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Plastic Clashes: Competition Among Closed and Open Payment Systems

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Plastic Clashes: Competition Among Closed and Open Payment Systems*

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Abstract

This paper analyses market competition between two different types of payment schemes: card associations and proprietary systems. The main focus is on the role of the collective setting of the interchange fee by members of the association. We describe the sterilising role of the interchange fee: when the interchange fee is set so as to maximise the sum of issuers' and acquirers' profits, the equilibrium values of platforms' profits, of the sum of the fees charged by each platform and their market shares are independent of the competitive conditions within the associated members on the two sides of the market and are affected by the strength of inter-platform competition. We also show that the privately set interchange fee is socially inefficient, although this is not due to anticompetitive reasons.

Keywords: credit cards, interchange fee, two-sided markets, network externalities.
JEL classification: G21, L13, L31, L42.

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1 Introduction

Spurred by the proliferation of payment cards, the literature dealing with the complex economic and strategic issues of the systems of payments has grown rapidly in the last ten years. Despite this growth and due mainly to the extremely intricate way in which such systems work and are organized, many issues surrounding the inner functioning of systems of payments are still little known. One of the issues that deserves further investigation concerns the impact of competition between payments systems and its effects on market equilibrium; more specifically, what is still very much unclear is how different systems compete and the role that the interchange fee may play in this respect.

Consider the market for credit cards: here, two different systems operate, associations and proprietary for-profit systems. The associations, like Visa and Mastercard, are owned and controlled by members (banks and other payment entities) that issue cards to consumers and process merchants' transactions. The second type of platforms are proprietary, vertically integrated for-profit organizations that directly issue cards, acquire merchants and set their fees. Probably, the most prominent example of this type of platforms is American Express.

In an association, the two payment card entities, that issuing the card to consumers (the issuer) and that processing the merchants' transactions (the acquirer) are often different; issuers and acquirers collect all the fees directly from individuals and merchants respectively. In addition to retail fees, platforms also set a "wholesale/interconnection" payment, the *interchange fee* in the industry jargon, that acquiring banks pay to the banks that have issued the card for each transaction between cardholders and merchants. Unlike in others physical networks such as telecommunications, these interconnection fees are set collectively by the members of the association and not through bilateral negotiations between the two interconnected parties (issuers and acquirers).

Since 1984, when National Bancard Corporation unsuccessfully sued Visa claiming that Visa's interchange fee was an illegal agreement, the business model of credit card associations has been the focus of increasing attention by economists and regulators; in particular, the collective setting of the interchange fee by associations has been and still is under close scrutiny in many countries. Several U.S. merchants have filed lawsuits against Visa and Mastercard for the collective setting of the interchange fee; in December 2007, the European Commission ruled against Mastercard's practice to set the interchange fees, seen as a practice that violates the Antitrust laws.[1] The Reserve Bank of Australia has recently proposed to

[1] For details on the EC's ruling out on Mastercard's, see Bolt (2008).

introduce a cost-based regulation of the interchange fees in order to promote the access of banks to credit card associations.[2]

All these lawsuits and antitrust proceedings hinge upon the strategic use of the interchange fee, often suspected of being used anticompetitively by card associations against proprietary systems of payments. In this paper we concentrate on this debated and largely unresolved issue; our aim is to model competition between proprietary vertically integrated systems and card associations, focusing on the strategic role of the interchange fee. This analysis raises interesting questions due to the different organizational structures of the two platforms.

As stressed above, the literature on the economics of payment cards is by now quite well developed.[3] A large part of the literature deals with the issue of efficient pricing of card services. A payments platform is a two-sided network that enables transactions between two sets of agents, buyers and sellers, whose decisions to join the platform are taken in an uncoordinated fashion. To be economically viable, platforms have to get both sides on board: buyers' benefits from joining a platform increase with the number of merchants where their card is accepted; at the same time merchants' benefits from joining are higher the more widespread the use of the card among consumers. It is widely accepted that appropriate pricing arrangements for payment instruments are extremely complex, and despite the growth of the economic literature on these issues, there is no general consensus on what constitutes an efficient price structure. Indeed, the type of interactions between the two parts of the network raises a coordination problem for the platform owner, which has to balance the two sides of the market so as to maximize the economic value of the platform; in two-sided markets, firms have to price in order to coordinate customers' choices independently taken on the two sides.[4]

A small number of recent papers discuss the role played by competition among payment networks. Rochet and Tirole (2003) extend a previous model (Rochet and Tirole, 2002) by considering network competition; for a wide range of governance models, they show how the platform owner must design its pricing structure so as to get both sides on board. They do not explicitly model the interchange fee, and they show that with competing platforms (either proprietary or not-for-profit associations), the optimal price structure depends on

[2]See Reserve Bank of Australia (2000); a critical discussion of the arguments put forward by the Reserve Bank of Australia can be found in VISA (2002).

[3]For a synthesis of the recent contributions see Bolt and Chakravorti (2008) and Rochet (2003).

[4]For discussions on the economics of two-sided markets see Parker and Val Alstyne (2005), Armstrong (2002) and Rochet and Tirole (2006).

the split of total costs between issuers and acquirers, the demand elasticities as well as the different degrees of competition on the two sides of the market.

Guthrie and Wright (2007) have recently extended Rochet and Tirole (2003) by considering strategic interactions between merchants that decide whether to accept payment cards in order to "steal business" from other retailers, They analyse competition between two identical payment networks (either associations or proprietary schemes) and show that, quite surprisingly, platform competition may lead to higher interchange fees: that is, merchants are charged more and consumers less. Not surprisingly, provided that they model competition between symmetric networks, Guthrie and Wright (2007) found that at the equilibrium, both networks charge the same interchange fee.

Also Chakravorti and Roson (2006) draw on Rochet and Tirole (2003) to model platform competition; the novelty of their analysis is the presence of imperfect competition and product differentiation between platforms. Their main objective is to study how product differentiation affects the structure of prices on the two sides of the network, and their focus is primarily on symmetric networks.[5]

It is apparent from this short review that the literature on competing platforms fails to capture a crucial feature of the industry, which is, instead, the primary focus of this paper: the strategic interaction between card associations and proprietary platforms. Competition between these two types of platform raises interesting questions due to their asymmetries. For-profit platforms are vertically integrated and have two separate instruments - buyers' and merchants' fees - and optimize on both; associations have only one instrument at their disposal - the interchange fee - the other fees being the result of intra-platform competition between its members. We analyse the role of the interchange fee and how it can be used by the association when it faces competition from a vertically integrated platform.

We assume duopolistic competition among platforms and intense intra-platform competition among issuing and acquiring banks. Using a generalized Hotelling model we derive a number of results concerning the competitive role played by the interchange fee, its effect on prices, total output and profits. We also study how intra-platform and inter-platform competition affect the optimal interchange fee.

The main theoretical contribution of this paper is that it highlights the different effects

[5]The emergence of skewed pricing strategies is a common feature of two-sided platforms. The literature on two-sided networks is now quite well developed; for theoretical analyses of pricing strategies in two-sided markets, see Parker and Val Alstyne (2005), Bolt and Tieman (2008) and Caillaud and Julien (2003) among others.

of inter-platform as opposed to intra-platform competition on the interchange fee and the immunization role played by this latter with respect to the degree of intra-platform competition. When the interchange fee is set so as to maximize the sum of issuers' and acquirers' profits, the equilibrium values of platforms' profits, price levels and their market shares are independent of the competitive conditions within the member banks and are affected by the strength of inter-platform competition. We show how, in equilibrium, the association, by appropriately setting its interchange fee, is able to make its competitive stance against the rival platform independent of its internal competition.

