Transaction Services, Inflation, and Welfare

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This paper is motivated by empirical observations on the comovements of currency velocity, inflation, and the relative size of the credit services sector. We document these comovements and incorporate into a monetary growth model a credit services sector that provides services that help people economize on money. Our model makes two new contributions. First, we show that direct evidence on the appropriately defined credit service sector for the United States is consistent with the welfare cost measured using an estimated money demand schedule. Second, we provide estimates of the welfare cost of inflation that have some new features.

I. Introduction

This paper is motivated by a variety of empirical observations, to be described later, on the comovements of currency velocity, inflation,

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and the relative size of the *credit services* sector. By the credit services sector, we mean the part of the banking and credit sector that provides means of transactions other than currency as well as other services that help people economize on currency. These observations motivate our development of a monetary growth model in which a costly credit services sector provides means of transactions other than currency, as in the model of Gillman (1993).

Aside from being consistent with the empirical observations that motivate our modeling, our model makes two new contributions. The first is to show that direct quantitative evidence on the welfare cost of low inflation is consistent with the welfare cost as measured by using an estimated money demand curve following the classic analysis of Bailey (1956) and the more recent analysis of Lucas (1993). This is done by showing that the model establishes a link between money demand and the welfare cost of inflation on the one hand and the welfare cost of inflation and the relative size of the credit services sector on the other hand.[1] We then show that when the model is calibrated from a semilog money demand function estimated from U.S. data, the resulting welfare cost estimate is remarkably consistent with direct measures of the relative size of an appropriately defined credit services sector for the United States: essentially the cost incurred by banks and credit unions in providing demand deposit and credit card services. The welfare cost of inflation under either measure is about 0.5 percent of gross national product (GNP).

The second contribution of this paper is to provide estimates of the welfare cost of inflation that have some new features. We find that the total welfare cost of inflation is bounded at a fairly low level. The total welfare cost of inflation in our model reflects two distinct effects of inflation. The first is the effect noted above, that inflation affects the share of total output that is devoted to transaction services provided by the credit services sector. The second is that inflation distorts labor supply and investment decisions and thereby affects total output as in Stockman (1981) and Cooley and Hansen (1989, 1991). It turns out that the nature of the inflation-induced distortions in labor supply and capital accumulation depends on the functional form of the money demand function. For our specification, which fits U.S. data quite well, these costs are bounded no matter how high inflation is. Further, the relative size of the credit services

views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

[1] See Lucas (1993, p. 33) for a discussion of the welfare implications of resources used for providing transaction services.

sector also remains bounded with inflation. Consequently, the total welfare cost of inflation remains bounded with inflation. For our parameterization, this bound occurs at about 5 percent of consumption.

The rest of this paper is organized as follows. In Section II, we describe the empirical observations concerning comovements in inflation, M0 velocity, and the relative size of the banking and credit sector that motivate our study and modeling approach. In Section III, we describe our model and show that it is consistent with these observations. In Section IV, we provide direct quantitative evidence on the welfare cost of low inflation and show that this evidence is consistent with the welfare cost measured using an estimated money demand curve. In Section V, we describe our model's quantitative implications for the welfare cost of inflation. Finally, in Section VI, we offer some concluding remarks concerning the robustness of our results to alternative specifications.

II. Comovements in Inflation, Velocity, and the Relative Size of the Banking and Credit Sector

In this section, we provide some evidence of comovements among inflation, M0 velocity, and the relative size of the banking and credit sector. This evidence is of two types. First, we show that in high-inflation countries, movements in velocity and the relative size of the banking and credit sector tend to parallel movements in inflation. Our evidence comes from Israel, Argentina, and Brazil, which experienced episodes of very high inflation during the 1980s, and from Austria, Hungary, Poland, and Germany, which experienced hyperinflations after World War I. Second, we show that for the United States, even after one accounts for the comovements of velocity with inflation, there is residual comovement between velocity and the relative size of the banking and credit sector in post–World War II data.

We acknowledge that the relative size of the banking and credit sector is an imperfect proxy for the relative size of the credit services sector. Banks perform many functions other than those that help people economize on currency, and many functions that help people economize on currency are performed outside of banks. Unfortunately, data limitations compel us to use these crude proxies. However, we feel it is plausible that for countries that have experienced episodes of very high inflation over a relatively short period of time, most of the movements in the relative size of the banking and credit sector are due to changes in services that help people economize on currency. In our discussion of velocity, we use M0 as the measure of money. We feel that this is appropriate for our purposes since we make the relevant distinction in our analysis between costlessly provided outside money and costly inside monies.

We first describe observations from some high-inflation countries.

High-Inflation Countries

The strong association between the relative size of the banking and credit sector and inflation is most transparent in economies that experienced an accelerating inflation and then an end to the inflation period. In figure 1*a*, we display data on inflation, the share of employment in banks, and the total number of bank accounts for Israel, which experienced a period of high and accelerating inflation from 1970 to 1985. This figure shows a significant upward trend in the share of employment in banks and in the number of bank accounts from 1968 to 1985. In July 1985, the Israeli government implemented a stabilization program, which resulted in an abrupt drop of the annual inflation rate from a high of close to 500 percent to a low of 16–20 percent. During the period from 1986 to 1989, the share of employment in banks and the total number of bank accounts dropped.[2]

Argentina also experienced a protracted period of accelerating inflation, as shown in figure 1*b*. In April 1991, the Argentinean government implemented a stabilization program that abruptly reduced the annual inflation rate from close to 350 percent to 10 percent over a period of several months. Figure 1*b* shows a strong positive relationship between the employment share in the banking sector and the inflation rate as measured by the consumer price index.[3] The banking employment share increased rapidly during the years 1975 and 1976, a period in which the annual inflation rate exceeded 150 percent. The banking employment share peaked in 1980 and then gradually fell thereafter. The number of bank branches shows a similar pattern of comovement with inflation.

Brazil also experienced a long period of accelerating inflation during the 1980s. The latest effort to reduce the inflation rate in Brazil began in December 1994, and it is still too soon to get data for the postinflation period. However, recent reports (see, e.g., "Brazil:

[2] Data on the number of teller machines per 100 people and the area of banks per 1,000 people also show a similar pattern of comovement with inflation (see Aiyagari and Eckstein 1966, table 1).

[3] The measure of banking sector employment summarized in this figure includes employees in private banks, public banks, and other financial entities. Employees of the central bank of Argentina are excluded.

