Discriminatory fees and coordination in shared ATM networks

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Abstract

The introduction of cash withdrawal fees and the partial incompatibility that is generated by the discriminatory nature of some of these fees have been major issues in debates and regulation on ATMs. This paper analyzes how consumers and banks react (in terms of withdrawal behaviour and ATM investment) to the introduction of a discriminatory withdrawal fee, and how welfare in the market is affected. In a setting where banks coordinate their investment decisions and retail fees for cash withdrawals are absent, we develop an empirical model in which consumers decide which ATM (or branch) to use for cash withdrawals and banks decide at which branch to deploy an ATM. We find that the investment behaviour after a discriminatory fee introduction critically depends on the consumers' price sensitivity, and that the effects on ATM availibility, usage and welfare differ substantially for foreign fees as compared to surcharges when banks invest in ATMs in a noncooperative way. While surcharges may result in welfare improvements when ATM availibility is increased, the introduction of a foreign fee always results in a reduction in ATM availibility and welfare as compared to a situation where retail fees for cash withdrawals are absent.

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1 Introduction

Since their introduction in the late sixties Automated Teller Machines (ATMs) have been subject of policy debates and regulation in many countries. A major issue in these debates is the welfare effect of the introduction of cash withdrawal fees and the partial incompatibility that is generated by the discriminatory nature of some of these fees. In ATM markets, compatibility depends on whether consumers can use their cards with other banks' ATM machines. This compatibility can be reduced by imposing retail fees on "foreign" transactions, i.e. transactions on ATMs that are not owned by the consumer's home bank. Such fees can be levied by the consumer's home bank (foreign or "on-others" fees) and/or the bank owning the ATM (surcharges), and may affect consumer welfare in two opposing ways.[1] On the one hand, consumers are harmed as it is more costly to derive benefits from the rival banks' ATMs. On the other hand, they may benefit if greater incompatibility causes banks to increase investment in their ATM networks. The incentives to increase investment may stem from the increased stand-alone revenues of ATMs as well as the indirect network effect between ATM cards and ATMs that provides opportunities for business stealing in the deposit market.

This paper examines the effects of introducing discriminatory fees for cash withdrawals. In particular, we analyze how consumers and banks react (in terms of withdrawal behaviour and ATM investment) to the introduction of a discriminatory withdrawal fee, and consider how welfare in the market is affected. Although the recent literature on ATMs has addressed several of these issues, we aim to contribute in a number of ways. A first policy question we address is to what extent the effects on consumers' and banks' behaviour and welfare differ for foreign fees as compared to surcharges. Although they are at least as prevalent as surcharges, foreign fees appear to have received much less attention in policy debates and the economic literature. Secondly, we analyze how the results are affected by the degree of coordination in the banks' network investment decisions. It is likely that the effect of an introduction of a discriminatory withdrawal fee is different for a market where banks coordinate their investment decisions as compared to markets where banks deploy ATMs in an noncooperative way.[2] Finally, we assess how banks' depositor bases affect their individual reactions to the discriminatory fee introduction.

[1] In addition to these retail fees, foreign ATM transactions involve a wholesale fee as well; the consumer's bank pays an interchange fee to the bank that owns the ATM in order to cover at least part of the cost incurred by the latter.

[2] The introduction of a discriminatory withdrawal fee may also affect the degree of coordination in the investment decisions in a network. Endogenizing the degree of coordination within the network is beyond the scope of this paper, however.

To address these questions we develop an empirical model of consumer cash withdrawal demand and ATM investment in a setting where banks coordinate their investment decisions and retail fees for cash withdrawals are absent. The model is similar to the one in Ferrari et al. (2007) in that a consumer's demand for branch and ATM cash withdrawals depends on ATM availability and the banks' ATM investment decisions involve a trade-off between variable transaction cost savings and additional fixed costs from expanding the network. The novelty of our model is that banks decide at which branch to deploy an ATM rather than on the number of ATMs, thereby internalizing location-based cannibalization effects as well as other banks' investment decisions. We explicitly model consumer and ATM locations and use actual ATM-level demand data to estimate the relevant utility parameters. The model measures how increased ATM availability induces consumers to substitute their cash withdrawals from branches to ATMs and assesses location-based cannibalization effects between ATMs within the network. Second, it allows us to infer the relative importance of fixed costs and variable cost savings from the observed investment decisions.

To estimate the model we have collected a unique data set on ATM cash withdrawals and the location of ATMs in Belgium, where until recently the banks jointly owned a single shared ATM network and coordinated their ATM investment decisions. At the same time, regulation prevented banks from charging cash withdrawal fees at either the shared ATMs or at their incompatible branches. As a result, an ATM was installed at a particular location if the variable cost savings induced by consumers shifting from branches to ATMs for their cash withdrawals were sufficiently high to cover the ATM's fixed cost and if, in addition, this substitution effect was not driven to a too large extent by cannibalization of other ATMs in the network. The situation in Belgium provides a quasi-natural experiment to identify the relevant demand and cost parameters and to analyze the introduction of discriminatory cash withdrawal fees.

We find that the outcome critically depends on the consumers' price sensitivity; when consumers are highly price sensitive the investment incentive of discriminatory fee revenues is dominated by the traditional cost saving incentive, while in the case of low price sensitivity the potential fee revenues from foreign transactions is driving investment behaviour. Second, we find that while in the case of coordinated ATM investment the introduction of a surcharge and a foreign fee result in exactly the same outcomes, these outcomes differ substantially when banks invest in ATMs in a noncooperative way. In the coordination case, the introduction of a discriminatory withdrawal fee increases welfare when consumers are not too price sensitive and are willing to bear the increased cost for foreign transactions. In the competition case, while we again find that surcharges may result in welfare improvement when ATM availability is increased, the introduction of a foreign fee always results in a reduction in ATM availability and welfare as compared to a situation where retail fees for cash withdrawals are absent. Finally, the more asymmetric the banks'depositor bases, the stronger the disparity in size of the banks' ATM networks will be.

These results are particularly relevant for policymakers in the light of recent discriminatory fee introductions and/or changes in the competitive market stucture in Belgium and several other European countries, as well as in the U.S. where the focus has traditionally been on surcharge introductions and foreign fees have been largely ignored.

The remainder of the paper is organized as follows. In section 2 we relate our research to the existing literature. Section 3 discusses the relevant industry background in an international context and takes a first look at our data set. Section 4 presents the empirical model of consumer behaviour and coordinated investment. In sections 5 and 6 respectively we discuss the estimation approach and the empirical results. Section 7 presents the policy counterfactuals and section 8 concludes.

2 Literature

This paper contributes to the small but growing empirical literature on ATMs.[3] Most of this literature has been motivated by the recent move to partial incompatibility after the introduction of surcharges in the U.S. Knittel and Stango (2008) estimate the parameters of a discrete choice model of demand for banks' deposit services and assess the welfare effects of the introduction of surcharges. Controlling for the increase in ATM availability after the introduction of surcharges, they conclude that although incompatibility reduces consumer welfare, the increase in ATM deployment that followed the widespread introduction of surcharing in 1996 sometimes completely offsets this welfare reduction.[4] Ishii (2005) estimates a similar model of demand for deposit services and endogenizes interest rate choice in the deposit market and ATM investment. She finds evidence that banks use ATMs strategically and that this strategic incentive causes overinvestment in ATMs. As a result, banks have an incentive to reduce their number of ATMs when surcharges are banned. Noting the problems of multiple equilibria, Ishii (2005) does not provide explicit predictions regarding equilibrium ATM deployment, so that it is not possible to draw conclusions regarding the overall welfare effects of surcharging from her results.

Both Knittel and Stango (2008) and Ishii (2005) infer the utility effects stemming from ATM networks and surcharging from a structural demand model with as dependent variable

[3]For a survey of the theoretical literature on ATMs, see e.g. McAndrews (2003).

[4]Other empirical contributions on the effects of greater incompatibility on ATM investment include Hannan and Borzekowski (2007) and Snellman (2006).

banks' deposit market shares. Using as a measure of ATM convencience a count of the number of ATMs, both studies ignore one of the primary characteristics of an ATM, namely its location.[5] Gowrisankaran and Krainer (2007) explicitly model consumer and ATM locations, and use this to identify the disutility from travel distance from a structural entry model. In addition, the firms' decision on the level of a (non-discriminatory) retail fee on ATM cash withdrawals is endogenized.[6] They find that a ban on ATM surcharges reduces ATM entry, increases consumer welfare and lowers producer profits. Total welfare remains about the same, but is about 17 percent lower than the surplus maximizing level. Important limitations of their approach are the inability of the model to deal with discriminatory fees and the fact that each firm is limited to owning a single ATM. In addition, Gowrisankaran and Krainer (2007) do not consider the indirect network effects of ATMs on the market for bank deposit services.

The abovementioned papers focus on respectively the strategic motives and stand-alone revenue motives from investing in ATMs. In contrast, Ferrari et al. (2007) focus on the pure cost saving motive for ATM investment and find evidence of substantial underinvestment. Their model of coordinated investment provides an estimate of variable cost savings from ATM cash withdrawals.[7] In addition, using actual demand data on ATM cash withdrawals and a count of ATMs at the local market level, they provide an assessment of the utility effect of a reduction in travel cost from increased ATM availability. Although their model allows to provide answers to several policy questions in a coordinated investment setting it is not suited to analyze the effects of discriminatory fees, as it contains no bank-specific asymmetries and banks are not explicitly modeled as interacting agents.

This paper extends the framework of Ferrari et al. (2007) in order to be able to answer questions related to the issues of partial incompatibility that are mainstream in the literature. In particular, we introduce asymmetries into the model by explicitly considering consumer and ATM locations and using ATM-level demand data to estimate the relevant utility parameters. Based on expectations of this location-specific demand and the cost of an ATM at a particular location, each bank decides on ATM network investment, thereby internalizing location-based cannibalization effects and other banks' investment decisions.

[5] On the other hand, using a count of the number of ATMs allows to also capture sources of utility other than geographical availibility, e.g. extended opening hours for withdrawing cash.

[6] For a test of the magnitude of the strategic incentive relative to the stand alone motive in the setting of surcharge levels, see Knittel and Stango (2007).

[7] Studies measuring cost savings from ATM withdrawals usually link bank cost data with the number of ATMs and number of bank branches, see e.g. Felgran (1984), Berger (1985), Humphrey (1994), or Humphrey et al. (2003). For a theoretical paper that allows for variable cost savings from ATM use, see Croft and Spencer (2003).

