' > 0$, on the other hand, the two effects described above are opposing and hence the sign of $\frac{\partial \pi_1}{\partial z_{ch}}$ is ambiguous, even with a fixed μ.

The effect of tax on credit card users, z_1, has the the same two effects on network profits we described above plus a negative effect through the reduction of x_1.

Therefore, the analysis so far has revealed that the shape of the demand, as represented by the sign of ε', plays a crucial role in determining the equilibrium taxes. Additionally, as will soon become apparent, it also influences the impact of merchant and network competition on these equilibrium taxes. It can be verified that

$$\varepsilon' = \frac{1}{X}\left(1 - \varepsilon \cdot (1 - E)\right), \tag{4.9}$$

so $\varepsilon' > 0 \Leftrightarrow \varepsilon < \frac{1}{1-E}$.[9] The locus $\varepsilon = \frac{1}{1-E}$ is an increasing and concave function in the admissible region ($\varepsilon < -\gamma$ and $E < \frac{2}{\gamma}$). This is the SC curve in Figures 2-4 in Mrázová and Neary (2017), which determines whether a demand is superconvex or subconvex.[10] Any point above the locus corresponds to $\varepsilon' > 0$, or subconvex demand, while any point below the locus to $\varepsilon' < 0$, or superconvex demand.[11]

4.3 Specific demands

Given the complicated nature of the problem, even before we introduce network competition, we utilize specific functional forms of demand functions in order to shed more light on how the merchant market structure interacts with the network structure in affecting the equilibrium variables and price distortions.

Recall that the parameter $\gamma \equiv \frac{\lambda}{n} \in [0, 1]$ measures the competitiveness of the merchant market either due to the mode of competition or the number of merchants. The value of $\gamma = 0$ corresponds to Bertrand competition, while $\gamma = 1$ corresponds to a monopoly merchant or to n merchants who have formed a perfect cartel; $\gamma = \frac{1}{2}$ can correspond to Cournot competition, $\lambda = 1$, between two merchants $n = 2$, and so on. Hence, as γ increases the product market becomes less competitive. In Table 1 we list the signs of the various parameters for the demand functions we use in the analysis that follows.

Types of demand functions	ε	E	ε'
Constant elasticity	$-$	$+$	0
Linear	$-$	0	$+$
Generalized Pareto	$-$	$-, 0, +$	$-, 0, +$

Table 1: The demand and inverse demand slope elasticities and how they change with aggregate output for the three types demands we use in the examples

The elasticity, ε, is always negative and it can be constant, increasing or decreasing in aggregate output. How aggregate output affects the elasticity, ε', will be very important for the subsequent analysis as it determines the sign of the elasticity effect that will be introduced shortly. The Generalized Pareto demand is quite flexible as it allows for ε' to take on any sign, i.e., demand can be either superconvex or subconvex. The elasticity of the slope of the inverse demand, E, can be zero, positive or negative. All

[9] Mrázová and Neary (2017) introduce the concept of a 'demand manifold' and show that, for all demand functions–other than the CES–that satisfy some mild conditions, the manifold is represented by a smooth curve in the (ε, E) space. The usefulness of this result lies in demonstrating that knowing the values of elasticity and convexity of demand a firm faces is sufficient to predict its responses to a wide range of exogenous shocks, such as changes in taxes.

[10] The SC curve is decreasing and convex because Mrázová and Neary (2017) use the absolute value of the elasticity, while in our paper ε is a negative number.

[11] Superconvexity of the inverse demand function is equivalent to superconvexity of the direct demand function, and implies log-convexity of the inverse demand function, which implies log-convexity of the direct demand function, which implies convexity of both demand functions; but the converses do not hold, see Lemma D.1 in Mrázová and Neary (2019).

demand functions we use are within the class of constant elasticity of the inverse demand, i.e., $E' = 0$.

The Generalized Pareto demand we consider in Section 4.3.3 encompasses the constant elasticity and linear demands as special cases. In our analysis, we initially present findings utilizing constant elasticity and linear demand functions. Subsequently, we expand our examination to include results derived from the Generalized Pareto demand function. Each scenario contributes uniquely to our comprehension of the market dynamics at play.

4.3.1 Constant elasticity demand

The elasticity of demand is $k > 1$. Recall that the constant elasticity demand is neither superconvex nor subconvex and consequently it serves as a useful benchmark. Using (4.1) and (4.4) the equilibrium aggregate output is

$$\begin{aligned} X &= \frac{(k-\gamma)^k}{(ck)^k}\left(\frac{\mu\cdot(1-\mu i)^k}{(1-r_1)^k} + (1-\mu)(1-\mu i)^k\right) \\ &\quad \text{(using } z_1 = \frac{1-r_1}{1-\mu i} \text{ and } z_{ch} = \frac{1}{1-\mu i}\text{)} \\ &= \frac{(k-\gamma)^k}{(ck)^k}\left(\frac{\mu}{z_1^k} + \frac{1-\mu}{z_{ch}^k}\right). \end{aligned} \tag{4.10}$$

The price merchants receive in the presence of a credit card is the same as the price without a credit card (i.e., using (4.4), P^m is not a function of z_1 or z_{ch}),

$$P^m = \frac{ck}{k-\gamma} \geq c. \tag{4.11}$$

Thus, consumers pay the entire burden of a tax or receive the entire benefit of a subsidy.

