What drives the network's growth? An agent-based study of the payment card market*

Biliana Alexandrova-Kabadjova† José Luis Negrín ‡

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Abstract

This paper investigates the impact of three factors on the network growth: the level of merchant discount, the level of Multilateral Interchange Fee (*MIF*), and the consumers' and the merchants' awareness of positive network externalities. In order to model the impact of the positive network externalities, we assume that consumers are aware of the existence of merchants accepting cards, whereas merchants are aware of the existence of consumers having cards. We simulate explicitly the interactions between consumers and merchants at the point of sale, where issuers and acquirers belong to the same network. We allow card issuers to charge consumers with fixed fees and provide net benefits from card usage, whereas acquirers could charge fixed and a transactional discount to the merchants *MD*. The *MIF* flows from acquirers to issuers. In this artificial environment given that merchants have homogeneous convenience benefits, consumers have homogeneous transactional and convenience benefits, we have first simulated a market in which acquirers charge the same *MD*. In this case we have

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†General Direction of Central Banking Operations, Banco de Mexico, E-Mail: balexandrova@banxico.org.mx

‡General Direction of Financial Sector Analysis, Banco de Mexico, E-Mail: jlnegrin@banxico.org.mx

found, similar to the theoretical literature, that there is a maximum level of merchant discount MD' above which there will be not card transactions in the market. In a different scenario, we allow acquirers to charge different levels of MD and we test this scenario under different MIF and different levels of end-users' awareness. The investigated effects are analyzed over the complete process of adoption. In the case of higher end-users' awareness we found that if the level of MIF is getting close to the MD' there are acquirers that charged MD higher than the MD' and in this case a network growth is observed in the market, but the level of growth is considerably lower than the growth achieved in the first scenario.

1 Introduction

The growing importance of credit and debit card as payment instruments has increased the interest in studying the complex structure of the payment card industry. One of the main motivations behind such interest is to make a fair judgment how competitive the payment card market is and if there is a place for authority intervention. The platform of the payment card industry is two-sided and it is shaped by the conjunction of business, law, economics, technology and public policy. The stronger competitors, Visa and Mastercard, organize their business in a four parties scheme, where there are four main participants: the consumers (the users of payment cards), the merchants (establishments that accept the payment cards), the issuers (the banks that provide card to the consumers) and the acquirers (the financial institutions that provide payment methods to the merchants). Inside the same network, there is a Multilateral Interchange Fees (MIF) that acquirers pay to the issuers for each card transaction between merchants and consumers. The focus in the literature has been on the determination of this MIF [7]. The extensive studies can generally be divided into models analysing the problems surrounding the use of a single card [11, 13, 14, 5, 9], and those that allow competition between payment methods as the models in [12, 8, 6]. A different approach in studying the competition was presented in [2] and [3], where the pricing strategy of the competitors was obtained by evolutionary computation algorithms in a multi agent-based model.

On the other hand, besides gaining understanding of the competition, the interest of the authority in studying the retail side of the payment systems

could be explained by the considerable savings that the efficient use of payment instruments could have not only for businesses and banks, but also for the society as a whole. For instance, in Norway, where 95% of the payments from deposit accounts are made electronically, the social cost of using and producing payment services is under half a per cent of the country's Gross Domestic Product (GDP). Another example is Portugal, where the share of card transactions have grown from 38% in 2000 to 46% in 2005, year, in which the total costs for operations related to payment systems are estimated to be 0.77% of Portugal's GDP.

Despite these international experiences, the adoption of cards as a payment instrument in Mexico has turned out to be a much slower process. For instance, in Mexico in 2004 the number of transactions at POS terminals per capital were 3.52 [1], whereas in this same year in Norway were 169.79 and in Portugal were 59.72 [2]. Another illustrative example could be made the comparison between the number and the value of the annual card and cheques transactions in Mexico: in 2004 the annual number of card transactions were 242.2 millions with a value of 13,334 million US dollars, whereas the number of annual cheques transactions were 595.1 millions with a value of 840,052 millions US dollars[3]. For those reasons, in 2004 the Mexican Central Bank (Banco de México) was given legal power to assess the competition of the banking industry and to regulate the retail payments services ([10, 4]). Since then, the authorities have been closely involved in the price setting in the payment cards market and in particular in the determination of the *MIF*, which was considerably reduced among other related actions. In 2008 the annual number of card transactions was 801 million[4], which represents an increase of 3.3 times in comparison to the 2004 figures. Nevertheless, given the two-sided nature of the payment card market, the participants, in particular financial institutions, merchants associations and central bank authorities, maintain different views with respect to the level on which the *MIF* must be set.

Along this line, in order to go further in the understanding of the underly-

[1]Banco de México, Payment Systems Statistics.

[2]European Central Bank, Blue Book Addendum, March 2006.

