Payment Arrangements and Inflation

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The past decade has been a period of commercial and technical innovation in payment arrangements that avoid, or economize on, the use of currency, bank reserves, and bank balances—the "outside and inside money" of prosaic monetary theory. Central bankers and scholars of central banking have begun to consider whether this development will ultimately affect how monetary policy should be conducted and whether policy can be effective (see Bank for International Settlements, 1996; Timo Henckel et al., 1999; Mervyn A. King, 1999; Charles A. E. Goodhart, 2000). A basic, if extreme, question in this vein is whether people will even remain willing to accept intrinsically worthless fiat money in exchange for valuable commodities, if alternative ways to conduct transactions become available. Unless technical change were someday to make money inessential, wise monetary policy presumably would not make it unacceptable. Of course, this issue would be most salient regarding a regime of high steady-state money growth that, through inflation, would impair the attractiveness of holding money.

In order to clarify the logic of the discussion that the central bankers are having, I will consider this question in the context of two explicit, coherent models of transactions in an economy under a regime of steady-state money growth. (I will only sketch the models here. The references provide complete, precise, expositions of related models.) The acceptability of fiat money has the status in these models of an equilibrium phenomenon that results, or may fail to result, from underlying features of the environment.[1] This feature is essential for a model to provide a nontrivial answer to the question posed here. Interestingly, the two models provide opposite answers in the high-inflation case. I will argue that their divergence is appropriate, since they represent two different types of conceivable economic arrangement that might perform in distinct ways. However, I will suggest that one type of arrangement (the one that does not affect the acceptability of fiat money) represents some arrangements that have actually been seen and that are likely to be seen in the near future.

The first model, in which operation of a payment arrangement could make fiat money unacceptable under high inflation, follows S. Rao Aiyagari and Stephen Williamson (1998) and Narayana Kocherlakota and Neil Wallace (1998). Those researchers model economic environments in which there is a comprehensive, dynamic contract (which they liken to a noncash-payment arrangement) for sharing unobservable risks. To focus on the interaction between contractual and cash transactions, the private-information, incentive-compatibility aspect of intermediation in the Aiyagari-Williamson and Kocherlakota-Wallace environments is ignored here. Nevertheless, as in those environments, it is assumed that risk-sharing depends on technology (such as a communication network) that suffers interruptions at random times. Traders hold cash balances as a contingency arrangement. They make cash transactions in order to consume their desired commodities at times when the communication channel to the intermediary does not function. A continuum of infinite-lived,

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[1] The models improve in this respect on Stacey L. Schreft (1992), who studies noncash payment arrangements in a modified cash-in-advance model.

discounted-utility-maximizing traders who are identical *ex ante* receive two units each of a single (or composite), perishable commodity at each date 0, 1, ... Each trader i maximizes the discounted utility $E\ \Sigma_{t=0}^{\infty}\ \beta^t u(c_{it},\ s_{it})$, where c_{it} is i's consumption at t and $s_{it} \in \{\text{h}, \ell\}$ (high or low marginal utility, respectively) is a random utility state that is identically and independently distributed Bernoulli(1/2). A tractable utility specification with the property that high inflation discourages mutually beneficial trade is chosen. Consider the following, piecewise-linear utility specification defined by positive constants $L < M < H$:

$$u(c,\ \text{h}) = Hc$$

$$u(c,\ell) = M \min(c,1) + L \max(c - 1,0).$$

The economy satisfies a "law of large numbers" that half of the traders are in state h at each date.

Suppose that there is a technology that allows each trader's current state to be directly observed and that traders can achieve *ex ante* efficiency by making a binding contract to exchange endowments on the basis of the information so provided. That is, traders in state ℓ will give their endowments to traders in state h without receiving money in return. Traders in the two states will receive utility levels 0 and $4H$, respectively.

Suppose that the intermediation technology just described only functions with probability $\rho < 1$. That is, whether or not the technology functions is a Bernoulli(ρ) process with states $\tau \in \{\text{f},\ \text{n}\}$ (functioning and not functioning, respectively). In state n, each trader's utility state is private information, and his trade action is also subsequently unknown. Thus, contractual incentives cannot affect traders' decisions at these random dates. Traders instead use money to buy and sell goods at parametric, market-clearing prices.