The profit function of the network, using (4.10) and (4.7), is

$$\pi_1(z_1, z_{ch}) = \left(\frac{k-\gamma}{ck}\right)^{k-1} \frac{\mu z_1 + (1-\mu)z_{ch} - 1}{z_1^k}. \tag{4.12}$$

The network chooses z_1 and z_{ch} to maximize π_1. It follows from (4.12) that $\frac{\partial \pi_1}{\partial z_{ch}} > 0$.[12] This implies that the interchange fee hits the exogenously given upper bound $i_1^* = \bar{i}$ and the tax for cash users is $z_{ch}^* = \frac{1}{1-\mu\bar{i}}$. We substitute z_{ch}^* into (4.12) and we maximize π_1 with respect to z_1. The solution to the

[12]It also follows from (4.8) because $\varepsilon' = 0$.

first-order condition is (second order condition is satisfied)

$$z_1^* = \frac{k \cdot (1-\bar{i})}{(k-1)(1-\mu\bar{i})}. \tag{4.13}$$

It can be easily verified that z_1^* is a decreasing function of demand elasticity k. Also, $z_1^* > 1$ if and only if $k < \frac{(1-\mu\bar{i})}{(1-\mu)}\frac{1}{\bar{i}}$.

It follows straightforwardly that equilibrium network profits increase, while aggregate equilibrium merchant profits decrease as competition in the merchant market intensifies.

Using (4.13) and $z_1 = \frac{1-r_1}{1-\mu i_1}$ we derive the equilibrium reward

$$r_1^* = \frac{\bar{i}k-1}{k-1}. \tag{4.14}$$

It then follows from (4.14) that $r_1^* < 0$ if and only if $k < \frac{1}{\bar{i}}$.

We summarize in the Lemma below.

Lemma 1 *Suppose the market demand is of the constant elasticity form ($k > 1$) and the fraction of credit and cash users is fixed. The equilibrium taxes and fees as a function of the demand elasticity are given as follows:*

1. *Low demand elasticity: $k \in \left(1, \frac{1}{\bar{i}}\right)$. Credit card users pay a fee $r_1^* < 0$ and their tax is higher than the tax for cash users $z_1^* > z_{ch}^* > 1$.*
2. *Intermediate demand elasticity: $k \in \left(\frac{1}{\bar{i}}, \frac{(1-\mu\bar{i})}{(1-\mu)}\frac{1}{\bar{i}}\right)$. Credit card users receive a reward $r_1^* > 0$ and their tax is lower than the tax for cash users $z_{ch}^* > z_1^* > 1$.*
3. *High demand elasticity: $k > \frac{(1-\mu\bar{i})}{(1-\mu)}\frac{1}{\bar{i}}$. Credit card users receive a reward $r_1^* > 0$ and a subsidy for using the credit card $z_{ch}^* > 1 > z_1^*$.*

As product market competition intensifies (lower γ):

a) the equilibrium taxes, interchange fee and reward are not affected,

b) equilibrium network profits increase,

c) aggregate merchant equilibrium profits decrease,

d) equilibrium prices all consumers pay decrease, and hence consumer welfare increases.

The taxes or subsidies are passed on 100% to all consumers.

Lemma 1 provides a preliminary set of results that will help us better understand the mechanisms when we endogenize shares, as detailed in Proposition 1.

4.3.2 Linear demand

When we depart from constant elasticity, the equilibrium credit card taxes are a function of product market competition (when $\gamma > 0$), even when μ is fixed. From (4.7) it is clear that γ interacts with z_1 and z_{ch} through the elasticity ε, when the latter is not constant. The influence of the elasticity on the equilibrium price is stronger the less competitive the merchant market is. For example, when the market is perfectly competitive, demand elasticity has no effect on pricing; on the other hand, for monopoly pricing market elasticity matters a lot. Furthermore, the effect of γ on z_1 crucially depends on the sign of ε', or whether demand is superconvex or subconvex. We term this the *elasticity effect*, that is described below.

When $\varepsilon' > 0$ (subconvex demand), a decrease in aggregate output X makes demand more elastic. This reduces marginal profitability when the network increases z_1. A higher tax z_1 lowers X, increasing demand elasticity and reducing merchant prices, thus lowering network revenue. As the elasticity effect strengthens, the network is more reluctant to raise taxes. Higher γ (weaker competition) amplifies this effect, leading the network to lower its tax.

