Credit and Identity Theft*

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Abstract

The quintessential crime of the information age is identity theft, the malicious use of personal identifying data. In this paper we model "identity" and its use in credit transactions. Various types of identity theft occur in equilibrium, including "new account fraud," "existing account fraud," and "friendly fraud." The equilibrium incidence of identity theft represents a tradeoff between a desire to avoid costly or invasive monitoring of individuals on the one hand, and the need to control transactions fraud on the other. Our results suggest that technological advances will not eliminate this tradeoff.

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1 Introduction

The quintessential crime of the information age is identity theft, the malicious use of personal identifying data. Although recent news reports have focused on a few spectacular incidents where hackers have gained access to large amounts of personal data, the more pervasive problem is with commonplace thefts of credit cards or social security numbers. A recent survey by the Federal Trade Commission (2003) found that 12 percent of Americans had been victims of some form of identity theft during the preceding five years.

The problem poses a dilemma for policymakers. While instances of identity theft provoke popular outrage, there has been a reluctance to impose stringent regulation on the data-gathering activities of banks, credit card companies, credit bureaus and other assimilators of personal data. This reluctance stems, in part, from the notion that the collection of personal data is essential to the process of allocating credit.

So far, economic theory has contributed little to the policy debate. This problem is a natural application for the branch of monetary theory which focuses on payment and credit. But this literature has generally emphasized the desirable aspects of the collection of personal data. As the cost of collecting and manipulating data falls, so the argument goes, credit constraints will be relaxed, lenders will be better able to assess the creditworthiness of individual borrowers, and welfare should rise.[1]

Clearly this simple information-gathering account does not encompass identity theft. This does not mean, however, that monetary theory has nothing to say on this issue: as evidence to the contrary, we develop a model of money and payments, in which identity theft is an equilibrium phenomenon. While the model is abstract, it is nonetheless capable of highlighting some of the relevant private and social costs associated with identity theft. As such, it may also provide some sorely needed guidance for policy debates in this area.

In Section 2, we analyze the issue of identity theft using a search model. Section 3 presents an extension to this model to analyze the relationship between credit and money, as well as an overlapping generations modification which incorporates an additional form of fraud. Our methodology for investigating identity theft is a general one, however, whose application is not necessarily tied to any particular approach.

[1] This argument is often associated with Kocherlakota (1998). Related papers include Townsend (1989), Taub (1994), Kocherlakota and Wallace (1998), Aiyagari and Williamson (2000), Camera and Li (2003), and Kahn, McAndrews, and Roberds (2005).

2 Model

The basic model is entirely focused on "fraud risk" (including various types of identity theft) of transactions as opposed to "credit risk." By *fraud risk*, we mean the risk that a debt cannot be enforced because the identity of the person incurring the debt cannot be ascertained. This is distinct from *credit risk*, which is the risk that an identified debtor cannot or will not discharge his debt. In the models we consider, people are either fundamentally creditworthy or not; no agent is ever uncertain about the amount of debt that he could possibly repay, and once a debtor is identified, he can always be forced to repay.

A key construct in our account is the notion of "identity." Economists are used to thinking of individuals' identities as including their transaction histories, i.e., lists of goods and services that they have bought and sold. Knowledge of such histories is insufficient for actual transactions using credit, however, because a credit-based payment system must have some way of correlating histories with particular transactors.[2] For a consumer to buy a bag of groceries on credit, it is not enough that the consumer have a good credit history—there must also be a way of matching the consumer at the checkout counter to the record of that consumer's actions. In other words, a viable payment system must be able to adequately contain fraud risk.

This last assertion is backed by ample empirical evidence. Credit card issuers in the U.S., for example, are willing to tolerate relatively high levels of credit risk (by value, around 4 percent of credit card transactions are never paid off) but at the same time virtually no fraud risk (reported to be only 5 basis points as a proportion of the value of total transactions). When credit card fraud rates rose to almost 16 basis points (by value) in the early 1990s, many costly investments were undertaken to bring this "high" incidence of fraud under control.[3] Evidently, an ability to associate debts

[2] We classify any transaction where the purchaser's obligation is not immediately and unconditionally discharged as a credit transaction. Thus, for our purposes "credit transactions" include purchases by check or debit card.

[3] Figures are from the Nilson Report (2005). Other types of payment systems display similar rates of transactions fraud. Industry estimates for check fraud amount to roughly 1 basis point by value (GreenSheet, 2004). The annual production of counterfeit U.S. currency is similarly on the order of 3 basis points as a proportion of currency outstanding (McIntyre, 2000); Judson and Porter (2003) estimate the proportion of circulating counterfeit currency at less than one basis point. While such figures do not provide precise estimates of the incidence of fraud, they support the qualitative conclusion that the prevalence of fraud risk is quite low in all successful payment systems.

with debtors is fundamental to credit-based payment.

To analyze fraud risk, we represent an individual's identity as simply a list of attributes. Note that this list is distinct from an individual's transactions history.

Definition 1 *An **identity** is a vector, a string of ones and zeros that describe the characteristics of an individual. Each individual's identity is unique.*

The dimension of this vector is large enough so that we will consider it to be infinite. This notion of identity is vacuous without a monitoring technology that allows for distinguishing an individual from an impersonator. We will consider some candidate technologies below. In the absence of such technologies there is no possibility of credit-based exchange, as there is no way to ensure reciprocity, and trade generally collapses.

2.1 Details of the model

Time is discrete.[4] All agents are risk neutral, infinitely lived, and have a common discount factor δ'. There are N agents and it will be convenient to think of each agent as identified with a distinct "location," where the list of agents' locations is public information.[5] A unique, indivisible, nonstorable consumption good can be produced and supplied at each location. In every period, one agent randomly wakes up "hungry" for the consumption good of another agent, randomly selected. When hungry, an agent desires exactly one unit of the particular supplier's good, which provides a utility of u. If not hungry, or if faced with a different supplier's good, the agent receives no utility.

Hungry agents then journey to the location of their preferred supplier. The identity of the hungry agent is never automatically revealed. It costs the supplier s utils to make a unit of the good. Each agent's supply cost is

Indeed it is difficult to find any example of a payment system that has flourished in the presence of significant fraud risk The 2002 failure of NextBank, widely attributed to its inability to contain online credit card fraud, attests to the ongoing relevance of containing this form of payments risk.

[4] Our initial search-theoretic model is closely related to that of Kahn, McAndrews, and Roberds (2005).

[5] I.e., the location at which an agent sells a good is always known, meaning that an individual's history as a seller is always known. The difficulty in organizing exchange will come in linking production histories to attempts at consumption. We are thus effectively excluding the possibility of seller-side fraud (e.g., selling nonexistent goods on e-bay). Incorporating seller-side fraud would be a natural extension of our model.

a draw from the distribution F with support $[\underline{s}, \overline{s}]$ and continuous density f, where $0 \leq \underline{s} < u < \overline{s}$. The agent's type (his value of s) is not directly observable by anyone other than the agent.

We confine our attention to limiting results, where $N \to \infty, N\delta' \to \delta > 0$, and the empirical distribution of all other individuals' draws of s is given by F.[6]

Because there is no double coincidence of wants in this structure, there is no possibility of barter. However, we will attribute two powers to a central authority which will make trade feasible in some circumstances.

We assume that if an agent does not supply goods, the refusal to supply is observable by the center, who can then make a public announcement of the fact. The center also has the power to punish an individual for deviations, *provided it can identify the individual.* We model this by assuming that the center has the resources to punish exactly one person up to a maximum disutility of X.[7]

At the beginning of the game, agents learn their value of s and then have the opportunity to form a club. We assume the simplest natural structure for club formation: The individuals simultaneously announce whether or not they are willing to join the club. The announcement is a "binding" commitment (subject to the limits of the enforcement technology); they are not allowed to change their minds upon learning, for example, the number of other members. Individuals who refuse to join a club cannot be punished by the center.[8] When a club is formed, we will let the fraction π denote the size of the membership. We will take X to be as high as necessary for enforcement of activities by members of the club; this will allow us clearly to distinguish between credit risk, which will be eliminated, and fraud risk, which will not.