Each trader is initially endowed with one unit of fiat money and receives additional "helicopter drops" of money thereafter. (These money injections will cause inflation in equilibrium.) At the beginning of each date $t > 0$, each trader receives $(\theta - 1)\theta^{t-1}$ units of money in addition to the money that he has carried over from date t. Thus, the aggregate nominal money stock at t is θ^t. Since each trader's money holding is a function of his history and his current utility state is independent of his history, another "law of large numbers" assumption is that half of the money stock is held by traders in state h.

An equilibrium consists of a price sequence $\langle p_t \rangle_{t=0}^{\infty}$ and, for each trader, a state-contingent consumption plan $\langle c_t \rangle_{t=0}^{\infty}$ and a state-contingent real-balance plan $\langle m_t \rangle_{t=0}^{\infty}$, where m_t is the trader's nominal money balance at t divided by p_t. These must satisfy the following conditions:

(i) c_t and m_t are nonnegative;

(ii) if $s_t = \text{h}$ and $\tau_t = \text{f}$, then $c_t = 4$ and $m_{t+1} = p_t m_t / p_{t+1}$;

(iii) if $s_t = \ell$ *and* $\tau_t = \text{f}$, then $c_t = 0$ and $m_{t+1} = p_t m_t / p_{t+1}$;

(iv) if $\tau_t = \text{n}$, then $m_{t+1} = p_t(m_t + 2 - c_t) \div p_{t+1}$;

(v) $\langle c_t \rangle_{t=0}^{\infty}$ and $\langle m_t \rangle_{t=0}^{\infty}$ maximize expected discounted utility, subject to the preceding constraints;

(vi) aggregated across all traders, $\langle c_t \rangle_{t=0}^{\infty}$ and $\langle m_t \rangle_{t=0}^{\infty}$ are market-clearing.

Now an equilibrium will be specified and verified for suitable parameter values of the economies. For each t, let $p_t = \theta^t$. Then utility maximization is characterized via a value function $v(m,\ s,\ \tau)$ that solves the following Bellman equation:

$$\begin{aligned} v(m,\ \text{h},\ \text{f}) &= 4H + \beta\{\rho[v([m + (\theta - 1)]/\theta,\ \text{h},\ \text{f}) \\ &\quad + v([m + (\theta - 1)]/\theta,\ \ell,\ \text{f})]/2 \\ &\quad + (1 - \rho)[v([m + (\theta - 1)]/\theta,\ \text{h},\ \text{n}) \\ &\quad + v([m + \theta - 1]/\theta,\ \ell,\ \text{n})]/2\} \end{aligned}$$

$$\begin{aligned} v(m,\ \ell,\ \text{f}) &= \beta\{\rho[v([m + (\theta - 1)]/\theta,\ \text{h},\ \text{f}) \\ &\quad + v([m + (\theta - 1)]/\theta,\ \ell,\ \text{f})]/2 \\ &\quad + (1 - \rho)[v([m + (\theta - 1)]/\theta,\ \text{h},\ \text{n}) \\ &\quad + v([m + \theta - 1]/\theta,\ \ell,\ \text{n})]/2\} \end{aligned}$$

$$v(m, s, \mathrm{n}) = \max_{0 \le c \le 2+m} u(c, s) + \beta\{\rho[v([(m+2) - c + (\theta - 1)]/\theta, \mathrm{h}, \mathrm{f}) + v([(m+2) - c + (\theta - 1)]/\theta, \ell, \mathrm{f})]/2 + (1-\rho)[v([(m+2) - c + (\theta - 1)]/\theta, \mathrm{h}, \mathrm{n}) + v([(m+2) - c + (\theta - 1)]/\theta, \ell, \mathrm{n})]/2\}.$$

Specify equilibrium consumption of a trader with real money balance m when $\tau = \mathrm{n}$ as follows:

$$\text{if } s_t = \mathrm{h}, \text{ then } c_t = 2 + m$$

$$\text{if } s_t = \ell, \text{ then } c_t = 1.$$

Note that this consumption plan, followed by all traders, is market-clearing. The traders with utility state h hold real money balances ½ in the aggregate, and they purchase ½ unit of endowment in the aggregate from traders with utility state ℓ.

