EUROPEAN CENTRAL BANK
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RETAIL PAYMENTS:
INTEGRATION AND INNOVATION

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AN AGENT-BASED STUDY OF THE PAYMENT CARD MARKET

by Biliana Alexandrova-Kabadjova
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by Biliana Alexandrova-Kabadjova[2]

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In 2009 all ECB publications feature a motif taken from the €200 banknote.

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Retail payments: integration and innovation

"Retail payments: integration and innovation" was the title of the joint conference organised by the European Central Bank (ECB) and De Nederlandsche Bank (DNB) in Frankfurt am Main on 25 and 26 May 2009. Around 200 high-level policy-makers, academics, experts and central bankers from more than 30 countries of all five continents attended the conference, reflecting the high level of interest in retail payments.

The aim of the conference was to better understand current developments in retail payment markets and to identify possible future trends, by bringing together policy conduct, research activities and market practice. The conference was organised around two major topics: first, the economic and regulatory implications of a more integrated retail payments market and, second, the strands of innovation and modernisation in the retail payments business. To make innovations successful, expectations and requirements of retail payment users have to be taken seriously. The conference has shown that these expectations and requirements are strongly influenced by the growing demand for alternative banking solutions, the increasing international mobility of individuals and companies, a loss of trust in the banking industry and major social trends such as the ageing population in developed countries. There are signs that customers see a need for more innovative payment solutions. Overall, the conference led to valuable findings which will further stimulate our efforts to foster the economic underpinnings of innovation and integration in retail banking and payments.

We would like to take this opportunity to thank all participants in the conference. In particular, we would like to acknowledge the valuable contributions of all presenters, discussants, session chairs and panellists, whose names can be found in the enclosed conference programme. Their main statements are summarised in the ECB-DNB official conference summary. Twelve papers related to the conference have been accepted for publication in this special series of the ECB Working Papers Series.

Behind the scenes, a number of colleagues from the ECB and DNB contributed to both the organisation of the conference and the preparation of this conference report. In alphabetical order, many thanks to Alexander Al-Haschimi, Wilko Bolt, Hans Brits, Maria Foskolou, Susan Germain de Urday, Philipp Hartmann, Päivi Heikkinen, Monika Hempel, Cornelia Holthausen, Nicole Jonker, Anneke Kosse, Thomas Lammer, Johannes Lindner, Tobias Linzert, Daniela Russo, Wiebe Ruttenberg, Heiko Schmiedel, Francisco Tur Hartmann, Liisa Väisänen, and Pirjo Väkeväinen.

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CONTENTS

Abstract

This paper investigates the impact on the network growth of the level of merchant discount, the level of Multilateral Interchange Fee (*MIF*), and the consumers' and the merchants' awareness of positive network effects. In an artificial market, in which issuers and acquirers belong to the same network, we simulate explicitly the interactions among consumers and merchants at the point of sale. We allow card issuers to charge fixed fees and provide net benefits from card usage, whereas acquirers could charge fixed and transactional fee. End users have homogeneous convenience benefits and are able to internalize network effects, because to a certain degree consumers are aware of the existence of merchants accepting cards and merchants are aware of the existence of consumers having cards. The *MIF* flows from acquirers to issuers. We assume there is a maximum level of merchants' discount MD' (reservation price) that the retailers are willing to pay, depending on the level of convenience benefits they receive. We study the case of imperfect competition, in which some acquirers charge a merchants' discount (MD) higher than MD', whereas other acquirers charge a MD lower than MD'. We found that in the case, in which consumers' and merchants' awareness is high, retailers face stronger externalities arriving from the set of cardholders that enjoy transactional benefits and the set of merchants that accept cards by paying lower transactional fees. In this conditions retailers could be obliged to pay variable fees higher than MD'.

Keywords: Card payment systems, interchange fees, agent-based modelling

JEL classification numbers: G20, G28, C63

1 Introduction

The growing importance that the credit and debit cards have achieved as payment instruments, has motivated the interest of the market authorities in understanding the underlying relationships in the industry. We visualize two main reasons behind this growing body of literature. The first is the assessment of the competitive nature of the payment card market; the second is related to the efficient use of payment instruments, which could imply considerable savings not only for businesses and banks, but also for the society as a whole.