[6] Restricting ourselves to limiting results is analytically convenient as we avoid the need to calculate sampling distributions. This restriction also brings the analysis closer to Kocherlakota's (1998) concept of credit as "memory." Essentially this requires that all matches be between agents without any previous contact.

[7] This formulation allows several advantages: Effectively the center cannot engage in collective punishment to enforce behavior on an unidentified individual. Since we are not considering collusive deviations where two individuals jointly engage in fraud, we do not need to consider situations in which the center would need to punish, for example, exactly two individuals.

[8] In general this is not an efficient mechanism; if we were to concentrate the distribution of s onto two values the announcements would be equivalent to direct revelation mechanisms.

2.2 Baselines: No identification and costless identification

If consumers cannot be identified, all allocations must allow them to consume with equal likelihood. In general then, each agent will have the same consumption whether or not he supplies. For example if a fraction π of agents supply to all comers and the rest do not supply at all, then the expected payoff to an agent who supplies is

$$U(s) = \frac{\pi u - s}{\delta} \tag{1}$$

and the expected payoff to an agent who does not supply is $\frac{\pi}{\delta}u$. Clearly then unless $s = 0$, an agent will not willingly supply.[9]

If workers' identities can be distinguished when they come to consume, it may be possible to arrange an allocation in which some agents form a "credit club"—members (and only members) consume whenever they are hungry for the goods of other members. Let π be the fraction of members in the total population. In such an arrangement the utility of a member is

$$V(s) = \frac{\pi}{\delta}(u - s) \tag{2}$$

Sustainability of a credit club depends on the threats available for maintaining the club. Given the membership, at any point where a member is expected to supply, the member will compare the expected value of remaining in the club, less the current cost of supply, with the penalty for failure to honor the agreement. Given individuals' identities, certainly the minimum penalty would be expulsion from the club. Thus the agent is certainly willing to honor his commitments if

$$V(s) - s \geq 0 \tag{3}$$

If greater penalties can be extracted, then the constraint is relaxed. If the center can impose a penalty of X for breach of contract,[10] then the condition becomes

$$V(s) - s \geq -X. \tag{4}$$

Ex ante, an individual is willing to join the club if $V(s)$ is non-negative. Since the sign of $V(s)$ is the same as the sign of $(u - s)$, independent of

[9] For finite N, it can be shown that for some parameterizations, equilibria exist where exchange is sustained by gift-giving, or a "social norm"; see Araujo (2004). Here we rule out such equilibria by taking N to be arbitrarily large.

[10] Given we are allowing the center only one punishment, it is also necessary that a public announcement of the breach be made, to ensure that the agent in breach does not continue to consume after the breach.

the realization of π, we know that it is both constrained efficient[11] and individually rational for all agents with costs less than or equal to u to join the credit club. So, provided that the penalties available are sufficient to deter the marginal member from failing to honor the contract—that is, provided (4) holds for all $s \leq u$—the constrained efficient outcome can be sustained by club membership. This condition reduces to the simple requirement that

$$X \geq u. \tag{5}$$

We conclude

Proposition 2 *Under (5), a club with members* $[\underline{s}, u]$ *is sustainable under full information.*

For this club $\pi = F(u)$.

In other words, the ability to identify customers perfectly as members or non-members of the club leads to an efficient level of membership; the inability to identify customers generally leads to autarky.[12]

2.3 Identity verification

Suppose it is possible to identify agents, but imperfectly, and at a cost. Then it still may be feasible to form a credit club. If a hungry consumer's identity can be verified to a sufficient degree of accuracy, the supplier will be willing to provide the consumer with his endowment good. If verification is not perfect, then sometimes non-members will prefer to impersonate members. A successful impersonator gains access to his desired consumption good, without the obligation to provide a good in return at some future date. Thus these non-members are free riders in the sense of Kahn and Silva (1993).

The timing of events within a period is displayed in Table 1.

[11] It is "constrained" efficient because an arrangement in which low cost individuals provided consumption to everyone (member or not), with appropriate transfers, would Pareto dominate.

[12] Proposition 2 establishes that information on club members' actions (their initial agreement to join the club, and their subsequent decisions to supply goods when called upon) can support intertemporal exchange. Along this dimension club members resemble the agents known as "bankers" in Cavalcanti and Wallace (1999) and related papers, i.e., agents whose actions are always public information. There are some noteworthy distinctions between the club members described above and Cavalacanti-Wallace bankers, however. Among these are: (1) club membership is voluntary; (2) club members agree to make themselves subject to a nonpecuniary penalty if they default; and (3) club members may not issue circulating liabilities (see footnote 16, page 12).

Table 1: Events within a period

a. Hungry agent and supplier are randomly chosen

b. Hungry agent journeys to supplier's location

c. Hungry agent's identity is verified

d. If verification successful, trade occurs

2.3.1 Verification technology and impersonation

The identity verification technology we consider is an examination of samples (substrings) of an individual's identity, at an effort cost to the monitor of k (utils) per bit sampled.[13] The monitor queries the agent for a sample of n distinct bits of his identity at random, and these are provided by the agent. If the agent is who he says he is, the agent can provide this information at no cost, and will always pass this test with probability one; there is no Type I error. If, on the other hand, the agent is not who he says he is, the agent gives the correct answer with probability z for each bit sampled. The verification of each bit of identity requested is independent,[14] so that the likelihood of an impersonator giving the correct answer to a query of length

[13] Below we treat k as a fixed parameter. If individuals place an innate value on privacy (incur disutility from revelation of their identities), k might instead be a choice variable. Kahn, McAndrews, and Roberds (2000, 2005) show the value of privacy in environments where enforcement is imperfect.

[14] Thus, we assume that each time an individual's identity is checked, a different sample is drawn. In other words, we build the simplest natural model of the process of identity verification, using statistical decision theory that is familiar to economists. In fact, the process of determining an individual's identity is much richer and more complicated: when trying to verify an identity, an interrogator does not always find a new and arbitrary aspect of the individual to query. Instead the typical interrogator reverts to the tried and true "passphrases": mother's maiden name, home address, social security number, etc. This is because in practice some dimensions of identity are less costly to verify than others. Real-world questioners are constantly confronted with the tradeoff between inexpensive, but easily stolen information, and information that is more costly but also more secure. The legal literature has been concerned with the issue of whether collectors of information get this tradeoff right. By allowing the different dimensions of individual identity to have different collection costs, we could greatly enrich our model, at the cost of an enormous loss of tractability.

n is

$$z^n. \tag{6}$$

A would-be impersonator suffers no penalty when his fraud is detected. For simplicity, we assume n is a continuous variable.

Suppose all agents attempt to consume when hungry. Suppliers will then sample until the marginal cost of verification k equals its marginal private expected benefit, i.e., a supplier of type s will seek to minimize the combined cost of monitoring and providing goods to impersonators

$$kn + s(1-\pi)z^n \tag{7}$$

where π again represents the fraction of club members in the population. The first-order condition for n is

$$k \geq s(1-\pi)\ln(z^{-1})z^n \tag{8}$$

with equality for positive n. The solution to (8) is a continuous function $n(s,\pi)$; it is straightforward to show that for small k, n increases with increasing s but falls with increasing π, k, or z. That is, the intensity of monitoring increases as the cost of supplying a good increases, the proportion of membership falls, the cost of monitoring falls, or impersonation becomes more probable.

In this economy the natural way to describe a credit club with verification is as follows: Each agent chooses whether to join the credit club. Those that do are obliged to supply goods to all who come and pass their identification test. Member agents who are hungry will therefore receive goods from any other member agent. Agents who are not members only receive goods from members if they manage to get through the screening process. Agents who are not members do not supply.

