Failures and successes: Notes on the development of electronic cash

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Abstract:

Between 1997 and 2001, two mid-sized communities in Canada hosted North America's most comprehensive experiment to introduce electronic cash and, in the process, replace physical cash for casual, low value payments. The technology used was Mondex and its implementation was supported by all the country's major banks. It was launched with an extensive publicity campaign to promote Mondex not only in the domestic but also in the global market, for which the Canadian implementation was to serve as a 'showcase.'

However, soon after the start of the first field test it became apparent that the new technology did not work smoothly. On the contrary, it created a host of controversies, in areas as varied as computer security, consumer privacy and monetary policy. In the following years, few of these controversies could be resolved and Mondex could not be established as a widely used payment mechanism. In 2001, the experiment was finally terminated.

Using the concepts developed in recent Science and Technology Studies (STS) this article analyses these controversies as resulting from the difficulties of fitting electronic cash, a new socio-technical system, into the complex setting of the existing payment system. Implementing a new technology is seen as a long process in which social and technological actors are required to adapt to one another. In the Mondex case, such adaptation did not happened sufficiently to stabilize the socio-technical network as a whole. However, in some limited areas mutual adaptation did occur and there the Mondex experiment produced some surprising successes. In this perspective, the story of Mondex not only offers lessons on why technologies fail, but also offers insight how short-term failures can contribute to long-term transformations. This suggests the need to rethink the dichotomy of success and failure.

Keywords: actor-network theory, smartcards, Mondex, electronic cash, security, privacy, private currencies, social transformations

Introduction

Since the early 1990s, most major banks have participated in the development of electronic cash. In the area of smartcard-based systems, most development has been done in Europe, where smartcards in general are more common and the penetration of debit and credit cards is, on average, weaker than in North America. In the mid 1990s, many European countries were implementing electronic cash systems on a national scale. With the development of the Internet and e-commerce, the demand for new payment systems grew considerably and the time of e-cash seemed to have come. The general excitement peaked when Nicholas Negroponte declared 1996 the "year of electronic cash" (Bernkopf 1996). Electronic cash was widely understood as a logical, even necessary, step in the broad transition towards what Manuel Castells (1996) calls "informational society", a society in which key activities center around the processing of electronic information.

Throughout the decade, very significant resources were invested in the development of technologies and their marketing to the public at large. By the late 1990s, the field of smartcard-based e-cash had consolidated into two major technological systems competing against each other. On the one side was the Belgium-developed Proton system backed by VISA; on the other the UK-based Mondex system which MasterCard had acquired in 1996.

Nevertheless, electronic cash has remained somewhat unreal. Even in countries where the technological infrastructure has been most advanced, it has hardly been used (Birch 1998). If money, or cash, is "what is commonly offered or received for the purchase or sale of goods, services or other things", as J.K. Galbraith (1995, p.3) famously defined it, then there has never been such thing as electronic cash. Early in the new decade, most of the European electronic cash systems are still in place but

continue to be underused (Van Hove 2000). They are, perhaps, better seen as placeholders for things to come, rather than fully developed systems in their own right. In North America, most trials have been terminated and electronic cash appears to be at least as distant a reality as it was a decade ago.

Is it, then, justified to say that smartcard-based electronic cash has been an inconsequential failure that – other than revealing a dead-end – had no lasting influence on the environment in which is was developed?

I think such a conclusion would be short-sighted in two regards. First, it would miss the valuable lessons that can be learned from the problems that electronic cash encountered. Second, perhaps more important, it would also miss the ways in which even short-term failures can contribute significantly to long-term development, although not necessarily in the way originally intended. By moving away from simplistic dichotomies of success vs. failure and by concentrating on the complex and often uneven process of transformation, we can develop a more realistic understanding of large scale socio-technical change.

As recent Science and Technology Studies (STS) suggest, the emergence of a new technological artifact is the result of the simultaneous stabilization of a new network of social and material relationships and processes which produce, sustain and integrate the new technological artifacts (see, for example, Bijker 1994; Callon & Law 1997; Latour 1993). To create a stable technology, diverse discursive and material, human and artefactual elements must be aligned. If such an alignment does not occur, the network which is necessary to sustain a technology does not stabilize and the technology itself cannot survive. It disappears (Latour 1996). However, if we look at the multiple adaptation processes that occurred in parallel during the Mondex experiment, we can see how some of these did succeed, and how these new actors are now becoming available for the

further development of the field. This allows us to understand how the failure of one system might prepare the ground for the success of its successor.

