Four models for mobile payments

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Abstract

This paper explores the economic models associated to different mobile-payment systems. We first present the existing experiences and exhibit their distinctive components: new technological possibilities to create direct links between users, new potential intermediaries, new economic models to coordinate the commercial interests of financial and non-financial operators. After a short review of the emerging literature, we then concentrate on four possible economic models in appropriate economic environments: the operator-centric model, the bank-centric model, the independent service provider model and the collaborative model. We analyze the potential of viability of each model: in each case, we find that the conditions of viability are more than correct, each system being able to improve without ambiguity the transaction technology in different economic and financial environments. If we limit the analysis to quite large distant payments, the operator-centric model seems adapted to emerging countries without a banking system sufficiently dense. In this case, a take-off phase is however necessary to observe the development of the level of externalities necessary to reach its best level of efficiency. The m-payment system is in this case more specially devoted to users making a relative few number of large distant payments. The bank-centric system is also viable, despite the necessity to verify in this case a minimal agreement between the banks which manage the system and the operators which provide the access to the SIM card. This kind of solution is more adapted to countries with a fully developed financial environment. We found also that it is more convenient to the users making a large number of quite small payments than to those making a small number of large payments. For this reason, it seems more adapted to some classes of professional users. The last two models seem also more adapted to the needs of agents making many large payments. Given the structure of the costs and the advantages that this system can provide in term of quality, the independent service provider (ISP) model seems more adapted for users making many payments and on the additional services that the ISP can provide to the merchants and final users. Users making large and many payments are the early adopters of the collaborative model which we could be specified differently, according the nature of the partnership and the distribution of property rights. This model can also introduce banking intermediation in a cash environment and suits to the "new business class" of emerging countries. We finally discuss the results and compare the potentiality of the four models.

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1 Introduction

The users of the early but insufficiently upgradeable French *Minitel* initiated the first electronic transactions. Electronic payments generalized indeed only few years after with the diffusion of the Internet. Virtual flows of currencies then developed as joint products of electronic commerce: they motivated the emergence of adapted technologies allowing safe and traceable online transactions. While these technologies and payments only currently increase the circulation of currencies already in use (and the performance of existing smart-cards), commercial or financial operators imagined at this stage the possible launch of private virtual currencies (labeled "e-currencies"), with distinct and restricted areas of acceptability. In the same way but with few success, electronic purses systems were introduced by many countries for off-line small payments. Their imperfect overlap with smart cards from one side and with coins and bills from the other side - added to the necessity for shopkeepers to use specific electronic terminals - did not permit this technology to succeed.

More recently, different models of mobile payments (m-payments) have emerged all around the world and increased the typology of electronic payments. They currently try to take advantage of the rapid development of mobile phones functionalities, of the large diffusion of this kind of terminals in all countries and generations of consumers, and of their easy use - at every hours of the day - inside and outside the areas of Internet access. Two contrasting uses of m-payments command attention: neighborhood small payments and large distant payments. For the small payments, the mobile-phone is far more efficient than electronic purse: it saves transaction costs for users and investment costs in specific terminals for shopkeepers. For large distant payments, m-payment offer services without any need of ATM, banking branch or Internet connection.

The neighborhood small payments version seems to be promoted by public authorities and operators in developed countries. In France, an experience founded on a collaboration model has been realized in November, 2007 in two cities, Caen and Strasbourg. Seven banks, the three French mobile operators and a MVNO proposed to the users ICT devices able to simplify their small payments of proximity. The experience "Payez mobile" is founded on an application of electronic payment quite close to the smart card system. The transfer of information is realized from the SIM cards of the users mobile phones to terminals endowed with the NFC technology.

The distant model is currently promoted in or between emergent countries where financial intermediation is incomplete. The *Flouss* experience provides an examples of this kind. *Flouss* is an initiative introduced in 2006 in partnership by *Accord Bank* and *MasterCard*. This system allows to make transfers of money with a mobile phone or by Internet by crediting a smart card in the hands of the recipient. The holder of the smart card can remove the credited amount in any ATM *Cirrus* of *Mastercard*.

We defend otherwise the idea that this model could also provide services in promoting cash / monetary transfers from developed to less developed countries[1]. In 2005, the money transfers amounted to approximately 163 millions dollars (World Bank 2005, p.87). Experts consider that the transfers made by informal channels (sent by mail or by friends or by the family for example) represent 40% - 100% of the volume of the official worldwide transfers (Special study of March, 2005 of Consultative Group to Assist the Poor - CGAP). These transfers offer a reasonable potential market for m-payments in its "large distant payments" version.

This paper is devoted to explore different models of distant m-payment. It rises the problem of the nature of the agent or group of agents coordinating the sub-system of intermediation built around the use of these new terminals of payment. It considers the kind of trust on which it is founded and the form of distribution of the property rights (conceived as the economic counterpart of the "business model" they involve) that it imposes to the partners. Section 2 presents the technical and institutional solutions that have been imagined until then to implement a system of distant m-payments, before a brief review of the (recent) issues risen by the academic literature on the subject. In section 3, we try to capture theoretically way the "Operator Centric" model could operate and substitute the traditional forms of monetary flows with a weak density of the banking system. In section 4, we test in a similar way the "Bank Centric" model in an area of weak density of the traditional monetary intermediation technology (ATM, banking branches,...). Section 5 analyzes a model intermediated by an independent service provider and section 6 presents a first form of collaborative model. Section 7 proposes elements of comparison of the four models and section 8 concludes.

2 Models and Issues

These last years, the emergence of the m-payment seems having slowed down for several reasons.

(i) First for technical motives: operators did not agree rapidly on the way to locate the "secure elements" in the mobile phone terminal. This is an important point because the place of this secure elements provides the control of the system to the agent who owns it. The Secure Element is a platform on which confidential information can be memorized, personalized and managed. The different partners interested by the new system (telecommunication operators, banks, hardware manufacturers, software editors, smart cards networks,...) defended different and non convergent views on this location. The option proposed by *Nokia* (the leader of the terminals market) was for instance to locate the secure element on a specific memory chip in order to keep the control of the transaction and to the distribution of the property rights. The main operators colluded to defend another option, *i.e.* locating it in the SIM card which they hold. The operators

[1] An experience has been promoted at University Nice - Sophia Antipolis (master MBDS) under the initiative of S. Miranda. It concerns distant payments in Morocco and Haïti.

won and it is now admitted that the secure element is (or will be) located in the SIM card. Beyond the technical options on the place of this strategic component, competition between partners already began about the governance of the innovative process to develop.

(ii) The other cause of the delayed launch of m-payment is the indecision around the definition of a viable economic model agreed by the different actors. Until now four sorts of models are discussed and seem to compete:

- the bank centric model: a bank is the central node of the model, manages the transactions and distributes the property rights.
- the operator centric model: the same scenario with the operator in the strategic role.
- the collaborative model: financial intermediaries and telephonic operators collaborate in the managing tasks and share cooperatively the proprietary rights.
- the independent service provider (ISP) model: in this model, a third party of confidence operates as an independent and "neutral" intermediary between financial agents and operators. Google or PayPal are the ISP the most frequently associated to this model in these last months.

Figure (1) ranges these four models according the level of implication of the two main partners, the operator(s) and the bank(s).

