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# Competition is Bad for Consumers: Analysis of an Artificial Payment Card Market

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[Received July 29, 2010; accepted December 31, 2010]

**This paper investigates the competition between payment card network platforms in an artificial payment card market. In the market, we model the interactions between consumers, merchants, and competing card schemes and obtain their optimal pricing structure. We allow platform operators to charge consumers and merchants with fixed fees, provide net benefits from card usage/acceptance, and engage in marketing activities. We assume that the consumer side exhibits lower demand elasticity. With these settings, we establish that consumers benefit from a reduction of the numbers of competing payment cards through lower fees and higher net benefits, while merchants remain largely unaffected. The two-sided nature of the market leads to the result that having more competitors actually reduces prosperity for customers.**

**Keywords:** two-sided markets, network externalities, agent-based modeling, competition

## 1. Introduction

In many countries, debit and credit cards – as payment cards are more commonly referred to – are replacing cash and cheque payments at a rapid rate and are competing strongly with alternative new payment methods. In terms of relative importance, in Canada and the USA, payment cards are the most commonly used instruments, accounting for 67.41% and 56.67%, respectively, of all registered transactions made in 2008 (see [1]). According to [2] in the European Union, their market share is reported to be 37.68%, which is the highest of all payment methods available, well ahead of direct credits, direct debits, and cheques. Given the prominent growth in the usage of payments cards, the line of research dedicated to study the competitive nature of the payment card market has attracted considerable attention from policy makers [3–5]. We have witnessed recently several regulatory initiatives such as the code of conduct for the credit and debit card

industry in Canada. The aim of the code is to ensure that merchants are fully aware of the costs associated with accepting credit and debit card payments. Furthermore, in order to encourage consumers to choose the lowest-cost payment option, merchants are provided with increased pricing flexibility and are able to freely choose which payment options they will accept.

Another prominent example is the USA financial reform, which, among other regulatory provisions, is aimed at setting up a new bureau in the Federal Reserve to regulate mortgages and credit cards. In addition, the bill also includes a reduction in the fees charged on debit card transactions. Similar efforts to reduce fees charged on debit card transactions are also made from the governments of Australia and Mexico. See [6, 7], for an overview.

The payment card market consists mainly of 6 competitors – Mastercard, Visa, American Express, Discovery, JCB, and Diners Club – where Mastercard and Visa dominate in terms of market share. The competition between these card issuers is not well understood in the academic literature. In this paper, we develop a model of this competition by using an agent-based approach allowing us to introduce complex interactions between the various market participants, which is not easily possible using other modeling approaches. We are able to derive the optimal pricing strategies for payment card issuers and compare them between scenarios with 2, 5, and 9 competing payment cards.

What distinguishes the market for payment cards from most other markets is that it is a two-sided market, i.e., both partners in the transaction – consumers and merchants – using a payment card need a subscription to this specific payment card. Modeling such markets is challenging, as the behavior of market participants is determined by a set of complex interactions between consumers and merchants as well as within the group of consumers and the group of merchants. Consumers and merchants will face network externalities as a larger number of merchants and consumers using a certain card makes the subscription more valuable, and card issuers will also

affect behavior by changing subscription fees and benefits associated with cards. Most models of the payment card market only give cursory consideration to these complex interactions and how they affect competition: the literature focuses on a peculiarity of the payment card market, the so-called interchange fee (see [8–14]). This fee arises as follows: card issuers do not directly issue payment cards to customers but rather allow banks to distribute them in their own name; card issuers only provide a service in form of administering the payments made using these cards. Similarly, merchants have a contract with a bank that allows them to accept payments made using a specific payment card. In the majority of cases, the consumer will have been given his card by one bank, with the merchant having a contract with another bank. In this case, the bank of the merchant will have to pay the bank of the consumer a fee, which is called the interchange fee, for making the payment. Not only is much of the academic literature focus on the interchange fee, it is also the focus of regulators (see [4, 15, 16]).

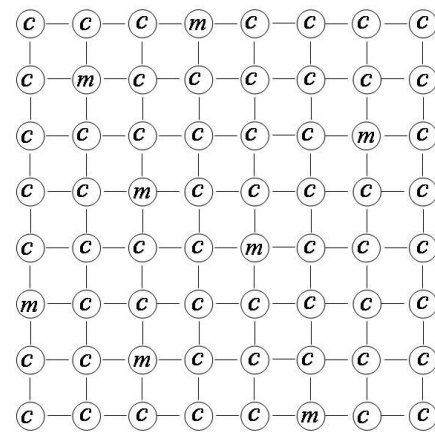
With the focus on the interchange fee, the literature makes a number of very simplifying assumptions on the behavior of consumers and merchants. In contrast, [17] with extensions in [18, 19], developed a multiagent-based model to study the competition among several payment cards. Following this approach, our paper will explicitly model the behavior of consumers and merchants and concentrate on the competition between payment cards to attract subscribers and transactions. We abstract from the interchange fee by implicitly assuming that payment cards are directly issued by card issuers, i.e., neglecting the role of banks in the market. This approach allows us to analyze all of the fees paid by consumers and merchants using payments cards rather than only the interchange fee. This will enable us to gain an understanding of the competitive forces in the payment card market and how the competition between different payment cards affects consumers, merchants, and the payment card issuers themselves. So far, no other paper has been able, to our knowledge, to investigate this issue adequately.

The remainder of this paper is organized as follows: the coming section introduces the artificial payment card market with its elements and interactions, Section 3 then briefly introduces the learning algorithm used to optimize card issuers’ strategies and discusses the parameter constellation used in computer experiments. The results of computer experiments are presented in Section 4, where we focus on the optimal pricing structure by card issuers and how they differ for the case of 2, 5, and 9 competing payment cards. Finally, Section 5 concludes with the findings of this paper.