[3]Working group on payment system issues of Latin America and the Caribbean (WGPS-LAC), Comparative Statistics on Payment Systems of Latin America and the Caribbean 2000-2004.

[4]Banco de México, Payment Systems Statistics.

ing complex structure of the market, [1] presented the first agent-based four-party scheme model which studies the *MIF*'s effect on the payment adoption rate in a non-saturated market. Through simulation of the consumers' and merchants' decisions related to commercial transactions, the growth of number of electronic payment instruments' users on both sides of the market and the number of card transactions are observed at the aggregated level. In the present paper, we use the same setting of the model presented in [1] in order to perform a complementary study, in which the effect of different factors on the network growth is analyzed over the complete process of adoption. The studied factors are: the level of merchant discount, the level of *MIF*, and the consumers' and the merchants' awareness of positive network externalities. In order to model the impact of the positive network externalities, we assume that the consumers are aware of the existence of merchants accepting cards, whereas merchants are aware of the existence of consumers having cards. Furthermore, the degree of consumers' and merchants' awareness, which is determined exogenously, could be different across simulations. This factor is incorporated into the consumers'/merchants' decision to have/to accept a card. This decision is taken in different time periods for each agent, whereas in each transaction consumers decide where to shop and which payment method to use.

In our artificial environment, issuers and acquirers belong to the same network. We allow card issuers to charge consumers with fixed fees and provide net benefits from card usage, whereas acquirers could charge fixed and a transactional discount to the merchants *MD*. The *MIF* flows from acquirers to issuers, merchants have homogeneous convenience benefits and consumers have homogeneous transactional and convenience benefits. First, we have simulated a market in which acquirers charge the same *MD*. We set the level of *MIF* lower than the *MD* and we have found, similar to the theoretical literature, that there is a maximum level of merchant discount MD' above which there will be not card transactions in the market. In a second scenario we allow acquirers to charge different levels of *MD* and we test this scenario under exogenously given different *MIF* and different levels of end-users' awareness. In this case, we found that if the *MIF* is sufficiently lower than the maximum level of merchant discount MD', in a way that all levels of *MD* charged to merchants are lower than MD', then the level of growth observed in the first scenario could be reach without alterations. Nevertheless, in the case in which the consumers' and the merchants' awareness

of positive network externalities is higher, we found that when the level of *MIF* is getting close to the MD' there are acquirers on the simulated market that charged *MD* higher than the MD'. In this case, even though a network growth is observed, the level of growth is considerably lower than the growth achieved in the first scenario.

The rest of the paper is organized as follows: in Section 2 we briefly describe the elements of the model, then in Section 3 we explain the agents' decision and finally in Section 4 the settings of the model and our findings are presented, together with suggestions for complementary research.

2 The Elements of the Intranetwork competition model

In this section we formally describe the elements of one network payment card market. We describe the four sets of market participants - consumers, merchants, card issuers and acquirers - with their attributes.

2.1 Merchants

Suppose we have a set of merchants $\mathcal{M}$. Each merchant $m \in \mathcal{M}$ is classified by a business line $b \in \mathcal{B}$. Each subset of merchants $\mathcal{M}_b$ that represents the specific business line b has an individual cardinality $|\mathcal{M}_b| = N_{\mathcal{M}_b}$. Additionally, $|\mathcal{M}| = N_{\mathcal{M}}$ is the sum of all $N_{\mathcal{M}_b}$. The goods offered across business lines are heterogenous, whereas inside each business line merchants are offering a homogeneous good at a common price and face individual marginal cost of production lower than this price. 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. We have adjusted the number of merchants per business line and the merchants' marginal profit distribution ϵ according to the 2004 Economic Census performed by the National Institute of Statistics, Geography and Informatics (Instituto Nacional de Estadística, Geografía e Informática, INEGI).

2.2 Consumers

The set of consumers is denoted by $\mathcal{C}$ with $|\mathcal{C}| = N_{\mathcal{C}}$. The remaining intersections of the above mentioned lattice are occupied by the consumers, where $N_{\mathcal{C}} \gg N_{\mathcal{M}}$ and $N^2 = N_{\mathcal{C}} + N_{\mathcal{M}}$. The individual budget constraint of consumers is adjusted according to the income distribution obtained by the 2006 Income Census performed by INEGI.

On each time period, all consumers perform individually a single commercial transaction with one merchant. The business line the merchants belong to imposes a restriction how frequently the consumer will demand the goods offered by those merchants and the amount of consumers' budget spent for those goods. In order to do their purchases, any consumer $c \in \mathcal{C}$ has to travel to a merchant $m \in \mathcal{M}_b$. We assume that by making those transactions the utility of the consumer increases, whereas the travelled distance imposes costs on consumers. Given that these costs reduce the attractiveness of visiting a merchant, in this study we explore the case where the connections among consumers and merchants are local. Moreover, the distance between the intersections on the lattice is measured by the "Manhattan distance" $d_{c,m}$. The distance between two neighboring nodes has been normalized to one. We further restrict the consumer to visit only the nearest merchants and denote by $\mathcal{M}_c$, the set of merchants selected from all existing business lines in the model. In subsection 3.1 we explain in detail the way this decision is designed.