Given this consumption plan and the functional form of the utility function, one suspects that the value function should be affine. Specifically, there should be positive coefficients U, V, W, X, Y, and Z that satisfy the following equations:

$$v(m, \mathrm{h}, \mathrm{f}) = 4H + U + Vm$$

$$v(m, \ell, \mathrm{f}) = U + Vm$$

$$v(m, \mathrm{h}, \mathrm{n}) = W + Xm$$

$$v(m, \ell, \mathrm{n}) = Y + Zm.$$

Existence of such coefficients is now shown to be equivalent to the pair of inequalities $L \le \beta(1 - \rho)H/[2\theta - \beta(1 - \rho)] \le M$. For any values of the discount factor β, the rate of money growth θ, and the marginal utilities L, M, and H, there is a range of the reliability ρ of the information technology for intermediation, in which the two inequalities will hold. Some neighborhood of 1 is above the range. If the reliability of technology ρ is in that neighborhood, then money is not valued and consumption is autarkic when $\tau = \mathrm{n}$.

This conclusion is shown by studying the Bellman equation. Rewriting the equation in terms of these coefficients, and assuming the maximizing consumption decisions specified above in the Bellman equation for $v(m, s, \mathrm{n})$ yields the following system of equations:

$$4H + U + Vm = 4H + \beta\{\rho(2U + V[m + (\theta - 1)/\theta]) + (1-\rho)[W + Y + (X + Z)(m + [\theta - 1]/\theta)]/2\}$$

$$U + Vm = \beta\{\rho(2U + V[m + (\theta - 1)/\theta]) + (1-\rho)[W + Y + (X + Z)(m + [\theta - 1]/\theta)]/2\}$$

$$W + Xm = H(2 + m) + \beta\{\rho[2U + V([\theta - 1]/\theta)] + (1-\rho)[W + Y + (X + Z)([\theta - 1]/\theta)]/2\}$$

$$Y + Zm = M + \beta\{\rho[2U + V([m + \theta]/\theta)] + (1-\rho)[W + Y + (X + Z)([m + \theta]/\theta)]/2\}.$$

The first equation is obtained from the second by adding $4H$ to both sides, so consider only the second through fourth equations. Consider both $m = 0$ and $m = 1$ to obtain six independent affine equations in the six coefficients. The unique solution characterizes the value function. From the third equation, it is evident that $X = H$.

Money m enters the first, second, and fourth equations in exactly the same way, so $V = Z$. The value of holding money in any state except (h, n) is the expected discounted value of spending it at the first date when (h, n) is entered, so $V = Z = \beta(1 - \rho)H/[2\theta - \beta(1 - \rho)]$.

Thus, the parameter restriction framed above, that $L \leq \beta(1 - \rho)H/[2\theta - \beta(1 - \rho)] \leq M$, is equivalent to $L \leq Z \leq M$. That is, when a trader is in state (ℓ, n), then the specified consumption level 1 is optimal because the marginal utility of consumption below 1 is at least the marginal value Z of accumulating real balances, while the marginal value of consumption above 1 is no more than Z. However, if ρ is very close to 1, then $Z < L$, so a trader in state (ℓ, n) would choose to consume his entire endowment, and autarky in state n would result.

This extreme result partly reflects the parametrization of the model with a utility function, adopted for analytic tractability, that has a finite right derivative at zero consumption. In general (with a logarithmic utility parametrization, for example), it seems that the payment arrangement would reduce the level of real balances that traders are willing to hold, although it might not make traders completely unwilling to hold money. In that case the inflation rate would be the same as without the arrangement, but the initial price level would be higher, and the real value of seigniorage would be lower than absent the arrangement.