The simplest case where $\varepsilon' > 0$ is the linear demand, $P = 1 - X$, see footnote 5. The equilibrium aggregate output, assuming all consumers buy strictly positive quantity, is

$$X(z_1, z_{ch}) = X_1(z_1) + X_{ch}(z_{ch}) = \mu \cdot \left(\frac{1 - cz_1}{1+\gamma}\right) + (1-\mu) \cdot \left(\frac{1 - cz_{ch}}{1+\gamma}\right). \qquad (4.15)$$

We assume that $\max\{z_1, z_{ch}\} < \frac{1}{c}$, so that $X_1 > 0$ and $X_{ch} > 0$. The profit function of the network is

$$\pi_1(z_1, z_{ch}) = \frac{(1 - cz_1)\mu \cdot (\mu z_1 + (1-\mu)z_{ch} - 1)(c \cdot (z_1 - z_{ch})\mu + \gamma + cz_{ch})}{(1+\gamma)^2(\mu z_1 + (1-\mu)z_{ch})}. \qquad (4.16)$$

When $\gamma = 0$, the equilibrium network profit function can be expressed as follows

$$\pi_1(z_1, z_{ch}) = \mu c \cdot (\mu z_1 + (1-\mu)z_{ch} - 1)(1 - cz_1).$$

As in the constant elasticity demand case in Section 4.3.1, π_1 is increasing in z_{ch}. We assume that the upper bound for i is such that $\frac{1}{1-\mu\bar{i}} < \frac{1}{c}$, so that consumers who pay with cash consume positive quantity in equilibrium. Hence, $z^*_{ch} = \frac{1}{1-\mu\bar{i}}$. Then, the equilibrium tax for credit card users is given by

$$z^*_1 = \frac{(1-\bar{i})c + 1 - \mu\bar{i}}{2c(1-\mu\bar{i})}. \qquad (4.17)$$

The equilibrium reward is given by

$$r_1^* = \frac{c(1+\bar{i}) - (1-\mu\bar{i})}{2c}. \tag{4.18}$$

The results when $\gamma = 0$ are very similar to the ones derived under constant elasticity demand in Section 4.3.1.

Next, we assume that competition in the product market is imperfect, $\gamma > 0$. Because $\varepsilon' > 0$, it follows from (4.8) that the effect of z_{ch} on network profits is ambiguous.

Closed-form solutions for z_1 and z_{ch} are not feasible due to the highly non-linear nature of the network profit function, as shown in (4.16). We proceed with numerical solutions.

1. Numerical examples with $\gamma > 0$.

We present the equilibria for various degrees of product market competition by setting a specific marginal cost, $c = 0.8$ and assuming that 25% of consumers use cash, $\mu = 0.75$.

We summarize in the following Result.

Result 1

4.3.3 Generalized Pareto demand

Within this class of demand functions we can choose parameters so that $\varepsilon' < 0$ (superconvex demand), and consequently the elasticity effect works in the opposite direction than in the linear demand example.

The distribution of consumer valuations v takes on the generalized Pareto distribution

$$F(v) = 1 - (1 + \xi \cdot (E-1)(v-1))^{\frac{1}{1-E}},$$

where $\xi > 0$ is the scale parameter and $E < 2$ is the shape parameter, see Bulow and Klemperer (2012) and Wang and Wright (2018). A lower ξ implies higher consumer willingness to pay in the first-order stochastic dominance sense. The generalized Pareto distribution implies the corresponding demand functions for merchants are defined by the class of demands

$$X(p) = 1 - F(p) = (1 + \xi \cdot (E-1)(p-1))^{\frac{1}{1-E}}, \tag{4.19}$$

with constant elasticity of the slope of the inverse demand given by E, see (4.5). When $E < 1$, the support of the distribution F is $\left[1, 1 + \frac{1}{\xi \cdot (1-E)}\right]$ and it has increasing hazard. Accordingly, the implied demand functions X are log-concave and include the linear demand function ($E = 0$) as a special case. Alternatively, when $1 < E < 2$, the support of F is $[1, \infty)$ and it has decreasing hazard. The implied demand functions are log-convex and include the constant elasticity demand function $(E = 1 + \frac{1}{\xi})$ as a special case. When $E = 1$, F captures the left-truncated exponential distribution $F(x) = 1 - e^{-\xi\cdot(v-1)}$ on the support $[1, \infty)$, with a constant hazard rate ξ. This implies the exponential (or log-linear) demand $X = e^{-\xi\cdot(p-1)}$.

