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Evolutionary Learning of the Optimal Pricing Strategy in an Artificial Payment Card Market

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Abstract

This paper introduces an artificial payment card market in which we model the interactions between consumers, merchants and competing card issuers with the aim of determining the optimal pricing structure for card issuers. We allow card issuers to charge consumers and merchants with fixed fees, provide net benefits from card usage and engage in marketing activities. The demand by consumers and merchants is only affected by the size of the fixed fees and the optimal pricing structure consists of a sizeable fixed fee to consumers, no fixed fee to merchants, negative net benefits to consumers and merchants as well as high a marketing effort.

Keywords: Two-sided markets, agent-based models, credit cards, debit cards, competition
JEL classification: D40, D83, M31

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1 Introduction

Payment cards - more commonly referred to as credit and debit cards - are of ever increasing importance for making payments. [7] report that in 2002 1.8 billion cards were used to buy products and services worth more than US$ 2.7 trillion with high growth rates since then. Despite the importance of payment cards the competition between the different card issuers, most prominently Mastercard, Visa, American Express, Discovery, JCB and Diners Club, is not well understood. This paper provides a first model of this competition by using an agent-based approach to model the complex interactions between the various market participants which is not easily possible using other modeling approaches. In our model we are able to derive the main driving factors of the demand for payment cards and the profits made by card issuers, as well as derive the optimal pricing strategy.

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 the card makes the subscription more valuable and card issuers will also affect behavior by changing subscription fees and benefits associated with the cards.

Most models of the payment card market only give cursory considerations to these complex interactions and how they affect competition. Most of the literature focuses on a peculiarity of the payment card market, the so called interchange fee, see [1, 2, 4, 3, 5, 7, 6]. 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 do 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 from a 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 for making the payment, which is called the interchange fee. Not only is much of the academic literature focussing on the interchange fee, it is also the focus of regulators, see [8, 9, 10, 11].

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, our paper will explicitly model the behavior of consumers and merchants and focus 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 focus on all the fees paid by consumers and merchants using payments cards rather than only the interchange fee. This will allow us to gain an understanding of the competitive forces in the payment card market and how consumers and merchants are affected by it. So far no other paper is able 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 the card issuers' strategies and discusses the parameter constellation used in the computer experiments. The results of the computer experiments are presented in section 4, where we focus on the demand and profits functions as well as the optimal pricing structure by card issuers. Finally section 5 concludes the findings of this paper.

2 The Artificial Market

In this section we introduce our model of an artificial payment card market by describing in detail the market participants - consumers, merchants and card issuers - and how they arrive at their decisions through interactions with each other.

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.

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 figure 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 traveled by a consumer c to a merchant m, is measured by the "Manhattan distance" $d_{c,m}$ between the intersections on the lattice, where 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 cards $\mathcal{P}$ 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

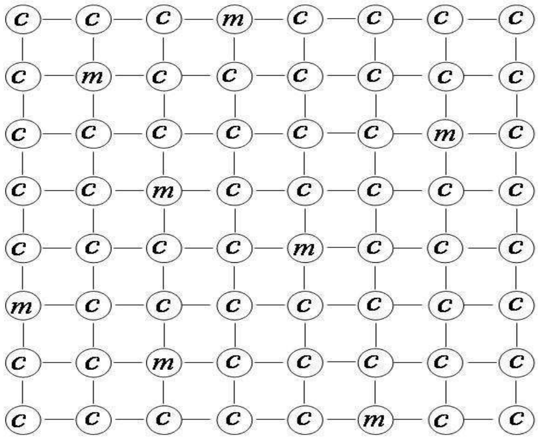

Figure 1: Sample of a lattice with consumers (c) and merchants (m)

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. Cash payments do not attract 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 methods and are assumed to be identical for all merchants for any given card. Note that the benefits β_p could have a negative value. This means that the variable fees paid by the merchant to the card issuer is bigger than the benefits he received from the same payment card in which they can be interpreted as a transaction fee. Cash payments do not provide any benefits.