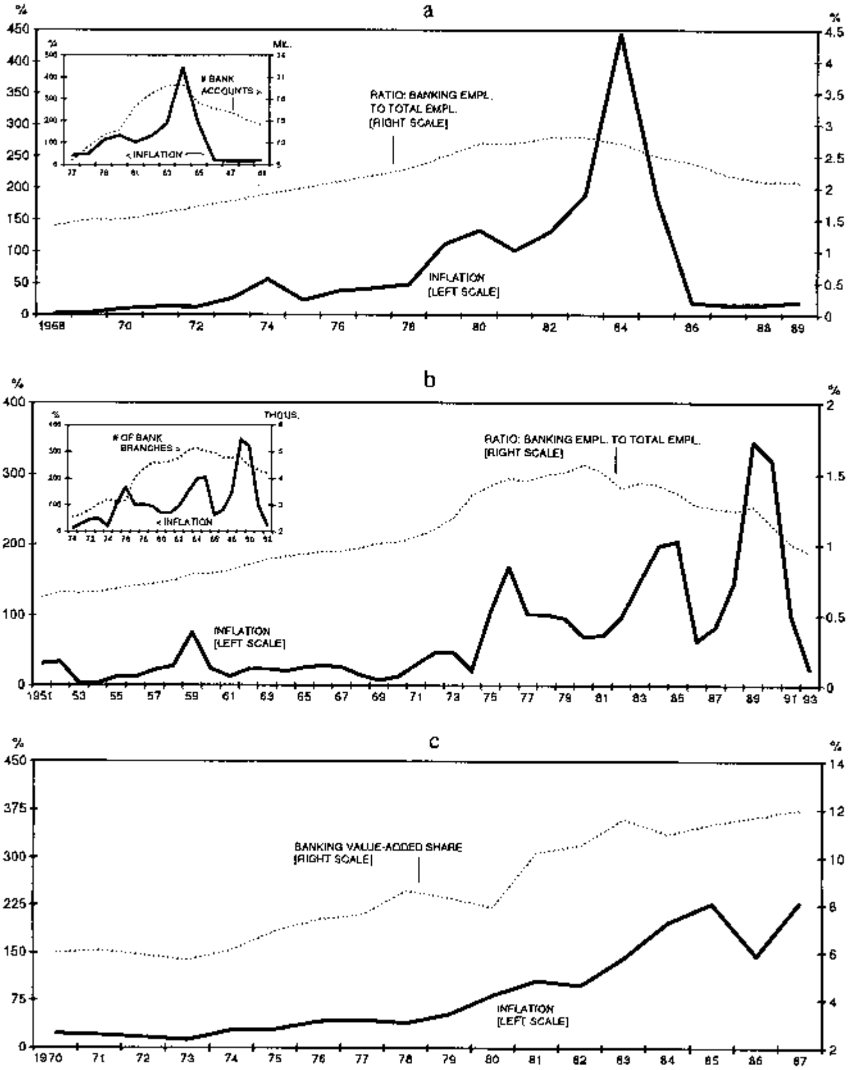

FIG. 1.—Banking sector indicators for Israel, Argentina, and Brazil. *a*, Israel, 1968–89; *b*, Argentina, 1951–92; *c*, Brazil, 1970–87.

Banking, It's Wonderful," 1995) suggest that the story of Israel and Argentina is being repeated in Brazil. Figure 1*c* displays data on the value-added share of the financial sector in gross domestic product (GDP) and data on inflation in Brazil. Once again, we see that the long period of accelerating inflation is accompanied by an increase in the relative size of the banking sector. Evidence on check clearing is also consistent with this view. During the late 1980s, Brazil cleared nearly twice as many checks annually (relative to GNP) as the United States. Moreover, checks were cleared faster in Brazil than in the United States. Evidence from Brazil and Argentina also indicates that banks tend to largely abandon traditional banking activities during high-inflation periods and focus, instead, on activities that help individuals economize on their holdings of cash.[4]

Wicker (1986) documents sharp increases in unemployment in the banking sector in Austria, Hungary, and Poland during the post-stabilization period in the 1920s. With reference to the Hungarian case, Wicker states that

> the most striking thing about these figures [incidence of trade union unemployment] is the extraordinary increase in the number of unemployed in the financial sector—31.5 percent of the total net increase of 13,000. All of this increase can be attributable to the ending of hyperinflation which had increased substantially the money market as well as other operations of the commercial banks. [P. 358]

For Austria, Wicker describes a similar pattern in which 10,000 workers in the banking sector lost their jobs immediately after stabilization. With regard to the German hyperinflation of the early 1920s and its stabilization, Bresciani-Turroni (1937), Graham (1967), and Garber (1982) indicate that there was a substantial increase in employment in the banking sector during the period of accelerating inflation and a decrease in employment in that sector after stabilization.

A Low-Inflation Country: The United States

The United States has never experienced such severe bouts of inflation as the countries described above. Still, even in the United States, there is statistical evidence that points to comovements between indicators of the banking sector and velocity. This point is illustrated in figure 2, which displays the time series of actual inverse velocity and its fitted values for two alternative regressions. The first set of fitted values is based on a regression of inverse M0 velocity on the nominal interest rate and a constant.[5] The second set of fitted values adds

[4] During periods of high inflation, banks make huge returns on the *float* they hold. "Brazil: Banking, It's Wonderful" notes that the top 40 Brazilian banks made as much from managing float as from traditional banking activities.

[5] Output is measured using GNP less net exports and government purchases, and the nominal interest rate is measured using the commercial paper rate. The data are annual, and the sample period runs from 1930 to 1989.

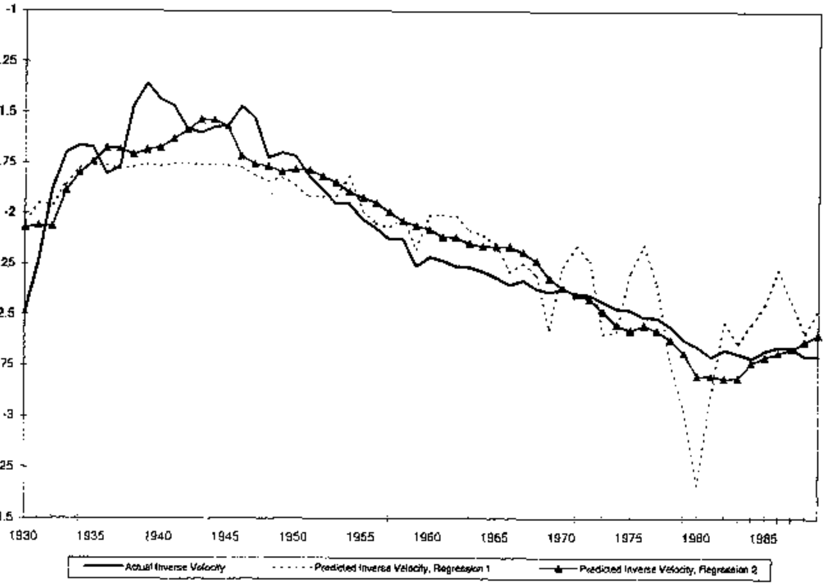

FIG. 2.—M0 inverse velocity: actual vs. predicted. Regression 1: $\ln(m_t/Y_t) = -1.687 - 10.02R_t + e_t$, $R^2 = .73$. Regression 2: $\ln(m_t/Y_t) = -0.8966 - 1.15R_t - 107.21ebnk_t + e_t$, $R^2 = .89$.

the employment share of the banking sector in total employment to the list of right-hand-side variables.[6]

First, notice that regression 1 captures well the secular movements in inverse velocity. However, large swings in the nominal interest rate in the period after 1965 produce fluctuations in predicted inverse velocity, from regression 1, that are at odds with the actual time path of inverse velocity. This phenomenon has been the source of a large literature on the stability of money demand and has provided the fuel for a debate that questions the usefulness of money aggregates as indicators of monetary policy.[7]

A number of studies suggest that economic activity in the financial

[6] The employment share of the banking sector in total employment is the ratio of employment of full-time and part-time employees in the banking sector to total employment of full-time and part-time employees. Both time series are taken from table 6.6B of the National Income and Product Accounts and are reported in various issues of the *Survey of Current Business*.