## 2. The Artificial Market

### 2.1. Model Elements

In this subsection, we formally introduce the three key elements of the model – merchants, consumers, and payment cards – with their attributes.



**Fig. 1.** Sample of a lattice with consumers (*c*) and merchants (*m*).

#### 2.1.1. Merchants

Suppose we have a set of merchants  $\mathcal{M}$  with  $|\mathcal{M}| = N_{\mathcal{M}}$ , who are offering a homogeneous good at a common price and face marginal cost of production lower than this price. With the elimination of price competition among merchants, we can concentrate on the competition among payment card providers and how the card choice affects merchants. The merchants are located at random intersections of a  $N \times N$  lattice, where  $N^2 \gg N_{\mathcal{M}}$ , see **Fig 1**. Let the top and bottom edges as well as the right and left edges of this lattice be connected into a torus.

#### 2.1.2. Consumers

Consumers occupy all the remaining intersections of the above lattice. The set of consumers is denoted  $\mathcal{C}$  with  $|\mathcal{C}| = N_{\mathcal{C}}$ , where  $N_{\mathcal{C}} \gg N_{\mathcal{M}}$  and  $N^2 = N_{\mathcal{C}} + N_{\mathcal{M}}$ . Each consumer has a budget constraint that allows him in each time period to buy exactly one unit of the good offered by the merchants in a single interaction with one merchant. By making this transaction the utility of the consumer increases. In order to obtain the good any consumer  $c \in \mathcal{C}$  has to travel to a merchant  $m \in \mathcal{M}$ . The distance imposes travel costs on consumers, which reduces the attractiveness of visiting a merchant. We have explored the case where the connections among consumers and merchants are local and the distance travelled by a consumer  $c$  to a merchant  $m$ , is measured by the “Manhattan distance”  $d_{c,m}$  between the intersections on the lattice. The distance between two neighboring nodes has been normalized to one. We further restrict the consumer to visit only the nearest  $m_c$  merchants and denote by  $\mathcal{M}_c$  the set of merchants a consumer considers going to.

#### 2.1.3. Payment Cards

We consider a set of payment methods  $\mathcal{P}$  with  $|\mathcal{P}| = N_{\mathcal{P}} + 1$  and  $N_{\mathcal{P}} \ll N_{\mathcal{M}}$ . The first payment method is the benchmark and can be interpreted as a cash payment, whereas all other payment forms are card payments. Cash is available to all consumers and accepted by all merchants. For a card payment to occur, the consumer as well

as the merchant must have a subscription to the card in question. We assume that card payments, where possible, are preferred to cash payments by both consumers and merchants. In each time period, a fixed subscription fee of  $F_p \geq 0$  is charged to the consumer and  $\Gamma_p \geq 0$  to the merchant.<sup>1</sup> Cash payments do not require any fees.

For each unit of goods sold using a payment card  $p \in \mathcal{P}$ , a merchant  $m \in \mathcal{M}$  receives net benefits of  $\beta_p \in \mathbb{R}$ . Such benefits may include reduced costs from cash handling, and could differ across payment cards, and are assumed to be identical for all merchants for any given card. Note that the benefits  $\beta_p$  could have a negative value. This means that the variable fees paid by the merchant to the card issuer are bigger than the benefits he receives from the same payment card, in which case they can be interpreted as a transaction fee. Cash payments do not provide any net benefits.

Consumers also receive net benefits from paying by card,  $b_p \in \mathbb{R}$ , but no net benefits from cash payments. Here, benefits may arise from delayed payment, insurance coverage, or cash-back options. As with benefits to merchants, benefits to consumers can also be negative and, again, represent a transaction fee.

In addition, the issuer of the payment card has to decide how much he should spend on marketing effort  $l_p \geq 0$  in order to increase awareness by consumers and merchants of the payment card that he is providing.

The strategy employed by a payment card issuer is defined as the set of variables controlled by him:  $\mathbb{S} = \{F_p, \Gamma_p, \beta_p, b_p, l_p\}$ . It is this set of variables that we will be optimizing for payment cards in Section 4.

## 2.2. Decision-Making by Market Participants

Decisions by market participants are arrived at through interactions with each other. This section sets out how these interactions drive decisions by consumers and merchants. Decisions on strategies chosen by card issuers are considered in Sections 3 and 4.

### 2.2.1. Decisions by Consumers

Consumers face three important decisions: which merchant to choose, which payment card to use in the transaction with the merchant, and which payment cards to subscribe to. This section addresses each of these decisions in turn.

*The consumers' choice of a merchant:* We assume that when deciding which merchant to visit, the consumer has not yet decided which of the cards he holds will be used. Suppose  $\mathcal{P}_{c,m}$  is the set of cards consumer  $c \in \mathcal{C}$  and merchant  $m \in \mathcal{M}$  have in common and let  $|\mathcal{P}_{c,m}| = N_{\mathcal{P}_{c,m}}$ . The more payment cards the merchant and the consumer have in common, the more attractive a merchant becomes, as the consumer always carries all of his cards with him. Additionally, the smaller the distance  $d_{c,m}$  between the

consumer and the merchant, the more attractive this merchant will be to the consumer. From these deliberations, we propose using a preference function for the consumer to visit the merchant as follows:

$$v_{c,m} = \frac{N_{\mathcal{P}_{c,m}}}{d_{c,m}} \cdot \frac{N_{\mathcal{P}_{c,m'}}}{\sum_{m' \in \mathcal{M}_c} \frac{N_{\mathcal{P}_{c,m'}}}{d_{c,m'}}} \quad (1)$$

Each consumer  $c \in \mathcal{C}$  chooses a merchant  $m \in \mathcal{M}$  with probability  $v_{c,m}$  as defined in Eq. (1). Consumers will continuously update their beliefs on the number of common payments they share with a particular merchant by observing the number of common payments to all shops they can visit – i.e., not only those actually visited – as subscriptions change over time in the way introduced below.