2.3 Payment Methods

In the four party scheme model, we consider two sets of payment card providers: card issuers $\mathcal{I}$ with $|\mathcal{I}| = N_{\mathcal{I}}$ and acquirers $\mathcal{A}$ with $|\mathcal{A}| = N_{\mathcal{A}}$. The issuers offer electronic payment cards to consumers, whereas in order to accept those cards the merchants require the electronic payment method offered by the acquirers. Except for the price, which differ among issuers and acquirers, the payment method offered by those payment card providers has the same characteristics, i.e. belongs to the same network.

Additionally, there is a benchmark payment method, which can be interpreted as a cash payment. Cash is available to all consumers and accepted by all merchants. For a card payment to occur, the consumer as well as the

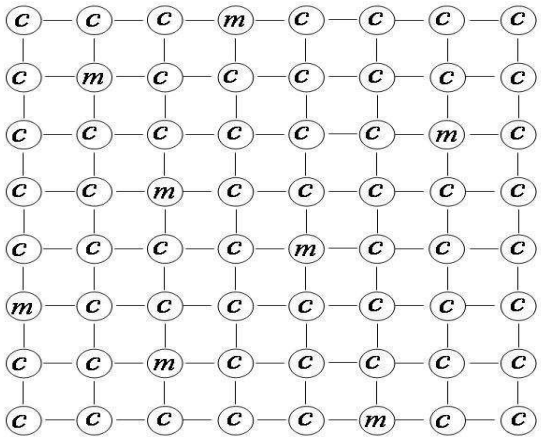

Figure 1: Sample of a lattice with consumers (c) and merchants (m)

merchant must have a subscription to any of the financial institutions that form part of the network. 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 $F_i \geq 0$ is charged to the consumer, and $\Gamma_a \geq 0$ to the merchant.

We assume merchants obtain convenience benefits b_m from accepting cards, because of accounting facilities, fraud protection and time savings at the counter relative to cash payments. Additionally, for each payment card transaction merchants pay a discount[5] γ_a to the acquirer. If the merchants' discount exceeds the convenience benefits, merchants will surcharge consumers that are using cards. Further we assume that the merchants' discount is established as a proportion of the *MIF* acquirers pay to issuers. In this study among other factors, we have explored how different levels of merchants' discount affect the usage and the subscription to electronic payment instruments. More precisely, we have simulated in separate runs merchants' discounts that represent different proportions of *MIF*. We have tested two cases: first case, in which acquirers charge equals merchants' discount in the market and second case, in which the merchants' discount is different across acquirers. Cash payments do not provide any net benefits to the merchants.

Consumers receive transaction benefits b_i from the card issuer as cash-

[5]In the model the value of the convenience benefits and the merchant discount is normalized to one.

back points as well as convenience benefits b_c from using a card, due to reduced risk for cash handling and delayed payment. Regarding the cash-back points receive in a commercial transaction, we assume that those points are used at the same moment the transaction is placed, i.e. the final amount spend for the specific purchase increased. For that reason, cardholders, whenever possible prefer to use card over cash for their shopping. Nevertheless, in the case when merchant has imposed a surcharged on card usage, the cardholder will use cash if the proportion of price increases is higher than sum of the convenience and the transactional benefits that he receives. Cash payments however do not provide any net benefits to the consumers.

3 Decision-making of market participants

This section presents the decisions of consumers and merchants driven by the interactions among them. At time $t = 1$ the prices charged by card issuers and acquirers are assigned under specific rules and are fixed during the simulation. The way the prices are constrained is explained in section 4, whereas here we explain the consumers and merchant decisions, which are taken under the consideration for those prices.

3.1 Consumers' Decisions

Consumers make two kind of decisions. The first is related to the activities of purchasing, which are performed at each time period. The second kind of decisions is related to the consumers' subscription to the electronic payment instrument and are taken with certain periodicity determined by a Poisson distribution. This section addresses each of these set of decisions in turn.

3.1.1 The consumers' shopping decisions

The process of purchasing consist of four consumers' decisions made in each interactions. Given that there are some variety of business lines in the model, first consumer has to select the goods of which business line he would like to demand for that time period. After that, from the set of the nearest merchants belonging to this business line, the consumer chooses a merchant to visit, then he must decide how much to spend [6] and finally he selects a

[6]The constrain on the maximum amount of budget spend varies across business lines

payment method to use in the transaction.

We assume a random consumers' choice for the selection of business line. This decision is biased according to the patterns of cardholders' behavior observed in the data reported quarterly to the Mexican Central Bank during 2007.