The following article consists of three parts. The first introduces relevant concepts and terms of the actor-network theory (ANT). ANT is best understood as a set of ideas developed both in theoretical and empirical studies which share the premise of the inseparability of the social and the technological. Central to ANT is the argument that agency is distributed among all actors, not only human, but also non-human actors. In recent years, this premise has informed various case studies in which information systems have been analyzed as actor-networks populated by humans and non-humans (for an overview, see Walsham 1997).The second part of this paper sketches the emergence and partial disintegration of the Mondex actor-network over almost a decade. The third part takes a closer look at the conflicts that characterized this process. These conflicts make visible the tension produced by trying to create a complex network involving multiple technological and social actors. The characteristics and roles of many these actors could not be defined so that they would contribute to the stabilization of the network as a whole. However, this closer look will reveal that some actors did accept their new roles willingly and successfully and thus laid the foundation for the future development of electronic cash.

The Worlds of Artifacts

Every (technological) artifact is dependent on a heterogeneous network that supports the specific ways in which this artifact is being used. A car without roads, gas stations, traffic rules, mechanics, spare parts and skilled drivers is of very limited use. The French sociologist of science and technology, Michel Callon, calls a network in which a technology is embedded “the world that this technical artifact structures and mobilizes”

(1993, p. 251). This world consists of everything that is needed for the technology to be useful so that people care to invest the necessary efforts to sustain the technology and its use. The world of a technology relates heterogeneous elements to one another for mutual stabilization. Drivers need gas stations as much as gas stations need roads. They give one another specific meaning and roles. Such a configuration is called an actor-network, since each of the elements plays an active part in determining the outcome of the network-building process (Latour 1997). An actor-network comprises, for example, existing technologies on which the new technology relies, social institutions which finance, support and maintain the new technology, legal frameworks that define rights and responsibilities, users who appreciate the potential of the technology, and many others elements.

A network ties together two sets of alliances: the social and the technical. The social alliances comprise people and institutions that are involved in the creation, distribution and maintenance of a technology. Focusing on this set leads to what Bruno Latour (1987) calls the “sociogram”: the domain of classical sociology, employing, for example, mapping techniques such as Network Analysis (Wellman 1983). Focusing on the technology leads to the “technogram” (Latour 1987), the description of technological dependencies and relationships. While these two sets of alliances are usually described separately, their dynamic and development can be understood only in their interrelation and interdependence. A change on one level will simultaneously change the other. Each alteration in one system of alliances is visible in the other. A modification in the technogram is often made to overcome a limitation in the sociogram and vice versa.

The human elements of the sociogram and the non-human elements of the technogram are linked together in a chain of translations. The concept of translation is a deliberate shift away from the related concept of interaction (Callon & Latour 1992). The difference is that interaction assumes two (or more) relatively stable entities that are linked together in a stimulus-

response relation: two players hitting a Ping-Pong ball back and forth, a child playing with a Gameboy. Translation, instead, focuses on the mutual (inter)definition of actors as they become linked together. One actor assigns another actor a new identity, a new role to play or new projects to carry out in order to reach its own goal, which, however, may change in the course of this translation process. Translation builds actor-worlds from otherwise unrelated entities. It attaches characteristics to them and establishes more or less stable relationships between them. Translation is a definition of roles, a distribution of roles and the delineation of a scenario. A chain of translations stabilizes when the actors are not only in sufficient accord with one another, but also dependent on the reproduction of the actor-network to maintain their identity. In this way, the actor-network becomes increasingly irreversible (Callon 1992). However, no translation can be taken for granted or happens without resistance (Callon 1986). The stronger the resistance of actors to being translated, the less stable the actor-network, and the lower its convergence, that is, the degree of accord reached in a series of translations.

Technologies and their networked worlds are intentionally created – under the influence of unintentional consequences and unanticipated events. It is a rare exception if the outcome of a complex network-building process conforms exactly to the original intention of the actors who initiated the process. All actors are implicated in the process of mutual shaping/adaptation, and often so are the goals of the entire project. In the field of IT management, this tendency of large technology projects to change their characteristics during the process of implementation has been called “technology drift” (Ciborra 1997; Ciborra & Hanseth 1998). What both ANT and concepts like drift point at is that the characteristics and functionality of a technology are not inherent in the artifact, but arise from the specific configuration in which it is placed. They are the result of complex negotiation processes, and if these negotiations do not reach some sort of agreement, the technology has no functionality at all.

The vocabulary of ANT, with its notion of heterogeneous actors giving shape to one another, provides the tools to examine the interplay of all actors that make up the development of a new technology and to locate where such mutual adaptation takes place and where it does not. This allows us to go beyond the simple dichotomy of success and failure to see how partial success and partial failures can occur at the same time.

The Mondex World

Assembling the actors of Mondex electronic cash began in 1990 when Tim Jones and Graham Higgins, two managers at the British National Westminster Bank (NWB), asked themselves a peculiar question: How would it be possible to replace physical coins and bills with an electronic system that would not only be cost effective to run, but also preserve the banks' central role in the circulation of money?

