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Market Structure and Information in Payment Card Markets*

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Summary. This paper investigates the market structure of the payment card market with consumers and merchants basing their subscription decisions on various information sets. We find that the market structure depends crucially on this information set, where we observe that a market with few cards dominating only emerges when decisions are based on very limited information. For more complete information sets, more and more cards survive in the long run. The use of an agent-based model focussing on the interactions between merchants and consumers as a basis for subscription decisions allows us to investigate the dynamics of the market rather than investigating only equilibrium outcomes.

Key words: Multi-homing, two-sided markets, network externalities, agent-based modeling, competition

1 Introduction

The main competitors in the market for credit and debit cards - often referred to simply as payment cards - are Visa and Mastercard. The other competitors, mainly American Express, Diners Club, Discover and JCB hold only a very small market share, often in niche markets. The dominance of Visa and Mastercard has increased in recent years with Visa gaining a small edge over Mastercard through the more important role of debit cards. It is crucial to understand the way competition between

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payment cards works and what its implications are, especially for any potential regulation of the market. This paper presents a novel way to model the market for payment cards by applying an agent-based approach which concentrates on the decisions of card holders and merchants to subscribe to cards rather than the card issuers and the fees they set.

For a successful transaction the payment card market requires both participants to hold the card (buyer/consumer) and accept the card as payment (seller/merchant), respectively. Thus the payment card market is a two-sided market. Holding (accepting) a specific card provides benefits which depend on how often the card can be used. The more consumers (merchants) hold (accept) the card, the more benefits the merchant (consumer) can obtain. These network externalities are of crucial importance for the competition between payment cards.

Most of the literature has in the past focused on the fee structure of payment cards, with an emphasis on the interchange fee. The interchange fee is the amount the bank of a merchant pays the bank of the consumer for each transaction with a card. The literature in this field can generally be divided into models with a single payment card, see e.g [1, 2, 3, 4], and those contributions that allow for competition between payment cards, see e.g. [5, 6].

Multi-homing in payment card markets, i. e. consumers holding or merchants accepting more than one payment card, has only recently attracted wider interest in the literature. The results of these contributions are that unless the costs of doing so are too high or too low, consumers or merchants might subscribe to different payment cards (multi-homing) [7]. Furthermore, multi-homing is mostly observed by either consumers or merchants rather than both as shown in [8, 9] and the majority of benefits arising from multi-homing go to consumers [10]. Finally, [11] point out that with multi-homing payment cards are becoming less compatible with each other.

Most of the models developed in the literature investigate equilibrium outcomes but ignore the dynamic paths that eventually lead towards them. Furthermore, the way competition enables merchants to attract consumers is usually not adequately considered. Addressing this issue we develop an agent-based model of the payment card market which focuses on the competition between merchants for consumers as well as the competition between payment cards. We do so by concentrating on decisions for adopting a card by consumers as well as merchants and analyze the emerging market structure. Evaluating the evolution of the market over time we observe the dynamics of our model and determine its key properties through a number of computer experiments in which consumers have different sets of information.

The following section introduces the the model elements before we describe the interactions between them in section 3. The outcomes of our computer experiments are analyzed in section 4 and section 5 concludes the findings.

2 Model elements

The model contains three relevant elements: merchants, consumers and the payment cards. All fees and benefits will be treated as exogenous variables, allowing us to focus on the interaction between consumers and merchants where the choice which payment cards to hold and accept determine the outcome. This approach can be justified with [12], whose result states that the degree of competition does not affect the fee structure but only the total level of fees.

2.1 Merchants

We consider a set of merchants $\mathcal{M}$ with $|\mathcal{M}| = N_{\mathcal{M}}$ who are offering a homogenous good at a fixed common price and face marginal cost lower than this price. Eliminating price competition between merchants allows us to concentrate on the competition between payment cards and how the card choice affects merchants. The merchants are located at random intersections of a $N \times N$-lattice, where $N^2 \gg N_{\mathcal{M}}$. Let the top and bottom edges as well as the right and left edges of this lattice be connected into a torus.