The model allows us to analyze the welfare effects of the introduction of a discriminatory fee, including changes in withdrawal behaviour and equilibrium investment responses. Like Gowrisankaran and Krainer (2007), we do not consider the link between ATM availability and deposit markets. However, the importance of these indirect network effects tends to reduce when depositors face a significant cost of switching banks.[8]

Apart from the literature on ATMs, this paper contributes to the empirical entry literature as initiated by Bresnahan and Reiss (1990, 1991) and Berry (1992). Our model consists of an entry and demand equation, as in Berry and Waldfogel (1999) and other recent related work, see e.g. Ishii (2005), Smith and O'Gorman (2008) and Ferrari et al. (2007). The demand equation relates to the literature on structural discrete choice demand models in the spirit of Berry (1994) and Berry et al. (1995). Our empirical model of ATM investment is one of coordinated entry, whereas usually models of free entry are considered.[9] We use Pakes et al.'s (2006) moment inequalities method for the estimation of the investment part of the model and allow banks to make decisions on a network of ATMs, more precisely at which of their branches to install an ATM, rather than on the number of ATMs. Pakes et al.'s (2006) method provides a more general alternative for the incomplete information entry models with endogenous location choice, as developed by Seim (2006).[10]

Finally, by allowing location and consumer characteristics to affect the ATM deployment decision for a particular branch, the paper also relates to the literature on the determinants of technology adoption in banking; see for example Hannan and McDowell (1984, 1987), Sharma (1993) and Saloner and Shepard (1995). Studies in the ATM literature that consider the (exogenous) determinants of ATM deployment are for example Hester et al. (2001) and Massoud et al. (2004).

[8] Evidence on switching costs in banking markets can be found in Sharpe (1997), Kim et al. (2001) and Kiser (2002). The empirical results on the effects of surcharges on deposit market shares are ambiguous. Prager (2001) and Hannan et al. (2003) find no evidence that larger banks are able to use surcharges to successfully steal business from smaller banks, while Massoud et al. (2004) provide evidence of consumer switching behaviour in order to avoid surcharges. Ishii (2005) finds that surcharges increase a bank's market share.

[9] An alternative location model, in which a welfare maximizing government chooses locations for gasoline stations, is found in Chan et al. (2005).

[10] Other applications of Pakes et al.'s (2006) moment inequality method are for example Ishii (2005), Ho (2007), Smith and O'Gorman (2008) and Holmes (2008). For an application similar to ours but in a product assortment choice setting and using Seim's (2006) methodology, see Draganska et al. (2007).

3 Industry background and data set

We study ATM investment and cash withdrawal demand in Belgium in 1994. Before developing the econometric model, we discuss the relevant industry background and the main features of our data set.

3.1 Industry background

3.1.1 International context

Banks traditionally used their branch networks to provide cash withdrawal services to their customers. In the late sixties and early seventies the first ATMs emerged, providing the banks with opportunities to reduce labour costs at their branches. The banks initially developed private ATM networks, accessible to their own customers only. However, both in the U.S. and Europe banks quickly started to cooperate, resulting in the development of shared networks, accessible to all customers of the participating banks.[11] However, parallel to these shared ATM networks, banks continued to provide cash withdrawal services to their own depositors through their traditional branch networks.

As for retail fees for (foreign) cash withdrawals there seems to have been a discrepancy between the U.S. and Europe.[12] In the U.S. banks' customers have been charged a foreign fee for foreign transactions already since the eighties. Surcharges have only become widespread since the lifting of the surcharge ban in 1996. In Europe, banks have a long tradition of zero or low variable retail fees for providing payment services to both own and rival customers. Only more recently, banks in Europe have started introducing discriminatory cash withdrawal fees. These fees are usually foreign fees; surcharges are still very uncommon in Europe.

3.1.2 Shared ATMs in Belgium

Against this background we analyze the shared ATM network in Belgium. First, we discuss the situation of the mid-nineties, which is the sample period of our empirical analysis. For this part, we heavily rely on Ferrari et al. (2007) and refer to the discussion in this paper for more details. Next, we briefly outline some recent developments in the Belgian ATM-

[11] See McAndrews (1991) for a discussion of the evolution to shared ATM networks in the early years in the U.S.; and Ishii (2005) for a review of the recent U.S. evolution and the introduction of surcharges. Details on the evolution of shared ATM networks in Europe can be found in Snellman (2006) and B.I.S. (1999, 2003).

[12] "On-us fees" have been rare in both the U.S. and Europe. McAndrews (2003) provides an overview of the various retail fees for ATM cash withdrawal services in the U.S. A survey of ATM fees in a number of European countries can be found in a study by Retail Banking Ltd. (2005) for the European Commission.

landscape, as this provides an additional motivation for studying the effect of discriminatory fees.

The mid-nineties In the late seventies cooperation between the large banks resulted in the emergence of two competing ATM networks (Mister Cash and Bancontact). Consumers could withdraw cash from any ATM of their own network, but had no access to the competing network. Because of cost considerations and public pressure to increase user convenience the two networks were made compatible in 1987, enabling all Belgian debit card holders to withdraw cash from ATMs of either network. A few years later, in 1990, the two networks merged completely to create a common network operator, Banksys, co-owned by all the banks. Banksys managed the shared ATM network and the emerging electronic services with debit cards.[13]

During 1990-2005, an ATM-committee within Banksys made the decisions to invest in additional ATMs, and replace or remove existing ones. This ATM-committee consisted of representatives of the larger banks, a representative of the smaller banks and a representative of the network operator. The committee decided on the number and location of ATMs. The ATMs were always installed at one of the banks' branches, hence never "off-premise" (e.g. in shopping malls). The banks had to bear the costs of the ATMs that were located at their branches, including the fixed investment and maintenance costs and the variable costs of cash withdrawals (e.g. refilling ATMs).[14]

Figure 1 shows the evolution of the total number of ATMs in Belgium since 1979. The shared ATM network has grown nearly linearly during the eighties to reach maturity in the early nineties. Our data set covers a cross-section of ATM locations in 1994. This year is well-suited for studying ATM investment and demand. First, Figure 1 shows that 1994 represents a mature long-term situation, making it reasonable to abstract from dynamic considerations. Second, in 1994 consumers still made only limited use of electronic payment services and of incompatible private ATMs, installed within the banks' own branches.[15]

[13] As in some other countries, there was one other very small network, Postomat, accessible only to the customers of the Belgian Postal Bank. This network joined forces with Banksys in 2000.

[14] The per transaction cost at ATMs is estimated to be in the range of \$0.15 to \$0.50, see Kimball and Gregor (1995) and Fasig (2001). According to the Belgian network operator Banksys, the fixed cost per ATM amounts to about €2,300 per month. This is similar to estimates quoted by Ishii (2005) for the U.S. Given these costs for the deployers of ATMs, a number of mechanisms to ensure cooperation among all banks were in place, see Ferrari et al. (2007).

[15] The incompatible private ATMs were exclusively for the bank's own customers, allowing for cash withdrawals and other traditional branch transactions, such as the ordering of documents and the transfering of funds. In 1994, less than one fifth of the branches were equipped with an incompatible private ATM, and we will simply treat them as an integrated part of the banks' branch networks.

As for retail fees for cash withdrawals, government regulation in Belgium has for a long time completely prevented the banks from charging retail fees for any payment related services, including cash withdrawals at branches or ATMs. Decreasing margins following intensified competition, a drop in the interbanking rates, and public demand for more transparency increased the banks' needs for charging retail fees. Intensive lobbying eventually resulted in stepwise liberalizations in 1991 and 1993, enabling the banks to charge variable retail fees for cash withdrawal services. In practice, however, a universal service obligation kept the variable fees equal to zero until the late nineties.[16] In sum, Belgian banks have generally charged zero variable retail fees, both for branch cash withdrawal services to their own customers and for the shared ATM cash withdrawals services to all debit card holders. Incentives for investment in a shared ATM network should therefore be found in variable cost savings from cash withdrawals at ATMs instead of branches, to be traded off against the fixed costs from setting-up and maintaining the shared ATM network.

Recent developments Banks' massive investment in private incompatible ATM networks within their branches and a series of bank mergers by the end of the nineties that led to a significant decrease in the number of bank branches triggered a debate on a perceived lack of nation-wide coverage by shared ATM networks. In 2005 the debate resulted in a mandatory sharing agreement, i.e. the banks were forced to make their private ATM networks accessible to rival banks' customers as well.[17] This mandatory sharing agreement resulted in a (larger) single shared ATM network, as was the case in the mid-nineties.

However, there are some important differences. Although a universal service obligation for the banks was maintained, the banks can now more freely decide on what level of fees to charge for which type of transactions. In addition, they are now allowed to bilaterally decide on the level of the interchange fee. As a result, investment no longer occurs in a coordinated way. This evolution will eventually move the Belgian ATM landscape, as well as the one in other European countries, into the direction of a more competitive market stucture like in the U.S., making an inquiry of the effect of discriminatory fees, both surcharges and foreign fees, as well as the role of the extent of coordination in ATM investment all the more relevant.

Summary Belgian banks have for a long time coordinated their investment decisions in the shared ATM network. In the absence of retail fees for cash withdrawal services, variable

[16] The universal service obligation forced banks to offer a minimum amount of payment services, including cash withdrawals at branches or ATMs at a low cost. In practice, banks only charge a small annual fixed fee for payment services and no variable retail fees.

[17] Furthermore, the way for off-premise installation of ATMs has been cleared.

cost savings from cash withdrawals at ATMs instead of branches, to be traded off against the fixed costs from setting-up and maintaining the shared ATM network, provided banks with an incentive to invest in a shared ATM network. These observations will motivate our empirical model of coordinated investment, developed and estimated in the next sections. The year 1994 is well-suited for an empirical analysis of ATM investment and demand since the network had matured and competing electronic payment services were still of limited importance. Recent evolutions in the Belgian as well as European ATM landscape makes an inquiry of the effect of discriminatory fees and the role of the extent of coordination in ATM investment all the more relevant.

3.2 The data

Our data set consists of three main components. The first set of data comprises cash withdrawal demand and location information for a cross-section of ATMs in Belgium in 1994. The second data source is location information for all bank branches in Belgium in 1994. Finally, we have available demographic information at the block group level. Table 1 provides precise definitions of our variables.

The data set on the ATMs was provided to us by the ATM network operator Banksys. These unique data provide cash withdrawal volumes for each ATM in the market in 1994. In addition, we know the geographic location of each ATM, the bank by which it is deployed and the "age" of the ATM. Table 2 presents information on ATM availability in the market (second column) and summary statistics of monthly ATM-level cash withdrawal volumes for the 1,094 ATMs in the sample. On average each ATM generates about 7,731 transactions per month, but a lot of variation exists over the different ATMs. The same information is provided at the level of the eight banks that we consider, which shows that there is some variation in withdrawal volumes at ATMs both between and within banks.[18]

The data on the branch locations were obtained from B.V.B., the Belgian Banking Federation. For 1994, we know the geographic location of all the banks' branches in Belgium. Given that the off-premise installation of ATMs was not allowed until 2005, these data thus provide us with a set of all potential ATM locations in 1994. The first column of Table 2 shows the number of branches for each bank in the market. The seven large banks have relatively similar market shares in terms of branches and, with some exceptions, provide a fraction of the total ATM network that is similar to this share.

The demographic characteristics were obtained from the N.I.S. (National Institute of

[18]We consider the seven large banks in Belgium (ASLK, Generale Bank, Gemeentekrediet, BBL, Kredietbank, Cera, BACOB) and aggregate the smaller banks into one group.