With respect to the consumer's choice of a merchant, it is driven mainly by two factors: the payment methods that the consumer can use with the merchant and the distance between this consumer and the merchant. Regarding the payment methods, that could be used, we assume that when deciding which merchant to visit, the consumer has not yet decided which payment method he will use. In order to handle the effect of this factor, suppose $\mathcal{P}_c$ is the set of payment methods the consumer $c \in \mathcal{C}$ has and $\mathcal{P}_{c,m}$ is the set of payment methods this consumer knows that can use with the merchant $m \in \mathcal{M}$. Let $|\mathcal{P}_c| = N_{\mathcal{P}_c}$, $|\mathcal{P}_{c,m}| = N_{\mathcal{P}_{c,m}}$ and $N_{\mathcal{P}_c} \geq N_{\mathcal{P}_{c,m}}$, i.e. any cardholder knows in advance which merchant in the neighborhood accepts card payments. Furthermore, in the case when a cardholder has previously visited a particular merchant, the consumer will also know that he will prefer a cash payment over card if card usage surcharge is applied and it is higher than the consumer's card benefits.

In addition, regarding the distance between the consumer and the merchant he is visiting, we assume that the smaller this distance $d_{c,m}$, the more attractive the 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:

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

Each consumer $c \in \mathcal{C}$ in each time period chooses a merchant $m \in \mathcal{M}$ with probability $v_{c,m}$ as defined in equation (1), indicating the frequency, with which the consumer will visit a merchant. Additionally, observing the acceptance of card payments of all shops in their neighborhood allows the consumers to continuously update their beliefs on the number of payment methods they share with a particular merchant. The subscriptions of both sides may change over time in the way introduced below.

How much the consumer will spend for his purchases is the next decision he faces during the shopping process. The consumer budged is constrained in two ways. First, we assume that only a fraction of the consumers income is spent, given that the higher the income the lower the fraction dedicated to

consumption. This fraction is adjusted according to the data reported in the 2006 Income Census performed by INEGI. Secondly, even when the exact amount for the transaction is assumed to be a random choice, the possible maximum amount spend is exogenously determined according to the business lines. The adjustment of this decision is made using data reported quarterly to the Mexican Central Bank regarding the cardholders' transactions during 2007.

Finally, the cardholder must decide which payment method he wants to use with the merchant he has selected. We assume a preferred card choice in the case when the merchant has not surcharge. In the case the merchant charge for the card usage, the consumer's decision is determined by the consumer's convenience benefits b_c from using card, the transactions benefits b_i, such as loyalty points received by the issuer, and the surcharge rate sr_m applied by the merchant. Let b_c, b_i and sr_m are normalized to zero. If $sr_m > b_c + b - i$, then the cardholder will use cash, otherwise he will prefer a card payment. In the case when the merchant does not accept card payments, the transaction is settled using cash.

3.1.2 Consumer card subscriptions

Apart from the shopping decisions, periodically [7] non-card consumers may decide to adopt an electronic payment method and consequently they have to choose to which issuers to subscribe to. Similarly, cardholders could decide to drop their card or to switch to a different card issuer.

Initially, in the market from different issuers randomly selected, payment cards are allocated to a random number of consumers. After certain number of interactions determined separately for each individual, the cardholders may decide to drop their card subscription or change to a different card issuer. In a similar fashion, the rest of consumers have to decide whether to have or not a payment card. In the case they do, they must select a card issuer. The frequency with which consumers take these decisions is defined by an individual Poisson distribution with a mean of λ time periods between decisions.

Two mayor factors drive the consumers' decision to have a payment card: the merchants' card acceptance and the consumers' convenience benefits b_c from using electronic payment method. The first is endogenously determined

[7] The periods are determined by a Poisson distribution.

from the interaction among consumers and merchants, whereas the second is exogenously given. In order to handle the endogenous factor, every consumer $c \in \mathcal{C}$ keeps track of the merchants accepting cards. Let ω_c^+ be the consumer's score for those merchants. Each time the merchant $m \in \mathcal{M}_c$ he is visiting accepts card payments, the consumer increases ω_c^+ by one. Assume that he decides to have a payment card with probability

$$\pi_c^+ = \frac{\exp(\alpha^+ \frac{\omega_c^+}{\omega_c} + b_c)}{x_c^+ + \exp(\alpha^+ \frac{\omega_c^+}{\omega_c} + b_c)}, \tag{2}$$

