PAYING FOR ATM USAGE: GOOD FOR CONSUMERS, BAD FOR BANKS?*

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We compare the effects on welfare of the three most common regimes for pricing shared ATM transactions: (i) free usage, (ii) foreign fees, and (iii) foreign fees and surcharges. Paradoxically, banks' profits decrease each time banks set an additional fee while consumers' welfare is higher when ATM usage is not free. Surcharging boosts ATM deployment and makes consumers better off if travel costs to reach cash are high. Our results are consistent with recent empirical works and also shed light on the Australian reform that consists in removing the interchange fee.

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I. INTRODUCTION

In most countries, banks share their automated teller machines (hereafter ATM's): a cardholder of a bank can use an ATM of another bank and make a 'foreign withdrawal'. This transaction generates two types of monetary transfers. At the wholesale level, the cardholder's bank pays an interchange fee to the ATM-owning bank. It is a compensation for the costs of deploying the ATM and providing the service. This interchange system exists in most places where ATM's are shared.[1] At the retail level, the pricing of ATM usage varies considerably across countries and periods. In the United Kingdom or France, banks do not levy any usage fee. In Australia, consumers pay a 'foreign fee' to their bank when they use an ATM of another bank. In the U.S.A., cardholders pay two separate fees per foreign withdrawal: a foreign fee to their bank and a 'surcharge' to the ATM-owning bank.

There have been substantial debates about the pricing of ATM networks since the beginning of the 90s. There are two main issues. At the wholesale level, banks choose the level of the interchange fee jointly in most countries. Some economists have argued that this level could be reflected in the ATM usage fees or the account fee so that banks may use the collective setting of the interchange fee at the wholesale level to relax price competition at the retail level (see the Cruickshank report [2000] for the U.K., Balto [2000] for the U.S.A., Donze & Dubec [2006] for France). Several attempts have been made to limit the possibility of collusion: for example in Australia and South Africa, regulation authorities have studied the possibility to replace the interchange system by a 'direct charging regime' in which each bank charges a single ATM usage fee to non-customers using its ATM's (see Reserve Bank of Australia & the Australian Competition and Consumer Commission [2000]; Competition Commission of South Africa [2007]).

At the retail level, consumers are reluctant to pay ATM usage fees. It is especially true in the U.S.A., where generally cardholders have to pay a foreign fee and a surcharge for using an ATM not operated by their bank.[2] This 'double charge' makes foreign withdrawals quite expensive (around 3$ in 2006, see Hayashi, Sullivan, Weiner [2006]), and consumers' associations have complained about surcharges, arguing that interchange fees are already charged to compensate banks for processing foreign withdrawals. On the other hand, banks and independent ATM deployers claim that the introduction of surcharging from 1996 has allowed them to deploy more ATM's and thus has facilitated access to cash. Empirical evidence shows that ATM deployment has been much faster from 1996.[3] Nowadays, the U.S.A. and Canada have much more ATM's per inhabitant than countries in which surcharging is not applied.[4] In the U.S.A., banks' profits have been affected since the lift of the surcharge bans in 1996. Indeed, the larger number of ATM's and rising surcharges have induced a sharp fall in the number of transactions per machine, notably the foreign acquired transactions that generate revenues in the form of surcharges and interchange fees.[5] The revenues per ATM have fallen and recent studies show that on average banks lose money on their ATM's.[6]

In this paper we study how the ATM pricing scheme affects the ATM deployment, consumers' welfare and banks' profits. We notably address the following questions: Do ATM usage fees harm or enhance consumers' welfare? Does the collective setting of the interchange fee favor collusion? Should the interchange fee be abandoned in favor of direct charging as proposed by the Australian Competition Commission?

To answer these questions, we develop a model where two horizontally differentiated banks first choose the interchange fee jointly and then deploy ATM's and compete for depositors non-cooperatively. We compare three regimes of retail ATM pricing. In all regimes, consumers pay a fixed account fee to join a bank. Under regime one, cardholders can freely access to all ATM's of the shared network (ATM usage fees are nil). Under regime two, cardholders pay a foreign fee to their bank per foreign withdrawal. Under regime three, they pay a foreign fee to their bank and a surcharge to the ATM-owning bank.

Consumers need a fixed amount of cash in a shopping space, that can range from a concentrated to a sprawling area. For a given number of ATM's, the average travel cost to withdraw cash is higher in a wider shopping space and consequently consumers' valuation of an additional machine is higher. The parameter reflecting the dispersion of the shopping space will play an important role in the comparison of consumers' welfare across the different regimes.

We find that the size of the shared network is sensitive to the pricing regime. Under regime one, ATM usage is free and hence all ATM's are identical for consumers. In this case, banks deploy ATM's not to attract new depositors but rather to generate interchange revenues. Under regime two and three, foreign withdrawals are not free and the two networks are differentiated by usage fees: consumers prefer to join a bank with a large ATM network in order to make less foreign withdrawals. In this case, each bank can increase its deposit market share by deploying more ATM's. We show that for a given interchange fee, this differentiation effect of ATM usage fees leads banks to deploy more ATM's under regime two than under regime one. In general the network is even larger under regime three: surcharging increases the revenue per non-customer's withdrawal above the interchange fee. Consequently banks are even more eager to open ATM's to attract foreign withdrawals.

Paradoxically, for a given interchange fee, consumers' welfare is larger when they pay foreign fees (regime two) than when ATM usage is free (regime one) while the opposite is true for banks' profits. As noted before, more ATM's are deployed under regime two which benefits consumers but increases deployment costs. Banks' pricing strategy reinforces this effect on surpluses and profits. Indeed, when ATM usage is free, cardholders make 'many' foreign withdrawals which generates a large gross surplus that banks can extract through the account fee. With the unitary foreign fees, consumers adjust the demand for foreign withdrawals downward and pay less to their bank.

Another striking result is that when banks set the interchange fee at the joint-profit maximizing level, profits are highest under regime one and lowest under regime three. When surcharges are prohibited, equilibrium profits depend on the interchange fee, so that banks can use the interchange fee as a collusive device. This possibility is especially profitable for banks under regime one because they can generate and extract a large consumers' surplus as explained above. Regime three is the worst for banks because many ATM's are deployed, leading to high deployment costs. Besides, we show that the interchange fee does not affect banks' profits anymore and cannot be used as a collusive device. The model predicts that under regime three, banks lose money on average on their ATM's, which is consistent with evidence presented earlier.

We also compare the consumers' surpluses at the profit-maximizing interchange fees. We show that banks can extract all consumer surplus under regime one. This is not the case when usage fees are levied. As noted before, more ATM's are deployed under regime three than under regime two and consequently, consumers benefit from a better but more expensive service. We show that consumers prefer regime three to regime two when the parameter reflecting the dispersion of the shopping space is high enough. In this case, accessing to a machine is more costly and consumers highly value each additional ATM: they are ready to pay for the large ATM network of regime three. When the shopping space is more concentrated, consumers are satisfied with the smaller but less expensive network of regime two. The importance of travel costs in comparing consumers' welfare is consistent with empirical evidence. Working with different local markets in the U.S.A., Knittel and Stango [2008] use the regime change of 1996 (from regime two to three) as a 'before and after experiment' to study the impact of the ATM pricing on ATM deployment and consumers' welfare. They find that 'consumers in high travel cost counties experience substantially higher welfare after 1996, while the net effect remains negative for consumers in low travel cost counties'. Our paper is the first theoretical work justifying the importance of travel costs in the welfare comparison.

At the regulatory level, we show that the 'direct charging scheme' where the interchange fee is suppressed and where customers pay a unique ATM usage fee to the ATM-owning bank is equivalent to regime three. This comes from the neutrality of the interchange fee under regime three. Direct charging hurts profits because banks deploy many ATM's to generate surcharge revenues. Still, consumers benefit from direct charging if the dispersion parameter is high enough.

Our analysis highlights the interactions between the 'withdrawal market' and the deposit market: in our model consumers' choice of where to open an account is endogenous and depends on the account fees, the number of ATM's deployed by each bank and the ATM usage fees. Empirical works dealing with the American ATM market have shown that these three variables matter. Massoud, Saunders and Scholnick [2006] find that higher surcharges give customers some incentives to switch accounts from smaller banks to larger banks in order to avoid high usage fees. Ishii [2006] and Knittel and Stango [2008] find that when banks levy usage fees, the relative size of banks' ATM networks has a significant impact on consumers' decisions where to bank. The two papers also show that ATM deployment increases with surcharging, which is consistent with our theoretical results. Knittel and Stango [2009] find that the surcharge ban removal in 1996 positively affected deposit account fees. Ishii [2006] also notes that a move to compatibility through the elimination of surcharges would raise average deposit interest rates. Our results also support the fact that price competition on the deposit market is less intense under regime three than under regime two: surcharging makes a gain in the deposit market share arise at the expense of surcharges revenues.

Our work is also related to an extensive theoretical literature on ATM pricing (see McAndrews [2003] for a survey). Donze and Dubec [2006] focus attention to regime one and show the collusive role of the interchange fee. We extend our model by considering a more general demand for withdrawals and new pricing regimes. Massoud and Bernhardt [2002] consider a framework where there is no interchange fee and ATM deployment is exogenous. They show that banks set high ATM usage fees for non-customers in order to raise the cost of foreign withdrawals and become more attractive. This indirect effect of surcharging on the deposit market also exists in our framework under regime three. In a work closely related to ours, Chioveanu, Fauli-Oller, Sandonis and Santamaria [2009] compare regimes two and three. They set up a model where banks install ATM's in malls isolated from each other. Consumers visit any of the malls randomly. Travel costs play no role in the demand for ATM services. Using numerical methods, the authors find that surcharging boosts ATM deployment and increases the price consumers have to pay for ATM usage. They show that in most cases, the effect on deployment outweighs the effect on prices so that consumer surplus increases. We obtain close results but our framework permits to take into account the role of travel costs when comparing welfare.

The paper is organized as follows. Section II builds up the model. Section III studies the regime without ATM usage fee (regime one). Sections IV and V examine the regimes with foreign fees (regime two) and foreign fees plus surcharges (regime three). Section VI compares welfare across regimes and studies the effect of suppressing the interchange fee. Section VII concludes.