Statistics), Ecodata (Federal Government Agency for Economics), and the R.S.Z. (the National Institute of Social Security) and consist of population (number of inhabitants), the fraction of foreigners, the fraction of young (under the age of 18) and elderly (over the age of 65), and income data at the block group level. Summary statistics on these demographic characteristics can be found in Table 3. The block group level of our data is more or less equivalent to the census block group level for U.S. data, so the data turn out to be at quite a detailed level. In particular, we have 18,614 block groups with an average population of 551. On average, each consumer has slightly more than 200 branches (of all banks) in a radius of 10 km, with the nearest branch (not necessarily one of the consumer's home bank) on average at about 1 km. As for ATM availability, the average number of ATMs within a 10 km radius is 38 and the average distance to nearest ATM is 2 km. There is, however, a large variation in both ATM availability in a radius of 10 km (up to 178) and distance to the nearest ATM (up to 18 km).

Finally, Table 4 provides some additional ATM location characteristics that may affect cash withdrawal volumes and/or the fixed cost of an ATM and will be used in estimation. The table includes summary statistics on demographic characteristics within a radius of 10 km of the location (population, per capita income and the fraction of foreigners, young and elderly), the number of ATM machines deployed at the locations, the "age" of the ATM, distance to the nearest town hall and distance to the nearest town hall of a large city. These variables are summarized for both locations with and without an ATM. Population within the 10 km distance band appears to be larger for locations with an ATM (around 355,000) than for locations without an ATM (around 260,000). This indicates that ATMs are deployed in areas with on average higher population, and hence, higher potential demand. For both sets of potential locations, a large variation exists in this potential demand. The remaining demographic characteristics within a radius of 10 km do not seem to differ for locations with and without an ATM. Turning to the location characteristics, the average distance to the nearest town hall is about 1.5 km for ATM locations and 2 km for branches without an ATM. The distance to the nearest town hall of a large city seems to be smaller for locations with an ATM as well (ca. 23 km versus 27 km). The variable age denotes the number of months the ATM has been in place in 1994 (before December). Most ATMs that were in place in December 1994 have been installed before January 1994, but at least some (4 %) have entered the market during 1994. Finally, banks may decide to provide multiple ATM machines in very attractive locations. This occurs only very rarely, however; there are 10 locations with 2 ATMs and 1 location with 3 ATMs.

The data described in this section will be used to estimate a model of demand for ATM cash withdrawals as well as a model of ATM investment. This will allow us to identify demand (utility) and cost parameters that can be used in the counterfactuals, in which we address our policy questions.

4 The model

4.1 Overview

We observe a cross-section of potential ATM locations or bank branches ($j = 1..J$), and for each location whether it has an ATM or not. For each location that has an ATM, we observe the number of cash withdrawals at this ATM (Q_{Aj}). In addition, we observe a set of consumer locations ($\ell = 1..L$), and for each of these locations a number of demographic variables. In this section we provide the setup of our empirical model that describes the consumers' demand for cash withdrawals at ATMs and the banks' investment decision in the ATM network.

The main intuition of the model is as follows. As for the consumers, we assume that for making cash withdrawals they can either go to an ATM of the shared ATM network or to a branch of their own bank. Consumers are expected to make more withdrawals at ATMs closer to their home location and the more ATMs they have available, the higher the fraction of total cash withdrawals that is performed at ATMs is expected to be. Concerning the investment decision, we consider banks that participate in a shared ATM network agreement and coordinate their investment decisions in the network. More precisely, each bank decides at which of her branches to deploy an ATM in order to maximize all banks' expected joint profits. In doing so, the bank assesses to what extent the entry of an ATM at a particular branch induces additional customers to switch from high variable cost branch transactions to low variable cost ATM cash withdrawals, and hence, to what extent deploying the ATM results in variable cost savings. Location-based cannibalization effects and other banks' investment decisions are internalized, and the additional variable cost savings are balanced against the fixed costs of installing the ATM.

Our empirical model extends the framework of Ferrari et al. (2007) by explicitly considering consumer and ATM locations and using ATM-level demand data to estimate the relevant utility parameters. In addition, banks are explictly introduced as interacting agents and decide at which branch to deploy an ATM rather than on the number of ATMs. We build on the earlier empirical entry literature as initiated by Bresnahan and Reiss (1990, 1991) and Berry (1992). Our model consists of an entry and demand equation, as in Berry and Waldfogel (1999) and other recent related work, see e.g. Ishii (2005), Smith and O'Gorman (2008) and Ferrari et al. (2007). The demand equation relates to the literature on structural discrete choice demand models in the spirit of Berry (1994) and Berry et al. (1995). Our empirical model of ATM investment is one of coordinated entry, whereas usually models of free entry are considered.

We first consider the demand for ATM cash withdrawals in more detail. Next, we discuss the most important features of the investment model.

4.2 Consumer behaviour

We develop a discrete choice demand model that describes the cash withdrawal behaviour of the consumers in the market. For making cash withdrawals, we assume that a consumer can either go to an ATM of the shared network or to a branch of the bank she is affiliated to. Consumers are expected to make more withdrawals at ATMs closer to their home location and the more ATMs they have available, the higher the fraction of total cash withdrawals that is performed at ATMs is expected to be.

In particular, we consider a set of consumer locations. Denote the population at location ℓ as S_ℓ. We assume that each consumer in ℓ makes a number of cash withdrawals Q_ℓ, so that the total number of cash withdrawals in the market equals $Q = \sum_{\ell} Q_\ell S_\ell$. For each cash withdrawal, the consumer has the choice between either using one of the ATMs in her vicinity or to use the outside good ($j = 0$), which is a branch of the bank she is affiliated to. In order to define the subset of ATMs that is in the vicinity of the consumer, let B be the set of potential ATM locations (branches) and A the subset of locations where there is an ATM. The set of ATMs in the vicinity of a consumer located at location ℓ is taken to be the set of ATMs within $\overline{d}$ kilometers of location ℓ, and hence is defined as:

$$A^\ell = \left\{ j | j \in A \text{ and } d_{\ell j} \leq \overline{d} \right\}$$

where $d_{\ell j}$ is the distance between locations ℓ and j. The indirect utility of a consumer located at location ℓ of making a cash withdrawal at the ATM at location j is:

$$u_{\ell j} = \alpha d_{\ell j} + g_\ell \mu + x_j \beta + \varepsilon_{\ell j} \tag{1}$$

with $d_{\ell j}$ the distance between locations ℓ and j, g_ℓ respectively x_j a vector of location ℓ- respectively location j-specific characterics, and $\varepsilon_{\ell j}$ is a random taste parameter from withdrawing cash at the ATM at location j for a consumer at location ℓ.

Indirect utility from using the outside good is normalized as follows:

$$u_{i0} = \varepsilon_{i0}$$

Let $\delta_{\ell j} \equiv \alpha d_{\ell j} + g_\ell \mu + x_j \beta$. Under the standard i.i.d. extreme value distribution for ε the probability that a consumer at location ℓ withdraws cash at the ATM at location j takes the following form:

$$\begin{aligned} s_{\ell j} &= \frac{\exp(\delta_{\ell j})}{1 + \sum_{k \in A^\ell} \exp(\delta_{\ell k})} \text{ if } j \in A^\ell \\ &= 0 \text{ otherwise} \end{aligned} \tag{2}$$

The probability that a consumer at location location ℓ withdraws cash at a branch of the bank she is affiliated to is:

$$s_{\ell 0} = \frac{1}{1 + \sum_{k \in A^\ell} \exp(\delta_{\ell k})} \tag{3}$$

These choice probabilities show that the probability of a consumer withdrawing cash at a particular ATM depends on the ATM network A^ℓ available to that consumer. The probability that a consumer withdraws cash at one individual ATM decreases when more ATMs become available (cannibalization). On the other hand, if more ATMs become available the consumer will withdraw cash at a branch of the bank she is affiliated to with a lower probability or, conversely, the probability of a cash withdrawal performed at an ATM will increase (substitution effect). The amount of cannibalization relative to the size of the substitution effect that is present in a given ATM network configuration will be an important determinant in the banks' decision on the optimal network.

The total amount of cash withdrawals at the ATM located at j equals:

$$Q_{Aj}(A) = \sum_\ell s_{\ell j}(A^\ell) Q_\ell S_\ell \tag{4}$$

and at banks' branches

$$Q_B(A) = \sum_\ell s_{\ell 0}(A^\ell) Q_\ell S_\ell \tag{5}$$

where the arguments A^ℓ and A indicate the conditionality on the ATM network configuration, as explained above.

4.3 Coordinated investment

Banks coordinate their ATM investment (or entry) decisions, in line with our discussion of Section 2. Let A_i be bank i's network choice. Then each bank ($i = 1..n$) decides at which of her branches to deploy an ATM, i.e. on A_i, in order to maximize all banks' joint profits $\Pi(A)$, where the total network of shared ATMs A results from the invididividual banks' network decisions A_i. The joint profits consist of a stand-alone component Π_0, independent of the ATM network configuration A, and of several other components that depend on A. There is a constant variable cost per ATM cash withdrawal of c_A, and a constant variable cost per branch cash withdrawal of $c_B > c_A$. In addition, there may be unobserved (both to the banks and the econometrician) factors $\upsilon_{1,A}$ in the variable profit part of the banks' joint profits. The fixed cost of an ATM at location j is F_j, which consists of both investment and maintenance costs. Banks do not charge retail fees for cash withdrawal at either ATMs or branches. The banks' joint profits in the market are then given by:

$$\Pi(A) = \Pi_0 - c_A Q_A(A) - c_B Q_B(A) + \upsilon_{1,A} - \sum_{j \in A} F_j \tag{6}$$

with $Q_A(A) = \sum_{j \in A} Q_{Aj}(A)$. This is simply the stand-alone profit component plus the unobserved variable profit factors, minus the total variable costs from ATM and branch cash withdrawals, minus the fixed costs of all shared ATMs in the market.[19] We allow these fixed costs to depend on location-specific observables w_j and an unobservable (to the econometrician) shock $\upsilon_{2,j,A}$ that affects ATM fixed costs at a particular location:

$$F_j = w_j \gamma + \upsilon_{2,j,A} \tag{7}$$

The bank's network configuration decision is affected by the unobserved part of the fixed cost of an ATM $\upsilon_{2,j,A}$ as it is observed by the bank at the time of the investment decision. Hence, $\upsilon_{2,j,A} \in I_i$, where I_i is bank i's information set. Since the unobserved variable profit factors $\upsilon_{1,A}$ are not only unobserved to the econometrician but to the banks as well, the banks base their decision on expected profits, taking $E[\upsilon_{1,A}|I_i] = 0$. That is, banks can make prediction errors in their assessment of for example the number of transactions at different ATMs.