In 1992 NWB partnered with another British bank, Midland Bank, and created a new institutional actor, Mondex UK. At the same time, partnerships with various technology providers were established to develop a set of custom-made artifacts: smart cards, readers, valets, point of sale (POS) terminals, and the like. In December, 1993, these front-end elements of Mondex technology were officially presented. In the next year, Mondex UK began to franchise the technology to international partners, each receiving an exclusive license to implement Mondex technology in a national territory. Subsequently, Mondex Canada (May 1995) and Mondex USA (April 1997) were founded.

During this time, Mondex developed the technogram of a stand-alone electronic purse system: chip cards devoted exclusively to storing and distributing monetary value. Mondex formed a closed system within which value could circulate from one card to another, thus enabling direct,

unaccounted peer-to-peer transfers of value that would be immediately reusable.

The Mondex technogram was structured around four types of cards: First, the *originator card* which created and destroyed value virtually out of nothing, just like a government's mint creates money out of metal and paper (Stuber 1996). This type of card communicated only with the second type of card, the *bank card*. These cards were designed to hold very large amounts of money and communicate with all other card types. The third type, the *merchant card*, was to hold large amounts of value, but distributed it primarily back to bank cards. The fourth type of card, the *consumer card*, was to hold only moderate sums of money but to accept money from and transfer to other consumer cards (peer-to-peer transfers), to transfer it to merchant cards when making a purchase, and to communicate with bank cards when withdrawing from or depositing to a bank account.

For a transaction, both Mondex cards were to be inserted in a card-reading device. Since Mondex cards communicated only with other Mondex cards, they were be used to authenticate one another using non-disclosed cryptographic algorithms. Transfer request and receipt were digitally signed. In the course of the transfer, value was to be deducted from the payer's card balance and added to the payee's card balance. All transfers were final and not validated by a third party. The receipts on both sides left an audit trail to be used for conflict resolution. The customer card stored the last ten transactions with time, name and amount, while the merchant terminal stored the last three hundred transfers. For the merchant this was similar to a log file in a debit-card terminal. At the end of the day, or as frequently as convenient, the merchant could deposit the money from the card back to the bank.

To enable this technogram a sophisticated sociogram had to be created, linking already existing institutions to newly formed ones. Each national franchisee, itself a new actor, was to create the so-called *Originator*. In the case of Mondex Canada, this was a separate legal entity whose main activity was to control the first type of smart card, the one which creates and destroys Mondex value (Crawford 1996). Since this value was then sold to the banks which issued Mondex value to the customers, the second important activity of the Originator was to hold the float, which equaled the total amount of Mondex value in circulation. This Originator, which essentially replicated the national mint, was the subject of a significant debate centering around the question whether or not a national regulator should permit a private institution to issue money and under which conditions such a privilege should be granted. I will return to this question in the third section of the paper.

In July, 1995, Mondex UK began its first public trial in Swindon, UK, aiming at substantially enlarging the sociogram by enrolling new actors – merchants and consumers – into its world. In July, 1996, different aspects of the Mondex operation were organizationally separated. A new company, Mondex International, was founded to control central aspects of the Mondex development: brand name, franchising, technology development and security. The public test in North America was opened on February 13, 1997, in Guelph, Ont. Despite announcements of system up-grades, the technogram remained relatively unchanged in the years following the first public trial in Swindon.

With the move into the open environment, and the enrollment of new actors, problems began to become apparent. Many of the new actors did not easily accept the roles which were provided for them in the Mondex plans. Up to then, the translations had worked smoothly. A vast network had been assembled that could translate executive decisions into artifacts,

transforming an internal research project into an international consortium with franchisees around the world.

However, real users, shoppers and merchants, did not behave like the ones which populated the forecasts. By and large, there was little interest in becoming a card-carrying member of the Mondex world and the Swindon test failed to reach a critical mass of users. It was closed down in July, 1998. To overcome the apparent difficulties of enrolling users, in the major North American test, in Guelph, Ont., more resources were invested in developing the sociogram. The city council was mobilized into the network. The council became an important actor, not only by welcoming Mondex into the city, but also by installing Mondex readers in public transport vehicles, thus giving the technology an almost official status and a stronger public presence than it had ever reached in Swindon. Almost all downtown merchants were enrolled in the test from the beginning. At the same time, an extensive public relations campaign was unleashed to propagate the virtues of Mondex cards.

The success of this strategy was limited. Cash, debit and credit card users – customers as well as merchants – still showed little interest in taking on their new role as Mondex users. It remained unclear what added value this would have for them. As the test progressed, even those who had initially participated began to drop out of the Mondex world so carefully built up for them. The Guelph trial terminated in December, 1998. However, this was not yet the end of Mondex in Canada. In order to overcome the difficulty of enrolling social actors into the Mondex network, the technogram was changed, hoping to make the Mondex card more suitable for other applications and thereby attract more users.