II. THE MODEL

We use the Hotelling framework. Two banks are located at the two ends of a linear product space of length 1. Consumers of banking services are distributed uniformly along this product space. Their number is normalized to one. Consumers do their shopping and withdraw money in *another* space, which we refer to as the shopping space. The shopping space consists of a fixed number of stores and can be more or less spread out. It is a shortcut to take into account travel costs to reach cash in the analysis. We will return to this point later. We assume that within the shopping space, consumers' location is uniform at any time they need cash. The total amount of cash withdrawn per cardholder is fixed.

II(i). *Banks*

They provide two kinds of services: (i) basic banking services (deposit management, possibility to withdraw cash at the bank's branch office,...) and (ii) access to a network of compatible ATM's. The marginal cost of providing the basic services is constant and denoted by c_b. The number of ATM's deployed by bank i is n_i and the total number of ATM's is $n = n_1 + n_2$. As the measure of consumers is one, n is a number of ATM's per consumer and 1 is clearly an upper bound for n. We assume that since consumers are uniformly distributed *in the shopping space* when they need cash, each bank uniformly deploys its ATM's. The cost of deploying and operating an ATM is denoted by c.[7] The marginal cost of processing a withdrawal is independent from the affiliation of the cardholder and it is normalized to zero. When a cardholder of bank i makes a withdrawal at an ATM of bank j, bank i pays an interchange fee, a, to bank j.

Bank i sets an account fee p_i for its cardholders. There are two possible ATM usage fees, f_i and s_i. Bank i charges its own cardholders a foreign fee f_i for each withdrawal made at an ATM of bank j (foreign withdrawal). Bank i charges cardholders of bank j a usage fee s_i (surcharge) when they use one of its ATM's. We assume that banks do not make their cardholders pay for domestic withdrawals, as it is usually observed. We will consider three pricing regimes. Under regime one, there is no ATM usage fees: $f_i = s_i = 0$. Under regime two, only surcharges are prohibited: $s_i = 0$. Under regime three, foreign fees and surcharges are allowed.

II(ii). *Consumers*

Their reservation utility is equal to zero. To become a cardholder of bank i located at a distance δ_i in the product space, a consumer must pay the account fee p_i to the bank. In this case, the consumer obtains a total surplus equal to:

$$w_i = v_b - t\delta_i + v_i - p_i. \tag{1}$$

The first term v_b is the fixed surplus from consuming basic services. The second term $t\delta_i$ is a differentiation cost *in the product space* (where $t > 0$). Parameters v_b, c_b and t have the following properties:

Assumption 1. (i) t is 'sufficiently large' and (ii) $v_b - c_b \geq 3t/2$.

Assumption 1(i) is required for the second-order conditions of the profit maximization to hold. Assumption 1(ii) guarantees that consumers want to join a bank even if there is no ATM. To ensure the existence of equilibria, v_b, c_b and t must satisfy one extra condition described later. The third term of expression (1), v_i, corresponds to the variable net surplus from consuming withdrawals. More precisely,

$$v_i = u_i(n_i, n_j, q_i^d, q_i^f) - (f_i + s_j)q_i^f, \tag{2}$$

where q_i^d (respectively q_i^f) is the number of domestic (respectively foreign) withdrawals made by a cardholder of bank i. To justify the shape of v_i and the resulting demands for withdrawals, we have in mind a framework *à la* Allais [1947], Baumol [1952], Tobin [1956]: consumers trade off the costs and the benefits of holding cash. The costs mainly consist of the forgone interests. However holding cash permits to use ATM's less frequently. This is a benefit because withdrawing cash at an ATM requires walking to the machine and possibly paying usage fees. Clearly, the average travel cost to reach a machine depends on the network size and the dispersion of the shopping space. In appendix 1, we define a quadratic gross surplus function $u_i(n_i, n_j, q_i^d, q_i^f)$. This function is built to generate individual demands for withdrawals in which the three key determinants are the number of ATM's, the dispersion parameter and the usage fees. For tractability, these demands are linear. Furthermore, the network size effect and the price effect are separated. We have

$$q_i^d(n_i, n_j, f_i + s_j) = \alpha \frac{n_i}{n} n^\gamma + \beta'(f_i + s_j) \tag{3}$$

and

$$q_i^f(n_i, n_j, f_i + s_j) = \alpha \frac{n_j}{n} n^\gamma - \beta(f_i + s_j), \tag{4}$$

with $\alpha > 0$, $\beta > \beta' \geq 0$ and $\gamma \in [0, 0.39]$.[8]

For given usage fees and ATM market shares $(n_1/n, n_2/n)$, the demands for withdrawals are increasing in n: a larger ATM network reduces the distance to reach a machine. Consequently, benefits to hold cash decrease and consumers make more withdrawals. However each extra machine reduces the distance less and less so that the number of withdrawals increases slower than the number of ATM's. Parameter α is a scale parameter. Parameter γ reflects the spread of the shopping space. As $n < 1$, the term n^γ is decreasing in γ. A small γ describes a case where the shopping space is concentrated so that the average travel cost to access cash is low. In this case, consumers make many withdrawals but do not attach a high value to an additional ATM. When γ is high, the shopping space is spread out and it is more costly to reach cash. Cardholders make fewer withdrawals and each additional ATM is more valued.

For given usages fees and a given total network size, cardholders make more domestic withdrawals and less foreign withdrawals when the ATM market share of bank i increases: a higher n_i/n increases the probability that the closest ATM belongs to bank i when the consumer needs cash.

Let us consider the price effect: raising the usage fee by one euro increases the number of domestic withdrawals by β' and decreases the number of foreign withdrawals by β. There is a substitution effect measured by the ratio $\beta'/\beta < 1$. Note that the linearity of demands guarantees their finiteness when fees tend to zero. This property is necessary to compare the three pricing regimes.

In order to obtain a network size lower than one under the different regimes, we need a second assumption:

Assumption 2. $c >> \dfrac{\alpha^2(3+\gamma)}{12(\beta-\beta')}$.

II(iii). *Competition and Profits*

We deal with cases where the market is entirely covered. Let δ denote the distance between bank 1 and the consumer who is indifferent between purchasing services from bank 1 or 2:

$$v_1 - t\delta - p_1 = v_2 - t(1-\delta) - p_2. \tag{5}$$

Bank i's market share of deposits is

$$D_i = \frac{1}{2} + \frac{1}{2t}(v_i - v_j - p_i + p_j). \tag{6}$$

Note that $D_1 + D_2 = 1$. The profit of bank i is

$$\pi_i = (p_i - c_b)D_i + (a + s_i)q_j^f(1 - D_i) + (f_i - a)q_i^f D_i - cn_i. \tag{7}$$

The term $(p_i - c_b)D_i$ is the net revenue from providing banking services. The term $(a + s_i)q_j^f(1 - D_i)$ corresponds to revenues coming from foreign withdrawals made by bank j's cardholders. The term $(f_i - a)q_i^f D_i$ corresponds to net revenues coming from foreign withdrawals made by bank i's cardholders. The term cn_i corresponds to the total cost of deploying and operating ATM's.

II(iv). *Timing of the Game*

In our model banks choose ATM deployment and pricing decisions simultaneously. We think this is a reasonable assumption because in reality, banks can adjust their networks quite easily without incurring important sunk costs: ATM's can be installed at reasonable costs 'through the wall" or inside existing retail establishments. They also can be resold. The timing of the game is the following:

- Stage one: banks choose the interchange fee a jointly.

- Stage two: banks choose the number of ATM's they deploy, n_1 and n_2, and the fees, p_1, f_1,s_1 and p_2, f_2, s_2, simultaneously and non-cooperatively.

- Stage three: each consumer chooses the bank that provides him with the highest positive surplus.

- Stage four: consumers make withdrawals in the shopping space.

II(v). *Resolution*

We look for the symmetric Nash equilibrium of the model for a given interchange fee. The four first-order conditions of the complete maximization problem are

$$(8)\quad \begin{cases} \dfrac{\partial \pi_i}{\partial n_i} = 0 \Longleftrightarrow \quad \widetilde{p_i}\dfrac{\partial D_i}{\partial n_i} + (f_i - a)\dfrac{\partial q_i^f}{\partial n_i}D_i + (a+s_i)\dfrac{\partial q_j^f}{\partial n_i}(1-D_i) - c = 0 & (i) \\ \dfrac{\partial \pi_i}{\partial p_i} = 0 \Longleftrightarrow \quad \widetilde{p_i}\dfrac{\partial D_i}{\partial p_i} + D_i = 0 & (ii) \\ \dfrac{\partial \pi_i}{\partial f_i} = 0 \Longleftrightarrow \quad \widetilde{p_i}\dfrac{\partial D_i}{\partial f_i} + (f_i - a)\dfrac{\partial q_i^f}{\partial f_i}D_i + q_i^f D_i = 0 & (iii) \\ \dfrac{\partial \pi_i}{\partial s_i} = 0 \Longleftrightarrow \quad \widetilde{p_i}\dfrac{\partial D_i}{\partial s_i} + \left((a+s_i)\dfrac{\partial q_j^f}{\partial s_i} + q_j^f\right)(1-D_i) = 0 & (iv) \end{cases}$$

with $\widetilde{p_i} = \left(p_i - c_b - (a - f_i)q_i^f - (a+s_i)q_j^f\right)$.

In each expression, the variation of the relevant decision variable has two effects on π_i: one through the demand for deposits faced by bank i and the other through the demands for withdrawals. The term $\widetilde{p_i}$ corresponds to the net revenue per additional depositor. We now detail the effects more precisely for each regime.

III. REGIME ONE: ATM USAGE FEES ARE PROHIBITED

We take $f_1 = f_2 = s_1 = s_2 = 0$: the account fee is the only tool available to banks to charge consumers. As withdrawals are free, cardholders consider all ATM's as equivalent and withdraw cash regardless of the ATM owner. We first derive the symmetric Nash equilibrium for a given interchange fee and then study how profits are affected when the interchange fee is modified.