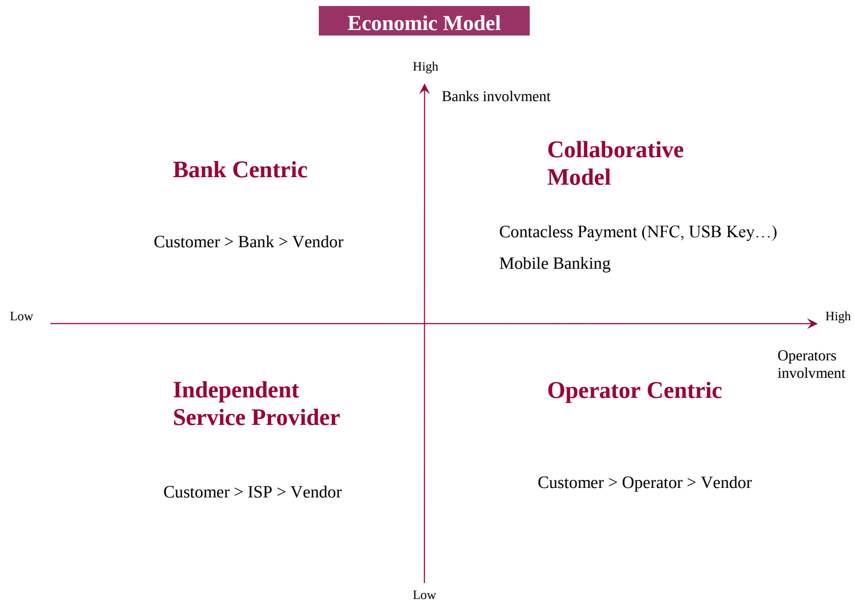

Figure 1: The four models and the level of implication of partners.

Quite all these models confer to a non-financial partner (generally a telecommunication operator but in some cases an ISP) the possibility to provide a service of financial intermediation. These possibility are allowed since the Lisbon Agenda which initiated in

2000 a Financial Services Action Plan. Two important initiatives the followed. In 2008, the Single Euro Payments Area (SEPA) has been introduced to harmonize the electronic payments for Euroland and turns the national markets for Euro payments into a single market. The SEPA which is a self-regulatory initiative initiated by the banking sector is complemented by the Payment Services Directive (PSD) implemented since November 2009 under the initiative of regulators. One of the characteristics of the PSD is to define which type of organizations can provide payment services. The PSD mentions explicitly the Electronic Money Institutions (EMI), introduced by the E-Money Directive (EMD) in 2000, and creates this new category of Payment Institutions with its own prudential regime rules. This new directive then opens the way for the possible leadership of Telecommunication Operations and ISP as central agents in m-payment systems.

Three conditions are required for the new payment system to be operational: Safety, Speed and Simplicity (3S):

- Safety: the financial information stored in mobile phones must be very secure. This is the role of the Secure Element. This element is then technically essential and the question of its control must be considered with attention also from security reasons.
- Speed: distant transactions are high speed ones. They are estimated five times quicker than the traditional means of payment (a payment made with a mobile lasts approximately 5 seconds while with the other means of payment the payment lasts about 22 seconds).
- Simplicity: people tend to always have their mobiles on them. It takes less space than a wallet, most transactions are done very easily through the NFC, where just the approach of a mobile phone payment terminal.

An emerging empirical literature rises since few years the main issues that faces the m-payment concept and development at the crossway between Economics, Management Science and Information Science. Four directions have been individualized.

(i) m-payment uses innovative technologies that associate the development of monetary flows to the development of information networks: what sort of specificities this association will imposes on its implementation and diffusion? Governments have probably an essential role for this development, for instance by creating working groups and private-sector advisory council. Technically speaking, the question of safety remains essential. At this level, safety is defined by 5 components: confidentiality, authentication, integrity, authorization and non-repudiation (Merz 2002). But safety is also a "subjective" concept associated to a given level of perception by the user of the technology. This aspect of safety perception - which is probably connected to the monetary nature of the flows - as also been considered by the literature (Linck, K., Pousttchi, Key and Wiedemann, Dietmar Georg, 2006).

(ii) At the regulatory level, the legal environment is not yet adapted to welcome the m-payment: what sort of improvement must we promote to make it more easy but also in harmony with the existing monetary rules and practices? Some authors have stress the interest to At the legal level, the environment, it is necessary to set up an ecosystem and to develop "national strategies to get all the players together" (Atkinson). Few has been proposed to find the necessary adaptations to include mobile operators as partners in financial intermediation, but also to bound and control their activity in this new activity.

(iii) Few works have been interested in the monetary implications of these innovative payment systems or have imagine links with the slightly older literature on electronic-money. The perception of electronic money by users is probably different that the perception of more usual means of payment (Khan, Craig-Less, 2009). In which amount this new way of circulation will change the respective weight of monetary aggregates? Does it will have implication on the nature of national and international currencies in use, especially in emerging countries? As far as we know, these issues are not yet considered by literature.

The rest of the paper will present then compare two formal models trying to capture the main features of bank centric and operator centric coordination of the payment system in the case of distant payments.

3 The Operator Centric Model

Many examples of Operator Centric Models are already available and operational. In this case, the telecommunication operator offers the technology, operates the transactions and compensates the system. Before payments, there is a necessary to connect the m-payment system and banking accounts or cash deposits. After the clearing of the last transactions, there is the same necessity to credit the accounts or to pay in cash the last recipients. At this level, a third party must provide the liquidity to the system and be compensated by the operator. This scenario is present in all the cases where the model is an operator centric model.

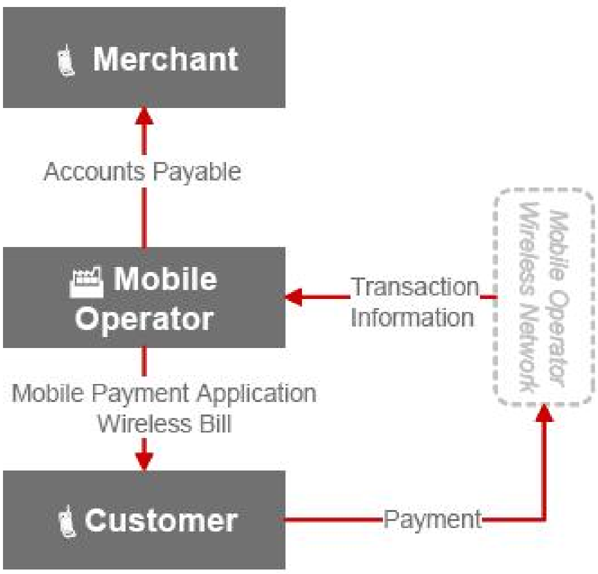

Figure 2: The coordinating role of the operator [2].

In this case, the operator develops and deploys applications for this service. The adoption of this mode of payment by retailers and consumers is however not immediate. Potential users may be afraid by the different risks that they associate to the system (possibility of fraud, blow to privacy...). Adoption costs also integrate material fixed costs (adaptation to the new technology, time to accept operators as financial partners...) incurred by retailers, clients and finally the operator which could be involved to differ adoption until their decrease.