where ω_c denotes the number of merchants visited, x_c^+ is a constant that accounts for the propensity of the consumer to have payment card and α^+ is another constant representing the consumers' awareness for the benefits arriving from the existing payment card network externalities [8]. At this point, lets explain the interpretation of α^+ in the context of the payment card market. There is some evidence from the different country's experience that consumers and merchants exhibit different rate of payment card adoption. For instance, France and Finland, both countries from the Eurozone, have been adopting the electronic payment methods on a different fashion. We could argue that there are some similarities in the business environment in which the card market have been developing, nevertheless the consumers' response for the subscription or the usage of the electronic payment instruments have been shown to be different. From those observations, we conclude that consumers perception of what are the cost, the benefits from using a payment card and the places they can used it, is a crucial factor for the successful adoption of those methods. As we said earlier, the efficient use of electronic payment instruments could result in substantial savings for the society, so racing the awareness of consumers and merchants for the potential benefits of the use of electronic payment methods could be a very important factor. In our model, we represent the factor of end-user awareness through the value of α^+. It reflects how much consumers or merchants appreciate the existence of merchants accepting cards or cardholders respectively.

In order to make it clear, for instance, assume we have two scenarios with two different values for α^+. In the case when the value of α^+ is smaller, the payment adoption rate on the consumers' side will be lower in comparison

[8] The awareness in this case is of those consumers that do not belong to the network and could be interpreted as the sensibility of the consumers to the existence of network externalities

to the case, in which consumers have a higher awareness of the existing positive network externalities, i.e. α^+ has a larger value. On this line, is important to mention that is difficult to obtain the value of α^+ empirically. For that reason, we have multiple feasible sets that allow us to reproduce different market scenarios. To that end, suppose we run several times the computational model and in each run we increase (with 0.1) the value of α^+, starting with $\alpha^+ = 1$. In order to determine which will be the lowest value of α^+ used for our studies we consider the first run, in which a network growth is observed in a card transaction market, e.g. $\alpha^+ = 6$. On thew other hand the highest feasible value of $\alpha^+ = 7$ is bounded by the last run, in which consumers and merchants drop their card subscriptions in a non-card transaction market. In this way we have been able to explore the effect that different values of α^+ has on the payment adoption curve.

On the other hand, cardholders may decide to drop their payment cards. In case, where consumer has a subscription to a card, ω_c^+ represents the number of merchants, with which the consumer can use his card. Therefore, if a merchant accepts cards, but the surcharge rate he applies is higher then the one the consumer is willing to pay, then the visited merchant is not considered a card accepting merchant. From those deliberation, assume cardholders with drop their payment cards with the probability

$$\pi_c^- = \frac{1}{x_c^- + \exp(\alpha^- \frac{\omega_c^+}{\omega_c} + b_c)}, \tag{3}$$

where x_c^- is a constant accounting for the consumers' inertia to abandon the payment card network and α^- is another constant representing the cardholders' awareness of the existing positive network externalities.

Finally, the cardholders decision to which card issuer to subscript is driven by the fees F_i and transaction benefits b_i, such as loyalty points, associated with the payment card. A card becomes more attractive to subscribe and existing subscriptions are less likely to be changed if the fixed fee charged is low and the benefits from each transaction are high. From these deliberations we propose to use a preference function for the consumer to select an issuer as follows:

$$v_{c,i} = \frac{\alpha_1 b_i - \alpha_2 F_i}{\sum_{i^* \in \mathcal{I}} \alpha_1 b_{i^*} - \alpha_2 F_{i^*}}. \tag{4}$$

where α_1 and α_2 are constants. Furthermore, with an exogenously given threshold τ_c, if $(\alpha_1 b_i - \alpha_2 F_i) < \tau_c$, the consumer will change his current subscription to a different issuer.

3.2 Merchants' Decisions

On the merchants' side, as with consumers, for a random number of retailers an initial subscription is assigned to a randomly selected acquirer. The merchants decisions are limited to the acceptance of cards, the choice of acquirer and the application of a surcharge for the card usage in the case the merchant discount γ_a is higher then their convenience benefits b_m. Those decisions are taken periodically, after observing the consumers' behavior at the point of sale. The frequency with which merchants review them is governed by a Poisson distribution specific to each individual with a common mean of λ time periods.

Merchants that do not accept cards keep track of the number of consumers presenting a card to them. Every time a consumer wants to pay with a card the score of θ_m^+ is increased by one and the probability to join the payment card network is given by

$$\pi_m^+ = \frac{\exp(\delta^+ \frac{\theta_m^+}{\theta_m} + b_m)}{x_m^+ + \exp(\delta^+ \frac{\theta_m^+}{\theta_m} + b_m)}, \tag{5}$$

where θ_m denotes the number of transactions made and x_m^+ is a constant. The interpretation of the term $delta^+$ follows the same lines as for consumers, i.e. it accounts for the merchants' awareness of the positive network externalities. Similarly here, in order to explore the effect of $delta^+$ on the merchant adoption rate, in separated runs, ceteris paribus we have tested with different values of $delta^+$. In addition the experiments are perform under different levels of MIF. The results are reported in section 4.