III(i). *The Equilibrium for a Given Interchange Fee*

To generate a network size smaller than one, we consider a given a smaller than $2c/\alpha$. We characterize the Nash equilibrium $\{n_1^*(a), p_1^*(a), n_2^*(a), p_2^*(a)\}$. Only conditions (8)*(i)* and (8)*(ii)* are relevant. It is convenient to start with the determination of the account fee. As all ATM's are equivalent for cardholders, cardholders obtain the same net variable surplus from consuming withdrawals whatever their home bank is: $v_1 = v_2$ for any n_1 and n_2. Hence we have

$$D_i = \frac{1}{2} + \frac{1}{2t}(p_j - p_i). \tag{9}$$

Using (8)*(ii)* and the symmetric condition on bank j, we get

$$p_i^*(a) = t + c_b + aq_i^{f*}(a) + aq_j^{f*}(a). \tag{10}$$

The equilibrium account fee is the sum of the differentiation parameter plus the total marginal cost for bank i of accepting a cardholder. This total marginal cost is composed of three parts: c_b is a marginal cost of basic services. The term aq_i^f corresponds to the interchange fees that bank i will have to pay for the q_i^f foreign withdrawals of this cardholder. The term aq_j^f can be interpreted as an opportunity cost: if the cardholder chose to become a cardholder of bank j, he would make aq_j^f foreign withdrawals at bank i's ATM's and bank i would receive aq_j^f. Hence, by accepting the customer, bank 1 loses aq_j^f, which appears in the equilibrium account fee.

Let us consider the deployment problem by rewriting expression (8)*(i)* as

$$\underset{(A1)}{t\frac{\delta D_i}{\delta n_i}} \quad + \quad \underset{(B1)}{a\frac{\partial q_j^f}{\partial n_i}(1 - D_i)} \quad + \quad \underset{(C1)}{(-a)\left(\frac{\partial q_i^f}{\partial n_i}\right) D_i} \quad = c. \tag{11}$$

The three terms of the LHS of expression (11) correspond to the three effects of deploying an additional ATM on bank i's profit:

- Term $(A1)$. As there is no ATM usage fee, the extra ATM yields the same benefit to all consumers: bank i does not attract new depositors: $\partial D_i / \partial n_i = 0$.
- Term $(B1)$. The cardholders of bank j make more foreign withdrawals $(\partial q_j^f / \partial n_i > 0)$. Consequently bank i receives more interchange fees.
- Term $(C1)$. The cardholders of bank i make less foreign withdrawals $(\partial q_i^f / \partial n_i < 0)$ and bank i pays less interchange fees to bank j.

Hence under regime one, a bank does not deploy ATM's to attract new depositors, but rather to process the withdrawals made by its competitor's cardholders and to limit the foreign withdrawals made by its own cardholders. Associating condition (11) with the symmetric condition on bank j yields the total network size as a function of a:

$$n^*(a) = \left(\frac{\alpha a}{2c}\right)^{\frac{1}{1-\gamma}}. \tag{12}$$

The total ATM network size is increasing in a: a higher interchange fee increases each bank's incentives to open ATM's in order to attract withdrawals from its own depositors and from non-customers. As we have assumed that $a < 2c/\alpha$, the network size is decreasing in γ: a wider shopping space means that cardholders incur a higher average travel cost to reach an ATM so that they make less withdrawals (for any given network size). Consequently banks' competition to process withdrawals is less intense and the equilibrium network size is smaller. At equilibrium the two banks deploy the same number of ATM's: $n_1^*(a) = n_2^*(a) = n^*(a)/2$. From expressions (3) and (4) we have $q_1^{d*}(a) = q_1^{f*}(a) = q_2^{d*}(a) = q_2^{f*}(a) = \alpha n^{*\gamma}(a)/2$. Interestingly, the total profit can be rewritten as

$$\pi_i^*(a) = \frac{t}{2} + a q_j^{f*}(a) - c\frac{n^*(a)}{2}. \tag{13}$$

At equilibrium, the interchange outflows per bank i's cardholder, aq_i^f, are entirely recouped through the account fee p_i. Consequently aq_i^f does not appear in the profit expression.

For the equilibrium to exist, we must verify two extra conditions:

(i) For the market to be covered, the surplus of the consumer who is indifferent between the two banks cannot be negative:

$$v_b - \frac{t}{2} + u_i\left(n_i^*(a), n_j^*(a), q_i^{d*}(a), q_i^{f*}(a)\right) - p_i^*(a) \geq 0. \tag{14}$$

In appendix 2, we show that the previous condition is verified for all a smaller than a^*, where a^* is the unique positive interchange fee verifying condition (14) with equality. The interchange fee a^* permits to extract all the surplus of the indifferent consumer and it appears in figure 1. It is not possible to characterize a^* explicitly. However, we will be able to compare the profits in the different regimes.

[Insert figure 1 approximatively here]

(ii) The second-order conditions must hold. We show that it is indeed the case if $v_b - c_b$ is 'not too large' in the sense defined precisely in appendix 3.

III.(ii) *The Effect of the Interchange Fee on Equilibrium Profits*

For any $a \leq a^*$, the equilibrium profit of a bank is (dropping subscript i),

$$\pi^*(a) = \frac{t}{2} + \left(\frac{\alpha a}{2^{2-\gamma}c^{\gamma}}\right)^{\frac{1}{1-\gamma}}. \tag{15}$$

Proposition 1. Under regime one, equilibrium profits are monotonically increasing in a on $[0, a^*]$. By setting $a = a^*$ banks extract all the surplus of the indifferent consumer.

To understand proposition 1, note that raising the interchange fee has two opposite effects on profits (see expression (13)): first, there is a more intense competition to attract both domestic and foreign withdrawals. Hence, banks deploy more ATM's and the deployment costs increase. Second, the revenues aq_j^f coming from the account fee and the interchange inflows increase. The effect on revenues outweighs the effect on deployment costs so that profits increase.

Proposition 1 shows that setting the interchange fee jointly allows banks to collude and extract consumers' surplus. As profits are monotonically increasing in a, collusion is only limited by the participation constraint of the marginal consumer. There could exist a different type of equilibrium for interchange fees above a^* yielding higher equilibrium profits. In this paper, we only consider equilibria of the type we have described.[9]

IV. REGIME TWO: SURCHARGES ARE PROHIBITED

We take $s_1 = s_2 = 0$. Each bank charges its cardholders the two-part tariff $p_i + f_i q_i^f$. We first determine the equilibrium for a given a and then the profit-maximizing interchange fee.

IV(i). *The Equilibrium for a Given Interchange Fee*

We consider a given interchange fee smaller than $4c/\alpha(3+\gamma)$. We characterize the symmetric Nash equilibrium $\{n_{1ff}^*(a), p_{1ff}^*(a), n_{2ff}^*(a), p_{2ff}^*(a), f_1^*, f_2^*\}$. It is convenient to start with the determination of the foreign fee. In appendix 4, we show that at equilibrium, the foreign fee set by bank i is equal to the interchange fee:

$$f_i^* = a. \tag{16}$$

Doing so, bank i maximizes its cardholders' surplus while recouping the cost of foreign withdrawals. The bank uses the fixed account fee p_i to recover a part of this surplus in a manner compatible with the competitive intensity.

Let us determine the equilibrium account fee. Using expressions (8)*(ii)*, (16) and the fact that $D_i = 1/2$ at the symmetric equilibrium, we obtain:

$$p^*_{i,ff}(a) = t + c_b + aq^{f*}_{j,ff}(a). \tag{17}$$

The interpretation of the equilibrium account fee under regime two is nearly the same as under regime one except that the account fee only recoups the opportunity cost of accepting an extra depositor, aq^f_j. The other part of the marginal cost, aq^f_i, is now recouped through the foreign-fee revenues $f_i q^f_i$.

Let us turn to the deployment problem of banks. Using (17), expression (8)*(i)* can be rewritten as

$$\begin{array}{ccccccccc} t\dfrac{\delta D_i}{\delta n_i} & + & a\dfrac{\partial q^f_j}{\partial n_i}(1-D_i) & + & (f_i - a)\dfrac{\partial q^f_i}{\partial n_i}D_i & = & c. \\ (A2) & & (B2) & & (C2) & & \end{array} \tag{18}$$

The LHS of expression (18) shows how deploying an extra ATM affects bank i's revenue:

- We show in appendix 5 that at the symmetric equilibrium $\delta D_i/\delta n_i = (\alpha/2t)an^{\gamma-1}$: term $(A2)$ is positive and consequently higher than term $(A1)$ of expression (11). As consumers pay for foreign withdrawals, they prefer to open an account in a bank with a larger network in order to make less costly foreign withdrawals. Hence, the deployment of an extra ATM by bank i makes this bank more attractive and increases its deposit market share ($\delta D_i/\delta n_i > 0$) and its revenues. In some sense, the existence of foreign fees creates differentiation between the ATM networks of the two banks. For a given interchange fee, this *differentiation effect* of foreign fees makes banks deploy more ATM's than under regime one.[10]

- Term $(B2)$ is positive and equal to term $(B1)$ of expression (11). As under regime one, deploying an extra ATM increases the interchange inflows of bank i.

- Term $(C2)$ is smaller than term $(C1)$ of expression (11). This is *the interchange recovery effect* of foreign fees: since the foreign fee is equal to the interchange fee, the foreign withdrawals made by bank i's cardholders become costless for this bank. Consequently limiting its cardholders' foreign withdrawals is no more a reason for bank i to deploy ATM's. This *interchange recovery effect* of foreign fees makes banks deploy fewer ATM's than under regime one.

Hence under regime two, banks deploy ATM's to attract new depositors and to generate interchange inflows. Note that the differentiation effect and the interchange recovery effect act in opposite directions on deployment. In appendix 5, we show using expressions (16) and (18) that the total number of ATM's deployed under regime two for a given interchange fee is

$$n^*_{ff}(a) = \left(\frac{\alpha(3+\gamma)a}{4c}\right)^{\frac{1}{1-\gamma}}. \qquad (19)$$

The number of ATM's deployed under regime two is increasing in the interchange fee, decreasing in the deployment cost, and decreasing in γ. Comparing expressions (12) and (19) shows that in our framework, banks deploy more ATM's under regime two than under regime one for a given interchange fee: the differentiation effect of foreign fees outweighs the interchange recovery effect. From expressions (3), (4), and (16), we have

$$q^{d*}_{1ff}(a) = q^{d*}_{2ff}(a) = \alpha n^{*\gamma}_{ff}(a)/2 + \beta' a, \qquad (20)$$

and

$$q^{f*}_{1ff}(a) = q^{f*}_{2ff}(a) = \alpha n^{*\gamma}_{ff}(a)/2 - \beta a. \qquad (21)$$

The equilibrium profit can be written as

$$\pi^*_{i,ff}(a) = \frac{t}{2} + aq^{f*}_{j,ff}(a) - c\frac{n^*_{ff}(a)}{2}. \qquad (22)$$

This expression is similar to expression (13) we obtained under regime one. However, the interchange outflows per cardholder of bank i, aq^f_i, are now entirely recouped through the foreign fee f_i and no more through the account fee p_i. Using expressions (19), (21) and (22) and dropping subscript i, we can write the equilibrium profit as a function of a:

$$\pi_{ff}^*(a) = \frac{t}{2} + \frac{1-\gamma}{8}\left(\frac{3+\gamma}{4}\right)^{\frac{\gamma}{1-\gamma}} \alpha^{\frac{1}{1-\gamma}} \frac{a^{\frac{1}{1-\gamma}}}{c^{\frac{\gamma}{1-\gamma}}} - \beta a^2. \tag{23}$$

We verify the second-order conditions of maximization in appendix 6.