All agents in the club have an incentive to monitor. Since each agent individually chooses an identity sample length, we call this arrangement *independent verification.*

2.3.2 Equilibrium

An *equilibrium under independent verification* can be characterized by a identity sample length function $n^*(s,\pi^*)$, a measure of club members $\pi^* \in (0,1)$, a cutoff level of supply cost $s^* \in (\underline{s}, u]$, and a function $V^*(s)$, such that (a) n^* satisfies condition (8) for $s \in (\underline{s}, s^*]$, (b) $\pi^* = F(s^*)$, and (c) the function $V^*(s)$ is specified by

$$V^*(s) = \delta^{-1}\left[(u-s)\pi^* - (1-\pi^*)z^{n^*(s,\pi^*)}s - kn^*(s,\pi^*)\right] \tag{9}$$

and for all $s \in [\underline{s}, s^*]$ must satisfy

$$V^*(s) \geq \frac{u\pi^*}{\delta} \int_{\underline{s}}^{s*} z^{n^*(s,\pi^*)} dF(s). \tag{10}$$

with equality for $s = s^*$, and

$$V^*(s) \geq s - X \tag{11}$$

The equilibrium continuation value of being a member with supply cost s is given by $V^*(s)$; by the maximum principle V^* is decreasing in s. Condition (10) requires that club members prefer membership to impersonation (and therefore to autarky, since attempted impersonation is costless), while condition (11) guarantees that members prefer to remain members. The latter requirement is automatically satisfied by making X sufficiently large. A penalty $X > u$ guarantees that no individual prefers to join the club only to be kicked out when he is first required to supply.

Proposition 3 *If (5) holds with strict inequality, then there exists an equilibrium under independent verification with $s^* \in (s, u)$ for $k > 0$ sufficiently small.*

Proof. Take $s \in (\underline{s}, u)$ and $\pi \in [F(\underline{s}), F(u)]$. Let $k \to 0$. Then from condition (8), it can be shown that $n^*(s, \pi) \to \infty$ and $kn^* \to 0$ for all $s \in [\underline{s}, s]$. Since the convergence is slowest for $s = \underline{s}$, it is also uniform. Likewise, the integral

$$\int_{\underline{s}}^{s} z^{n^*(\xi,\pi)} dF(\xi) \tag{12}$$

is bounded above by

$$z^{n^*(\underline{s},\pi)} F(s) \tag{13}$$

which tends to zero as $k \to 0$ and $n^*(\underline{s}, \pi) \to \infty$.

(a) Condition (10): Define the function $\widetilde{V}(s, \pi)$ as

$$\delta \widetilde{V}(s,\pi) \;=\; (u-s)\,\pi - (1-\pi)\,z^{n^*(s,\pi)} s - kn^*(s,\pi) - u\pi \int_{\underline{s}}^{s} z^{n^*(\xi,\pi)} dF(\xi) \tag{14}$$

It then follows that as we drive $k \to 0$, $\widetilde{V}(s, \pi) \to (u - s)F(s)$, which is positive for $s \in (\underline{s}, u)$. But for $k > 0$ it must also be the case that $\widetilde{V}(u, \pi) < 0$. Hence by continuity there must exist for each $\pi \in [F(\underline{s}), F(u)]$ an $\widetilde{s} \in (s, u)$ such that $\widetilde{V}(\widetilde{s}; \pi) = 0$.

Now define the mapping $T : [F(\underline{s}), F(u)] \to [F(\underline{s}), F(u)]$ as $F(\widetilde{s})$. In addition we have

$$\delta \widetilde{V}_s(\widetilde{s}; \pi) = -\pi - z^{n^*(s,\pi)}[(1-\pi) - u\pi f(s)] \tag{15}$$

which is negative for small k; hence from the implicit function theorem, $T(\pi)$ is unique and continuous. From Brouwer's theorem, there then exists a fixed point π^* of T and hence an $s^* \in [\underline{s}, u]$ s.t. (10) holds with equality for $s = s^*$. It is straightfoward to show that s^* must be interior.

(b) Condition (11): From part (a) LHS (11) is non-negative for small k. Also, RHS (11) is strictly negative under the hypothesis. Hence (11) holds for small k. ■

Since verification entails costs, an equilibrium cannot in general replicate the constrained-efficient allocation under costless identification. In other words, since $s^* < u$ there will generally be some agents with $s < u$ who do not engage in transactions since it would be too costly to verify potential buyers. It is straightforward to show that there are equilibrium allocations under independent verification that approach the constrained efficient allocation as $k \to 0$, however.

2.4 Credit card model

Credit transactions in the economy above do not closely resemble actual transactions since verification of a buyer's identity is necessary for each purchase. Relative to a more "realistic" case this may be inefficient since buyers are verified too often. Also since buyers are verified each period and verification is costly, the intensity of verification (length of the identity sample) may be undesirably short in some cases. A more desirable world would be one where a thorough verification is done on joining the club, after which the outcome of the verification is signaled to subsequent suppliers that the buyer interacts with. We now describe one technology that allows for sharing of information on buyers' identities.[15]

Suppose, then, that agents have a chance to join the club at time zero. The club center has the technology to observe the outcome of a verification. The club can also issue to the member a *credit card*. The credit card consists of a string of bits created by the club at a cost of ℓ_i utils per bit created. The costs of the initial verification are shared pro-rata by all agents in the

[15] As "digital" entities, club members' identity samples qualify as "information goods" in the sense of Varian (1998). In contrast to the information goods considered by Varian, knowledge about identities cannot be shared at zero marginal cost in our setup.

club. Initially we will assume that with the availability of credit cards, there are no other opportunities for agents to obtain credit.[16]

When the member is hungry, he provides the seller with his credit card. The credit card cannot be read by the seller but the seller forwards the credit card to the club center who verifies it at a cost of ℓ_c utils per bit "charged" to the seller. The seller can, if he wishes, engage in additional verification.[17]

The potential advantage of the credit card technology is that the per-bit cost of credit card creation and verification is less than the per-bit cost of verifying an individual's identity, i.e.,

$$\ell_i, \ell_c < k \tag{16}$$

In other words, it is easier to either create or verify invented information than to discover it anew.

Note that in this environment, both cards and identities may be imitated. If the initial identity sample is of length n and the card of length m the probability of a successful identity or card imitation is z^x, where $x = n$ or m, respectively. In contrast to the previous case, these lengths are not set by individual suppliers, but are common to all members of the club.

2.4.1 A special case

Begin by considering the case of "uncounterfeitable" credit cards, i.e., cards for which $\ell_i = \ell_c = 0$. In this case, the credit cards can be made infinitely long and thus cannot be successfully cloned. People can still be impersonated, however, by a successful imitation of their identity sample. For the moment exclude the possibility of verification outside of the club.

[16] We use the term "credit card" as this is probably the most familiar credit-based payment system. With appropriate modification, this construct could also be thought of as a stylized representation of a checking account, a debit card, or an account with an online payment provider such as PayPal.

The structure of the model does not allow credit cards to function as privately issued banknotes. This restriction accords with historically prevalent laws and regulations in most countries that forbid the private issue of banknotes or their equivalent.

Section 3.1 below explores the potential benefits of allowing for circulating instruments, for the special case where such instruments cannot be counterfeited, and where there is a single issuer. We defer a more general examination of the desirability of circulating versus non-circulating payment instruments to future research.

[17] It is also conceivable that a seller might refuse to verify a card and instead opt for independent verification. Below it is shown that this will not occur under suitable restrictions. However, if we opted for a greater degree of heterogeneity in the frequency of purchases at various stores, arrangements with a variety of credit card clubs would become possible–mirroring the history of the rise in charge accounts and their replacement by credit cards; see Evans and Schmalensee (1999).