[7] The literature on this issue has not reached a firm conclusion (see, e.g., Goldfeld and Sichel 1990; Mishkin 1998, pp. 548–53). Recently, though, Lucas (1988) and Stock and Watson (1993) have considered specifications like regression 1 and argued that there is a stable long-run relationship between money, output, and interest rates.

sector is correlated with velocity (see, e.g., Judd and Scadding 1982; Dotsey 1985; Melnick 1995). Regression 2 follows this suggestion. It can be seen, by a visual inspection of figure 2, that predicted inverse velocity smoothly follows actual velocity. This is also borne out by the improvement in R^2. These results indicate that movements in inverse velocity are strongly correlated with one measure of the size of the banking sector.[8]

In the next section, we describe our monetary growth model and show that this model predicts comovements between indicators of the size of the banking sector and inflation and comovements between indicators of the banking sector and velocity that are consistent with the observations from the high-inflation episodes of Argentina, Brazil, and Israel as well as the regression results for the United States.

III. A Monetary Growth Model with Credit Goods Production

We use a variant of the cash-in-advance (CIA) model. The key feature of our model is that cash goods and credit goods are perfect substitutes in consumption and investment but differ in their production technologies. Specifically, the production of credit goods is a resource-using activity.[9] The model is a competitive equilibrium model and is described in terms of the behavior of its three decision units—namely, the households, the producers, and the government—and in terms of the equilibrium conditions. We start by describing the technology and the behavior of the representative producer.

The Technology and Producer Optimization

Total output, denoted Y_t^*, is produced using capital (K_t) and labor (N_t) with a constant returns to scale production function F. Total output can be used to produce goods (Y_t) for investment and consumption on a one-to-one basis or can be used to produce credit

[8] Note that the estimated value of the interest elasticity is much lower in regression 2. We attribute this decline in the estimated value of the interest elasticity to the .88 simple correlation between the employment share of the banking sector and the nominal interest rate.

[9] This approach is unlike the cash goods/credit goods model of Lucas and Stokey (1987), in which cash goods and credit goods are perfect substitutes in production but not in preferences. The approach is similar to that of Gillman (1993). For example, our approach says that gasoline is gasoline, regardless of whether one pays for it with cash or credit.

services (S_t), where one unit of credit services requires q_{st} units of total output. Therefore, we have

$$Y_t^* = F(K_t, \theta_t N_t) = Y_t + q_{st} S_t. \tag{1}$$

The labor-augmenting technology shock θ_t is assumed to follow a trend stationary stochastic process with an average growth rate of g. The cost of producing credit services q_{st} is assumed to follow a stationary stochastic process. Later, we shall assume that the production function F is Cobb-Douglas so that data on the labor share can be used to estimate its parameter. Empirically, the labor share in the banking and credit sector is not much different from the labor share in GNP. The goods-producing sector of the model is identified with GNP less net exports, government purchases, and value added in the banking and credit sector. Using U.S. annual data from 1947 to 1989, we find labor shares of .62 and .59 in the banking and credit sector and the goods-producing sector, respectively.

The output of goods Y_t is assumed to be uniformly distributed across a continuum of types indexed by $z \in [0, 1]$. A unit of the type z good can be used in two ways: It can be used to produce a unit of the cash good on a one-to-one basis, or it can be combined with $\mathcal{R}(z, \epsilon_t)$ units of credit services and used to produce a unit of the credit good. We assume that $\mathcal{R}$ is strictly increasing in z with $\mathcal{R}(0, \epsilon_t) = 0$. That is, a good that is indexed with a higher value of z requires more services to be transformed into a credit good.[10] A random variable ϵ_t is assumed to follow an exogenous stationary stochastic process that is independent of θ_t and q_{st}.

A unit of the type z good (either a cash good or a credit good) can be either consumed or used for gross investment, that is, to produce new capital goods.[11] If we let i_t and $i_t(z)$ be gross investment and the amount of the type z good used for gross investment, then the technology for gross investment is the following Leontief fixed-coefficients type:

$$i_t = \inf_z \{i_t(z)\}. \tag{2}$$

We now describe some implications of producer optimization. It is obvious that $p_{st}/p_{1t} = q_{st}$, where p_{1t} and p_{st} denote the prices of cash goods and credit services, respectively. Further, $w_t = \theta_t F_2(K_t, \theta_t N_t)$

[10] This specification of the technology for producing credit goods is similar to that of Gillman (1993).

[11] Thus we do not arbitrarily designate consumption goods as cash goods and investment goods as credit goods as, e.g., Cooley and Hansen (1989) do.

and $r_t = F_1(K_t, \theta_t N_t)$, where w_t and r_t are, respectively, the wage and the rental on capital in units of the cash good. Letting $p_{2t}(z)$ denote the price of type z credit goods, we have

$$p_{2t}(z) = p_{1t} + p_{st}\mathcal{R}(z, \epsilon_t) = p_{1t}[1 + q_{st}\mathcal{R}(z, \epsilon_t)], \tag{3}$$

which follows from the fixed-coefficients technology for the production of credit goods. Notice that our assumptions on $\mathcal{R}(\cdot)$ imply that the credit price of a good is increasing in the type index z.

The Representative Household

There is a representative infinitely lived household that has one unit of labor endowment available each period. The household consumes the amount $c_t(z)$ of type z goods and supplies the amount n_t of labor input in each period t. The household's preferences are given by the following expected discounted sum of utilities of consumption and leisure:

$$E_0\left[\sum_{t=0}^{\infty} \beta^t U(c_t, 1 - n_t)\right], \quad 0 < \beta < 1, \tag{4a}$$

where

$$c_t = \inf_z\{c_t(z)\} \tag{4b}$$

is (composite) consumption.[12]

The household purchases $\chi_t(z)$ units of the type z good and uses these goods for consumption and gross investment. In view of (2) and (4b), we have

$$\begin{aligned} i_t(z) &= i_t, \\ c_t(z) &= c_t, \\ \chi_t(z) &= \chi_t \quad \text{for all } z, \end{aligned} \tag{5a}$$

where

$$\chi_t = c_t + i_t = c_t + k_{t+1} - (1 - \delta)k_t. \tag{5b}$$

In (5b), k_t is the stock of capital that the household has at the beginning of period t and δ is the depreciation rate of capital.

We now describe the household's optimization problem. We start with the household's CIA and budget constraints. The total purchases χ_t will be partly in the form of cash goods and partly in the

[12] Our specification is the same as that used by Schreft (1992).

form of credit goods. Since the cash price of goods is constant across types, whereas the credit price of goods is increasing in the type index z, there will be a particular cutoff index z_t^* such that the household will purchase goods with indices below z_t^* as credit goods and purchase goods with indices above z_t^* as cash goods. Thus purchases of credit goods equal $\chi_t z_t^*$ and purchases of cash goods equal $\chi_t(1 - z_t^*)$.

In addition to capital, the household begins period t with m_t units of money and b_t units (in terms of face value) of nominal bonds. The household also receives nominal lump-sum transfer payments from the government in the amount of X_t. As is usual in CIA models of money, there is a financial market in which the household can rearrange its portfolio of money and bonds. Once this is done, the financial market closes and the goods markets (for purchasing cash goods and credit goods) open. In the cash goods market, the household can purchase cash goods subject to the following CIA constraint:

$$\frac{m_t + X_t}{p_{1t}} + \frac{b_t}{p_{1t}} - \frac{b_{t+1}}{(1 + R_t)p_{1t}} \geq \chi_t(1 - z_t^*), \tag{6}$$

where R_t is the nominal interest rate from t to $t + 1$. Note that the left side of (6) is the amount of cash the household has available after the close of the financial market.