We compare network sizes, banks' profits and consumers' surpluses under regime one and two for a given interchange fee. We can consider the surplus of the indifferent consumer denoted by $\widetilde{w}(a)$. At the symmetric equilibrium: $\widetilde{w}(a) = v_b - \frac{t}{2} + v(a) - p(a)$. Dropping subscripts, we have:

Proposition 2. For any given interchange fee $a \in]0, a^*]$, switching from regime one to regime two yields

(i) a larger network: $n_{ff}^*(a) > n^*(a)$.

(ii) lower account fees: $p_{ff}^*(a) < p^*(a)$.

(iii) lower profits for each bank: $\pi_{ff}^*(a) < \pi^*(a)$.

(iv) a higher consumer surplus: $\widetilde{w}_{ff}^*(a) > \widetilde{w}^*(a)$.

Proof: appendix 7.

As noted before, for a given interchange fee, banks deploy more ATM's under regime two because of the differentiation effect of foreign fees. The increase in deployment costs outweighs the change in revenues so that banks' profits are lower under regime two.[11] Account fees are also smaller because under regime two banks recoup the interchange outflows through the foreign fees, and not through the account fee.

Consumers are better off with foreign fees. There are two reasons: first, the network size is larger and accessing to cash is easier; second, consumers prefer to pay for their foreign withdrawals through the ATM usage fees of regime two rather than through the lump account fee of regime one: in the latter case, cardholders consume (and pay for) 'too many' foreign withdrawals.

IV(ii). *The Effect of the Interchange Fee on Equilibrium Profits*

Contrary to regime one, $\pi^*_{ff}(a)$ has a unique maximum, characterized by

$$a^*_{ff} = \left(\frac{\alpha(3+\gamma)^\gamma}{2^{4-2\gamma}\beta^{1-\gamma}c^\gamma} \right)^{\frac{1}{1-2\gamma}}. \tag{24}$$

The profit function $\pi^*_{ff}(a)$ is increasing in a up to the point a^*_{ff} and decreasing thereafter. To understand why, let us consider the effect of increasing the interchange fee in expression (22). In a first time, the profit follows the increase in revenue per foreign withdrawal, a, and in a second time, the declining demand for foreign withdrawals and the ever-increasing deployment costs make the profit fall. In appendix 8, we verify that when $a = a^*_{ff}$, the surplus $\widetilde{w}^*_{ff}$ of the indifferent consumer is positive. We sum up the results in the following proposition.

Proposition 3. Under regime two, equilibrium profits are monotonically increasing in a on $[0, a^*_{ff}]$ and decreasing thereafter. When $a = a^*_{ff}$, banks leave a positive surplus to the indifferent consumer.

As under regime one, banks can collude by setting the interchange fee jointly. Nevertheless, their ability to extract consumers' surplus by raising the interchange fee is reduced: cardholders react to the resulting rise of the foreign fee by adjusting their demand for foreign withdrawals downward. Hence, the profit-maximizing interchange fee a^*_{ff} is smaller than the interchange fee a^* associated to regime one. This is proved formally in appendix 8.

The size of the network for the profit-maximizing interchange fee is

$$n^*_{ff}(a^*_{ff}) = \left(\frac{\alpha^2(3+\gamma)}{64\beta c} \right)^{\frac{1}{1-2\gamma}}. \tag{25}$$

Note that assumption 2 guarantees that $n^*_{ff}(a^*_{ff})$ is lower than one. The associated individual profit is

$$\pi^*_{ff}(a^*_{ff}) = \frac{t}{2} + 4^{\frac{2\gamma-4}{1-2\gamma}}(1-2\gamma)\left(3+\gamma\right)^{\frac{2\gamma}{1-2\gamma}}\alpha^{\frac{2}{1-2\gamma}}\left(\frac{1}{\beta}\right)^{\frac{1}{1-2\gamma}}\left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}}. \tag{26}$$

We will compare the profits for the profit-maximizing interchange fees across the different regimes subsequently.

V. REGIME THREE: THE CASE WITH FOREIGN FEES AND SURCHARGES

Under regime three, each bank i charges its own cardholders the two-part tariff $p_i + f_i q_i^f$ and charges non-customers the linear tariff $s_i q_j^f$.

V(i). *The Equilibrium for a Given Interchange Fee*

As in regime two, banks maximize their cardholders' surplus by setting the foreign fee equal to the marginal cost of a foreign withdrawal ($f_i^* = a$) and extract it back through the account fee. This is proved in appendix 3. Using expression (8)*(ii)* and the fact that $D_i = 1/2$ at the symmetric equilibrium, we obtain the equilibrium account fee of bank i:

$$p^*_{i,sur}(a) = t + c_b + (a + s_i^*(a))q^{f*}_{j,sur}(a). \tag{27}$$

The opportunity cost of accepting an additional cardholder must now take into account the surcharges $s_i q_j^f$ that this cardholder would pay to bank i if he had chosen bank j. As under regime two, the interchange outflows per cardholder, aq_i^f, are recouped through the foreign-fees revenues $f_i q_i^f$ and not through the account fee p_i.

At the symmetric equilibrium, expression (8)(i) can be written as

$$\begin{array}{ccccccc} t\dfrac{\delta D_i}{\delta n_i} & + & (a+s_i)\dfrac{\partial q_j^f}{\partial n_i}(1-D_i) & + & (f_i - a)\dfrac{\partial q_i^f}{\partial n_i}D_i & = & c. \\ (A3) & & (B3) & & (C3) & & \end{array} \tag{28}$$

This expression shows that the qualitative reasons to deploy ATM's are the same as in regime two. First each bank deploys ATM's in order to increase its deposit market share:

term $(A3)$ is positive. We show in appendix 9 that at the symmetric equilibrium $\delta D_i/\delta n_i = (\alpha/2t)(a+s_i)n^{\gamma-1}$. Second, deployment permits to generate more interchange inflows: $(B3)$ is positive. As under regime two, the third term is nil at equilibrium. In fact expression (28) is the same as expression (18), except that a is replaced by $a+s_i$. The surcharge adds to the interchange fee and permits double marginalization: the revenue per foreign withdrawal is higher. Consequently, surcharging boosts ATM deployment.

Let us now examine the factors determining the level of the surcharge. Using expression (27), one can rewrite expression (8)(iv) as

$$t\frac{\partial D_i}{\partial s_i} + \left((a+s_i)\frac{\partial q_j^f}{\partial s_i} + q_j^f\right)(1-D_i) = 0. \tag{29}$$

The LHS of expression (29) measures the effect of a marginal increase of s_i on bank i's profit:

- The first term of the LHS is positive and equal to $\frac{1}{2}q_j^f$ (see appendix 10): raising s_i increases the price per foreign withdrawal for the cardholders of bank j. This has a negative effect on the surplus derived from joining bank j and bank i becomes more attractive for depositors. Hence, a higher surcharge permits bank i to enlarge its deposit market share and increase its profit. This effect is known in the literature as the depositor-stealing motive for surcharging (see Massoud and Bernhardt [2002] or McAndrews [2003]) and explains why banks choose surcharges above the level that maximizes their ATM revenues considered as a stand-alone activity.

- Bank i has also to consider the effect of raising the surcharge on the revenue coming from non-customers. This effect is measured by the second term of expression (29). A higher surcharge yields higher revenues per foreign withdrawal but non-customers use bank i's machines less frequently.

Using the fact that $f_i^* = a$, expressions (28), (29) and symmetry, we obtain

$$
\left\{
\begin{array}{r}
s_1^*(a) = s_2^*(a) = s^*(a) = \alpha n^{*\gamma}(a)/3\beta - a \\
n_{sur}^*(a) = \left(\dfrac{\alpha(3+\gamma)(a+s^*(a))}{4c}\right)^{\frac{1}{1-\gamma}}
\end{array}
\right. . \tag{30}
$$

The two previous equations show that there is a reinforcement effect between the surcharge level and the network size: for a given level of a, double marginalization induces a bigger ATM network than under regime two. Demands for foreign withdrawals shift upward and banks can set higher surcharges. In turn the higher surcharges increase the double margin, and so on. Solving the previous system we have

$$
n_{sur}^* = \left(\frac{\alpha^2(3+\gamma)}{12\beta c}\right)^{\frac{1}{1-2\gamma}} . \tag{31}
$$

We verify the second-order conditions of maximization in appendix 11.

V(ii). *The Neutrality of the Interchange Fee*

When foreign fees and surcharges are permitted, the interchange fee affects neither the equilibrium number of ATM's, n_{sur}^*, nor the account fee p_{sur}^*, nor the total price per foreign withdrawal, $f^* + s^* = \alpha n_{sur}^{*\gamma}/3\beta$. Banks' profits are therefore independent from a:

$$
\pi_{sur}^* = \frac{t}{2} - 2^{\frac{4\gamma-3}{1-2\gamma}} 3^{\frac{2\gamma-2}{1-2\gamma}} (5+3\gamma)(3+\gamma)^{\frac{2\gamma}{1-2\gamma}} \alpha^{\frac{2}{1-2\gamma}} \left(\frac{1}{\beta}\right)^{\frac{1}{1-2\gamma}} \left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}} . \tag{32}
$$

To understand the neutrality of the interchange fee, consider the situation where bank i obtains interchange revenues equal to $a + s_i^*$ for each withdrawal made by a cardholder of bank j, and bank j receives $f_j^* - a$ for each foreign withdrawal made by its own cardholders. Cardholders of bank j pay $f_j^* + s_i^*$ per foreign withdrawal. Suppose now that the interchange fee is increased by Δa. Banks can preserve the equilibrium payoffs and cardholders' demands are unchanged if bank i reduces s_i^* by Δa while bank j increases f_j^* by Δa. The total usage fee paid by bank j's cardholder is still equal to $f_j^* + s_i^*$, the number of foreign withdrawals and banks' revenues are unchanged. Since the equilibrium network size and the total usage fee are unaffected by the interchange fee, consumers' welfare is also independent from a. We sum up the results in the following proposition:

Proposition 4. When foreign fees and surcharges are allowed, the interchange fee is neutral in the following sense: (i) its level does not affect the equilibrium deployment of ATM's, nor banks' equilibrium profits. (ii) its level does not affect consumers' welfare.