The line of research dedicated to study the competitive nature of the payment card market, is aimed at understanding the driving factors of the price structure. It has risen the argue that the price setting mechanism leaves place for authority intervention [8, 30, 9]. The platform of the payment card industry is two-sided and it is shaped by the complex conjunction of business, law, economics, technology and public policy [33, 16, 27]. The strongest competitors, Visa and Mastercard, organize their business in a four party scheme, where there are four main participants: consumers (users of payment cards), merchants (retail establishments that accept payment cards), issuers (banks that provide the cards to the consumers) and acquirers (financial institutions that provide electronic terminals to merchants). Platform operators that belong to the same network establish a specific level of Multilateral Interchange Fees (*MIF*), which usually flows from acquirers to issuers

for each card transaction between merchants and consumers. The focus in the literature has been on the determination of the *MIF* [24, 15], due to the fact that financial institutions, merchants associations and market authorities, maintain different views regarding its level. These studies can generally be divided into models analyzing the problems surrounding the use of a single card [25, 29, 32, 11], and those that allow competition between payment methods as in [26, 19, 12, 10]. In addition [2, 3], developed a multi-agent based model to study competition among several competitors, which was extend in [4], where the pricing strategy of the competitors is obtained by an evolutionary computation algorithm.

Further, as we said earlier, the interest of the market authority in understanding the retail side of the payment systems is also explained by the considerable savings that the efficient use of payment instruments could have for the society [31]. Nevertheless, in this line of research only few studies provide insights about the private and social cost of using and producing payment services [7, 14, 5]. In United States, where in 2000 the annual average number of cheque transactions per capita was 148 and the annual average number of card transactions per capita was 86[1] [17], the cost of payments was estimated to be as high as 3% of the country's Gross Domestic Product (GDP) [20]. In Norway in 2008, 97% of the payments from deposit accounts were made electronically; the social cost of using and producing payment services there was under 0.5% of the GDP [6]. Many assumptions are behind these, nevertheless the individual choices of payment services and their price are of significant relevance among them.

In this international context, the adoption of cards as a payment instrument in Mexico has turned out to be a slow process. In 2004 the average number of card transactions per card holder was 5.25, whereas the average number of cheque transactions per account holder was 15 [22]. 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, including the interchange fee ([23, 21]). Since then, the authorities have been closely involved in the price setting in the payment cards market

[1]From 2000 to 2007 a significant switch in the consumers preferences of payment methods is observed, in a way that in 2007 the annual average number of cheque transactions per capital was 94, whilst the annual average number of card transactions per capital was 178 ([18])

and in particular in the determination of the *MIF*. Four years letter, in 2008 the annual average number of card transactions per cardholders was 9.75 [2], with an annual increase of 16%. Despite this, the card usage in Mexico is lower than in other countries with similar characteristics [13].

Along this line, in order to go further in the understanding of the underlying complex structure of the market, Alexandrova presented the first agent-based four-party scheme model which studies the *MIF*'s effect on the payment card adoption rate in a non-saturated market [1]. Through simulation of the consumers' and merchants' decisions related to commercial transactions at the point of sale (POS) and to the choice of payment instruments, the growth of the payment card network is observed at the aggregated level. The network's growth is measured in three dimensions: number of card holders, number of electronic terminals at the POS and number of card transactions. The model internalize the impact of the positive network effects into the consumers' and merchants' decision to join the payment card network. In the present paper, we use the same setting to analyzed the effect of different factors on the network growth over the complete process of adoption in two scenarios, described above.