*The consumers' choice of a payment card:* The consumer decides which payment card he wants to use with the merchant he has selected. We assume a preferred card choice in which he chooses the card with the highest benefits  $b_p$  from the set  $\mathcal{P}_{c,m}$ ; if there are multiple cards with the highest net benefits, the card is chosen randomly from them. In cases where the merchant does not accept any of the consumer's cards, the transaction is settled using cash payment.<sup>2</sup>

*Consumer subscriptions:* Initially, consumers are allocated payment cards such that each consumer is given a random number of randomly assigned payment cards. Consumers have to decide periodically whether to cancel a subscription to a card they hold and whether to subscribe to new cards. The frequency with which consumers make these decisions is defined by a Poisson distribution with a mean of  $\lambda$  time periods between decisions. For that reason, every consumer  $c \in \mathcal{C}$  keeps track of whether the cards he owns,  $\mathcal{P}_c$ , are accepted by a merchant or not. If a card  $p \in \mathcal{P}_c$  is accepted by the merchant  $m \in \mathcal{M}_c$  he is visiting, the consumer increases the score of the card  $w_{c,p}^-$  by one.<sup>3</sup>

Let  $\mathcal{P}_c$  be the set of consumer payment cards with  $|\mathcal{P}_c| = N_{\mathcal{P}_c}$ . Assume that the consumer cancels his subscription to a card with probability<sup>4</sup>

$$\pi_{c,p}^- = \frac{x_c^- k}{x_c^- k + e^{-\frac{\omega_c^-}{\omega_c}}} \quad (2)$$

where  $\omega_c$  denotes the number of merchants visited and  $x_c^- k$  accounts for the propensity of the consumer to cancel his subscription to the payment card. We define  $k = 1 + F_p + N_{\mathcal{P}_c} + \frac{\epsilon}{\kappa + b_p}$ ,  $\epsilon$  and  $x_c^-$  are constants and  $\kappa$

1. Fixed fees represent the annual fees that consumers/merchants pay in order to have access to the payment card network. In some countries those fees are not charged.

2. Please note that even for a negative  $b_p$  consumers prefer to use payment cards. Without changing the argument we also could associate a large transaction fee with cash payments to justify our previous assumption that card payments are preferred.  
3. Please note that here consumers only take into account the merchant he actually visits. This is in contrast to the decision which merchant he visits where he is aware of the number of common cards for potential merchants.  
4. The probabilities defined in Eqs. (2) and (3) are also affected by the marketing effort of each payment card provider. Its role is explained in Section 2.2.3.

is another constant with the restriction that  $\kappa + b_p > 0$ . A larger value for  $x_c^- k$  implies that for a given number of merchants accepting the card, the consumer is more likely to cancel his subscription. As long as  $x_c^- k < 1$ , we can interpret the influence of this term as the inertia to cancel a subscription. The parameter constellation used below ensures that, with optimized strategies, we find  $x_c^- k < 1$  and obtain the realistic case of inertia in consumers with respect to their changing *status quo*.

The decision to cancel a subscription is also affected by the fees and benefits associated with a payment card. A card becomes more attractive to subscribe to and existing subscriptions are less likely to be cancelled if the fixed fee charged is low and the net benefits from each transaction are high. Furthermore, the more cards a consumer holds, the less attractive it becomes to maintain a subscription as the consumer has many alternative payment cards to use with merchants.

Let  $\mathcal{P}_c^- = \mathcal{P} \setminus \mathcal{P}_c$  denote the set of cards the consumer does not subscribe to, with  $|\mathcal{P}_c^-| = N_{\mathcal{P}_c^-}$ . If the merchant and the consumers have no payment card in common, i.e.,  $\mathcal{P}_{c,m} = \emptyset$ , and the merchant accepts at least one payment card, i.e.,  $\mathcal{P}_m \neq \emptyset$ , the consumer increases the score  $\omega_{c,p}^+$  by one for all  $p \in \mathcal{P}_m \cap \mathcal{P}_c^-$ .

With  $x_c^+$  a constant, the probability of subscribing to a card not currently held by the consumer is then determined by

$$\pi_{c,p}^+ = \frac{e^{\frac{\omega_{c,p}^+}{\omega_c}}}{x_c^+ k + e^{\frac{\omega_{c,p}^+}{\omega_c}}} \dots \dots \dots (3)$$

This probability uses the inertia of consumers to subscribe to new cards through the use of  $x_c^+ k$ . A large value for this term implies that consumers are less likely to subscribe to new cards for a given number of merchants accepting the payment card.

2.2.2. Decisions by Merchants

Decisions by merchants are limited to the choice of card subscriptions. Similar to consumers, the frequency with which merchants review their subscriptions is governed by a Poisson distribution specific to each individual with a common mean of  $\lambda$  time periods, the same as for subscription decisions by consumers. As with consumers, initial subscriptions of merchants are a random number of randomly selected payment cards.