The neutrality of the interchange fee under regime three is a general result that was first explained intuitively by Salop [1990] and proved by Croft and Spencer [2004] in a framework where ATM deployment is exogenous. The main consequence of proposition 4 is that under regime three, the interchange fee cannot be a collusive tool for banks anymore. Interestingly, bank i's accounting net revenue per ATM is equal to

$$\frac{(a+s_i^*)q_{j,sur}^{f*}(a)D_j^*}{n_{i,sur}^*(a)} - c = -\frac{7+3\gamma}{9+3\gamma}c,$$

which is negative. As noted before, this prediction is consistent with empirical observations that in the U.S.A., ATM's operated by banks lose money on average (see footnote 6).

VI. COMPARISON OF THE THREE PRICING REGIMES

In this section, we compare banks' profits and consumers' surplus across the three regimes when banks choose the interchange fee to maximize their joint profits. We also study the consequences of replacing the interchange system by a direct charging scheme.

VI(i). *Comparison of Profits and Consumers' Surplus*

Under regime one, individual profits $\pi^*(a)$ are monotonically increasing in the interchange fee up to a^*, where a^* is defined by condition (14) verified with equality. Consequently, to maximize their joint profits, banks choose the interchange fee a^*. Individual profits are $\pi^*(a^*)$. Under regime two, banks choose a_{ff}^* defined by (24). Each bank obtain $\pi_{ff}^*(a_{ff}^*)$

defined by (25). Under regime three the choice of the interchange fee is irrelevant and each bank obtains π^*_{sur} defined by (32). We obtain the following proposition:

Proposition 5. Suppose that under each regime banks set the interchange fee at the level that maximizes their joint profits, then

(i) the network is larger under regime one and regime three than under regime two:

$$n^*(a^*) > n^*_{ff}(a^*_{ff}) \quad \text{and} \quad n^*_{sur} > n^*_{ff}(a^*_{ff});$$

(ii) account fees are higher under regime one and regime three than under regime two:

$$p^*(a^*) > p^*_{ff}(a^*_{ff}) \quad \text{and} \quad p^*_{sur} > p^*_{ff}(a^*_{ff});$$

(iii) banks prefer regime one to regime two and regime two to regime three:

$$\pi^*(a^*) > \pi^*_{ff}(a^*_{ff}) > \pi^*_{sur};$$

(iv) there exists a value $\overline{\gamma}(\beta'/\beta)$ above which consumers prefer regime three to regime two:

$$\forall\gamma < \overline{\gamma}(\tfrac{\beta'}{\beta}),\ \widetilde{w}^*_{ff}(a^*_{ff}) > \widetilde{w}^*_{sur} > \widetilde{w}^*(a^*) = 0;$$
$$\forall\gamma > \overline{\gamma}(\tfrac{\beta'}{\beta}),\ \widetilde{w}^*_{sur} > \widetilde{w}^*_{ff}(a^*_{ff}) > \widetilde{w}^*(a^*) = 0.$$

where $\overline{\gamma}(\beta'/\beta) = \frac{1}{2}\left(1 - \ln\frac{16}{3}/\ln(\frac{99+29\frac{\beta'}{\beta}}{8+16\frac{\beta'}{\beta}}).\right)$

Proof: appendix 12.

The threshold $\overline{\gamma}(\beta'/\beta)$ is represented in figure 2.

[Insert figure 2 approximatively here]

When banks choose the profit-maximizing interchange fee, fewer ATM's are deployed under regime two than under regime one. The reason is that a^*_{ff} is smaller than a^*: under regime two, foreign fees are equal to the interchange fee so that banks' joint choice of the interchange fee is constrained to keep sufficiently high demands for foreign withdrawals. Under regime one, a^* is less constrained as it comes from consumers' participation condition.

This difference between a^* and a^*_{ff} reinforces result (ii) of proposition 2: account fees are smaller under regime two than under regime one.

More ATM's are deployed under regime three than under regime two. This is because the revenue per foreign withdrawal under regime two, a^*_{ff} is lower than the revenue with surcharges, $a^*_{ff} + s^*(a^*_{ff})$. The empirical work of Knittel and Stango [2008] supports the idea that in the U.S.A., a surge in ATM deployment accompanied the shift to surcharging. Using counterfactual experiments Ishii [2006] also notes that banks are predicted to respond to a surcharge ban by reducing the number of their ATM's.

Interestingly account fees are higher under regime three than under regime two. The reader may be puzzled by this result since the interchange fee being neutral under regime three, one could expect a more intense price competition on the deposit market. Nevertheless, switching from regime two to regime three increases the cost for banks of accepting depositors (the forgone surcharge revenues) and consequently, price competition is relaxed. This prediction is consistent with empirical evidence. Knittel and Stango [2009] study a panel of banks competing in local markets across the United States from 1994 to 1999. They show that deposit account prices are positively correlated with incompatibility, and are roughly 20% higher after the advent of surcharging.

Despite the higher account fees, regime three is the worst for banks because the boost in deployment induces very high deployment costs.

For a given substitution rate β'/β, consumers prefer regime three to regime two for sufficiently high values of the dispersion parameter γ. In this case, *ceteris paribus*, travel costs to withdraw cash are higher and consumers appreciate the large network of regime three even if they have to pay higher account fees and higher ATM usage fees. When the shopping space is more concentrated consumers prefer the smaller and less expensive network of regime two. Knittel and Stango [2008] find that after the introduction of surcharging in 1996 in the U.S.A., consumers' welfare increased in high travel cost counties while it decreased in low travel cost counties.

Regime one is the most profitable for banks and the worst for consumers because the collusive power of the interchange fee is only limited by the participation constraint of the marginal consumer. By banning usage fees banks can maximize consumers' gross surplus and extract it back through the account fee. Under regime two, banks' individual objectives do not coincide with the industry objectives: at equilibrium banks independently set foreign fees equal to the interchange fee to maximize their individual profits while it would be better for them to agree on nil foreign fees and to increase the account fee.

VI(ii). *Direct Charging*

The ATM markets in Australia and South Africa work under a regime close to regime two. Recently, the Australian and the South African regulation authorities have proposed to use a 'direct charging model' whereby the interchange fee applicable to each foreign transaction would be removed and ATM owners would be free to set their own fee for foreign ATM transactions (see Reserve Bank of Australia & the Australian Competition and Consumer Commission [2000]; Competition Commission of South Africa [2007]). According to its proponents, there are two main objectives of the reform. First, removing the interchange system limits banks' possibility to collude. The second objective is to favor price competition on ATM fees between ATM deployers. The resulting price flexibility is to be opposed to the stickiness of interchange fees. One can study the consequences of such a regulation scheme in our model.

Proposition 6. The direct charging scheme is equivalent to regime three. When the shopping space is concentrated, switching from regime two to direct charging diminishes both consumer surplus and bank profits: total welfare decreases.

Proof: setting $a = f_1 = f_2 = 0$ in the system of equations (8) yields the solution characterized by (31).

According to propositions 5 and 6, the welfare change of switching from regime two to direct charging crucially depends on the dispersion parameter, and hence on travel costs to reach cash. The quality of ATM service is enhanced but account fees and ATM usage fees are higher. When the dispersion parameter is high, direct charging is good for consumers but bad for banks.

VII. CONCLUSION

We have proposed a tractable model to study the effect of ATM pricing on welfare in which the relationships between the deposit market and the withdrawal market are highlighted. We have shown that increasing the number of usage fees make ATM networks more differentiated which provide banks with more incentives to deploy ATM's. The potential increase in revenues from adding usage fees is not sufficient to cover the additional deployment costs and the model predicts that banks' profits diminish when one switches from regime one to two and from regime two to three. Regime three is specially bad for banks since the neutrality of the interchange fee is further added to the large ATM deployment.

From the regulator's perspective, our analysis shows the importance of travel costs to reach cash when deciding to ban surcharges or not: consumers prefer regime three (or direct charging) to regime two only when travel costs to reach cash are high.

Our results are consistent with recent empirical works showing that in the U.S.A., the advent of surcharging triggered a boost of ATM deployment, higher account fees, and a positive change in consumer surplus in places where travel costs are high.

Several questions remain unanswered. First while regimes two and three are well documented empirically, there are fewer studies about regime one (an exception being the recent paper by Ferrari [2008]). Notably, it would be interesting to study to what extent banks use the collusive power of the interchange fee under regime one. Second, it would be worthwhile to verify empirically the prediction that account fees are higher under regime one than under regime two. Third, it would be interesting to study how the existence of independent ATM deployers affects the ATM market and welfare.