If the outcome of the above decision drive the merchant to join the payment card network, then he must select an acquirer. Similarly to the consumers, this decision is driven by price: the fixed fees Γ_a and the merchant's discount γ_a charged by the different financial institutions. The preference

function proposed for this case is as follows:

$$v_{m,a} = \frac{\frac{1}{\delta_1 \gamma_a + \delta_2 \Gamma_a}}{\sum_{a^* \in \mathcal{A}} \frac{1}{\delta_1 \gamma_{a^*} + \delta_2 \Gamma_{a^*}}}. \tag{6}$$

where δ_1 and δ_2 are constants.

If the merchant $m \in \mathcal{M}$ accepts cards, every time a card is presented to him, he increases the score of θ_m^- by one. The probability to stop accepting a card then is given by

$$\pi_m^- = \frac{1}{x_m^- + \exp(\delta^- \frac{\theta_m^-}{\theta_m} + b_m)}, \tag{7}$$

where x_m^- is a constant that represents the merchants' inertia to leave the payment card network.

Finally, in our model merchants that accept electronic payments are allowed to surcharge the card usage, i. e. they may apply a price differentiation according to the payment method used in a transaction. They will do so, if the convenience benefits are lower than the merchants' discount $b_m < \gamma_a$.

4 Results and conclusions

In this section we explain how we have established the different simulations in order to make a quantitative assessment of the impact on the network growth that the three analyzed factors have. The analyzed factors are the level of *MIF*, the merchants' discount and the end-users' awareness of positive network externalities. We start by listing the values of the parameters introduced in the previous section, those are presented in tables 1 and 2. These values are keep the same for all runs, in addition the lower values of end-users' awareness are $\alpha^+ = 6$ and $\delta^+ = 5$, whereas for highest values of such awareness are $\alpha^+ = 7$ and $\delta^+ = 6$. In table 3 we list the intervals from which the prices of the payment methods are adjusted by each issuer or acquirer respectively. The initial proportion of consumers having cards is given exogenously and is 34%, the same as the initial proportion of merchants accepting cards, which is 23%.

Symbol	Description	Value
$N_{\mathcal{M}}$	Number of Merchants	864
$N_{\mathcal{C}}$	Number of Consumers	20745
$N_{\mathcal{I}}$	Number of Issuers	10
$N_{\mathcal{A}}$	Number of Acquirer	7
$N_{\mathcal{B}}$	Number of business lines	5
$N_{\mathcal{M}_b}$	Total number of merchant to be visited by the consumer	21
$N_{\mathcal{M}_1}$	Number of merchant to be visited by the consumer (line 1)	3
$N_{\mathcal{M}_2}$	Number of merchant to be visited by the consumer (line 2)	12
$N_{\mathcal{M}_3}$	Number of merchant to be visited by the consumer (line 3)	2
$N_{\mathcal{M}_4}$	Number of merchant to be visited by the consumer (line 4)	2
$N_{\mathcal{M}_5}$	Number of merchant to be visited by the consumer (line 5)	2

Table 1: Parameters

Symbol	Description	Value
x_c^-	Consumers' inertia to drop cards	2
x_c^+	Consumers' inertia to add new cards	40
α^-	Consumers' awareness of externalities when drop cards	0.8
b_c	The consumers' convenience benefits	0.02
x_m^-	Merchants' inertia to drop cards	1
x_m^+	Merchants' inertia to add new cards	45
δ^-	Merchants' awareness of externalities when drop cards	4
b_m	The merchants' convenience benefits	0.02

Table 2: Constants

In the present study we analyze two cases, both in a market with homogeneous convenience benefits of consumers and merchants. In the first case given the same end-users awareness, for each run, acquirers charge the same merchants' discount, which is different across runs. We present in figure 2 the resulting card transactions' growth, given different levels of merchants' discount. In this figure we observe that there is certain level of merchants' discount, denoted as MD', above which there are no card transactions in the market. It is also visible that all merchants willing to accept cards are also willing to cover the merchants' discounts lower than this same level of MD'. This is explained by the homogeneous convenience benefits that end-users have, i.e. if the merchants' discount is lower than the join convenience bene-

Symbol	Description	Interval
F_e	Consumer Fixed Fee	[1,7]
Γ_a	Merchant Fixed Fee	[20,30]
b_e	Benefits to the Consumers	[0,0.1]