2.2 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 $N^2 = N_{\mathcal{M}} + N_{\mathcal{C}}$.

Each consumer has a budget constraint that allows him in every time period to buy exactly a single unit of the good offered by the merchants. He will do so only by visiting a single merchant. The utility gained from the consumption of this good exceeds the utility from not buying the good and saving the money for later consumption. In order to obtain the good any consumer $c \in \mathcal{C}$ has to travel to a merchant $m \in \mathcal{M}$, where the distance of this travel is measured by the "Manhattan distance" $d_{c,m}$ between the locations on the lattice; the distance between two adjacent intersections is normalized to unity.

This distance imposes travel costs on consumers which reduces the attractiveness of visiting a merchant. As we will show below, consumers prefer card payments over cash payments. Let us for now assume that when deciding which merchant to visit the consumer has not yet decided which of the cards he holds will be used. In this case the more common payment cards the merchant and the consumer have, $\nu_{c,s}$, the more attractive a merchant becomes. From these deliberations we propose to use a preference function for consumer $c \in \mathcal{C}$ to visit merchant $m \in \mathcal{M}_c$, where $\mathcal{M}_c$ denote the set of merchants a consumer considers to go to:

$$\upsilon_{c,m} = \frac{\frac{\nu_{c,m}}{d_{c,m}}}{\sum_{m' \in \mathcal{M}_c} \frac{\nu_{c,m'}}{d_{c,m'}}}. \quad (1)$$

2.3 Payment cards

There exists a set $\mathcal{P}$ of payment methods with $|\mathcal{P}| = N_{\mathcal{P}} + 1 \ll N_{\mathcal{M}}$. The first payment method is the benchmark and can be interpreted as cash payment while all other payment forms are card payments. In order for a card payment to occur, the consumer as well as the merchant will have to have a subscription to the card in question.

For each unit of the good bought using a payment card, a merchant $m \in \mathcal{M}$ receives positive net benefits, i.e. benefits minus fees paid. These benefits may include reduced costs from cash handling and differ across merchants, but are identical for all cards for a given merchant thus eliminating competition between payment cards arising from differences in benefits they are able to provide. Cash payments do not produce any net benefits.

Consumers also receive net benefits from paying by card, but no benefits from cash payments. The benefits may arise from the delayed payment, insurance cover or cash-back options. We again assume these benefits to be equal across payment cards.

3 Interaction of elements

The three elements of our model are in constant interaction with the payment cards only being passive, while consumers and merchants make active decisions. The decisions by the merchants are limited to the choice of payment cards they subscribe to. The consumers, on the other hand, have to make decisions affecting the subscription to payment cards, which merchant to choose for their purchase and which payment card to use in a transaction.

3.1 Choice of merchant

Each consumer $c \in \mathcal{C}$ chooses a merchant $m \in \mathcal{M}_c$ with probability $\upsilon_{c,m}$ as defined in equation (1). The consumers will continuously update their beliefs on the number of common payments, $\nu_{c,m}$ by observing the number of common payments of all merchants they may visit. We restrict consumers to the five nearest merchants. In the case of several merchants having the same distance from a consumer the merchants are chosen randomly for the length of the experiment.

3.2 Choice of payment card

The consumer decides which payment card he wants to use. We only consider a random card choice, in which the consumer presents any of the cards he holds, and the merchants accepts (common cards), with equal probability. In [13] we also investigate the case of a consumer always choosing the card giving him the largest net benefits, which are assumed to vary between payment cards randomly but unsystematically for each consumer. It has been shown there that these two types of card choices give rise to the same results, although the speed of adjustment differs. If the merchant does not accept any card the consumer holds, the transaction is settled using cash payment.