APPENDICES

Appendix 1. Surplus from Consuming Withdrawals

We assume that the variable *gross* surplus from consuming withdrawals takes the following quadratic shape:

(33)

$$u_i = \frac{1}{\beta^2 - \beta'^2}\left[(\alpha\beta\frac{n_i}{n}n^\gamma + \alpha\beta'\frac{n_j}{n}n^\gamma)q_i^d - \frac{\beta}{2}(q_i^d)^2 + (\alpha\beta\frac{n_j}{n}n^\gamma + \alpha\beta'\frac{n_i}{n}n^\gamma)q_i^f - \frac{\beta}{2}(q_i^f)^2 - \beta' q_i^d q_i^f\right]$$

The variable net surplus is $v_i = u_i - (f_i + s_j)q_i^f$. Writing $\partial v_i/\partial q_i^d = 0$ and $\partial v_i/\partial q_i^f = 0$ and inverting the system yields the individual demands for withdrawals. Using expressions (3), (4) and (33), we obtain the optimized expression of v_i,

$$(34)\ \ v_i = \frac{\alpha^2}{2(\beta^2 - \beta'^2)}\left[\beta n_i^2 n^{2\gamma-2} + \beta n_j^2 n^{2\gamma-2} + 2\beta' n_i n_j n^{2\gamma-2}\right] + \frac{\beta}{2}(f_i + s_j)^2 - \alpha(f_i + s_j)n_j n^{\gamma-1}.$$

Appendix 2. Characterization of a^*

Under regime one, the two last terms of expression (34) are equal to zero. By setting $n_i^*(a) = n_j^*(a) = n^*(a)/2$ we obtain

$$(35)\qquad v_1 = v_2 = \frac{\alpha^2 n^{*2\gamma}(a)}{4(\beta - \beta')}.$$

Condition (14) can be rewritten with equality under the following shape:

$$(36)\qquad v_b + \frac{\alpha^2 {n^*}^{2\gamma}(a)}{4(\beta - \beta')} - \frac{t}{2} - p_1^*(a) = 0,$$

or using expressions (10) and(12),

$$(37)\qquad v_b - c_b - \frac{3t}{2} + \frac{\alpha a^{\frac{2\gamma}{1-\gamma}}}{(2c/\alpha)^{\frac{\gamma}{1-\gamma}}}\left(\frac{\alpha}{4(\beta - \beta')(2c/\alpha)^{\frac{\gamma}{1-\gamma}}} - a^{\frac{1-2\gamma}{1-\gamma}}\right) = 0.$$

The LHS of expression (37) is the function represented in figure 1 and the equation has a unique positive solution, a^*. In general, it is not possible to determine a^* explicitly.

However, by setting $v_b - c_b - 3t/2 = 0$, we obtain the minimum interchange fee for a given set of parameters $(\alpha, \beta, \beta', \gamma, c)$ that we denote by $a^*_{\min}$. We have

$$a^*_{\min} = \left(\frac{\alpha}{2^{2-\gamma}(\beta - \beta')^{1-\gamma}c^{\gamma}}\right)^{\frac{1}{1-2\gamma}}. \tag{38}$$

The associated network size is

$$n^*(a^*_{\min}) = \left(\frac{\alpha^2}{8(\beta - \beta')c}\right)^{\frac{1}{1-2\gamma}}. \tag{39}$$

$n^*(a^*_{\min})$ is a lower bound for deployment under regime one that will play a role in the welfare comparison.

Appendix 3. The Second-Order Conditions under Regime One

The Hessian matrix of second derivatives of the profit function must be negative definite. The matrix is

$$H = \begin{pmatrix} \partial^2\pi_i/\partial n_i^2 & \partial^2\pi_i/\partial n_i\partial p_i \\ \partial^2\pi_i/\partial n_i\partial p_i & \partial^2\pi_i/\partial p_i^2 \end{pmatrix} \underset{(eq)}{=} \begin{pmatrix} \alpha a(\gamma-1) & \alpha\dfrac{a}{2t}\gamma n^{\gamma-1} \\ \alpha\dfrac{a}{2t}\gamma n^{\gamma-1} & -1/t \end{pmatrix}.$$

We obtain $Det(H_{11}) = \alpha a(\gamma - 1) < 0$. Furthermore $Det(H) = \alpha a(1-\gamma)n^{\gamma-2}/t - \alpha^2 a^2\gamma^2 n^{2\gamma-2}/4t^2$. Using the fact that $n^*(a) = (\alpha a/2c)^{\frac{1}{1-\gamma}}$ we get $Det(H) = 2c(1-\gamma)/tn - c^2\gamma^2/t^2$. Clearly $Det(H) > 0$ if $\gamma = 0$. Suppose $\gamma > 0$, $Det(H) > 0$ is equivalent to $n^*(a) < 2(1-\gamma)t/c\gamma^2$ or equivalently,

$$a < \frac{2c}{\alpha}\left(\frac{2(1-\gamma)t}{c\gamma^2}\right)^{1-\gamma} \equiv a_{\max}. \tag{40}$$

The latter condition is verified if $a^* < a_{\max}$, where a^* is the solution of (37). This last inequality can be rewritten

$$v_b - c_b < \frac{3t}{2} + \frac{2(1-\gamma)t}{\gamma^2} - \frac{\alpha^2}{4(\beta - \beta')}\left(\frac{2(1-\gamma)t}{c\gamma^2}\right)^{2\gamma}. \tag{41}$$

One can verify that the RHS of expression (41) is decreasing with γ. When $\gamma \to 0$, the RHS of expression (41) is infinite. When $\gamma = 1/2$, the RHS is close to $11t/2$ because assumption 2 guarantees that $\frac{\alpha^2}{4c(\beta-\beta')}$ is small. Condition (41) must hold together with assumption 1.

Appendix 4. Proof that $f_i^* = a$ under regimes 2 and 3

Under regimes 2 and 3, bank i's demand for deposits is $D_i = 1/2 + (1/2t)(v_i - v_j - p_i + p_j)$. Hence

$$\frac{\partial D_i}{\partial p_i} = -\frac{1}{2t}. \tag{42}$$

Let us calculate the effect of f_i on D_i. We have

$$\frac{\partial D_i}{\partial f_i} = \frac{1}{2t}\frac{\partial v_i}{\partial f_i}. \tag{43}$$

Using expression (2), we obtain

$$\frac{\partial v_i}{\partial f_i} = \frac{\partial u_i}{\partial q_i^f}\frac{\partial q_i^f}{\partial f_i} - q_i^f - (f_i + s_j)\frac{\partial q_i^f}{\partial f_i}. \tag{44}$$

As $\partial v_i / \partial q_i^f = 0$, we have $\partial u_i / \partial q_i^f = f_i + s_j$ so that $\partial v_i / \partial f_i = -q_i^f$. Finally we obtain

$$\frac{\partial D_i}{\partial f_i} = -\frac{1}{2t} q_i^f. \tag{45}$$

Condition (8)*(ii)* can be rewritten:

$$\widetilde{p}_i = p_i - c_b - (a - f_i)q_i^f - (a + s_i)q_j^f = -D_i / \frac{\partial D_i}{\partial p_i} = 2tD_i. \tag{46}$$

Plugging this result into condition (8)*(iii)*, we obtain

$$2tD_i\frac{\partial D_i}{\partial f_i} + (f_i - a)\frac{\partial q_i^f}{\partial f_i}D_i + q_i^f D_i = 0. \tag{47}$$

Using expression (45), we have

$$(f_i - a)\frac{\partial q_i^f}{\partial f_i}D_i = 0. \tag{48}$$

hence $f_i^* = a$ for any D_i. ∎

Appendix 5. The Equilibrium Network Size under Regime Two

Using expressions (6) and (34), we have

$$\frac{\partial D_i}{\partial n_i} = \frac{1}{2t}\frac{\partial(v_i - v_j)}{\partial n_i} = \frac{\alpha}{2t}(f_j \left(n^{\gamma-1} + (\gamma-1)n_i n^{\gamma-2}\right) - fi(\gamma-1)n_j n^{\gamma-2}). \tag{49}$$

At the symmetric equilibrium we have $f_i = f_j = a$ and $n_i = n_j$. Hence,

$$\frac{\partial D_i}{\partial n_i} = \frac{\alpha}{2t} a n^{\gamma-1}. \tag{50}$$

Using expressions (16) and (50), we can rewrite expression (18) as

$$\frac{\alpha}{2} a n^{\gamma-1} + \frac{\alpha(1+\gamma)}{4} a n^{\gamma-1} - c = 0, \tag{51}$$

which yields expression (19). ■

Appendix 6. The Second-Order Conditions under Regime Two

Let us calculate the Hessian matrix at $(n^*_{ff}(a), p^*_{ff}(a), f^* = a)$. We have

$$H = \begin{pmatrix} \partial^2\pi_i/\partial n_i^2 & \partial^2\pi_i/\partial n_i\partial p_i & \partial^2\pi_i/\partial n_i\partial f_i \\ \partial^2\pi_i/\partial n_i\partial p_i & \partial^2\pi_i/\partial p_i^2 & \partial^2\pi_i/\partial p_i\partial f_i \\ \partial^2\pi_i/\partial n_i\partial f_i & \partial^2\pi_i/\partial f_i\partial p_i & \partial^2\pi_i/\partial f_i^2 \end{pmatrix}$$

or

$$H = \begin{pmatrix} -A - B/t & c/t & c q^{f*}_{i,ff}(a)/t \\ c/t & -1/t & -q^{f*}_{i,ff}(a)/t \\ c q^{f*}_{i,ff}(a)/t & -q^{f*}_{i,ff}(a)/t & -\beta/2 - q^{f*}_{i,ff}(a)^2/t \end{pmatrix}$$

with $A = \frac{c}{n^*_{ff}(a)}\frac{(1-\gamma)(\gamma+6)}{3+\gamma} > 0$ and $B = 8c^2\frac{1+\gamma}{(3+\gamma)^2} > 0$. A and B do not depend on t.

$Det(H_{11}) = -A - B/t$ is negative.

$Det(H_{22}) = (tA + B - c^2)/t^2$ is positive for t sufficiently large.

$Det(H) = -0.5\beta(tA + B - c^2)/t^2$ is negative for t sufficiently large.

