The Demand for Money, Financial Innovation, and the Welfare Cost of Inflation: An Analysis with Household Data

Orazio P. Attanasio

University College London, Institute for Fiscal Studies, and National Bureau of Economic Research

Luigi Guiso

University of Sassari, Ente Luigi Einaudi, and Centre for Economic Policy Research

Tullio Jappelli

University of Salerno and Centre for Economic Policy Research

We use microeconomic data on households to estimate the parameters of the demand for currency derived from a generalized Baumol-Tobin model. Our data set contains information on average currency, deposits, and other interest-bearing assets; the number of trips to the bank; the size of withdrawals; and ownership and use of ATM cards. We model the demand for currency accounting for adoption of new transaction technologies and the decision to hold interest-bearing assets. The interest rate and expenditure flow elasticities of the demand for currency are close to the theoretical values implied by standard inventory models. However, we find significant differences between individuals with an ATM card and those without. The estimates

We thank an anonymous referee and the editor for very valuable comments. We also received useful suggestions from seminar participants at the Universities of Chicago, Freiburg, Mannheim, Northwestern, and Warwick and the Bank of England, the Bank of Italy, the European Central Bank, the Bank of Portugal, Banco de la Republica (Bogotà), Centro de Estudios Monetarios y Financieros (Madrid), and Pontificia Universidad Catolica (Rio de Janeiro). The Training and Mobility of Researchers Network Program of the European Commission, Directorate-General XII, the Italian National Research Council, and the Ministry of the University and Scientific Research provided financial support.

[*Journal of Political Economy,* 2002, vol. 110, no. 2]

of the demand for currency allow us to calculate a measure of the welfare cost of inflation analogous to Bailey's triangle, but based on a rigorous microeconometric framework. The welfare cost of inflation varies considerably within the population but never turns out to be very large (about 0.1 percent of consumption or less). Our results are robust to various changes in the econometric specification. In addition to the main results based on the average stock of currency, the model receives further support from the analysis of the number of trips to and average withdrawals from the bank and the ATM.

I. Introduction

The generalized move toward lower inflation in both the United States and Europe has stimulated considerable interest in the welfare gains from price stability. One component of the welfare costs of inflation is that induced by the distortions related to the efficient management of cash balances for transaction purposes when a (nominal) interest-bearing asset is available. Evaluating this component of the welfare cost of inflation requires estimates of the interest and transaction sensitivity of money demand. The theoretical framework behind most money demand functions is that of models of cash management in the tradition of Baumol (1952), Tobin (1956), and Miller and Orr (1966). Recently, Lucas (2000), Mulligan and Sala-i-Martin (2000), and others have provided empirical estimates of the welfare cost of inflation linked to cash management using versions of these models. Many empirical questions, however, are still open, mainly because of two important issues. First, the concept of cash balances or "money" in the theoretical models of the Baumol-Tobin variety does not obviously correspond to any of the monetary aggregates, such as M1, that are used in time-series studies, especially over periods of time in which large components of the money stock become interest-bearing. Second, aggregation problems are important. Aggregate time series are unlikely to be informative when the costs of cash management vary across different consumers and firms. In particular, heterogeneity in fixed costs can induce important nonlinearities, so that only micro data allow the aggregation of individual money demands.

Nonlinearities are most likely to arise when there are fixed costs in the adoption of interest-bearing financial instruments, as stressed by Mulligan (1997) and Mulligan and Sala-i-Martin (2000), or when financial innovation introduces new financial instruments and means of payment, which are themselves costly to adopt. If new instruments alter the costs involved in cash management, they also affect the parameters of the demand for money and bias the parameters estimated with time-series data. It is therefore crucial to estimate the relevant relations using microeconomic data and evaluate the welfare cost of inflation aggregating these relations. At the micro level, however, there is very little evidence, partly because data sets containing information on cash holdings are few and far between. And even when available, they lack information on interest rates on assets alternative to money, making it difficult to estimate the interest rate elasticity of the demand for money. The empirical literature on money demand has therefore lagged behind that on consumption and investment, where empirical studies routinely address aggregation issues and use household- or firm-level data extensively. Only recently have some papers sought to estimate the elasticity of money with respect to transaction variables using household or firm data sets (Mulligan 1997; Mulligan and Sala-i-Martin 2000); but none has provided definitive estimates of the interest rate elasticity. In particular, Mulligan and Sala-i-Martin estimate this parameter from the extensive margin faced by individuals who decide whether to hold an interest-bearing asset. They lack data on household-specific interest rates and use the marginal tax rate faced by each household to proxy for the rate of return. The problem with this source of variation is that it is highly collinear with wealth.

In this paper we present evidence from a unique data set that contains direct information, at the household level, on currency and cash management activities (such as the average amount of currency held and the number and size of withdrawals), interest rates, various financial assets, the adoption and use of new technology, as well as consumption and income flows and demographic and occupational variables. In short, the data set we use appears tailor-made for estimating a sophisticated version of the Baumol-Tobin model of the demand for money.

Our empirical specification controls for corner solutions in the use of interest-bearing assets and for the adoption of new transaction technologies, such as that offered by automated teller machine (ATM) cards, on which we have detailed information. The richness of the data set and the variability observed across households and over the sample period allow us to identify the structural parameters of the demand for money and present methodologically sound estimates of the demand for currency and of the implied welfare cost of inflation.

The data are drawn from a household survey run by the Bank of Italy every two years. We use the surveys collected between 1989 and 1995 and merge them with two additional data sets on interest rates on checking and savings accounts and measures of financial innovation. Using Italy as a case study is of particular interest for a variety of reasons. The most important is that in Italy a large portion of (M1) money, including all checking and savings accounts, is interest-bearing. This implies that demand deposits, on which we have detailed information in terms of both amounts held and interest rates paid, represent the natural interest-bearing asset to be considered alternative to currency in models of the Baumol-Tobin variety. This institutional feature allows us to cut through a number of definitional issues that plague other studies of money demand using either time-series or cross-sectional data. Second, nominal interest rates on deposits display a remarkable degree of regional variation that can be exploited to estimate the relevant elasticity of currency. In addition to the cross-sectional variability, during our period, inflation (and nominal interest rates with it) declined significantly in Italy, from about 6 to 4 percent. Third, the payments system underwent considerable change and modernization, notably (and most significantly for our purposes) the diffusion of ATM cards, whose ownership tripled during the sample period. As we have information on both use of ATM cards and number of ATM points in the province of residence, we can model the ATM adoption and hence the effects of technological progress on the demand for money and on the welfare cost of inflation.

We obtain precise estimates of the parameters of the demand for money. We find an interest rate elasticity of between -0.3 (for non-ATM users) and -0.6 (for ATM users) and substantial economies of scale in cash management (a consumption elasticity well below unity). Our estimates are robust with respect to changes in the empirical specification and to the methodology used to correct for selectivity biases and potential endogeneity of the adoption of new transaction instruments. The welfare cost of inflation varies considerably within the population but is never very large (0.1 percent of consumption or less). This contrasts with the estimates obtained by other researchers. We argue that the main reason for this difference is that inflation carries low welfare costs in economies in which a large portion of the money stock is interest-bearing.

The rest of the paper is organized as follows. In Section II, we present our data and discuss some descriptive evidence on the consistency of measures of average cash holdings, withdrawal size, and number of trips to the bank. In Section III, we lay down a simple theoretical framework that allows us to derive an empirically tractable demand for money nesting the most popular models of cash management, and we present estimates of a demand for currency on the whole sample, ignoring selectivity problems arising from the decision to adopt interest-bearing assets and alternative transaction technologies. In Section IV, we extend our empirical specification to deal with these issues and discuss the relevant econometric problems. We present our basic results in Section V, where we show separate estimates for the demand for currency for ATM users and non-ATM users accounting for the decision to hold a bank account. Section VI discusses the implications of our estimates for the computation of the welfare cost of inflation. We place particular emphasis on the connection between the demand for money and the welfare cost of inflation in the presence of innovations in the transaction technology, and we contrast our estimates with those of previous literature. In Section VII, we exploit additional information available in the data set and find that the estimated equations for the size of withdrawals, the fraction of income received in currency, and the number of trips to the bank are all consistent with inventory models of money demand. Section VIII presents conclusions.

II. Descriptive Analysis

We start presenting the survey of Italian households we use to estimate our model of cash management and confronting the data with some of the basic predictions of the inventory model. In doing so, we also describe some of the institutional features of the Italian payment system.

Our data set contains very detailed information on many of the variables that one needs to estimate the inventory model, such as average currency holdings, number of trips to the bank, size of withdrawals, and so on. Moreover, because in Italy checking and savings accounts are interest-bearing assets, for the vast majority of the sample, bank deposits effectively represent the relevant alternative to currency. Therefore, the nominal interest rate on deposits provides a proper measure of the opportunity cost of holding currency. This allows us to obtain a precise definition of the appropriate monetary aggregate to consider in the inventory model. Furthermore, as we document and discuss below, deposit interest rates exhibit both geographical and time variability. We use this variation to identify the interest rate elasticity of the demand for currency. Finally, over the sample period we observe a substantial increase in the adoption of new transaction technologies, namely ATM cards. The survey tracks ownership and use of these transaction cards, allowing us to identify the effect of technological innovation on the demand for money.