To illustrate the banks' incentive to invest in a shared ATM network in the absence of per transaction fees for cash withdrawals let us consider the expected marginal joint profit of adding an ATM at location j. If we let $A \backslash j$ be the network of shared ATMs without an ATM at location j, bank i's expectation on the banks' marginal joint profits from deploying

[19] Note that the joint profits do not depend on the interchange fees, which banks pay to each other through the network operator. These interchange fees are simply transfers between banks and cancel out when adding up the banks' individual profits to obtain joint profits. If firms would choose ATMs in an uncoordinated way to maximize their individual profits, then the interchange fees become potentially relevant and may serve as a mechanism to soften competition for depositors; see Matutes and Padilla (1994) and Donze and Dubec (2006) for analyses of the strategic use of interchange fees when banks do not coordinate their ATM investment decisions.

an ATM at location j are:

$$E\left[\Pi(A) - \Pi(A\backslash j)|I_i\right] = E\left[-c_A\left(Q_A(A) - Q_A(A\backslash j)\right) - c_B\left(Q_B(A) - Q_B(A\backslash j)\right) - F_j|I_i\right].$$

To interpret this economically, substitute out $Q_B(A)$ using $Q(A) = Q_A(A) + Q_B(A)$. The expected marginal joint profits can then be rewritten as:

$$E\left[\Pi(A) - \Pi(A\backslash j)|I_i\right] = E[\underbrace{(c_B - c_A)\left(Q_A(A) - Q_A(A\backslash j)\right)}_{\substack{\text{variable cost saving} \\ \text{due to substitution}}} - \underbrace{c_B\left(Q(A) - Q(A\backslash j)\right)}_{\substack{\text{variable cost increase} \\ \text{due to market expansion}}} - F_j|I_i]. \tag{8}$$

This says that the change in banks' joint profits from adding an ATM at location j consists of three components. First, the additional ATM at location j induces consumers to substitute from high variable cost cash withdrawals at branches to low variable cost cash withdrawals at ATMs. Second, an additional ATM at location j may increase the total number of cash withdrawals, which generates additional variable costs. Third, there is a fixed cost involved in installing an additional ATM at location j. If total cash withdrawal demand $Q(A)$ is inelastic, the second term cancels so that adding an ATM to the network reduces to a simple trade-off between variable cost savings and an additional fixed cost.

Each bank chooses its network of shared ATMs A_i to maximize the banks' expected joint profits, taking the network configurations of the other banks A_{-i} as given. The network of shared ATMs $A^* \equiv (A_i^*, A_{-i}^*)$ is optimal if for each bank we have:

$$E[\Pi(A^*) - \Pi(A')|I_i] \geq 0 \tag{9}$$

i.e. the banks' expected joint profits when the shared ATM network of bank i is A_i^* for a given network configuration of other banks A_{-i}^* should be at least as high as expected joint profits for any alternative network configuration $A' \equiv (A_i', A_{-i}')$. This expected joint profit-maxizing decision involves an assessment of the amount of cannibalization relative to the size of the substitution effect that is present in a given ATM network configuration as well as the fixed cost of deploying an ATM at a particular location. An ATM is installed at a particular location only if the variable cost savings induced by the substitution effect are sufficiently high to cover the ATM's fixed cost and if, in addition, this substitution effect is not driven to a too large extent by cannibalization of other ATMs in the network.

5 Estimation

The model is estimated in two stages: first we estimate the demand model, then we feed the results of this first stage into the joint profit function and estimate the cost parameters of the investment model. We first discuss our approach to estimate the parameters of the demand model for given locations of the ATM network. Second, we describe how to obtain bounds on the cost parameters of the investment model.

5.1 Demand

The demand model is estimated conditional on the observed ATM network configuration A. For given values of the parameters (β, μ, α) we can plug in the data on ATM and consumer location characteristics and obtain the predicted values for the amount of cash withdrawals at ATMs at each location $Q_{Aj}(A)$. In the data we observe the amount of cash withdrawals at each ATM Q_{Aj}.

Let η_j be the difference between log observed withdrawals and log predicted withdrawals at location j:

$$\eta_j = \ln Q_{Aj} - \ln Q_{Aj}(A)$$

The error term η_j is the model's prediction error and can be interpreted to stem from measurement error. An alternative interpretation would be one of unobserved ATM location characteristics. Demand models of this type typically incorporate unobserved product (in our case ATM location) characteristics directly into the consumer utility (1) in order to introduce an error term into the model. For computational reasons we assume in our empirical setting that the observed consumer and ATM location characteristics capture most of the unobserved variation in cash withdrawal volumes, and add the error term in a linear way.[20]

To obtain the parameters of the demand model, we minimize the sum of squared deviations of log predicted withdrawal amounts from log observed withdrawal amounts:

$$(\beta, \mu, \alpha) = \arg\min \ (\eta' \eta) \tag{10}$$

For the empirical implementation we assume that $Q_\ell = 2$ for all consumers in each location ℓ and we define the set of ATMs in the consumer's vicinity as the set of ATMs within a radius of 10 km of the consumer's location.[21]

[20] Our model can therefore be interpreted as a first-order approximation to a model with the error term introduced directly into the indirect utility. The latter would require the use of a contraction mapping in the spirit of Berry et al. (1995) to linearize the model in each iteration of the optimization procedure and would substantially increase the computational burden, which is already high given the large amount of consumer locations in the data. An additional argument of introducing a linear error term can be found in Draganska et al. (2007); if we were to allow the banks to not (perfectly) observe the unobserved location characteristics at the time of the investment decision, this would require taking expectations over a nonlinear function of the unobservables, which is a nontrivial exercise.

[21] The estimate of 2 cash withdrawals per month is based on recent 2004 information at the national level

The variables included are the distance (and its squared) from the consumer's location to the ATM, and other consumer characteristics such as per capita income, and the fraction of foreigners, young (under 18) and elderly (over 65). In addition, we have ATM location characteristics such as bank fixed effects, a variable that captures the availability of multiple ATMs in one location, the age of the ATM, and the distance to the nearest town hall respectively the distance to the nearest town hall of a large city.

5.2 Investment

Pakes et al. (2006) provide a flexible methodology to obtain bound estimators from moment inequalities. The intuition of the estimator is to infer bounds on the unobserved cost parameters from the observed parts of the inequality condition for network optimality (9). If we substitute our functional forms for joint profits (6) into the inequality condition (9) we get[22]:

$$E\left[\left(c_B - c_A\right)\left(Q_A(A^*) - Q_A(A')\right) - \left(\sum_{j\in A^*} F_j - \sum_{j\in A'} F_j\right)|I_i\right] \geq 0$$

Denoting $\Delta Q_A(A^*, A') = Q_A(A^*) - Q_A(A')$, the previous inequality condition is equivalent to:

$$E\left[\Delta Q_A(A^*, A') - \left(\sum_{j\in A^*} \widetilde{F}_j - \sum_{j\in A'} \widetilde{F}_j\right)|I_i\right] \geqslant 0 \tag{11}$$

with $\widetilde{F}_j = \dfrac{F_j}{(c_B - c_A)}$. Hence, the profit maximizing moment inequalities will provide us with bounds on the fixed cost of an ATM at location j relative to the per transaction cost saving of an ATM transaction.

If we were to replace $\widetilde{F}_j = w_j\widetilde{\gamma} + \widetilde{v}_{2,j,A}$, where the $\widetilde{}$ denotes that its argument is expressed as relative to the variable cost saving $(c_B - c_A)$, an unobserved term $\widetilde{v}_{2,A^*,A'} = \sum_{j\in A^*} \widetilde{v}_{2,j,A^*} - \sum_{j\in A'} \widetilde{v}_{2,j,A'}$ would appear in (11). As $\widetilde{v}_{2,A^*,A'}$ is unobserved to the econometrician but known to the bank at the time when it decides on its ATM network configuration, a selection issue may arise. The fact that bank i chooses $A_i = A_i^*$ may be a signal of the realization of $\widetilde{v}_{2,A^*,A'}$

on cash withdrawals. Note that the government also used an estimate of 2 cash withdrawals per month in its universal service obligation proposal for the banks.

[22] Our assumption that each consumer makes 2 cash withdrawals per month implies that the total amount of transactions in the market does not depend on the size of the ATM network A, so that this term cancels. In order to reduce notation, we already drop the unobserved variable profit factor $v_{1,i,A}$ from the equation, as it is zero in expectation and will drop out anyway.

being sufficiently negative, so that $E[\widetilde{v}_{2,A^*,A'}|I_i] < 0$. If this is the case, the joint profit-maximizing condition does not imply that the expectation conditional on bank i choosing $A_i = A_i^*$ of the observed part of (11) is positive, so we cannot infer consistent bounds from the observed profit deviations.

Pakes et al. (2006) provide several ways to deal with this issue. In general, a set of instruments z_i such that the expectation of a linear combination of the $\widetilde{v}_{2,A^*,A'}$-terms conditional on a positive-valued function of these instruments is positive, is required to have the observed part of (11) to be positive. In particular, if $h(z)$ is a positive-valued function of z, we obtain the following inequality condition:

$$E\left\{\sum_i \left[\Delta Q_A(A^*, A') - \left(\sum_{j\in A^*} w_j\widetilde{\gamma} - \sum_{j\in A'} w_j\widetilde{\gamma}\right)\right] |h(z_i)\right\} \geqslant 0 \tag{12}$$

Bounds on the investment cost parameters are obtained by considering for each bank a number of deviations from the observed ATM network configuration A^* and for each deviation creating the sample analogue of the condition in (12)[23]:

$$\sum_i \left\{\left[\Delta Q_A(A^*, A') - \left(\sum_{j\in A^*} w_j\widetilde{\gamma} - \sum_{j\in A'} w_j\widetilde{\gamma}\right)\right] h(z_i)\right\} \geqslant 0 \tag{13}$$

As deviations from A^* we can in principle consider each possible combination of zeros and ones for all locations in the market. This yields $2^J - 1$ possible alternative network configurations A'. As the number of potential locations (branches) in the market is high, this number of alternative network configurations is prohibitive. Therefore, we derive moment inequalities from only four sets of possible deviations:

1. Remove all ATMs of bank i from the market. Hence, A_i' becomes a vector of zeros.

2. Add ATMs to all locations of bank i in the market where no ATM is deployed initially. Hence, A_i' becomes a vector of ones.

3. Add ATMs to all locations of bank i in the market where no ATMs were deployed initially and remove the ones from the locations of bank i where ATMs are deployed initially. Hence, A_i' is the observed vector of zeros and ones with the zeros replaced by ones and vice versa.

4. Move a number of ATMs from locations of bank i in areas with low values for a given location characteristic to locations of bank i in areas with high values for that location

[23] In Ishii (2005) and Smith and O'Gorman (2008) firms' decisions in M local markets are considered. In their case, the sample analog of the expectation in (12) is the sample mean over all markets. We have $M = 1$.

characteristic. Hence, A_i' is the observed vector of zeros and ones with a number of ones replaced by zeros and a same number of zeros replaced by ones. We do the same with moving ATMs from areas with high values for the location characteristic to areas with low values for the location characteristic.