Appendix 7. Proof of Proposition 2

Part (i). Let us compare $n^*(a)$ and $n^*_{ff}(a)$. We have $n^*_{ff}(a) = \lambda n^*(a)$ with

$$\lambda = \left(\frac{3+\gamma}{2}\right)^{\frac{1}{1-\gamma}} (\geq \frac{3}{2}). \tag{52}$$

Hence $n^*(a) > n^*_{ff}(a)$. ■

Part (ii). Let us compare $p^*(a)$ and $p^*_{ff}(a)$. We can rewrite (10) as $p^*(a) = t + c_b + \alpha a n^{*\gamma}(a)$. Using the fact that $a = 2cn^{*1-\gamma}(a)/\alpha$, we can write everything as a function of $n^*(a)$: $p^*(a) = t + c_b + 2cn^*(a)$. We can also rewrite (17) as $p^*_{ff}(a) = t + c_b + a(\alpha n^{*\gamma}_{ff}(a)/2 - \beta a)$. Using the fact that $a = 4cn^{*1-\gamma}_{ff}(a)/(\alpha(3+\gamma))$, we obtain $p^*_{ff}(a) = t + c_b + 2cn^*_{ff}(a)/(3+\gamma) - 16\beta c^2 n^{*2-2\gamma}_{ff}(a)/(\alpha^2(3+\gamma)^2)$. Hence using (52) and the fact that $\lambda^\gamma < 2$, $p^*_{ff}(a) < t + c_b + 2cn^*_{ff}(a)/(3+\gamma) = t + c_b + \lambda^\gamma cn^*(a) < t + c_b + 2cn^*(a) = p^*(a)$. ■

Part (iii). Let us compare $\pi^*(a)$ and $\pi^*_{ff}(a)$. We express everything in $n^*(a)$. We have $n^*_{ff}(a) = \lambda n^*(a)$. Furthermore using (12) we have $a = 2cn^{*1-\gamma}(a)/\alpha$. Hence,

$$\pi^*(a) = \alpha\frac{a}{2}n^{*\gamma}(a) - \frac{c}{2}n^*(a) = \frac{c}{2}n^*(a). \tag{53}$$

Furthermore,

$$\pi^*_{ff}(a) = \alpha\frac{a}{2}n^{*\gamma}_{ff}(a) - \beta a^2 - \frac{c}{2}n^*_{ff}(a) = \alpha\frac{a}{2}\lambda^\gamma n^{*\gamma}(a) - \beta a^2 - \frac{c}{2}\lambda n^*(a) \tag{54}$$

$$= (2\lambda^\gamma - \lambda)\frac{c}{2}n^*(a) - \beta a^2 = \left(\frac{3+\gamma}{2}\right)^{\frac{\gamma}{1-\gamma}}\left(\frac{1-\gamma}{2}\right)\frac{c}{2}n^*(a) - \beta a^2. \tag{55}$$

As $\left(\frac{3+\gamma}{2}\right)^{\frac{\gamma}{1-\gamma}}\left(\frac{1-\gamma}{2}\right) < 2 * \frac{1}{2} = 1$, we have $\pi^*(a) > \pi^*_{ff}(a)$. ■

Part (iv). Let us calculate the sign of $w^*_{ff}(a) - w^*(a)$:

$$w^*_{ff}(a) - w^*(a) = \left(\frac{\alpha^2 n^{*2\gamma}_{ff}(a)}{4(\beta-\beta')} + \frac{3\beta}{2}a^2 - \alpha a n^{*\gamma}_{ff}(a)\right) - \left(\frac{\alpha^2 n^{*2\gamma}(a)}{4(\beta-\beta')} - \alpha a n^{*\gamma}(a)\right). \tag{56}$$

Note first that $w^*_{ff}(a) - w^*(a) > 0$ for $\gamma = 0$. Let us take $\gamma > 0$. We express everything in $n^*(a)$. We have $a = 2cn^{*1-\gamma}(a)/\alpha$. As before we can write $n^*_{ff}(a) = \lambda n^*(a)$ where λ is defined by (52). (56) becomes

$$(57)\ w^*_{ff}(a) - w^*(a) = \frac{\alpha^2 n^{*2\gamma}(a)}{4(\beta-\beta')}(\lambda^{2\gamma}-1) + \frac{6\beta c^2 n^{*2-2\gamma}(a)}{\alpha^2} - 2(\lambda^\gamma - 1)cn^*(a)$$

$$(58)\quad = n^*(a)\left(\frac{\alpha^2(\lambda^{2\gamma}-1)}{4(\beta-\beta')}n^{*2\gamma-1}(a) + \frac{6\beta c^2}{\alpha^2}n^{*1-2\gamma}(a) - 2(\lambda^\gamma-1)c\right).$$

We can use the fact that $\min_X(A/X + BX) = 2\sqrt{AB}$ to verify that

$$(59)\quad \min_n\left(\frac{\alpha^2 n^{2\gamma-1}}{4(\beta-\beta')}(\lambda^{2\gamma}-1) + \frac{6\beta c^2 n^{1-2\gamma}}{\alpha^2} - 2(\lambda^\gamma-1)c\right) =$$

$$(60)\quad \left(\sqrt{6\frac{\beta}{\beta-\beta'}(\lambda^{2\gamma}-1)} - \sqrt{4(\lambda^\gamma-1)^2}\right)c.$$

Expression (60) is positive because $6\frac{\beta}{\beta-\beta'}(\lambda^{2\gamma}-1) > 6(\lambda^{2\gamma}-1^2) > 4(\lambda^\gamma-1)^2$ for any $\lambda > 1$. Hence $w^*_{ff}(a) - w^*(a) > 0$ for any $n^*(a) > 0$, that is for any $a > 0$. ■

Appendix 8. Consumer surplus under regime two. Comparison of a^* and a^*_{ff}.

Under regime two, the surplus of the indifferent consumer is

$$(61)\quad w^*_{ff}(a^*_{ff}) = v_b - c_b - \frac{3t}{2} + \left(\frac{\alpha^2}{4(\beta-\beta')} - \frac{29\alpha^2}{512\beta}\right)(n^*_{ff})^{2\gamma} > 0.$$

We know from appendix two that $a^* \geq a^*_{\min}$ where $a^*_{\min}$ is defined by expression (38). It is easy to verify that $a^*_{\min} > a^*_{ff}$ where a^*_{ff} is defined by (24). Hence $a^* \geq a^*_{ff}$. ■

Appendix 9. Effect of n_i on Bank i's Deposit Market Share, under Regime Three

Using expressions (6) and (34), we have

$$(62)\quad \frac{\partial D_i}{\partial n_i} = \frac{1}{2t}\frac{\partial(v_i - v_j)}{\partial n_i} = \frac{\alpha}{2t}((s_i + f_j)\left(n^{\gamma-1} + (\gamma-1)n_i n^{\gamma-2}\right) - (s_j + fi)(\gamma-1)n_j n^{\gamma-2}).$$

For $f_i = f_j = a, n_i = n_j$ and $s_i = s_j = s$ we obtain

$$(63)\quad \frac{\partial D_i}{\partial n_i} = \frac{\alpha}{2t}(a+s)n^{\gamma-1}.$$

Appendix 10. Effect of s_i on Bank i's Deposit Market Share, under Regime Three

Using expressions (2) and (6) one can write

$$\frac{\partial D_i}{\partial s_i} = -\frac{1}{2t}\frac{\partial v_j}{\partial s_i} = -\frac{1}{2t}\left(\frac{\partial u_j}{\partial q_j^f}\frac{\partial q_j^f}{\partial s_i} - q_j^f - (f_j + s_i)\frac{\partial q_j^f}{\partial s_i}\right). \tag{64}$$

However $\partial u_j/\partial q_j^f = f_j + s_i$ so that $\partial v_j/\partial s_i = -q_j^f$. Hence we have

$$\frac{\partial D_i}{\partial s_i} = \frac{1}{2t} q_j^f. \tag{65}$$

Appendix 11. The Second-Order Conditions under Regime Three

We show that the Hessian matrix at $(n_{sur}^*, p_{sur}^*, f^*, s^*)$ is negative definite when t is large enough. We have

$$H = \begin{pmatrix} \partial^2\pi_i/\partial n_i^2 & \partial^2\pi_i/\partial n_i\partial p_i & \partial^2\pi_i/\partial n_i\partial f_i & \partial^2\pi_i/\partial n_i\partial s_i \\ \partial^2\pi_i/\partial n_i\partial p_i & \partial^2\pi_i/\partial p_i^2 & \partial^2\pi_i/\partial p_i\partial f_i & \partial^2\pi_i/\partial p_i\partial s_i \\ \partial^2\pi_i/\partial n_i\partial f_i & \partial^2\pi_i/\partial f_i\partial p_i & \partial^2\pi_i/\partial f_i^2 & \partial^2\pi_i/\partial f_i\partial s_i \\ \partial^2\pi_i/\partial n_i\partial s_i & \partial^2\pi_i/\partial p_i\partial s_i & \partial^2\pi_i\partial f_i\partial s_i & \partial^2\pi_i/\partial s_i^2 \end{pmatrix}$$

or

$$H = \begin{pmatrix} -A - B/t & c/t & cD/t & E/t + F \\ c/t & -1/t & -D/t & 0 \\ cD/t & -D/t & -\beta/2 - D^2/t & 0 \\ E/t + F & 0 & 0 & -3\beta/2 + D^2/t \end{pmatrix}$$

with $A = \frac{c}{n_{sur}^*}\frac{(1-\gamma)(\gamma+6)}{3+\gamma} > 0$, $B = 8c^2\frac{1+\gamma}{(3+\gamma)^2} > 0$, $D = \alpha(n_{sur}^*)^\gamma/6 > 0, E = \alpha^2\frac{1-\gamma}{72\beta}(n_{sur}^*)^{3\gamma-1} > 0$ and $F = \alpha\frac{\gamma+1}{2}(n_{sur}^*)^{\gamma-1} > 0$

$Det(H_{11}) = -A - B/t < 0$

$Det(H_{22}) = (tA + B - c^2)/t^2$ is positive for t sufficiently large.

$Det(H_{33}) = -0.5\beta(tA + B - c^2)/t^2$ is negative for t sufficiently large.

$Det(H_{44}) = 0.25\beta \left[t^2(3A\beta - 2F^2) - 2AtD^2 + 3B\beta t - 2BD^2 - 3c^2\beta t + 2c^2D^2 - 2E^2 - 4EFt\right]/t^3$ is positive when t is large enough. Indeed $\gamma < \frac{\sqrt{129}-9}{6} \simeq 0.393$ guarantees that $3A\beta - 2F^2 > 0$.