A. *Data Sources*

We construct a sample merging data from three sources. The first is the 1989–95 Survey of Household Income and Wealth (SHIW), a collection of four large cross sections of Italian households (1989, 1991, 1993, and 1995). Each cross section is representative of the Italian population. Respondents supply information on consumption, financial wealth, and several variables describing cash management: average currency balances, ATM and credit card use, size of withdrawals (separately at ATMs and bank counters), amount of bank or postal deposits, number of trips to the bank (distinctly for withdrawals at ATMs or at bank counters), minimum amount of currency balances before making a withdrawal, and fraction of income received in cash. The Appendix reports the main features of the survey, variables' definitions, and averages of the variables used in estimation. To the best of our knowledge, the only other survey with detailed information on currency holdings is the U.S. 1984 Survey of Currency and Transaction Account Usage (Avery et al. 1986), and even this survey does not measure many of the relevant variables to estimate inventory models (for instance, it does not have data on financial wealth, interest rates, and consumption).[1]

The second data set is the Bank of Italy Monetary Statistics Survey. This survey provides average interest rates on checking and savings accounts on a quarterly basis, aggregated by the 95 Italian administrative provinces. We can thus impute an interest rate that varies by year and province for each household in the sample. The third data set, also collected by the Bank of Italy, provides on a yearly basis the number of ATM points in each province. This will be one of our instruments to model the decision to actually use an ATM card and proves to be particularly useful to identify the demand for currency.

B. *Currency, Withdrawals, and Trips*

Table 1 reports sample means of several variables related to cash management from 1989 to 1995. All monetary variables are deflated by the consumer price index, expressed in 1995 lire and then converted to euros. The main feature that emerges from table 1 is the high level (over 500 euros in 1989) of average "currency usually held at home." This confirms that in Italy the demand for currency is high by international standards (Humphrey, Pulley, and Vesala 1996). Between 1989 and 1995, currency declines in real terms by 7 percent per year. Over the same period the fall in nondurable consumption can explain only a small portion of the reduction in currency. In fact, the currency-consumption ratio also declines, from almost 4 percent in 1989 to 2.8 percent in 1995. Other factors must therefore be at work to explain the shrinking currency.

The fraction of households with an interest-bearing account is about 85 percent in each of the sample years. Included are checking accounts, savings accounts, and postal deposits; they are simply denoted bank accounts from now on. In Italy, as elsewhere, the introduction and dif-

[1] The survey includes 2,500 households. Some features of the survey are similar to ours. About 14 percent of households used only currency to make transactions. At the time of the survey, 42 percent of families had ATM cards. On average, individuals who use ATMs maintain average cash holdings that are significantly smaller, and they replenish them more often. We find similar patterns in our survey. For various reasons, however, the U.S. survey is not strictly comparable with ours (for instance, currency includes money orders, the sample design is different, etc.).

TABLE 1
Currency and Financial Innovation

Variable	1989	1991	1993	1995
Fraction with a bank account	86.83	85.77	84.87	84.60
Fraction using ATMs	14.93	29.31	34.42	39.97
Nondurable consumption	17,106	16,488	15,869	15,620
Deposits	9,714	6,714	6,660	6,822
Financial wealth	20,470	14,637	17,213	17,350
Currency	579	475	338	374
No bank account	570	497	306	371
With bank account	581	471	343	374
No ATM card	571	492	351	397
With ATM card	624	432	313	339
Currency/consumption (%)	3.88	3.52	2.52	2.78
No bank account	5.66	5.41	3.56	4.10
With bank account	3.63	3.22	2.34	2.54
No ATM card	4.04	4.02	2.94	3.37
With ATM card	2.98	2.30	1.74	1.89
Average withdrawal at a bank	…	429	544	482
No ATM card	…	425	551	478
With ATM card	…	441	534	488
Average withdrawal at an ATM	…	219	207	198
Minimum currency	125	124	120	90
No ATM card	121	120	123	94
With ATM card	150	133	116	85
Total number of trips (yearly basis)	…	28	26	30
To the bank (no ATM card)	…	18	13	13
To the bank (with ATM card)	…	14	12	11
To the ATM	…	34	36	39
Fraction of income received in currency	52.19	46.29	45.60	44.85
Number of observations	7,973	8,127	7,663	8,100

Note.—The table reports data on consumption, deposits, financial wealth, currency, withdrawals, trips, and fraction of income received in currency in 1989–95. Bank accounts include checking accounts, savings accounts, and postal accounts. All averages are computed using sample weights. Nondurable consumption, deposits, financial wealth, and currency are deflated by the consumer price index, expressed in 1995 lire and then converted to euros. Data are drawn from the 1989–95 SHIW. See the Appendix for variables' definitions.

fusion of ATM cards have been one of the main innovations in transaction technology of the last decades. Table 1 shows a massive increase in the fraction of respondents using ATM cards, from 15 percent in 1989 to 40 percent in 1995. As we shall see, the diffusion of ATM cards is the main factor explaining the shrinking currency. The currency-consumption ratio is considerably higher for households with no bank account and, among those with a bank account, for those that do not hold an ATM card. Over time, the pattern of this variable is similar across the different groups.

In addition to the average currency, the survey contains information on the amount of currency that triggers a withdrawal and, after 1991, on average amounts withdrawn (both at a bank counter and, for those that hold a card, at an ATM point) and number of trips to banks and to ATMs. Positive minimum currency before withdrawals is inconsistent with a literal interpretation of the Baumol-Tobin model. However, uncertainty in the flow of expenditures and high transaction costs at very low levels of currency can justify a positive level for the "minimum currency" variable. It is interesting to notice that the minimum currency is slightly lower for households with an ATM card.

The average withdrawal at bank counters increases from 429 euros in 1991 to 544 euros in 1993 and declines to 482 euros in 1995. Withdrawals at ATMs are substantially smaller, a reflection of a cheaper transaction technology and daily limits on withdrawals at ATMs. The total number of trips to banks or ATMs ranges from 26 to 30 per year. However, the average hides rather different time patterns because trips to banks fall (from 18 to 13), whereas trips to ATMs increase (from 34 to 39).

Table 1 also shows that, on average, almost 50 percent of income is received in currency. This high fraction indicates how important currency still is in the Italian payment system. The average tells only part of the story. The fraction is much higher for some population groups, such as pension recipients (pensions are typically paid in currency at the post office) or households headed by those who are self-employed (for instance, shopkeepers' income is typically received in currency). There are also substantial geographical differences. The higher level of income received in currency in the South reflects the higher fraction of pension recipients and self-employed and the importance of the underground economy.

The information reported in the survey allows us to perform a first, important check about the mutual consistency of these variables. The average withdrawal (403 euros) times the number of withdrawals (27) should be equal to the flow of cash expenditures, which is approximately 0.62 percent of nondurable consumption. In 1993 and 1995, we observe all these quantities. The reported flow of cash expenditures (on a yearly basis) is, on average, 10,188 euros, to be compared with $403 \times 27 = 10,881$ euros. This is a first, important check on the reliability of the survey responses. In a second check, consider that, according to the standard inventory model of cash management, the average stock of currency should be roughly equal to the sum of currency before withdrawals plus currency held for transaction purposes or, equivalently, half the average withdrawal plus minimum currency:

$$\hat{m} = \frac{\text{consumption}}{2 \times \text{number of withdrawals}} + \text{minimum currency} \qquad (1)$$

and

$$\hat{\hat{m}} = 0.5 \times \text{average withdrawal} + \text{minimum currency}. \qquad (2)$$

As we mention in the previous paragraph, we have already checked the

TABLE 2
Interest Rates and Characteristics of the Banking System, 1989–95

	1989	1991	1993	1995
After-tax interest rate on Treasury bills	9.19	9.15	7.72	7.92
After-tax interest rate on deposits	4.62	4.37	4.27	3.54
	(.38)	(.39)	(.32)	(.27)
Number of ATM points (per million residents)	100	170	240	280
	(70)	(110)	(130)	(150)
Share of deposits of the 5 largest banks	.502	.503	.505	.511
	(.150)	(.144)	(.140)	(.130)
Share of deposits of cooperative banks	.129	.130	.130	.132
	(.064)	(.064)	(.064)	(.064)

Source..—Data are drawn from the Bank of Italy Monetary Statistics Survey.
Note.—The numbers in parentheses are standard deviations.

equality of $\hat{m}$ and $\hat{\hat{m}}$. However, since we have independent information on minimum currency, we can compare these two estimates of average currency with the self-reported level of such a variable. The 1993–95 medians of $\hat{m}$ and $\hat{\hat{m}}$ are 310 and 232 euros, respectively. They can be compared with 286 euros, the median of reported currency in 1993–95. From these experiments we conclude that the variables in our data set are broadly consistent with each other and with standard inventory models of money demand.

C. *Interest Rates and the Payment System*

Table 2 reports summary statistics on after-tax nominal interest rates and other bank characteristics.[2] Although in Italy nominal interest rates on checking and savings accounts are rather sticky, partially reflecting imperfect competition in the banking sector, they do vary considerably across years, provinces,[3] and deposit size (being substantially larger for larger deposits). The table shows that nominal interest rates declined 1.08 percentage points, from 4.6 percent in 1989 to 3.5 in 1995. In any given year, the standard deviation of the interest rate is between 0.3 and 0.4, or about 10 percent of the mean. The average reduction in after-tax nominal interest rates on deposits matches almost exactly the reduction in the after-tax nominal interest rates on short-term Treasury bills (1.27 percent). This implies that the spread between the two interest rates is roughly constant, suggesting that the wedge between the nominal interest rate on Treasury bills and bank deposits is independent of inflation, which has itself declined by 1.1 percentage points between 1989

[2] During the sample period, nominal interest rates on deposits are subject to a 30 percent flat rate withholding tax, which is therefore netted out to obtain after-tax measures.

[3] The Italian territory is divided into 95 provinces corresponding broadly to U.S. counties.

and 1995. As we shall see in Section VI, this property is critical for computing the welfare cost of inflation.

The most likely reasons for the geographical variability are the regional differences in the cost of intermediating funds and in the degree of competition between banks in local markets.[4] We take these characteristics as given and do not try to model the behavior of the banking system in this paper. In table 2 we report the mean and standard deviation of some measures of competition in local credit markets, namely the share of deposits of the five largest institutions in each province and the average interest rate differential between loans and deposits.