Deviation sets 1 to 3 each provide one moment inequality (per instrument). These inequalities result in bounds on the average ratio of fixed cost over variable cost savings across locations. The deviations in set 4 each generate two inequalities per location characteristic (and per instrument) and provide bounds for the location-specific variables on which we allow the ratio of fixed cost over variable cost savings to depend. In particular, we allow monthly fixed cost over variable cost savings to depend on several demographic characteristics within a 10 km radius from the ATM's location (population, per capita income, and the fraction of foreigners, young and elderly) and ATM location characteristics (distance to the nearest town hall and distance to the nearest town hall of a large city). This results in a total of 17 moment inequalities per instrument. The instruments that we use are a constant term and the sums of the cost ratio determinants across all ATM locations of the alternative network A', $\sum_{j \in A'} w_j$, which we believe to be independent of the unobservable $\widetilde{v}_{2,A^*,A'}$.

Finally, although the banks' expected joint profits in the observed network configuration $A^* \equiv (A_i^*, A_{-i}^*)$ are at least as high as expected joint profits for any alternative network configuration $A' \equiv (A_i', A_{-i}')$, we only consider the individual banks' network devations A_i' while keeping the network configuration of other banks fixed at the observed value A_{-i}^*.[24]

6 Empirical results

We observe a cross-section of potential ATM locations or bank branches ($j = 1..J$), and for each location whether it has an ATM or not. For each location that has an ATM, we observe the number of cash withdrawals at this ATM (Q_{Aj}). In addition, we observe a set of consumer locations ($\ell = 1..L$), and for each of these locations a number of demographic variables. The model is estimated in two stages: first we estimate the demand model, then we feed the results of this first stage into the joint profit function and estimate the cost

[24] We also considered the deviation sets 1-4, while at the same time considering the same deviations for the network configurations of all other banks. These additional inequalities were usually not binding, however. Following Ho (2007), we could in fact allow the other banks to optimally readjust their networks in response to the individual bank's deviations and derive moment inequalities from the resulting networks, but due to the large amount of potential locations this is computationally infeasible.

parameters of the investment model. In this section we discuss the parameter estimates from the demand and investment model.

6.1 Demand

6.1.1 Parameter estimates

Table 5 shows the results of the estimation of the demand model. In a first specification, we let the consumer's indirect utility depend linearly on distance to the ATM's location, while in the second we add a squared term for distance. Distance from the consumer's home location to the ATM's location seems to affect indirect utility in a significantly negative way, as expected. The further away the ATM, the lower utility. The second specification shows that the marginal disutility of distance appears to be decreasing in distance, however.

Some of the other consumer location characteristics also appear to enter the model in a significant way. While foreigners seem less likely to use ATMs, consumers under 18 (or their parents) are more likely to opt for ATMs. Consumers from high income areas and elderly (over 65) are more likely to go to a branch for their cash withdrawals, but these latter effects are not significant.

Turning to the ATM location characteristics, we find that bank fixed effects may partially explain variation in withdrawal volumes of ATMs. In particular, ATMs deployed by banks 1, 3, 5, 6 and 7 generate significantly more cash withdrawals than ATMs installed by a small bank (base group). There are several alternative explanations for this finding. One may be that some of the large banks' branches are located at more attractive locations than the ones of small banks. Another explanation may be that large banks' customers use branches for transactions other than cash withdrawals and then use the ATM at that branch in order to make cash withdrawals. Another finding is that the variable that captures the availability of multiple ATMs in one location is significantly positive. This is as expected, as this variable captures very attractive locations. The time that the ATM has already been installed also enters significantly positive. This may indicate that consumers need some time to find out that an ATM has entered at a particular location and that the transactions volume of a new ATM needs some time to mature. An alternative explanation may be of a more dynamic nature, namely that banks first install ATMs at attractive locations and in a later stadium at less attractive locations. Distance of the ATM's location to the nearest town hall does not seem to significantly affect cash withdrawal volumes, but it has the expected negative sign. Finally, the probability that a given consumers uses an ATM appears to be significantly positively affected by the distance to the nearest town hall of a large city.

6.1.2 Distance, cannibalization and substitution effects

In the following exercise we assess how these parameter estimates translate into demand-side cannibalization and substitution effects. In particular, from the estimated demand model with distance entering linearly we predict the number of transactions by consumers living in a single block group at a particular ATM and let the consumers' distance to the ATM vary. Next, we consider entry of an additional ATM at various distances to the consumers and assess the effect on the number of transactions at the first ATM (cannibalization effect) and on the total number of ATM withdrawals (substitution effect). The two ATMs are assumed to only differ in their distance to the consumers; the remaining characteristics as well as the consumer characteristics are evaluated at sample means.

The first panel of Table 6 shows the amount of ATM cash withdrawals at the first ATM for various distances between this ATM and the consumers. In the first column we find for various distances the number of transactions at this ATM when the second ATM has not entered yet. The next columns show the amount of transactions at this first ATM after the entry of a second ATM, and this for entry at various distances to the consumers. The values in the table are normalized, with the amount of withdrawals when the distance between the ATM and the consumers is zero and the second ATM has not entered yet normalized to 100. The first column in the first panel column of Table 6 shows that the number of transactions at the ATM is decreasing in the distance to the consumers. For instance, increasing the distance between the ATM and the consumers from 5 to 10 km decreases the number of withdrawals at the ATM from 25.21 to 6.11. From the next columns we conclude that the amount of cannibalization is larger when the entering ATM is relatively closer to the consumers' location. For example, the amount of cash withdrawals at the first ATM (at 5 km) drops to 23.94 when the second ATM enters at 1 km of the consumers' location but only to 25.11 when the distance between the consumers and the additional ATM is 10 km.

The second panel of Table 6 presents the corresponding normalized total amounts of ATM withdrawals in the market. The first column coincides to the one in the first panel, as in this case the first ATM is the only ATM in the market. In the next columns we see how the entry of a second ATM at various distances affects the total number of transactions in the market.[25] We find that the closer the additional ATM is to the consumers' location, the more it induces consumers to switch from branches to ATMs, e.g. the total amount of ATM withdrawals increases from 25.11 (when the first ATM is at 5 km) to 99.11 when the

[25] The values in these columns can be obtained from the values in the first panel as follows. In the symmetric case where both ATMs are at an equal distance of the consumers' locations, the (bold-faced) diagonal elements should be doubled. In asymmetric cases, the total amount of ATM withdrawals in the market is the sum of the value below the diagonal and its mirror image above the diagonal.

second ATM enters at 1 km of the consumers' location and only to 31.12 when the distance between the consumers and the additional ATM is 10 km. It follows that although there is a higher amount of cannibalization in the former case, the substitution effect is nevertheless dominating. Furthermore, often it is more efficient (in terms of substitution effects) to have only one ATM relatively close to the consumers as compared to two ATMs further away from the consumers. For example, having one ATM at 2.5 km yields 50.65 ATM transactions, while having two ATMs at respectively 5 and 10 km results in only 31.12 cash withdrawals at ATMs.

This exercise clearly demonstrates the role of distance and ATM availability in shifting additional consumers from branch to ATM transactions. The main result is that not only the number of ATMs but also the location of these ATMs plays an important role in cannibalization and substitution effects.

6.2 Investment

For the estimation of the bounds on the ratio of monthly fixed cost over variable cost savings we use the demand estimates from the second model with the linear distance effect in order to obtain $\Delta Q_A(A^*, A')$ in the sample inequalities (13).[26]

Table 7 shows the bounds estimates for the ratio of monthly fixed cost over variable cost savings. In a first specification, we simply estimate the ratio of fixed cost over variable cost savings as a constant, implying that the ratio is the same for each potential location. Applying the inequality method as described above, we obtain a value for this ratio of €2,541. The fact that we obtain a singleton rather than an interval implies that not all inequality constraints are satisfied.

In a second specification we allow the cost ratio to vary for each potential ATM location. In particular, we allow monthly fixed cost over variable cost savings to depend on several demographic characteristics within a 10 km radius from the ATM's location (population, per capita income, and the fraction of foreigners, young and elderly) and ATM location characteristics (distance to the nearest town hall and distance to the nearest town hall of a large city). We find that the ratio of fixed cost over variable cost savings is likely to be lower in areas with a higher fraction of foreigners and young (under 18) people. Locations with a higher population and locations that are further away from the nearest town hall

[26] In the prediction of demand under a given ATM network structure, we use the observed values for the demand model's prediction error η for the ATMs in the sample, while we assume the error η to be zero (as it is not observed) for the potential ATM locations that do not have an ATM in our observed sample. Using fitted values results in wider but similar bounds. The variable age is set at its maximal value (11) for all observations.

and the nearest town hall of a large city are found to have a higher ratio of fixed cost over variable cost savings. The effects of the other variables seem to be not significantly different from zero, as the parameter intervals include zero. The average implied cost ratio with the additional variables included is estimated to be in the interval €2,493 and €4,041. Using external information that the average monthly fixed cost of an ATM is €2,300, we infer from this interval that the per transaction cost saving of an ATM transactions is situated in the interval €0.57 and €0.92. This is fully in line with the findings of Ferrari et al. (2007) and the earlier literature.[27]

7 Policy counterfactuals

Discriminatory cash withdrawal fees can be levied by the consumer's home bank (foreign or "on-others" fees) and/or the bank owning the ATM (surcharges), and may affect consumer welfare in two opposing ways. On the one hand, consumers are harmed as it is more costly to derive benefits from the rival banks' ATMs. On the other hand, they may benefit if greater incompatibility causes banks to increase investment in their ATM networks. The incentives to increase investment may stem from the increased stand-alone revenues of ATMs as well as the indirect network effect between ATM cards and ATMs that provides opportunities for business stealing in the deposit market.

In this section we examine the effects of introducing discriminatory fees for cash withdrawals. In particular, we analyze how consumers and banks react (in terms of withdrawal behaviour and ATM investment) to the introduction of a discriminatory withdrawal fee, and consider how welfare in the market is affected. We analyze to what extent these effects on consumers' and banks' behaviour and welfare differ for foreign fees as compared to surcharges and how the results are affected by the degree of coordination in the banks' network investment decisions. In addition, we assess how banks' depositor bases affect their individual reactions to the discriminatory fee introduction.

Before we present the results of our policy counterfactuals, we first discuss our approach to address these questions.

[27] While precise estimates are difficult to find, it is well-known that the variable costs for cash withdrawal services are considerably higher at branches than at ATMs. Berger (1985) and Humphrey (1994) find that the variable costs are about twice as high at branches than at ATMs. According to Kimball and Gregor (1995), the per transaction cost is $0.27 at ATMs, compared to $1.07 at branches, while Fasig (2001) states that transaction costs vary between $0.15 to $0.50 for an ATM and $1 to $2 for a teller. From their structural model of coordinated investment, Ferrari et al. (2007) infer a variable cost saving of about €0.60.