Merchants keep track of all cards presented to them by consumers. Every time a card  $p \in \mathcal{P}$  is presented to the merchant  $m \in \mathcal{M}$  and he has a subscription to this card, i.e.,  $p \in \mathcal{P}_m$ , he increases the score of  $\theta_{m,p}^-$  by one. With  $|\mathcal{P}_m| = N_{\mathcal{P}_m}$  the probability of cancelling this subscription<sup>5</sup> is given by

$$\pi_{m,p}^- = \frac{x_m^- q}{x_m^- q + e^{\frac{\theta_{m,p}^-}{\theta_m}}} \dots \dots \dots (4)$$

5. The probabilities defined in Eqs. (4) and (5) are also affected by the marketing effort of each payment card provider. Its role is explained in Section 2.2.3.

where  $\mu_m$  denotes the number of cards presented and  $x_m^- q$  represents the propensity to cancel the subscription similar to that of consumers, with  $x_m^-$  being a constant and  $q = 1 + \Gamma_p + N_{\mathcal{P}_m} + \frac{\epsilon}{\kappa + \beta_p}$ .  $\kappa$  takes the same value as for consumers and has to fulfill the additional restriction that  $\kappa + \beta_p > 0$ . The interpretation of the term  $x_m^- q$  follows the same lines as for consumers and parameter setting ensures inertia by merchants to cancel their subscriptions with optimized payment card strategies.

Similarly, if the merchant does not have a subscription to the card, i.e.,  $p \in \mathcal{P}_m^-$ , the score of  $\theta_{m,p}^+$  is increased by one and the probability of subscribing to a card is given by

$$\pi_{m,p}^+ = \frac{e^{\frac{\theta_{m,p}^+}{\theta_m}}}{x_m^+ q + e^{\frac{\theta_{m,p}^+}{\theta_m}}} \dots \dots \dots (5)$$

where once again,  $x_m^+$  is a constant.

2.2.3. Decisions by Card Issuers

Card issuers have to decide on all variables in their strategy space  $\mathbb{S}$ , i.e., decide on the fees and net benefits of consumers and merchants as well as marketing expenses. While optimizing these variables will be the main subject of the following sections, we want to determine the impact that these variables have on the profits of card issuers as well as the impact of the marketing effort on decisions by consumers and merchants.

The total profit  $\Phi_p$  of a card issuer is calculated applying the following equation:

$$\Phi_p = \Phi_{\mathcal{C}_p} + \Phi_{\mathcal{M}_p} - \mathcal{L}_p, \dots \dots \dots (6)$$

where  $\Phi_{\mathcal{C}_p}$  are the profits received from consumers and  $\Phi_{\mathcal{M}_p}$  those from merchants. These profits are given by

$$\Phi_{\mathcal{C}_p} = \sum_{t=1}^I N_{t,\mathcal{C}_p} F_p - \sum_{t=1}^I N_{t,T_p} b_p, \dots \dots \dots (7)$$

$$\Phi_{\mathcal{M}_p} = \sum_{t=1}^I N_{t,\mathcal{M}_p} \Gamma_p - \sum_{t=1}^I N_{t,T_p} \beta_p, \dots \dots \dots (8)$$

where the additional index  $t$  denotes the time period,  $I$  the number of time periods considered by the card issuer, and  $N_{T_p}$  the number of transactions using card  $p$ . Fees and net benefits set by card issuers will affect the number of subscriptions and transactions using a card, which then determine the profits for card issuers. We have thus established a feedback link between the behavior of card issuers on the one hand and consumers and merchants on the other hand.

The sum of all publicity cost is denoted  $\mathcal{L}_p$  and is calculated as

$$\mathcal{L}_p = \sum_{t=1}^I l_p = \Pi_p, \dots \dots \dots (9)$$

where  $l_p$  denotes the publicity costs for each time period, which we assume to be constant.

These publicity costs now affect the probabilities with

which consumers and merchants maintain their subscriptions and subscribe to new cards. The probabilities, as defined in Eq. (2)–(5), are adjusted due to these publicity costs as follows:

$$\xi = \tau\pi(1 - \pi) \dots \dots \dots (10)$$

where  $\pi$  represents  $\pi_{c,p}^+, \pi_{c,p}^-, \pi_{m,p}^+$ , or  $\pi_{m,p}^-$ , as appropriate, and  $\tau = \alpha(\varphi - e^{-l_p})$ .

Constants  $\alpha$  and  $\varphi$  are chosen such that the constraint  $0 \leq \pi + \xi \leq 1$  is satisfied. Revised probabilities used by consumers and merchants are then given by  $\pi' = \pi + \xi$ .

Card issuers now seek to maximize their market share as measured through the number of transactions conducted by optimally choosing their strategies. The way this optimization is accomplished by card issuers is discussed in the coming section.

### 3. Set-Up of Computer Experiments

The above model is implemented computationally and the optimization of strategies chosen by card issuers is conducted using machine learning techniques.

#### 3.1. The Optimization Procedure of Card Issuers

Card issuers determine their optimal strategies using a Generalized Population-Based Incremental Learning algorithm (GPBIL) as introduced in [20] and extended by [21]. This algorithm divides the domain of a variable  $x[a; b]$  into  $n$  subdomains  $a \leq a_1 < a_2 < \dots < a_{n-1} < a_n \leq b$ . We can now define subintervals as  $\left[ a; \frac{a_1+a_2}{2} \right), \left[ \frac{a_1+a_2}{2}; \frac{a_2+a_3}{2} \right), \dots, \left[ \frac{a_{i-1}+a_i}{2}; \frac{a_i+a_{i+1}}{2} \right), \dots, \left[ \frac{a_{n-1}+a_n}{2}; b \right]$ .