3.3 Consumer subscriptions

Consumers have in every period of time to decide whether to cancel a subscription to a card they hold and whether to subscribe to new cards. Every consumer $c \in \mathcal{C}$ keeps track whether a card he presented has been accepted or rejected. If card $p \in \mathcal{P}$ has been rejected by the merchant, he increases the score $\omega_{c,p}^{-}$ by one. With ω_c denoting the number of merchants visited, we assume that he cancels his subscription with probability

$$p_{c,p}^{-} = \frac{\exp\left(\frac{\omega_{c,p}^{-}}{\omega_c}\right)}{a + \exp\left(\frac{\omega_{c,p}^{-}}{\omega_c}\right)}, \tag{2}$$

where a accounts for the inertia of consumers to change cards. Similarly on every visit to a merchant he notices that he may accept another card the consumer does not possess, in this case he increases the score of the card he notices, $\omega_{c,p}^{+}$, by one. The probability of subscribing to this card is then given by

$$p_{c,p}^{+} = \frac{\exp\left(\frac{\omega_{c,p}^{+}}{\omega_c}\right)}{a + \exp\left(\frac{\omega_{c,p}^{+}}{\omega_c}\right)}. \tag{3}$$

3.4 Merchant subscriptions

Merchants keep track of all cards presented to them by consumers. Every time a card $p \in \mathcal{P}$ the merchant $m \in \mathcal{M}$ subscribes to is presented he increases the score of $\theta_{m,p}^{-}$ by one; and if he does not subscribe to the card, the score of $\theta_{m,p}^{+}$ is increased by one. He decides to subscribe to a new card with probability

$$\pi^+_{m,p} = \frac{\exp\left(\frac{\theta^+_{m,p}}{\theta_m}\right)}{\alpha + \exp\left(\frac{\theta^+_{m,p}}{\theta_m}\right)}, \tag{4}$$

where θ_m denotes the number of cards presented. Similarly he decides to cancel the subscription of a card with probability

$$\pi^-_{m,p} = \frac{\alpha}{\alpha + \exp\left(\frac{\theta^-_{m,p}}{\theta_m}\right)}, \tag{5}$$

where α represents the inertia to changes as before.

3.5 Information sets of consumers and merchants

We consider three different information sets the consumer can have in order to decide on his card subscriptions. The first information set we call *limited information*. With this information set the consumer only obtains information on the card he presents if it is rejected by the merchant, increasing the score of $\omega^-_{c,p}$. No information is obtained for cards not in his possession nor not presented to the merchant.

In the case of *partial information* the consumer obtains information on all the cards he holds. For each card he owns and which is not accepted by the merchant the consumer increases $\omega^-_{c,p}$ by one. As before, no information is obtained for cards not in his possession.

Finally, with *full information* the consumer considers all cards in the market and increases the score of $\omega^-_{c,p}$ if a card he owns is not accepted by the merchant and increases $\omega^+_{c,p}$ if a card he does not own is accepted. Furthermore, the merchant also learns which cards the consumer holds and increases $\theta^+_{m,p}$ and $\theta^-_{m,p}$ for cards he holds and does not hold. This is in contrast to the two cases above in which he only changes the scores for a card used in the transaction.

4 Computer experiments

Using the above model we conducted a number of experiments using the following fixed parameters settings: $N_{\mathcal{C}} = 1100$, $N_{\mathcal{M}} = 125$, $N_{\mathcal{P}} = 9$, $a = 8$, and $\alpha = 15$. We investigated the model over 1000 time periods for each of the three information sets outlined above.

The initial card holdings of consumers and acceptances of merchants are determined randomly and every consumer as well as merchant can conduct a transaction using cash. The ability to conduct cash transactions is maintained throughout. Each consumer and merchant is allocated a random number of cards between zero and nine with equal probability and then obtains each card with equal probability. We also set $\theta^-_{m,p} = \theta^+_{m,p} = \omega^-_{m,p} = \omega^+_{m,p} = 0$.