In our artificial environment, the set of issuers and the set of acquirers belong to the same network. We allow card issuers to charge consumers with fixed fees and provide transactional benefits from card usage(loyalty points), whereas acquirers could charge fixed fees and a transactional discount to the merchants *MD*. The *MIF* flows from acquirers to issuers. Merchants and consumers have homogeneous convenience benefits, whereas the cash is the benchmark payment method. In this market we study the impact of the following factors on the network growth: the level of merchant discount, the level of *MIF*, and consumers' and merchants' awareness of positive network externalities [3]. In order to incorporate the impact of the network effects in the consumers and merchants decisions to join the network, we assume that to a certain degree the consumers are aware of the existence of merchants accepting cards, whilst to a certain extend merchants are aware of the existence of consumers holding cards. In other words, the consumers' and the merchants' do not have perfect knowledge of the real size of the network

[2]Banco de México, Payment Systems Statistics.

[3]These network externalities are also referred in the literature as network effects

on the other side, but rather an individual perception of it, based on their interactions at the point of sale. Further, assuming that different consumers value differently the presence of merchants accepting cards, as well as different merchants appreciate at different degrees the existence of cardholders, in our model the end-users' perception is exogenously constraint. From now on, this constraint is referred in the paper as the degree of consumers'/merchants' awareness. We study the effect of different degrees of agents' awareness across scenarios, whilst for each instantiation[4] of the model the degree of awareness across consumers and merchants is homogeneous[5]. This factor is integrated into the consumers'/merchants' decision to join the payment card network. Agents take this decision in different time periods, whereas on each transaction, consumers decide where to shop and which payment method to use. Consequently, in the paper the network's growth is a result of the consumers' and merchants' demand for payment cards usage. We assume that the operational cost of acquirers and issuers is covered by the fixed and transactional fees charged.

We start by creating a basic scenario of a payment card market in which all acquirers charge the same *MD*. We assume the level of *MIF* is lower than the *MD* for all levels of merchants' discount rates. We generate different instantiation of the model resulting from variations on the level of *MD*. We observe that there is a reservation price MD' above which there are no card transactions in the market. In the cases when the *MD* is lower than MD', the rate of network growth remain the same regardless the merchants' transactional fee. This observation is consistent with our assumption that merchants are willing to accept cards as long as their convenience benefits are higher than the transactional fees they need to pay to the acquirer (see figure 1).

Further, in our extended scenario, we assume an imperfect competition among acquirers and allow them to apply different merchants' discount rates. We compare independent instantiation of the model produced by different levels of *MIF* and end-users' awareness, provided exogenously. We test three cases determined by the relation between *MIF* and the merchants' reserva-

[4] A instantiation of model is a state, in which all parameters have assigned value

[5] We leave for further research the assessment of the effect of heterogeneous agents' awareness at the same instantiation

tion price MD': 1) $MIF \ll MD'$, 2) $MIF < MD'$ and 3) $MIF{=}MD'$.

We observe in the first case, in which MIF is strictly lower than the reservation price MD' and all acquirers charge MD lower than MD', that the same rate of growth as in the basic scenario is achieved. In the second case the value of MIF is lower to the MD', in such a way that some acquirers charge MD higher than MD' and other acquirers charge MD lower than MD'. This case is tested with the highest and the lowest degree of consumers' and merchants' awareness. With the highest degree of consumers' and merchants' awareness a network growth is observed, nevertheless the rate of growth is lower than the one observed in the basic scenario (see 2). In an instantiation of the model with the lowest degree of consumers' and merchants' awareness, ceteris paribus, no card transactions are observed at the outcome. Finally, in the third case, when the MIF is equal to the reservation price MD', and consequently acquirers charge MD higher than MD', there are not card transactions in the market[6].

From the presented observations, we argue that the artificial agent-based model reproduces a feasible outcome of a payment card market. Furthermore, the elements incorporated in the model allow us to represent a situation, in which some merchants face transactional fees higher than their reservation price and at the same time they are in the presence of externalities arriving from merchants accepting cards with lower transactional fees and cardholders receiving transactional benefits (loyalty points). These conditions rise the question, among others, to what extend merchants in this situation are obliged to pay these high fees[28]. The answer required further research and deeper understanding of the process of merchants' internalization of the externalities observed in the market.

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.

[6]This observation is consistent with the outcome achieved in the first scenario.