The household's budget constraint is

$$\begin{aligned}\frac{m_t + X_t}{p_{1t}} + \frac{b_t}{p_{1t}} + w_t n_t + r_t k_t \geq{}& \chi_t(1 - z_t^*) \\ &+ \left[\frac{\int_0^{z_t^*} \chi_t p_{2t}(z)\,dz}{p_{1t}}\right] + \frac{m_{t+1}}{p_{1t}} + \frac{b_{t+1}}{(1 + R_t)p_{1t}},\end{aligned} \tag{7}$$

where $\int_0^{z_t^*} \chi_t p_{2t}(z)\,dz$ is the total nominal cost of purchasing credit goods.

Note that wage and rental income is received after the close of the financial market and cannot be used for purchases of cash goods. Further, labor and capital services are treated as costless credit goods; that is, they do not require credit services for exchange.

The household maximizes the expected discounted sum of utilities in (4a) subject to the following constraints: total purchases equal purchases for consumption and investment (5b), the CIA constraint (6), and the budget constraint (7). The solution to the consumer's optimization problem is characterized by the following first-order necessary conditions (FONCs):

$$\frac{U_{1,t}}{U_{c,t}} = \frac{w}{1 + \tau_t}, \tag{8a}$$

$$\frac{U_{c,t}}{1 + \tau_t} = \beta E_t \left[\frac{U_{c,t+1}(p_{1t}/p_{1,t+1})(1 + R_{t+1})}{1 + \tau_{t+1}} \right], \tag{8b}$$

$$U_{c,t} = \beta E_t \left[\left(\frac{1 - \delta + r_{t+1}}{1 + \tau_{t+1}} \right) U_{c,t+1} \right], \tag{8c}$$

$$1 + R_t = \frac{p_{2t}(z_t^*)}{p_{1t}}, \tag{8d}$$

where

$$1 + \tau_t = (1 - z_t^*)(1 + R_t) + \frac{\int_0^{z_t^*} p_{2t}(z)\, dz}{p_{1t}}, \tag{9}$$

and $U_{1,t}$ and $U_{c,t}$ denote the marginal utilities of leisure and consumption, respectively, in period t.

Government

The government sets the money growth rate $x_t \equiv (M_{t+1} - M_t)/M_t$ in such a way that x_t follows a stationary stochastic process that is independent of $\{\theta_t, q_{st}, \epsilon_t\}$.

Equilibrium

The following conditions (which are pretty self-explanatory) need to hold in equilibrium:

$$F(K_t, \theta_t N_t) = Y_t + q_{st} S_t, \tag{10a}$$

$$\chi_t = Y_t = C_t + K_{t+1} - (1 - \delta) K_t, \tag{10b}$$

$$Y_t \int_0^{z_t^*} \mathcal{R}(z, \epsilon_t)\, dz = S_t, \tag{10c}$$

and

$$(k_t, n_t, c_t, m_t) = (K_t, N_t, C_t, M_t), \quad \text{with } K_0, M_0 \text{ given.} \tag{10d}$$

In (10c), the expression on the left is the total amount of credit services used in producing credit goods.

This completes the description of the model.

We now show that the qualitative predictions of the model are consistent with the empirical observations in Section II. These observations are that inflation, the relative size of the banking and credit sector, and velocity tend to comove and that there is residual comovement between the relative size of the banking and credit sector and velocity, even after one accounts for the comovement due to inflation. The key element of our model, on which its implications rest, is the link between money demand and the value-added share of the credit services sector, which we now proceed to derive.

Money Demand

The money demand function in our model is derived from the household's FONC (8d), which is a Baumol (1952)–type condition that sets the opportunity cost of cash equal to the cost of credit services for the marginal good. Either a household can purchase an extra unit of the cash good at price p_{1t} by borrowing in the financial market at the interest rate R_t, thereby reducing its cash holdings at $t + 1$, or it can purchase a unit of the marginal credit good (with index z_t^*) at the price $p_{2t}(z_t^*)$, reducing its cash holdings in period $t + 1$. Since cash goods and credit goods are perfect substitutes in consumption and investment, the marginal condition (8d) must hold.

We can use (3) to rewrite (8d) in the following way:

$$R_t = q_{st}\mathcal{R}(z_t^*, \epsilon_t). \tag{11}$$

This condition determines the cutoff index z_t^* as illustrated in figure 3. Goods with indices lower than z_t^* are purchased as credit goods, and goods with indices higher than z_t^* are purchased as cash goods. If the relative price of credit services is held fixed, an increase in the nominal interest rate leads to an increase in the fraction of goods bought on credit (since $\mathcal{R}$ is increasing) and, hence, a decrease in the fraction of goods bought with cash.

Letting $m_t = M_{t+1}/p_{1t}$ denote real balances and noting that (10b) and the CIA constraint imply that $z_t^* = 1 - (m_t/Y_t)$, we can rewrite (11) to obtain the following inverse money demand function for our model:

$$R_t = q_{st}\mathcal{R}\left(1 - \frac{m_t}{Y_t}, \epsilon_t\right). \tag{12}$$

From this equation, we see that the money demand function for our model reflects the technology for producing credit goods.

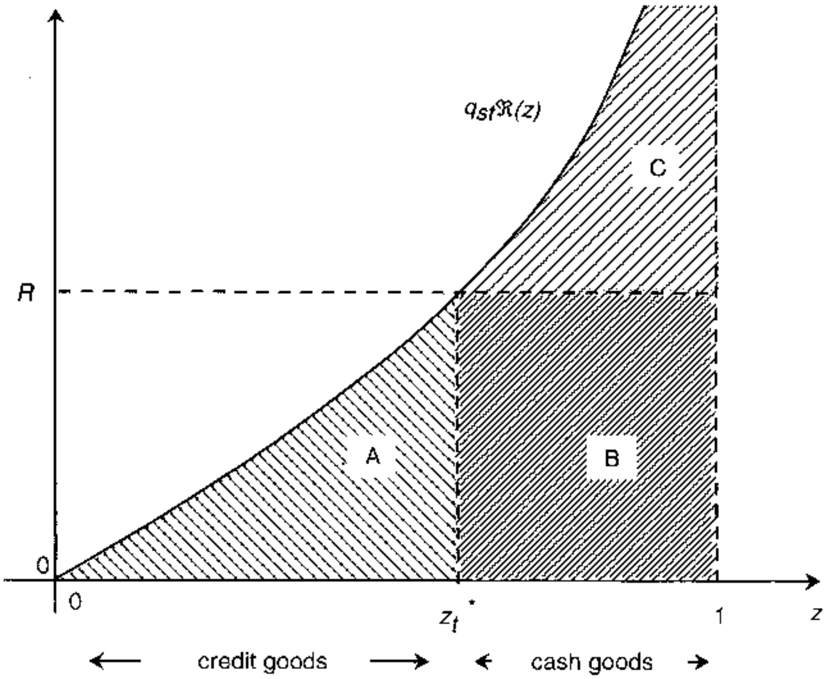

FIG. 3.—Credit goods production. Area A equals resources used for credit goods (a_t), area $A + B$ equals the effective inflation tax rate (τ_t), and area $B + C$ equals resource saving from money.