Thus the initial market share of each payment card is random, but approximately equal. Some cards will obviously have a larger market share, thus gaining a competitive advantage over other cards. We could interpret these differences as a first mover advantage in a dynamic market.

As we assume that the net benefits are identical across cards, the only difference between the cards is their market share and the size of networks externalities they generate as a result of this market share. When we simulate the above model with their different information sets over some length of time, we observe that the outcome depends in the information set we use for the consumers. The only common result is that cash payments are nearly driven out of the market, which arises from the fact that the net benefits of card usage are positive, while zero in the case of cash payments. Thus all consumers use cards whenever possible and only in cases of a coordination failure do we observe cash payments.

4.1 Limited information

When conducting experiments of the above model we see from figures 1(a) - 1(c) that in the case of only limited information available to consumers for choosing payment cards the market quickly becomes dominated by two payment cards of approximately the same market share and a third payment card having a much smaller market share. This result remains robust whether we define market share in terms of transactions conducted, consumers holding the payment card or merchants accepting it. We also observe that given the positive net benefits of card payments, cash payments are reduced quickly; they nevertheless retain a significant market share as with three cards present in the market we observe regularly a mismatch between card holdings of consumers and acceptances of merchants.

Finally we observe that those cards with the largest initial market share, which is random, are going to dominate the market after a few time steps. This result shows the importance of the network externalities as this small initial advantage is sufficient to gain momentum and become a dominant market player in later stages. We thus find evidence for the importance of a first-mover advantage in markets with network externalities.

The advantage of cards with a large market share is, however, mitigated by multi-homing, which denotes the case of consumers and merchants subscribing to multiple cards. While we see from figure 1(d) that multi-homing is uncommon for consumers who in most cases only hold a single card, figure 1(e) shows that a significant number of merchants are accepting two cards and a very small minority even all three surviving cards. This multi-homing of merchants reduces the need for consumers to coordinate their card holdings into a single payment card together with merchants.

Our result is thus similar to that of [8, 9] who find that multi-homing is usually observed for either consumers or merchants, but not both. Positive externalities from coordinating decisions which cards to subscribe to are reduced for consumers once the number of cards in the market has reduced sufficiently. These reduced network effects give rise to the coexistence of a small number of cards in the long run, a similar effect was obtained by [14] for a very different model, but whose result follows the same intuition.

We finally observe that the card usage is concentrated in distinct geographical zones, see figure 1(f), and it is at the boundaries of these zones that most multi-homing takes place and the coordination between card holdings of consumers and acceptances by merchants break down, resulting in the few cash transactions we observe. Inside their respective zones the cards enjoy local monopolies with no consumers holding or merchants accepting other cards.

The results shown in figure 1, as well as the other figures following, show a typical, although not necessarily representative outcome of an experiment. Averaging the results would destroy many of the features we observe in individual experiments and is thus not attempted here. While the outcome of three cards surviving, of which one maintains only a very small market share, is specific to this experiment, we generally find that between two and four cards survive, of which in most cases one or two are dominating in terms of their market share.

4.2 Partial information

If we increase the information on which consumers base their subscription decisions for payment cards, we observe that the coordination of consumers and merchants to use only a small number of cards fails. As we can clearly see for the case of partial information from figures 2(a) - 2(c), a total of five payment cards survive in the long run. Furthermore, the dominance of the two largest cards is much less significant than with limited information. Although multi-homing of consumers and merchants is slightly increased, see figures 2(d) and 2(e), it does not constitute a significant change from the case of limited information. The main reason for multi-homing not to increase is that the market maintains distinct geographical areas of card usage as shown in figure 2(f), thus the benefits of multi-homing are not large for consumers and many merchants do not find it beneficial to accept more than two cards.

The reason for this development lies in the way consumers now use information on all cards they own rather than only the card they are actually presenting to the merchant. This additional information leads consumers to quickly drop cards not accepted by merchants they visit, but on the other hand they will not easily drop cards accepted by the merchant but not used by the consumer. The consumer continues to hold such a card and may thus present it in the following time step given the random card choice, maintaining a certain diversity in the card holding. Although consumers and merchants will coordinate on one or two cards in most cases, the choices will be more diverse than when having only limited information to base the decision on.