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 heterogeneous, whereas inside each business line merchants offer 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 $N^2 \gg N_{\mathcal{M}}$. 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 and Geography (Instituto Nacional de Estadística y Geografía, 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 on the frequency at which consumers demand goods offered by those merchants and the amount spent on them. 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 $|\mathcal{A}| = N_{\mathcal{A}}$. Issuers offer electronic payment cards to consumers, whereas in order to accept those cards, merchants need the electronic payment method (terminal) offered by acquirers. Except for the price, which differs among issuers and acquirers, the payment method offered by all payment card providers 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 and merchant must have a "subscription" to any of the financial institutions that conform 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. For each card transaction merchants pay a discount fee[7] γ_a to the acquirer. 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 mer-

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

chants' 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: a basic case, in which acquirers charge equals merchants' discount and a second case of imperfect competition, in which merchants' discount rate are 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 loyalty points as well as convenience benefits b_c from using a card, due to reduced risk for cash handling and delayed payment. Cash payments however do not provide any net benefits to the consumers. For that reason, cardholders, whenever possible prefer to use card over cash for their shopping.

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. Here we explain consumers and merchants decisions, which are taken under consideration for price determination.

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 is taken periodically following a Poisson distribution. This section addresses each of these sets of decisions in turn.

3.1.1 Consumers' shopping decisions

The process of purchasing consists of four consumers' decisions made in each interaction. Given that there are several business lines, the consumer has to select first the business line he would like to demand goods at that time period. Second, the consumer chooses a merchant to visit from the set of

nearest merchants belonging to this business line; he also decide how much to spend [8] and finally he selects a payment mean for the transaction. We assume a random consumers' choice for the selection of business line[9].

The consumer merchant's choice is driven mainly by two factors: the payment mean the consumer can use at that merchant and the distance between this consumer's original location and the merchant. Regarding the payment methods, that could be used, we assume that when deciding which merchant to visit, the consumer does not know which payment mean 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 expects that can be used at merchant $m \in \mathcal{M}$. Let $|\mathcal{P}_c| = N_{\mathcal{P}_c}$, $|\mathcal{P}_{c,m}| = N_{\mathcal{P}_{c,m}}$ and $N_{\mathcal{P}_c} \geq N_{\mathcal{P}_{c,m}}$, note that the consumer's expectations regarding card acceptance are formed based on previous interactions with the merchant.

In addition, regarding the distance $d_{c,m}$ between consumer and merchant he is visiting, we assume that the smaller this distance, the more attractive the merchant is 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 at all shops in their neighborhood allows consumers to continuously update their beliefs on the payment methods they share with a particular merchant. The subscriptions of both sides may change over time in the way introduced below.

The next decision is how much the consumer spends at the selected merchant. The consumer budget is constrained in two ways. First, we assume that only a fraction of the consumers income is spent, given that the higher

[8] The constraint on the maximum amount of budget spent varies across business lines

[9] This decision is biased according to the patterns of cardholders' behavior observed in the data reported quarterly to the Mexican Central Bank during 2007.

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 spent 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 decides on the usage of payment method at the selected merchant. If the retailer accepts cards, we assume a preferred card choice. 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[10] non-card consumers may decide to adopt an electronic payment method and consequently they have to choose the issuer they subscribe to. Similarly, cardholders periodically may decide to switch to a different card issuer or to drop their card.

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: merchants' card acceptance and consumers' convenience benefits b_c. The first is endogenously determined 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 merchants that have accepted his cards in past interactions. Let ω_c^+ be the consumer's score for

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

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 she 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 consumer propensity to have payment card and α^+ is another constant representing the consumers' awareness for the benefits arriving from the existing payment card network externalities [11]. At this point, let us explain the interpretation of α^+ in the context of the payment card market. There is some evidence from several countries' experience that consumers and merchants exhibit different rates of payment card adoption. For instance, France and Finland, have been adopting the usage of electronic payment methods on a different rates. We could argue that there are some similarities in the business environment in which the card market is developing, nevertheless consumers' response for card subscription or usage have been different ([12]). From those observations, we conclude that consumers perception of what the costs and benefits from using a payment card, including the places it be used at, are crucial factors for the successful adoption of these methods. As we said earlier, the efficient use of electronic payment instruments could result in substantial savings for society, so it may be important to increase the awareness of consumers and merchants for the potential electronic payment benefits. In our model, we represent the factor of end-user awareness through the value of α^+. It reflects how much consumers value the existence of merchants accepting cards or merchants appreciate the presence of cardholders.