For this special case, a *credit card club* is characterized by an initial identity sample of length n^c, a measure of club size $\pi^c \in (0,1)$, a supply cost $s^c \in (\underline{s}, u)$, where s^c represents the highest supply cost for which an agent will join the club and $\pi^c = F(s^c)$, and a function $V^c(s)$ which gives the continuation value of being in the club, i.e.,

$$V^c(s) = \delta^{-1}[(u-s)\,\pi^c - (1-\pi^c)z^{n^c}s] \tag{17}$$

Participation in the club requires that this value, minus the cost of the initial verification, be more tempting than impersonation (which is in turn more tempting than autarky), i.e., for $s \in (\underline{s}, s^c)$ we must have

$$V^c(s) - \frac{kn^c}{\pi^c} \geq \frac{\pi^c u z^{n^c}}{\delta} \tag{18}$$

with equality for $s = s^c$. In addition, members of a club must have an incentive to remain members, i.e., for $s \in (\underline{s}, s^c)$ it must be the case that

$$V^c(s) \geq s - X \tag{19}$$

An *equilibrium for the credit card club* (n^c, π^c, s^c, V^c) exists if (18) and (19) are simultaneously satisfied.

Proposition 4 *If $\ell_i = \ell_c = 0$ and (5) holds with strict inequality, then for any $s \in (\underline{s}, u)$, there exists an equilibrium with a credit card club with $s^c \in (s, u)$ for $k > 0$ sufficiently small.*

Proof. Drive k to zero and simultaneously drive n^c to infinity, where the former decreases faster than the latter increases, so that $kn^c \to 0$.

(a) Condition (18): Define

$$\widetilde{W}(s) = \delta^{-1}\left[(u-s)\,F(s) - (1-F(s))\,z^{n^c(s)}s - uz^{n^c}F(s)\right] - \frac{kn^c}{F(s^c)} \tag{20}$$

As $k \to 0$, $\widetilde{W}(s) \to \delta^{-1}F(s)\,[u-s] > 0$ for $s \leq u$, but $\widetilde{W}(u) < 0$ for positive k. By continuity there exists some $s^c \in (s, u)$ such that $\widetilde{W}(s^c) = 0$ and (19) is satisfied with equality for some s^c in $(\underline{s}, u)$ and strict inequality for $s \in (\underline{s}, s^c)$.

(b) Condition (19): For small $k > 0$, LHS (18) is non-negative, while RHS (19) is negative under the hypothesis. ■

Compared with independent verification, the credit card arrangement trades off a potentially higher initial monitoring cost versus a smaller per-transaction cost. As people become more patient, the credit card arrangement dominates. We can formalize the relationship between the equilibrium outcomes of the two arrangements as follows.

Proposition 5 *Suppose $\ell_i = \ell_c = 0$ and (5) holds strictly. Let (n^*, π^*, s^*, V^*) be an equilibrium under independent verification. Then for $\delta > 0$ sufficiently small (a) there exists an equilibrium with a credit card club (n^c, π^c, s^c, V^c) for some $s^c \in (s^*, u)$, and (b) for $k > 0$ sufficiently small all agents in the credit card club are better off than under independent verification.*

Proof. Part (a). Initially we show the existence of a credit card club where $s^c = s^*$ and $\pi^c = F(s^*)$. (Recall that $s^* < u$.) Initially fix $s^c \in (s^*, u)$ and $n^c \geq n^*(s^*)$.

(a1) Condition (18): Evidently this condition holds for sufficiently small δ; if this inequality is strict for $s = s^c$, increase n^c until the condition holds with equality.

(a2) Condition (19): For $n^c \geq n^*(s^*)$, LHS (19) $\geq$ LHS (11) ≥ 0, where the latter inequality must hold if there is an equilibrium under independent verification. Hence if RHS (19) < 0 as it must be when (5) holds, (19) must also hold.

Part (b). Follows from comparison of LHS (10) to LHS (18). The credit card arangement strictly dominates if $n^* > 0$, for k and δ sufficiently small. ■

Intuitively, Proposition 5 says the following about the potential benefits of a credit card arrangement, provided people are patient enough. First, the low-cost suppliers will agree to monitor at least as much as the highest-cost supplier under independent verification (i.e., at least as much as s^*): in other words, there is no incentive for any member of the club to engage in additional verification of buyers beyond what the club provides. Club members agree to monitor intensively because they know that once this initial monitoring is done, the incidence of fraud will be low enough to make production worthwhile. Second, this arrangement also benefits the high-cost suppliers, since more frauds are excluded under the credit card arrangement. Third, employing a credit card club lowers the cost of transactions, so that the set of people willing to supply goods expands.

2.4.2 Counterfeitable cards

We now consider the slightly more realistic case where cards can be counterfeited. A would-be fraud who fails at impersonation can attempt to copy a credit card. Such attempts are successful with probability z^{m^c}, where m^c is the length of credit cards issued by the club. Success in copying a credit card

differs from impersonation in that it brings benefits only for one period.[18]

The arrangement works as follows: The "balance" on each agent's card (his net transaction position) is reported to the agent after each period.[19] If a transaction has been reported where none has occurred, the agent reports that the card has been copied, the old card becomes illegitimate and a new one is issued. To maintain club members' incentives to report card copying, the costs of issuing new cards are borne equally by all agents in the club.[20]

Again we initially exclude the possibility of additional monitoring beyond what the club would provide.

The continuation value of being in the club becomes

$$\begin{aligned} V^c(s) &= \delta^{-1}[(u-s)\,\pi^c - \\ &\quad (1-\pi^c)(z^{n^c} + \left(1-z^{n^c}\right) z^{m^c})s - \left(1-z^{n^c}\right) z^{m^c} \ell_i m^c - \ell_c m^c] \end{aligned} \tag{21}$$

Condition (18) is replaced by

$$V^c(s) - \frac{kn^c}{F(s^c)} - \ell_i m^c \geq \delta^{-1}[\pi^c u \left(z^{n^c} + \left(1-z^{n^c}\right) z^{m^c}\right)] \tag{22}$$

with equality for $s = s^c$. Condition (19) is replaced by

$$V^c(s) \geq s - X + \delta^{-1}\pi^c z^{m^c} u \ , \tag{23}$$

since a defaulting club member can always try and counterfeit credit cards. Finally, it must be the case that club members have an incentive to verify credit cards, i.e., we must have

$$s \geq [\pi^c + (1-\pi^c)(z^{n^c} + \left(1-z^{n^c}\right) z^{m^c})]s + \ell_c m^c \tag{24}$$

A credit card club now consists of an initial sample size n^c *and* a card length m^c, as well as a measure of members π^c, cutoff supply cost s^c,

[18] Counterfeitable cards raise the possibility of seller-side fraud. That is, a non-member of the club could pretend to be willing to supply goods, in order to obtain club members' credit card information. Since we are only interested in investigating buyer-side fraud, we assume that each club member receives a "terminal" that cannot be moved from his native location. Would-be buyers can immediately and costlessly verify the club membership of potential sellers by the presence of this terminal.

[19] To simplify calculations, we assume only legitimate club members' cards can be copied, and not cards issued to impersonators. Weaker assumptions make for more algebra but do not change the results.

[20] Note that each individual club member bears the risk of producing for non-members, however. This is inconsequential given risk neutrality. In practice, individual credit card holders are largely insured against the money costs of credit card fraud, but often bear substantial effort costs when fraud occurs. See Federal Trade Commission (2003).

and continuation value V^c. An equilibrium exists with a credit card club $(n^c, m^c, \pi^c, s^c, V^c)$ when (22), (19), and (24) are simultaneously satisfied for $\pi^c = F(s^c)$. Parallel to the previous section we can show the following (proofs are almost identical and are omitted):

Proposition 6 *If (5) holds strictly, then for any $s \in (\underline{s}, u)$ and for $\ell_i, \ell_c, k > 0$ sufficiently small, there exists an equilibrium with a credit card club where $s^c \in (s, u)$.*

Proposition 7 *Suppose (5) holds strictly. Let (n^*, π^*, s^*, V^*) be an equilibrium under independent verification. Then for $\ell_i, \ell_c, \delta, k > 0$ sufficiently small (a) there exists an equilibrium with a credit card club $(n^c, m^c, \pi^c, s^c, V^c)$ for some $s^c \in (s^*, u)$, and (b) all agents in the credit card club are better off than under independent verification.*

In other words, when credit cards are costly they are still beneficial, provided that the costs of issuing and verifying cards is low enough.