3.1 The *M-Pesa* case in Kenya

According to a 2006 survey by FinAccess, only 27% of the population of Kenya has a banking account. According to the Financial Sector Deepening Kenya (FSDK), 86% of the Kenyans make money transfers, either through friends and family either by commissioning bus or van drivers. These traditional systems are very risky. Moreover, if 38% of Kenyan people come from rural areas and have no bank. In the same time, more than one half of the population owns a mobile-phone according to the financial officer of *Safaricom* (the local branch of *Vodafone*), the mobile network managing *M-Pesa* in Kenya. In this context an Operator Centric m-payment model has been implemented quand ?. Each time a user makes a transfer, he pays a fee to the operator, depending on the amount of the transfer. The receiver is not obliged to be registered with *M-Pesa*, but the transfer will be slightly cheaper if he is. Users tend to consider this new system as a new way to access to banking and financial services. For this reason, the *M-Pesa* system is currently a great success because the transfers are almost instantaneous, simple and secure.

With the *M-Pesa* experience, information is stored in the SIM card which is the property of the operator. All finally depends on this location of the secure element which determines the "operator centric" nature of this model. The nature and brand of the mobile is then indifferent. The SIM card of each customer must be *Safaricom* in Kenya (or *Vodacom* in Tanzania): this is the only necessary condition to participate to the payment system in the best conditions (to have both the possibility to pay and to be paid). Users open accounts near a "certified agent". They pay this agent in cash; the certified agent creates as a counterpart an amount of virtual *M-Pesa*. At all moment, the same certified agent realizes also the conversion of virtual currency in cash and pay back the agents at the end of their transactions. Fees and transaction costs are payed to the certified agent when a new account is opened or closed. Registration is free but each transaction is submitted to the payment of fixed fees to the operator.

3.2 The setting

We present a simplified setting integrating the essential features of an operator-centric model, as close as possible to the *M-Pesa* case. We introduce the three kind of agents (heterogeneous users, the operator, a network of certified agents) and their interactions. We however suppose that only users and the operator are active and that certified agents only accept negotiated payment from the operator according the amount of conversions.

[2] IBM Analysis: Ovum "Mobile payment value chain and business models"

3.2.1 Users

There are n heterogeneous users, indistinctly firms or households. They are uniformly distributed on the segment $[0, m]$ according the number of distant payments or transfers that they must realize. The user located at point i (conventionally "user i") !on the segment $[0, m]$ must realize i distant payments. Each payment provides to each user an intrinsic constant utility (or profit) $\bar{u}$. Users have the choice between reservation (renouncing to make distant transaction) and two technologies of payment: the "traditional technology" and the "m-payment" technology.

If the user i chooses the traditional technology, her total utility is given by equation (1):

$$U_i = i\bar{u} - f(i) \tag{1}$$

where $f(i)$ figures the "transaction" costs that user i incurs as a function of the number of the payments she realizes. This function captures (i) the commission that the user pays to the carrier (more generally the cost of use of the traditional payment system) and (ii) the monetary evaluation of the risk that she supports. We supposes that $f(i)$ is a variable cost which increases a a decreasing rate (the carrier proposes decreasing fees and the auto-assurance coverage is not proportional to the amount of the realizes payments $(f'(i) > 0, f''(i) < 0), \lim_{i \to 0} f(i) > 0$.

If the user i chooses the m-payment technology, her total utility is given by equation (2):

$$V_i = i\bar{u} - g(i, n') + ije + ihn' \tag{2}$$

where $g(i, n')$ is the cost of use of the m-payment system. This cost integrates two terms: (i) for each transaction, the operator charges fixed fees (it is the case for M-Pesa) and (ii) users must also pay a fixed fees at each withdraw of cash near the certified agents. The payment by transaction decreases with the extent of the number of users (greater is the number of transactions to compensate, smaller is the expected amount of cash needed to clear each transaction). The term je (with $j > 0$) figures the quality of the system (it includes the extension of the certified agents network, the accessibility, reliability and facility of use of the m-payment service, the availability of annex online and off-line services...). We suppose that this term increases proportionally to the level of effort e of the operator to improve the technology. The term ihn' (with $h > 0$) is a network externalities term, that we suppose linear on the number n' of users of the m-payment technology (more they are, easier it is for each user to find a partner accepting this form of payment). Equation (2) can finally be rewritten as (3),

$$V_i = i\bar{u} - ig_1 + ig_2n' + ije + ihn' \tag{3}$$

where ig_1 (with $g_1 > 0$) encapsulates the proportional costs (transaction and conversion fees) associated to each transaction and ig_2n' (with $g_2 > 0$) the positive advantages associated to each transaction according to the number of users (we use for simplifying the model a linear approximation of this last advantage which probably underestimates the level of externalities on compensation when the number of users increases).

From the analysis of equations (1) and (3) for a given level of effort e, we deduce the following lemmas:

Lemma 1. *Whatever the level of effort e of operators, the condition $u > g_1$ is always sufficient to the existence of a positive level of adoption of m-payment.*

Proof: see Appendix 1.

Lemma 2. *When $f'(i)$ decreases sharply, the two technologies coexist: users making few payments use the m-payment technologies and those making a large number of payment maintain their choice of the traditional technology. When $f'(i)$ decreases more slowly, the m-payment technology crowds out the traditional method of payments.*

Proof: see Appendix 2.

Note that the possibilities offered by m-payment make irrelevant the case of reservation that was always prevalent with the traditional payment system. This case corresponds to agents with a very few number of payments to realize. With the traditional technology, these agents are deterred by the amount of the fees (not yet decreasing at this level) and the other transaction costs associated to the payments.

3.2.2 The Operator

The receipts of the operator are the fees $g_1 \int_1^{n'} (xm/n)dx$ payed by the m-payment users. Its costs are (i) fixed infrastructure costs C, (ii) the payment of the certified agents that we suppose increasing proportionally both with the number of m-payment users n' and with the number of payments of the largest users i^* (and not to the total number of payment using the new technology), (iii) the variable costs that we associate to its effort to improve the service $c(e)$. We suppose $e \in [0, 1]$, $c'(e) > 0$, $c(0) = 0$ and $\lim_{e \to 1} c(e) = +\infty$.

The profit π_o of the operator is then expressed as expression (4):

$$\pi_o = g_1(i^{*2}n/2m) - C - \phi_1 i^* - \phi_2 i^* n/m - c(e) \quad (4)$$

where ϕ_1 and ϕ_2 are positive constants and $i^{*2}n/2m$ the number of m-payments, *i.e.* the expression of $\int_1^{n'} (xm/n)dx$ given the assumption that m-payments do not cover the market (see lemma 2).

The possible control variables are the amount of the fees g_1 and the level of effort e. We can consider that in the period of adoption the fees are chosen at a relatively low level (it is necessary to create the market, then to choose $g_1 < \bar{u}$) but at a sufficiently high level however to test the profitability of the market. It is then reasonable to take them as fixed and to select the variable costs (or the variable of effort) as the adjustment variable. This variable appears directly and negatively in the cost $c(e)$. It also appears indirectly in the costs $\phi_1 i^* + \phi_2 i^* n/m$ (negatively) and in the demand $i^{*2}n/2m$ (positively).

We then deduce the following result:

Lemma 3. *For all values of the parameters such that $\bar{u} \geq g_1$, there exists a strictly positive level of effort e^* maximizing the profit of the operators. This level increases with the dimension $g_2 + h$ of the network externalities.*

Proof: see Appendix 3.

We then deduce the following Proposition:

Proposition 1. *Only high infrastructure costs can make non-profitable the implementation of a m-payment system in an area of weak financial intermediation. When the system is implemented, it is fully adopted by the users making a reasonable number of payments or transfers once $\bar{u} \geq g_1$.*

Proof: see Appendix 4.