There are persistent geographical differences in the frequency of ATM users. While in the North the use of ATMs was relatively widespread even in the earlier part of the period, the financial sophistication of the South lags considerably behind even in recent years. It is this time-series and cross-sectional variability in the diffusion of technology that allows us to estimate the adoption decision as well as the effect of financial innovation on money demand. The decision to use an ATM is likely to depend not only on demographic characteristics, transaction variables, and the opportunity cost of using currency but also on the use made by other people and, ultimately, on the availability of ATM points in each location. Table 2 indicates that there has been a substantial increase in ATMs between 1989 and 1995 (from 100 to 280 per million residents).

Finally, note that the SHIW contains information on the province of residence of the respondents. So we can merge the information in table 2 with the microeconomic data and assign to each household a nominal after-tax interest rate and other characteristics of the banking system that vary by province and year.

III. The Transaction Demand for Money

We derive our empirical specification of the demand for currency from the McCallum and Goodfriend (1987) extension of the Baumol-Tobin model. Let us assume that people need time to make transactions and that money is a way to save on transaction time. The consumer chooses optimal money balances in order to trade off the time cost of transactions against the cost of holding money instead of an interest-bearing asset yielding a nominal return of R per period. The time cost of transactions results from the shadow value of time and, possibly, from the fixed cost of withdrawing currency. Thus the consumer chooses money m to minimize the sum of the cost of transaction time τw (the product

[4] The correlation coefficient between the interest rate on deposits and an index of bank concentration (the share of deposits of the five largest banks in each province) is −.35, significant at the 1 percent level.

of transaction time τ and the time cost of transactions w) and forgone interest Rm, subject to a transaction technology:

$$\min \tau w + Rm$$
$$\text{subject to } \tau = Ac^{\gamma}\left(\frac{c}{m}\right)^{\beta}, \tag{3}$$

where A measures technology improvements and c is consumption. Money demand is then

$$m = \left(\frac{wA\beta}{R}\right)^{1/(1+\beta)} c^{(\beta+\gamma)/(1+\beta)}. \tag{4}$$

This equation encompasses several models. By setting $\gamma = 0$ and $\beta = 1$, one obtains the Baumol-Tobin square root formula. If $\gamma = 0$ and $\beta = 2$, equation (4) reduces to the Miller and Orr solution.[5] If $\gamma \neq 0$, the demand for money is not homogeneous of degree zero in consumption and in the interest rate. Taking logs and assuming that the term wA depends only on calendar time t, one can regress the log of average currency on the log of nondurable consumption, the log of the interest rate on deposits in the province of residence, and a quadratic time trend:

$$\underset{(0.177)}{\ln m = 1.000} - \underset{(0.008)}{0.172t} + \underset{(0.001)}{0.008t^2} - \underset{(0.047)}{0.709 \ln R} + \underset{(0.008)}{0.368 \ln c}, \tag{5}$$

where standard errors are reported in parentheses. The number of observations in our pooled cross-sectional data is 31,861, and the estimated parameters imply $\hat{\beta} = 0.410$ and $\hat{\gamma} = 0.109$. Thus the estimated consumption and interest rate elasticities are not too far from the values predicted by the Baumol-Tobin model, though the assumption that they are equal to one-half is rejected. The quadratic trend indicates that, on average, the demand for money falls over the sample period.[6]

The finding that the demand for currency responds to consumption, interest rates, and economic incentives in general is important because very little is known about the demand for currency at the microeconomic level. Sprenkle (1993) presents descriptive evidence drawn from the 1984 and 1986 *Federal Reserve Bulletin* that mean monthly currency expenditure increases with family income less than proportionately, suggesting substantial economies of scale in cash management. However,

[5] In the model that we consider, the flow of transactions is deterministic and constant over time, whereas Miller and Orr assume stochastic and infrequent cash flows.

[6] Replacing the time trend with year dummies changes the results only slightly. The consumption elasticity is unchanged, and the interest rate elasticity is slightly reduced at 0.5 (with a standard error of 0.048). We prefer to model technical progress as a quadratic trend rather than with time dummies, in order to exploit at least part of the time variability in interest rates.

Sprenkle also points out that household demand for currency is largely independent of the value of time and usual measures of opportunity costs. Rather, people choose a standardized amount of currency to obtain, for instance, making a withdrawal of $50 or $100 regardless of the interest rate (see Sprenkle 1993, p. 181). Our empirical results strongly contradict this view.

The simple regression ignores several important problems. First, equation (5) is the relevant equation of the demand for currency only for households that have interest-bearing deposits. In commenting on table 1, we pointed out that about 15 percent use only currency for making transactions. Estimation of the demand for currency must tackle this classic selection problem. Second, transaction costs and even the parameters of the transaction technology may differ for households with access to ATM technology. Given the increased use of ATMs over time, it is therefore important to control for this factor while recognizing that, in all likelihood, card holding is an endogenous decision. Finally, the time cost of transactions is likely to differ across individuals according to education, employment, and demographic variables. In the next section we present an econometric specification that deals explicitly with each of these problems.

IV. Econometric Specification

The decisions to hold an interest-bearing asset and an ATM card are discrete choices and therefore involve similar conceptual (and econometric) issues. But there is one important difference. The adoption of a new technology, such as an ATM card, can affect the parameters of the demand for currency but does not change the qualitative nature of that demand. For individuals who do not hold interest-bearing assets at positive interest rates, however, there is no immediate opportunity cost of holding currency. This is why we shall estimate the demand for currency only for households that hold the relevant alternative assets, correcting for selection bias. At the same time, we allow the parameters of our model to differ across regimes according to ATM card ownership, while taking into account the possible endogeneity of ownership.

We generalize the McCallum-Goodfriend framework to take into account innovations in the transaction technology and the fact that many consumers do not hold interest-bearing assets. Given transaction or adoption costs or both, ownership of such assets and adoption of new payment technologies are choice variables. The consumer chooses to open an account if the benefits (less interest forgone) exceed its adoption costs. Conditional on having a checking account, similar considerations apply to the adoption of the ATM technology. As the conceptual issues are similar, here we discuss only the adoption of a new technology and how money demand is modified by the use of ATM cards. Similar considerations apply to the decision to hold a checking account.

When considering adoption costs, one should distinguish between costs per period (such as annual fees) and one-shot costs (such as learning costs). While these two types of costs are both relevant and might have different implications for dynamic general equilibrium models, our analysis focuses on costs per period. In Section V, we present some evidence on their importance and provide some bounds for them. We also argue that costs per period are important.

Let H denote an indicator variable that equals one if the consumer has an ATM card, zero if not. If adoption has a cost, a consumer will switch to the ATM technology only if the benefit exceeds that cost. Let the cost of adoption $Z(\mathbf{x})$ depend on a vector $\mathbf{x}$ of consumer characteristics and on other variables affecting the adoption decision, such as the availability of the ATM technology and the monetary cost of using the card. Adoption of the new transaction technology will thus take place if

$$\text{benefit} = w(\tau_{H=0} - \tau_{H=1}) + R(m_{H=0} - m_{H=1}) > Z(\mathbf{x}), \tag{6}$$

where $m_{H=i}$ and $\tau_{H=i}$ denote, respectively, optimal money balances and transaction time conditional on $H = i$ $(i = 0, 1)$. Since all variables affecting the demand for money also affect the benefit from adoption, they will also affect the decision in (6). In particular, the benefit depends on the value of time w and on the interest rate R. If the ATM technology implies a proportional gain in time, it can be easily shown that an increase in either w or R makes adoption more likely. Furthermore, an increase in the volume of transactions c raises both money holdings and the time spent transacting, thus increasing the benefit from adopting a superior technology. Finally, the decision to adopt the new technology depends on the vector of variables that affect the cost of adoption, $\mathbf{x}$. This second group of variables is crucial for identification, as discussed further in Section V. Similar considerations apply to the decision to hold a bank account, as discussed by Mulligan and Sala-i-Martin (2000).

In the empirical application, we estimate the demand for currency controlling for the bias induced by the choice of having an interest-bearing asset (a bank deposit) and by the choice of switching to the ATM technology. We model the two discrete decisions as probit models. In particular, we estimate a probit for having a bank account on all the observations. We then estimate a probit for having an ATM card in the sample of households with a bank account. Finally, we estimate the money demand equation correcting with the appropriate Mills ratios. The currency equation is estimated separately for the sample with bank accounts and ATM cards and with bank accounts and no ATM card.

Denote by $D = \delta_D x_D + u_D$ and $H = \delta_H x_H + u_H$ the indexes that determine the decisions to open a bank account and to have an ATM card, respectively. The correction terms in the currency equation are then $E[e|u_D > -\delta_D x_D \cap u_H > -\delta_H x_H]$ for households with a bank account and an ATM card and $E[e|u_D > -\delta_D x_D \cap u_H < -\delta_H x_H]$ for those with a bank account but without an ATM card. Since we are interested in ATM use *conditional on holding a checking account,* we can estimate the two probits sequentially and not simultaneously. Formally, the model has four regimes and is estimated as a switching model with two endogenous shifts.

If one does not want to rely on the nonlinearity of the Mills ratio alone to achieve identification, it is necessary that some variables affecting the decision to have a bank account and the decision to have an ATM card do not directly affect the demand for currency. While two variables are sufficient for identification, we use several (their selection is discussed in the next section). In addition to the identifying variables, we introduce in the probit regressions all variables that affect the demand for money. They include nondurable consumption, the log of the nominal interest rate, calendar time, and proxies for heterogeneity in the value of transaction time (education, occupation, and family structure).

Once it is recognized that H (the decision to use an ATM card) and D (the decision to use a bank account) are choice variables, it is clear that the interest rate affects optimal money balances also through H and D. Ignoring the endogeneity of alternative payment systems and of the decision to use a bank account can bias the interest rate elasticity, particularly in periods of intense financial innovation.