7.1 Approach

We analyze the effects of introducing a retail fee for foreign ATM transactions, i.e. transactions on ATMs that are not owned by the consumer's home bank, on welfare, network availability and usage measures. In particular, we consider banks' (joint) profits (Π, π_i), consumer surplus (CS), total welfare (W), the number of ATMs in the market (N, N_i), the fraction of total transactions that is executed at ATMs (s_A, s_{Ai}), and the fraction of foreign transactions in the total amount of ATM transactions (ϕ, ϕ_i). We allow consumers to adjust their withdrawal behaviour in reaction to these fee introductions as well as banks to reoptimize their network of ATMs. In a first step, coordination on ATM investment between the banks remains ("coordination"). In a second case, we relax the assumption of banks coordinating their investment decision and allow them to choose their ATM investment to maximize their own profits ("competition"). In the latter case, multiple equilibria may arise. We therefore simplify our analysis and aggregate the eight banks in our sample into two groups of banks (networks).[28] When discriminatory fees are introduced, we assume that these are only charged when consumers use an ATM that is owned by a bank in the rival network. This implies that the notion of banks within the two networks no longer exists, and we therefore refer to the two networks as "bank 1" and "bank 2".[29] As a consequence, our policy exercise can be interpreted as follows. In the coordination case the two banks coordinate their ATM investment, while in the competition case the two banks invest in ATMs in a noncooperative way. The introduction of discriminatory cash withdrawal fees creates partial incompatibility between the two banks' ATM networks and makes it more costly for the consumer to reap benefits from the rival bank's network. Finally, we vary the banks' depositor bases in order to see how these affect their reactions to a discriminatory fee introduction. The benchmark case is the one observed in the data, where bank 1 has 37 % of the depositors and bank 2 has a share of 63 %. In the two other cases we decrease one bank's share of the depositor base by a factor ten and assign these to the other bank. This

[28] The two networks are selected on the basis of historical reasons. In particular, we replicate the two competing networks that were present in the market in the eighties; the first one consists of banks 2, 4, 5 and 8 in our sample, the second one of the remaining banks. The two networks are of about the same size in terms of number of branches. In terms of deposit market shares, the division is 37%-63%.

[29] An alternative approach would be to define every transaction at an ATM that is not owned by the consumer's *actual* home bank as a foreign transaction, regardless of which network the bank is part of. In this case, the notion of banks within the two networks continues to play a role. The main results are robust to this approach, but we believe that the one followed in the text provides a more clear intuition and is closer to actual situations.

gives market shares of 3.7 % and 96.3 % respectively 93.7 % and 6.3 %.[30]

The bank's individual profits stemming from ATM transactions consist of the following components. First, on each transaction at one of its own ATMs by one of its own customers, the bank saves the cost of a branch transaction c_B but bears a cost c_A to process the transaction (the traditional cost saving incentive). Second, the variable cost of a branch transaction c_B is also saved when the bank's customer withdraws cash at one of the rival bank's ATMs, and in addition the bank earns the foreign fee f and pays the interchange fee a to its rival. Finally, for the rival bank's customers' transactions at the bank's own ATMs, the bank bears a transaction cost c_A, but earns the surcharge p and the interchange fee a.

The number of own and foreign transactions at each ATM are obtained as follows. From our ATM-level demand model we know the probability that a consumer in a given location chooses for a particular ATM. Information on the banks' market shares then allows us to derive the fraction of own and foreign transactions at each ATM.[31] Denote bank i's market share among consumers in location ℓ by $m_{\ell i}$. The total amount of transactions made by bank i's customers is then $Q^i = \sum_{\ell} m_{\ell i} Q_\ell S_\ell$. The number of withdrawals made by bank i's clients at ATM j are $Q^i_{Aj}(A,p,f) = \sum_{\ell} m_{\ell i} s_{\ell j}(A^\ell, p, f) Q_\ell S_\ell$ and the number withdrawals made by the rival bank's $-i$ clients at ATM j are $Q^{-i}_{Aj}(A,p,f) = \sum_{\ell} (1 - m_{\ell i})\, s_{\ell j}(A^\ell, p, f) Q_\ell S_\ell$. Hence, bank i's expected profits can be written as:

$$\begin{aligned} E\left[\pi_i(A,p,f)|I_i\right] &= E[\pi_{0i} - c_B Q^i(A,p,f) - \sum_{j \in A_i} F_j \\ &\quad + (c_B - c_A) \sum_{j \in A_i} Q^i_{Aj}(A,p,f) \\ &\quad + (f + c_B - a) \sum_{j \in A_{-i}} Q^i_{Aj}(A,p,f) \\ &\quad + (p + a - c_A) \sum_{j \in A_i} Q^{-i}_{Aj}(A,p,f)|I_i] \end{aligned} \tag{14}$$

where the remaining terms are a stand-alone component π_{0i}, an additional variable profit term from cash withdrawals, and the fixed cost of bank i's ATM network. When making its network decision, each bank i will select its ATM network A_i such that the expected

[30] We keep the banks' number of branches fixed. One could argue that smaller banks have fewer branches, but potential locations could be considered to be off-premise as well.

[31] In the absence of an ATM-level demand model an assumption such as consumers using a rival bank's ATMs in proportion to that bank's share of the total ATM network is required; see e.g. Ishii (2005).

joint profit of both banks respectively the bank's expected own profit is maximized in the coordination respectively competition case, taking as given the rival bank's (optimal) network decision A_{-i}. Note that the withdrawal amounts now also depend on the retail fees p and f, in addition to the ATM network A.

When we compare the different welfare, network availability and usage measures under the status quo with a situation where a discriminatory fee is charged and/or an alternative degree of coordination in banks' network investment is assumed, we would ideally consider the impact on ATM networks at the national level. Given the high number of potential ATM locations (7751), this is computationally infeasible.[32] We therefore restrict consumers to only make ATM transactions within the boundaries of the local market (municipalities) m where they reside. In this way markets become isolated and reoptimization of networks can be considered at a this lower geographical level, without having to consider network decisions and changes in welfare components in other municipalities. Given that even in this case the number of potential network configurations (2^{J_m}) becomes high very fast, we restrict the counterfactual exercise to local markets with at most 10 branches. In these 290 (out of 589) markets there are 224 ATMs (118 of bank 1 and 106 of bank 2) for a total population of 2,685,016. For each of the markets in our counterfactual exercise, we use our demand and cost estimates to predict the banks' profits for each possible network configuration and select the configuration that is consistent with Nash equilibrium.[33] For this equilibrium we compute the relevant welfare, network availability and usage measures. We only consider equilibria in pure strategies, and in case of multiple equilibria we assume that the equilibrium in which the banks' joint profits are maximal is selected.[34]

[32] Jia (2007) proposes a methodology to consider entry decisions at large number of potential locations. In each iteration of this methodology, however, we need to compute marginal contributions to joint profits for each potential location given the decision in other locations, which turns out to be computationally burdensome.

[33] To account for the fact that the potential market size for an ATM is lower when we move from our national-level empirical model to the restricted local market model, we reestimate the constant term (and dummy variables) in the indirect utility function, keeping the other parameters fixed. The prediction error is set equal to its estimated value for the potential locations that actually have an ATM and to zero for the other potential locations. The cost parameters are evaluated at their mean values and the location-specific unobservable $v_{2,j,A}$ is selected such that the marginal joint profit of an ATM at that location (given the observed network at other locations) is consistent with the observed presence or absence of an ATM.

[34] The number of equilibria per market is usually restricted to two. The results under the alternative equilibrium selection mechanism where the equilibrium with the lowest joint profits is selected yields similar results.

7.2 The effects of surcharging and foreign fees

We now turn to the results of our policy counterfactuals. We analyze the effects of introducing discriminatory cash withdrawal fees by comparing banks' (joint) profits (Π, π_i), consumer surplus (CS), total welfare (W), the number of ATMs in the market (N, N_i), the fraction of total transactions that is executed at ATMs (s_A, s_{Ai}), and the fraction of foreign transactions in the total amount of ATM transactions (ϕ, ϕ_i), in the situation where retail fees for cash withdrawals are absent to a situation in which consumers are charged a surcharge p or a foreign fee f of €1 for foreign transactions.[35] In a first step, there is coordination on ATM investment between the two banks. In the competition case, the two banks noncooperatively invest in ATMs. For each regime, we also vary the banks' depositor bases in order to see how this affects their reactions to a discriminatory fee introduction. Finally, note that consumers reactions in terms of withdrawal behaviour depend on the relative weight of price and distance in the consumer utility function. Given that we only estimate the utility effect of distance, we assume two different values for the consumers' travel cost per km (€0.10 and €0.25) in order to obtain the consumers' price sensitivity.

7.2.1 Coordination

Table 8 shows our welfare, network availability and usage measures under a situation of no fees, a situation with a €1 surcharge and a situation with a €1 foreign fee, and this for varying divisions of the depositor bases among the two coordinating banks. A first important observation is that for each of the cases coordination between the banks results in the same outcome (except for the banks' individual profits) after a discriminatory fee introduction, regardless of whether a surcharge or a foreign fee is introduced. The intuition behind this result is straightforward; consumers pay the same amount for a foreign transaction, only the recipient differs. Equal consumer responses and maximization of joint profits rather than individual profits then result in the same investment incentive structure in the case of a surcharge and a foreign fee.

A second observation is that the results of a discriminatory fee introduction critically depend on the consumers' price sensitivity relative to their distance aversion. Assuming a low value of the travel cost per km implies a high price sensitivity of the consumers, and vice versa. When consumers are highly price sensitive, a discriminatory fee will induce

[35] In our counterfactuals, we assume that the interchange fee a equals €0.40, the variable cost of an ATM transaction c_A =€0.10 and the variable cost saving of an ATM transaction $c_B - c_A$ =€0.70, which is in the middle of the interval inferred from our cost estimates. These values are in line with averages observed in reality (this is also true for the €1 surcharge and foreign fee) and are kept constant during the counterfactuals.

them to make foreign transactions less often and switch to ATMs and branches of their home bank. In order to avoid losses due to foregone variable cost savings in the latter case the banks have a strong incentive to increase the ATM availability to consumers of the bank with the larger depositor base. This increase in ATMs of the large bank reduces the profitability of investing in ATMs for the bank with the smaller depositor base; the more asymmetric the banks' depositor bases, the stronger the disparity in network size will be. Since the potential fee revenues are low and do not provide an investment incentive when consumers are highly price sensitive, total ATM availability only improves moderately. In terms of ATM usage, consumers affiliated to the large bank will be able to avoid paying the discriminatory fee and in addition, will shift to branches for their cash withdrawals only to a very small extent as a consequence of the increase in their own bank's ATMs. The smaller bank's customers are more likely to decrease their ATM usage due to a decrease in their bank's ATM network and the increased cost of foreign transactions. If the disparity in the banks' ATM networks is large, the fraction of foreign transactions in the total of ATM withdrawals may increase for the small bank's customers, despite the discriminatory fee. The overall effect of a discriminatory fee introduction on the different welfare components is negative. The banks' profits are decreased as variable cost savings are foregone and fee revenues are low. Consumers lose as it becomes more costly to reap benefits from the rival bank's ATM network and this additional cost is not compensated by a sufficient increase in ATM availability.