The effect of aggregate output on the elasticity is given by

$$\varepsilon' = \frac{1 - \xi \cdot (E-1)}{X^{2-E}}, \tag{4.20}$$

which is negative if and only if $E > 1 + \frac{1}{\xi}$. Using (4.4), the equilibrium aggregate quantity as a function of the credit card tax z is

$$X(z) = \left(\frac{1 - \gamma \cdot (E-1)}{1 - \xi \cdot (E-1)(1-cz)}\right)^{\frac{1}{E-1}}.$$

The sign of ε', which affects the elasticity effect, also determines the degree of credit card tax pass-through. We can easily show, using $X(z)$ from above, that the equilibrium price when $z = 1$, i.e., zero tax, is $P = \frac{(1-\xi\cdot(E-1))\gamma + c\xi}{(1-\gamma\cdot(E-1))\xi}$. Using this price and equation (2.10) for ad-valorem tax pass-through in Delipalla and Keen (1992), over-shifting occurs, evaluated at $t_v = 0$, when $\frac{dP}{dt_v} > P$ (where t_v is the ad-valorem tax), which holds if and only if $E > 1 + \frac{1}{\xi}$, or $\varepsilon' < 0$.[13] Therefore, when $\varepsilon' < 0$, and $\gamma > 0$, consumers pay more than 100% of the credit card tax, as expected given that demand is superconvex.

2. A numerical example with $\varepsilon' < 0$, to contrast the results with those under linear demand.

5 Analysis with a monopoly network and an endogenous number of credit card users

We assume that credit and cash are 'differentiated'. We model differentiation using the circular model of Salop (1979).[14] In particular, on a unit circumference circle, network 1 is located at 0, cash is located at $\frac{1}{2}$ and users/consumers are uniformly distributed on the circumference with density one. We assume that each consumer receives a gross benefit $V > 0$, pays a price P^{b_1} when making purchases with credit card, a price $P^{b_{ch}}$ from making purchases with cash and incurs a linear per-unit of distance to a credit card transportation cost $t > 0$. The parameter t captures the degree of differentiation between credit and cash. For tractability, we assume that V is independent of the volume of transactions. Thus, the consumer located at $x \in \left[0, \frac{1}{2}\right]$, if he uses the credit card obtains a net utility $V - P^{b_1} - tx$ and if he uses cash obtains a net utility $V - P^{b_{ch}} - t\left(\frac{1}{2} - x\right)$. The mass of consumers who uses the credit card is

[13] Weyl and Fabinger (2013) offer a general analysis regarding tax pass-through and tax incidence, but only under a specific tax.

[14] See Jeon and Rey (2022) for a similar assumption regarding differentiation between two platforms.

given by

$$\mu = \frac{1}{2} + \frac{P^{b_{ch}} - P^{b_1}}{t} = \frac{1}{2} + \frac{c \cdot (z_{ch} - z_1)}{t \cdot \left(1 + \frac{\gamma}{\varepsilon}\right)}. \tag{5.1}$$

Using implicit differentiation, the effect of the tax for credit card users on the fraction of cardholders is

$$\frac{d\mu}{dz_1} = -\frac{\gamma\mu\frac{dx_1}{dz_1} \cdot (z_1 - z_{ch})\varepsilon' c + \varepsilon \cdot (\varepsilon + \gamma)c}{c\gamma \cdot (x_1 - x_{ch})(z_1 - z_{ch})\varepsilon' + t \cdot (\varepsilon + \gamma)^2}. \tag{5.2}$$

Observe that as the two payment modes become sufficiently differentiated, $t \to \infty$, z_1 has no effect on market share, i.e., $\frac{d\mu}{dz_1} \to 0$. In this case, competition between credit and cash would be equivalent to the case when μ is fixed. Using (5.1), the network profit function (4.7) can be expressed as follows

$$\pi_1(z_1, z_{ch}) = \frac{c \cdot (\mu(z_1, z_{ch})z_1 + (1 - \mu(z_1, z_{ch}))z_{ch} - 1)}{1 + \frac{\gamma}{\varepsilon(\mu(z_1,z_{ch})x_1(z_1),(1-\mu(z_1,z_{ch}))x_{ch}(z_{ch}))}}\mu(z_1, z_{ch})x_1(z_1). \tag{5.3}$$

The only difference between (4.7) and (5.3) is that in the latter the shares μ depend on the two taxes.

We continue our analysis using specific demands.

5.1 Constant elasticity demand

We continue the analysis of Section 4.3.1, but with credit and cash shares being endogenously determined. The network profit function, after we substitute (5.1) into (4.12), is given by

$$\pi_1(z_1, z_{ch}) = \frac{k\left(\frac{k-\gamma}{ck}\right)^k c \cdot \left(\left(\left(\frac{z_1}{2} + \frac{z_{ch}}{2} - 1\right)t - c(z_1 - z_{ch})^2\right)k - \frac{t\gamma \cdot (z_1 + z_{ch} - 2)}{2}\right) z_1^{-k}}{t \cdot (k - \gamma)^2}. \tag{5.4}$$