Each subinterval is equally likely to be selected, i.e., with probability  $1/n$ . The algorithm changes the location of the parameters  $a_i$  such that subintervals with the best performance are selected with a higher likelihood. This learning is achieved through a positive and negative feedback mechanism. Suppose we have a value of  $x$  in  $[a; b]$ ; we can then determine the new value of  $a_i$  with the help of  $a_j$ , the value closest to  $x$ . If the outcome associated with  $x$  is positive, we then determine the updated  $\hat{a}_i$  as follows:

$$\hat{a}_i = a_i + \zeta v_x h_\delta(i, j)(x - a_i), \dots \dots \dots (11)$$

where  $\zeta$  denotes the learning rate, the role of  $v_x$  is explained below, and

$$h_\delta(i, j) = \begin{cases} 1 & \text{if } |i - j| \leq \delta \\ 0 & \text{if } |i - j| > \delta \end{cases} \dots \dots \dots (12)$$

denotes the neighborhood in which learning occurs, where  $\delta$  denotes the cylinder size of the kernel. This ensures that values close to  $x$  get chosen more frequently. In the case of a negative outcome, we want values on either side of  $x$  to be chosen less frequently and therefore use the

**Table 1.** Domains of the strategy variables.

| Description                       | Symbol     | Value range |
|-----------------------------------|------------|-------------|
| Consumer fixed fee                | $F_p$      | [0; 10]     |
| Merchant fixed fee                | $\Gamma_p$ | [0; 10]     |
| Net benefits of consumers         | $b_p$      | [-1; 1]     |
| Net benefits of merchants         | $\beta_p$  | [-1; 1]     |
| Publicity costs                   | $l_p$      | [0; 20]     |
| Number of subintervals            | $n$        | 5           |
| Learning rate                     | $\zeta$    | 0.1         |
| Kernel size for positive outcomes | $\delta$   | 2           |
| Kernel size for negative outcomes | $\delta'$  | 1           |

**Table 2.** Parameter settings.

| Description  | Symbol            | Value      |
|--|-------------------|------------|
| Network size   | $N$               | 35         |
| Number of consumers  | $N_c$             | 1100       |
| Number of merchants  | $N_m$             | 125        |
| Number of payment cards                                    | $N_{\mathcal{P}}$ | 2, 5 and 9 |
| Number of merchants considered by each consumer            | $N_{m,c}$         | 5          |
| Inertia/propensity with respect to net benefits            | $\epsilon$        | 1          |
| Inertia/propensity with respect to net benefits            | $\kappa$          | 1.1        |
| Propensity of consumers to cancel their subscriptions      | $x_c^-$           | 0.05       |
| Inertia with respect to consumers making new subscriptions | $x_c^+$           | 2          |
| Propensity of consumers to cancel their subscriptions      | $x_m^-$           | 0.05       |
| Inertia with respect to merchants making new subscriptions | $x_m^+$           | 9          |
| Size of the probability adjustment due to marketing effort | $\alpha$          | 0.1        |
| Size of the probability adjustment due to marketing effort | $\varphi$         | 0.05       |
| Expected time between subscription decisions               | $\lambda$         | 20         |
| Number of time steps                                       | $T$               | 20000      |

following rule on updating the values of  $a_i$ :

$$\hat{a}_i = \begin{cases} a_i + \zeta v_x h_{\delta'}(i, j)(a_{i-\delta'} - a_i) & \text{if } a_i \leq x \\ a_i + \zeta v_x h_{\delta'}(i, j)(a_{i+\delta'} - a_i) & \text{if } a_i > x \end{cases} \quad (13)$$

If  $a_{i-\delta'}$  and  $a_{i+\delta'}$  are not defined, we set them as  $a$  and  $b$ , respectively. In our model, a positive outcome is achieved if the market share of the payment card as determined by the number of transactions using the payment card is higher than the average market share, i.e.,  $1/N_{\mathcal{P}}$ ; otherwise, it is regarded as a negative outcome.

Once it has been determined whether an outcome is positive or negative from its market share, positive and negative outcomes are put in ascending order according to profits achieved from the strategy. The position of a strategy  $x$  determines its weight in the updating of values through  $v_x$ . If we denote by  $\phi$  the number of positive or negative outcomes, respectively, and by  $1 \leq \rho(x) \leq \phi$  the position, we define  $v_x = \rho(x)/\phi$ .

The domain of strategy variables as well as parameters of the learning algorithm are shown in **Table 1**.

#### 3.2. Parameter Constellations Investigated

The model is characterized by a large number of free parameters, which need to be externally fixed in experiments. **Table 2** provides an overview of the values chosen for further analysis. In [22], a detailed study of a wide

**Table 3.** Optimized payment card strategies in 10 experiments for the case of 9 competing payment cards. The results denote the converged strategies of all payment cards during the last 100 time steps.

| Experiment | Consumer fixed fee | Merchant fixed fee | Consumer net benefits | Merchant net benefits | Marketing costs | Total profits |
|------------|--------------------|--------------------|-----------------------|-----------------------|-----------------|---------------|
| 1          | 7.57               | 0.00               | -1.00                 | -1.00                 | 11.11           | 6,048,995.23  |
| 2          | 5.33               | 0.00               | -1.00                 | -1.00                 | 7.66            | 5,275,214.86  |
| 3          | 3.51               | 0.00               | 1.00                  | -1.00                 | 11.81           | 3,204,527.52  |
| 4          | 6.03               | 0.00               | 0.48                  | -1.00                 | 11.82           | 4,356,514.63  |
| 5          | 5.46               | 0.00               | -1.00                 | -1.00                 | 10.49           | 5,333,885.81  |
| 6          | 6.03               | 0.00               | -1.00                 | -1.00                 | 13.85           | 5,562,761.79  |
| 7          | 5.98               | 0.00               | -1.00                 | -1.00                 | 8.39            | 5,551,276.47  |
| 8          | 6.48               | 0.00               | -1.00                 | -1.00                 | 9.97            | 5,738,453.78  |
| 9          | 5.38               | 0.00               | -1.00                 | -1.00                 | 10.24           | 5,299,438.88  |
| 10         | 5.66               | 0.00               | -1.00                 | -1.00                 | 10.82           | 5,423,793.36  |
| Mean       | 5.75               | 0.00               | -0.65                 | -1.00                 | 10.62           | 5,179,486.23  |
| Median     | 5.85               | 0.00               | -1.00                 | -1.00                 | 10.66           | 5,378,839.59  |