Credit Services

Let $\phi_t = q_{st}S_t/Y_t^*$ denote the value-added share of credit services in GNP. We now derive the relation between ϕ_t and money demand. To exhibit this, it is convenient to let a_t denote q_{st} times the integral in (10c). Thus a_t measures the amount of credit services used (in units of goods) per unit of goods produced (see area A in fig. 3 for an illustration). Note that a_t is also the area under the inverse money demand curve normalized by the highest possible value of real balances. To see this, let A_t denote the area under the inverse money demand curve and note that

$$a_t \equiv \int_0^{z_t^*} q_{st}\mathfrak{R}(z, \epsilon_t)\,dz = \frac{\displaystyle\int_{m_t}^{Y_t} q_{st}\mathfrak{R}\left(1 - \frac{m}{Y_t}, \epsilon_t\right)dm}{Y_t} = \frac{A_t}{Y_t}. \qquad (13)$$

The relation between a_t and ϕ_t is as follows:

$$a_t \equiv \int_0^{z_t^*} q_{st}\mathcal{R}(z, \epsilon_t)\, dz = \frac{q_{st}S_t}{Y_t} = \frac{\phi_t}{1 - \phi_t}. \tag{14}$$

Equation (14) exhibits the key link in our model between the value-added share of the credit services sector and money demand. This link arises because in our model, the area under the inverse money demand curve measures the amount of credit services that are used, which implies that anything that affects velocity will affect the value-added share.

Comovements with Inflation

Equation (14) implies a positive comovement between inflation and the relative size of the credit services sector. As inflation and the nominal interest rate rise, the opportunity cost of cash goods rises and pushes consumers to purchase fewer cash goods and more credit goods (see [12] and fig. 3). Thus real balances fall, velocity rises, and the share of credit goods in total goods rises. The fall in real balances raises the normalized area under the inverse money demand curve a_t. Equivalently, the greater quantity of credit goods requires a greater quantity of credit services (see [14] and fig. 3). Hence, capital and labor move into the credit services sector, and its value-added share (ϕ_t) rises. Thus our model can account for the comovement among inflation, velocity, and the relative size of the banking and credit sector.

Our model is also consistent with the strong linkage between inverse velocity and the employment share of the banking and credit sector that remains after one accounts for comovement due to inflation (see fig. 2 and the discussion in Sec. II). This is true because, in addition to inflation, improvements in the technologies for producing credit services and credit goods can generate comovements between velocity and the value-added share of credit services. Such technological improvements can be interpreted as decreases in q_{st} and in ϵ_t. Both of these types of decreases lower the cost of buying goods on credit and thereby increase the share of credit goods, reduce money demand, and, hence, raise currency velocity. Noting that $z_t^* = 1 - (m_t/Y_t)$ and using (12) and (14), we can express m_t/Y_t and ϕ_t as functions of $(R_t, q_{st}, \epsilon_t)$:

$$\frac{m_t}{Y_t} = M(R_t, q_{st}, \epsilon_t) \tag{15a}$$

and

$$\phi_t = \Phi(R_t, q_{st}, \epsilon_t). \tag{15b}$$

Therefore, movements in velocity that are unexplained by interest rates ought to be correlated with movements in the value-added share that are unexplained by interest rates. Alternatively, the value-added share ϕ_t (equivalently, the employment share) ought to improve the fit of the money demand equation. Thus our model is consistent with figure 2, which is discussed in Section II.

Having shown that our model is consistent with the qualitative evidence linking inflation, currency velocity, and the banking and credit sector, we now examine direct quantitative evidence on the welfare cost of inflation, which is consistent with an empirically estimated money demand function. This evidence is one of the two main contributions of this paper and is described in the next section.

IV. Direct Quantitative Evidence of the Welfare Cost of Inflation

As we have previously discussed, a key feature of our model is that a rise in inflation leads to an expansion of the credit services sector. It is easy to see that resources allocated to this sector represent a social waste. In order to focus on this misallocation of resources, let us assume temporarily that labor supply is inelastic and fixed at n and that gross investment is exogenously fixed at the constant fraction $(g + \delta)$ of the capital stock so that the capital stock grows exogenously at the same rate as θ. We can rewrite (10b) using (10a) as follows:

$$C_t + K_{t+1} - (1 - \delta)K_t = Y_t = (1 - \phi_t)F(K_t, \theta_t n_t). \tag{16}$$

Now note that when the nominal interest rate is zero, all goods are sold as cash goods, and the share of credit goods z_t^* is zero (see [11] and fig. 3). Hence, the normalized area under the inverse money demand curve a_t is zero, and thereby the value-added share ϕ_t is zero (see [13] and [14]). It follows that consumption is at its highest. When the nominal interest rate is positive, ϕ is positive and acts as a tax on GNP, which reduces consumption and, hence, welfare. It is obvious that ϕ is an exact measure of the loss in consumption, relative to GNP, when total resources are held fixed. Thus we have shown that resources diverted to the credit services sector from the goods production sector are misallocated and that the value-added share in the credit services sector is one component of the welfare cost of inflation.

Therefore, one way to measure the welfare cost of inflation is to directly measure the relative size of an appropriately defined credit services sector. A second way to measure the welfare cost of inflation is to calculate the area under the inverse money demand curve (with Y_t held fixed). To see that this is equivalent, note that the welfare cost (denoted ΔW) can be written as

$$\begin{aligned}\Delta W_t = -\Delta C_t = \phi F(K_t, \theta_t n_t) = q_s S_t = q_s Y_t \int_0^{z_t^*} \mathcal{R}(z, \epsilon)\, dz \\ = \int_{m_t}^{Y_t} q_s \mathcal{R}\left(1 - \frac{m}{Y_t}, \epsilon\right) dm.\end{aligned} \tag{17}$$

Thus, from the last equality in (17), we see that the welfare cost corresponds exactly to the area under the inverse money demand curve.[13]

We now provide empirical evidence from U.S. data, which shows that the area under an estimated money demand curve does, indeed, match well with direct measures of the relative size of an appropriately defined credit services sector for the United States.

We first describe how the model is parameterized.

Parameterization

We start with the specification of the money demand function. The only restrictions on the functional form of money demand are that it have a unit income elasticity, be decreasing in the nominal interest rate, and be bounded, even as the nominal interest rate goes to zero (see [12]). The last restriction is due to the CIA nature of our model so that money demand remains bounded by Y_t. Thus our model accommodates a wide variety of functional forms for money demand within a one-sector monetary growth model with standard specifications of preferences, technology, and growth and can be calibrated from empirically estimated money demand functions. We use the semilog form of money demand. This specification can be obtained from the following specification of the $\mathcal{R}(\cdot)$ function:

$$\mathcal{R}(z, \epsilon_t) = -\eta[\ln(1 - z) - \epsilon_t]. \tag{18}$$

This specification leads to the following semilog specification of money demand:

[13] This is the component of the welfare cost of inflation captured in the models of Lucas (1993). It is interesting to note that Lucas finds his numbers to be approximately the same as the area under the inverse money demand curve; in our model, they are exactly the same as this area.

$$\ln(m_t) = \frac{-R_t}{q_{st}\eta} + \ln(Y_t) + \epsilon_t. \tag{19}$$

Before we estimate the parameters of the model, equation (19) has to be converted from the time frequency of the model to the frequency of our data, which is annual. Let d be a factor for expressing the model frequency in periods per year, so that if $d = 6$ then the model frequency is $12/6 = 2$ months. Next let Y_a and R_a be the corresponding annual values for output and the nominal interest rate. Then, setting $Y_t = Y_a/d$, $R_t = R_a/d$, and $m_t = m_a$ and substituting into equation (19) yields

$$\ln\left(\frac{m_a}{Y_a}\right) = -\ln(d) - \frac{R_a}{dq_{st}\eta} + \epsilon_a. \tag{19$'$}$$

From this expression it can be seen that if q_{st} is constant, equation (19′) is exactly regression 1 in figure 2. Moreover, equation (15b) implies that all the right-hand-side variables in (19′) are correlated with the value-added share ϕ_t and the employment share of the banking sector. Hence, the model is consistent with the improved fit of regression 2 in figure 2 and the high correlation between the employment share and the nominal interest rate. In particular, even if q_{st} is constant, movements in ϵ_t, the shock to credit goods production, and movements in θ_t, the shock to goods production, will produce movements in both R_t and ϕ_t.