Table 3: Prices of the Payment Method

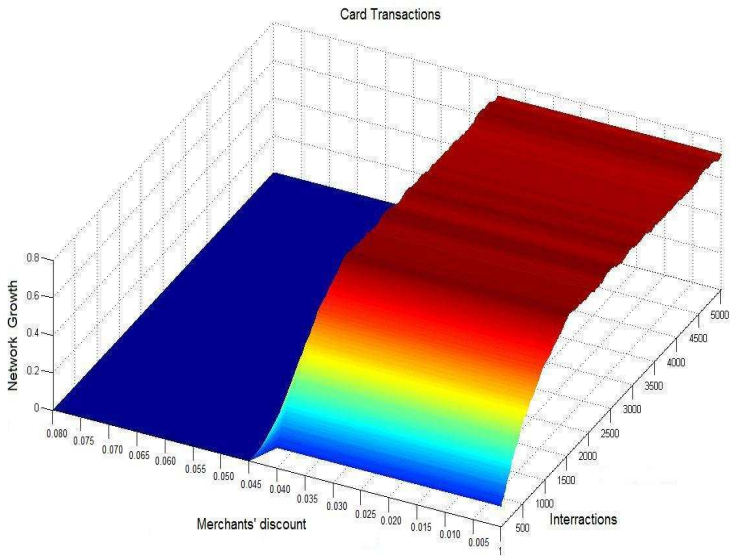

Figure 2: Acquirers charge the same merchant's discount

fits of consumers and merchants, then there will be card transactions in the market, which will grow regardless the level of merchants' discount. We have repeated these simulations with different levels of MIF lower than MD' and the growth observed is the same as the one presented in figure 2.

In our second case of study we allow acquirers to charge different levels of merchants' discount, which for each runs are selected from the intervals reported in table 4. The resulting card transactions' growth is presented in figure 3. In this case we observe that in the cases of intervals, in which simultaneously there are values of merchants' discount lower and higher than MD', the number of card transactions grow, but less rapid than the growth achieved in the first case.

Furthermore, we test this scenario with different levels of end-user aware-

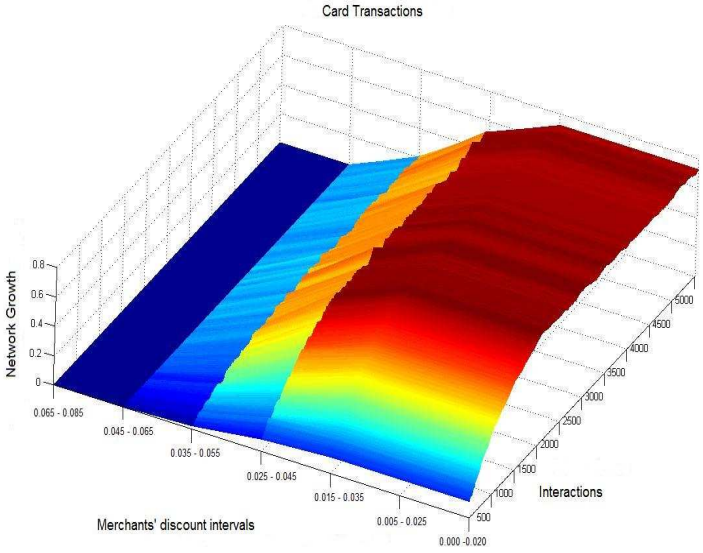

Figure 3: Acquirers are allowed to charge different merchants' discount

ness, given that the *MIF* is kept lower than *MD′*. The results obtained are reported in figure 4 representing the impact of consumers' awareness of network externalities. We observe in this figure that the end-user awareness modify the card transactions curve, whereas given that the levels of *MIF* and *MD* are lower than *MD′*, those factors do not affect the growth.

Moreover, we explore the impact of end-users' awareness, given that the *MIF* is closer to *MD′*, in particular we have tested the case of $MIF = 4.2\%$ and *MD* are between 4.5% and 5.0%. The results of this experiments are reported in figure 5 representing the impact of consumers' awareness of network externalities. We observe that the awareness of consumers have an impact on the card transactions' growth, but the level of *MIF* and consequently the levels of *MD* do alter the card transactions curve and the market does no achieve the same growth as in the first case of study.

Given the present results we consider necessary to explore in depth the scenarios we have studied. Here, we have analyzed the cases, in which consumers and merchants have homogeneous convenience benefits and the level of *MIF* is lower or closer to the *MD′* accepted in the market. We believe that studying the case of heterogeneous convenience benefits will open the number of cases that is necessary to analyze in detail. Furthermore, we think

Scenario	Merchants' discount interval
1	0.000 - 0.020
2	0.005 - 0.025
3	0.015 - 0.035
4	0.025 - 0.045
5	0.035 - 0.055
6	0.045 - 0.065
7	0.065 - 0.085

Table 4: Interval of merchants' discount per case

that exploring these possibilities through experimentation will allow us to understand better in which cases lowering the level of interchange fee will result in a higher adoption of the payment cards.

References

[1] Biliana Alexandrova-Kabadjova. The impact of the interchange fees on a non-saturated multi-agent payment card market. *Inteligent Systems in Accounting, Finance and Managment*, forthcoming, 2008.