**Table 4.** Optimized payment card strategies in 10 experiments for the case of 5 competing payment cards. The results denote the converged strategies of all payment cards during the last 100 time steps.

| Experiment | Consumer fixed fee | Merchant fixed fee | Consumer net benefits | Merchant net benefits | Marketing costs | Total profits |
|------------|--------------------|--------------------|-----------------------|-----------------------|-----------------|---------------|
| 1          | 0.07               | 0.00               | 1.00                  | -1.00                 | 7.81            | 83,193.46     |
| 2          | 3.33               | 0.00               | 0.43                  | -1.00                 | 9.52            | 4,030,092.77  |
| 3          | 4.21               | 0.00               | 0.53                  | -1.00                 | 10.56           | 4,527,125.71  |
| 4          | 0.00               | 0.00               | 1.00                  | -1.00                 | 2.23            | -5,576.79     |
| 5          | 1.40               | 0.00               | 0.37                  | -1.00                 | 8.74            | 2,202,551.73  |
| 6          | 3.82               | 0.00               | 0.78                  | -1.00                 | 10.83           | 4,213,727.65  |
| 7          | 0.00               | 0.93               | 0.10                  | -1.00                 | 8.75            | 561,356.43    |
| 8          | 3.71               | 0.00               | 0.61                  | -1.00                 | 10.64           | 4,210,577.77  |
| 9          | 0.37               | 0.00               | 0.71                  | -1.00                 | 8.64            | 706,220.40    |
| 10         | 0.00               | 0.00               | 0.57                  | -1.00                 | 7.17            | 203,547.22    |
| Mean       | 1.69               | 0.09               | 0.61                  | -1.00                 | 8.49            | 2,073,281.64  |
| Median     | 0.89               | 0.00               | 0.66                  | -1.00                 | 8.75            | 1,454,386.07  |

range of parameter constellations has shown that the results related to the interaction among consumers and merchants need not be set very sensitively to these values, and we can thus treat them as qualitatively representative examples for the remainder of this discussion. In their study, even with different nomenclature, the authors model the decisions by consumers and merchants to add/cancel a card subscription using the same functions that the one used in the present model. In order to make a comparison between these two models, we can say that parameters  $q$  and  $k$  applied in our study, in [22] could be considered as constants set to 1. Furthermore, consumers' inertia parameters  $x_c^-$  and  $x_c^+$  are represented only by one parameter denoted  $a_1$ , which was tested with the integer values in the interval [1; 23]. In addition, merchants' inertia parameters  $x_m^-$  and  $x_m^+$  are denoted by only one parameter  $\alpha_1$ , which was tested with the same integer values. We should acknowledge that, at the current stage, we have not incorporated an empirical calibration of consumer and merchant behavior.

It might be noted that the inertia resulting from net benefits  $\varepsilon$  is relatively small compared to the fixed fee. We can justify this choice by pointing out that consumers and merchants will, in many cases, not be aware of the size of these benefits because they are not commonly recognized, e.g., small charges for overseas usage are hidden in a less favorable exchange rate. Empirical evidence suggests that such hidden charges and benefits are much less relevant than fees directly charged to customers.

It is also for this reason that we limit the domain of net benefits to  $[-1; 1]$  such that we avoid having them become too visible to consumers and merchants in relation to the

fixed fee. In doing so, we willingly accept a possible corner solution in the optimal pricing strategy.

#### 4. Outcomes of Computer Experiments

Using the model of the payment card market as developed in the previous sections, we can now continue to analyze the resulting properties of the market. Using the GP-BIL algorithm as introduced above, we derive the optimal pricing strategy of card issuers. The results of optimization are presented in **Tables 3–5**. We also observe that market shares of all competing payment cards are approximately equal, providing evidence for the effectiveness of the learning algorithm and the convergence of learning.

One striking characteristic of the pricing strategy is that merchants are not charged fixed fees but rather negative net benefits, which we can interpret as a transaction fee. It has been established by [18] that subscriptions by merchants are more sensitive to fixed fees but not much to transaction fees; this observation gives rise to this specific pricing structure for merchants. For consumers, we found a similar result, but with them being less sensitive to the fixed fees than merchants, they are charged a significant fixed fee in order to generate sufficient revenue for payment card issuers. The negative impact of this fixed fee on cancelling subscriptions and new subscriptions is partially offset by a high marketing effort.

By comparing the cases of 5 and 9 payment cards, we can clearly see that in the presence of only 5 cards, consumer fixed fees are significantly lower and they receive positive net benefits. For merchants, we do not observe

**Table 5.** Optimized payment card strategies in 10 experiments for the case of 2 competing payment cards. The results denote the converged strategies of all payment cards during the last 100 time steps.

| Experiment | Consumer fixed fee | Merchant fixed fee | Consumer net benefits | Merchant net benefits | Marketing costs | Total profits |
|------------|--------------------|--------------------|-----------------------|-----------------------|-----------------|---------------|
| 1          | 0.90               | 0.00               | 0.28                  | -1.00                 | 7.64            | 2,564,890.41  |
| 2          | 0.18               | 0.00               | 0.10                  | 0.03                  | 8.13            | 202,368.56    |
| 3          | 0.00               | 0.00               | 0.12                  | -1.00                 | 7.09            | 1,047,601.18  |
| 4          | 0.00               | 0.00               | 0.24                  | -1.00                 | 9.40            | 896,259.56    |
| 5          | 0.00               | 0.00               | 0.12                  | -1.00                 | 4.67            | 1,051,471.54  |
| 6          | 0.00               | 0.00               | -0.18                 | -1.00                 | 6.08            | 1,392,978.45  |
| 7          | 0.00               | 0.00               | 0.05                  | -1.00                 | 5.22            | 1,140,280.84  |
| 8          | 0.00               | 0.00               | -0.42                 | -1.00                 | 6.06            | 1,585,689.79  |
| 9          | 0.00               | 0.00               | 1.00                  | -1.00                 | 9.14            | -22,840.06    |
| 10         | 0.00               | 0.00               | 0.04                  | -1.00                 | 6.25            | 1,145,044.41  |
| Mean       | 0.11               | 0.00               | 0.13                  | -0.90                 | 6.97            | 1,100,374.47  |
| Median     | 0.00               | 0.00               | 0.11                  | -1.00                 | 6.67            | 1,095,876.19  |