Thus consumers using more information on the cards they hold prevents the market from becoming dominated by only a very small number of cards. In that sense the outcome reflects the current market situation with two large cards and a number of smaller players. Again this described outcome is specific to the experiment conducted, but in other experiments using the same model specification we observe generally the survival of four to six payment cards with one or two cards having a significantly larger market share than the others.

4.3 Full information

In the case of full information consumers and merchants use all information on all cards available in the market. In this case we see from figures 3(a) - 3(c) that no card will be dominating in the long run. All cards obtain roughly the same market share, though it fluctuates widely. We also observe a widespread multi-homing of consumers and merchants, with most consumers holding between three and five cards, see figures 3(d) and 3(e). Any distinct geographical zones in the card usage have disappeared, figure 3(f), and cash transactions appear to be slightly more common than in the case of limited or partial information.

This finding is in stark contrast to that of limited and partial information where we observed that the network externalities caused only a limited number of payment cards to survive and them obtaining a near monopoly in certain geographical areas. The reason for this very different result is that when consumers and merchants use information on all cards available, there is no incentive for any market participant to change his subscriptions, apart from the stochastic element we introduced. With all cards being equal in the initial allocation and no card having a systematic advantage over other cards in terms of net benefits, the incentives modeled do not result in the network externalities dominating the subscription decisions and the market remains essentially unchanged from the initial allocation of cards. In particular we assumed that subscribing to and accepting a card imposes no costs on the consumer or merchant, thus providing no incentives to reduce the number of cards and multi-homing is widespread for consumers as well as merchants.

4.4 Discussion and policy implications

The above cases show that when consumers and merchants base their subscription decisions on more information about the payment cards, a larger number of these cards survive in the market. When evaluating the economic efficiency of this market it is apparent that this is not optimal given the existence of network externalities. With network externalities and our assumption that net benefits are not dependent on the competitiveness of the market it would be most efficient if only a single card survives. Thus in our model it is not optimal to provide more information to market participants on which to base their subscription decisions.

The reason for this outcome is that with more information market participants do not see any significant differences between cards, thus any changes to current subscriptions will be mostly random. Therefore the market position of all cards remains essentially unchanged. In contrast to this with less information market participants only obtain information from their own actions or in the case of merchants from actions of their customers. Although this information in itself may be random, it establishes a positive feedback loop which becomes self-enforcing and causes the market shares of the cards to change significantly. The more information is available to market participants the less well this feedback loop can work and cards maintain their initial positions.

A key feature of our model is that all payment cards are identical to consumers and merchants, i.e. net benefits do not vary systematically across cards, and with less cards surviving in the market the surviving cards do not gain market power. As long as this assumption holds it would not be optimal to provide incentives for consumers and merchants to base their subscription decisions on more information.

We finally have to notice that even with perfectly competitive cards only a small number will survive unless information is very detailed. Analyzing the payment card market in terms of the interconnection fee, as much of the current literature does, may easily be misplaced. What drives the market shares is the way consumers and merchants make their choices on card subscriptions, and the model we developed here shows that the limit to competition in this case is not an interconnection fee but rather the multi-homing of merchants, and to a degree of consumers. The existence of multi-homing is also the reason for multiple cards to survive in the long run when consumers and merchants base their subscription decisions only on partial or limited information and thus preventing a single card from obtaining a monopoly. In order to ensure a competitive market it is thus essential to maintain and promote multi-homing, particularly of merchants.

While we might want to conclude that the properties of the model with partial information is closest to reality, the main difference is the emergence of very distinct geographical zones of card usage which is clearly not replicated in reality. Although differences exist in the market shares of payment cards across countries, they are significantly less pronounced than in our model. [15] finds a correlation between the cards held by consumers and acceptance by merchants, leading to a certain degree of regional concentration of card usage through a local interaction loop, but the regional differences are by no means as distinct as we find in our model.