We now describe how equation (19′) is used to parameterize our model. In our model q_{st} always appears as a product multiplying η. Consequently, to evaluate the steady-state welfare cost of inflation, it is sufficient to estimate the product $q_s\eta$, where q_s is the mean of q_{st}. This is convenient because, as we noted above in Section III, q_{st} is equal to the relative price of the banking sector in equilibrium, and thus the scale of this variable is not identified.

The simplest way to proceed is to assume that q_{st} is constant. Under this assumption, we can use regression 1 in figure 2 to identify the period length, d, and $q_s\eta$. The estimated value of the constant from this regression is -1.687. This implies a model frequency of 5.4 periods per year. The estimated semielasticity is 10. This provides an estimate for $q_s\eta = .1/5.4$. A potential problem with these estimates is that R_t is correlated with ϵ_t. Assuming that ϵ_t is exogenous and independently and identically distributed implies that it is uncorrelated with lagged values of R_t. Moreover, the intertemporal structure of the model implies that R_t is serially correlated. So R_{t-1} can be used as an instrument for R_t. Reestimating (19′) using the same data and R_{t-1} as the instrument produces the following instrumental variable estimates: $\ln(m/y) = -1.633 - 11.05R$. Notice that they are not significantly different from those reported in figure 1.

Regarding the second regression reported in figure 2, the question is whether one can use this regression to uncover alternative estimates of $q_s\eta$. The answer is no. Regression 2 does not provide any direct evidence on the parameters of the model. It only reflects the existence of correlations predicted by the model that are described in equation (15b). Note, for instance, that inverse velocity, R_t, and ϕ_t are all functions of θ_t. Adding ϕ_t as a right-hand-side variable to (19′) will pick up on these correlations and alter the estimated coefficient on R_t. However, the coefficient on R_t in the second regression is not a consistent estimate of $q_s\eta$. Our model implies that regression 1 is the correct specification for estimating $q_s\eta$, not regression 2.

An alternative way to calibrate the parameters of the money demand, $q_s\eta$, is to fix the period length ex ante. If we suppose that the period length is 2 months and assume that ϵ_t is zero, then we can calibrate $q_s\eta$ using means of annual M0 velocity and the nominal interest rate. Using the last 20 years of data in our sample to do this, we find that the calibrated value of $q_s\eta$ is equal to $-(R/6) \times \{1/[\ln(m/y) + \ln(6)]\} = -(.085/6) \times [1/(-2.65 + 1.79)] = .098/6$. Not surprisingly, this calibration method produces almost the same value of $q_s\eta$ as the regression analysis.[14] Lucas (1988), who uses M1 as his definition of money, also estimates $q_s\eta$ to be close to .1 using annual data. On the basis of this evidence, we set $q_s\eta = .1$ for annual interest rates.

The rest of the model specification is as follows. The period length is set to be 2 months. The utility discount factor $\beta = .9516$ (annual), and the utility function is taken to be log-linear in consumption and leisure, with the weight on consumption equal to .311. These values are chosen to match the real return to capital and the share of hours worked in total hours. The production function is taken to be Cobb-Douglas with a capital share parameter of .36. The annual deprecia-

[14] We also estimated d and $q_s\eta$ using (19′) and a measure of q_{st} based on the model. Though we have no direct measures of q_{st}, an equilibrium condition of our model is that q_{st} is equal to the relative price of the banking and credit sector. Using the national accounts data, we have an annual implicit price of GNP as it is defined by the model (see nn. 5 and 6) and an annual implicit price level for the banking and credit sector from 1947 to 1987. It is well known that these relative prices do not control well for quality, and therefore, they have a positive trend. As a result, we detrended the relative price and used the residuals, with a normalized mean of one, as a measure for q_{st}. When R_{t-1}/q_{st-1} is used as an instrument, the estimated semiannual elasticity of eq. (19′) for the 1947–87 period is 7.9 and d is 6.3 months. The calculations that we report below regarding the value-added share of the banking sector and the welfare cost of inflation are virtually the same when we use this alternative estimate of $q_s\eta$.

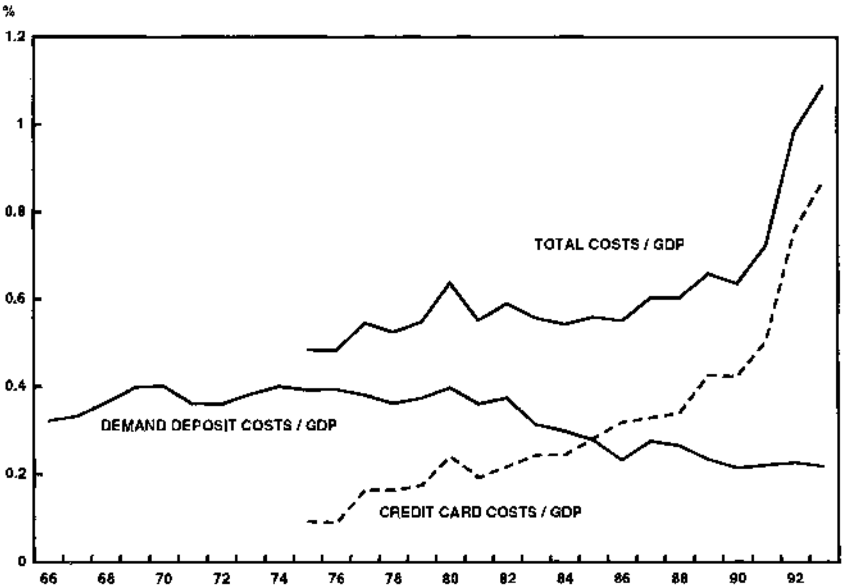

FIG. 4.—Costs associated with transaction service relative to GDP, annual data, 1966–93.

tion rate of capital is set at .06, and the annual exogenous trend growth rate of the economy is set at .02.

Before reporting the welfare cost of inflation that is calculated from the specification of the model discussed above, we measure the cost of inflation by the direct cost of providing the transaction services that replace cash in the U.S. economy. In figure 4, we display a time series of the costs (as a percentage of GDP) of U.S. commercial banks that arises from the provision of transaction services, specifically, demand deposits and credit cards. The numbers for figure 4 are constructed as follows. The Functional Cost and Profit Analysis (FCPA) report on commercial banks provides data on the volume of demand deposits and the costs associated with the demand deposit function for banks participating in the report. Using these numbers, we calculate costs as a percentage of demand deposits for the reporting banks, multiply this ratio by total demand deposits, and then divide by GNP in order to get an estimate of costs as a percentage of GNP associated with the demand deposit function. The FCPA reports for commercial banks also provide numbers on total credit card balances and the costs associated with the credit card function for reporting banks. These numbers are used to calculate costs as a percentage of total credit card balances for reporting banks. This number is then multiplied by total credit card balances and divided by GNP to obtain an estimate of costs as a percentage of GNP associated with the credit card function. We then take the sum of costs as a percentage of GNP associated with the demand deposit function, and the credit card function as a rough estimate of costs associated with transaction services.[15] As can be seen, these costs average to about 0.5 percent of GNP.