Appendix 12: Proof of proposition 5

Part (i). Let us compare $n^*(a^*)$ and $n^*_{ff}(a^*_{ff})$. From appendix 2 we know that $n^*(a^*) \geq n^*(a^*_{\min})$. It is easy to verify that $n^*(a^*_{\min}) > n^*_{ff}(a^*_{ff})$. ■

Part (ii). Let us compare $p^*_{ff}(a^*_{ff})$ and p^*_{sur}. Using (30), we have

$$p^*_{sur} = t + c_b + (a + s^*_i(a))q^{f*}_{j,sur}(a) = t + c_b + \frac{\alpha^2}{18\beta} n^{*2\gamma}_{sur}. \tag{66}$$

Furthermore $p^*_{ff}(a^*_{ff}) = t + c_b + a(\alpha n^{*\gamma}_{ff}(a^*_{ff})/2 - \beta a^*_{ff})$. Using expression (25) and the fact that $a^*_{ff} = 4cn^{*1-\gamma}_{ff}(a^*_{ff})/(\alpha(3+\gamma))$, we have

$$\begin{aligned}
p^*_{ff}(a^*_{ff}) &= t + c_b + \frac{2cn^*_{ff}(a^*_{ff})}{3+\gamma} - \frac{16\beta c^2 n^{*2-2\gamma}_{ff}(a^*_{ff})}{\alpha^2(3+\gamma)^2} && (67)\\
&= t + c_b + n^{*2\gamma}_{ff}(a^*_{ff}) \left[\frac{2cn^{*1-2\gamma}_{ff}}{3+\gamma} - \frac{16\beta c^2 n^{*2-4\gamma}_{ff}(a^*_{ff})}{\alpha^2(3+\gamma)^2}\right] && (68)\\
&= t + c_b + \frac{7\alpha^2}{256\beta} n^{*2\gamma}_{ff}(a^*_{ff}). && (69)
\end{aligned}$$

Clearly $p^*_{ff}(a^*_{ff}) < p^*_{sur}$. ■

Part (iii). Let us compare $\pi^*(a^*)$ and $\pi^*_{ff}(a^*_{ff})$. Let us consider particular values of the parameters: v^0_b, c^0_b and t^0 that satisfy $v^0_b - c^0_b - 3t^0/2 = 0$. They yield the minimum interchange fee $a^*_{\min}$ that we obtained in appendix 2 (expression 38). According to expression (15), the associated profit under regime one is

$$\pi^*(a^*_{\min}) = \frac{t^0}{2} + \left(\frac{\alpha a^*_{\min}}{2^{2-\gamma}c^\gamma}\right)^{\frac{1}{1-\gamma}} = \frac{t^0}{2} + 4^{\frac{\gamma-2}{1-2\gamma}} \alpha^{\frac{2}{1-2\gamma}} \left(\frac{1}{\beta - \beta'}\right)^{\frac{1}{1-2\gamma}} \left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}}. \tag{70}$$

Let us consider parameters v_b, c_b and t such that $v_b - c_b - 3t/2 \geq 0$. The corresponding interchange fee a^* is higher than $a^*_{\min}$. The associated profit is

$$\pi^*(a^*) = \frac{t}{2} + \left(\frac{\alpha a^*}{2^{2-\gamma}c^\gamma}\right)^{\frac{1}{1-\gamma}}. \tag{71}$$

Under regime two, according to expression (26), we have

$$\pi^*_{ff}(a^*_{ff}) = \frac{t}{2} + 4^{\frac{2\gamma-4}{1-2\gamma}}(1-2\gamma)\,(3+\gamma)^{\frac{2\gamma}{1-2\gamma}}\,\alpha^{\frac{2}{1-2\gamma}}\left(\frac{1}{\beta}\right)^{\frac{1}{1-2\gamma}}\left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}}. \tag{72}$$

One can verify that

$$4^{\frac{\gamma-2}{1-2\gamma}}\alpha^{\frac{2}{1-2\gamma}}\left(\frac{1}{\beta}\right)^{\frac{1}{1-2\gamma}}\left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}} > 4^{\frac{2\gamma-4}{1-2\gamma}}(1-2\gamma)\,(3+\gamma)^{\frac{2\gamma}{1-2\gamma}}\,\alpha^{\frac{2}{1-2\gamma}}\left(\frac{1}{\beta}\right)^{\frac{1}{1-2\gamma}}\left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}}. \tag{73}$$

Hence,

$$\pi^*(a^*) = \frac{t}{2} + \left(\frac{\alpha a^*}{2^{2-\gamma}c^\gamma}\right)^{\frac{1}{1-\gamma}} \tag{74}$$

$$> \frac{t}{2} + \left(\frac{\alpha a^*_{\min}}{2^{2-\gamma}c^\gamma}\right)^{\frac{1}{1-\gamma}} = \frac{t}{2} + 4^{\frac{\gamma-2}{1-2\gamma}}\alpha^{\frac{2}{1-2\gamma}}\left(\frac{1}{\beta-\beta'}\right)^{\frac{1}{1-2\gamma}}\left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}} \tag{75}$$

$$> \frac{t}{2} + 4^{\frac{2\gamma-4}{1-2\gamma}}(1-2\gamma)\,(3+\gamma)^{\frac{2\gamma}{1-2\gamma}}\,\alpha^{\frac{2}{1-2\gamma}}\left(\frac{1}{\beta}\right)^{\frac{1}{1-2\gamma}}\left(\frac{1}{c}\right)^{\frac{2\gamma}{1-2\gamma}} = \pi^*_{ff}(a^*_{ff}). \tag{76}$$

■

Part (iv). We compare the surplus of the indifferent consumer under regimes 2 et 3. We have

$$\widetilde{w}^*_{ff}(a^*_{ff}) = v_b - c_b - \frac{3t}{2} + \left(\frac{\alpha^2}{4(\beta-\beta')} - \frac{29\alpha^2}{512\beta}\right)(n^*_{ff})^{2\gamma}, \tag{77}$$

and

$$\widetilde{w}^*_{sur} = v_b - c_b - \frac{3t}{2} + \left(\frac{\alpha^2}{4(\beta-\beta')} - \frac{\alpha^2}{6\beta}\right)(n^*_{sur})^{2\gamma}. \tag{78}$$

As $n^*_{sur} = (\frac{16}{3})^{\frac{1}{1-2\gamma}} n^*_{ff}(a^*_{ff})$, writing $w^*_{ff}(a^*_{ff}) > w^*_{sur}$ yields $\gamma < \overline{\gamma}(\beta'/\beta)$. ■

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Notes

[1]Banks also pay the network a switch fee per foreign transaction and an annual membership fee to cover its costs. See McAndrews [2003].

[2]In Great Britain in 1999, consumer protests over an attempt by several banks to introduce surcharges were so strong that the banks have not only abandoned their surcharge plans but also eliminated existing foreign fees.

[3]After growing at an annual rate of 9.2% from 1991 to 1996, the number of ATM's per million inhabitants increased at an annual rate of 16.7% between 1996 and 2001, and 3.3% between 2001 and 2006. This made this number grow from 331 in 1991 to 524 in 1996, 1136 in 2001 and 1335 in 2006 (source: Bank for International Settlements - statistics on payment and settlement systems in selected countries).

[4]In 2006 in the U.S.A., there are 1335 ATM's per million inhabitants and in Canada, 1630 ATM's per million inhabitants. In both countries, cardholders pay foreign fees and surcharges. These figures have to be compared with the 968 ATM's per million inhabitants in the United Kingdom or the 761 ATM's per million inhabitants in France. In both countries, banks do not usually charge ATM usage (source: *ibid*)

[5]In the U.S.A., the monthly transactions per ATM declined from 6400 in 1996 to 3500 in 2001, and 2130 in 2006 (source: American Bankers Association, ATM fact sheet, 2007].

[6]In 2006, according to Dove consulting [2006 ATM deployer study), deployers earned an average of $1,104 per month at their on-premise ATM's, and $1,013 at their off-premise ATM's. On the spending side, deployers incurred average monthly expenses of $1,444 per on-premise ATM, and $1,450 per off-premise ATM.

[7]This cost includes the purchase costs of the machine (depreciated over its lifetime), installation, site rental, maintenance, communications, cash replenishment and the opportunity cost of the cash.

[8]The upper bound on γ is needed for the second order conditions of the profit maximization.

[9]See Donze & Dubec [2006] for an example of derivation of such equilibria above a^* with less general demands for withdrawals.

[10]The empirical literature (eg Knittel and Stango [2008] or Ishii [2006]) talks of 'the incompatibility effect'

of ATM usage fees, and more particularly of surcharges.

[11]Note that the effect of introducing foreign fees on the demand for foreign withdrawals (and hence on revenues) is ambiguous since more ATM's are available at a higher usage fee.

Figure 1: determination of a^*

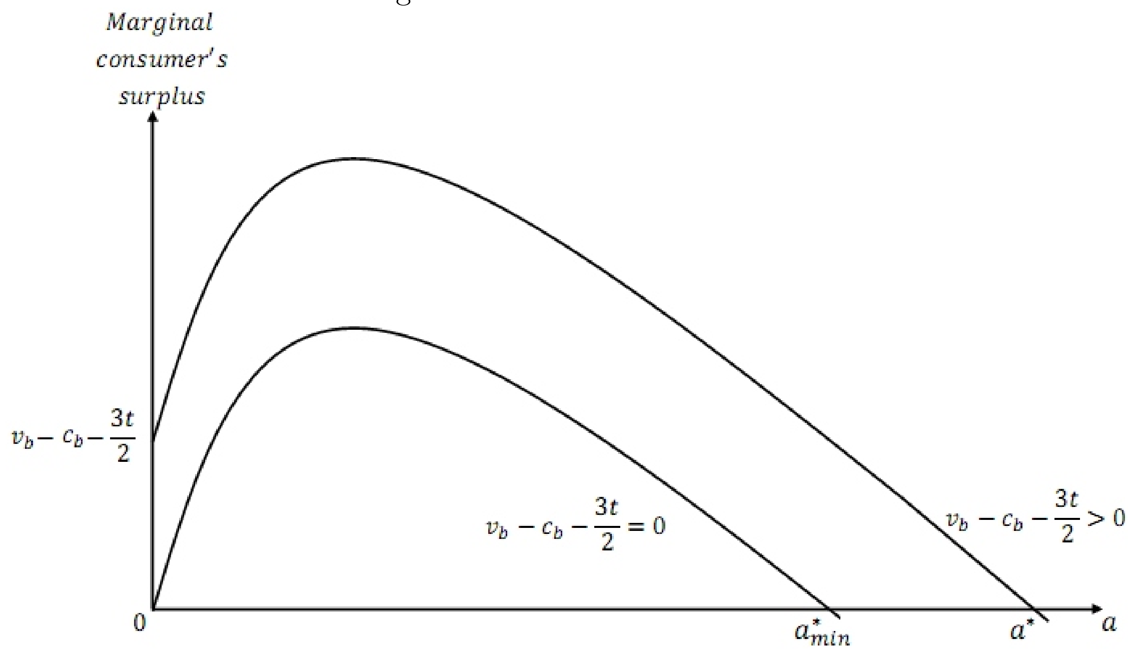

Figure 2: comparison of consumers' welfare under regime two and regime three