[2] Biliana Alexandrova-Kabadjova, Andreas Krause, and Edward Tsang. An agent-based model of interactions in the payment card market. In *IDEAL-07 Proceedings*, Lecture Notes in Computer Science, pages 1063–1072. Springer Berlin / Heidelberg, 2007.

[3] Biliana Alexandrova-Kabadjova, Edward Tsang, and Andreas Krause. Evolutionary learning of the optimal pricing strategy in an artificial payment card market. In Anthony Brabazon and Michael O'Neill, editors, *Natural Computing in Computational Economics and Finance*, Studies in Computational Intelligence, pages 233–251. Springer, 2008.

[4] Sara G. Castellanos, Ricardo Medina, Alberto Mendoza, José Luis Negín, and Francisco Solis. Interchange Fees for Bank Payment Card Transactions at Point of Sales in Mexico. Working paper, Banco de México, 2008.

[5] Sujit Chakravorti and William R. Emmons. Who pays for credit cards? *Journal of Consumer Affairs*, 37:208–230, 2003.

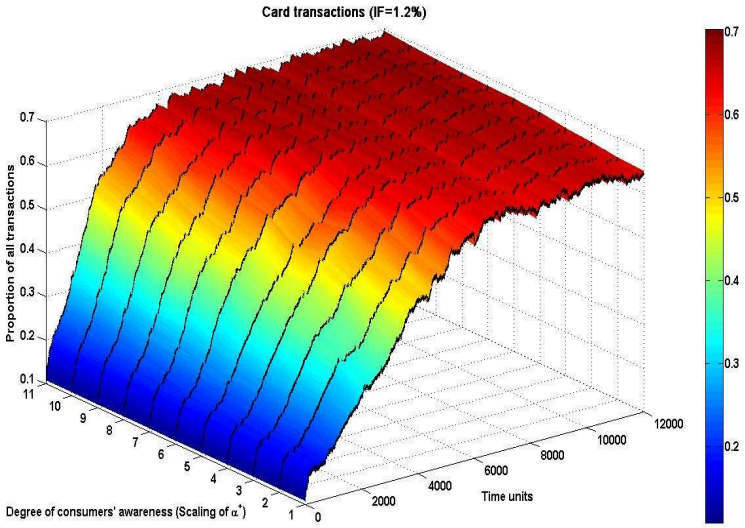

Figure 4: The consumers' awareness impact

[6] Sujit Chakravorti and Roberto Roson. Platform competition in two-sided markets: The case of payment networks. Working Paper WP-04-09, Federal Reserve Bank of Chicago, May 2005.

[7] David Evans and Richard Schmalensee. The economics of interchange fees and their regulation: An overview. Working Paper 4548-05, MIT Sloan, May 2005.

[8] Graeme Guthrie and Julian Wright. Competing payment schemes. Working Paper 0311, National University of Singapore, Department of Economics, 2003.

[9] Sheri M. Markose and Yiing Jia Loke. Network effects on cash-card substitution in transactions and low interest rate regimes. *The Economic Journal*, 113:456–476, April 2003.

[10] Gillermo Ortiz. Remarks on interchange fees: Central bank perspectives and options. In *International Policy Payments Conference: Interchange Fees in Credit and Debit Card Industries. What Role for Public Authorities?*, pages 289–295. Federal Reserve Bank of Kansas City, 2005.

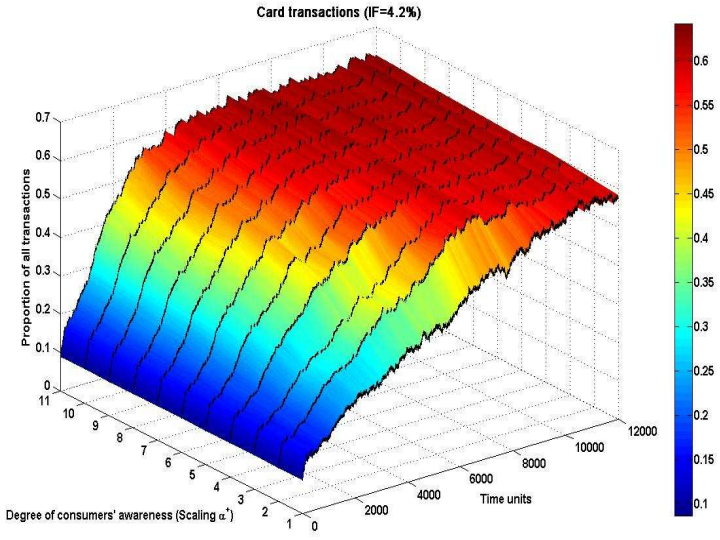

Figure 5: The consumers' awareness impact

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

[12] Jean-Charles Rochet and Jean Tirole. Platform competition in two-sided markets. *Journal of the European Economic Association*, 1:990–1029, June 2003.

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

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