Using the estimated model described above, we display in figure 5 the values of ϕ for various values of the nominal interest rate. The ϕ values are calculated using (14), where a_t is calculated from the estimated semilog money demand function. For moderate inflation rates (e.g., 3–8 percent annually), the corresponding values of ϕ are about 0.5 percent of GNP.[16] Thus these values are remarkably consistent with independent measures of the costs of transaction services displayed in figure 4. This is striking evidence in favor of our model and the estimated money demand function.

In the next section, we focus on the second main contribution of our paper: our model's implications for the welfare cost of inflation, with particular emphasis on some new implications.

V. The Welfare Cost of Inflation

The *Friedman rule,* that is, setting the nominal interest rate R to zero, is clearly optimal in this economy. At the optimum, all goods are

[15] We implicitly assume that all the costs associated with credit cards arise from the transaction services provided and that none arise from the borrowing feature. The 1989 Survey of Consumer Finances reports that average monthly charges for convenience users (those who do not incur finance charges) were \$524 in 1989, whereas average outstanding balances were \$2,090 in 1989. This suggests that convenience users had average balances of \$262 (one-half of \$524) and, therefore, may have accounted for only about 10 percent of the total costs associated with credit cards. If this is right, then the costs associated with credit card use for transactions may be considerably smaller than shown in fig. 4. Figure 4 also ignores credit unions. This may be an important omission because credit unions have a substantial share of the credit card business, and costs as a percentage of outstanding balances are significantly lower for credit unions than for commercial banks. For instance, in 1993, credit cards issued by credit unions had outstanding balances that were more than three times larger than balances on credit cards issued by commercial banks. Further, costs as a fraction of outstanding balances were .055 for credit unions compared to .213 for commercial banks. Averaging over commercial banks and credit unions yields a figure of .091 for costs as a fraction of outstanding balances, which is slightly less than one-half the figure based on commercial banks alone. This factor also suggests that costs associated with credit cards may be lower than shown in fig. 4. Unfortunately, whereas the FCPA reports for commercial banks date back almost 30 years, the FCPA reports for credit unions are available only for the years 1992 and 1993.

[16] The real interest rate is assumed to be 7 percent annually, so that annual nominal interest rates of 10–15 percent correspond to annual inflation rates of 3–8 percent.

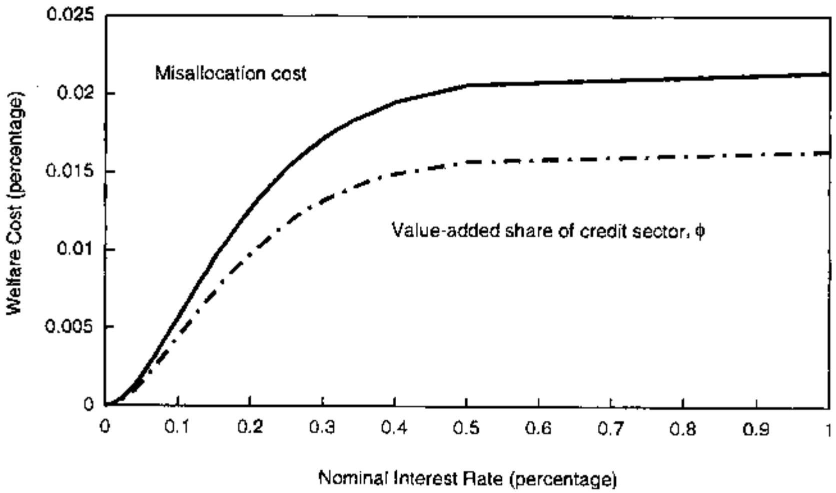

FIG. 5.—Misallocation costs of inflation and the value-added share of the credit services sector.

cash goods: no credit services and credit goods are produced, and the allocation is the same as in the standard growth model without money (see fig. 3).[17] We now discuss the welfare costs of a positive nominal interest rate using the zero nominal interest rate allocation as the benchmark.

The welfare cost can be decomposed into two parts. As explained in Section IV, one part arises from the misallocation of existing resources away from the goods sector and into the credit services sector. This part is captured by the rise in ϕ, which is the value-added share of the credit services sector.[18]

The other component of the welfare cost of inflation arises because of changes in labor input and the capital stock (when labor

[17] This allocation is not the same as the allocation that would arise in our model without money since, in that case, all goods are credit goods, which are costly to produce. For instance, if the $\mathcal{R}(\cdot)$ schedule is bounded, then there is some value of R, e.g., R_{max}, at which money will lose value and all goods will be credit goods. Even if the $\mathcal{R}(\cdot)$ schedule is not bounded, as long as the area under it is finite, there exists a well-defined equilibrium without money in which all goods are credit goods. Analogous to overlapping generations models, our model can have a well-defined nonmonetary equilibrium that is worse, in welfare terms, than the monetary equilibrium. This is true because money permits the purchase of the most costly credit goods with cash, thereby saving some resources. This saving in resources (per unit of goods produced) corresponds to the area $B + C$ illustrated in fig. 3. Thus our model captures the welfare-improving role of money in the economy.

[18] As shown earlier, the welfare cost also corresponds to the traditional area under the inverse money demand curve measure of the welfare cost of inflation.

supply is elastic and investment is endogenous), which are due to the usual inflation distortions that have further effects on consumption and leisure and thereby on welfare.[19] These distortions can be seen in the household's FONCs (10a), (10c), and (11), where the term $1 + \tau_t$ distorts the household's labor/leisure and intertemporal consumption choices. For this reason, we shall refer to τ_t as the *effective inflation distortion tax rate.*

A key implication of our analysis is that both the misallocation component and the inflation distortion tax component of the welfare cost of inflation depend on the nature of the credit services technology and, hence, on the nature of money demand. The former connection was already established in Section IV. To see the latter connection, notice that the inflation distortion appears in the form $1 + \tau_t$ rather than the more usual $1 + R_t$. Since the $p_{2t}(z)$ schedule depends on the $\mathcal{R}(z, \epsilon)$ schedule, which determines the money demand function, it follows from (9) that the effective inflation distortion tax rate τ_t depends on the nature of the money demand function.

The feature discussed above has very important implications for the effects of the inflation distortion tax in our model. Specifically, depending on the nature of the money demand function, the effective inflation distortion tax rate τ_t may remain bounded with inflation. To understand this, note that $1 + R_t$ is the shadow price of cash goods purchases, and

$$\frac{1}{z_t^*}\left[\frac{\int_0^{z_t^*} p_{2t}(z)\,dz}{p_{1t}}\right]$$

is the average price of purchases of credit goods. From (9), we then see that the effective inflation distortion tax rate is a weighted average of the shadow price of purchases of cash goods and the average price of purchases of credit goods, weighted by the respective shares of purchases of cash goods and purchases of credit goods in total purchases. Therefore, by changing the mix of purchases between cash goods and credit goods, consumers can potentially limit their exposure to the inflation distortion tax. Consequently, depending

[19] This component is due to the change in total income, which shifts the money demand curve. Normally, this effect is very small since inflation-induced changes in labor supply and, hence, total income are very small. Consequently, the area under the inverse money demand curve captures most of the welfare cost of inflation. However, in our model, this is not the case because we treat goods used for consumption symmetrically with goods used for investment and do not arbitrarily designate consumption goods as cash goods and investment goods as credit goods that do not require any credit services.

on the nature of the money demand function, the welfare losses due to the inflation distortion tax effect can remain bounded.