Clearly, variations in the strength of competition, both inter- and intra-platform, affect the level of the optimal interchange fee. An increase in the level of intra-platform competition, generated from either the issuers' or the acquirers' side, induces a change in the optimal interchange fee that increases the price of the less competitive side. This implies that if, for example, the acquirers' side is less competitive than the issuers' side, a further increase of competition on the issuers' side will lead to an increase of the optimal interchange fee. If inter-platform competition is not too asymmetric on the two sides, changes in its level produce the same effects on the optimal level of the interchange fee as those discussed above for intra-platform competition. Finally, we show that the interchange fee set by the association is socially inefficient, although this is not because the association uses the interchange fee anticompetitively.

In the last part of the paper, we show that our main results are still valid under different specifications of the model. We demonstrate that the immunisation role of the interchange does not depend on the presence and strength of cross-network effects. This holds both with general trading patterns between the two sides of the market and when intra-platform competition results in different and more articulated (endogenous) price-cost markups set by associated banks.

The rest of the paper is organized as follows: section 2 sets up the model of platform competition and describes consumers' and sellers' behavior; the main results are derived and discussed in section 3. In section 4 we show that the basic economics of the model remain largely unchanged when different specifications of the model are considered. Section 5 concludes.

2 The model

2.1 Assumptions

We model the competition between two platforms providing payment services. Platform 1 is an association jointly run by its members; platform 2 is a proprietary platform. In platform 1, the fees charged to buyers and sellers are independently set by the issuing and acquiring banks respectively. Platform 1 also sets an interchange fee, denoted by a, which is set so as to coordinate the two sides of the market. It is customarily assumed that the interchange fee flows from acquirers to issuers. We adhere to this custom and we allow a to take positive or negative values.

The objective of platform 1 is to maximise the value of the platform, which is customarily assumed to be measured by the joint profits of its members. In order to simplify the analysis, we also normalise to zero any fixed or variable cost directly incurred by the platform. Given these two assumptions the total amount of interchange fees paid by one side exactly offsets the amount received by the other. In line with the existing literature we make the simplifying assumption that issuers and acquirers are different entities.[6]

Platform 2 directly sets the fees for the two sides of the market. For simplicity, we restrict the attention to linear per-transaction prices and do not consider two-part tariffs. Although cardholders often have to pay annual fees, options without such fees are frequently available[7] and merchants generally face no or very low fixed fees for accepting cards.

Economic value is created by "transactions" between pairs of end users, buyers and sellers; these transactions are mediated by a platform. We assume that neither buyers nor sellers *multihome*, so they can be affiliated to at most one platform, and that the two populations of buyers and sellers have mass one. The "no-multihoming" assumption is taken for simplicity; in the last part of the paper we discuss why this is not a serious limitation of the analysis and we report under what conditions this assumption could be lifted without affecting our results.

Consider a (buyer, seller) pair and let us assume that each such pair corresponds to one potential transaction. Actual transactions can take place only if both parties are affiliated to the same platform.

[6] "On-us" transactions, where the issuer and the acquirer are the same bank, are an exception. This assumption makes the exposition simpler but it does not affect our main results.

[7] For instance, in the U.S. more than 60% of issuers do not charge fixed fees. See Chakravorti and Shah (2003).

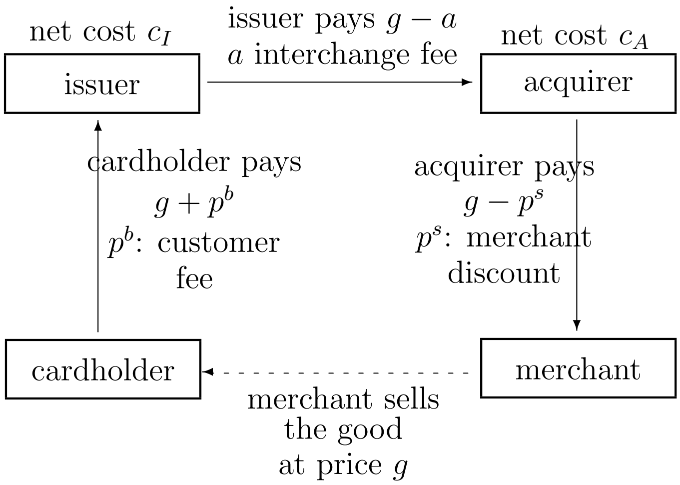

Figure 1: flow of funds in card associations

We also assume that both platforms impose a *no-surcharge rule* that prohibits merchants from passing some or all of the costs of processing transactions to those buyers who prefer to pay with the card rather than with cash. In the credit cards market, explicit no-surcharge rules are quite common for associations like Visa and MasterCard and, even when not explicitly forbidden, in many countries surcharging is rarely observed. The two platforms offer a differentiated service to both cardholders and merchants. On platform 1, issuing banks compete for cardholders and acquiring banks compete for merchants. We assume that intra-platform differentiation is small compared with inter-platform differentiation.

Since they play an important role in our model, it is useful to define neatly the two concepts of intra-platform and inter-platform competition. The former relates to the competitive conditions within platform 1 and it is affected by the number of issuing and acquiring banks operating on that platform and the degree of differentiation in the services they provide. The latter concept relates to the degree of competition between the two platforms on both sides of the market. The intensity of competition depends on the degree of substitutability between the two platforms. Figures 1 and 2 graphically summarize the flows of funds within the two platforms.

The timing of the model is as follows: in the first stage, platform 1 sets its interchange fee, in stage 2 market competition takes place between member banks and platform 2 which compete on prices. Since the interchange fee is fixed by the association only periodically, it is natural to assume that a is set before affiliated banks compete in prices. We assume that side payments between issuing and acquiring banks are not allowed; this implies that the optimal interchange fee cannot yield negative profits for member banks.

Both sides of the market are described using a variation of the standard Hotelling model

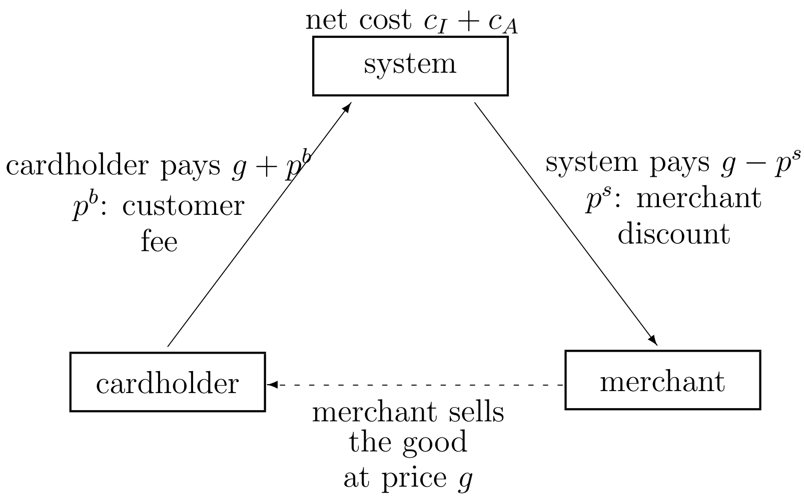

Figure 2: flow of funds in proprietary platforms

with the two platforms located at the two ends of a unit length segment. Buyers and sellers are uniformly distributed along the line representing each side of the market.