2.5 Discussion

Although the "credit card club" modeled above is clearly stylized, it offers a useful construct for analyzing identity theft.

In the model, equilibria with credit card clubs share a number of features with real-world payment environments. The first of these is that small, but positive rates of transactions fraud or identity theft occur in equilibrium. Fraud rates are low even though identities are verified only rarely (once in our model), because the outcome of a successful verification can be preserved through the creation and verification of artificial "quasi-identities" in the form of credit cards or other transactions accounts.

A second feature is that the credit card equilibria in the model allow for two types of transactions fraud, both of which are significant problems for real-world payment systems (Federal Trade Commission, 2003): "existing account fraud," which most often means the theft of credit cards or other transactions account data, and "new account fraud," which is the use of data about another person to obtain a transactions account in their name.[21] It is the latter type of fraud that has captured the public's imagination (partly

[21] Other terms have been employed to describe these phenomena; our terminology follows the classification in the FTC report. Industry specialists have devised much more detailed fraud typologies; see for example Burns and Stanley (2002). Another broad category of fraud, "friendly fraud," is discussed below.

because it tends to be much more costly in terms of money and time), and this is the type of fraud commonly associated with the term "identity theft."

The model predicts that new account fraud appears in an environment where the cost of agents' initial identity verification (here, measured as proportionate to sample length) is not particularly great, relative to the cost of identifying instruments. We would argue this corresponds to the current situation "on the ground." Improvements in information technology have resulted in a precipitous fall in the costs of creating and monitoring transactions accounts. The costs of obtaining accurate identifying information on people (which we would argue still means the sacrifice of some "shoe leather") have also fallen, but by not nearly so much.[22] The emergence of new account fraud has been the result, but this type of fraud is to some extent a by-product of the success of credit-based exchange.

Neither new nor existing account fraud exists in equilibrium under independent verification, since there are no "accounts" under this arrangement. Would-be frauds are forced to repeatedly attempt impersonation. This arrangement is inefficient, however, to the extent that it does not allow agents to exploit information gathered by other agents. More efficient arrangements increase the scope and reliability of credit-based exchange, but can also increase the absolute incidence of fraud.

Finally, the model offers some insights into the technological "arms race" between payment systems and fraudsters that is often alluded to in popular accounts of identity theft. In the model, an improvement in information technology may be thought of as a fall in the "information parameters" k, ℓ_i, and ℓ_c. A decrease in these parameters slackens constraints (19) and (22) and so makes participation in credit-based exchange more tempting. This in turn, widens the use of credit, which increases the return to identity theft. In particular, the payoff to fraud (RHS of condition (22)) increases as participation increases, which tightens constraint (22). Attempts to rectify this problem by increasing the complexity of the initial monitoring and/or the complexity of the credit card only serve to further tighten (22) and may backfire as a result. In other words, an improvement in information technology increases the use of credit, but this increase can be self-limiting.

[22] LoPucki (2003) argues that the cost of obtaining such information on people has actually *increased* in recent decades as people have developed a taste for privacy.

3 Extensions

3.1 Extension 1: money versus credit

The first extension returns to a theme of recent work in monetary theory which explores the relative merits of money versus credit.[23] In this literature an agent's money holdings serve as an imperfect proxy for the history of the agent's actions. As technology drives down the cost of recording an agent's history, so the argument goes, money becomes superfluous.

We would argue that this view of money versus credit is incomplete, because it misses a crucial distinction between the two. That is that fiat money is not tied to the purchaser's identity, while credit necessarily is. Money's legitimacy does not derive from the verification of anyone's identity, but instead only from the authenticity of the money itself.

Ceteris paribus, advances in information technology increase the chances that a given transaction is legitimate, be it money or credit. But if the pace of this technological improvement is uneven, money may have an advantage. In particular, if the cost of issuing and verifying cards and other "quasi-identities" (parameters ℓ_i and ℓ_c in the model of section 2) falls faster than the cost of verifying a person's identity (parameter k), transactions that may not be feasible for credit will be feasible for money.

To illustrate this point we consider a variant of the model of section 2.4 which incorporates a form of money.

3.1.1 The model with money

Consider the same special case considered in section 2.4.1, in which $\ell_i = \ell_c = 0$, so that credit cards cannot be counterfeited. Money takes the form of cards that can only be issued by a single benevolent agent, and like credit cards, cannot be counterfeited.[24] Money is by its nature indivisible, and, in the tradition of Kiyotaki and Wright (1989), an agent can hold at most one unit of it. Counterfeiting of money and credit card cloning are impossible, but since the cost of identity verification k remains positive, fraud is possible by means of "new account fraud," i.e., impersonation.

As above, agents have the opportunity to join the credit card club at time zero. Agents who join the club can purchase goods on credit from other club members. Agents who do not join the club still have the option

[23] Some papers in this literature are cited in footnote 1, page 2.

[24] Several models have explored the implications of the counterfeiting of money; see the literature review below.

of trading for money. Agents who are members of the club may desire to hold money for purposes of trading with non-members.

Agents who are not members of the credit club may attempt to obtain consumption goods by impersonating a club member. If n^c is the length of the identity verification demanded by the club, then an impersonation succeeds with probability z^{n^c}.

To keep calculations manageable, we make a simplifying assumption, which is that successful impersonation can only be attempted by those agents for whom $s > u$, i.e., those for whom production is inefficient. This assumption reduces the measure of potential impersonators from 1 to $1 - F(u)$, but since the possibility of impersonation still exists, agents must still be verified before engaging in credit-based exchange.

To analyze this economy, we will first consider the case where trade takes place only on a credit basis. We then consider exchange with money only, and finally allow for exchange with either money or credit.

3.1.2 Trade with credit only

Suppose momentarily that money is not available, so that exchange is only possible through entry into the credit card club. As in section 2.4.1, an equilibrium for the credit card club is defined by (n^c, π^c, s^c, V^c), where $\pi^c = F(s^c)$, the value of being in the club V^c is given by (cf. (17)) is given by

$$V^c(s) = \delta^{-1}[(u - s)\,\pi^c - (1 - F(u))z^{n^c} s] \tag{25}$$

Condition (19) must hold for $s \in [\underline{s}, s^c]$ and as well as the following condition

$$V^c(s) \geq \frac{kn^c}{\pi^c} \tag{26}$$

with equality for $s = s^c$ (cf. condition (18); note that condition (18) is relaxed by virtue of the additional assumption). Since (26) is less stringent than (18), Propositions 4 and 5 apply. That is, if k is small enough and people are patient enough, then (a) a credit card club exists, and (b) a credit card club will dominate a credit club under independent verification.

3.1.3 Trade with money only

Now momentarily suppose that the cost of identity verification k is high enough so that credit is not feasible for any agent. Agents may still attempt to trade by using money, however. Let π^M be the fraction of agents in the economy willing to engage in monetary trade. Let $M \in \left(0, \pi^M\right)$ be the

fraction of agents holding money, and let $\underline{V}(\mu; s)$ be the value function of an agent willing to trade, who has $\mu \in \{0, 1\}$ units of money and supply cost s. Limiting versions of the flow Bellman equations for each type of agent are given by[25]

$$\delta \underline{V}(0; s) = M\left(-s + \underline{V}(1; s) - \underline{V}(0; s)\right) \tag{27}$$

$$\delta \underline{V}(1; s) = \left(\pi^M - M\right)\left(u + \underline{V}(0; s) - \underline{V}(1; s)\right) \tag{28}$$

Solving (27) and (28) we obtain

$$\underline{V}(0; s) = \frac{M}{\delta}\left[\frac{(\pi^M - M)(u - s) - \delta s}{\pi^M + \delta}\right] \tag{29}$$

$$\underline{V}(1; s) = \left(\frac{\pi^M - M}{\delta}\right)\left[\frac{\pi^M(u - s) + \delta u}{\pi^M + \delta}\right] \tag{30}$$

A *monetary equilibrium* (π^M, s^M, M) consists of a fraction $\pi^M \in [F(\underline{s}), F(u)]$ of agents, a supply cost s^M where $\pi^M = F(s^M)$, and a per-capita money stock $M \in (0, \pi^M)$ such that

$$\underline{V}(0; s) \geq 0 \tag{31}$$

for all $s \in \left[\underline{s}, s^M\right]$, with equality for $s = s^M$.