Rather than continuing Mondex as an application on a dedicated card, a new type of card was introduced: the multi-application smartcard which could not only serve as an electronic purse, but also hold other applications

and raise the overall usefulness of the card. Mondex International developed a new operating system for smartcards called MAOS (Multi Application Operating System). This OS was intended to expand the Mondex world by allowing more actors to enter it, for example credit and debit card providers, and also retailers, through their loyalty schemes, each contributing to the stabilization of the overall network and Mondex electronic cash with it.

However, before new actors could be enrolled into the expanded network, the new multi-application OS had to become independent from Mondex. To raise the trustworthiness of the new actor, it was necessary to transform the Mondex-developed OS into a standard open even to Mondex competitors. To support this technological transition, a new social actor was spun off Mondex International in 1997: MAOSCO Ltd. This new actor was a not-for-profit company, an industry consortium which was to guarantee that the OS was open to everyone and not controlled by Mondex. [1] This actor's mandate was to foster the creation of as many compatible applications as possible. From the point of view of this new actor, Mondex was but one of many possible applications.

Back in Canada, in September, 1999, Mondex was relaunched in another community-wide test in Sherbrooke, QB. The technogram had changed considerably. The Mondex cards were now equipped with the new multi-application OS and more powerful processors. However, the sociogram had also changed, though not as intended. Under the pressure of the previous failure, not all major banks were willing to commit additional resources to the project and the second test was only supported by a minority of banks. If the hope was that the availability of the multi-application OS on the card would lead to the development of additional applications by third parties, then these hopes were not fulfilled. Given the complexities of smartcard

[1] MAOSCO is a consortium of companies interested in developing and promoting the MULTOS standard. For the listing of its current members, see http://www.multos.com

development, the remaining banks could not convince any merchants or other potential users to develop applications for the new platform. For the users, despite the substantive technological advances that the new Mondex cards represented, they were essentially indistinguishable from the old stand-alone cards. Not surprisingly, the reception was similarly lukewarm. In early 2001, the last public trial of Mondex in North America was terminated.

Tensions in the Mondex World

The development of the Mondex world was characterized by multiple tensions and internal contradictions that made it ultimately impossible to stabilize the world in its original form. The friction was created by actors which together were to comprise this world but were ill-adapted to one another. The actors diverged significantly in assessing their respective roles and characteristics. Reaching mutual interdefinition proved much more difficult than the banks promoting Mondex had anticipated.

The divergence over the characteristics and roles of key actors manifested itself in three major controversies. One focus of contention was the technological actor: the characteristics of the chip and its suitability to sustain the relatively unaccounted transfers that were to be a defining element of the Mondex world.[2] A second area of contention concerned the characteristics of the Originator and, by extension, of the Mondex value itself. What was the status of a private entity issuing currency in an environment that was shaped by a long tradition of government monopoly in this area? The third tension arose from the status of the consumer in the Mondex world. What were their risks, both in terms of loss of privacy and stability of the currency, and what were they getting in return for accepting these risks? The banks promoting Mondex argued that there were no risks

[2] Mondex was the only smartcard-based electronic cash system that allowed peer-to-peer transfers among consumers without third party clearing.

and that consumers would get convenience in return. However, consumers, for various reasons, were not pleased with the shape of the Mondex world and, by and large, refused to become part of it.

A closer examination of these three tensions shows that even though they manifested themselves in different areas, they were closely connected, each exacerbating the difficulties of stabilizing the Mondex world as a whole.

The Mondex card: strong or weak an actor?

The world of Mondex was built around a technological innovation: a smartcard-based electronic purse for general purpose money.[3] For Mondex International and Mondex Canada, the technology was a powerful actor but also a difficult partner. Powerful because it was the key element in a new payment system which promised extremely low transaction costs. Difficult because its characteristics and consequent reliability were a matter of considerable controversy. MXI, of course, characterized its technology as secure and trustworthy. However, a diverse group of computer scientists in the academic and private sectors argued that smartcards could never be strong enough to support the proposed currency scheme.

In 1996, for example, a team of academics at the Cambridge University Computer Laboratory had issued a cautionary note on the security potential for tamper-resistant smartcards. They wrote:

> We conclude that trusting tamper resistance is problematic; smartcards are broken routinely, and even a device that was described by a government signals agency as 'the most secure processor generally available' turns out to be vulnerable. Designers of secure systems should consider the consequences with care. (Anderson & Kuhn 1996)

[3] Electronic purses for special purpose value were being used since the mid 1980s, for example as telephone cards.

Based on this general assessment of the potential of tamper-resistant smartcards, the Mondex card was insecure, vulnerable to attacks and an insufficient basis for a full-scale alternative to cash. Anderson concluded "that 'floating systems' such as Mondex [are] probably not viable given that they embod[y] all the conditions necessary for their encryption key material to be retrieved – including multiple instances of the device, unhindered access to it and huge financial incentive" (quoted in Brown 1997). Anderson had never actually attempted to reverse engineer a Mondex card, because Mondex had never provided him with cards and the assurance not to prosecute him under the British Computer Misuse Act, which made it illegal to break into a computer system (Carroll 1996).