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

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

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

2.2 Decision-making of 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. The decisions on the 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 to which payment cards to subscribe to.

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 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 to use a preference function for the consumer to visit the merchant as follows:

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

Each consumer $c \in \mathcal{C}$ chooses a merchant $m \in \mathcal{M}$ with probability $v_{c,m}$ as defined in equation (1). The 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 of all shops they can visit - i. e. not only those actually visited - as subscriptions change over time.

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 the merchant does not accept any of the consumers' cards, the transaction is settled using cash payment.[1]

[1]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 negative transaction fee with cash payments to justify our previous assumption that card payments are preferred.

Consumer subscriptions Initially consumers are allocated payment cards such that each consumer is given a random number of randomly assigned payment cards. Periodically consumers have to decide whether to cancel a subscription to a card they hold and whether to subscribe to new cards. The frequency with which consumers take these decisions is defined by a Poisson distribution with a mean of λ 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 the 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 $\omega^-_{c,p}$ by one.[2]

Assume that he cancels his subscription to a card with probability[3] [4]

$$\pi^-_{c,p} = \frac{x^-_c k}{x^-_c k + e^{\frac{\omega^-_{c,p}}{\omega_c}}}, \tag{2}$$

where ω_c denotes the number of merchants visited and $x^-_c k$ accounts for the inertia of the costumer in changing cards. We define $k = 1 + F_p + N_{\mathcal{P}_c} + \frac{\varepsilon}{b_p}$, and ε and x^-_c are constants. A larger value for $x^-_c k$ implies that for a given number of merchants accepting the card, the consumer is less likely to cancel his subscription, but rather maintaining the *status quo.* The decision is also affected by the fees and benefits associated with a payment card. A card becomes more attractive to subscribe and existing subscriptions are less likely to be canceled if the fixed fee charged is low and the net benefits from

[2]Please note that here consumer only takes 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.

[3]The probabilities defined in equations (2) and (3) are also affected by the marketing effort of each payment card provider. Its role is explained in section 2.2.3.

[4]

each transaction are high. Furthermore, the more cards a consumer holds, the more attractive it becomes to hold this card as a wider acceptance in the future can be expected.

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 $p \in \mathcal{P}_m \subset \mathcal{P}_c^-$.

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

$$\pi_{c,p}^+ = \frac{e^{\frac{\omega_{c,p}^+}{\omega_c}}}{x_c^+ k + e^{\frac{\omega_{c,p}^+}{\omega_c}}}. \tag{3}$$

This probability uses the inertia of consumers to subscribe to new cards through the use of $x_c^+ k$ in a similar way to the decision of canceling a subscription as discussed before.

2.2.2 Decisions by merchants

The decisions of 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. As with consumers the 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 canceling this subscription[5] is given by

$$\pi^-_{m,p} = \frac{x^-_m q}{x^-_m q + e^{\frac{\theta^-_{m,p}}{\theta_m}}}, \tag{4}$$

where θ_m denotes the number of cards presented and $x^-_m q$ represents the inertia to changes similar to that of consumers with x^-_m being a constant and $q = 1 + \Gamma_p + N_{\mathcal{P}_m} + \frac{\varepsilon}{\beta_p}$. 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

$$\pi^+_{m,p} = \frac{e^{\frac{\theta^+_{m,p}}{\theta_m}}}{x^+_m q + e^{\frac{\theta^+_{m,p}}{\theta_m}}}, \tag{5}$$

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 the marketing expenses. While optimizing these variables will be the main subject of the following sections, we want to establish the impact these variables have on the objective function of the card issuers as well as the impact of the marketing effort on the decisions of consumers and merchants.