The network chooses z_1 and z_{ch} to maximize π_1. It follows from (4.8) that when $\varepsilon' = 0$ and μ fixed $\frac{\partial \pi_1}{\partial z_{ch}} > 0$. However, when μ is endogenous, and since from (5.2) $\frac{d\mu}{dz_{ch}} > 0$, there is a negative effect on the network profit, when z_{ch} increases and $z_{ch} > z_1$, given by $-\frac{\partial \mu}{\partial z_{ch}}(z_{ch} - z_1) < 0$. Hence, a solution for z_{ch} can be interior, which is confirmed below. The profit-maximizing taxes, which are the solutions to the system of first-order conditions, as a function of all the key parameters, are given by

$$z_1^* = \frac{(16c - t)k + \gamma t}{16c(k - 1)} \text{ and } z_{ch}^* = \frac{(16c + 3t)k^2 - (3\gamma + 4)tk + 4\gamma t}{16(k - 1)ck}. \tag{5.5}$$

In Appendix A.2, we show that the network profit function is quasi-concave in z_1 and z_{ch} if and only if $t < \frac{16ck}{k-\gamma}$. This condition ensures that the first-order conditions are sufficient for a maximum and also guarantees $z_1^* > 0$. Also, $z_{ch}^* - z_1^* = \frac{t \cdot (k-\gamma)}{4ck} > 0$, which implies that, in equilibrium, $\mu = \frac{3}{4}$, i.e., 75% of consumers use the credit card and 25% cash. Moreover, $z_1^* < 1$ if and only if $k > \gamma + \frac{16c}{t}$, or $t > \frac{16c}{k-\gamma}$.

Finally, $\frac{\partial z_1^*}{\partial \gamma} > 0$ and $\frac{\partial z_{ch}^*}{\partial \gamma} > 0 \Leftrightarrow k < \frac{4}{3}$.

Using (5.5) and $z_1 = \frac{1-r_1}{1-\mu i_1}$ and $z_{ch} = \frac{1}{1-\mu i_1}$ we can derive the unique equilibrium interchange fee and reward

$$i_1^* = \frac{12k^2t - ((12\gamma+16)t - 64c)k + 16\gamma t}{(48c+9t)k^2 - (9\gamma+12)tk + 12\gamma t} \text{ and } r_1^* = \frac{4(k-\gamma)(k-1)t}{(16c+3t)k^2 - (3\gamma+4)tk + 4\gamma t}.$$

It can be verified that $\frac{\partial i_1^*}{\partial \gamma} > 0 \Leftrightarrow k < \frac{4}{3}$ and $\frac{\partial r_1^*}{\partial \gamma} < 0$.

Without cash as an alternative payment mode, the interchange fee and reward cannot be uniquely determined. Only the tax $z \equiv \frac{1-r}{1-i}$ would be relevant for the equilibrium variables; see, for example, Shy and Wang (2011) who derive such an indeterminacy result in a model with constant elasticity demand, one payment network and no cash. Therefore, without cash, we cannot perform meaningful comparative statics to analyze how product market competition and other key parameters affect the interchange fee, rewards, taxes for different payer groups, and ultimately consumer welfare

The equilibrium price merchants receive, P^m, is the same as with a fixed μ, see (4.11). P^m would also be the equilibrium price in an all-cash economy. The equilibrium price credit card users pay is $P^{b_1} = z_1^* P^m = \frac{(16c-t)k^2+\gamma kt}{16(k-1)(k-\gamma)} \lesseqgtr P^m$ and the equilibrium price cash card users pay is $P^{b_{ch}} = z_{ch}^* P^m = \frac{(16c+3t)k^2-(3\gamma+4)tk+4\gamma t}{16(k-1)(k-\gamma)} > P^m$. It can be verified that both prices are increasing in γ.

The equilibrium network profits, after substituting (5.5) into (5.4), are given by

$$\pi_1(z_1^*, z_{ch}^*) = \frac{((16c-t)k+\gamma t)\left(\frac{16(k-\gamma)}{ck}\right)^k \left(\frac{(16c-t)k+\gamma t}{c(k-1)}\right)^{-k}}{16(k-1)(k-\gamma)}.$$

It can be verified that $\frac{\partial \pi_1}{\partial \gamma} < 0$, if $t < \frac{16ck}{k-\gamma}$. The equilibrium total merchant profit is

$$\begin{aligned} \Pi^m &= (P^m - c)X = \frac{c\gamma}{k-\gamma}\frac{(k-\gamma)^k}{(ck)^k}\left(\frac{3}{4(z_1^*)^k} + \frac{1}{4(z_{ch}^*)^k}\right) \\ &= \frac{c\gamma(ck)^{-k}(k-\gamma)^{k-1}\left(3\cdot 16^k\left(\frac{(16c-t)k+\gamma t}{k-1}\right)^{-k} + \left(\frac{(16c+3t)k^2-(3\gamma+4)tk+4\gamma t}{16(k-1)ck}\right)^{-k}\right)}{4}. \end{aligned}$$

While $\frac{\partial \Pi^m}{\partial \gamma} > 0$ for low γ, because $\Pi^m = 0$ at $\gamma = 0$, we have shown numerically that for a wide range of permissible parameter values Π^m is inverse U-shaped in γ.