This very schematic setting and first results seem to show that the operator-centric model is well adapted to an environment characterized with a weak development of financial intermediation. In this case, its development is however dependent on the initial importance of infrastructure costs. Another reason of failure (or slow emergence) could be the psychological adaptation of potential users. Regulations and rules must evolve to increase the safety of the transactions: symmetrically, governments must probably be interested to the welfare advantages of this form of m-payment. In the long run, this kind of experience cannot however preclude the development of a real system of financial intermediation in the countries under consideration. At this stage, the collaborative model could become the most efficient one.

4 The Bank Centric Model

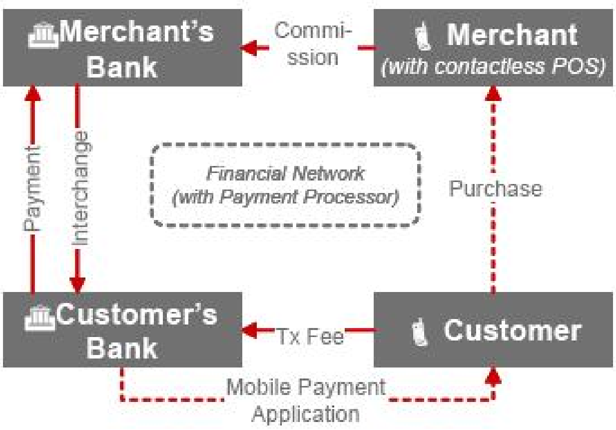

Figure 3: The banks and the payments [3].

[3]ISources: Smart Card Alliance industry research and Interviews; IBM Analysis; Ovum "Mobile payment value chain and business models"

The model is less frequent than the operator model, probably because operators have two advantages over banks: (i) they hold the technology and particularly the secure element and (ii) they usually frequently compete with a few number of partners. Banks face generally a very different environment. They have many competitors and do not hold the technology. They must compete or more successfully cooperate with other financial partners and collaborate with mobile operators without any substantial bargaining advantage. The Bank Centric Model can be considered as an evolution of the credit card model. Users (households or firms) are in relation with their bank which provide them the way of payment (the mobile-phone). The users receiving the payments (frequently commercial intermediaries) are not generally clients of the same bank than the payer. A general compensation system must then operate between banks with or without connections with the classic inter-bank flows. The partners banks of this compensation system must also pay fees to one or many mobile operators associated to the operation. We will present a generic bank-centric model, as close as possible to the existing examples *CashEdge* and *Flouss* that we first present briefly.

4.1 The *CashEdge* example

CashEdge is a private company which conceives advanced Internet applications for financial services. *CashEdge* has its headquartered in New York and Milpitas (California), and benefits from the support of private equity funds as Z Partners, General Atlantic Partners, Marsh & McLennan Major, International Real Returns, as well as of the Royal Bank of Canada. The company is presented as "the preeminent provider of online funds transfer services to financial institutions for nearly ten years and, today, provides its Intelligent Money Movement services to hundreds of financial institutions, including the majority of the nation's largest banks" (http://en.wikipedia.org/wiki/CashEdge). The services that *CashEdge* provides are devoted to an area covered by a fully developed banking system (The online Demo is clearly oriented to professionals customers). M-payment is presented by *CashEdge* as integrated in a bundle of services including also an "aggregation services to the brokerage and wealth management industry" (*ibid.*). The interest is for the banks associated to the company to generate new transaction-based revenue in lucrative P2P payments space. The financial partners of the company probably use the m-payment service as a loss leader to attract customers to other joint financial services that they provide themselves. The strong participation of private equity (more than retail banks) suggests however that this is not the only objective of the company. Users endowed with the system *PoPmoney* proposed by *CashEdge* can send money to anyone, at any time using existing online and mobile banking applications, eliminating the need for cash, checks and in-person meetings. Payments use email addresses, cell phone numbers as well as bank accounts informations. *CashEdge* proposes a large range of possibilities of payment ranging from immediate payments to recurring payments for ongoing expenses. The system is presented as secure, with a track payment history easily online. Retail banks can affiliate to the *PopMoney* system. In order to use *CashEdge* system, the user is obliged to have a bank which issues *PoPmoney* but not the agent who receives the payment. If the bank of the receiver offers *PoPmoney*, the receiver can credit its own banking account. Otherwise, she must register to *PoPmoney.com* to obtain a lower level of services (the difference between the advantages of the clients and non-clients creates an incentive to open an account to a bank issuing *PoPmoney*).

4.2 A generic Bank-Centric setting

As the M-Pesa experience, the CashEdge case proposes also a 3 agents model, once we consider as a single bank the retail banks issuing *PoPmoney.com*. The three agents are a banking network, a set of heterogeneous users and one or more mobile operators. In this case also, the third agent is quite passive: the banking network has negotiated fixed fees payed by users to use the mobile operators associated to the system and a fixed access that it pays directly to the operator for the use of the SIM card. The services proposed to the customers are mainly banking and financial services, in an environment where each user has already one or more banking affiliation, but not always near a bank associated to the m-payment service. We present first users decisions, then the choices of the banking network.

4.2.1 Users

We still suppose n heterogeneous users, indistinctly firms or households, like in the operator-centric case. Users decompose in two subpopulations: a first subpopulation of n_1 users is not affiliated to the banks associated with the m-payment system. The other subpopulation of $n_2 = n - n_1$ users is affiliated. Users all make the same total amount of payments of m monetary units but their number of transactions is distributed uniformly (and independently from their affiliation) on the segment $[0, m]$ (those making m transactions make many small payments of one single monetary unit...). The total payment provides to each user an intrinsic constant utility (or profit) $m\bar{u}$. All agents are fully endowed with existing payment services: we then consider as the reservation case the use of traditional banking services for direct payments among users. Users have the choice between reservation (using the traditional banking intermediation services to realize user to user payments) and the use of the "m-payment" technology.

If the user i chooses the traditional technology, her total utility is given by equation (5):

$$T_i = m\bar{u} - it \qquad (5)$$

where $f(i)$ figures the unitary transaction cost that user i incurs for each payment she realizes with the traditional banking technology.

If the user i chooses the m-payment technology, her total utility depends on its banking affiliation. If she is affiliated its utility is given by equation (6):

$$W_i^a = m\bar{u} - ig_1 - ig_3 + ije \qquad (6)$$

where g_1 and g_3 figure respectively the unitary fees payed for each transaction to the bank and to the operator and je the utility generated at each transaction by the joint services provided by the m-payment system. We have neglected the externalities that do not appear so clear in this case.

If the user of the m-payment technology is not affiliated, her utility is given by equation (7):

$$W_i^{na} = m\bar{u} - ig_1 - ig_3 + ije - A \tag{7}$$

where $A > 0$ figures the fixed adjustment cost associated to the affiliation to a bank associated to the m-payment system (or the desutility associated to the non-affiliation).