2.2 Intra-platform competition on platform 1

Issuers compete for cardholders while acquirers compete for merchants. The fee charged to cardholders and merchants are set independently by member banks. Issuers and acquirers have constant marginal costs denoted by c_A and c_I respectively;[8] considering the interchange fee, total per transaction costs become $c_A + a$ and $c_I - a$. For later use, let us define the platform total per transaction cost: $c = c_I + c_A$.

Affiliated banks on the two sides of the market are little differentiated; as in Rochet and Tirole (2003), we assume that there exists an intense intra-platform competition resulting in equilibrium prices charged on merchants and cardholders that depend on the degree of competition between issuing and acquiring banks and on their marginal costs, c_i and a. For the moment, let us proceed in the simplest possible way and assume that equilibrium prices are linear in banks' marginal cost; formally, this is equivalent to assuming exogenous price-cost markups on the two sides of the market:

$$p_1^{s*} = \sigma\left(c_A + a\right) \quad \Rightarrow \quad \frac{p_1^{s*} - \left(c_A + a\right)}{p_1^{s*}} = \frac{\sigma - 1}{\sigma}, \tag{1}$$

[8]Issuers generally face higher costs than acquirers since they not only face the costs of processing card transactions, but also those associated with the risk of providing credit to customers and of providing a guarantee in case of disputed transactions; issuers also provide insurance against fraudulent uses of the card. For a detailed discussion of the transactions costs for issuers and acquirers, see Gans and King (2001).

$$p_1^{b*} = \beta\,(c_I - a) \quad \Rightarrow \quad \frac{p_1^{s*} - (c_I - a)}{p_1^{b*}} = \frac{\beta - 1}{\beta}, \tag{2}$$

where $\sigma > 1$ and $\beta > 1$ are constant margins that can be interpreted as the degree of intra-platform competition between acquiring and issuing banks respectively.[9] This amounts to assuming that members of the association are little differentiated in a direction orthogonal to that of platform differentiation. In a generalized model of Hotelling competition between platforms, the only admissible equilibrium prices for platform 1 are given in (1) and (2). Platform 2 anticipates this, and sets its optimal prices.

2.3 Buyers' behavior

We assume that the buyer's benefit from consumption net of the price of the good is independent from the means of payment used (cash or card) and we normalise this net utility to zero. Given linear per-transaction prices, the actual benefit that a buyer enjoys when adopting a card depends on the per transaction benefit. This way of modelling buyers' behavior, which is common in the literature, is consistent with the observation that when individuals endorse a platform, they do not know in advance how many transactions they will perform, and they take the adoption decision on a per transaction basis.[10] This also helps simplify the model considerably, since we do not have to model the uncertainty of each individual's future number of purchases.

Without multihoming, each buyer is confronted with the choice of which platform to adopt, given that the two networks are differentiated. We model this choice within an Hotelling framework; let k denote the transportation cost incurred by each consumer and let M_j, $j = 1, 2$ be the expected number of merchants operating on platform j. Expressions (3) and (4) give the individual per-transaction utility from using the card issued on platform 1 and by platform 2 respectively:

$$v^b(M_1) - p_1^b - kx, \tag{3}$$

$$v^b(M_2) - p_2^b - k(1 - x), \tag{4}$$

where p_1^b and p_2^b are the per-transaction prices charged by issuing banks on platform 1 and

[9] It should be noted that a constant margin is consistent with an iso-elastic demand function; more generally, smaller margins may be associated with either more competition between member banks or a higher demand elasticity.

[10] Often, and equivalently, it is assumed that independently of their affiliation, buyers make a fixed number of purchases; again, this implies that they affiliate to the platform which guarantees the higher per-transaction benefit.

by platform 2 respectively, and $v^b(\cdot)$ is the benefit from paying with the card; $v^b(\cdot)$ is a positive (weakly) increasing function of M_i, the expected number of merchants affiliated to the same platform.[11] This functional form captures the idea that cardholders' benefits from holding a card increase with the expected number of merchants that accept the card they own. Widespread card acceptance by sellers makes it easier for the buyer to find a merchant accepting the card and therefore to conclude a transaction, and this effect is captured by the additive term $v^b(\cdot)$.

The presence of cross-markets effects at the buyers and sellers level is a well known feature of payments networks.[12] The formal analysis of these effects requires one to make assumptions about the ability of banks and platforms to affect buyers' and sellers' expectations and then the derivation of a fulfilled expectations equilibrium. The algebraic complexity of the model is greatly simplified by assuming away such effects at the customer level without altering the basic economics of the system; for this reason the main analysis will be conducted assuming v^b as independent of the number of merchants adopting each platform. In the last part of the paper we reintroduce cross-markets effects and show how the qualitative results remain largely unchanged.

The proportions of buyers who are willing to use platform 1 and platform 2 are determined by the location of the consumer indifferent between joining one or the other platform, and they are given, respectively, by:

$$d_1 = \frac{1}{2} + \frac{p_2^b - p_1^b}{2\,k} \quad \text{and} \quad d_2 = \frac{1}{2} + \frac{p_1^b - p_2^b}{2\,k}. \tag{5}$$

2.4 Sellers' behavior

We adopt a specification of the seller's benefit of affiliation to a certain platform similar to that used for buyers. As for buyers, also a merchant faces an uncertainty since she/he does not know in advance which card a customer wishing to buy has his/her pocket; as before, we assume that the affiliation decision is made on a per-transaction basis.

The benefit of selling the good through platform 1 and platform 2 are given by:

$$v^s(D_1) - p_1^s - t\,x,$$

[11] Evidence has shown that the benefits from card usage include the possibility to conclude transactions whether or not the cardholder is known to the merchant, the security advantages due to the possibility to minimise holding of cash balances, the possibility to do transactions on-line or over the phone and to make purchases abroad.

[12] Network externalities have a number of implications for the evolution and efficiency of payment networks, see Economides (1993).

$$v^s(D_2) - p_2^s - t\,(1-x),$$

where p_i^s is the merchant discount charged on platform i and D_i is the expected number of cardholders on the same platform. As for the buyers, for the moment we assume away cross-markets effects (that we will reintroduce in the last part of the paper) and let v^s be a positive constant.[13]

The location of the merchant indifferent between platform 1 and 2 gives the proportion of merchants willing to join platform 1; the remaining part of the segment is the proportion of merchants willing to affiliate to platform 2. Formally:

$$m_1 = \frac{1}{2} + \frac{p_2^s - p_1^s}{2t}, \quad \text{and} \quad m_2 = \frac{1}{2} + \frac{p_1^s - p_2^s}{2t}. \tag{6}$$

The two parameters t and k reflect the degree of substitution between the two platforms on the acquirers' and issuers' side respectively. The lower their values the more intense the competition between platforms. Since we are interested in the effects of different degrees of competition on the two sides, we keep t constant and equal to 1 and let k vary. The parameter k can then be interpreted as a relative measure of the degree of substitution between platforms on the two sides of the market. This results in little loss of generality because it turns out that, in equilibrium, the effect of changes in the two parameters are symmetric.