V. Results

Table 3 gives our main results. Columns 1 and 2 report the estimates of the probit models for the decision to have a bank account and the decision to have an ATM card, conditional on having a bank account. Columns 3 and 4 contain the coefficients of the demand for cash for households with and without an ATM card.

As discussed above, all variables that enter the demand for currency also determine the choice of using a particular transaction technology. Furthermore, identification of the money demand equation requires that some variables that affect the choices of having a bank account and an ATM card do not affect the average stock of currency. Ideal candidates are fixed costs associated with these discrete choices. Unfortunately, a direct measure of these costs is problematic. We rely, instead, on variables that are likely to be related to such costs. In particular, we consider the number of ATM points in the area of residence at the end of the past year. If there are network externalities, the cost of adoption

TABLE 3
Determinants of Bank Accounts, ATM Use, and the Demand for Currency

	Probit		Demand for Currency	
	For Bank Account (1)	For ATM (2)	With Bank Account and ATM Card (3)	With Bank Account and No ATM Card (4)
Log(consumption)	.173	.532	.347	.437
	(.040)	(.026)	(.026)	(.020)
Log(interest rate)	.923	.397	−.592	−.271
	(.171)	(.122)	(.105)	(.070)
Time	.153	.291	−.115	−.034
	(.029)	(.019)	(.019)	(.013)
Time squared	−.015	−.020	.007	.002
	(.004)	(.002)	(.002)	(.001)
Less than elementary school	−.714	−1.033	−.132	−.254
	(.100)	(.067)	(.076)	(.037)
Elementary schooling	−.569	−.726	−.108	−.136
	(.094)	(.037)	(.032)	(.027)
Junior high school	−.235	−.362	−.070	−.057
	(.094)	(.034)	(.025)	(.024)
High school	.096	−.081	−.080	−.057
	(.097)	(.033)	(.023)	(.024)
Male head	−.006	.095	.046	.114
	(.037)	(.026)	(.022)	(.014)
Living in rural areas	−.138	−.288	…	…
	(.063)	(.049)		
Living in the suburbs	−.092	.066	…	…
	(.064)	(.023)		
Living in semicenter	−.197	.092	…	…
	(.065)	(.024)		
Log(financial wealth)	.918	.073	…	…
	(.013)	(.007)		
Number of ATMs in the province	1.911	2.326	…	…
	(.149)	(.086)		
Mills ratio:				
Bank account	…	…	.150	.137
			(.008)	(.006)
ATM card	…	…	−.603	.377
			(.043)	(.030)
Constant	−5.632	−5.868	.998	.346
	(.700)	(.479)	(.393)	(.264)
R^2	.596	.250	.177	.184
Sample size	31,863	26,922	9,334	17,588

Note.—In the probit regressions the dependent variable equals one if the household has a bank account (an ATM card), zero otherwise. Bank accounts include checking accounts, savings accounts, and postal accounts. In the currency equations the dependent variable is the logarithm of real currency. The regressions also include number of children, number of adults, age, age squared, number of income recipients, a dummy for gender, and dummies for employed, self-employed, and retired heads.

declines with the fraction of the population that has already adopted the technology and, especially, with the availability of ATM points in the area of residence. We expect that network externalities increase the probability of using an ATM card.

We also consider dummies for the area of residence (city center, semicenter, or outskirts), which capture the notion that households living in rural areas face different costs and benefits of opening and operating a bank account or holding an ATM card. The connotation of residence areas in Italy (and more generally in Europe) is different from that in North America. Often what we define as “outskirts” is equivalent in terms of social status to the American inner cities. Vice versa, the “city center” is often the most exclusive residential area. Finally, according to our model, financial wealth should not affect the demand for currency (once we condition on consumption); however, financial wealth is likely to affect portfolio choice and the fixed cost incurred when operating a new transaction technology.

Table 3 indicates that the nominal interest rate and consumption coefficients are positive and significantly different from zero in both probit equations. In particular, the size of the interest rate coefficient in the ATM probit is about half that in the bank account probit. Consumers with lower education are less likely to use a bank account and an ATM card than consumers with a college degree (the reference group). Finally, all variables that identify the model (number of ATM points, area of residence, and financial wealth) are generally significantly different from zero and have the expected signs. In particular, the number of ATM points in the province is a very strong predictor of both probabilities.

There are two objections that can be raised against the use of the number of ATM points as an identifying instrument: (*a*) that it can be endogenous if the installation of ATM points is demand driven and (*b*) that it also affects the demand for currency directly, perhaps because it reduces precautionary currency holdings at least among cardholders. To address the first problem, we replace the number of ATMs in the probit regressions with two indicators of the structure of the banking sector: the share of deposits held by the five largest banks in the province and the share of deposits in the province held by cooperative banks. Both correlate with the introduction of ATMs and are significant in the probits.[7] The results of the second-stage regressions are essentially unaffected.

[7] While market structure is affected by both demand and supply factors, we think that, in the short run, supply factors affect it more directly. We find that banking concentration discourages adoption of both bank accounts and ATM cards, consistent with the idea that market power (as measured by market concentration) raises adoption fees for deposits and ATM cards. The share of cooperative banks, on the other hand, favors the adoption

The second objection is unlikely to be relevant for individuals not using an ATM card. Furthermore, as the model is still formally identified, we can add the number of ATM points to the second-stage regressions of the demand for currency. When we estimate this regression, we obtain an insignificant coefficient. Finally, the use of the industry structure variables discussed above as an alternative to the number of ATM points also addresses this potential problem.

Columns 3 and 4 of table 3 report the estimates of the endogenous switching regressions for the demand for currency separately for households with a bank account and an ATM card and for households with a bank account but no ATM card. The consumption and the interest rate elasticities have the expected sign and are precisely estimated in both equations. However, important differences between the two regimes emerge. The consumption elasticity is larger for households with no ATM card (0.44 and 0.35, respectively), whereas the interest rate elasticity is twice as large (in absolute value) for households with an ATM card (-0.59 compared to -0.27). The implied structural coefficients of the transaction technology are $\hat{\beta} = 0.69$ and $\hat{\gamma} = -0.10$ for the group with an ATM card and $\hat{\beta} = 2.69$ and $\hat{\gamma} = -1.07$ for the group without an ATM card, leading to the following transaction technologies:

$$\tau_{H=1} = A_{H=1}\frac{c^{0.35}}{m^{0.69}}, \quad \tau_{H=0} = A_{H=0}\frac{c^{0.44}}{m^{2.69}}. \tag{7}$$

In the group with an ATM card, transaction time is close to being homogeneous of degree zero with respect to consumption and money balances ($\hat{\gamma}$ is close to zero). This implies that money demand is close to being homogeneous of degree zero with respect to consumption and the interest rate, as in the Baumol-Tobin model. In the group without ATM cards, the homogeneity property does not hold, but $\hat{\beta}$ is close to the theoretical value of two of the Miller and Orr model. The difference between the two groups implies that there are significant nonlinearities in the aggregate demand for money.

Substituting the optimal value of currency in equation (7), one can also derive an expression for the ratio of optimal transaction time for ATM and non-ATM users as a function of c, R, technological change, and all the other terms that appear in the money demand equation:

$$\frac{\tau_{H=1}}{\tau_{H=0}} = \frac{K_{H=1}^{-0.35}}{K_{H=0}^{-0.44}}\frac{1}{R^{0.32}c^{0.09}}, \tag{8}$$

where $K_{H=i} = (wA\beta)_{H=i}$ for $i = 0, 1$ as estimated in the two equations

of ATM cards. The reason is that cooperative banks in Italy are linked through their association and can more easily internalize the network externalities from faster installation of ATMs. Results are available on request.

for currency for ATM users and nonusers.[8] The ratio between the two estimates of transaction time is a useful measure of the efficiency gain entailed by the ATM technology. The expression can be calculated for each individual in the sample. On average, the ATM technology reduces transaction time by 42 percent. Given the assumed form of the transaction technology, note from equation (8) that the gain in transaction time is proportional to the reduction in the demand for money following the adoption of the ATM technology.

Equation (8) allows us to put some bounds on the estimated adoption costs. Consider first those who have not adopted the ATM card, and rewrite equation (6) as

$$\text{minimum benefit} = w\tau_{H=0}\left(1 - \frac{\tau_{H=1}}{\tau_{H=0}}\right) + Rm_{H=0}\left(1 - \frac{m_{H=1}}{m_{H=0}}\right).$$

Since these consumers have not adopted, their benefits represent a lower bound on adoption costs. Using the estimated parameters for those with $H = 1$ and the gain in transaction time from equation (8), we can compute the expression above for each individual in the sample; on average, it is equal to 11.3 euros (with a standard deviation of 7.8 euros). With the same line of reasoning, one could consider the adopters and compute the loss that they would suffer had they not adopted. This amounts to estimating an upper bound on adoption costs of 28.1 euros (with a standard deviation of 14.3 euros). As expected, these costs are not particularly high.

The estimated adoption costs are broadly consistent with direct evidence we have on the adoption fees charged by Italian banks when one considers that adoption costs must also include the value of time spent learning the new technology. In Italy, only a few banks do not supply ATM cards. Most of those that do charge a fixed annual fee and a fee for each transaction. On a sample of 38 banks for which we obtained information, the average yearly adoption fee is 6.2 euros (the standard deviation is 3.1 euros). Four banks charge no fee, and among those charging a fee, the average is 6.9 euros per year. Since consumers have different incentives to search for a bank that provides an ATM card, access to the ATM technology is effectively a choice variable.