From the analysis of equations (5) to (7) and for a given level of effort e, we deduce the following lemmas:

Lemma 4. *Whatever the level of effort e of operators, the m-payment system is active only if the affiliated users choose it.*

Proof: The immediate comparison of expressions (5), (6) and (7) shows that is a potential user is affiliated, she adopts the m-payment technology if $g_1 + g_3 - je \leq t$ whereas is she is not affiliated, she adopts if $g_1 + g_3 - je \leq t - A/i$. One deduces that if there exists a user i not affiliated who adopts the m-payment system, all the affiliated ones adopt it also ■

Lemma 5. *Whatever the level of effort e of operators, if the m-payment system is active the number of users is given by*

$$n^*(e) = \frac{(m - A/(t - g_1 - g_3 + je))n_1}{m} + n_2 \tag{8}$$

Proof: The critical user (for which the two technologies are equivalent) is a non-affiliated user such that $T_i = W_i^{na}$, *i.e.* $g_1 + g_3 - je \leq t - A/i$. The population of m-payment users is then deduced from the sum of two subpopulations: the n_2 affiliated users and the $\frac{(m-A/(t-g_1-g_3+je))n_1}{m}$ not affiliated users ■

4.2.2 The Banking network

The costs of the banking network are (i) fixed management costs C_1, (ii) fixed costs C_2 payed to the operator for the use of the SIM card for the informations associated to the system, (iii) variable costs $c(e)$. We still suppose as in the operator-centric model that $e \in [0, 1]$, $c'(e) > 0$, $c(0) = 0$ and $\lim_{e \to 1} c(e) = +\infty$. The receipts of the banking network are the fees $g_1 mn^*(e)$ payed by the m-payment users increased by the evaluation of the monetary advantage associated to the attraction of a part of the non-affiliated users on the traditional financial services of the banks associated to the system. We evaluate this last term to $(n^*(e) - n_2)d$, with $d \geq 0$.

The profit of the banking network is finally given by (9):

$$\pi_b = g_1 mn^*(e) + (n^*(e) - n_2)d - C_1 - C_2 - c(e) \tag{9}$$

We still consider as variable of action the level of effort e of the bank. We then deduce the following result:

Lemma 6. *There exist a level of effort e^* of the banking network maximizing its profit.*

Proof: see Appendix 5.

Finally, we deduce from lemmas 3 to 5 Proposition

Proposition 2. *There is few rational reasons for a Bank-Centric model implementation to fail when mobile operators agree to its development.*

Proof: see Appendix 6.

This quite optimistic result must be moderated by three remarks. (i) We have supposed that the system emerges in a monopolistic setting, *i.e.* that there is only one banking network. If there are most, traditional forms of competition will emerge among financial intermediaries, with maybe the necessity to conclude limited or full agreements to maintain the system profitable. (ii) We have also supposed that the extent of the network is reasonable: in this way, m-payment services can be considered by the associated banks as a way to increase their share of market on other activities. When the size of the network is increased indefinitely, this advantage decreases rapidly: if this process is conceived dynamically, this extension of the network will probably create an incentive for the introduction of a new improvement of the payment system. (iii) We have last supposed passive mobile operators. This assumption is hardly acceptable given that they hold the SIM card which is necessary to the development of the system. It is probably reasonable to expect that the future systems will be more collaborative than the benchmark that we chose in this section.

5 The independent service provider model

In this model, a third party, distinct from a financial agent or a telephone operator, plays the role of intermediary between banks, operators, traders and final users. This new actor concentrates all the organizational prerogatives held by banks or operators in the previously presented models. The independent service provider (ISP) manages the distribution of property rights between the operators and the banks, which are in this case less decisional in the coordination process. Internet companies are the ideal candidates to intervene as ISP given their previous experience with monetary transfers and the organization of electronic commerce websites.

5.1 PayPal example:

Created in 2000, then bought in 2002 by eBay Inc., PayPal is a online payment service performing payment processing for online vendors and other commercial users. PayPal allows to any company or person who holds a bank account and an e-mail address to make online transactions. This network is based on the existing financial infrastructure of cards or bank accounts and provides an instantaneous online payment solution. PayPal

[4] Smart Card Alliance"Proximity Mobile Payments Business Scenario: Research Report on Stakeholder Perspectives"

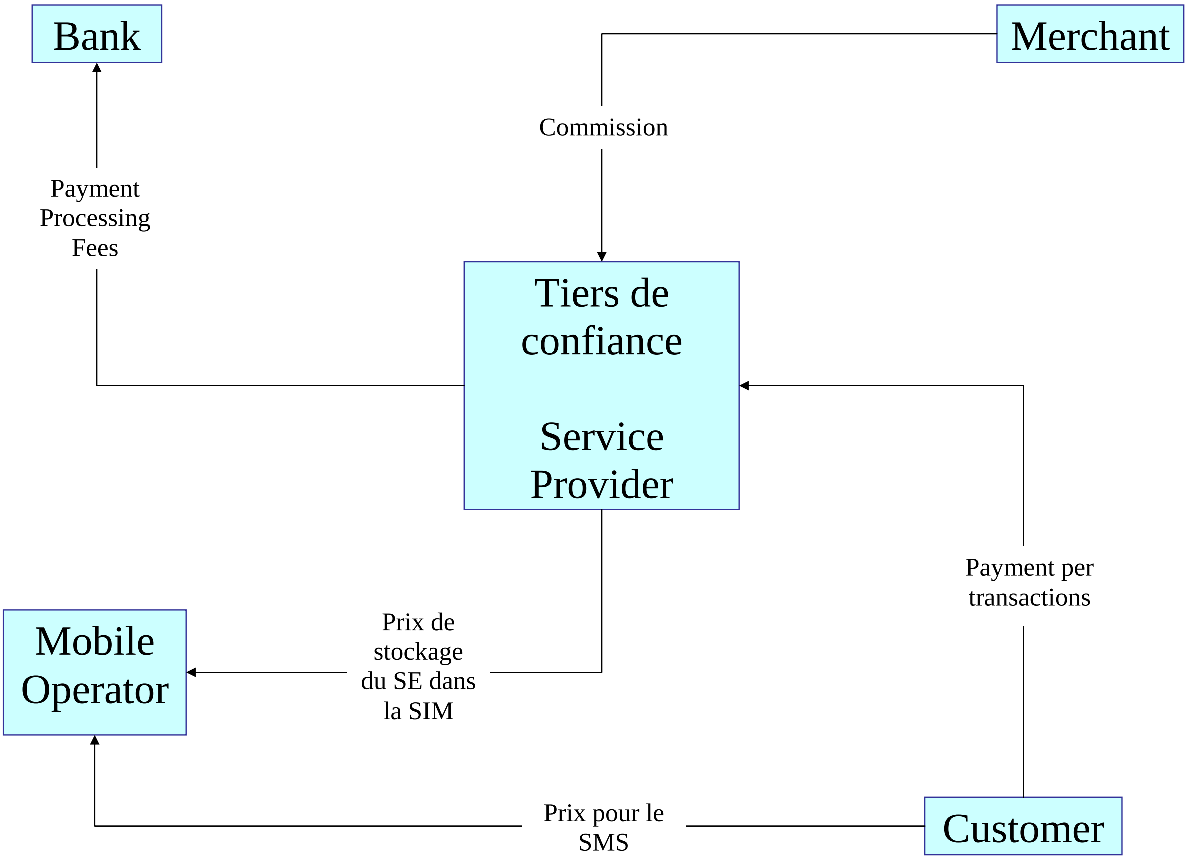

Figure 4: The coordinating role of the independant service provider [4].

Mobile has been created on December 2008 allowing users to use PayPal services from their mobile phones. This new service allows sending or receiving money securely from its own mobile phone or pay online goods or services on websites or marketplaces. To access this service, the potential user creates for free a PayPal account, under only two conditions: having a mobile phone and a bank account. PayPal accounts can be fund in three different ways: with a bank account, a PayPal account, or a credit card. Transfers are free if issuer uses his/her bank or PayPal account. If the remittance is made from a card, receiver will pay $3.4\% + 0.25$ euro. The operator surcharges also the SMS necessary for each transfer. Registration is free for merchants and the unit transaction fees decrease with the volume of monthly activity realized with PayPal.