2.5 Trading patterns and platforms' profits

Platform profits depend on the number of transactions. Each pair (buyer, seller) on the same platform corresponds to a potential transaction. Therefore, the number of total transactions on platform i is a function the number of consumers adopting the card, d_i, and the number of merchants accepting it, m_i, $i = 1, 2$. Let us define $g_i(d_i, m_i)$ as the number of transactions on platform i; we first solve the model for the simplest possible scenario, which occurs when each consumer affiliated to platform i makes one and only one transaction with each merchant accepting the same card; in this case, $g_i(\cdot) = d_i\, m_i$. In the economics of networks jargon, this scenario is defined as "balanced trading pattern".[14]

Given the two expressions for platform 1 equilibrium prices, (1) and (2), the profits for

[13]Notably, the benefits to merchant of accepting cards include convenience effects in transactions where the alternative method of payment is more costly, as happens in on-line and mail-order sales, and in risk shifting benefits when the risks of fraud or default are passed to the issuers.

[14]This is a standard assumption in the literature; see, Schmalensee (2002) among others.

acquiring and issuing banks on platform 1 and profits for platform 2 are:

$$\pi_{1,A} = (\sigma - 1)(c_A + a)\, d_1 m_1, \tag{7}$$

$$\pi_{1,I} = (\beta - 1)(c_I - a)\, d_1 m_1, \tag{8}$$

$$\pi_2 = (p_2^s - c_A)\, d_2 m_2 + (p_2^b - c_I)\, d_2 m_2, \tag{9}$$

where c_i and m_i, $i = 1, 2$, are given in (5), and (6). Platform 1 total profits can be written as:

$$\pi_1 = \pi_{1,A} + \pi_{1,I} = H(a)\, d_1 m_1, \tag{10}$$

where

$$H(a) \equiv (\sigma - \beta)\, a + (\beta - 1)\, c_I + (\sigma - 1)\, c_A,$$

is the per-transaction margin over total costs for platform 1. Clearly, if $\sigma = \beta$, i.e. same degree of intra-platform competition on both sides of the market, the per-transaction margin is independent from the interchange fee while it increases (resp. decreases) with the interchange fee if $\sigma > \beta$ (resp. $<$). When competition among issuers is stronger ($\sigma > \beta$), the per-transaction margin is greater with a high interchange fee: setting a higher a is a way to transfer funds from the more competitive side of the market to the less competitive (and more profitable) one.[15] The use of the interchange fee to transfer funds across the two sides of the market is well known (Baxter, 1983; Wright, 2004); as will become clear in the following section, it represents a crucial element also in our model.

3 Equilibrium with balanced trading pattern, no externalities and constant markups

We are now ready to solve the model and to study the characteristics of the optimal interchange fee. In this section we deal with the simplest and most tractable case, namely when the trading pattern is balanced, there are no externalities and platform 1 intra-platform competition results in constant and exogenous price-cost markups.

In this very stylised framework, we are able to fully characterise the solution; in the last section of the paper we remove the above assumptions to check the robustness of our results.

[15] The opposite applies when $\sigma < \beta$.

3.1 The equilibrium for given interchange fee

Platform 2 maximises profits taking a, p_1^{b*} and p_1^{s*} as given. From the usual first order conditions the optimal prices charged by platform 2 on the two sides, as a function of the interchange fee a, are:

$$p_2^b(a) = \frac{2\,k - 1 + (1-\sigma)c_A + (1+2\beta)c_I - (\sigma+2\beta)a}{3}, \tag{11}$$

$$p_2^s(a) = \frac{2 - k + (1-\beta)c_I + (1+2\sigma)c_A + (\beta+2\sigma)a}{3}. \tag{12}$$

Using (1), (2), (11) and (12) we can derive the equilibrium total profits for the two platforms as a function of the interchange fee:

$$\pi_1(a) = \frac{(H(a) - 5 + k)\,(H(a) - 5\,k + 1)H(a)}{36\,k}, \tag{13}$$

$$\pi_2(a) = \frac{(H(a) + k + 1)^3}{108\,k}. \tag{14}$$

Visual inspection of the second stage profit functions shows the following result:

Proposition 1. *Suppose that platform competition is described by the above Hotelling model:*

1. *when intra-platform competition is symmetric ($\sigma = \beta$), the equilibrium platform profits are independent of the interchange fee;*
2. *platform 2 profits increase with the interchange fee if $\sigma > \beta$ and decrease otherwise.*

Although the proof of the proposition above is straightforward, the economic intuition behind it is not. Consider an increase in the interchange fee; this produces the same qualitative effects on the prices charged by the two platforms, raising merchants' fees and lowering buyers' fees. This is obvious for platform 1 prices, while for platform 2 it can be seen by taking the derivatives of expressions (11) and (12) with respect to a: $dp_2^b(a)/da = -(2\beta+\sigma)/3$ and $dp_2^s(a)/da = (\beta+2\sigma)/3$. The two derivatives have opposite signs, and the absolute value of the second is larger than that of the first if $\sigma > \beta$.

The impact of an increase in the interchange fee on platform 2 profits is therefore clear: when $\sigma > \beta$, a reduction of the price margin on the buyers' side is more than compensated by the price increase on the merchants' side and platform profits increase. For these same reasons, when $\beta > \sigma$, platform 2 profits are monotonically decreasing in the level of the interchange fee. When $\sigma = \beta$, the two effects cancel each other out; the net effect of a change in a on profits is zero and this is true for both platforms.

This discussion shows how the setting of the interchange fee harms platform 2, reducing its profits when certain conditions occur. In this respect, one of the main concerns of many regulatory authorities and of proprietary closed systems like American Express (American Express International, 2001), is that card associations, like Visa, may actually use the interchange fee anti-competitively. We address this much debated issue in the following corollary:[16]

Corollary 1. *Provided that $a \in [-c_A, c_I]$, platform 1 cannot set the interchange fee so as to drive the rival out of the market.*

This corollary simply states that the level of the interchange fee that would drive the rival network out of the market cannot be set by platform 1 since it would yield negative profits for member banks. This result is interesting and suggests that the interchange fee cannot be used by platform 1 as an instrument to foreclose the market. The message is therefore clear: market foreclosure should not be used as an argument for banning the interchange fee; we shall take these antitrust considerations somewhat further in the next section, once we have derived the optimal interchange fee.

3.2 The optimal interchange fee

In the first stage, platform 1, anticipating the second stage outcome, chooses the interchange fee to maximize total profits earned by banks participating in its network. As mentioned, we assume that side payments between issuing and acquiring banks are not allowed; this implies that the optimal interchange fee is constrained in the interval $[-c_A, c_I]$ to ensure non-negative profits for member banks. Platform 1's maximization problem is:

$$\begin{array}{cc} \max\limits_{a} & \pi_1(a) \\ s.t. & a \in [-c_A, c_I] \end{array}$$

Before moving to the main propositions of the paper, it is useful to define the following expressions:

$$a^{opt} = \frac{1}{3}\frac{3(\beta-1)c_I + 3(\sigma-1)c_A - 4(k+1) + R}{\beta - \sigma}, \tag{15}$$

and $G \equiv 1 + \frac{4(k+1)-R}{3c}$, $G' \equiv 1 + \frac{4(k+1)+2R}{3c}$, where $R \equiv \sqrt{31 - 46k + 31k^2}$.

[16] All proofs are in the Appendix.