The specifications in columns 3 and 4 of table 3 also include several demographic variables: dummies for the education of the household head, number of adults and children in the household, number of income recipients, gender and age of head, dummies for employees and for the self-employed, and a dummy for retired heads. These variables proxy for differences in the value of time and, more generally,

[8] We compute the term $wA\beta$ as the exponential of the sum of all the terms in the demand for money equation except for consumption and the interest rate.

in transaction costs across different population groups. Most of them are important determinants of money demand. As they reflect several factors, the interpretation of these coefficients is not straightforward. In some cases, like the education dummies, their relative magnitude is consistent with an interpretation in terms of the value of time.[9] The Mills ratios in both equations are significantly different from zero, showing that ignoring selection problems would bias the estimated coefficients.

The results we obtain are robust to changes in the specifications reported in table 3. For instance, we considered alternative definitions of consumption, we excluded from our sample retired household heads, and we replaced the time trend with year dummies. This specification search does not affect the main results reported in table 3. In particular, we consistently find that there are small differences in consumption elasticities between the two regimes and that households with ATM cards have a much higher elasticity to the interest rate than households with no cards. The different elasticities are reflected in different transaction technologies between the two groups shown in equation (8).

To take into account the possibility of regional fixed effects, we have also included dummies for the region of residence (South and center of the country) both in the probits and in the money demand equation. These variables might proxy for the relevance of the underground economy and delinquency, which might raise the demand for currency. The signs of the estimated coefficients are not entirely consistent with this interpretation: the underground economy and criminal activities are deemed to be more widespread in the South than in the rest of the country, whereas our results indicate that currency is higher in the South *and* in the center than in the North. In any event, the sign and magnitude of the coefficients on consumption and interest rates are robust to the inclusion of these variables. As a further check on the potential impact of the underground economy, we exclude the self-employed, and the results are once again basically unaffected.

VI. The Welfare Cost of Inflation

Bailey (1956) first showed that the welfare cost of inflation arising from the inefficiencies of carrying out transactions with means of payment that do not pay interest can be measured by the integral under the demand for money. In this section we evaluate the implications of our

[9] Unfortunately our data set does not contain a variable that measures with precision the hourly wage and therefore the cost of time. Furthermore, for households with multiple earners or out of the labor force, it would not be easy to proxy the cost of time even if wage rates were available. For similar reasons, it is difficult to give a straightforward interpretation of the coefficients of these demographic variables.

estimates for such a welfare cost and compare our results to previous evidence. We stress, however, that in these computations we ignore other possible costs arising from inflation, such as the distortions built into the tax system, the possibility that relative price changes are confused with general price increases, and other nonneutralities arising from inflation. Moreover, our results refer only to the household welfare cost since we do not consider the demand for money by firms.

A. *The Existing Evidence*

Lucas (2000) has recently evaluated the welfare cost of inflation deriving the money demand equation from two general equilibrium models (the Sidrauski model and a general equilibrium version of the McCallum and Goodfriend model). He calibrates various welfare cost functions using estimates of the interest rate elasticity in low-frequency time-series data. Assuming a constant elasticity money demand function of the form $m = AyR^{-0.5}$, where y is real gross domestic product and A a constant term, Lucas estimates that in the United States the welfare cost of reducing inflation from 14 percent to 3 percent is on the order of 0.8 percent of GDP. He shows that the specific functional form (logarithmic or semilogarithmic) of the money demand equation does not affect this calculation much (except at very low interest rates). Any correction of the welfare cost that comes from different assumptions about the fiscal transfer policy adopted to implement a given interest rate reduction affects only trivially the welfare cost computations.[10]

The magnitude of the welfare cost of inflation depends not only on the functional form of the demand for money or assumptions about fiscal policy, but also on two other crucial factors. The first factor is the definition of money and of interest-bearing assets. As welfare costs are proportional to the money stock held by consumers and firms, different definitions provide very different results. For instance, Lucas defines monetary assets as M1, the sum of currency and demand deposits, an aggregate that ranges from 15 to 30 percent of GDP in most industrialized countries (18 percent in the United States and 30 percent in Italy in 1998). The crucial assumption here is that currency and deposits are the only means of payments and that they pay no interest. However, Feldstein (1997) points out that the demand deposit component of M1 is now interest-bearing and defines as monetary assets currency plus bank reserves, an aggregate that is on the order of 6 percent in both the United States and Italy. Using an interest rate elasticity of the mon-

[10] Several studies provide estimates of the welfare cost of inflation in general equilibrium models: see Cooley and Hansen (1989), Gomme (1993), Dotsey and Ireland (1996), and Bullard and Russell (1997).

etary base of −0.2, Feldstein places the welfare cost of inflation originating from the distortion of the demand for money at less than 0.1 percent.[11]

The second factor is the proportion of consumers who hold interest-bearing assets in addition to monetary assets. In the presence of transaction and adoption costs, not everyone will choose to invest in both assets, and aggregation issues become crucial in evaluating the interest rate elasticity of money. In this context, significant progress has been made by Mulligan and Sala-i-Martin (2000). They note that almost 60 percent of U.S. households interviewed in the 1983 Survey of Consumer Finances (SCF) held no financial assets other than currency and checking accounts. They interpret this fact as evidence of high transaction costs in investing in interest-bearing assets. Mulligan and Sala-i-Martin evaluate the elasticity of money demand at low interest rates by looking at the elasticity of the decision to hold interest-bearing assets at small quantities of assets.

Mulligan and Sala-i-Martin's estimates also suggest that the interest rate elasticity is indeed small at low levels of the interest rate. The reason is that when the interest rate falls, more and more households choose not to incur the transaction cost, and fewer and fewer households use resources to economize on cash holdings. In other words, when the interest rate tends to zero, only households with interest-bearing assets incur the time costs associated with holding monetary assets, but they become fewer. Ignoring transaction costs and zero holdings of interest-bearing assets can therefore overestimate the welfare cost of inflation at low levels of inflation. The money concept Mulligan and Sala-i-Martin use is even broader than the one used by Lucas, since they define as monetary assets the sum of checking and savings accounts (with the exclusion of currency). In the remainder of this section we provide calculations of the welfare cost of inflation using our estimates. We then replicate Lucas's and Mulligan and Sala-i-Martin's concepts of welfare costs and compare them with our own set of estimates.

B. Our Evidence

As in Bailey (1956), the welfare cost of inflation corresponding to a given nominal interest rate R, $W(R)$, can be measured as the area under

[11] Even though the welfare costs of inflation are bound to be low in monetary economies in which a substantial portion of the money stock is interest-bearing, Feldstein stresses that the welfare gain from reducing inflation is a permanent benefit. He evaluates the welfare gain of moving from 2 percent inflation to price stability at about 1 percent of GDP. He finds that most gains from price stability do not derive from an increase in money demand (unlike Lucas, he uses a narrow concept of money), but from the reduction in inflation-induced tax distortions in the intertemporal allocation of consumption and in the demand for housing.

the (inverse) money demand function in the interval $m(R) - m(0)$. This measure of the welfare cost implicitly assumes that the socially optimal currency $m(0)$ is that of an economy in which monetary policy induces a steady deflation at the Friedman optimal rate, so that $R = 0$. From (4), the welfare cost is given by

$$W_m(R) = \int_0^R m(R) - Rm(r) = (wA\beta)^{1/(1+\beta)}\beta^{-1}c^{(\gamma+\beta)/(1+\beta)}R^{\beta/(1+\beta)}. \quad (9)$$

The first term, $(wA\beta)^{1/(1+\beta)}$, is the exponential of the constant term in a log-log estimate of money demand; $\beta/(1+\beta)$ and $(\gamma+\beta)/(1+\beta)$ can be readily inferred from the interest rate and consumption elasticities.[12]

Equation (9) is the welfare cost of inflation for an individual with a bank account and access to a given payment technology. However, when computing the welfare cost, we must also take into account the effects of interest rate changes on the asset ownership and on the selection of the technology. Given our model, the overall welfare cost is a weighted average of the welfare costs of households with and without ATM cards, the weights given by the proportion having a card. In turn, the welfare cost is multiplied by the proportion of households with a bank account:

$$\text{welfare cost} = F_D(\bar{R})\{F_H(\bar{R})W(\bar{R})_{D=1,H=1} + [1 - F_H(\bar{R})]W(\bar{R})_{D=1,H=0}\}, \quad (10)$$

where $F_D(\bar{R})$ is the probability of having a bank account evaluated at the interest rate $\bar{R}$ and $F_H(\bar{R})$ the probability of having an ATM card evaluated at $\bar{R}$. Equation (10) highlights that the interest rate has three effects on the welfare cost of inflation. The direct effect is the change in money demand following the change in the interest rate; this direct effect is different in the two regimes. The two other effects are indirect, because changing the interest rate changes the fraction of people with a bank account and the fraction with an ATM card through the $F_D(\cdot)$ and $F_H(\cdot)$ functions. We know from Section V that these indirect effects are important since both choices are affected by the nominal interest rate.

Equation (10) also highlights that to compute the welfare cost of inflation we do not need to look at the behavior of those without bank accounts ($D = 0$). The reason is the same as in Mulligan and Sala-i-Martin, but applied to the choice between currency and bank accounts (our interest-bearing assets), not between bank accounts and other interest-bearing assets. Other things equal, people who have chosen not

[12] Note that this equation truly measures welfare costs only if one assumes that the government can finance its expenditures by nondistorting taxes (Fischer 1981; Lucas 2000).