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

The total profit Φ_p of a card issuer is calculated applying the following equation:

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

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

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

$$\Phi_{\mathcal{M}_p} = \sum_{t=1}^{I} N_{t,\mathcal{M}_p} \Gamma_p - \sum_{t=1}^{I} N_{t,I_p} \beta_p, \tag{8}$$

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. The fees and net benefits set by the card issuers will affect the number of subscriptions and transactions using a card, which then determine the profits for the card issuers. Thus we have 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

$$\mathcal{L}_p = \sum_{t=1}^{I} l_p = I l_p, \tag{9}$$

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 equations (2) - (5), are adjusted due to these publicity costs as follows:

$$\xi = \tau\pi\left(1-\pi\right), \tag{10}$$

where π represents , π_c^+, π_c^- , π_m^+ , or π_m^-, as appropriate and $\tau = \alpha\left(\varphi - e^{-l_p}\right)$. The constants α and φ satisfy the constraints $\pi - \xi \geq 0$ and $\pi + \xi \leq 1$. The revised probabilities as used by consumers and merchants are then given by $\pi' = \pi + \xi$.

Card issuers now seek to maximize their total profits by optimally choosing their strategies. The way this optimization is conducted by card issuers is discussed in the coming section.

3 Set-up of the computer experiments

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

3.1 The optimization procedure of card issuers

Card issuers determine their optimal strategies using a Generalized Probability-based Incremental Learning algorithm (GPBIL). This algorithm divides the domain of a variable x, $[a; b]$, into n sub-domains $a \leq a_1 < a_2 < \cdots < a_{n-1} < a_n \leq b$. We can now define subintervals as $\left[a; \frac{a_1+a_2}{2}\right)$, $\left[\frac{a_1+a_2}{2}; \frac{a_2+a_3}{2}\right)$, ..., $\left[\frac{a_{i-1}+a_i}{2}; \frac{a_i+a_{i+1}}{2}\right)$, ... $\left[\frac{a_{n-1}+a_n}{2}; b\right]$.

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

$$\widehat{a}_i = a_i + \zeta h(i, j)(x - a_i), \tag{11}$$

where ζ denotes the learning rate and

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

denotes the neighborhood in which learning occurs. 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 following rule on updating the values of a_i:

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

Table 1: Domains of the strategy variables

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

If $a_{i-\delta}$ or $a_{i+\delta}$ 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. $\frac{1}{N_{\mathcal{P}}}$; otherwise it is regarded as a negative outcome.

The domain of the strategy variables as well as the 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 exogenously fixed in the experiments. Table 2 provides an overview of the values chosen for further analysis. An analysis of a wide range of parameter constellations has shown the results to be not very sensitive to these values and we can thus treat them as qualitatively representative examples for the remainder of the analysis.

It might be noted that the inertia resulting from net benefits, ε, 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 is hidden in a less favorable exchange rate. Empirical evidence also suggest that such hidden charges and benefits are much less relevant than fees directly charged to the customer.

4 Outcomes of the 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. Before evaluating the optimal strategies chosen by payment card issuers, we will assess the resulting demand function for the payment cards by consumers as well as merchants.

4.1 Demand for payment cards

We evaluate the demand for payment cards by assigning each card a random strategy as detailed in table 3. Using these fixed strategies we conduct a single computer experiment from which we estimate the demand function at the end of the experiment; it has to be noted that the results from this single experiment is representative and was confirmed for other random strategies.[6]

[6]It has also been confirmed that the demand for payment card had stabilized considerable time before the end of the experiment.

Description	Symbol	Value
Network size	N	35
Number of consumers	$N_{\mathcal{C}}$	1100
Number of merchants	$N_{\mathcal{M}}$	125
Number of payment cards	$N_{\mathcal{P}}$	10
Number of merchants considered by each consumer	$N_{\mathcal{M}_{\mathcal{C}}}$	5
Inertia with respect to net benefits	ε	1
Inertia with respect to consumers canceling subscriptions	x_c^-	0.05
Inertia with respect to consumers making new subscriptions	x_c^+	2
Inertia with respect to merchants canceling 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	α	0.1
Size of the probability adjustment due to marketing effort	φ	0.05
Expected time between subscription decisions	λ	20
Number of time steps	I	20000