any difference in the fees charged to them. Finally, marketing costs are slightly lower in the case of 5 payment cards and total profits made by card issuers are significantly lower. We can conclude from these results that if there exist only 5 cards rather than 9 cards, consumers will benefit through lower fees and higher net benefits and payment card issuers will generate less profit.

We can see that the fixed fee for consumers is reduced significantly more than the net benefits are increased. This result is due to the property of the model established by [18] that consumer subscriptions react more sensitively to fixed fees than net benefits and therefore card issuers change more for this part. The negative impact of the fixed fee on consumer subscriptions is partially offset by marketing efforts; with this fee now reduced, we also observe marketing costs to be diminished.

When we further reduce the number of competing payment cards to only 2, we see that competition benefits consumers even more by virtually eliminating the fixed fee. The observed slight reduction in net benefits is less pronounced than the reduction in the fixed fee. Once again, merchants are not affected by the change in the number of competitors.

Competition for consumers thus increases if we reduce the number of competing payment cards. This result is very surprising at first, as it is commonly assumed that the presence of more competitors increases competition between providers and thus benefits their customers through lower fees and higher benefits, and allows competitors to generate less profit.

This result – counterintuitive on first sight – can be explained with the properties of two-sided markets. Given the requirement that for a successful transaction using a payment card, the consumer as well as the merchant have to subscribe to this specific payment card, we need to achieve a certain degree of coordination between all market participants. If there are fewer payment cards available to consumers and merchants, this coordination of subscriptions becomes easier, given the reduced possibilities for subscriptions. Evidence for the improved coordination of consumers and merchants in their card subscriptions is the observation that cash transactions observed in the presence of 9 cards is about 35%, for 5 cards it is 18%, and for 2 cards only 16%.

It has been shown by [22] that payment cards tend to establish regional monopolies and, with fewer cards, regions held by each card tend to be larger. If a payment card offers more favorable conditions, the reduced number of competitors will then enable card issuers to attract a significant number of new consumers and merchants. The switching of subscriptions is facilitated by easier coordination of consumers and merchants due to fewer cards being available to choose from. It is thereby that competition increases. Most importantly, the number of consumers and revenue generated from them by far exceeds that of merchants and it is for this reason that competition affects the pricing structure for consumers rather than merchants.

We have thus established that due to the two-sided nature of the market for payment cards, a larger number of competitors does not necessarily lead to more competition between them. It may actually be that particular consumers would benefit from fewer competitors in the market through lower fees and higher net benefits; merchants do not seem to be affected by the degree of competition. Optimally, the market should thus have a small number of competitors – even as low as only 2 in the market investigated here – to ensure the best outcome for consumers.

There does exist a small number of similar results in the literature. The most commonly known result is in network industries such as telecommunications. The origin of the results in this class of models is, however, economies of scale, and it is found that the presence of more competitors increases prices. Another example from the literature with the result that more competitors actually reduce competition can be found for market entry games with costly entry fees. More potential entrants might reduce competition among incumbents. See, e.g., [23–25] In our model, however, we have neither economies of scale nor market entries, so the result we obtained is not compatible with those examples from the literature.

It is to be noted, however, that with only a small number of competing payment card issuers, their potential market power could be significant. It can easily be imagined that competitors start to collude in determining their pricing strategy in order to increase their profits at the expense of consumers in particular; such collusion is becoming more and more difficult to sustain as the number of competitors

increases. Even with the possibility of collusion among competitors – which we did not account for in our model – we can conclude that for consumers, a small number of competitors would be the preferred market structure. In the presence of a large number of competitors, consumers would face higher fees.

It would therefore not be in the interest of consumers for market regulators to encourage the entry of additional competitors into the payment card market. Ensuring that no collusion is sustainable in the small number of competitors would benefit consumers most.

We have also compared the performance of optimized strategies in a market populated with otherwise random strategies and found that optimized strategies achieve a significantly higher market share and also outperform random strategies in terms of profits generated. These results provide evidence that the optimization of strategies has indeed produced strategies that are performing superior to randomly generated strategies.

## 5. Conclusions

We have developed an artificial payment card market in which consumers and merchants interact with each other through payment made for purchases. Based on the usage and acceptance of payment cards, merchants and consumers continuously review their subscriptions to payment cards and card issuers seek to maximize their profits by setting optimal fees and marketing efforts. Using the Generalized Population-Based Incremental Learning algorithm (GPBIL) we were able to determine the optimal pricing strategy for card issuers.

Comparing the cases of 2, 5, and 9 competing payment cards, we found most importantly that competition for consumers between payment cards, as evidenced by the fees charged, is highest in the case of 2 payment cards. It was observed that in this case, consumers benefit from lower fixed fees and higher net benefits of card usage, while conditions for merchants remain largely unaffected by the number of competitors and profits for card issuers were significantly lower. Hence, increasing the number of competitors does not necessarily benefit consumers. The reason for this apparently counterintuitive result is the fact that the market for payment cards is a two-sided market and the easier coordination of subscriptions by consumers and merchants in the presence of less choice increases competitive force and generates the described outcome. Our model therefore establishes that from the viewpoint of consumers, it is optimal to have a relatively small number of competing payment card issuers.