We summarize in the Proposition below.

Proposition 1 *Suppose the market demand is of the constant elasticity form ($k > 1$), the fraction of credit and cash users are endogenously determined and $t < \frac{16ck}{k-\gamma}$. The equilibrium taxes and fees as a* *function of the demand elasticity are given as follows:*

1. *Low demand elasticity:* $k < \gamma + \frac{16c}{t}$*. Both groups of consumers pay a tax. Credit card users receive a reward* $r_1^* > 0$*. Cash users pay a higher tax than credit card users,* $z_{ch}^* > z_1^* > 1$*.*
2. *High demand elasticity:* $k > \gamma + \frac{16c}{t}$*. Cash users pay a tax, while credit card users are subsidized by receiving a relatively high reward,* $z_{ch}^* > 1 > z_1^*$*.*

As product market competition intensifies (lower γ*):*

a) *the equilibrium interchange fee decreases if and only if product demand elasticity is low,* $k < \frac{4}{3}$*,*

b) *the equilibrium reward increases,*

c) *the equilibrium tax of credit card users decreases,*

d) *the equilibrium tax of cash users decreases if and only if product demand elasticity is low,* $k < \frac{4}{3}$*,*

e) *equilibrium network profits increase,*

f) *aggregate merchant equilibrium profits are inverse U-shaped, and*

g) *equilibrium prices all consumers pay decrease, and hence consumer welfare increases.*

The taxes or subsidies are passed on 100% to all consumers.

It is widely recognized among academics and practitioners that positive rewards imply cash users are 'subsidizing' credit card users. However, this does not clarify whether the presence of credit cards imposes a tax on credit card users, meaning the price they pay, after factoring in the reward, is still higher than what they would have paid in an all-cash economy. Proposition 1 reveals that when demand elasticity is relatively high, credit card users are indeed subsidized, paying a lower price than they would in the absence of credit cards. Conversely, when demand elasticity is low, credit imposes a tax on both groups of consumers, though the tax is lower for credit card users due to the rewards.

The effect of merchant competition arises from the influence of γ on μ, given that the elasticity effect is absent. It can be understood as follows. From (5.1), as γ decreases, μ also decreases for a fixed $z_{ch} - z_1 > 0$. Intuitively, in a more competitive merchant market, prices are lower. Since taxes are ad valorem, a tax differential in favor of credit provides a smaller advantage to credit relative to cash. Therefore, the network has an incentive to increase $z_{ch} - z_1 > 0$ to restore its market share. This is achieved by decreasing z_1 and increasing z_{ch} or decreasing z_{ch} but at a lower rate.

Aggregate merchant profits can increase as competition in the product market intensifies. This occurs because the network, which is competing with cash, lowers the tax on credit card users, who constitute the majority of consumers, thereby encouraging increased consumption. This result contrasts with the findings of Shy and Wang (2011), who show that aggregate merchant profits monotonically decrease as the market becomes more competitive. In their study, there is no cash as an alternative payment mode, so their results align with those in Lemma 1, where shares are exogenous.

Next, we consider a linear demand, which allows us to incorporate the elasticity effect as well.

5.2 Linear demand

The network profit function is derived by substituting (5.1) into (4.16).

3. Numerical results for $\gamma \geq 0$. The main focus should be how changes in γ affect the equilibrium taxes and incidence.

5.3 Generalized Pareto demand

4. Choose parameter values so that $\varepsilon' < 0$. We will check the effect of γ on equilibrium taxes and contrast the results with those derived under a linear demand.

6 Two networks with endogenous number of users

A second network, $l = 2$, enters the market. Network 1 and cash are relocated on the Salop circle so that all three payment modes are equidistantly located. Specifically, network 1 is located at 0, network 2 at $\frac{1}{3}$ and cash at $\frac{2}{3}$ on the circle. We denote by $x_{12} \in \left(0, \frac{1}{3}\right)$ the consumer who is indifferent between the two credit cards, by $x_{2ch} \in \left(\frac{1}{3}, \frac{2}{3}\right)$ the consumer who is indifferent between cash and credit card 2 and by $x_{1ch} \in \left(\frac{2}{3}, 1\right)$ the consumer who is indifferent between cash and credit card 1. The consumer indirect utilities are the same as specified in Section 5. Let $\boldsymbol{i} = [i_1, i_2]$ be the vector with the interchange fees and $\boldsymbol{r} = [r_1, r_2]$ the vector with the rewards. The market share of network 1 is

$$\mu_1 = x_{12} + x_{1ch} = \frac{1}{3} + \frac{P^{b_2} + P^{b_{ch}} - 2P^{b_1}}{2t} = \frac{1}{3} + \frac{c \cdot (2r_1 - r_2)}{2t \cdot \left(1 + \frac{\gamma}{\varepsilon}\right)(1 - \mu_1 i_1 - \mu_2 i_2)} \tag{6.1}$$

and the market share of network 2 is

$$\mu_2 = x_{2ch} - x_{12} = \frac{1}{3} + \frac{P^{b_1} + P^{b_{ch}} - 2P^{b_2}}{2t} = \frac{1}{3} + \frac{c \cdot (2r_2 - r_1)}{2t \cdot \left(1 + \frac{\gamma}{\varepsilon}\right)(1 - \mu_1 i_1 - \mu_2 i_2)}. \tag{6.2}$$