Google made a first attempt in 2007 to provide a mobile payment via mobile phones with GPay - a payment service via a Google's mobile phone. It worked like PayPal except Google did not charged fees on each transaction, operators didn't surcharge the SMS: in this case financial institutions generated fees payed to Google. As Apple, Google has new projects which could be proposed to the mobile users of Android of iPhone users in 2011-2012.

5.2 The model:

We still present a generic model which admits that PayPal solution as a specification. As in the PayPal service, users send a surcharged SMS to the operator.

5.2.1 Users

There is again n heterogeneous users, firms or households. They are still distributed on $[0, m]$ according the number of purchases or transfers they have to realize. User located at the point i on $[0, m]$ realizes i purchases or transfers. Each payment provides an intrinsic utility (or intrinsic profit) $\bar{u}$. Users have the choice between reservation, traditional and mobile payment technologies.

If user i chooses the traditional technology, his total utility is given by (10):

$$U_i = i\bar{u} - if \tag{10}$$

where if figures transaction costs that user i incurs as a function of the number of payment she realizes. These costs that we supposed linear capture the costs of conversion of fiat money in cash, opportunity costs and the costs supported for making distant payments. We have neglected the fixed fees of opening and managing accounts that are also supported in the alternative mobile payments.

If user i choose the m-payment method, her utility is given by (11) :

$$N_i = i\bar{u} - g_1(i)p - ig_2 - ig_3 + ije \tag{11}$$

where p represents the unit fee or operating costs debit made by the ISP for each monetary transaction. These cost are decreasing, *i.e.* $(g_1'(i) > 0, g_1''(i) < 0), \lim_{i \to 0} g_1(i) > 0$ and $g(1) = 1$. The parameters g_2 and g_3 represent respectively fees paid to the bank and to the operator for the extra costs of the SMS. The ISP's positive effort to improve the service is noted e and j is a positive parameter capturing the efficiency of this effort.

Lemma 7. *When the two technologies of payments are activated, users making a great n umber of payments use mobile payment. The others use the traditional technology.*

Proof : The comparison between equations (10) and (11) determines the threshold user for whom the two technologies are equivalent. This user realizes i^* transactions and is such that $g_1(i^*)/i^* = (f - g_2 - g_3 + je)/p$. Given the form of $g_1(i^*)$, users i' such that $i' < i^*$ realize traditional payments (cheque, card and cash payments) whereas users i'' such that $i'' > i^*$ use mobile payment ■

5.2.2 The ISP

The receipts of the ISP are given by the payments realized by users given by $p \int_{n'}^{n} g_1(xm/n)dx$ where n' is the rank of the threshold user $(n' = ni^*/m)$. The cost of the ISP are given by C_1 which corresponds to the installation and maintenance costs and C_2 which corresponds to the fixed amount charged by the operator for the storage of confidential informations on the Sim card. Finally, the cost of the effort of the ISP for improving the quality of the service is noted $c(e)$. We still suppose that $e \in [0, 1]$, $c'(e) > 0$, $c(0) = 0$ and $\lim_{e \to 1} c(e) = +\infty$.

The operator's profit is finally given by (12) :

$$\pi_t = p \int_{n'}^{n} g_1(xm/n)dx - C_1 - C_2 - c(e) \tag{12}$$

The control variables are the unitary fees p and the effort e. The analyze of the equation (12) provides the following lemma:

Lemma 8. *There exists a couple (p, e) maximizing the receipts of the ISP.*

Proof: see Appendix 7.

Different cases emerge from the study of expressions (10), (11) and(12). If the benefits of mobile payment system in terms of transaction costs are relatively limited (if f is low) while the costs implementation and operation costs (C_1 et C_2) are high, it is necessary to plan additional benefits in terms of services (represented by the term (je)) such as to make this new kind of payment attractive compared with the older. Possibilities are probably not completely extensive in a fully intermediated environment: we think about services for holding a bank account, or maybe other services associated with mobiquity, the major one being the ability to make real time payment, at any time and any place which creates a real advantage on traditional payment technologies.

Proposition 3. *The success of the adoption of a ISP based m-payment solution is based on its early adoption by the agents making many payments and transfers. This success seems conditioned to the individual advantages of mobiquitous services.*

The first part of the proposition is a consequence of the lemma 8, in the case where the service is implemented. The additional cost associated with the new service will be better supported by users making many payments. This result obviously ignores imitation effects, usual in the mobile phone's world. The service adoption can rely on some users on payments in terms of utility related to the identification to a group or to other inter-individual components of utility functions. The strong development of services offered by banks, in particularly the SMS management of bank accounts however leaves apparently a few place for new and original services. An extension of the model presented here would probably consider a differentiation between agents linked to their need for banking services in a mobility situation (sensitivity to mobiquity component of m-payment).

6 The collaborative model

This model involves a collaboration between operators, banks and the participation of a third party which creates a link between the two main partners. All partners derive their revenue from fees charged to merchants and final users: these different sources of revenue are however still subject of disagreements between partners. Investment costs generally split between banks, operators and sometimes the third party providing an escrow service. An inquiry by the Smart Card Alliance shows that the collaborative model is considered by 86% of the participants like having the greatest potential for long term propagation. This model seems more viable than the others because it allows each partner to concentrate on his own skills. Banks concentrate on financial responsibility and operators on the transmission network [5]. This model is then seemingly easier to implement than the other ones because each party is in its natural role. The distribution of profits and the management of property rights however remains an open problem: it requires to imagine an advanced collaborative process requiring a learning period for rather suspicious partners.

6.1 The SEMOPS example

SEMOPS has been launched in 2002: it allows users to access at any time to online banking services, to pay at point of sale (POS) and to make person to person (P2P) transactions in Europe. This model is based on cooperation between banks and operators: the revenues of the system are shared between them. SEMOPS then operates as a third party and manages the link between banks and operators. Users sign a contract with their bank or their mobile operator but have no direct contact with SEMOPS. The main characteristic of this model is that there is and advanced cooperation between banks and mobile operators. Two consequences are as follow: the model combines in a "single technology" the resources and skills of each partners are combined while the benefits are shared between them. Banks concentrate on macro-payments and operators on micro-payments. The income depends on the revenues generated by different services. Structural costs are low. Data are stored on a secure element in the SIM card. The service is invoiced directly to the user by the MNO if the transaction is made by the MNO. If the transaction is made by the bank, the user also pays the MNO for the stored informations. The operator charges a first fee directly or indirectly to the merchants if they use the content of the SIM card and a second one for using the infrastructure of the system. Banks' debits may vary according the type of transaction, the transaction channel and the nature of the service provided to the merchant or the user.

6.2 The model

We present an exploratory model illustrating this scenario. We have presented the components of this model to differentiate the contribution of the banks and of the operators, as well as their contribution to the price supported by the final user. We have neglected the trusted third party the contribution and profit of which could be reintroduced in a more advanced version.

[5] "Has to be the collaboration model, however relies on keeping key processes unchanged. Banks do what they do the best - financial transactions for standard payment methods; mobile operators do what they do the best - securing the mobile network.