In order to make this concept clearer, assume we have two instantiation of the model with two different values for α^+, with α_1^+ and α_2^+, where $\alpha_1^+ < \alpha_2^+$. In the case, in which α_1^+ occurs, the payment adoption rate on the consumers' side will be lower in comparison to the case, when α_2^+ occurs, since in the letter consumers have higher awareness of the positive network externalities. On this line, is important to mention that it is difficult to obtain the value

[11] 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

[12] European Central Bank Statistics, http://sdw.ecb.europa.eu/browse.do?node=3447413

of α^+ empirically. For that reason, we determine α^+ experimentally. We have created multiple feasible sets of the model instantiation that allow us to reproduce different market scenarios. To that end, suppose our computational model is instantiate several times and in each time the value of α^+ is increased by 0.1 steps, starting with $\alpha^+ = 1$. In this way we have been able to explore the effect that different values of α^+ has on the payment adoption curve.

Further, in order to determine the lowest acceptable level of α^+, we identify the first value of this constant, in which a network growth is observed, e.g. $\alpha^+ = 6$. On the other hand the highest feasible level of α^+ is determined in a market, in which no card transactions are observed. In these circumstances the value of $\alpha^+ = 7$ is constrained by the last instantiation of the model, in which consumers and merchants decide to drop their card subscriptions. In other words, if we continue to increase the value of α^+, that will create an unrealistic situation, in which each side of the market will appreciate the subscriptions on the other side very high, in a way that neither consumers nor merchants will drop their electronic payment instruments, even if they do not using them.

Following the explanations of the consumers decisions, cardholders could also 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 expect to use his card. From those deliberations, assume cardholders will 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 consumers' inertia to abandon the payment card network and α^- is another constant representing cardholders' awareness of the existing positive network externalities.

Finally, cardholders decision regarding which issuer to subscribe is driven by 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 considerations 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 changes 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 to the card network is assigned to a randomly selected acquirer. Merchants decisions are limited to cards acceptance and acquirer choice. These decisions are taken periodically, after observing consumers' behavior at points of sale. The frequency with which merchants review these decisions is governed by a Poisson distribution specific to each retailer with a common mean of λ time periods.

Merchants that do not accept cards keep track of the number of consumers have the intention to pay with 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 δ^+ follows the same lines as for consumers, i.e. it accounts for the merchants' awareness of the positive network externalities. Given the difficulties to determine δ^+ empirically, we identify its value experimentally. In order to explore the effect of δ^+ on the merchant adoption rate, in separated instantiations of the model, ceteris paribus we have tested with different values of δ^+.

If the merchant decides to join the payment card network, then she must select an acquirer. This decision is driven by the fixed fees Γ_a and the

merchant's discount γ_a charged by 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 exogenously given constants.

If the merchant $m \in \mathcal{M}$ accepts cards, every time a card is presented to her, it 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.

4 Results and conclusions

For our experiments we have created two scenarios, basic and extended. In this section we explain the instantiations of the model that allow us to evaluate the impact on network growth that the three analyzed factors have in each scenario. The analyzed factors are the level of *MIF*, the *MD* level and the end-users' awareness of positive network externalities. We refer as a different instantiation of the model, the state in which there is a variation in the value of any parameter used across simulations.

First, the values of the parameters and other variables that remain constant in all exercises are listed in tables 1 and 2. In addition, the initial proportion of consumers having cards (34%), the initial proportion of merchants accepting cards (23%) and the homogeneous convenience benefits of consumers and merchants are given exogenously and are also kept the same for both scenarios. We identify limits on the values of end users' awareness, which are $\alpha^+ \in [6, 7]$ for consumers and $\delta^+ \in [5, 6]$ for merchants. Those limits are adjusted according to the feasible outcome produced by the model.