Proposition 2. *In the Hotelling model of platform competition, the optimal interchange fee set by platform 1 is given by the following:*

if $\sigma > \beta$

$$a^* = \begin{cases} a^{opt} & if \quad \beta < G < \sigma < G' \\ c_I & otherwise \end{cases}$$

if $\beta > \sigma$

$$a^* = \begin{cases} a^{opt} & if \quad \sigma < G < \beta < G' \\ -c_A & otherwise \end{cases}$$

The optimal interchange fee can assume both positive and negative values. Three variables crucially affect a^*: the relative intensity of intra-platform competition on the two sides of the market captured by the sign of $(\sigma - \beta)$ and the relative intensity of inter-platform competition measured by k. The next proposition states our main result concerning the role of the optimal interchange fee. Define the price level on each platform as the sum of buyers's fee and merchants' discount $P_j = p_j^b + p_j^s$, $j = 1, 2$ and the same-side platform price differential as $\Delta^i = p_1^i - p_2^i$, $i = b, s$.

Proposition 3. *Let* $\min\{\sigma, \beta\} < G < \max\{\sigma, \beta\} < G'$. *The optimal interchange fee sterilises the effects of different degrees of intra-platform competition on the equilibrium price levels, price differentials, total quantities and platforms profits.*

This result is interesting. While previous papers have concentrated on the monopoly case or on competition between symmetric platforms, this proposition shows that the optimal interchange fee makes platform 1 immune from the degree of competition between member banks on the issuing and acquiring side. Total profits for the platform will depend only on inter-platform competition, summarised by the parameter k in the model. This result has interesting consequences; what really matters is competition between rival platforms, increasing competition within platforms is not associated with the usual effects on prices.

This also shows that card associations have little incentive to impose barriers against entry by new banks into the system since the effect of increased intra-platform competition is neutralised by the choice of the interchange fee. It should be noted that the imposition of entry barriers by platforms is a concern of several regulatory authorities. Our main message is that, whereas for the issuing and acquiring banks the effect of increased intra-platform competition produces the obvious effect of decreasing the bank's individual profits, the total value of the platform, measured by the level of aggregate profits remains unchanged.

Whether or not entry barriers are lifted by associations therefore depends on the governance mechanisms of this type of platform.

It is interesting to note that buyer's fees and merchants' discounts do depend on the conditions of market competition, both intra and inter-platform; it is the total price level on each platform that is kept constant by means of the optimal interchange fee.

The competitive stance of platform 1 compared to platform 2 is not affected by its internal competition, as the constant price differentials Δ^i clearly demonstrate. Market shares on both sides of the market are also independent of the level of intra-platform competition. How the optimal interchange fee accomplishes this role is described in the next corollary.

Corollary 2. *Let* $\min\{\sigma, \beta\} < G < \max\{\sigma, \beta\} < G'$*. The optimal interchange fee* a^* *exhibits the following properties:*

1. *it is undetermined when* $\sigma = \beta$*;*

2. *it is used to balance the different degrees of intra/inter-platform competition:*

   i) a^* *is set to transfer funds to the less competitive (and more profitable) side of the market; formally,* $sign\left(\frac{da^*}{d\sigma}\right) = sign\left(\frac{da^*}{d\beta}\right) = sign\left(\beta - \sigma\right)$*;*

   ii) when competition between platforms is relatively strong, platform 1 reacts to a further increase in inter-platform competition by increasing (respectively decreasing) the interchange fee if associated issuers compete more (respectively less) fiercely than acquirers. Formally, there exists a value $\tilde{k} = 0.143$ *of inter-platform competition such that if* $k < \tilde{k}$ *then* $sign\left(\frac{da^*}{dk}\right) = sign\left(\sigma - \beta\right)$*; if* $k > \tilde{k}$ *the converse is true.*

When $\sigma = \beta$, acquiring and issuing banks face the same degree of competition; the indeterminacy of the optimal interchange fee results, in our model, from the assumed symmetry of the intra-platform demand on the two sides of the market. Claim $2i$) is related to the effect of changes in the overall competition within platform 1. The interchange fee is used by platform 1 as an instrument to balance prices on the two sides of the market. An increase in the overall degree of intra-platform competition (either σ and/or β decrease) is matched by a change in the interchange fee such that the price of the less competitive side is increased. On the contrary, platform 1 reacts to a reduction in the degree of intra-platform competition by lowering the price on the less competitive side. The effect on the price level P_1 is zero, but the two prices are pushed in opposite directions so as to keep them in balance. Summing up, the interchange fee is set to transfer funds to the less competitive (and more profitable) side of the market.

Claim $2ii$) is related to the effect of inter-platform competition captured by the parameter k representing the relative intensity of competition across platform 1 and 2; for instance, a low level of k may be interpreted as more intense competition between platforms on the issuing side of the market. The effect of changes in k on the optimal interchange fee shows an intricate pattern. We identify a threshold level of the intensity of inter-platform competition $\tilde{k} > 1$ such that below this threshold the sign of the derivative of a^* with respect to k is the same as the sign of $\sigma - \beta$; above the threshold the sign of the derivative is reversed. The basic intuition behind the result is the same as before: platform 1 uses a in order to keep the two sides of the market balanced.

To see this, suppose that inter and intra-platform competition are such that $k = 1$ and $\sigma > \beta$: inter-platform competition has the same intensity on the two sides, while the acquirers' side is less (intra-platform) competitive that the issuers' side; consequently acquirers earn higher margins than issuers, for a given interchange fee. Now consider what happens if competition across platform becomes tougher: if $k < 1$, then both intra-platform ($\sigma > \beta$) and inter-platform competition are stronger on the issuers' side. This depresses the price p_1^b; to balance the prices, following a reduction in k, platform 1 reduces a^* thus increasing p_1^b and lowering p_1^s. Things do not change for slightly larger values of k: if $1 < k < \tilde{k}$, inter-platform competition is lower on the issuer side but the effect of $\sigma > \beta$ still dominates, so that a reduction in k produces the same effect on a^* as above. For a further reduction in inter-platform competition, i.e. k greater than the threshold level $\tilde{k}$, the effect of stronger intra-platform competition on the issuers' side is dominated and a reduction in k prompts an increase in a^* so as to reduce p_1^b.

Although in a different setting, this result is reminiscent of Guthrie and Wright (2007); these authors also show that network competition may lead to merchants being charged higher prices due to higher interchange fees. Summing up, this analysis shows how the interchange fee is used to maintain balance between the prices on the two sides of the market, irrespective of the level of intra and inter-platform competition.

3.3 Welfare

Now that it is clear how payments networks compete, and now that the strategic nature of the privately optimal interchange fee set by platform 1 is evident, it is interesting to evaluate the performance of the market from the social welfare perspective.

The welfare function can be defined as the sum of the surplus enjoyed by consumers and platforms on both sides of the market:

$$W = CS_1^b + CS_2^b + CS_1^s + CS_2^s + \pi_1 + \pi_2, \tag{16}$$

where CS_i^b (resp. CS_i^s) indicates the surplus enjoyed by buyers (resp. sellers) on platform i, and π_i are the profits obtained by platform i, $i = 1, 2$.

Using the individual per-transaction utility function given in (3), CS_1^b can be defined as follows:

$$CS_1^b = \int_0^{d_1} (v^b - p_1^b - kx)dx = \frac{d_1(2v^b - kd_1 - 2p_1^b)}{2}.$$

Following similar arguments, CS_2^b, CS_1^s and CS_2^s are simply given by:

$$CS_2^b = \frac{d_2(2v^b - kd_2 - 2p_2^b)}{2} \quad CS_1^s = \frac{m_1(2v^s - m_1 - 2p_1^s)}{2} \quad CS_2^s = \frac{m_2(2v^s - m_2 - 2p_2^s)}{2},$$

where d_1,d_2,m_1 and m_2 are the two platform markets shares on the two sides of the market given in expressions (5) and (6).