6.2.1 Users

Users are differentiated by their ability to the different services proposed by the mobile payment system. For simplicity, we suppose that all users make the same number of small payments m' providing each one an intrinsic utility $\bar{u}'$. We suppose in contrast that they make a different number of large payments or transfers. The n potential users are then distributed on the segment $[0; m]$ according to the number of "large" payments they make: each "large" payment provides them a gross utility $\bar{u}$. Each users has of course the possibility to use traditional means or m-payment as an alternative to m-payments.

If the user i chooses the traditional means of payment, her utility is given by expression (13):

$$D_i = m'\bar{u}' + i\bar{u} - (m' + i)t \tag{13}$$

where t represents the unit user cost for the traditional means of payment.

When the consumer uses the m-payment device, her utility is given by the expression (14) :

$$R_i = m'\bar{u}' + i\bar{u} - m'g_1 - ig_2 + m'je + i(je + hf) \tag{14}$$

where g_1 and g_2 figure respectively the fees applied respectively to small and large payments by the operator or the bank. For simplicity, we have not applied a decreasing scale to these fees. The operator provides the effort e and the bank the effort f. The efficiency of these efforts is related to the level j and h, $(j, h > 0)$. It is not completely simple to decide which kind of transactions could benefit the most from these efforts. An option is to suppose that the operator's effort applies to the all transactions (when the operators improve the technical quality of the transfers, the utility all types of transfers increases) while the bank effort will benefit only to large transactions (only those transaction need banks services). This option (which could be reconsidered with available observations) explains how we write the end of the expression (14).

Lemma 9. *If the m-payment system involves a partial adoption, it is adopted by agents making many large payments.*

Proof: If the m-payment device adoption is partial, the threshold user is defined by the equality of (13) and (14). We verify that the number i^* of large payments making equal (13) and (14) is given, whatever g_1, g_2, e and f by $i^* = \frac{m'(g_1 - t - je)}{je + hf + t - g_2}$. This expression is positive when bank fees g_2 have a reasonable value and when there is a positive advantage $(g_1 - t - je > 0)$ of the service provided by operators ■

In terms of adoption, the predictions provided by the collaborative model and by the ISP model are rather similar. Early m-payment adopters are large payments makers.

6.2.2 The partnership

We assume that the partnership takes the form of sharing costs and resources and maximizing joint profit. This profit is the result of a bargaining process among participants: we will not develop precisely this point. Others forms of partnerships are of course possible: for instance, partial agreements on prices and/or efforts without an explicit redistribution of profits. By convenience, but also because this solution can plays the role of a norm in a fair partnership, we consider that partners maximize joint profits which can be written as 15) :

$$\Pi = m' g_1 \left(n - \frac{i^* n}{m} \right) + g_2 \int_{n'}^{n} \frac{xm}{n} dx - C - c(e) - \chi(f) \tag{15}$$

The first term of the right part represents the receipts from small payments. The second term figures the receipts from large payments, given that $n' = i^* n/m$. C represents the fixed costs supported by the two partners, $c(e)$ and $\chi(f)$ are their variable costs. We attribute to the function $\chi(f)$ the same properties at those of $c(e)$; f is finally defined as e between 0 and 1.

Lemma 10. *There is a set of variables control (g_1, g_2, e, f) maximizing joint profit of both partners.*

Proof : see Appendix 8.

Proposition 4. *Collaborative models of m-payment's have promising conditions viability. Their activation may take different forms depending on the way of redistribution of the profits resulting from the partnership between banks, mobile operators and possible third parties.*

Proof:This is a consequence of the two lemmas and of the discussion on our working assumptions.

The collaborative model has a encouraging potential of viability. It has also many possible specifications, not necessary all conform to the presentation adopted here. Although we have considered its implementation in a fully financially intermediated area, it may also be adaptable to an environment without a full financial intermediation system. Potential users can contract with their mobile operator: this last has a partnership with a bank able to manage with it the payment services for the large amounts. In developing countries, the cooperative model could be an interesting alternative to the cash economy associated to the operator centric model. It may help to familiarize users with bank services, increase the safety and decrease the costs of large and distant transactions and monetary transfers.

7 Elements of comparison of the models

Given the specific environment of each models, it is not possible to use a single scale to rank the efficiency of these models. Each one seems to have its own advantages and limits.

Operators centric models probably provide the good solution with an environment poorly endowed in financial intermediation devices. In this case, the mobile operator can create the missing link between users and improve the efficiency of the currency system of intermediation. As in the other cases but especially with the operator centric model where new agents provide financial intermediation services, it is essential to verify the reliability of the system and the level of responsibility of each partner. New regulatory principles are maybe necessary to manage the new risks associated with this form of intermediation still out of the control of tye existing regulatory commissions. Externalities are generated by the size of the network: they are probably strong enough to accelerate the diffusion of the transaction technology once the service is available and already diffused by the early adopters. Given the role of adoption externalities, we could imagine that governments promote their emergence with incentives actions or subsidies.

Other conditions must pre-exist in the implementation of the operator centric system. The first is that there exist a real density of remote payments. This condition is fulfilled when some kind of economic activity provides these remote payments. Two examples come to mind. The first example is the transfer between migrant workers and their families. These transfers generate major and regular flows which could provide a permanent activity to the operator centric system. Another example lies in monetary transfers of the farmers in emerging zones or countries. These payments can be important transfers for which a high level of safety is necessary.

The bank-centric model is apparently adapted the environments characterized by a full system of financial intermediation: it appears as a way to create efficient monetary links between users without any technological limitations like appeared rapidly evident in the experiences of electronic purses or private currencies. The electronic purse were found limited to small transactions, while requiring numerous and discouraging conversions from bank money to cash/electronic money. Private currencies have a limited domain of acceptability which bounds their development. Mobile payments backed on a bank centric model require nothing else than mobile phones or smartphones which are very diffused in the developed countries where this solution could be adapted. Again, this solution probably requires legal adjustments to adapt banks to new responsibilities. This model has less propensity to generate network externalities (we obviously ignored the externalities associated to effects of imitation which have probably a role in this domain). For this reason, once introduced, we could probably expect a rapid emergence of the use of this kind of m-payment solution but its diffusion could be regular and free from new advantages generated by the early adopters. For this reason, incentives and subsidies are probably not efficient in this case. Once fully this technology will be proposed, this form of m-payment system seems to answer rather well to the needs of companies, the professional users and high revenue consumers.

The last two models seem rather close to the bank centric model because of their strong long-term viability but also because they target users making large payments as early adopters.

The independent service provider model is perfectly adapted to many environments (with or without a fully installed banking system of intermediation). This model seems to target users making many payments and valuating the mobiquitous properties of the

ISP model. The legal environment for the implementation of this payment solution has evolved much notably with the creation of payment institutions since the PSD in November 2009. The ISP interested in the service are generally very dynamic companies in the Internet: users know them and trust them. Their emergence as mobile payment service providers does not seem illogic: their previous experience in of the Internet and the Mobile Internet is for these companies an advantage over banks and other financial intermediaries. ISPs can manage alone the network, but if they want to invest in more stable solutions and limit the number and nature of the future conflict with potential competitors, they can initiate a cooperation with other players, banks, other financial agents, mobile operators and other ISPs.