One limitation of our analysis is that we did only allow consumers to visit the five nearest merchants and ignored any consumers traveling longer distances, e.g. for consumers being on holidays or business journeys. Including such long-distance travel into our model, such as the inclusion of small-world effects in the network structure, might actually change the results of our model and need to be explored in more detail. It is a widely accepted fact that the network topology can have significant impact on the outcomes of any dynamics using its structure. [16] provides an example for the different outcomes of a repeated prisoner's dilemma played on various types of networks and it is reasonable to expect similar differences in our model.

5 Conclusions

We analyzed an agent-based model of the market for payment cards where the interaction between merchants and consumers drove the decision to subscribe to a payment card and subsequently the market shares. We found that the resulting market structure depended on the information on which these subscription decisions were based. For decisions based on less information we obtain the dominance of a small number of cards, each concentrated in distinct geographical areas, while for more information we do not observe any reduction in the number of cards available nor any geographical concentration of usage. Furthermore, multi-homing does become widespread for merchants and consumers rather than being restricted to merchants accepting two or three cards.

Using an agent-based approach to model the payment card market yielded additional insights into the dynamics of the market which conventional models with their emphasis on equilibrium outcomes cannot provide. It became clear that as long as the subscription decisions are not based in too much information, the multi-homing of merchants enables the survival of a small number of payment cards, despite the presence of network externalities. The emergence of multi-homing prevents the quick appearance of a monopolistic market with only a single card surviving, thus preserving competition between cards.

A large number of extensions can be thought of to improve the model further and make it more realistic. The effect different ways of consumers choosing between the cards they hold has been investigated in [13]. As was already mentioned above, it would be further of interest to evaluate the importance of the network topology for the results in our model. Enabling payment cards to react to changes in their market shares through giving different net benefits to consumers and merchants as an incentive to subscribe to the card and actually use it, might provide further insights into the dynamics of the payment card market.

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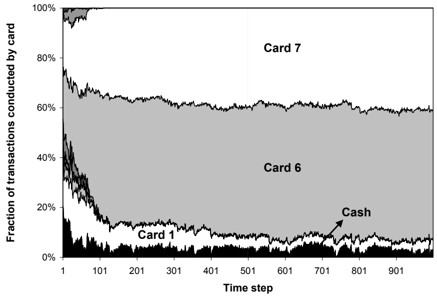
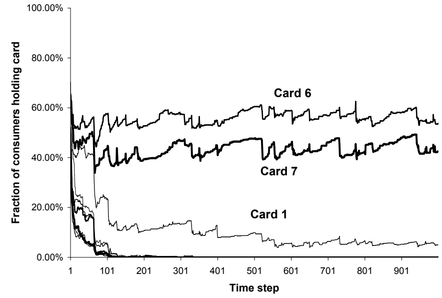
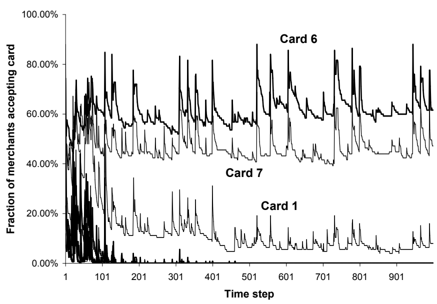


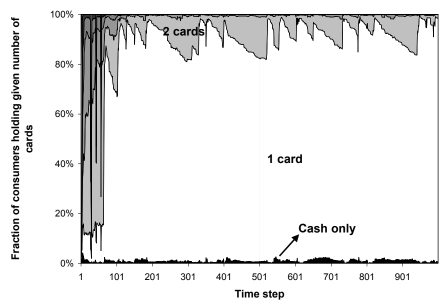
(a) Fraction of transactions of each payment method evolving over time for a typical run.