The diverging assessments of the characteristics of the Mondex card reflected more than self-serving strategies on each side. It reflected a more fundamental disagreement on how to achieve and evaluate computer security. The Mondex engineers based their assessment of the security on the quality of their own engineering and on the secrecy of their methods. The card was secured by three lines of defense, one based on hardware, the second based on software and the third on legal restrictions. The last one made any attempt to infringe upon the integrity of the card, successful or not, a criminal offense. It also sealed off the algorithms through intellectual property, copyright and non-disclosure agreements.

Such a reliance on secrecy and a trust in the superiority of their own methods is not untypical for large institutions (military, governmental or commercial) which traditionally hold what, following Harrold Innis (1950), one could call "monopolies of knowledge": bodies of knowledge available only to a select set of members. The financial industry has traditionally relied extensively on such monopolies. However, critics argued that in the area of smartcards such a monopoly no longer existed. Not only was this because smartcards had become commonplace by the end of the decade, but also because key pieces of the Mondex network – consumer and

merchants cards – were available for public inspection in settings that the financial industry could not control, such as independent laboratories as well equipped as those of the financial industry. This was a major difference from other elements of the payment network. ATMs, for example, could only be accessed in environments controlled, or at least monitored, by the banks.

The independent computer security community characterized this approach as "security through obscurity" and as harmful because it made independent security testing impossible, thus potentially leaving the vulnerabilities open to be exploited in secret, by criminals. The proposed counter-strategy was to make systems available for testing and to publish security weaknesses so that remedies could be found. Publicizing vulnerabilities was important so that the community as a whole could learn, rather than being obliged to make individually the same mistakes over and over again (Anderson 1994).

The assumption underlying such their calls for open review processes was that virtually all systems could, and eventually would, get compromised. And, according to Anderson, the problem was getting worse. Given the rate of proliferation of laboratories that had the necessary resources to carry out a hostile attack, the likelihood of one actually happening was increasing. He concluded, "tamper resistance at the chip level is getting further and further away" (quoted in Brown 1997).[4]

MXI, however, refused to open its technology, likely fearing that the publication of a theoretical security vulnerability would undermine public trust in the technology and the stability of the currency.

[4] In a similar vein, the Bank of International Settlements wrote: "It can be assumed that even the most sophisticated tamper-resistant features may eventually be breached, potentially permitting analysis and reproduction of the contents of the device" (CPSS 1996, p.22).

Anderson's argument, purely theoretical in the context of Mondex, was soon experimentally demonstrated. At the Eurocrypt conference in 1997, Ernst Bovenlander, from the Dutch consulting firm TNO, gave details of a successful attack on a Mondex-like chip. The attack exploited a common feature of tamper-resistant smartcards. In order to protect the memory content, a fuse on the card was blown after the card had been initialized. This blocked access to certain parts of the card's memory. The published attack consisted of bridging the link interrupted by the blown fuse with two microprobes. In this fashion, the link activated a test mode in which the card contents were simply dumped to the serial port and hence made accessible.[5]

Although it had been demonstrated that, under laboratory conditions, it was possible to crack open tamper-resistant smartcards, the question of the exact characteristics of the Mondex chip was still not settled. On the contrary, in September 1999, Mondex and the operating system MULTOS were awarded a security rating of Level E6, the highest possible rating achievable in ITSEC (Information Technology Security Evaluation Criteria). It was the first commercial product to be awarded a rating of this level. ITSEC, a set of criteria for evaluating computer security, were originally published in 1990. It represented a uniform standard supported by governments across Europe and Australia. The UK ITSEC scheme, which awarded the rating, was managed by the Communications-Electronics Security Group, the British government's National Technical Authority for the use of cryptography and information security in generally.

However, while the ITSEC process was popular with governments and likely to ensure the regulator's confidence in the technology, the program's authority was not undisputed. As Ross Anderson (1994) wrote:

> Even a cursory comparison with the ITSEC programme shows that this has a long way to go....It is clear that ITSEC (and TCSEC) will

[5] This type of attack is documented in detail in Kömmerling & Kuhn (1999).

> have to change radically … and we would recommend that the next versions of these standards take much more account of the environments in which the components are to be used, and especially the system and human factors.

Consequently, the characteristics of one of the central actors in the Mondex scheme, the chip holding the electronic purse, were still disputed after some 10 years of existence. Was this hardware and software able to effectively render hackers of all sorts ineffective? Was it secure or not? Did it provide a reliable basis for a currency system? The question could not be decided. Ultimately, as Sholom Rosen, then Vice President of emerging technologies at Citicorp's Citibank unit said, “nobody will know how secure a system is until large volumes of money are flowing through it” (quoted in Templin 1996).