When price sensitivity is lower and distance is more important to the consumers, the outcome of a discriminatory fee introduction is more in line with the one provided to us by the literature. In this case consumers are less likely to shift to branches for their cash withdrawals, so that the banks' incentive to invest in ATMs can focus on the maximization of potential fee revenues rather than on minimizing the amount of forgone variable cost savings. In particular, ATM availability is increased at the locations of the bank with the smaller depositor base and decreased at the locations of the larger bank. Again, the larger the disparity in the banks' depositor bases, the large will be the asymmetry in their ATM network sizes. Given their low price sensitivity the large depositor base of the large bank will not shift to branches but rather increase their fraction of foreign withdrawals, so that overall, the revenue incentive results in a big increase of total ATM availability. In contrast to the high price sensitivity case, the effect on the different welfare components is more likely to be positive. Banks' joint profits increase as a consequence of fee revenues in addition to the traditional variable cost savings. As for the consumers, in the case with symmetric depositor bases the benefits of increased ATM availability appear to outweigh the negative price effect of the discriminatory fee introduction, so that consumer surplus increases as well. When the banks' shares in the depositor base are more asymmetric, consumers are worse off, despite an even larger increase in ATM availability. The decrease in consumer surplus stems from the increased cost of foreign transactions for the large bank's customers, but this negative effect is outweighed by the increase in banks' profits, so that total welfare increases.

7.2.2 Competition

The effects on welfare, network availability and usage measures under a situation of a €1 surcharge respectively €1 foreign fee introduction for varying divisions of the depositor bases among the two competing banks is shown in Table 9. Before we present the results of a discriminatory fee introduction within the context of competition, we briefly discuss the difference in the outcomes of the coordination and competition case in the absence of retail fees. We find that since the banks only consider the effect of ATMs on their own individual profits, ATM investment serves to only shift their own customers from branches to ATMs and the positive externality of cost savings from the other bank's customers' switching behaviour is no longer internalized. Hence, investment behaviour will be generally proportional with the bank's depositor base; the large bank invests more in ATMs than the small bank does and the larger the disparity in depositor bases, the bigger the difference in ATM network size. In our particular case, the introduction of competition results in a moderate increase in total ATM availability.

Turning to the introduction of a discriminatory fee within the context of competition, we see that although the outcome of the exercise is still dependent on the price sensitivity of the consumers, the results are no longer identical for a surcharge introduction as compared to when a foreign fee is introduced. The reason for this is that the banks no longer coordinate their investment decisions in order to maximize their joint profits but rather invest in ATMs in a noncooperative way to maximize their individual profits. When consumers are highly price sensitive, potential fee revenues are low and the main incentive for investing in ATMs remains the traditional variable cost saving incentive. Therefore, except for a small increase in the discrepancies in the banks' network sizes, the investment behaviour does not differ too much from the competition case without retail fees as explained above, and the resulting outcomes are comparable to the ones obtained in the coordination section.

More interesting are the results when the consumers are relatively little price sensitive. In this case, whether a surcharge or a foreign fee is introduced results in substantially different outcomes. The distinction stems from differences in the behaviour of the bank with the smaller depositor base. In the cases where the disparity between the banks' depositor bases is very large we find that while the large bank mainly focuses on the variable cost saving incentive as there is little potential for fee revenues when a surcharge is introduced, the small bank massively invests in ATMs in order to attract as many as possible transactions from consumers from the rival bank. This results in an overall increase of the ATM network and has positive effects on ATM usage as well as the different welfare components. In contrast, the small bank no longer has this investment incentive when a foreign fee is introduced, as the revenues from foreign transactions from the large bank's customers flow to the bank with the larger depositor base. In fact, the small bank even reduces its ATM availability, thereby forcing some of its customers to make foreign cash withdrawals, on which it earns foreign fee revenues. Although this increases banks' profits, the additional cost of foreign transactions and the decrease in ATM availability makes consumers worse off and total welfare decreases. When the banks' depositor bases are more symmetric, both banks have incentives to invest in ATMs in order to attract foreign transactions in the case of a surcharge introduction and to decrease the number of ATMs in the case of foreign fee introduction. This results in an even higher respectively lower ATM availability than in the asymmetric depositor base cases and hence, the conclusions of a positive welfare effect in the case of a surcharge introduction and a negative one in the case of a foreign fee introduction remains.

8 Concluding remarks

We have examined the effects of introducing discriminatory fees for cash withdrawals on ATM investment, usage, and welfare. A first important observation is that the outcome critically depends on the consumers' price sensitivity; when consumers are highly price sensitive the investment incentive of discriminatory fee revenues is dominated by the traditional cost saving incentive, while in the case of low price sensitivity the potential fee revenues from foreign transactions is driving investment behaviour. Second, we find that while in the case of coordinated ATM investment the introduction of a surcharge and a foreign fee result in exactly the same outcomes, these outcomes differ substantially when banks invest in ATMs in a noncooperative way. In the coordination case, the introduction of a discriminatory withdrawal fee increases welfare when consumers are not too price sensitive and are willing to bear the increased cost for foreign transactions. In the competition case, while we again find that surcharges may result in welfare improvement when ATM availability is increased, the introduction of a foreign fee always results in a reduction in ATM availability and welfare as compared to a situation where retail fees for cash withdrawals are absent. Finally, the more asymmetric the banks'depositor bases, the stronger the disparity in size of the banks' ATM networks will be.

These results are particularly relevant for policymakers in the light of recent discriminatory fee introductions and/or changes in the competitive market stucture in Belgium and several other European countries, as well as in the U.S. where the focus has traditionally been on surcharge introductions and foreign fees have been largely ignored. Although our paper provides a significant contribution to policy debates on discriminatory fee introductions in the ATM market and the economic literature, we believe that there are still several ways to move forward in future research. Ideally, one would combine detailed deposit data with ATM-level demand data in order to consider stand-alone as well as strategic incentives and to provide a full welfare analysis of a discriminatory fee introduction. Extensions that are less data demanding would be to endogenize the pricing decisions on both retail and wholesale (e.g. the interchange fee) fees and/or the decision on to which extent to coordinate ATM investment decisions.

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Table 1: Variable description

ATM withdrawals (Q_{Aj})	monthly number of cash withdrawals at shared ATM j
distance	distance between a consumer location and a potential ATM location
per capita income	per capita income in the block group
foreign	fraction of foreigners in the population in the block group
young	fraction of population under 18 in the block group
elderly	fraction of population over 65 in the block group
population_r	population within a radius r of the potential ATM location
per capita income_r	per capita income within a radius r of the potential ATM location
foreign_r	fraction of foreigners within a radius r of the potential ATM location
young_r	fraction of population under 18 within a radius r of the potential ATM locati
elderly_r	fraction of population over 65 within a radius r of the potential ATM locatio
bank i	dummy variable that equals one if the ATM is deployed by bank i
multiple	variable that captures the availability of multiple ATMs at one location
age	number of months in 1994 (before December) that the ATM is in place
distance_th	distance to the nearest town hall
distance_cth	distance to the nearest town hall of a large city

Table 2: Summary statistics on ATM cash withdrawal volumes

	number of		ATM withdrawals (Q_{Aj})			
	branches	ATMs	mean	st.dev.	min	max
all	7,751	1,094	7,731	3,040	701	28,521
small	1,234	99	6,997	2,873	701	18,113
bank 1	1,176	232	7,549	2,672	1,701	17,012
bank 2	628	73	6,359	2,311	1,701	13,010
bank 3	945	137	7,867	3,824	2,802	28,521
bank 4	952	53	6,803	2,565	1,801	13,510
bank 5	985	178	8,154	2,513	1,201	18,213
bank 6	1,091	222	8,462	3,644	1,601	28,020
bank 7	740	100	7,811	2,194	3,202	13,710

Notes: For a description of the variable, see Table 1. Sources: Banksys and B.V.B.

Table 3: Summary statistics on demographics at the block group level

	mean	st.dev.	min	max
population (S_ℓ)	551	639	1	$7,452$
per capita income	1.17	0.27	0	9.67
foreign	0.08	0.10	0	1.00
young	0.21	0.05	0	0.83
elderly	0.17	0.06	0	1.00
branches within 10 km	208	214	0	796
branch average distance	0.90	1.00	0	12.21
ATMs within 10 km	38	49	0	178
ATM average distance	2.04	2.10	0	18.41

Notes: For a description of the variables, see Table 1. The summary statistics (except for population) are population-weighted. Income per capita is in 10,000. Location average distance respectively ATM average distance are (population-weighted) average distances to the nearest branch respectively ATM. The number of neighbourhoods is 18,614. Sources: Banksys, B.V.B., N.I.S., Ecodata and R.S.Z.

Table 4: Summary statistics on potential location and ATM characteristics

	ATM		no ATM	
	mean	st.dev.	mean	st.dev.
population_10	354.35	352.00	262.40	291.91
per capita income_10	1.16	0.13	1.17	0.13
foreign_10	0.10	0.08	0.08	0.07
young_10	0.21	0.01	0.21	0.01
elderly_10	0.17	0.02	0.17	0.02
number of ATMs at location	1.01	0.11	0	
age	10.80	1.12	0	
distance_th	1.51	1.03	2.01	1.43
distance_cth	22.79	20.85	27.04	19.91

Notes: For a description of the variables, see Table 1. Per capita income is in 10,000 euros, population is expressed in 1,000s. Sources: Banksys, N.I.S., Ecodata and R.S.Z.

Table 5: Demand model estimates

	param.	st.err.	param.	st.err.
	consumer characteristics (α, μ)			
distance	−0.28	(0.08)	−0.81	(0.28)
distance^2			0.06	(0.03)
per capita income	−0.28	(0.46)	−0.40	(0.46)
foreign	−6.82	(1.01)	−6.41	(1.00)
young	26.44	(4.85)	22.63	(5.37)
elderly	−3.22	(3.67)	−3.57	(3.66)
	ATM characteristics (β)			
constant	−7.67	(1.86)	−5.93	(2.11)
bank 1	0.19	(0.08)	0.19	(0.09)
bank 2	0.07	(0.11)	0.06	(0.11)
bank 3	0.23	(0.09)	0.23	(0.09)
bank 4	0.09	(0.12)	0.08	(0.12)
bank 5	0.27	(0.09)	0.26	(0.09)
bank 6	0.30	(0.09)	0.30	(0.09)
bank 7	0.20	(0.10)	0.20	(0.10)
multiple	0.72	(0.28)	0.72	(0.28)
age	0.11	(0.02)	0.11	(0.02)
distance_th	−0.02	(0.02)	−0.02	(0.02)
distance_cth	0.01	(0.00)	0.01	(0.00)
R^2	0.18		0.19	

Notes: For a description and summary statistics of the variables, see Tables 1, 2 and 3. Per capita income is in 10,000 euros. Standard errors are in parentheses.

Table 6: Distance, cannibalization and substitution effects

distance	.	0	1	2.5	5	7.5	10
	Cannibalization effects						
0	100.00	**93.72**	95.20	96.82	98.42	99.22	99.62
1	76.40	71.52	**72.67**	73.93	75.17	75.79	76.10
2.5	50.65	47.36	48.14	**48.99**	49.82	50.24	50.45
5	25.21	23.55	23.94	24.37	**24.79**	25.00	25.11
7.5	12.44	11.61	11.81	12.02	12.23	**12.34**	12.39
10	6.11	5.70	5.80	5.90	6.01	6.06	**6.09**
	Substitution effects						
0	100.00	**187.43**					
1	76.40	166.73	**145.35**				
2.5	50.65	144.19	122.07	**97.97**			
5	25.21	121.97	99.11	74.19	**49.59**		
7.5	12.44	110.83	87.60	62.26	37.24	**24.67**	
10	6.11	105.32	81.90	56.35	31.12	18.45	**12.17**

Notes: The shares of cash withdrawals at ATMs are taken from the demand specification with distance entering linearly. The parameters are evaluated at their estimated values and the ATM location and consumer characteristics are evaluated at sample means.