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 Acquirers	7
$N_{\mathcal{B}}$	Number of business lines	5
$N_{\mathcal{M}_b}$	Total number of merchants to be visited by consumer	21
$N_{\mathcal{M}_1}$	Number of merchants to be visited by consumer (line 1)	3
$N_{\mathcal{M}_2}$	Number of merchants to be visited by consumer (line 2)	12
$N_{\mathcal{M}_3}$	Number of merchants to be visited by consumer (line 3)	2
$N_{\mathcal{M}_4}$	Number of merchants to be visited by consumer (line 4)	2
$N_{\mathcal{M}_5}$	Number of merchants to be visited by 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 when drop cards	0.8
b_c	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 when drop cards	4
b_m	Merchants' convenience benefits	0.02

Table 2: Constants

Further, each issuer and acquirer sets a level price for the payment methods they offer. In table 4 we list the intervals, from which the values of the price levels are chosen. These values are adjusted according to prices observed in the Mexican payment card market.

In the basic scenario, all acquirers charge the same *MD*. We generate different instantiation of the model resulting from variation in the level of *MD*. We test these experiments with the lowest values of end-users' awareness ($\alpha^+ = 6$, $\delta^+ = 5$). We set the level of *MIF* lower than *MD*. We observe that there is merchants' reservation price *MD′* above which there are not card transactions in the market. In the cases when the *MD* is lower

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

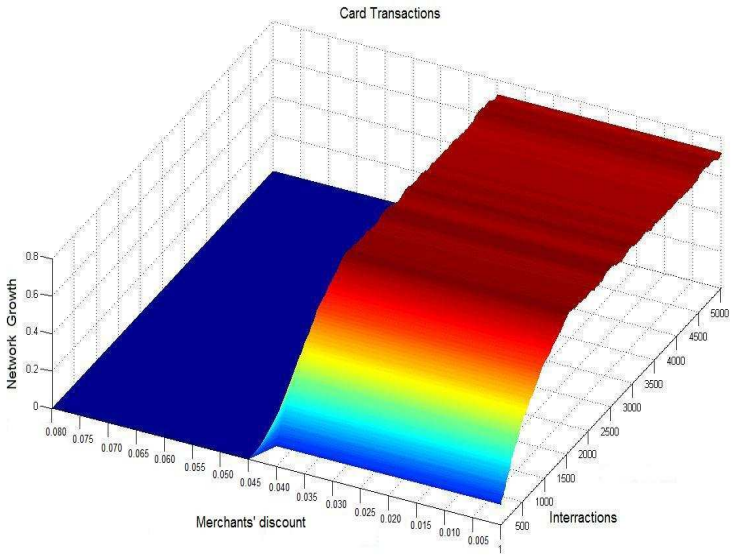

Figure 1: Acquirers charge the same merchant's discount rate

than MD', the achieved network growth rate is the same regardless the merchants' transactional fee. This observation is consistent with our assumption that merchants are willing to accept cards as long as their convenience benefits are higher than the transactional fees they pay to acquirers (see figure 1).

In our extended scenario, we allow acquirers to apply different percentage of merchants' discount. At this stage we do not consider different MD per merchants categories. We compare independent instantiation of the model produced by exogenously given levels of MIF and merchants' discount as well as different levels of end-users' awareness ($\alpha^+ = 6$, $\delta^+ = 5$ as well as $\alpha^+ = 7$, $\delta^+ = 6$). First, we establish three cases determined by the relationship between MIF and MD'. Each case is instantiated with the highest and the

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 4: Prices of the Payment Method

lowest level of consumers' and merchants' awareness. We present our brief analysis for those cases in what follows.