TABLE 4
WELFARE COST OF INFLATION FOR HOUSEHOLDS WITH AND WITHOUT AN ATM CARD (5 Percent Interest Rate)

	With ATM			No ATM			Total Sample		
Year	Group Size	Welfare Cost	W/C	Group Size	Welfare Cost	W/C	Group Size	Welfare Cost	W/C
1989	1,212	29.29	.13	5,729	8.69	.05	7,973	11.06	.07
1991	2,321	21.12	.10	4,612	7.05	.04	8,127	10.07	.06
1993	2,608	16.95	.08	3,801	6.27	.04	7,663	9.56	.06
1995	3,193	14.79	.07	3,446	5.87	.04	8,100	9.03	.06
Total	9,334	18.88	.09	17,588	7.18	.05	31,863	9.93	.06

NOTE.—Welfare costs are computed on the basis of the estimated coefficients of table 3 and are expressed in euros. W/C denotes the welfare cost as a percentage of nondurable consumption.

to use a bank account at the going interest rate will not choose to open one at lower interest rates. For them, the welfare cost is zero.

By comparison with previous studies, there are three main advantages of our data set and approach. We can estimate the interest rate elasticity of money demand exploiting geographic and time variation in interest rates. We can address the selection problem discussed by Mulligan and Sala-i-Martin, and we can estimate the effect of the interest rate on adoption decisions. Finally, we allow for different transaction technologies whose adoption can be endogenous.

The welfare costs for the two regimes and for the population as a whole are reported in table 4. The computation uses the estimated coefficients in table 3 and assumes that initially the interest rate is 5 percent for each household ($\bar{R} = 0.05$) and that the socially optimal inflation rate requires $\bar{R} = 0$. Overall we find that the welfare gain of a five-point reduction in inflation is only about 10 euros, or 0.06 percent of nondurable consumption (0.10 percent for a 10-point reduction in inflation).

For households with an ATM card the welfare cost is considerably larger than for the other group. There are two reasons for this difference. First, the interest rate elasticity for this group is larger in absolute value than for the group with no ATM (-0.59 compared to -0.27; see table 3). Second, the ATM group includes a larger number of people with higher education and, more generally, a higher value of time, corresponding to higher transaction costs.

The welfare cost generally declines over time, particularly in the sample with ATM cards, reflecting the negative time trend affecting the money demand equation. Note that the aggregate welfare cost is fairly constant because the declining impact of the time trend is offset by an increase in the fraction using ATMs. This highlights the importance of aggregation issues during periods of financial innovation. The same issue of aggregation also emerges in table 5, where we tabulate the

TABLE 5
Welfare Cost of Inflation by Education

	5 Percent Interest Rate		10 Percent Interest Rate	
	Welfare Cost	W/C	Welfare Cost	W/C
Less than elementary school	4.89	.05	9.46	.10
Elementary school	7.64	.06	13.39	.10
Junior high school	10.54	.06	17.18	.10
High school	13.02	.07	20.10	.10
College	14.28	.06	21.59	.08
Total sample	9.93	.06	16.25	.10

Note.—Welfare costs are computed on the basis of the estimated coefficients of table 3 and are expressed in euros. W/C denotes the welfare cost as a percentage of nondurable consumption.

welfare cost by education for two levels of the interest rate (5 and 10 percent). The welfare cost increases with education, reflecting the higher shadow value of time for individuals with higher education.

The experiment computes the welfare cost assuming a nominal interest rate of 5 percent for each household, about the level prevailing at the beginning of the sample period. But in fact we know that interest rates vary across provinces and years in our sample. Thus we compute the welfare gain from reducing the nominal interest rate by five percentage points for each household in the sample starting from a level of 5 percent plus its sample value. The pattern of welfare costs is similar to that in table 4.

In principle, the evaluation of the welfare cost of inflation should also take into account the distortions involved in the management of other monetary assets, not only currency. However, this would involve taking a stance on the effect of a reduction in inflation on the interest rate differential between other financial assets and bank deposits ($R_B - R$). While it is reasonable to assume that a change in inflation is reflected in an equal change in the after-tax nominal interest rate, the interest rate differential depends on technology parameters as well as on the market structure of the banking sector. Therefore, it is not clear how it will be affected by a change in the rate of inflation.[13] As in Feldstein (1997), if $R_B - R$ is independent of inflation, to compute the welfare cost of inflation it is sufficient to consider the effect of changes in the nominal interest rate on the demand for currency. We provide evidence that $R_B - R$ is relatively constant in the sample in Section II*C* (see table 2).

[13] Marimon, Nicolini, and Teles (1997) present a general equilibrium model with multiple means of payments and show that the equilibrium interest rate differential depends on the cost of providing “electronic money” and on the market structure of the financial sector.

C. *Comparing Our Results with Those of Lucas and Mulligan and Sala-i-Martin*

The difference between our approach and that in Lucas (2000) depends on the selection issue and a different monetary aggregate. If we were to ignore the selection issue and use the baseline specification (5) rather than equation (10), the cost of inflation would be higher (39 euros, or 0.2 percent of annual consumption). The difference with respect to the welfare cost displayed in table 3 is explained by the facts that households without a bank account have a welfare cost of zero in equation (10) and that the estimated interest rate elasticity derived from equation (5) is higher in absolute value (-0.7) than in each of the two groups in equation (10). Suppose now that we also ignore that bank accounts are interest-bearing, include them in the monetary aggregate as in Lucas's paper, and apply the same parameters in equation (5) to this larger monetary aggregate. We would obtain a welfare cost of inflation of 3.2 percent of consumption. This is a consequence of the fact that deposits are 42 percent of nondurable consumption, whereas currency is less than 3 percent of consumption. Thus focus on a different monetary aggregate is the main source of difference with Lucas.

There are also two differences between our approach and that of Mulligan and Sala-i-Martin. First of all, they focus on the extensive margin, that is, on the effect of the interest rate on the adoption decision of interest-bearing assets, because they do not observe interest rate variation in their sample. We can take into account explicitly and without further assumptions both the intensive and the extensive margins. The second difference is that Mulligan and Sala-i-Martin use different monetary and interest-bearing aggregates (savings and checking accounts on the one hand and stocks and bonds on the other). They do not observe currency and ignore that bank accounts might pay interest.

To compare our estimates with those of Mulligan and Sala-i-Martin, we estimate a money demand function in which the monetary aggregate is defined as bank accounts (checking and savings accounts). The opportunity cost of money in this specification is the spread between the nominal interest rate on Treasury bills and the nominal interest rate on deposits ($R_B - R$). The correct estimation strategy is to estimate a money demand function correcting for two sources of selection. First, not all households have a bank account (15 percent in our survey). This problem is ignored by Mulligan and Sala-i-Martin, who drop 25 percent of the sample, that is, households without bank accounts (currency is not observed in the SCF). The second source of selection is the fact that only 58.7 percent of households have financial assets besides demand deposits (41 percent in the SCF). This is the adjustment that Mulligan and Sala-i-Martin make to their money demand equation.

For comparison, we thus estimate a money demand equation on the sample of those with a bank account and with financial assets other than a bank account (denoted by the indicator variable dummy B, 58.7 percent of the sample), correcting for the two sources of selection bias. We use the same specification as for bank accounts in table 3 for the two first-stage probits and for the money demand equation. Results are qualitatively similar to those of Mulligan and Sala-i-Martin. In particular, the log of financial wealth is positive and highly significant in the probit equations. The consumption elasticity in the money demand equation is 0.058 (with a t-statistic of 2.52), which is similar to the effect that Mulligan and Sala-i-Martin and Bomberger (1993) obtain from transaction variables in the demand for deposits. The elasticity of money demand with respect to $R_B - R$ is precisely estimated at -0.34 with a t-statistic of 4.81.[14] Following the same steps that lead to equation (10), this model implies that the welfare cost of driving the spread $S = R_B - R$ to zero is

$$\text{welfare cost} = F_D(\bar{S})[F_B(\bar{S})W(\bar{S})_{D=1,B=1}], \tag{11}$$

where $F_D(\bar{S})$ is the probability of having a bank account evaluated at the spread $\bar{S}$ and $F_B(\bar{S})$ the probability of having financial assets other than bank accounts evaluated at $\bar{S}$. Equation (11) highlights that the spread has three effects on the welfare cost of inflation: a direct effect, because changing the spread changes the demand for deposits; and two indirect effects through the $F_D(\cdot)$ and $F_B(\cdot)$ functions, because changing the spread changes the fraction of people who have a bank account and the fraction of people who invest in interest-bearing assets. We know from Mulligan and Sala-i-Martin that the decision to invest in interest-bearing assets is important in their sample. They instead ignore the other margin (the decision to open a bank account).

Evaluating the expression (11) for a spread of 5 percent (i.e., driving to zero a 5 percent spread between the bond rate and the deposit rate) results in a welfare cost of 0.8 percent in the sample of those with a bank account and other financial assets, the term $W(\bar{S})_{D=1,B=1}$ in the brackets in equation (11). Accounting for both sources of selection reduces the welfare cost to 0.5 percent. The contribution of this reduction comes mainly from the Mulligan and Sala-i-Martin correction. Ignoring the bank account decision affects trivially the estimated welfare cost.

[14] The complete set of results is omitted for brevity and is available on request.

VII. Withdrawals and Trips

As we discussed in Section II, in addition to the data on average cash holdings, the SHIW contains additional information on various aspects of cash management. In Section II, we have shown that the figures independently reported for average currency holdings, average withdrawals, minimum currency, number of trips, and consumption flows are internally consistent. It is interesting to establish the extent to which these variables react to changes in interest rates and consumption flows. While the interpretation of the results that follow is not at times as straightforward as that for the average currency, they provide useful information on the way in which cash management is potentially affected by inflation.

A. Average Withdrawals

Inventory models of the demand for money, such as the Baumol-Tobin and the Miller-Orr models, imply that the average money balances are a constant fraction of the size of withdrawals (or cash deposits). Thus, in these models, one should obtain the same parameter estimates if withdrawal amounts are used instead of currency as a left-hand-side variable. In practice, however, the two sets of estimates need not deliver the same results. First, the restrictions imposed by inventory models may not hold in practice. For instance, if a withdrawal is made when currency hits some *positive* lower bound rather than when it is completely depleted (as in Baumol and Miller and Orr), then the proportionality between average holdings and the size of withdrawals may fail. Second, average currency is self-reported, and there is no guarantee that households report the *mean* currency rather than some other index of central tendency.