One of the reasons why it was so difficult to assess the characteristics of the Mondex technology and its ability to play the intended role in the Mondex world was that the characteristics of the technology were not found to be exclusively determined by the artifact itself, but by the relationships between the artifact and other actors in the network. The technology was only one aspect in the overall security of the Mondex world, particularly when the stability of the system was evaluated in commercial terms. Credit cards, for example, are highly insecure and fraud is common in the system, which, nevertheless, is very stable because its so profitable that such losses can be absorbed easily. Security, then, as Bruce Schneier (2000) argued, is relative, it is about risk management. And risk management was also something the regulator was very concerned with when in the early 1990s, banks started to present serious plans to issue their own currencies.

What is Electronic Cash, legally speaking?

One of the reasons that made it impossible to settle the question if the Mondex technology was suitable for its purpose, or if it was a threat to the stability of the financial system, was that the status of the Mondex value as

money was quite unclear for a long time. By issuing Mondex value denominated in Canadian Dollars (or Pounds in the UK) Mondex value appeared to be equal to coins and bills. However, it was not. Rather than issued by the government as legal tender, Mondex was to be issued by a completely new institution, the Originator, whose legal status was not yet defined.

For 30 years or more, imaginative people within the financial industry had been dreaming about the “cashless society” (Anderson 1966) but their visions were not judged to be realistic enough to warrant any real attention from policy makers. In Canada this changed when the Royal Bank, the largest bank in Canada, presented plans to develop Mondex to the regulators in 1995. Suddenly, the cashless society seemed like a real possibility and was raising urgent questions about the status of cash.

Central banks feared that the technology might have the potential to deprive them of parts of their revenue (loss of seignorage) and change the financial landscape significantly by introducing an entirely new and as yet undefined institution: the Originator, issuer of a currency.

The first report, issued by the European Monetary Institute (EMI), the precursor of the European Central Bank, expressed the sense of urgency prevalent at the time.

> The possibility of proliferation of such cards is a real one. In the future, if electronic purses were used in a great number of retail outlets, they would become a direct competitor not only to cashless payment instruments already in existence, but also to notes and coins issued by central banks and national authorities. Given the potential of electronic purse schemes to attain widespread acceptance, central banks need to formulate their views on the issues raised by this payment instrument. Once such schemes have been introduced and are widely used, redressing undesired situations might be much more difficult. (EMI 1994)

Among the most far-reaching implications the various form of electronic money was thought to have was to disable entirely governmental control

over the flows of money (Wriston 1992). Libertarians giddily anticipated that electronic money would aid the denationalization of currency (May 1997), long advocated by the economist Friedrich Hayek (1976). Similarly dramatic views of how the new technologies of electronic money might affect governmental policies and, consequently, national sovereignty, focussed on issues such as the increase of money laundering and tax evasion (Davis 1997; Morris 1997; Kobrin 1997; Kyriakou 1997).

However, after an examination of the existing electronic cash schemes and their position within, rather than outside, the already highly regulated financial industry, the G10 report concluded:

> [E]merging electronic money products are currently focused on low-value, consumer transactions which may present less of a concern to law enforcement authorities because they are less likely to attract the attention of criminals. In many cases, market incentives and supervisory arrangements exist that are complementary to the interests of law enforcement authorities. (G10 1997, pp. 17-18)

Furthermore, there was no system operating at a scale sufficiently large to be attractive to organized crime. This, however, could change with the expansion of the schemes. Some reservation lingered for the security potential of schemes like Mondex that allow for unaccounted peer-to-peer transfers. “It is the potential unavailability of transaction information for security monitoring purposes, rather than the transferability feature itself, which may pose greater challenges to security” (CPSS 1996, p.2). For the time being, the central banks deemed the systemic risk created by electronic cash schemes to be manageable.

Similarly, the threat of tax evasion due to electronic cash was assessed to be minimal (Congressional Budget Office 1996). Early musings on the impact of (anonymous) electronic cash foresaw that “the payment of taxes might become more or less voluntary” (Barlow 1993, p.22), due to the government’s inability to monitor encrypted information exchanges and the

international character of the Internet (Kyriakou 1997). However, as Michael Froomkin (1997) pointed out:

> Most production and even more consumption involves transactions that are easily monitored for tax compliance. Income tax non-compliance requires payor as well as payee to participate in avoidance. Widespread deduction and reporting of tax at source makes this unlikely.

In a similar vein, the BIS committee (G10 1997, p.25) concluded that for card-based electronic money products the feasibility of an issuer implementing a system from an offshore country was impractical, because of the physical infrastructure needed to distribute and maintain cards and terminals, as well as gain acceptance by consumers and merchants.

The relative ease with which the actual issuers of electronic cash could be identified, and the fact that most of them were already subject to the extensive regulation governing the financial industry, also limited the potential of electronic cash to significantly disrupt the central banks' ability to conduct their monetary policies, contrary to what the libertarian fringe had hoped.