Table 2: Parameter settings

Estimates of the demand for payment cards held by consumers $N_{\mathcal{M}_p}$, merchants $N_{\mathcal{C}_p}$ and the number of transactions N_{T_p} as well as the profits made by the card issuers, Φ_p, are given as follows:

$$\begin{aligned}
\ln N_{\mathcal{C}_p} &= 6.433 - 0.156 F_p, \\
\ln N_{\mathcal{M}_p} &= 4.339 - 0.088 F_p - 0.0222 \Gamma_p, \\
\ln N_{T_p} &= 10.837 - 0.208 F_p - 0.244 \Gamma_p, \\
\ln \Phi_p &= 16.769 + 0.054 F_p - 0.091 \beta_p.
\end{aligned}$$

We only show those strategy variables which were found to have a significant impact on the demand or profits. The equations presented above provide a nearly perfect fit of the data and the coefficients are highly significant. It is interesting to note that the demand is not affected by the net benefits consumers and merchants receive from each transaction; instead the demand is entirely driven by the fixed fees. We also observe a feature of two-sided markets as the demand by merchants depends on both the consumer and merchant fixed fee, where the consumer fixed fee is much more relevant than the merchant fixed fee. The reason for this outcome can be found in the importance of consumer demand and usage for the subscription of merchants. For the transaction demand we observe that both fees are of similar importance.

Interestingly, the profits made by card issuers only depend on the consumers fixed fee and the net benefits given to merchants; the increased revenue of a potential fixed fee to merchants is offset by a reduced usage resulting in its insignificance for the outcome. It has also to be noted that while

Card number	Consumer fixed fee	Merchant fixed fee	Consumer net benefits	Merchant net benefits	Marketing costs
1	3.16	3.95	-0.66	-0.88	0.69
2	6.91	7.36	-0.44	-0.41	8.67
3	6.85	7.61	-0.03	0.23	5.85
4	2.87	7.35	-0.13	0.50	14.98
5	8.00	5.63	0.03	-0.34	1.39
6	2.09	4.22	-0.79	-0.62	13.32
7	2.16	2.59	-0.27	0.15	8.99
8	7.02	6.45	0.47	-0.51	12.04
9	2.42	1.77	0.55	0.41	12.72

Table 3: Random payment card strategies

these outcomes are statistically significant, their economic impact is relatively small, e. g. by increasing the fixed fee for consumers from zero to 10 (the maximum value), the profits would only increase by about 3% and an increase of the net benefits to the merchant from -1 to 1 would decrease the profits only by about 1%. Thus the sensitivity of the profits to these strategies is very low. The demand itself reacts more sensitive with changes of up to 20%.

A final observation is that despite 9 cards being present in the market, the fraction of cash transactions remains high at 46.6%, implying frequent mismatches between the cards subscribed to by consumers and merchants.

Having investigated the demand function for payment cards we can now proceed to evaluate the optimal payment card strategies.

4.2 Optimal payment card strategies

With the total profits of the payment card issuers as the objective function the above results on demand and profits would imply that an optimized strategy should consist of a high fee to consumers and negative net benefits to merchants. At the same time the intermediate assessment of strategies via their market share in the determination of positive and negative outcomes in the learning algorithm would put a limit on the size of the fixed fee to consumers as well as imply a low fixed fee to merchants.

The results of the optimization using the the GPBIL algorithm described in the previous section are presented in table 4. They confirm the assertions made fully. We furthermore observe that the market share of all nine payment cards are approximately equal, providing evidence for the effectiveness of the learning algorithm.

The negative net benefits to consumers and merchants would make the payment cards less attractive to prospective subscribers and make existing subscribers more likely to cancel their subscription while only having a limited influence on the profits of the issuer. This negative effect is, however, offset by the relatively high marketing effort the issuers make; essentially the revenue generated by the negative net benefits is used for marketing purposes. Hence the negative impact on the payment card switching behavior by applying negative net benefits is offset by marketing activities. We also observe a weak positive relationship between the size of the fixed fee to consumers and the marketing costs, providing further evidence for an offsetting relationship between these costs charged to users and marketing efforts.