Table 7: Bounds estimates of the ratio of monthly fixed cost over variable cost savings

	lower	upper	lower	upper
constant	$2,541$	$2,541$	$-26,036$	$72,401$
population			11	19
per capita income			$-15,317$	$6,345$
foreign			$-43,093$	$-39,260$
young			$-141,885$	$89,165$
elderly			$-132,310$	$-24,778$
distance_th			313	544
distance_cth			41	142
implied cost ratio	$2,541$	$2,541$	$2,493$	$4,041$

Notes: For a description and summary statistics of the variables, see Tables 1, 2, 3 and 4. The bounds were obtained from network configuration deviations 1-4. The instrument used are a constant term and the sums of the cost ratio determinants across all ATM locations of the alternative network A', $\sum_{j \in A'} w_j$. Population, per capita income, foreign, young and elderly are within a 10 km radius of the ATM's location. Per capita income is in 10,000 euros, population is expressed in 1,000s.

Table 8: The effects of a discriminatory fee introduction: the coordination case

	37-63			3.7-96.3			93.7-6.3		
	no fees	sur-charge	foreign fee	no fees	sur-charge	foreign fee	no fees	sur-charge	foreign fee
	low travel cost								
$\Delta\Pi$	0	−0.26	−0.26	0	−0.08	−0.08	0	−0.15	−0.15
$\Delta\pi_1$	0	−0.17	−0.12	0	−0.07	−0.07	0	−0.08	−0.07
$\Delta\pi_2$	0	−0.08	−0.13	0	−0.01	−0.01	0	−0.07	−0.08
ΔCS	0	−0.24	−0.24	0	−0.02	−0.02	0	−0.17	−0.17
ΔW	0	−0.49	−0.49	0	−0.11	−0.11	0	−0.32	−0.32
N	220	270	270	220	242	242	220	251	251
N_1	77	85	85	77	36	36	77	203	203
N_2	143	185	185	143	206	206	143	48	48
s_A	0.33	0.25	0.25	0.33	0.32	0.32	0.33	0.28	0.28
s_{A1}	0.33	0.16	0.16	0.33	0.10	0.10	0.33	0.29	0.29
s_{A2}	0.33	0.30	0.30	0.33	0.32	0.32	0.33	0.11	0.11
ϕ	0.44	0.07	0.07	0.30	0.01	0.01	0.69	0.02	0.02
ϕ_1	0.72	0.22	0.22	0.72	0.50	0.50	0.72	0.01	0.01
ϕ_2	0.28	0.02	0.02	0.28	0.01	0.01	0.28	0.34	0.34
	high travel cost								
$\Delta\Pi$	0	0.32	0.32	0	0.49	0.49	0	0.65	0.65
$\Delta\pi_1$	0	0.25	−0.20	0	0.54	−0.78	0	−0.02	1.47
$\Delta\pi_2$	0	0.07	0.52	0	−0.05	1.27	0	0.67	−0.82
ΔCS	0	0.23	0.23	0	−0.34	−0.34	0	−0.07	−0.07
ΔW	0	0.55	0.55	0	0.15	0.15	0	0.57	0.57
N	220	443	443	220	504	504	220	511	511
N_1	77	305	305	77	461	461	77	30	30
N_2	143	138	138	143	43	43	143	481	481
s_A	0.33	0.38	0.38	0.33	0.32	0.32	0.33	0.34	0.34
s_{A1}	0.33	0.42	0.42	0.33	0.48	0.48	0.33	0.33	0.33
s_{A2}	0.33	0.35	0.35	0.33	0.32	0.32	0.33	0.52	0.52
ϕ	0.44	0.39	0.39	0.30	0.76	0.76	0.69	0.81	0.81
ϕ_1	0.72	0.20	0.20	0.72	0.04	0.04	0.72	0.89	0.89
ϕ_2	0.28	0.52	0.52	0.28	0.81	0.81	0.28	0.02	0.02

The number of markets is 290. The low respectively high travel costs are €0.10 respectively €0.25. The interchange fee a is assumed to be €0.40, the variable cost of an ATM transaction c_A =€0.10 and the variable cost saving of an ATM transaction $c_B - c_A$ =€0.70. Profit and welfare changes are in millions of euros.

Table 9: The effects of a discriminatory fee introduction: the competition case

	37-63			3.7-96.3			93.7-6.3		
	no fees	sur-charge	foreign fee	no fees	sur-charge	foreign fee	no fees	sur-charge	foreign fee
	low travel cost								
$\Delta\Pi$	0	-0.24	-0.24	0	-0.07	-0.07	0	-0.11	-0.12
$\Delta\pi_1$	0	-0.17	-0.12	0	-0.06	-0.06	0	-0.02	-0.02
$\Delta\pi_2$	0	-0.08	-0.12	0	0.00	0.00	0	-0.09	-0.10
ΔCS	0	-0.24	-0.36	0	-0.15	-0.16	0	-0.21	-0.23
ΔW	0	-0.49	-0.60	0	-0.21	-0.22	0	-0.33	-0.34
N	262	288	249	270	247	236	270	253	235
N_1	98	103	79	72	39	30	175	207	202
N_2	164	185	170	198	208	206	95	46	33
s_A	0.32	0.26	0.23	0.34	0.32	0.31	0.33	0.28	0.28
s_{A1}	0.32	0.19	0.15	0.34	0.10	0.09	0.33	0.29	0.29
s_{A2}	0.32	0.30	0.28	0.34	0.32	0.32	0.33	0.10	0.09
ϕ	0.45	0.06	0.06	0.21	0.01	0.01	0.36	0.02	0.02
ϕ_1	0.69	0.16	0.20	0.82	0.47	0.54	0.34	0.01	0.01
ϕ_2	0.31	0.02	0.02	0.18	0.01	0.01	0.66	0.36	0.44
	high travel cost								
$\Delta\Pi$	0	0.20	0.15	0	0.19	0.07	0	0.33	0.10
$\Delta\pi_1$	0	0.07	0.07	0	0.12	-0.01	0	0.09	0.13
$\Delta\pi_2$	0	0.13	0.08	0	0.07	0.08	0	0.24	-0.03
ΔCS	0	0.42	-1.01	0	0.24	-0.51	0	0.31	-0.68
ΔW	0	0.62	-0.86	0	0.43	-0.44	0	0.64	-0.58
N	262	447	186	270	437	223	270	478	213
N_1	98	224	78	72	222	46	175	187	156
N_2	164	223	108	198	215	177	95	291	57
s_A	0.32	0.38	0.23	0.34	0.38	0.31	0.33	0.37	0.27
s_{A1}	0.32	0.37	0.22	0.34	0.35	0.21	0.33	0.37	0.28
s_{A2}	0.32	0.38	0.24	0.34	0.38	0.31	0.33	0.41	0.20
ϕ	0.45	0.26	0.31	0.21	0.23	0.09	0.36	0.38	0.16
ϕ_1	0.69	0.31	0.41	0.82	0.33	0.70	0.34	0.40	0.14
ϕ_2	0.31	0.24	0.26	0.18	0.23	0.08	0.66	0.16	0.56

The number of markets is 290. The low respectively high travel costs are €0.10 respectively €0.25. The interchange fee a is assumed to be €0.40, the variable cost of an ATM transaction c_A =€0.10 and the variable cost saving of an ATM transaction $c_B - c_A$ =€0.70. Profit and welfare changes are in millions of euros.

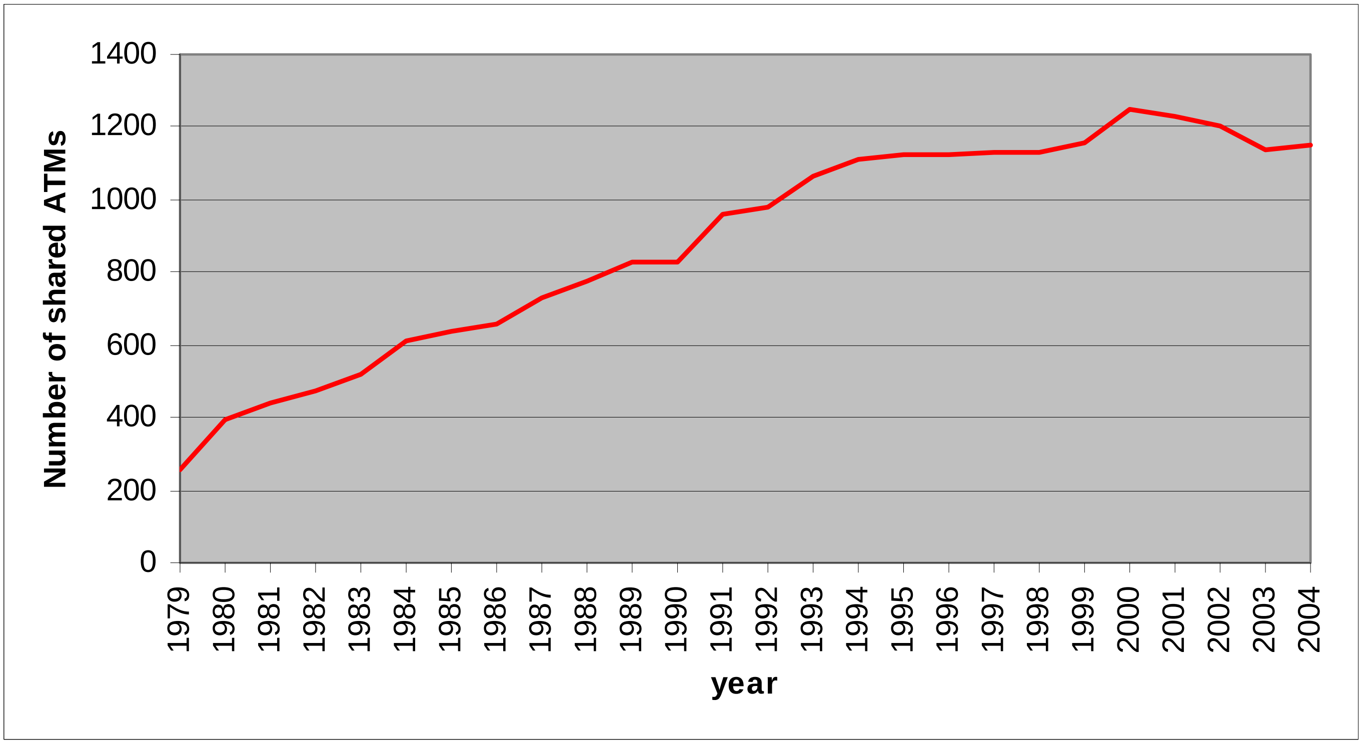

Figure 1: Evolution of the shared ATM network in Belgium (1979-2004)