The first case of the extended scenario is analyzed briefly in what follows. The established conditions are that the *MIF* is strictly lower than MD' and all *MD* charged by acquirers are lower than the maximum level of merchant discount MD'. With the lowest end-users' awareness ($\alpha^+ = 6$, $\delta^+ = 5$) we observe that the expected[13] level of growth is achieved without alterations. The outcome of these initializations are presented in figure 2, in the part of the graph, where the merchants' discounts are lower than MD'. In addition to that, in the case of the highest end-users' awareness ($\alpha^+ = 7$, $\delta^+ = 6$) we observe the same pattern of network growth rate, but with higher penetration in the market. Furthermore, the more the participants value the card services the faster the growth of the network is.

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 5: Interval of merchants' discount per case

In the second case of study, we instantiate the model with levels of *MIF* lower than MD', in a way that some of the merchants' discount rate charged by adquirers are lower than the reservation price MD', whereas other charged *MD* higher than MD'. The case of the lowest end-users' awareness ($\alpha^+ = 6$,

[13]The expected level of growth is the one presented in the basic scenario

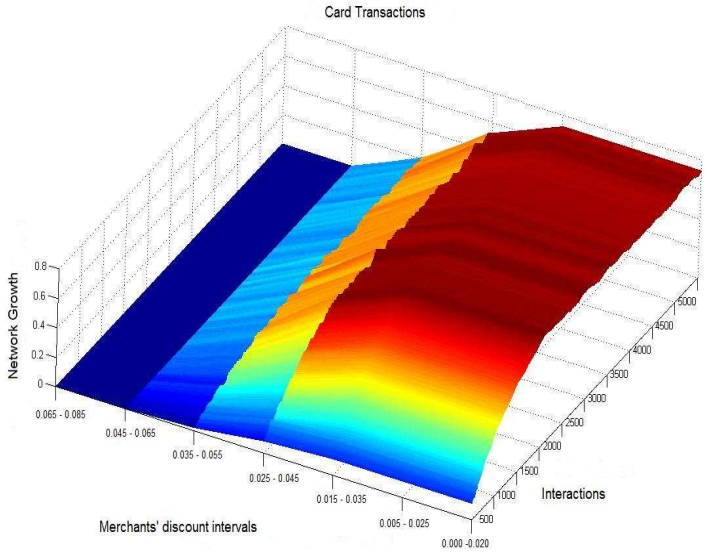

Figure 2: Acquirers are allowed to charge different merchants' discount rates

$\delta^+ = 5$), is in a market, in which consumers do not value strongly the presence of merchants accepting cards the same as merchants do not appreciate the presence of cardholders. When this case occurs no card transactions are observed. Nevertheless in the case, in which the end-users' awareness is the highest ($\alpha^+ = 7$, $\delta^+ = 6$), i.e. both side of the market value the electronic instruments subscriptions on the other side, a network growth is observed, but with lower penetration than the previous case (see figure 2).

We argue that the agent-based market allows us to represent a situation with strong network externalities, which is not trivial to model following an analytical approach. In the presented instantiation of the model some merchants face transactional fees higher than their reservation price; at the same time they are in the presence of externalities arriving from merchants accepting cards with lower transactional fees and cardholders receiving loyalty points. These conditions rise the question, among others, to what extend merchants in this situation are obliged to pay the higher merchants' discount rate. The answer required further research and deeper understanding of the process of merchants' internalization of the externalities observed. Its implications are especially for any potential regulation of the market.

In the third case we test the model with a level of *MIF* equal to the merchants reservation price MD' in a way that all merchants discount rates are higher than MD'. In this instantiation no card transactions are observed, regardless the level of consumers' and merchants' awareness.

From the presented observations, we argue that the artificial agent-based model reproduces a feasible outcome of a payment card market. Given the presented results we consider necessary to explore in depth the scenarios we have studied. Here, we have analyzed scenarios, in which consumers and merchants have homogeneous convenience benefits. We believe that studying the case of heterogeneous convenience benefits will prove us with more insights of the internalization of the network externalities. Furthermore, we think that exploring these possibilities through experimentation will allow us to identify better the cases, in which lowering the level of *MIF* will result in a higher adoption of the payment cards.

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