Competition at the retail level occurs as above; hence, given a certain interchange fee, second period prices are still those shown in expressions (1), (2), (11) and (12). On plugging these prices into expression (16), it is possible to write the welfare as a function of the interchange fee, $W(a)$. The socially optimal interchange fee a^w can then be easily obtained.

Proposition 4. *In the Hotelling model of platform competition, it is socially optimal to set the interchange fee so as to minimise the price of the side with less intra-network competition:*

$$a^w = \begin{cases} -c_A & if \quad \beta < \sigma \\ c_I & otherwise. \end{cases}$$

This result is not surprising. In one-sided markets, social welfare is maximised by setting prices at marginal cost. Here, the market is made up of two sides and platforms charge one price for each side of the market; these prices depend not only on the interchange fee set by platform 1 in the first place, but also on the degree of intra-network competition between platform 1 members. The regulator therefore faces an alternative: by mandating platform 1 to set the interchange fee at $-c_A$ (respectively c_I), it increases the efficiency on the acquirers side (respectively the issuers side), at the cost of a higher inefficiency on the other side of the market. Proposition 4 shows that by setting a^W in a way such that the marginal cost, and hence the price, of the less competitive side is driven down to zero, the increase in market efficiency generated on this side more than compensates the larger inefficiency on the other. Indeed, this latter inefficiency is not too large provided that on this side competition between member banks already keeps prices at a low level.

On comparing the social efficient interchange fee with the privately optimal one given in expression (15) it is immediately evident that, whenever an interior solution occurs, platform 1 tends to set a too high interchange fee when $\sigma > \beta$ and a too low interchange fee when $\beta > \sigma$.

This result is also useful for evaluating the validity of the regulatory proposal of the Reserve Bank of Australia known as "balancing approach". Following Gans and King (2003), this regulatory approach involves a comparison of the costs of issuing and acquiring with the revenues obtained by each side of the credit card market. The basic idea is that the interchange fee can be used to offset any shortfall in revenue by either issuers or acquirers. Since, in our model, both sides are financially viable, there is no need to use the interchange fee to offset shortfalls and $a = 0$.[17] In light of Proposition 4, we can state that there is no reason to believe that such a proposal would increase the market's efficiency.[18]

4 Relaxing the model using different specifications

So far, we have proceeded under the three simplifying assumptions of *i*) a balanced trading pattern (i.e. each pair buyer/seller affiliated to the same platform corresponds to an actual transaction), *ii*) the absence of cross-network effects, and *iii*) constant and exogenous platform 1 price-cost markups. In this last section of the paper, we move away from these assumptions in order to verify the validity of the model under different specifications. We start from the trading pattern and let us assume that the number of transactions between buyers and sellers follows a more general (not necessarily balanced) trading pattern.

4.1 The model with unbalanced trading pattern

The total amount of actual transactions on platform i, increases with the number of consumers and/or with the number of merchants affiliated to the same platform.

[17]For obvious reasons, in Australia a ban on the interchange fee is also strongly supported by the local retailers association; see Australian Retailers Association (2002). Note that if there is a shortfall on both sides of the market, the credit card association would not be financially viable.

[18]Furthermore, it is possible to show that this form of regulation may also harm Platform 2. The proof of this statement is available upon request from the authors.

In the more general case, the trading pattern is unbalanced, namely a buyer/seller pair may or may not correspond to one transaction. Formally, the actual number of transactions taking place on platform i, $g_i(d_i, m_i)$, may be represented by any function of the number of platform i's affiliated consumers and merchants; clearly, $g_i(\cdot)$ is positively correlated with the number of consumers and merchants having adopted platform i: $\partial g_i/\partial d_i > 0$ and $\partial g_i/\partial m_i > 0$. A possible, and reasonably general, unbalanced trading rule may take the following form:

$$g_i(d_i, m_i) = d_i^{\epsilon}\, m_i^{\eta}, \qquad \epsilon, \eta > 0, \tag{17}$$

where ϵ and η are positive constant; the more ϵ and η differ from 1 the more unbalanced the trading pattern. In this case, it is possible to prove the following:[19]

Corollary 3. *Proposition 3 holds also for any unbalanced trading pattern of the form $g_i(d_i, m_i) = d_i^{\epsilon}\, m_i^{\eta}$, $\forall \epsilon, \eta > 0$.*

Formally, equilibrium profits, price levels and price differentials for this case are:

$$\pi_1 = \frac{\left(\eta\left(k\left(2\eta^2+1+5\eta\right)+\eta+1\right)-A+8\right)\left(\eta\left(k\left(2\eta^2+11+9\eta\right)-\eta-5\right)+A-8\right)\left(\frac{A+8-\eta k\left(2\eta^2+7\eta+5\right)+\eta(3\eta+11)}{4(2+\eta)^2}\right)^{\eta}}{8k\left(2+\eta\right)^3\eta^2},$$

$$\pi_2 = \frac{\left(\frac{2\eta^3k+5\eta k+5\eta+\eta^2-A+7\eta^2k+8}{4(2+\eta)^2}\right)^{\eta}\left(2\eta^3k+5\eta k+5\eta+\eta^2-A+7\eta^2k+8\right)^2}{8k\left(2+\eta\right)^4\eta^2},$$

$$P_1 = \frac{2\eta^3k+\left(2c+5k-1\right)\eta^2+\left(4c+k+1\right)\eta-A+8}{2\eta\left(2+\eta\right)},$$

$$P_2 = \frac{2\left(c+k\right)\eta^3+\left(7k+2c(3+\epsilon)+1\right)\eta^2+\left(5+4c(\epsilon+1)+5k\right)\eta-A+8}{2\left(\epsilon+1+\eta\right)\eta\left(2+\eta\right)},$$

$$\Delta^b = \frac{2k\left(\epsilon-1\right)\eta^3+\left(5k\epsilon-6k+\epsilon\right)\eta^2+\left(5\epsilon-4k+k\epsilon\right)\eta-A\epsilon+8\epsilon}{2\left(\epsilon+1+\eta\right)\eta\left(2+\eta\right)},$$

$$\Delta^s = \frac{2\eta^3k+\left(7k-1\right)\eta^2+\left(5k-1-2\epsilon\right)\eta+4-4\epsilon-A}{2\left(\epsilon+1+\eta\right)\left(2+\eta\right)},$$

where A is given by

$$\left(\eta\left(4\eta^4k\left(\eta k+5k-1\right)+\left(1-14k+37k^2\right)\eta^3+\left(2-24k+38k^2\right)\eta^2+\left(9-62k+25k^2\right)\eta+48-80k\right)+64\right)^{\frac{1}{2}}.$$

From visual inspection, it is easy to check that also with unbalanced trading pattern, equilibrium platforms profits, price levels and price differentials are not affected by the degree of intra-platform competition, β and σ. The immunisation role of the interchange fee perfectly applies in this case as well.

[19] Clearly, G and G' must be recomputed. The proof of this Corollary proceeds in the same way as the proof of Proposition 3. For the sake of brevity we omit this proof but we make it available on request.