In table 6 we report estimates of the determinants of the size of withdrawals. We retain the same specification as in the demand for average currency. In this case, however, we report estimates for three types of withdrawals: those at the bank's counter by ATM cardholders, those at the counter by non-ATM cardholders, and ATM withdrawals. The pattern of coefficients is similar across equations. In all cases the interest rate elasticity is negative, significantly different from zero, and somewhat larger (in absolute value) for nonholders of ATM cards. The transaction variable is positive, and its elasticity is similar in size to that reported in table 3 except for the size of withdrawals at an ATM. For this group the elasticity with respect to the scale of transactions is only 0.12, revealing substantial economies of scale. While the interest rate elasticity for the group of nonholders is comparable to (and is not dramatically different from) that reported in table 3, the elasticities for

TABLE 6
Determinants of the Size of Withdrawals

	Withdrawal at a Bank		Withdrawal at an ATM with ATM Card
Variable	With ATM Card (1)	No ATM Card (2)	(3)
Log(consumption)	.213	.304	.130
	(.033)	(.025)	(.019)
Log(interest rate)	−.361	−.392	−.161
	(.137)	(.095)	(.081)
Time	.314	.436	.003
	(.057)	(.041)	(.032)
Time squared	−.031	−.043	−.003
	(.006)	(.004)	(.003)
Less than elementary school	.107	.009	.000
	(.085)	(.047)	(.051)
Elementary school	.082	.015	−.066
	(.040)	(.036)	(.023)
Junior high school	.083	−.008	−.022
	(.032)	(.034)	(.018)
High school	−.046	−.017	−.025
	(.029)	(.034)	(.016)
Mills ratio:			
Bank account	.075	.064	.040
	(.010)	(.007)	(.005)
ATM card	−.008	−.101	−.076
	(.052)	(.031)	(.029)
Constant	1.551	.853	3.597
	(.573)	(.416)	(.332)
R^2	.087	.133	.067
Sample size	5,132	8,910	7,196

Note.—The dependent variable is the logarithm of the average currency withdrawals at a bank (including the postal system) or at an ATM. The sample excludes observations from the 1989 SHIW. The first-stage regressions are the same as in table 3. The regressions also include number of children, number of adults, age, age squared, number of income recipients, a dummy for gender, and dummies for employed, self-employed, and retired heads.

the groups of cardholders are conceptually different since they correspond to different types of withdrawals.

B. *The Number of Trips to the Bank and Income Received in Cash*

At the root of the welfare cost discussed in Section VI is that households shift their use of time from productive purposes to cash management in order to shield themselves from inflation. Faced with high nominal interest rates, consumers reduce cash balances and substitute time for money. In fact, the transaction technology specified in equation (1) implies that time spent transacting and money holdings should be negatively correlated. For the same reason, an increase in the nominal interest rate should increase the time spent transacting. But this is not the only channel through which consumers reduce their exposure to inflation. The results in table 3 show that as the nominal interest rate increases, more households choose to invest in interest-bearing assets (deposits) and also to use more efficient technologies (ATM cards). In this subsection we extend the evidence in two directions. We use information available in the survey on the number of trips to the bank that households make to deposit or withdraw currency. Also, we show that an additional channel to protect against inflation is to alter the way income is received.

Starting with the number of trips to the bank, note that transaction time τ and the number of trips to the bank, n, are linked by the relation $\tau = kn$, where k is the average time per trip. Substituting in the money demand equation (4) and ignoring integer constraints, one obtains the optimal number of transactions:

$$n = \left(\frac{A}{k}\right)\left(\frac{wA\beta}{R}\right)^{-\beta/(1+\beta)} c^{(\gamma+\beta)/(1+\beta)}. \tag{12}$$

While the consumption elasticity in the trip equation is the same as in the demand for currency, the interest rate elasticity is positive and, except for the Baumol-Tobin case, different in absolute value. Table 7 reports the estimates of an equation for the number of trips. To account for the integer nature of trips, we use an ordered probit estimator, with trips coded in eight groups (zero trips, fewer than one trip per month, two, three, four, five, six, and more than seven per month).[15] Column 1 reports estimates for the total number of trips. Since questions on trips were not asked in 1989, estimates refer only to 1991–95. Consistent with inventory models of the demand for money, the number of trips increases with the volume of transactions and with the interest rate with elasticities equal to 0.511 and 0.244, respectively. These estimates are broadly consistent with those obtained from the currency equation, reported in table 6.

One problem with these estimates is that the total includes both trips to the bank to make withdrawals and deposits and those to an ATM, whereas the two types of trips are different objects since trips to the ATM require less time. Therefore, in column 2, we report separate estimates for the number of trips to ATMs. Even though the overall pattern of the estimated coefficients is similar to that for total trips, trips to the ATM are more responsive to the interest rate, with an elas-

[15] The category "zero trips" includes households that do not hold a bank account. Similarly, the category "zero trips to ATM" includes households that do not have an ATM card.

TABLE 7
Determinants of Trips and of the Fraction of Income Received in Currency

	Total Number of Trips (1)	Number of Trips to ATM (2)	Fraction of Income Received in Currency (3)
Log(consumption)	.511	.642	−.455
	(.020)	(.025)	(.024)
Log(interest rate)	.244	.655	−.913
	(.097)	(.126)	(.108)
Time	−.521	−.139	−.085
	(.040)	(.051)	(.017)
Time squared	.049	.022	.006
	(.004)	(.005)	(.002)
Less than elementary school	−.748	−1.041	.828
	(.042)	(.068)	(.049)
Elementary school	−.564	−.764	.550
	(.032)	(.036)	(.037)
Junior high school	−.309	−.385	.239
	(.030)	(.033)	(.035)
High school	−.092	−.133	.056
	(.029)	(.031)	(.035)
Living in rural areas	−.094	−.241	−.103
	(.034)	(.048)	(.040)
Living in suburbs	.070	.064	−.081
	(.018)	(.023)	(.021)
Living in semicenter	.079	.067	−.112
	(.019)	(.024)	(.022)
Log(financial wealth)	.178	.088	−.139
	(.005)	(.006)	(.006)
Number of ATMs in the province	1.442	1.978	−2.076
	(.062)	(.077)	(.082)
R^2	.116	.163	.137
Sample size	23,890	23,890	31,683

Note.—The coefficients in cols. 1 and 2 are estimated by an ordered probit model for the number of trips, coded in eight groups (zero trips, fewer than one per month, two, three, four, five, six, and more than seven). The ordered probits exclude 1989 observations. The regression in col. 3 is a two-limit Tobit for the fraction of income received in currency. This variable ranges from zero to one. The regressions also include number of children, number of adults, age, age squared, number of income recipients, a dummy for gender, and dummies for employed, self-employed, and retired heads.

ticity that is about two times greater than that for total trips.[16] Overall, these results are qualitatively similar to those obtained estimating the equation for cash and provide independent support for inventory models of the demand for money.

The results for the number of trips, particularly those for the total number of trips, should be taken with caution. The variable "trips to the bank" is not clearly defined and might differ substantially from the theoretical concept in equation (12). Furthermore, because of the dis-

[16] These elasticities are not directly comparable with those reported in col. 3 of table 3, which refer to currency holdings for those using an ATM card. These balances are the reflection of trips to both the bank and the ATM among ATM cardholders. The estimates in table 7 refer instead to trips to ATMs alone.

crete nature of the variable and the use of an ordered probit model, we do not take proper account of the selectivity problem that might arise if the equation were estimated using only information for households with a bank account and, in the case of the equation in column 2, for those with an ATM card. The evidence we present, however, is generally consistent with that presented in the previous sections.

The share of income received in currency is also a signal of the development of the payment system. In 1989 the sample average of this variable was 52 percent. Parallel to the other developments in cash management, the fraction declined to about 40 percent by 1995. Column 3 of table 7 reports a two-limit Tobit estimate for the share of income received in currency. Our hypothesis is that when the nominal interest rate is high, individuals seek protection against inflation by altering the way they receive payments, opting for channels that minimize time of cash in hand. The estimates reported are consistent with this conjecture. In particular, the interest rate has a strong and highly significant negative effect on the fraction of income received in currency.

VIII. Conclusions

The welfare cost of inflation we consider in this paper arises from the increased effort to manage currency in periods in which the nominal interest rate deviates from Friedman's optimal monetary rule. One way to measure such a cost is to integrate the area under the money demand curve. This requires information on its parameters, in particular the transaction and interest rate elasticities. These parameters have often been inferred by aggregate money demand functions estimated on time-series data, as in Lucas (2000). Recently Mulligan and Sala-i-Martin (2000) have pointed out that the aggregate interest rate elasticity depends on the fraction of households holding interest-bearing assets. If this fraction is small, the interest rate elasticity is low, particularly at low levels of the interest rate.

We estimate the demand for currency using a data set that provides detailed information on the management of cash balances, interest rates on alternative assets, and the adoption of new technology. Moreover, the data refer to Italy, where bank deposits are interest-bearing and therefore constitute the natural alternative to currency. These features allow us to exploit the cross-sectional and time variability of nominal interest rates and estimate a version of the Baumol-Tobin model with micro data. In this respect our paper constitutes an advance over Mulligan and Sala-i-Martin's since they are forced to focus on the extensive margin to identify the effects of changes in the interest rate. Moreover, we model both the access to interest-bearing assets and the choice of

ATM technology and find significant interest rate and transaction effects in the equation for the ownership of both an interest-bearing checking account and an ATM card.