Over the course of their reviews, regulators and central banks relaxed their view of the potential of electronic cash to affect negatively the financial system and their own supervision. The research findings supported the already dominant notion that the best way to encourage innovation and efficiency was to let the private sector lead. This view of the benefit of private sector leadership and minimal regulatory supervision was well adjusted to the general tone of the policy frameworks on electronic commerce adopted at the same time throughout the G10 countries. Overwhelmingly, these also advocated that the private sector should lead and governments should pursue a "hands-off" approach in order not to stifle innovation that would lead to a more efficient, "unmediated" market place (see, for example, Clinton & Gore 1997).

The most important issue took the longest to resolve: who should be allowed to issue electronic cash? Initially the EU viewed that only regulated financial institutions should be allowed to issue electronic cash (EMI 1994). This view was somewhat relaxed into the recommendation that the issuer should be subject to, at least, "prudential supervision" (EMI 1998; European Central Bank 1998). In October 2000, this policy was formalized in the directive 2000/46/EC (EU 2000).

The American position, on the other hand, was to simply recommend that electronic cash does not qualify as a deposit, and hence was not insured by the Federal Deposit Insurance Corporation (FDIC) in case of failure of the issuer (FDIC 1996; 1997) Beyond that, the field was left open to all interested parties. In other words, anyone could issue electronic cash, but if the system were to fail, the risk would be with issuers and users alone.

Canada, as usual, wavered somewhat in between the Europeans and the Americans. When the Royal Bank announced its intention to implement Mondex on a large scale, the Bank of Canada was suddenly faced with the need to make a decision without having real policies in place. In 1996, it decreed that during the Guelph trial the Originator was to be operated as a joint-venture between the banks. Rather than setting policy, the central bank decided ad hoc to keep the Originator within the framework of financial institutions for now, while leaving future options open. For the financial institutions and the regulator, this was a good compromise allowing them to continue to work together to find a long-term definition of the Originator and the value it issued. It signaled that, while the details needed to be worked out, there was no reason to assume that the issuing of private currencies would be opposed by the government in principal.

This arrangement, however, did not satisfy consumers who, if they cared at all, were deeply suspicious of the Mondex world and demanded well-defined protection against a potential collapse.

Consumers Refuse to Play their Role

Cash is a consumer product and the role envisioned for consumers in the Mondex world was peculiar. They were supposed to behave as if nothing had changed, except that instead of paying cash they were to pay with Mondex. To drive home this idea of substitution of cash with its electronic equivalent, an extensive advertisement campaign was part of the field test. In this campaign, cash was portrayed as bulky and cumbersome where as Mondex was light and convenient.

For consumers, however, this made no sense. Cash was normal, well established and easy to use. However, they realized that Mondex would do different things to them than cash. Throughout the test, the banks were evasive over whether they would later charge for the use of Mondex. Cash was free and accepted virtually everywhere for small value purchases, whereas Mondex could only be accepted where there was a terminal, just like credit and debit. cards However, when lost, the Mondex value behaved like cash in a wallet, that is, all value was lost too. Other electronic payment technologies were much less risky in this regard.

Most problematic, however, was that Mondex did not helped consumers to do something that they could not do with cash or credit/debit cards. Faced with no clear incentive what to use the technology for, most consumers who had signed up for a card out of curiosity simply dropped out of the Mondex world. Some, however, began to question more critically their role within it. Two issues were of particular concerns: first the distribution of risk in case of system failure, and, second, the collection of personal information with transactional data.

Consumer advocates were quick to point out that the FDIC explicitly stated that in case of system failure, electronic cash was not insured and that consumers could lose the money stored on their purses. Noone could

accurately estimate the risk of system failure, but the ongoing dispute over the reliability of the Mondex technology did little to reassure the critics that possibility of such an event was negligible (Jones 1997). Confronted with consumer concerns about the reliability of the system, the banks were quick to say how secure the system was, but consistent with the security-through-obscurity approach, they offered little to placate critics. And the public was not willing to blindly trust banks, particularly since the banks were unwilling to give a guarantee to honor all value stored in Mondex cards no matter what. It seemed that not even the banks fully trusted the ability of the technology to keep fraud at bay. Only after being hard-pressed during the Guelph trial did the leading banks issue this guarantee, but not without limiting it to this one test only (Stalder 1998).

The second major issue that made consumers feel uneasy with their role in the Mondex world was also related to the opacity of the technology. Many suspected the card, like credit or debit cards, would leave extensive data trails, thus producing an even finer-grained picture of their purchasing habits ready for the banks to compile. However, no clear information on this issue could be gained, since the inner workings of the card remained locked away. Initially, Mondex was marketed as anonymous, but later the company was forced to admit that some data could be collected (Davies 1996, Jones 1997). The characteristics of the technology remained dubious and unstable, particularly since Mondex stressed when talking to central banks, which were concerned about the systemic risk of unaccounted transfers, that more detailed data could be collected should this become necessary (Beric 1997). Once again the flexibility of the technology made it impossible to assess it characteristics in isolation. Depending on the context, the chip could do different things – it could be privacy protective or privacy invasive.