An interesting interpretation of Corollary 3 relates to the assumption, maintained so far, of "no multihoming". According to this assumption, each buyer/merchant can join only one platform. In reality, multihoming is often observed, especially on the merchants' side of the market where shops and retailers frequently accept more than one card. Introducing multihoming into the model may be done at the cost of increased complexity; nevertheless, Corollary 3 may help understanding of what may happen in this case.

Multihoming impacts on the trading pattern, i.e. the amount of transactions that occurs on the two platforms. Corollary 3 suggests that our main results are still valid also when multihoming is allowed, provided that the number of transactions on each platform is positively related to the number of buyers and sellers having adopted that platform. In other words, the level of adoption of the two cards on the two sides of the market is not relevant in our model, but rather the number of transactions occurring between buyers and sellers. Corollary 3 extends Proposition 3 to a fairly general transaction pattern; hence it provides an indirect intuition for the validity of the model to the presence of multihoming on the two sides of the market.

4.2 The model with network effects

In this subsection we reintroduce cross-network effects at the individual level for buyers and sellers. The utility functions are those given in Sections 2.3 and 2.4 and we assume a linear specification for the network effects: $v^b(M_i) = rM_i$ and $v^s(C_i) = vC_i$, with $i = 1, 2$, where the constant positive parameters r and v measure the strength of network effects.

The timing of the game remains unchanged. For each set of expectations, which we assume to be identical for all buyers and sellers, there is a corresponding equilibrium; the one we consider is derived by imposing fulfilled expectations, where the expected size of each side of the market is equal to the actual one.

Buyers' and sellers' demand functions with network effects are:

$$d_1 = \frac{1}{2} + \frac{p_2^b - p_1^b - v(M_1 - M_2)}{2\,k},$$

$$m_1 = \frac{1}{2} + \frac{p_2^s - p_1^s - r(D_1 - D_2)}{2\,t},$$

$$d_2 = 1 - d_1, \qquad m_2 = 1 - m_1.$$

For the sake of simplicity, here we consider only the case of symmetric inter-platform competition, $k = t = 1$; in this simplified scenario, it is possible to prove the following corollary:

Corollary 4. *Proposition 3 holds also with linear cross-network effects of the form* $v^b(M_i) = rM_i$ *and* $v^s(D_i) = vD_i$*, with* $i = 1, 2$*, and* $v, r > 0$.[20]

The optimal interchange fee is then derived as above and is given by:

$$a^{opt} = \frac{(\sigma - 1)c_A + (\beta - 1)c_I}{\beta - \sigma} + \frac{12 - 3(r + v)}{(\beta - \sigma)(2(r + v) - 9)}. \tag{18}$$

Clearly, for $v = 0$, $r = 0$, the above expression is equivalent to (15) with $k = 1$. Proposition 3 holds, with the two conditions that ensure an interior solution appropriately modified.[21] As in the previous case, price levels, price differences and platform profits are independent of the degree of intra-platform competition. It can be shown that the equilibrium is characterised by the following:

$$P_1 = c + \frac{3(v + r) - 12}{2(v + r) - 9}, \qquad P_2 = c + \frac{2(v + r) - 10}{2(v + r) - 9},$$

$$\Delta^b = \frac{v - 1}{2(v + r) - 9}, \qquad \Delta^s = \frac{r - 1}{2(v + r) - 9},$$

$$\pi_1 = 3\left(\frac{v + r - 4}{2(v + r) - 9}\right)^3, \qquad \pi_2 = 2\left(\frac{v + r - 5}{2(v + r) - 9}\right)^3.$$

Price levels, price differences and platform profits are instead affected by network effects. It actually turns out that network effects play a role similar to that of inter-platform differentiation that we have already discussed. Intra-platform competition is not affected by the presence of network effects and, therefore, the immunisation result derived in Proposition 3 is still valid.

4.3 The model with endogenous markups

So far, we have proceeded under the assumption that, on platform 1, intra-platform competition results in constant and exogenously given price-cost markups. While a constant margin is consistent with an iso-elastic demand function, in more general cases the price-cost margin also changes with the marginal cost. Since in our model the marginal cost depends on the interchange fee which is endogenously determined, it is interesting to extend the model to the case of endogenous markups.

In a more general framework, when setting the interchange fee, platform 1 takes into account that the per transaction profitability of its member banks also changes. A reasonably

[20] We omit the formal proof of this Corollary. The proof runs along similar lines of those of previous sections. It is, however, available on request.

[21] In this case, $G = G' \equiv 1 + \frac{3(r+v)-12}{(2(r+v)-9)\,c}$.

general pricing rule to represent the relationship between price and marginal cost is to assume the following platform 1 equilibrium prices:

$$p_1^{s*} = \sigma\, c_A + \rho_A a, \quad \text{and} \quad p_1^{b*} = \beta\, c_I - \rho_I a, \tag{19}$$

where $\rho_i > 0$, with $i = I, A$, describes how much of the interchange fee is passed on to consumers and merchants by issuing and acquiring banks.[22]

Note that according to the above expressions, the price-cost markups now become:

$$\frac{p_1^{s*} - (c_A + a)}{p_1^{s*}} = \frac{c_A(\sigma - 1) - a(1 - \rho_A)}{\sigma c_A + \rho_A a} \qquad \text{and} \qquad \frac{p_1^{b*} - (c_I - a)}{p_1^{b*}} = \frac{c_I(\beta - 1) + a(1 - \rho_I)}{\beta c_I - \rho_I a},$$

which clearly do depend on a.

When platform 1 equilibrium prices are described according to expressions (19), it is possible to prove the following:[23]

Corollary 5. *Proposition 3 holds also for platform 1 endogenous price-cost markups.*

As for the general model, the interchange fee is used by platform 1 to balance the two sides of the market, and it therefore perfectly neutralises the impact of different degrees of cost pass-through ρ_I and ρ_A on the two sides of the market. Note that equilibrium platforms profits, price levels and price differentials are exactly the same as in section 3.

5 Conclusions

Our aim has been to shed new light on the determinants and the competitive role of the interchange fees collectively set by members of card associations facing competition by vertically integrated proprietary systems. The previous literature, surveyed in the introduction, has clarified the balancing role of the interchange fee in "getting both sides of the market on board". We show that the interchange fee plays the additional strategic role of making the competitive position of the card association, as opposed to the vertically integrated platform, independent from the conditions of intra-platform competition. When the interchange fee is set so as to maximize the sum of issuers' and acquirers' profits, the equilibrium values of

[22] It is useful to note that the exogenous case is a special case of the endogenous extension: in fact, when $\rho_A = \sigma$ and $\rho_I = \beta$, then we are back to the basic model.

[23] The optimal interchange fee is now: $a^{opt} = \frac{1}{3}\frac{3(\beta-1)c_I + 3(\sigma-1)c_A - 4(k+1) + R}{\rho_I - \rho_A}$. Clearly, G and G' must be recomputed. The proof of this Corollary goes the same way as the proof of Proposition 3. For the sake of brevity we omit this proof but we make it available on request.

platforms' profits, price levels and their market shares are independent of the competitive conditions within members and are affected by the strength of inter-platform competition.

Variations in the strength of competition, both inter and intra-platform, affect the level of the optimal interchange fee. An increase in the level of intra-platform competition, generated either on the issuers' or the acquirers' side, induces a change in the optimal interchange fee that increases the price of the less competitive side. This implies that if, for example, the acquirers' side is less competitive than the issuers' side, a further increase in competition on the issuing side will lead to an increase in the optimal interchange fee.