Now consider a second model, according to which a payment arrangement would not affect the acceptability of fiat money. This model follows Scott Freeman (1996) and Green (1997) in using assumptions about the timing of intra-cohort trade in an overlapping-generations economy to motivate cash payment. The payment arrangement modeled is net payment of intra-cohort trade, rather than the comprehensive risk-sharing arrangement considered in the preceding model.

A nonatomic population of identical traders, collectively of unit mass, are born at date 1, live only at date 1, and receive no endowment. This population, cohort 0, is divided arbitrarily into three equal-size groups, denoted by C_{01}, C_{02}, and C_{03}.

At every date $t = 1, 2, 3 \ldots$, an additional cohort of traders, collectively of unit mass, are born and live for two periods. Each trader in cohort t is endowed with one unit of a perishable good at date t, and receives no endowment at date $t + 1$. There are three goods, indexed by 1, 2, and 3, at each date. One-third of the traders in each cohort are endowed with each good. The set of cohort-t traders endowed with good ι is denoted by $C_{t\iota}$.

A trader in cohort 0 desires to consume the cohort-1 endowment good with his index. In subsequent cohorts, a trader $i \in C_{t\iota}$ desires to consume his own endowment good ι and also good $\iota + 1$ (mod 3) in his first period of life, and also to consume good ι in the second period. Let c_i, c_i', and c_i'' denote these three consumption levels. For example, for $i \in C_{t1}$, c_i, c_i', and c_i'' represent goods 1 and 2 at t and good 1 at $t + 1$, respectively.

Assume that traders maximize expected utility. The utility function of trader i is $u(c_i, c_i', c_i'', \alpha_i) = (1 - \alpha_i)\ln(c_i) + \alpha_i \ln(c_i') + \ln(c_i'')$, where $\alpha \in (0, 1)$ is randomly distributed in the population and independent of the endowment type. A trader i does not learn his value α_ι until after he has made his initial trade, as will be explained fully below.

The desired consumption pattern requires both intra-cohort and inter-cohort trade. Because of the overlapping-generations structure, intergenerational trade requires money to be used and accepted. Assume that every trader in cohort 0 is provided with one initial unit of money at date 1 and that, at each date t, every trader in cohort $t - 1$ is provided with $(\theta - 1)\theta^{t-1}$ units of new money. Note that a cohort-0 trader is provided with $1 + (\theta - 1)\theta^0 = \theta$ units of money in total.

Double coincidence of wants also fails to exist in intra-cohort trade. In an environment where three-trader coalitions cannot form to make explicit bargains, and where members of a cohort will be assumed not yet to have money when their opportunity to trade occurs, trade credit can be used to achieve or approximate the efficient allocation. However, assume that use of trade credit has a real cost. Specifically, assume that γ units of the buyer's endowment must be used in debt issuance for each unit of a seller's endowment good purchased. Assuming that the cost of payment depends on the real size of the trade reflects a supposition that the nominal price level should not affect the resources required.

In particular, consider a sequential "trading post" economy, the equilibria of which will correspond closely to competitive price-taking equilibria in an overlapping-generations economy (see Fumio Hayashi and Akihiko Matsui, 1996; Irasema Alonso, 1999). Consider arbitrary ι and κ in $\{1, 2, 3\}$ satisfying $\kappa = \iota + 1$ (mod 3). The following sequence of events at date t takes place concurrently for each of the three pairs (ι, κ). These events may be conceived of as operations of a trading institution that conducts two markets for each good, works according to gross payment, and can, by issuing fiat money, fulfill the obligations of a trader who defaults. This sequence and the limitations of participation in various markets to traders of particular cohorts and types are assumed to result from technological constraints in the environment. Let P_t denote the population measure on cohort t.

(i) Intra-cohort supply is provided. Each trader $k \in C_{t\kappa}$ deposits an amount $y(k)$ of his endowment that he will supply to members of $C_{t\iota}$. At this time, k does not yet know the value of his preference parameter α_k. He maximizes expected utility with respect to the parameter's probability distribution.

(ii) Each trader i learns his preference parameter, α_i.