Proposition 8 *For sufficiently small $\delta > 0$, there exists a monetary equilibrium.*

Proof. Define $M' = M/\pi^M$, i.e., M' is the proportion of agents willing to trade who have money. Condition (31) is equivalent to

$$F(s^M) \geq \frac{\delta s}{(1 - M')(u - s)} \tag{32}$$

Choose s^M to be a point for which (32) is satisfied with equality. Such a point will always exist for $\delta > 0$ sufficiently small. Since RHS(32) is increasing in s, it follows that (32) will hold for $s \in \left[\underline{s}, s^M\right]$. ■

In other words, a monetary equilibrium exists if people are patient enough. Depending on the distribution of supply costs F, there may be multiple monetary equilibria.

[25] As in section 2, we let $N \to \infty$ and $N\delta' \to \delta > 0$ in order to simplify computations. "Longhand" versions of the Bellman equations presented here can be found in Kahn, McAndrews, and Roberds (1995).

3.1.4 Trade with money and credit

We now consider an "intermediate" environment, i.e., one where values of the verification cost k and the distribution of supply costs F are such that there may be no credit card club for which $\pi^c = F(u)$. In this case, agents with supply costs s less than but sufficiently close to u are excluded from credit arrangements. For these agents, the utility from consumption does not provide enough benefit to cover the cost of identity verification. We consider whether in such an environment, additional opportunities for exchange will exist in the presence of money.

Suppose that at time zero, a credit card club of size $\pi^c < F(u)$ is feasible. Momentarily suppose also that π^M agents (including club members and non-members) are willing to engage in monetary trade when the per-capita amount of money in the economy is M, and that $\pi^M > \pi^c$. The measure of agents who can trade only for money is given by $\pi^N = \pi^M - \pi^c$. Since trade with credit is ruled out for this type of agent, their value function is given by $\underline{V}(\mu; s)$ above. For club members, flow Bellman equations are given by

$$\begin{aligned} \delta \underline{V}^c(0;s) &= \pi^c(u-s) - (1-F(u))z^{n^c}s \\ &\quad + M^N\left(-s + \underline{V}^c(1;s) - \underline{V}^c(0;s)\right) \end{aligned} \tag{33}$$

$$\begin{aligned} \delta \underline{V}^c(1;s) &= \pi^c(u-s) - (1-F(u))z^{n^c}s + \\ &\quad \left(\pi^N - M^N\right)\left(u - \underline{V}^c(1;s) + \underline{V}^c(0;s)\right) \end{aligned} \tag{34}$$

where $\underline{V}^c(\mu; s)$ is the value function of an agent with money holdings $\mu \in \{0, 1\}$ and supply cost s who is in the club, and M^N is the per-capita quantity of money held by people who are not in the club. Algebraic manipulation of (33) and (34) yields

$$\underline{V}^c(0;s) = V^c(s) + \frac{M^N}{\delta}\left[\frac{(\pi^N - M^N)(u-s) - \delta s}{\pi^N + \delta}\right] \tag{35}$$

$$\underline{V}^c(1;s) = V^c(s) + \left(\frac{\pi^N - M^N}{\delta}\right)\left[\frac{\pi^N(u-s) + \delta u}{\pi^N + \delta}\right] \tag{36}$$

An *equilibrium with money and credit* can be defined as follows. Let C be a credit card equilibrium (n^c, π^c, s^c, V^c) for which $\pi^c < F(u)$. Then an equilibrium with money and credit is a vector $\left(\pi^M, s^M, M, C\right)$ such that $\pi^M = F(s^M)$,

$$\pi^c, M < \pi^M \leq F(u), \tag{37}$$

and appropriate participation constraints hold. These are given by (31) for all s s.t. $F(s) \in \left[\pi^c, \pi^M\right]$ with equality for $s = s^M$, and by

$$\underline{V}^c(0;s) \geq \max\left\{V^c(s), \underline{V}(0;s)\right\} \tag{38}$$

for all $s \in [\underline{s}, s^c]$. Condition (31) guarantees that non-club members prefer trade with money to autarky, and condition (38) guarantees that club members prefer trade with both money and credit to either trade exclusively with credit or trade exclusively with money. In addition, the equilibrium per-capita amount of money held by club members $M - M^N$ and non-members M^N must be consistent with the appropriate transition probabilities. This requirement can be shown to reduce to a pair of conditions, the first of which

$$\frac{\pi^N - M^N}{M^N} = \frac{\pi^M - M}{M} \tag{39}$$

says that money holdings are distributed proportionately across both types of traders, and is automatically satisfied if $\pi^N > 0$. The second condition

$$M > \frac{\pi^M}{2} \tag{40}$$

says that money must be abundant enough to justify exchange with money only.

We can now show:

Proposition 9 *Suppose that C is a credit card equilibrium (n^c, π^c, s^c, V^c) for which*

$$1/2 < \pi^c < F(u) \tag{41}$$

and

$$\left(F(s^c) - 1/2\right)\left(u - s^c\right) > \delta s^c. \tag{42}$$

If, in addition, $F(u)$ is sufficiently close to one, then (a) there exists an equilibrium with money and credit $\left(\pi^M, s^M, M, C\right)$, and (b) the equilibrium with money and credit dominates the credit card equilibrium.

Proof. Part (a). Define $g(s) = \left(F(s) - 1/2\right)\left(u - s\right) - \delta s$. Since $g(u) < 0$, and, by (42), $g(s^c) > 0$, it must be the case that $g(s') = 0$ for some $s' \in (s^c, u)$. To construct an equilibrium with money and credit, take $s^M = s'$ and $M = 1/2$.

By construction, (31) holds for $s \in [s^c, s^M]$. Hence, under the proposed equilibrium, agents with supply costs in (s^c, s^M) have an incentive to supply goods for money.

Now consider agents in the club, i.e., those for whom for $s \in [\underline{s}, s^c]$. By construction we have $\underline{V}^c(0;s) \geq V^c(s)$ (i.e., transacting with money and credit is preferred to transacting with credit alone). For $F(u)$ close to one, it must also be the case that $\underline{V}^c(0;s) \geq \underline{V}(0;s)$ (i.e., transacting with money and credit is preferred to transacting with money alone), implying that under the proposed equilibrium, (38) holds for agents in the credit card club.

Finally, condition (40) holds by construction.

Part (b). Follows since (31) holds with strict inequality for at least some $s \in (s^c, s^M)$. ■

3.1.5 Discussion

Proposition 9 lays out sufficient conditions for money and credit to serve as complementary transactions technologies. Credit itself must be viable and widespread but not universal. People must be sufficiently patient. Finally, the problem of impersonation must be sufficiently contained so that the use of money is not more attractive than credit. Under these conditions, there are always agents who would be excluded from trade under credit arrangements, who find it advantageous to trade for money. Consequently the availability of money as an alternative transactions technology can be welfare-improving.[26]

3.2 Extension 2: a model of "friendly fraud"

The model of section 2 illustrates how the use of costly identity verification can widen opportunities for credit-based exchange. However, the model does not incorporate an important type of fraud risk known as "friendly fraud." Friendly fraud is said to occur when a consumer enters into a transaction and subsequently denies that a legitimate debt was incurred (or equivalently, when a consumer impersonates an impersonator). Actual consumers have an incentive to engage in friendly fraud so as to evade limits on their indebtedness, but this incentive does not arise in our initial model. Once an agent joins the credit club, his history (i.e., one could think of the agent's "balance" as net number of goods supplied) becomes irrelevant. Since agents have, in effect, an infinite credit line (subject to the constraint they can consume at most one good per period), and the center can always impose

[26] Taub (1994) shows an equivalence between allocations under money and credit, in a model that differs from ours along several dimensions. Some key distinctions in our setup include an expanded role for credit, and costly verification of identities.

penalties on a known agent, agents have no motive to deny debts once they have joined the credit club.