Given these open and unpleasant questions, most people decided that cash was in no need of replacement and the Mondex world was not attractive for

them. This conclusion was made even easier by the fact that not entering the Mondex world produced no discernable disadvantages. It was ultimately the lack of consumer support that destabilized the Mondex networks and led to the termination of the project.

Conclusion

Real innovation is slow. Even something as innocuous as the computer mouse took more than decade from prototype (1968) to mass adoption (early 1980s). Many changes in cultural attitudes and system design were necessary for the mouse to become useful. Developing a new currency is an unusually comprehensive and complex project combining simultaneous technological innovation, revisions of the policy framework and quite significant shifts in behaviour of buyers and sellers, without which there is no need for a new currency. Not only is each of these areas in itself complex and full of diverging actors, but also all three areas must be adapted to one another. A new technology is only as good as it supports new patterns of behaviour. Even then, as the Napster case showed, if the technology-supported new transactions conflict strongly with the legislative framework, a popular technology still cannot stabilize. Furthermore, as a process subjected to strong network externalities – i.e. the more people use electronic cash, the more useful it becomes – it is difficult to start out small (Van Hove 1999). Finally, our money is based on nothing but trust, which itself is based on social experience. We use coins and bills not only because they are legal tender, but more importantly because we have the generations worth of experience that they are universally accepted. While there might be some theoretical possibilities of system breakdown (for example, mass insertion of counterfeit currency) we assume these to be remote since nothing of this sort has happened in our lifetime.

Given the scale of the transformations, the processes of creating a new currency should be measured in decades, rather than in years. But if we

look at the development of electronic cash only within a narrow time frame, say the last 10 years, Mondex appears symptomatic for the colossal failure of the entire project.: Most critics failed to be convinced by prowess of the technological actors. For them, Mondex was a “house of cards” (Jones 1997). The public deeply distrusted the new currency as potentially unstable, hence risky, and as an invasion of their privacy. Since nobody had any experience with it, nobody could really know if these theoretical possibilities had any practical reality or not.

Furthermore, squarely aimed as it was at cash replacement, a goal attractive only to banks, the technology did not in any way promote or even relate to new behavioural patterns emerging around electronic commerce. Since the new currency did seem to incorporate substantive risk but did not allow one to do anything that couldn’t be done with well established payment technologies, even the early adopters remained unimpressed and distrustful. Electronic cash, once a promise, was turned out to be a disappointment.

However, if we look at the last 10 years as the first phase in a much longer process of social transformation, the picture looks quite different. Perhaps most dramatic is the fact that governments, after some initial hesitation, have been quite willing to accept the issuance of private currencies. In historical terms, this represents a very substantial policy shift, considering that every government has fought long and hard to gain the monopoly and that the national currency has been one of the central symbols of national sovereignty (Davies 1994). In the early 1990s, only the libertarian fringe was talking about private currencies. They saw it as a means to undermine the nation state. A decade later, even central bankers had warmed up to the idea. This change in the regulatory environment that brought private currencies from the fringe into the (policy) main stream is – for better or worse – a very significant contribution of the early electronic cash technologies to the long-term development of the field. The regulator

signaled that it would accept a new, reduced role in the emerging world of private currencies. Virtually unnoticed by the public, in the late 1990s the nation states allowed their monopoly to issue currency to be broken.

But this was not the only substantive transformation resulting from the Mondex development. Some of the technological actors stabilized as well. Since early 2001, MULTOS has been used by MasterCard as the platform of choice in its migration of credit cards from magnetic stripe to smartcards, a transition well under way in the UK and Australia. In other words, for Mondex's majority owner, MasterCard, the Mondex investment has already produced a reliable actor well adapted to advance their established business strategy. So far, though, the success of MULTOS has not contributed to a stabilization of Mondex. Even on the new smartcard-based credit cards, it is nowhere to be found.

But even so, it is still to early to close the books on Mondex as a failed technology. It is currently being redesigned. Cash replacement is no longer the goal. Clearly, a second phase of the development of electronic cash has begun. Now, the integration of other smartcard-based applications, such a pay-per-view TV and mobile phones, is being pursued as a way to connect electronic cash to the wider world.

Innovations on a societal scale tend to be extensive in terms of the time frame in which they take place and in terms of the heterogeneity of actors that need to the aligned to one another for the new to stabilize. In such large spaces, partial "successes" and partial "failures" often occur simultaneously. These partial successes transform some actors which then can be assembled later into new and stable configurations. Rarely, if ever, are all actors transformed at the same time. The failed often contains the seeds of the new, and the successful is often build on the basis of the failed. If we look only at successful technologies and their social implications, development seems rapid, discontinuous and deterministic.

However, if we include all technologies into our examination of social transformations, we see how slow, continuous and open social change really is.

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