We have established a model of the payment card market that allows us to analyze the impact of competition on consumers, merchants, and the card issuers themselves. The model itself offers the possibility for exploring a wide variety of extensions and modifications that would allow further analysis of the competition between payment card issuers, e.g., evaluating the impact that different social network structure among merchants and consumers has

on the outcome, the introduction of interchange fees into the model, or the evaluation of a particular aspect of regulatory initiatives in the market. This aspect could be of particular importance given the interest of policy makers in understanding the competitive nature of the payment card market. Nevertheless, in order to perform a sensitive analysis of the effect of any regulatory intervention in the market, the interaction among consumers and merchants needs to be calibrated with empirical studies. Ideally, having data that gives insights into over-the-counter consumer behavior related to the usage of payment methods could be of particular value in representing interactions among consumers and merchants more realistically at the point of sale.

## References:

- [1] BIS, "Statistics on payment and settlement systems in selected countries – figures for 2007," Report 86, Bank for International Settlements, 2009.
- [2] ECB, "Payment statistics," Report, European Central Bank, 2008.
- [3] J. Vickers, "Public policy and the invisible price: competition law, regulation and the interchange fee," In: Int. Policy Payments Conf. Interchange Fees in Credit and Debit Card Industries. What Role for Public Authorities?, Federal Reserve Bank of Kansas City, pp. 231-247, 2005.
- [4] W. Bolt and S. Chakravorti, "Economics of Payment Cards: A Status Report," DNB Working Paper No.193, De Nederlandsche Bank, 2008.
- [5] S. Weiner, "The federal reserve's role in retail payments: Adapting to a new environment. Economic Review," Federal Reserve Bank of Kansas City Fourth Quarter, pp. 36-63, 2008.
- [6] RBA, "Payments system board annual report," Tech. rep., Reserve Bank of Australia, 2008.
- [7] S. G. Castellanos, R. Medina, A. Mendoza, J. L. Negin, and F. Solis, "The Role of Interchange Fees in Mexico's Retail Payment System: from Theory to Practice," Working paper, Banco de Mexico, 2008.
- [8] D. Evans and R. Schmalensee, "The economics of interchange fees and their regulation: An overview," Working Paper 4548-05, MIT Sloan, 2005.  
<http://ssrn.com/abstract=744705>
- [9] J. Gans and S. King, "A Theoretical Analysis of Credit Card Regulation," Working paper 2002-11, Melbourne Business School, 2002.
- [10] J. C. Rochet and J. Tirole, "Cooperation among competitors: Some economics of payment card associations," RAND J. of Economics Vol.33, No.4, pp. 549-570, 2002.
- [11] J. C. Rochet and J. Tirole, "Tying-in two-sided markets and the honour all cards rule," CEPR Discussion Papers 6132, C.E.P.R. Discussion Papers, 2007.  
<http://ideas.repec.org/p/cpr/ceprdp/6132.html>
- [12] R. Schmalensee, "Payment systems and interchange fees," J. of Industrial Economics, Vol.50, pp. 103-122, 2003.
- [13] J. Wright, "Optimal card payment systems," European Economic Review, Vol.47, pp. 587-612, 2003.
- [14] J. Wright, "Pricing in debit and credit card schemes," Economics Letters, Vol.80, pp. 305-309, 2003.
- [15] D. Cruickshank, "Competition in UK Banking, Report to the Chancellor of the Exchequer," 2000.  
<http://www.bankreview.org.uk>
- [16] S. Chakravorti and R. Roson, "Platform competition in two-sided markets: The case of payment networks," Working Paper, WP-04-09, Federal Reserve Bank of Chicago, 2005.
- [17] B. Alexandrova-Kabadjova, A. Krause, and E. Tsang, "An agent-based model of interactions in the payment card market," Proc. of the 8th Int. Conf. Intelligent Data Engineering and Automated Learning – IDEAL 2007, H. Yin, P. T., E. Corchado, W. Byrne, and X. Yao (Eds.), Vol.4881 of Lecture Notes in Computer Science. University of Birmingham, UK, pp. 1063-1072, 2007.
- [18] B. Alexandrova-Kabadjova, E. Tsang, and A. Krause, "Evolutionary learning of the optimal pricing strategy in an artificial payment card market," Natural Computing in Computational Economics and Finance, Studies in Computational Intelligence, A. Brabazon and M. O'Neill (Eds.), pp. 233-251, 2008.
- [19] B. Alexandrova-Kabadjova, "The impact of the interchange fees on a non-saturated multi-agent payment card market," Intelligent Systems in Accounting, Finance and Management, Vol.16, pp. 33-48, 2009.



- [20] S. Baluja, "Population-based incremental learning: A method for integrating genetic search based function optimization and competitive learning," Working paper CMU-CS-94-163, School of Computer Science, Carnegie Mellon University, 1994.
- [21] M. Kern, "Parameter adaptation in heuristic search: A population-based approach," Ph.D. thesis, Department of Computer Science, University of Essex, 2006.
- [22] B. Alexandrova-Kabadjova, E. Tsang, and A. Krause, "Market structure and information in payment card markets," Int. J. of Automation and Computing, 2011. (to be appeared)
- [23] K. O. Nti, "More potential entrants may lead to less competition," J. of Economics, Vol.49, pp. 47-70, 1989.
- [24] K. O. Nti, "Potential competition and coordination in a market-entry game," J. of Economics, Vol.71, pp. 149-165, 2000.
- [25] W. Elberfeld and E. Wolfstetter, "A dynamic model of bertrand competition with entry," Int. J. of Industrial Organization, Vol.17, pp. 513-525, 1999.



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