In this section we present a related model where transaction histories matter, so that friendly fraud is possible. In order to do so, we place restrictions on agents' abilities' to "repay" consumption debt. At the same time, we provide additional opportunities for agents to consume.

3.2.1 Overview of the model

As before, there are a large number N of agents with distinct identities. In contrast to previous models, agents share locations, and there are a large number L of locations. As before we will focus our attention on a limiting case. In particular, L and N grow without bound, but L/N approaches zero.

Time is again discrete and infinite. Agents are organized into overlapping generations. A new generation is born each period, and each agent lives for three periods. During the first two periods of life (*youth*), all agents have opportunities to consume. During the last period of life (*old age*), a fraction ϕ of each generation (known as *producers*) have the opportunity to produce a perishable good unique to their location while the remaining $1-\phi$ (known as *drones*) have no opportunities to produce. Young agents know at birth whether they are producers or drones, but this information is private. All goods are produced in variable quantities, and the disutility to a producer of producing y goods is simply y.

During their youth, all agents desire to consume a good specific to other, randomly selected islands, where these locational preference shocks are serially independent and independent across agents. All generation t drones receive utility

$$w(x_t^t) \tag{43}$$

from consuming x_t^t goods on a randomly selected preferred island during period t, where w is strictly increasing, strictly concave, twice differentiable, and satisfies the Inada conditions as well as $w(0) = 0$.

Generation t producers are randomly selected as either "early" or "late" consumers, each with probability one half. Early consumers of generation t prefer to consume only during period t. Following Shi (1997), during period t each early consumer splits into a number of buyers who visit I randomly selected islands, where the buyer on island i purchases $x_{t,i}^t$ desired goods. End-of-period consumption x_t^t of a composite good is given by

$$x_t^t = I \min_i \{x_{t,i}^t\} \tag{44}$$

Early consumers have lifetime utility given by

$$w(x_t^t) - y_{t+2}^t \tag{45}$$

Late consumers of generation t prefer to consume during period $t+1$. As with early consumers, they send buyers out during $t+1$ to purchase I randomly selected goods, and at the end of the period consume the composite good x_{t+1}^t, defined analogously. They also enjoy consumption of a randomly selected time t good $\widetilde{x}_t^t$, so that their lifetime utility is given by

$$\theta \widetilde{x}_t^t + w(x_{t+1}^t) - y_{t+2}^t$$

where $0 < \theta < 1$.

Trade proceeds as follows. In each period, all young agents wishing to consume travel or send their buyers to the islands where their desired consumption goods are produced. There they meet with old agents who are each willing to produce a given quantity of the island's native good. The traveling young agents who wish to consume the island's good are then each given an equal share of the island's production, i.e., "markets clear" in the usual sense. The consumption goods are then taken home and consumed.

3.2.2 Baseline cases

If agents cannot be identified in this setup, then trade collapses as no old agent has an incentive to supply.

Suppose, then, that agents' identities can be costlessly verified, and that it is also costless to keep records of which transactions agents have entered into. As soon as each new generation is born, but before preference shocks are realized, agents have an opportunity to join a credit club. Members of the club reveal their identities to the center, and are in return entitled to consumption of a specified amount of their desired goods during one period of their youth, in return for a promise to supply another amount (possibly different) during old age. As before, the center can impose a disutility of X on defaulters.

If producers' preferences are public information, then for sufficiently large X, a constrained-efficient allocation[27] can be implemented by allowing each club member consumption of $x^* = (w')^{-1}(1)$ composite goods during the "hungry" period of his youth, and requiring each club member to supply $y^* = x^*$ in his old age. Note that all producers will have an incentive to join

[27] The term "constrained efficient" is again appropriate because this allocation places zero weight on the welfare of both drones and the initial old generation.

such an arrangement, while drones will not join, so as to avoid punishment for default.

If preference shocks for producers are unobservable, then the same constrained efficient allocation can be implemented as long as agents' histories can be recorded. In this case, agents who "exceed their credit limit" by consuming during two periods suffer the nonpecuniary penalty X.

If agents can be identified, but consumption histories cannot be recorded, late consumers will always take advantage of this arrangement to consume during each of the first two periods of life.[28] Such an arrangement is clearly inefficient since the marginal utility of the non-hungry young agents is below the cost of production. Furthermore, if

$$\Psi(x) = w(x) - \left(\frac{3-\theta}{2}\right) x < 0 \tag{46}$$

for $x = \underline{x}$ where $\underline{x}$ maximizes $\Psi(x)$, then the value of being in the credit club is dominated by autarky, and trade collapses.

3.2.3 Credit club with costly verification

Now suppose the mere occurrence of a transaction can be costlessly recorded, but that identities can only be detected only through costly sampling, as in the model of section 2. Specifically, agents who decide join the credit club submit an identity sample of length n which is verified at cost of k utils per bit sampled, which is borne by "sellers," i.e., old agents. As above, this verification is always successful if the agent tells the truth, and succeeds with probability z^n if the agent is an impersonator.

Successful verification at time t entitles an agent to consumption of a given quantity of the agent's desired consumption good during either period t or $t+1$, but not both. This is accomplished by issuing verified agents a credit card. Each buyer of a verified agent receives a copy of the card. To simplify calculations we again consider the limiting case where issue and verification of cards is costless, and cards cannot be counterfeited.

Since verification of agents' identities is imperfect, drones will have an incentive to commit fraud by impersonating club members. The possibility of impersonation opens up the possibility of friendly fraud, which occurs when a generation-t late consumer consumes a good in period t instead of $t+1$, but then claims to have been impersonated. On the one hand, it is

[28] This temptation is specific to producers, since drones are excluded from consuming on credit.

desirable to insure late consumers against the risk of impersonation, but on the other, providing such insurance may undermine incentives to participate in the club arrangement.

To guard against friendly fraud, the club may require a buyer to provide a second identity sample of length p with each trade. We call this second sample a *signature*. Signatures are not verified at the same time as a trade occurs, but become immediately available thereafter. They are only verified when a dispute arises concerning whether a transaction was fraudulent. In such cases, and only in such cases, there is again a cost of k per bit verified.[29] Barring disputes, there is no cost to collecting and storing the signature.[30]

In submitting a signature, an agent may choose to either submit his own identity sample, which is in a dispute is verified as authentic with probability one, or to attempt friendly fraud by forging another agent's signature. If an agent is a drone impersonating a producer, there is no payoff to forgery, since drones by assumption are only interested in consuming once. If the agent is a producer and decides to forge, he succeeds with probability z^p and fails with probability $1 - z^p$.

Signatures are only consulted when a late-consuming producer claims to have been defrauded by someone using his identity during the previous period. If the signature is verified as a forgery (by a drone), the agent retains his right to consume, and the fraud loss is absorbed by the credit card club. On the other hand, if the protesting consumer is found guilty of attempting friendly fraud, this results loss of opportunities to consume during second period of life, as well as application of the nonpecuniary penalty X.

Since all producers who are late consumers have identical preferences, either all late consumers or none will attempt friendly fraud. Under condition (46), trade cannot proceed unless incentives for friendly fraud are ruled out. This requires that the expected punishment from friendly fraud exceed the expected consumption benefit; when all producers join the credit card club, this reduces to the condition

$$(1 - z^p)\,(X + w(x^c)) \geq z^p \theta x^c \tag{47}$$

where x^c is the per-period consumption quantity promised to young members of the credit card club. Thus, under (46), a successful credit club will

[29] This timing mimics the use of handwritten signatures in payment card transactions where the cardholder is physically present at the point of sale. In such transactions, signatures are recorded but only examined in case of disputes.