Let $\mu_1(\boldsymbol{i}, \boldsymbol{r})$ and $\mu_2(\boldsymbol{i}, \boldsymbol{r})$ be the solution to the system (6.1) and (6.2) with respect to μ_1 and μ_2. In what follows, to save space, we suppress the dependence of μ_1 and μ_2 on $\boldsymbol{i}$ and $\boldsymbol{r}$.

Using (4.7), network l's profit function is given by

$$\pi_l(\boldsymbol{i}, \boldsymbol{r}) = \frac{c\mu_l x_l(\boldsymbol{i}, r_l)(i_l - r_l)}{\left(1 + \frac{\gamma}{\varepsilon(\mu_1 x_1(\boldsymbol{i}, r_1) + \mu_2 x_2(\boldsymbol{i}, r_2) + (1-\mu_1-\mu_2) x_{ch}(\boldsymbol{i}))}\right)(1 - \mu_1 i_1 - \mu_2 i_2)}. \tag{6.3}$$

5. First, we can use the constant elasticity and then the linear demand. Ideally, we could also use the Pareto. We will examine the effect of network competition on the equilibrium taxes.

7 Conclusion

We develop a model to study payment networks that differs in a number of assumptions from classic two-sided models that have been introduced in the literature. One of our main goals is to be more flexible in modeling the product demand and competition amongst merchants, while also allowing for ad valorem pricing. All these very important and realistic elements have been missing from most of the two-sided models that study payment systems. We know from the taxation literature that ad valorem taxation yields different predictions than specific taxation, especially under 'flexible' product demand. There is no reason why this is not the case in payment networks. Hence, for sound antitrust recommendations these elements ought to be incorporated in a model.

We construct a model that initially considers a monopoly payment network, with cash as an alternative payment mode, and later extends to a duopoly network framework. This network determines the interchange fees that merchants incur and the rewards (or fees) allocated to consumers. Subsequently, n merchants compete within the product market, offering a homogeneous good and operating under a general demand function. Each network aims to maximize its total profit. The presence of credit cards imposes taxes on both cash and credit card users. These credit card taxes are pivotal in determining prices, profits, and welfare. Drawing parallels from the taxation literature, factors such as demand elasticity, demand curvature, and the intensity of product market competition play crucial roles. They are instrumental in determining the extent of credit card tax pass-through, the incidence of credit card tax, and the overall welfare impact.

We are interested in the effects of competition both among networks and among merchants. Under a monopoly network and constant elasticity demand, as competition in the product market intensifies, the equilibrium tax paid by credit card users decreases, whereas the equilibrium tax for cash users decreases if and only if demand elasticity is low. When demand elasticity is high, credit card users are subsidized, meaning the equilibrium reward is so high that they pay a lower price than they would in an all-cash economy. Cash users always pay a higher tax than credit card users.

Then, we assume that a second network enters. If networks do not compete to attract users, then entry results in higher equilibrium credit card taxes if and only if demand becomes more elastic as aggregate output decreases. This is due to the elasticity effect. A higher network tax lowers aggregate output, and if demand becomes more elastic (subconvex demand) the market price decreases and so does the network revenue. With two networks, own network tax has a smaller impact on aggregate output, so the negative elasticity effect weakens, making the networks less reluctant to increase their own tax. As a result, entry increases the credit card tax while reducing profits and welfare. The reverse is true when market demand becomes less elastic as aggregate output decreases (superconvex demand).

We then allow networks to compete for users, assuming networks are horizontally differentiated. Each network in order to attract users lowers its tax, and consequently the price users pay to make purchases with the network's credit card; the competition effect. When networks are not much differentiated, the competition effect dominates the elasticity effect, and entry of a second network lowers the equilibrium tax and increases welfare, if demand becomes more elastic when aggregate output decreases (which is true when, for example, demand is linear). When, however, the two networks are sufficiently differentiated, entry results in higher credit card taxes, higher product prices and lower welfare.

In our analysis, we categorize demand functions based on how demand elasticity varies with aggregate output, which corresponds to subconvexity or superconvexity. This property is crucial as it influences competition and credit card tax pass-through at both the merchant and network levels. While prior literature has explored the impact of these properties on competition and pass-through in the product market, our paper is the first to highlight the complexities and novelties that emerge in two-sided or vertically related markets.