(iii) Intra-cohort exchange is conducted. Each trader $i \in C_{t\iota}$ specifies a nominal debt $D(i, \alpha_i)$ that he promises to pay at date $t + 1$ in return for his consumption at t of good κ, and receives $c'(i, \alpha_i) = (\int_{C_{t\kappa}} y\, dP_t / \int_{C_{t\iota}} D\, dP_t)D(i, \alpha_i)$ units of good κ. Each trader $k \in C_{t\kappa}$ receives $C(k) = (\int_{C_{t\iota}} D\, dP_t / \int_{C_{t\kappa}} y\, dP_t)y(k)$ units of claims on money, which he carries over to date $t + 1$.

(iv) Each trader $k \in C_{(t-1)\kappa}$ receives $(\theta - 1)\theta^{t-1}$ units of money, which is added to $M(k, \alpha_k)$ units of money that he has carried over from trade with cohort $t - 2$ at date $t - 1$. [For $k \in C_{0\kappa}$, $M(k, \alpha_k) = 1$.]

(v) Trader k provides $D(k, \alpha_k)$ units of money to the trading institution and receives $C(k)$ units of money from the trading institution. If the trader has not defaulted on payment of $D(k, \alpha_k)$, then he holds $M'(k, \alpha_k) = M(k, \alpha_k) + (\theta - 1)\theta^{t-1} - D(k, \alpha_k) + C(k)$ units of fiat money at the conclusion of these transactions. If he has defaulted, then his money is confiscated and $M'(k, \alpha_k) = 0$. If necessary, the trading institution issues additional fiat money to satisfy the obligations of traders who default.

(vi) Inter-cohort trade is conducted. Each trader $k \in C_{t\kappa}$ deposits an amount $z(k, \alpha_k) \leq 1 - [y(k) + \gamma c'(k, \alpha_k)]$ of his endowment that he will supply to members of $C_{(t-1)\kappa}$. Each trader $k \in C_{(t-1)t\kappa}$ deposits his money holdings $M'(k, \alpha_k)$ with the trading institution and receives $c''(k, \alpha_k) = (\int_{C_{t\kappa}} z\, dP_t / \int_{C_{(-1)t\kappa}} M'\, dP_t)M'(k, \alpha_k)$ units of good κ. Each trader $k \in C_{t\kappa}$ receives from the trading institution $M(k, \alpha_k) = (\int_{C_{(t-1)t\kappa}} M'\, dP_t / \int_{C_{t\kappa}} z\, dP_t)z(k, \alpha_k)$ units of money, which he carries over to date $t + 1$.

The equilibrium concept for this sequential trading-post economy is Nash equilibrium, in which each trader i specifies $y(i)$, $D(i, \alpha_i)$, and $z(i, \alpha_i)$ optimally in the context of what other traders specify. Because no nonatomic trader can individually affect market aggregates, equilibrium is characterized by parametric price-taking. Intra-cohort trade is conducted at price $p_t = \int_{C_{t\iota}} D\, dP_t / \int_{C_{t\kappa}} y\, dP_t$. Inter-cohort trade is conducted at price $q_t = \int_{C_{(t-1)t\kappa}} M'\, dP_t / \int_{C_{t\kappa}} z\, dP_t$.

To model net payment in this environment, assume that, by using a fixed amount ν of endowment, a trader i can bear only the real variable cost $\gamma \max\{[c'(i, \alpha_i) - z'(i, \alpha_i)], 0\}$ rather than $\gamma c'(i, \alpha_i)$ to extinguish the debt for his intra-cohort trade. Moreover, a net-payment constraint against default, that $p_t(c_i' - z_i') \leq M(i) + (\theta - 1)\theta^{t-1}$, replaces the gross-payment constraint in stage (v). Even if the gross-payment constraint against default is not binding (as in this logarithmic-preference specification), traders whose net intra-cohort purchases are much smaller than their gross intra-cohort purchases (i.e., for whom α_i is not too large) will prefer net payment if ν is low. Net payment will affect the equilibrium. Notably it can break the no-arbitrage condition that $p_t = q_t$. Supplying endowment to the inter-cohort market for a good is not equivalent to supplying it to the intra-cohort market, because supplying an additional unit to the intra-cohort market can reduce the resource cost of purchasing a given quantity of the good acquired in intra-cohort trade. However, given the constant-income-shares property of demand in an economy where traders have logarithmic preferences, net payment affects intra-cohort allocation, while inflation affects inter-cohort allocation. Consequently, since the acceptability of fiat money derives from its usefulness in inter-cohort allocation, net payment does not impair its acceptability even in a high-inflation regime. While this particular dichotomy is specific to the overlapping-generations environment, it may instantiate a more general insight. Payment situations where noncash or net-payment arrangements are feasible and profitable to operate may not be the ones that are most crucial to determining whether fiat money is valued in equilibrium. If this conjecture were indeed true, then possibly the existence of such arrangements might have only limited implications, if any, for the design and implementation of monetary policy.