It turns out that, for our semilog specification of money demand, the effective inflation distortion tax rate τ indeed remains bounded, even as R goes to infinity. To see this, we can rewrite (9) as follows, after substituting for $p_{2t}(z)$ from (3):

$$\begin{aligned}\tau &= (1 - z^*)R + \int_0^{z^*} q_s\mathcal{R}(z)\,dz \\ &= \int_0^1 \min\{R,\ q_s\mathcal{R}(z)\}dz.\end{aligned} \tag{20}$$

Thus τ equals the area under the $q_s\mathcal{R}(\cdot)$ schedule up to z^* plus the area under the height R from z^* to unity (area $A + B$ in fig. 3).

The following three implications can be drawn from (20). First, we can see that when R is zero, τ is zero and is increasing in R. Second, τ is always less than R. This is true because τ is a weighted average of the shadow price of cash goods and the prices of credit goods. Since only goods with credit prices below R are purchased as credit goods (see fig. 3), it follows that τ is always less than R. Third, τ remains bounded as R goes to infinity. To see this, note that from (8d) and the specification of the $\mathcal{R}(\cdot)$ schedule (see [18]), the first term in (20) goes to zero as R goes to infinity. The second term in (20) is exactly equal to the area under the normalized inverse money demand curve (see [13] and fig. 3), which approaches $q_s\eta$, that is, the inverse of the semielasticity of money demand, as R goes to infinity. Therefore, given our parameter values, the effective inflation distortion tax rate τ is bounded above by 1.67 percent.

In figures 5 and 6, we show the welfare cost of inflation (expressed as a percentage of consumption) as a function of the (annual) nominal interest rate. We show separately the misallocation component and the value-added share ϕ in figure 5 and the total welfare cost (including the inflation distortion tax component) in figure 6.[20]

There are two key results to be noted in these figures. The first, and perhaps the most important, is that both components of the welfare cost of inflation (and, hence, the total welfare cost of inflation) are bounded at less than 5 percent of consumption. The misallocation component behaves like the value-added share, asymptoting to a fairly low value, even as inflation reaches very high values. As explained before (see [14] and [17]), both the misallocation

[20] The misallocation component differs slightly from the value-added share because the welfare cost is expressed as a percentage of consumption and not GNP.

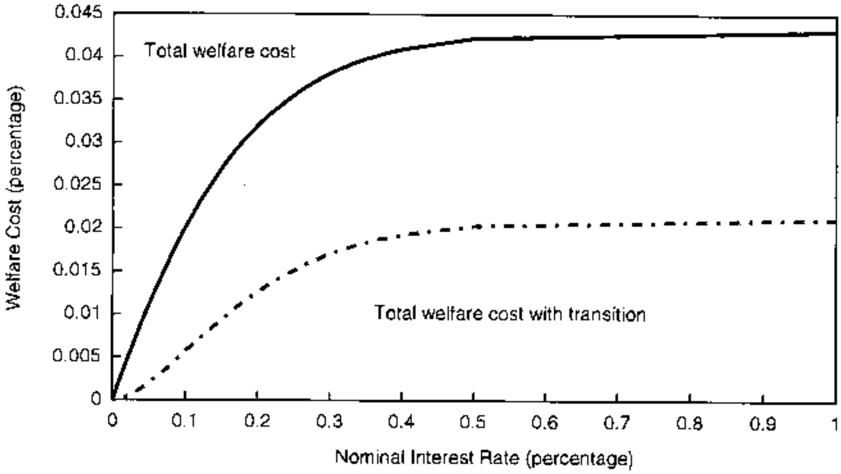

FIG. 6.—Welfare cost of inflation with and without a transition

component and ϕ are closely related to a_0, the normalized area under the inverse money demand curve, which is bounded above by the inverse of the money demand semielasticity. The component of the welfare cost of inflation that is due to the inflation distortion tax effects also remains bounded, because the effective inflation distortion tax rate remains bounded, even as the inflation rate goes to infinity.

The second result is that at low to moderate inflation rates, the inflation distortion tax component, which is the difference between the total welfare cost and the misallocation component, is roughly from two to three times the misallocation component. At very high inflation rates, the inflation distortion tax component is still about the same magnitude as the misallocation component. Thus the inflation distortion tax component is quite significant, even though the effective inflation distortion tax rate τ remains very low at all inflation rates.[21]

[21] This result is entirely due to the inflation distortion tax effect on investment. In our model, as the annual nominal interest rate rises from zero to 10 percent, 30 percent, 50 percent, and 500 percent, the effective inflation distortion tax rate rises from zero to 1 percent, 1.6 percent, 1.66 percent, and 1.67 percent. As a result, the share of investment in output falls from 22 percent to 21.7 percent, 21.6 percent, and 21.55 percent. One way to see that the welfare consequences of the inflation distortion arise mostly through investment is to consider the following results for an alternative version of the model in which goods used for investment do not require any credit services; thus investment goods are always purchased as credit goods at the same price as cash goods. This alternative version is obtained by making the following changes in the model of Sec. III. Replace χ_t with c_t in (6) and (7), add purchases of investment goods $k_{t+1} - (1 - \delta)k_t$ to the right side of (7), and replace Y_t with c_t in (10c). It is then easy to verify that the effective inflation distortion tax

Finally, figure 6 also reports calculations of welfare cost that take into account the transition period. The transitional dynamics are approximated by log-linearizing the equations that characterize the model's solution path around the steady state, where the nominal interest rate is zero. As can be seen in figure 6, taking the transition period into account can have a significant impact on the welfare cost of inflation. In figure 6, the welfare cost of a 10 percent nominal interest rate falls from 2.0 percent to 0.5 percent of consumption when the transition is taken into account.

VI. Concluding Remarks

We end the paper with a brief discussion of the robustness of our results to alternative specifications. Two features of our specification are worth mentioning.

One is the Leontief specification of composite investment and consumption. This specification makes it possible for us to retain the one good structure of the standard monetary growth model. If some substitutability were allowed, then this convenience would be lost since the relative price of goods with different z indices would change with inflation. Further, the empirical evidence presented in Section IV is quite consistent with our Leontief specification. The other noteworthy feature of our specification is that all labor is sold as *credit* labor and all capital is rented as *credit* capital without using up any credit services. It is this feature that leads to the inflation distortion on labor supply and investment and to the distinction between the misallocation component and the inflation distortion component of the welfare cost of inflation. If this feature of the specification were modified, then all of the welfare cost of inflation would appear only as the misallocation of resources into the credit services sector. However, it is not clear that this would make much difference to our main conclusions regarding the welfare cost of inflation. With this modification, there would be no inflation distortion component, but the misallocation component would be larger. Hence, the overall welfare cost of inflation may not be affected. Further, the feature of the welfare cost that we emphasize, namely, that

rate τ_{t+1} will no longer appear in (8c). In such a model, investment is no longer subject to an inflation distortion tax. If we redo the welfare cost calculations for this version of the model, the misallocation component varies from 0.44 percent to 1.6 percent and 1.67 percent, the total welfare cost varies from 0.52 percent to 1.61 percent and 1.67 percent, and the annual nominal interest rate varies from 10 percent to 50 percent and 100 percent, respectively. From these calculations, it is obvious that the misallocation component and, hence, the usual area under the inverse money demand curve capture most of the welfare cost of inflation if investment requires no credit services.

the welfare cost remains bounded with inflation, is also likely to remain unaffected. This is true because, given our specification of the money demand function, which fits U.S. data quite well, the misallocation component is bounded at less than 5 percent of consumption.

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