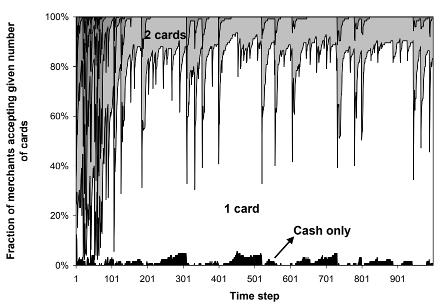
(b) Fraction of consumers subscribing to a given card evolving over time for a typical run.



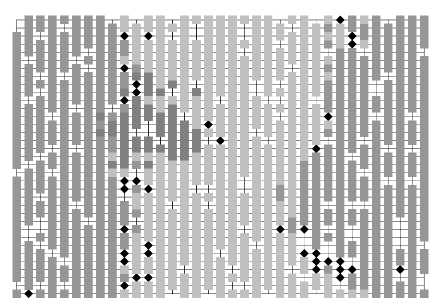
(c) Fraction of merchants accepting a given card evolving over time for a typical run.



(d) Multi-homing of consumers evolving over time for a typical run.

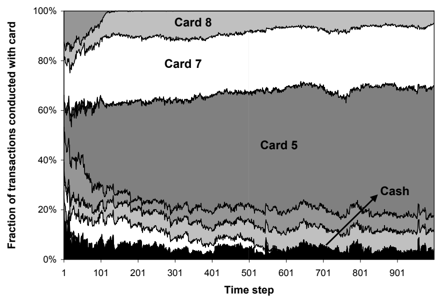


(e) Multi-homing of merchants evolving over time for a typical run.



(f) Regional use of payment cards by consumers after 1000 time steps. Different colors denote different cards, empty cells the location of merchants and a rhombus the use of cash.

Fig. 1. Market structure in the case of limited information.



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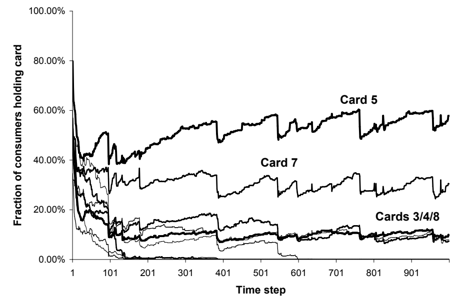
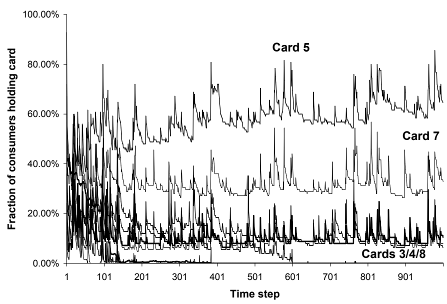
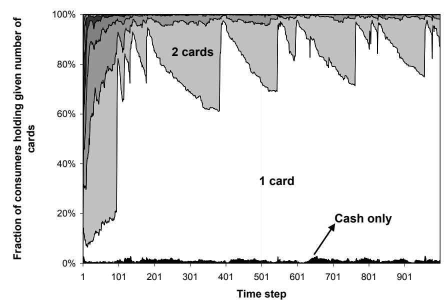


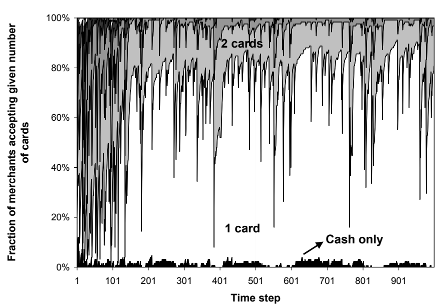
(b) Fraction of consumers subscribing to a given card evolving over time for a typical run.