There are a number of novel policy implications that follow from our model. First, the model illustrates when and why having additional payment networks can increase or decrease welfare. Two networks competing for essentially the same transactions will be pro-competitive, relative to monopoly, as long as the networks are competing intensely for card users, due to, for instance, lack of differentiation. Otherwise, merchants and consumers can be made worse off by the presence of two networks that are not competing aggressively.

Second, merchants typically worry about the potential shift of profits away from their businesses towards networks and consumers, especially in less competitive retail markets. When the slope of the elasticity of the product demand with respect to aggregate output is positive, a more competitive retail environment tends to result in a higher credit card tax, primarily borne by consumers. Conversely, a negative slope leads to a lower tax, with merchants bearing a higher fraction of the cost. Policymakers should consider that increased competition among merchants could lead to higher credit card taxes, potentially diminishing some of the advantages that come with intensified competition in the product market.

Finally, it is crucial to note that within our model, implementing a cap on interchange fees alone may be partially undermined by the networks' downward adjustment of consumer rewards.[15] Nevertheless,

[15]This phenomenon aligns with the 'waterbed effect' observed in regulatory theory, which suggests that regulation of only

the overall credit card taxes will decrease and all consumers will become better off.

For the sake of simplicity and analytical convenience, we have operated under the assumption that both issuing and acquiring banks lack market power, which is concentrated at the level of the network. A potential direction for future research could involve attributing a degree of market power to issuing banks.

a subset of prices can lead to compensatory adjustments in unregulated prices. This concept is supported by the findings in the studies by Genakos and Valletti (2011) and Hong et al. (2023), which provide empirical evidence of such regulatory outcomes.

A Appendix: Proofs of Lemmas and Propositions and Some Further Results

A.1 Effect of interchange fee on aggregate output

The first order condition (4.4) can be written as follows

$$(1-\mu i)\left(P_X X\gamma + P\right) - c = 0.$$

We invoke the implicit function theorem to derive the effect of i on aggregate output X

$$\frac{\partial X}{\partial i} = \frac{\mu \cdot (P_X X\gamma + P)}{(1-\mu i)(P_X(1+\gamma) + P_{XX}X\gamma)} = \frac{\mu X \cdot (\varepsilon + \gamma)}{(1-\mu i)(1+\gamma(1-E))} < 0 \tag{A.1}$$

given our assumptions $\gamma + \varepsilon < 0$ and $1 + \gamma(1-E) > 0$. Hence, $\frac{\partial X_1}{\partial z_1} < 0$. Following similar steps, we can show $\frac{\partial X_{ch}}{\partial z_{ch}} < 0$.

A.2 Constant elasticity demand with endogenous shares: Second order condition

The network profit function is given by (5.4). Network chooses z_1 and z_{ch} to maximize $\pi_1(z_1, z_{ch})$. The second derivative of the network profit with respect to z_1 is given by

$$\frac{\partial^2 \pi_1}{\partial z_1^2} = -\frac{A}{t(k-\gamma)^2},$$

where $A \equiv c z_1^{-2-k}\left(\frac{k-\gamma}{ck}\right)^k k^2(c(k-1)(k-2)z_1^2 - 2((cz_{ch}+t/4)k - \gamma(t/4))(k-1)z_1 + (1+k)((cz_{ch}^2 - (1/2)tz_{ch} + t)k + t\gamma(z_{ch}-2)/2))$. When we evaluate the second derivative at the solutions to the first order conditions, (5.5), it is negative if and only if $t < \frac{16ck}{k-\gamma}$. The second derivative of the network profit with respect to z_2 is given by,

$$\frac{\partial^2 \pi_1}{\partial z_2^2} = -\frac{\left(\frac{k-\gamma}{ck}\right)^k z_1^{-k} 2k^2 c^2}{t(k-\gamma)^2} < 0.$$

The determinant of the Hessian matrix of $\pi_1(z_1, z_{ch})$ is given by

$$\frac{\left(k(z_1 - z_{ch})^2(k-1)c^2 + \frac{3\left(\left(z_1 - \frac{z_{ch}}{3} - \frac{2}{3}\right)k - z_1 + \frac{z_{ch}}{3} - \frac{2}{3}\right)t(k-\gamma)c}{2} + \frac{t^2(k-\gamma)^2}{8}\right) 2k^4 \left(\frac{k-\gamma}{ck}\right)^{2k} c^2 z_1^{-2-2k}}{t^2(k-\gamma)^4},$$

which when evaluated at the solutions to the first order conditions, (5.5), is positive if and only if $t <$

$\frac{16ck}{k-\gamma}$.

Therefore, if (and only if) $t < \frac{16ck}{k-\gamma}$, the network profit function is quasi-concave and the first-order conditions are sufficient for a maximum.

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