If inter-platform competition is not too asymmetric on the two sides, changes in its level produce the same effects on the optimal level of the interchange fee as those discussed above for intra-platform competition. Finally, we have shown that the privately set interchange fee is socially inefficient and that a welfare optimizing regulator would set the interchange so as to minimise the price on the less competitive side of the market.

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Appendix.

Proof. of Corollary 1. Suppose that $\beta > \sigma$. In this case, platform 2 profits decrease with a; for an interchange fee above a certain level, platform 2 makes negative profits (foreclosure). From (14) it is easy to see that $\pi_2 \leq 0$ if

$$a \geq \frac{k+1+(\beta-1)c_I+(\sigma-1)c_A}{\beta-\sigma}.$$

Clearly, this level of the interchange fee cannot be fixed by platform 1 since it is always greater than c_I. Similar arguments can be applied when $\sigma > \beta$; in this case the level of the interchange fee which forecloses the market is always lower than $-c_A$ and cannot be chosen by platform 1. □

Proof. of Proposition 2. The solution to the unconstrained maximization problem is given by a^{opt}. The second order condition evaluated at $a = a^{opt}$ is:

$$\left.\frac{d^2\pi_1}{da^2}\right|_{a\,=\,a^{opt}} = -\frac{(\beta-\sigma)^2 R}{18k} < 0\ ,$$

and it is clearly satisfied for all values of k. To complete the proof we need to verify *i*) under what conditions the constraints are satisfied and *ii*) the optimality conditions at the corners. Let us start with *i*) and assume that $\sigma > \beta$; we need to check when $a^{opt} < c_I$ and $a^{opt} > -c_A$. The first inequality holds for: $\sigma > G$, the second condition requires $\beta < G$. When one of the two is violated, the corresponding constraint is binding. When $\beta > \sigma$ matters are reversed.
In order to check the optimality conditions at the corners, use (13) to compute platform 1 profits when $a = -c_A$, $a = c_I$ and $a = a^{opt}$:

$$\pi_1(-c_A) = (\beta-1)\,c\frac{[(\beta-1)\,c-5k+1]\,[(\beta-1)\,c-5+k]}{36k},$$

$$\pi_1(c_I) = (\sigma-1)\,c\frac{[(\sigma-1)\,c-5k+1]\,[(\sigma-1)\,c-5+k]}{36k},$$

$$\pi_1(a^{opt}) = \frac{(R-4(k+1))\,(11k-7+R)\,(7k-11-R)}{972k}.$$

Start from $\sigma > \beta$; it can be verified that in this case $\pi_1(c_I) > \pi_1(-c_A)$. Therefore we need to contrast $\pi_1(c_I)$ *vs* $\pi_1(a^{opt})$; simple calculations show that for $\sigma > G'$ the profits of platform 1 are higher at the corner ($a = c_I$) than when setting $a = a^{opt}$. Similar, but reversed, arguments apply when $\beta > \sigma$. □

Proof. of Proposition 3. The proof is very straightforward. Using (15) into the expressions for price levels P_j, gives the following:

$$P_1 = c + \frac{4(k+1)-R}{3} \qquad \text{and} \qquad P_2 = c + \frac{7(k+1)-R}{9},$$

which show that the price levels are constant margins above total costs.

Equilibrium price differentials are:

$$\Delta^b = \frac{7-2k-R}{9} \qquad \text{and} \qquad \Delta^s = \frac{7k-2-R}{9}.$$

Finally equilibrium platform profits (13) and (14) become:

$$\pi_1 = \frac{(R-4(k+1))(11k-7+R)(7k-11-R)}{972k}, \quad \text{and} \quad \pi_2 = \frac{(7(k+1)-R)^3}{2916k}.$$

As for quantities, the result follows straightforwardly from what we have already shown. □

Proof. of Corollary 2. Claim 1) is clear from (15). To show claim 2i) differentiate a^* with respect to σ and β and get:

$$\frac{da^*}{d\sigma} = \frac{c_I - a^*}{\beta - \sigma} \quad \text{and} \quad \frac{da^*}{d\beta} = \frac{c_A + a^*}{\beta - \sigma}.$$

It turns out that the numerator is positive in both cases so that the sign of the derivative is given by the sign of denominator.

Claim 2ii) is proved by taking the derivative of a^* with respect to k:

$$\frac{da^*}{dk} = \frac{1}{3(\sigma-\beta)}\left[4 + \frac{23-31k}{R}\right].$$

The term in square brackets is positive (negative) for $k < 1.43$ ($k > 1.43$). Therefore the sign of the derivative is given by the sign of $(\sigma - \beta)$ if $k < 1.43$ and by the opposite sign otherwise. □

Proof. of Proposition 4. Using the various definitions of consumer surplus and the second stage platform profits given in expressions (13) and (14), it is possible to derive the welfare as a function of the interchange fee:

$$\begin{aligned} W(a) \quad = \quad & \frac{(\sigma-1)^3 c_A^3}{27k} + \frac{(\beta-1)^3 c_I^3}{27k} + \frac{(\sigma-1)^2 c_A^2}{18k}(2(\beta-1)c_I + 2(\sigma-\beta)a - k - 1) \\ & + \frac{(\beta-1)^2 c_I^2}{18k}(2(\sigma-\beta)a - k - 1) + \frac{M(a)}{54k}c_A + \frac{J(a)}{54k}c_I + \frac{X(a)}{54k}, \end{aligned}$$

where:

$$\begin{aligned} M(a) \quad &= \quad 6(\beta-1)^2(\sigma-1)c_I^2 + 6(\beta-1)(\sigma-1)((2(\sigma-\beta)a - k - 1)c_I + 6(\sigma-1)(\sigma-\beta)^2a^2 \\ & \quad -6(\sigma-1)(\sigma-\beta)(k+1)a + 3 - 6\sigma k - 48k - 3\sigma k^2 - 3\sigma + 3k^2), \\ J(a) \quad &= \quad 6(\beta-1)(\sigma-\beta)^2a^2 - 6(\beta-1)(\sigma-\beta)(k+1)a - 3\beta - 48k + 3k^2 + 3 - 6\beta k - 3\beta k^2, \\ X(a) \quad &= \quad (\sigma-\beta)(2(\sigma-\beta)^2a^3 - 3(\sigma-\beta)(k+1)a^2 - 3(k+1)^2a) + 2(k^3+1) - 21k(k+1) \\ & \quad +54k(v^b + v^s). \end{aligned}$$

Solving the first order condition it is possible to determine the unconstrained interchange fee that maximises $W(a)$:

$$a^W_{unc} = \frac{2\,(\beta-1)\,c_I + 2\,(\sigma-1)\,c_A + (k+1)\left(\sqrt{3}-1\right)}{2(\beta-\sigma)}$$

Suppose now that $\beta > \sigma$; it is simple to verify that if the regulator were able to maximise welfare without the constraint $a \in [-c_A, c_I]$, it would like to set the interchange fee above c_I: formally $a^W_{unc} > c_I$ which implies that, at the optimum, the constraint is binding at the top and the best the regulator can do is to set $a^W = c_I$. In addition, when evaluating the level of welfare at the two extremes of the range of admissible values of the interchange fee, it is possible to verify that $W(c_I) > W(-c_A)$, which is enough to prove that when $\beta > \sigma$, $a^W = c_I$.

Following a similar procedure, it can be shown that when $\sigma > \beta$, the constraint $a \in [-c_A, c_I]$ is binding at the bottom, and $a^W = -c_A$. $\square$