Finally, the collaborative model is also an interesting solution for users. Note that as the operator centric model, it can operate in a pure cash economy. Moreover, it has the advantage to generate from users the need for bank services and to introduce banks in a non-orthodox way. For all its advantages, this is probably the long-term solution. Each partner concentrates on its own skills and competences: this specialization facilitates the implementation of the system and decreases its cost of use. Collaborative solutions are interesting for macro-payments. Their implementation is helped by the involvement of banks which are already authorized to make monetary transfers and compensations. However, the emergence of this kind of solution needs a delicate alchemy: it necessitates a high level of cooperation between players not naturally inclined to make concessions to partners that they sometimes consider as aggressive new entrants. Cases of real competition and conflicts between banks and mobile operators are not excluded in the future concerning the implementation and development of these cooperative or pre-cooperative forms of mobile payments.

8 Comments and conclusions

The objective of this paper has been to explore the economic models corresponding to different mobile-payment systems. We have presented these models, ranging from the independent service providers solutions to the collaborative models. We have considered their distinctive components: In which kind of economic environment each one has the more chance to impose? On which kind of users each one can target more easily? Which kind of coordination problem must be solved in each case? After a short review of the literature, we have developed four simplified models trying to capture the conditions economic viability of the four models - the operator-centric mode:, the bank-centric model, the independent service provider model and the collaborative model. These models present different solutions to coordinate the actions of mobile-phone operators, banks and possible third parties. We tested the viability of each solution. It appears that each of them present its advantage and limit. The operator-centric model is probably more suited to an economy of cash money: it is a adapted to small but distant transactions for which it decreases the costs and the risk of transfer. It is convenient for low revenue users that it could help to realize a few number of useful transfers. This model can possibly compensate in an emerging country or a in a isolated region the low density of

bank branches by a new form of financial intermediation without financial agent. The independent service provider formula and overall the bank centric model and are more adapted to regions characterized with a high level of development of financial intermediation. The experience of ISP and their coordinating role are the main advantages to the ISP system the hybrid form which could adapt to many types of users. The bank centric system meets the needs of individual and professional uses in financially developed environments. Finally, the collaborative model, which associate in an ideal partnership mobile operators, banks and other financial agents is an fragile alchemy able to provide the more efficient solutions if partners involved in the system are able to find consensual ways to share the property rights.
Many questions are left open by this paper and require extensions: bandwagon and imitation effects as well as psychological resistance have been neglected. Mobiquitous component has probably been underestimated in all proposed alternatives. Finally, the regulatory options have to be considered in a separated paper.

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Appendix

Appendix 1: Proof of lemma 1

For a given e, each user compares, according to its own amount of payments, the utility given by (1) that she could obtain from using the traditional payment system and the utility (3) that she could obtain from the use of the m-payment system. Given the form of equation (1) and particularly of the function $f(i)$, the utility of the traditional payment technology users increases with i at an increasing rate. The critical agent, for which the utility obtained by the two systems is strictly the same, makes a number of payments i^* equalizing equations (1) and (3), from which we deduce the condition $f(i^*)/i^* = g_1 - je - (g_2 + h)n'$. From the properties of $f(i)$, we deduce that $f(i^*+1)/(i^*+1) < g_1 - je - (g_2 + h)n'$. We conclude that whatever e and n', if i^* represents the level of payments that makes indifferent the choice of the two technologies, the users making more than i^* payments use traditional payments and the users realizing less than i^* transactions use m-payments. We deduce the value of n' as $n' = i^*n/m$. We then express V_i according expression (3) and verify that when $\bar{u} > g_1$, the expression $V_i = \bar{u}i - g_1 i + jei + (g_2 + h)i^2 n/m$ which vanishes for $i = 0$ increases with i when $i > 0$. From $U_0 < 0$, we then deduce lemma 1 ■

Appendix 2: Proof of lemma 2

The critical value i^* such that the user i^* is indifferent to the two technologies in then obtained as a solution of $\bar{u}i - f(i) = \bar{u}i - g_1 i + jei + (g_2 + h)i^2 n/m$. Expressions (1) and (3) are then both increasing functions of i. As $f(0) > 0$, there is a conditional intersection between the two maps for positive values of i under conditional comparative slops of the two curves (see figure (1)). When the costs of the traditional system decrease sufficiently rapidly, only users making a few number of transactions adopt the new payment technology and the other case, m-payment "takes all" ■

Appendix 3: Proof of lemma 3

The profit of the operator given by equation (4) has four terms depending on e. The first is $i^{*2}n/2m$). When $\bar{u} > g_1$, i^* then $i^{*2}n/2m$ increase with e. The three other terms vary in the opposite sense of e: $-\phi_1 i^*$ varies as $-e$ and $-\phi_2 i^* n/m$ as $-e^2$. The last term is $c(e)$. Given our assumptions, this term goes to infinity when e comes close to 1. Under the condition $\bar{u} \geq g_1$, all terms are continuous. The consequence is that there exists a value of e strictly smaller than 1 maximizing expression (4) given expressions (1) and (3) ■

Appendix 4: Proof of Proposition 1

Given the term $C > 0$, the profit of the operator is not always strictly positive. If we consider the reservation profit as equal to 0, the operator can renounce to operate the m-payment system due to the amount of the fixed costs. It is the only case where the value of e^* is not strictly positive and the system not implemented. Once it is implemented, we deduce from lemmas 1 and 2 that the market is covered: agents making a few number of payments use m-payments and the other the traditional system ■

Appendix 5: Proof of lemma 6

The profit of the operator given by equation (9) has three terms depending on e. The first is $g_1 mn^*(e)$. Given lemma 3, this term is always defined when $e \in [0, 1]$. Given lemma 4, it increases with e on this same interval. The term $(n^*(e) - n_2)d$ is also continuous and increases with e. The last term $c(e)$ decreases, sharply when e is close to 1. Our assumptions on the variations of $c(e)$ then involve the existence of a maximum of π_b in e ■

Appendix 6: Proof of Proposition 2

Given the term $C > 0$, the profit of the bank network is not always strictly positive. This cost must clearly be compared with the advantage $(n^*(e) - n_2)d$ resulting from the contact with new potential clients. When the share of market of the network is not too large, d is not negligible and could compensate rapidly the fixed implementation costs C. It however remains not fully rational reasons for the system to fail: the time of adaptation of users to the new technology can for instance be longer than expected ■

appendix 7: Proof of lemma 8

Consider the ISP profit given by equation (12). The term $p \int_{n'}^{n} g_1(xm/n)dx$ is the only one to depend on p. Given the properties of (10) and (11), it is continuous on p. It vanishes when $p = 0$ for any finite value of e. It also vanishes when $p \to +\infty$ for each finite value of e and it is not decreasing with p remains positive near $p = 0$. We deduce that this term admits a maximum in p for all finite value of e. Consider now expression (12). The first term is continuous, increasing with e and the last is continuous and decreasing. When $e \to 1$, (12) tends to $-\infty$ whatever p and is still finite when e is smaller than 1. We deduce that the expression (12) has at least one maximum for a finite p and e ■

Appendix 8: Proof of lemma 10

The expression (15) is continuous in all variables, on the whole domain of definition for g_1, e, f and its variation range insuring a partial adoption of m-payment for g_2. The first term of the expression (15) is quadratic of g_1, reaches a maximum in g_1 and tends to $-\infty$ whatever the values of variables and parameters compatible with the use of m-payment when $g_1 \to \infty$. The first term is decreasing with g_2. The second term is first increasing then decreasing with g_2 on its definition interval. Others terms do not depend on g_2. As the two first terms increase linearly and the last two decrease sharply when e and f are close to 1, a maximum in e and f also exists. We deduce from these observations that there exists a vector (g_1, g_2, e, f) of optimal controls ■