To summarize, model 1 represents noncash transactions as a type of contractual arrangement that achieves superior risk-sharing to spot-market exchange, whether monetary or nonmonetary. Such an arrangement would enhance welfare under optimal monetary policy. However, if policy were suboptimal (particularly if inflation were very high), then technical progress that makes the noncash-payment arrangement almost completely reliable could spoil the acceptability of fiat money. Of course, except in some exceptional situation such as there being no public-finance alternative to heavy taxation through seigniorage, the incompatibility of a high-inflation regime with a beneficial risk-sharing arrangement would count as a criticism of high inflation rather than of risk-sharing. Model 2 provides a contrasting formalization of innovation in payment arrangements as adoption of net payment, a feature of many actual arrangements. The model shows how such arrangements can reduce transaction costs, but it does not suggest that net payment would fundamentally affect (and plausibly improve significantly) economic relationships in the way that substituting contractual risk-sharing for spot-market transactions would do. Also, because net payment of intra-cohort trades does not provide a way to avoid using fiat money for inter-cohort trade, it does not seem that such an arrangement would spoil the acceptability of fiat money in a high-inflation regime. Given that a variety of innovative payment arrangements are being tried today, both of these models may be applicable to the actual economy. The divergence between their conclusions suggests taking a cautious attitude toward generalizations about the welfare effects and policy implications of payment innovations.

REFERENCES

Aiyagari, S. Rao and Williamson, Stephen. "Money and Dynamic Credit Arrangements with Private Information." Mimeo, University of Iowa, 1998.

Alonso, Irasema. "Patterns of Exchange, Fiat Money, and the Welfare Costs of Inflation." Mimeo, University of Rochester, 1999.

Bank for International Settlements. "Implications for Central Banks of the Development of Electronic Money." Basel: Bank for International Settlements, 1996.

Freeman, Scott. "The Payments System, Liquidity, and Rediscounting." *American Economic Review*, December 1996, *86*(5), pp. 1126–38.

Goodhart, Charles A. E. "Can Central Banking Survive the IT Revolution?" *International Finance*, July 2000, *3*(2), pp. 189–209.

Green, Edward J. "Money and Debt in the Structure of Payments." *Monetary and Economic Studies*, May 1997, *15*(1), pp. 63–87; reprinted in *Federal Reserve Bank of Minneapolis Quarterly Review*, Spring 1999, *23*(2), pp. 13–29.

Hayashi, Fumio and Matsui, Akihiko. "A Model of Fiat Money and Barter." *Journal of Economic Theory*, January 1996, *68*(1), pp. 111–32.

Henckel, Timo; Ize, Alain and Kovanen, Arto. "Central Banking without Central Bank Money." International Monetary Fund Working Paper No. WP/99/92, 1999.

King, Mervyn A. "Challenges for Monetary Policy: New and Old." *Bank of England Quarterly Bulletin*, November 1999, *39*(4), pp. 397–415.

Kocherlakota, Narayana and Wallace, Neil. "Incomplete Record-Keeping and Optimal Payment Arrangements." *Journal of Economic Theory*, August 1998, *81*(2), pp. 272–89.

Schreft, Stacey L. "Transaction Costs and the Use of Cash and Credit." *Economic Theory*, April 1992, *2*(2), pp. 283–96.