[30] What is important to our analysis is that the cost of storage and verification is less than the cost of full-blown verification. Zero cost is a convenient proxy.

choose a signature sample length $p = p^*$, where p^* is the smallest value of value of p satisfying (47).

The steady-state value of participation in the club is given by the utility of a typical member's consumption, minus the cost of supplying goods and verifying identities. If there is no friendly fraud, this reduces to

$$W(x^c, n, p) = w(x^c) - x^c \left(\frac{\phi + (1-\phi) z^n}{\phi} \right) - kn \tag{48}$$

An equilibrium for the credit club is a value (x^c, n, p) that satisfies $W(x^c, n, p) \geq 0$ and $p \geq p^*$. It is straightforward to show

Proposition 10 *Suppose that (46) holds. For sufficiently small $k > 0$, then: (a) there exists an equilibrium for the credit club, (b) in such an equilibrium, there is a positive rate of impersonation of producers by drones in equilibrium, but a zero rate of friendly fraud.*

Proof. Part (a). Take $p \geq p^*$ and $x^c = x^*$. Then let $k \to 0$ while $n \to \infty$ and $kn \to 0$. Since $w(x^*) - x^* > 0$, then for sufficiently small k and large n, $W(x^c, n, p) > 0$. Part (b). The measure of drones who are successful at impersonation is given by $(1-\phi)z^n$, while for $p \geq p^*$, the measure of friendly frauds is zero from (47). ■

The constrained efficient credit club is one that maximizes $W(x^c, n, p)$. First-order conditions for x^c and n are given by

$$w'(x^c) = \left(\frac{\phi + (1-\phi) z^n}{\phi} \right) \tag{49}$$

$$k \geq \frac{1-\phi}{\phi} x^c \ln(z^{-1}) z^n \tag{50}$$

From (49) and (50) it can be shown that as monitoring technology improves and $k \to 0$, the optimal length of the initial identity sample n will increase. This results in better detection of impersonators and an increase in the optimal consumption of club members x^c. As there is no additional benefit from increasing the signature sample length p, however, once (47) is satisfied, p will remain the same with decreasing k.

For this case it is straightforward to show that the use of cards will again dominate independent verification. As in the models above, the issue of cards reduces the cost of verifying buyers' identities. Even if additional information must be collected with each transaction in the form of a signature, this information need not be verified if its primary purpose is to deter agents already known to the center.

3.2.4 Discussion

The model of this section indicates how our approach can be extended to the problem of friendly fraud. The potential for friendly fraud complicates the management of fraud risk within a credit-based payment system, since identities of buyers must be matched to specific histories. Somewhat offsetting this complication is the fact that, an agent must be known to the system in order to commit friendly fraud, and hence the deterrent effect of threatened punishments will be greater for this type of fraud than for a fraud committed by an anonymous impersonator.

Extensions of this model would allow for positive rates of friendly fraud in equilibrium as well as multiple means of payment. The goal of this section has been to demonstrate how other forms of fraud, such as friendly fraud, can be incorporated into our framework.

4 Literature review

The money literature has generally not focused on topic of identity theft. Very often this literature has modeled economies where trades occur between purely anonymous agents (e.g., Kiyotaki and Wright 1989) or where trades involve "famous" agents whose identities and transaction histories are public information (e.g., Kocherlakota 1998). Other papers (e.g., Cavalcanti and Wallace 1999) have analyzed environments in which both anonymous and famous agents are present, i.e., environments in which agents are inherently either costlessly identifiable or never identifiable. In these structures, there is no possibility of identity theft.

Two papers that touch on the issue of fraud in credit transactions are Camera and Li (2003) [CL] and Kahn, McAndrews, and Roberds (2005) [KMR]. In CL, transactions fraud can occur in the sense that debtors are sometimes able to deny debts without such denials becoming known to other agents. They show that if punishment of unsuccessful fraud attempts is sufficiently lax, equilibria can occur with positive rates of fraud. In KMR, purchasers who use credit may be subject to the risk of outright theft if their credit transactions are widely observed. In both the CL and KMR models, as in the model of section 3.1, limitations on the center's ability to punish miscreants (defaulters and thieves, respectively) increase the attractiveness of money. Equilibria in which both money and credit are used may dominate equilibria where only one type of transaction technology is employed.

A number of papers in the money literature have considered transactions fraud stemming from the use of counterfeit currency. Green and Weber

(1996), Kultti (1996), and Monnet (2005) present models in which counterfeit and genuine notes can circulate side-by-side in equilibrium. Williamson (2002) and Nosal and Wallace (2004) also construct models where counterfeiting is possible, but does not occur in equilibrium. A typical result in this literature is that trade can occur only when counterfeiting is sufficiently repressed (often when it is reduced to zero). As is the case with identity theft, a low equilibrium rate of counterfeiting belies its potential to disrupt exchange.

Legal scholars (LoPucki 2001, 2003, Solove 2003) who have analyzed the issue of identity theft have argued, in essence, that the current process of identity verification in the marketplace is either insufficiently intense (i.e., in our model, roughly corresponding to n "too low") or too infrequent (i.e., something closer to "independent verification" would be appropriate). They point out that while the typical victim of identity theft may be partly insured against monetary losses directly resulting from identity theft, he usually incurs considerable costs in subsequently re-establishing his legitimate identity. Credit bureaus and other compilers of identifying information do not internalize these costs, it is argued, and hence are insufficiently motivated to ascertain the veracity of the information they collect.

Our present model does not incorporate enough detail to allow us to investigate the validity of this last claim. Even if it is true, however, it would not change the fundamental character of our results. In particular, the optimal degree of identity verification cannot be infinite, and an efficient use of credit will entail some amount of identity theft.

Finally, our notion of identity and its use in transactions is related to Clarke's (1994) discussion of "knowledge-based" versus "token-based" identification of individuals. In brief, knowledge-based identification requires that an individual provide information about himself that ordinarily only he would be expected to know, while token-based identification requires that an individual provide some documentary evidence of a previous encounter. In terms of this dichotomy, we are arguing that modern payment systems are efficient because they at least partly substitute (cheaper) token-based identification for (more expensive) knowledge-based identification. In the case of money, this substitution is complete and possession of the relevant token (money) provides sufficient proof that a potential buyer is legitimate.

5 Conclusion

Above we have presented a model of "identity" and its use in credit transactions. Various types of identity theft can occur in equilibrium, including "new account fraud," "existing account fraud," and "friendly fraud." The equilibrium incidence of identity theft represents a tradeoff between a desire to minimize costly monitoring of individuals on the one hand, and the need to control transactions fraud on the other. The phenomenon of identity theft, while clearly undesirable in of itself, also reflects the success of credit-based exchange.

An often-discussed remedy for the problem of identity theft would be to increase the complexity of consumers' identifying instruments (for example, moving from magnetic stripe-based to chip-based payment cards). While such a change will lower the incidence of existing account fraud, it will not be a panacea, since it will do little to discourage new account fraud or friendly fraud. Indeed, to the extent that "better" cards lead to more extensive use of cards, some types of fraud could actually increase.

Other suggested remedies propose to limit the extent of personal data that could be collected by credit bureaus and other data aggregators. In the model this would correspond to a cap on the intensity of the initial verification and would unambiguously increase incentives to engage in new account fraud. Attempts to counteract these incentives by increasing the complexity of ID cards, or signatures, may have limited effect.

Our analysis points in the opposite direction, i.e., that identity theft can be better controlled through more and not less intense initial monitoring of individuals' identities. Mandating more intense identity verification may be undesirable, however, if it leads to undue restrictions on the use of credit or loss of privacy.

Society may ultimately have to decide on a rate of identity theft that balances its preference for privacy with its tolerance for transaction fraud. Our results on money and credit suggest that the availability of money may improve this tradeoff: there are some circumstances where the best type of "payment card" is one with no one's name on it.

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