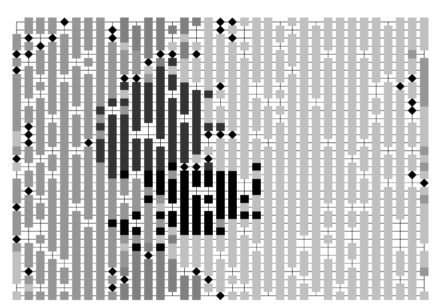
(c) Fraction of merchants accepting a given card evolving over time for a typical run.



(d) Multi-homing of consumers evolving over time for a typical run.

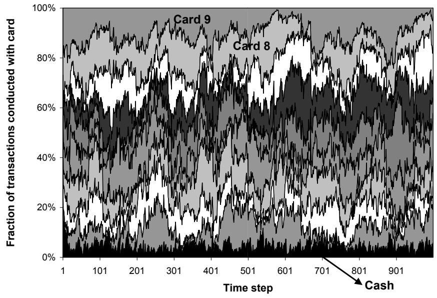


(e) Multi-homing of merchants evolving over time for a typical run.

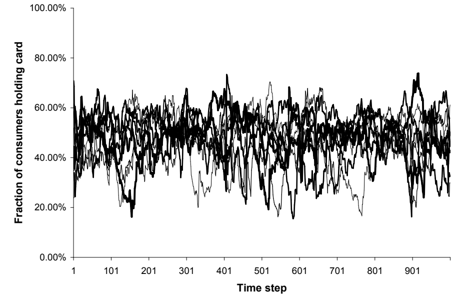


(f) Regional use of payment cards by consumers after 1000 time steps. Different colors denote different cards, empty cells the location of merchants and a rhombus the use of cash.

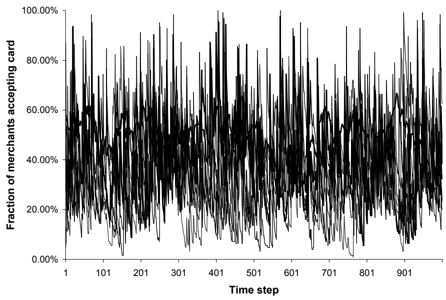
Fig. 2. Market structure in the case of partial information.



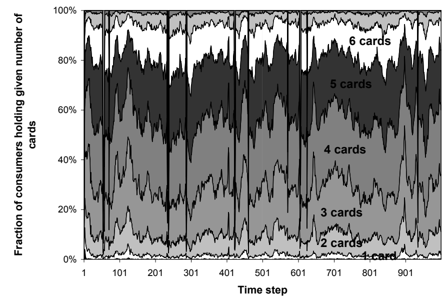
(a) Fraction of transactions of each payment method evolving over time for a typical run.



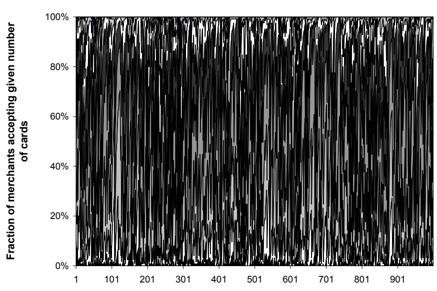
(b) Fraction of consumers subscribing to a given card evolving over time for a typical run.



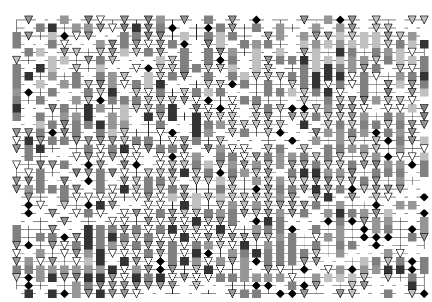
(c) Fraction of merchants accepting a given card evolving over time for a typical run.



(d) Multi-homing of consumers evolving over time for a typical run.



(e) Multi-homing of merchants evolving over time for a typical run.



(f) Regional use of payment cards by consumers after 1000 time steps. Different colors and symbols denote different cards, empty cells the location of merchants and a rhombus the use of cash.

Fig. 3. Market structure in the case of full information.