The parameters of the demand for currency are estimated precisely. We find an interest rate elasticity of around -0.5 and substantial economies of scale in cash management (a consumption elasticity well below unity). Furthermore, we find substantial differences in the equations for ATM cardholders and nonholders. The demand for currency of those who choose to have an ATM card is considerably more elastic to the interest rate than that of the households that do not hold such a card. These nonlinearities are important in evaluating the aggregate welfare cost of inflation.

The evidence we obtain from average balances is also confirmed by our study of withdrawals, trips to the bank, and types of payments for income. Overall, our detailed data set provides consistent and encouraging evidence for the model of cash balance management we have studied. Not only are the basic quantities measured in the data consistent with each other, but the estimates we obtain for the demand for money function yield sensible and precisely estimated parameters, which imply reasonable differences in the effect of the new transaction technology.

Our estimates of the welfare cost of inflation vary considerably within the population but turn out to be small. On average, the yearly welfare cost of inflation is around 0.1 percent of nondurable consumption. If intensive cash management is the only distortion induced by inflation and if a large portion of the money stock is interest-bearing, consumers are able to shield themselves against the inflation tax, and reducing inflation would result in limited welfare gains. But in reality there are several other inflation-induced distortions that we have not considered in this paper and that can make the goal of price stability desirable.

Data Appendix

A. *Variable Definitions*

Information on sample design and response rates of the Survey of Household Income and Wealth can be found in Brandolini and Cannari (1994). In the empirical estimates, all demographic variables—age, education, occupation, and sector—refer to the head of the household (the husband, if present). If instead the person who would usually be considered the head of the household works abroad or was absent from the household at the time the interview took place, the head of the household is the person responsible for managing the household's resources. All monetary variables are deflated using the consumer price index, expressed in 1995 lire and then converted to euros.

ATM ownership.—In each year, respondents report ownership of an ATM card. The surveys also contain information about the use of ATMs. In practice, virtually all those reporting having an ATM card also report using the ATM card.

Currency.—The following question was asked of household heads in each of the surveys: “What is the average amount of currency usually held in your family?”

Minimum amount of currency.—The following question was asked to household heads in each of the surveys: “Usually, what is the amount of currency that you have at home before you choose to make a currency withdrawal?”

Number of withdrawals and average withdrawal.—The following questions were asked to household heads in each of the surveys: “Think about a normal month. How many currency withdrawals are made by you or members of your household? What is the average currency withdrawn?” These questions are asked separately for withdrawals at a bank, at a post office, and at an ATM point.

Consumption.—Consumption is the sum of the expenditure on food consumption, entertainment, education, clothes, medical expenses, housing repairs and additions, and imputed rents. Expenditures on durable goods (vehicles, furniture and appliances, or art objects) are therefore not included in the definition of consumption.

Deposits.—Include checking accounts, savings accounts, and postal deposits.

Education of the household head.—This variable is originally coded as follows: no education (zero), completed elementary school (five years), completed junior high school (eight years), completed high school (13 years), completed college (18 years), and graduate education (more than 20 years). The variable is coded according to the values given in parentheses. For the highest class we assume a value of 20 years.

Financial wealth.—Sum of currency, checking accounts, savings accounts, postal deposits, government paper, corporate bonds, mutual funds and other managed accounts, and stocks. For 1989, total financial wealth is readily available. For other years it must be estimated because the categories of financial assets (except cash holdings) are provided in 15 bands; the average value between the lower and the upper band was used in determining the level of each asset.

Interest rate on deposits.—We have data on the average nominal interest rate on checking accounts by year (1989, 1991, 1993, and 1995) and 95 provinces. The source is the Bank of Italy Monetary Statistics Survey.

Interest rate on government paper.—In order to compute the interest rate differential used in estimating the demand for deposits, we use as a reference asset the average after-tax interest rate on short-term (one-year maturity or less) Treasury bills.

Number of ATM points per province.—Data on the number of ATM points in each year/province are provided by a special survey of the Bank of Italy. This data set is then merged with the 1989–95 SHIW.

B. Summary Statistics

Table A1 presents weighted sample averages of the demographic variables used in the estimation. The development of these demographic variables matches that of population surveys, as documented by Brandolini and Cannari (1994). To the extent that demographic variables affect the demand for money, population aging, the decline in the number of children per household, and the increase in the number of income recipients should all be taken into account. The last row of the table indicates that with respect to the original sample, 828 observations (2.5 percent of the original sample) are lost because of missing values, mainly because some households do not report information on currency or ownership of an ATM card or a bank account. The sample is therefore reduced from 32,691 potential observations to 31,863. Since the number of missing ob-

TABLE A1
SAMPLE MEANS OF DEMOGRAPHIC VARIABLES USED IN THE ESTIMATION

	1989	1991	1993	1995
Less than elementary	.08	.08	.10	.09
Elementary school	.36	.37	.35	.33
Junior high school	.25	.25	.28	.27
High school	.22	.22	.21	.24
College	.08	.07	.06	.06
Male head	.81	.80	.73	.72
Number of adults	2.31	2.33	2.31	2.31
Number of children	.67	.65	.66	.58
Age	52.05	53.28	53.06	54.07
Number of income recipients	1.72	1.74	1.76	1.79
Employed head	.46	.43	.39	.36
Self-employed head	.17	.16	.14	.14
Retired head	.22	.24	.26	.26
Living in northern regions	.50	.47	.49	.49
Living in central regions	.19	.19	.19	.18
Living in southern regions	.31	.33	.32	.33
Living in rural areas	.05	.04	.07	.07
Living in the suburbs	.39	.41	.36	.32
Living in the semicenter	.30	.27	.31	.32
Living in the center	.25	.27	.26	.29
Sample size	8,271	8,188	8,097	8,135
Sample size used in the estimation	7,973	8,127	7,663	8,100

NOTE.—All averages are computed using sample weights and using the original sample size. Data are drawn from the 1989–95 SHIW.

servations is relatively low, we do not attempt to model the probability of nonresponse.

References

Avery, Robert V.; Elliehausen, Gregory E.; Kennickell, Arthur B.; and Spindt, Paul A. "The Use of Cash and Transaction Accounts by American Families." *Fed. Reserve Bull.* 72 (February 1986): 87–108.

Bailey, Martin J. "The Welfare Cost of Inflationary Finance." *J.P.E.* 64 (April 1956): 93–110.

Baumol, William J. "The Transactions Demand for Cash: An Inventory Theoretic Approach." *Q.J.E.* 66 (November 1952): 545–56.

Bomberger, William A. "Income, Wealth, and Household Demand for Deposits." *A.E.R.* 83 (September 1993): 1034–44.

Brandolini, Andrea, and Cannari, Luigi. "Methodological Appendix: The Bank of Italy's Survey of Household Income and Wealth." In *Saving and the Accumulation of Wealth: Essays on Italian Household and Government Saving Behavior,* edited by Albert Ando, Luigi Guiso, and Ignazio Visco. Cambridge: Cambridge Univ. Press, 1994.

Bullard, James, and Russell, Steven. "How Costly Is Sustained Low Inflation for the US Economy?" Paper presented at the conference on Macroeconomic Theory and Monetary Policy, Federal Reserve Bank of Philadelphia, October 23–24, 1997.

Cooley, Thomas F., and Hansen, Gary D. "The Inflation Tax in a Real Business Cycle Model." *A.E.R.* 79 (September 1989): 733–48.

Dotsey, Michael, and Ireland, Peter N. "The Welfare Cost of Inflation in General Equilibrium." *J. Monetary Econ.* 37 (February 1996): 29–47.

Feldstein, Martin. "The Costs and Benefits of Going from Low Inflation to Price Stability." In *Reducing Inflation: Motivation and Strategy,* edited by Christina D. Romer and David H. Romer. Chicago: Univ. Chicago Press (for NBER), 1997.

Fischer, Stanley. "Towards an Understanding of the Costs of Inflation: II." *Carnegie-Rochester Conf. Ser. Public Policy* 15 (Autumn 1981): 5–41.

Gomme, Paul. "Money and Growth Revisited: Measuring the Costs of Inflation in an Endogenous Growth Model." *J. Monetary Econ.* 32 (August 1993): 51–77.

Humphrey, David B.; Pulley, Lawrence B.; and Vesala, Jukka M. "Cash, Paper, and Electronic Payments: A Cross-Country Analysis." *J. Money, Credit and Banking* 28, no. 4, pt. 2 (November 1996): 914–39.

Lucas, Robert E., Jr. "Inflation and Welfare." *Econometrica* 68 (March 2000): 247–74.

Marimon, Ramon; Nicolini, Juan Pablo; and Teles, Pedro. "Electronic Money: The End of Inflation?" Paper presented at the conference on Macroeconomic Theory and Monetary Policy, Federal Reserve Bank of Philadelphia, October 23–24, 1997.

McCallum, Bennett T., and Goodfriend, Marvin S. "Demand for Money: Theoretical Studies." In *The New Palgrave: A Dictionary of Economics,* edited by John Eatwell, Murray Milgate, and Peter Newman. London: Macmillan, 1987.

Miller, Merton H., and Orr, Daniel. "A Model of the Demand for Money by Firms." *Q.J.E.* 80 (August 1966): 413–35.

Mulligan, Casey B. "Scale Economies, the Value of Time, and the Demand for Money: Longitudinal Evidence from Firms." *J.P.E.* 105 (October 1997): 1061–79.

Mulligan, Casey B., and Sala-i-Martin, Xavier. "Extensive Margins and the Demand for Money at Low Interest Rates." *J.P.E.* 108 (October 2000): 961–91.

Sprenkle, Case M. "The Case of the Missing Currency." *J. Econ. Perspectives* 7 (Fall 1993): 175–84.

Tobin, James. "The Interest-Elasticity of Transactions Demand for Money." *Rev. Econ. and Statis.* 38 (August 1956): 241–47.