The high marketing costs by card issuers provide a good example how market participants can get locked into certain strategies by competitive pressures, although they are not beneficial to them and even detrimental to other market participants. Once a card issuer decides to increase its marketing effort, his competitors will have to follow to avoid loosing market share. To offset the incurred costs those fees to which market participants react least sensitively are likely to increased, which in our case are the net benefits to consumers and merchants.

We have also compared the performance of the optimized strategies in a market populated with otherwise random strategies and find that the optimized strategies achieve a significantly higher market share and also outperform the random strategies in term of profits generated. This results provides evidence that the optimization of the strategies has indeed produced strategies

Card number	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

Table 4: Optimized payment card strategies in 10 experiments. The results denote the converged strategies of all payment cards during the last 100 time steps.

that are performing superior to randomly generated strategies.

5 Conclusions

We have developed an artificial payment card market in which consumers and merchants are interacting with each other through payments made for purchases. Based on the usage and acceptance of payment cards, merchants and consumers continuously review their subscription to payment cards and card issuers seek to maximize their profits by setting optimal fees and marketing efforts. Evaluating such a model we were able to derive the demand function for payment cards as well as the profit function of card issuers, observing that most importantly the fixed fees charged by the card issuers drive demand and profits.

The optimized strategies of payment card issuers are characterized by a relative high fixed fee to consumers, no fixed fee to merchants as well as large negative net benefits (i. e. a transaction fee) to consumers and merchants alike and high marketing costs. Such a fee structure with high fixed and transaction fees to consumers can be observed in many markets where substantial annual fees are charged along transaction fees in the form of higher-than-usual interest on purchases or fees on the use of payment cards overseas. Similarly merchants pay a considerable fee for each transaction while not being charged a fixed fee. These characteristics are replicated in our model, along with the high marketing costs card issuers often face.

For the first time in the literature we have been able to reproduce realistic properties of the payment card market with our model. While our model can be extended in a wide range of manners, e. g. by using different numbers of competitors, different physical locations of merchants and consumers to name only two possibilities, it provides a first foundation for the analysis of this market which does not limit itself to the interchange fee between different card issuers as commonly done in the literature.

References

[1] Richard Schmalensee. Payment systems and interchange fees. *Journal of Industrial Economics*, 50:103–122, 2002.

[2] Jean-Charles Rochet and Jean Tirole. Cooperation among competitors: Some economics of payment card associations. *The RAND Journal of Economics*, 33:1–22, 2002.

[3] Julian Wright. Optimal card payment systems. *European Economic Review*, 47:587–612, 2003.

[4] Joshua Gans and Stephen King. A Theoretical Analysis of Credit Card Regulation. Working paper 2002-11, Melbourne Business School, 2002.

[5] Julian Wright. Pricing in debit and credit card schemes. *Economics Letters*, 80:305–309, 2003.

[6] Jean Charles Rochet and Jean Tirole. Tying-in two-sided markets and the honour all cards rule. CEPR Discussion Papers 6132, C.E.P.R. Discussion Papers, February 2007. available at http://ideas.repec.org/p/cpr/ceprdp/6132.html.

[7] David S. Evans and Richard Schmalensee. *Paying with Plastic: The*

Digital Revolution in Buying and Borrowing. MIT Press, second edition, 2003.

[8] Don Cruichshank. *Competition in UK Banking. Report to the Chancellor of the Exchequer.* http://www.bankreview.org.uk, March 2000.

[9] Sujit Chakravorti. A theory of creidt card networks: A survey of the literature. *Review of Network Economics*, 2:50–68, June 2003.

[10] Federal Reserve System. The 2004 Federal Reserve Payments Study: Analysis of Noncash Payments Trends in the United States: 2000 - 2003. Technical report, Federal Reserve System, December 2004.

[11] Commission of the European Communities. Communication from the Commission - Sector Inquiry under Art 17 of Regularion 1/2003 in retail banking (Final Report). Technical report, Commission of the European Communities, January 2007.