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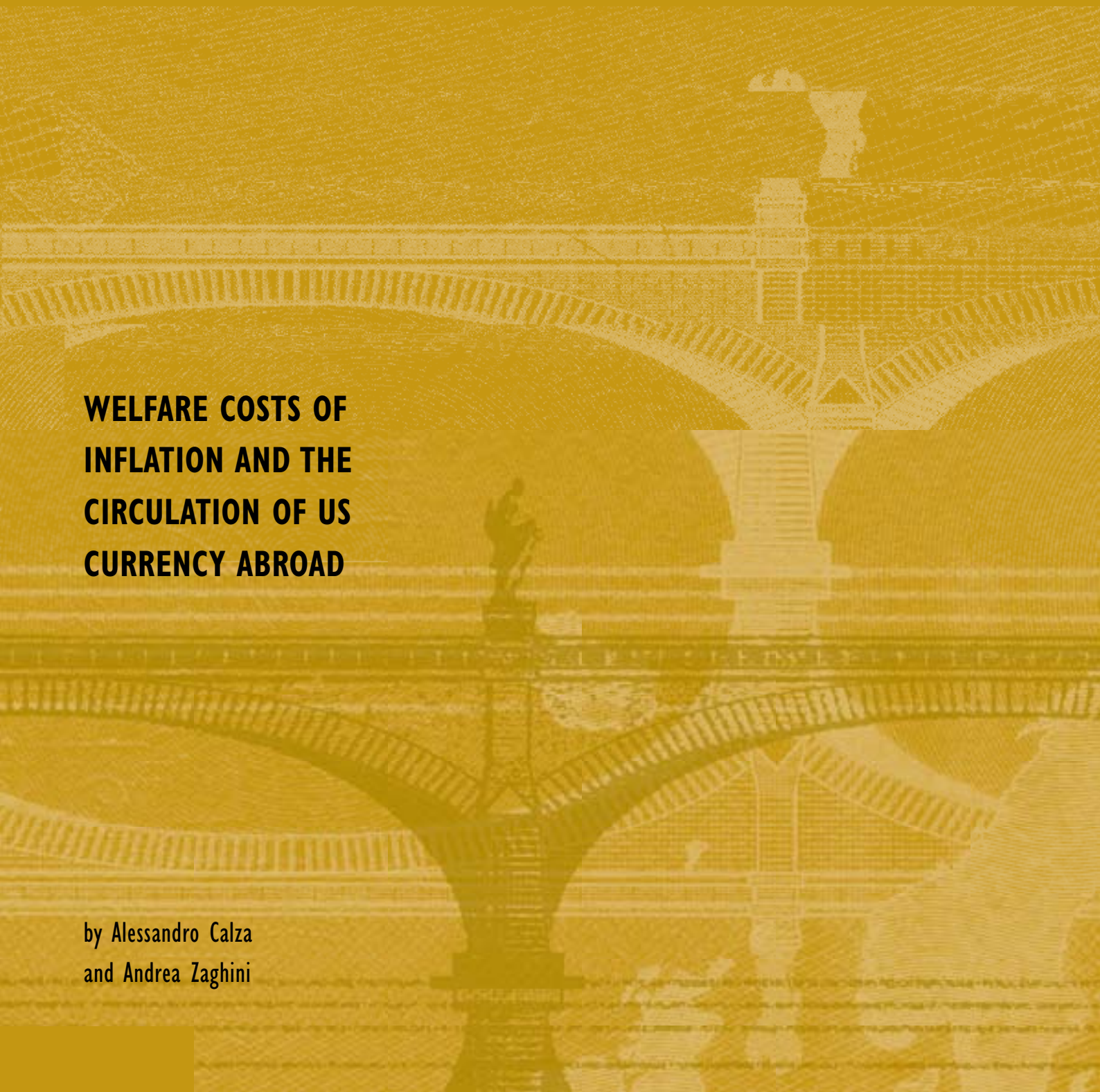

WELFARE COSTS OF INFLATION AND THE CIRCULATION OF US CURRENCY ABROAD

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by Alessandro Calza[2]

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Abstract

Empirical studies of the "shoe-leather" costs of inflation are typically computed using M1 as a measure of money. Yet, official data on M1 includes all currency issued, regardless of the country of residence of the holder. Using monetary data adjusted for US dollars abroad, we show that the failure to control for currency held by non residents may lead to significantly overestimating the shoe-leather costs for the domestic economy. In particular, our estimates of shoe-leather costs are minimized for a positive but moderate value of the inflation rate, thereby justifying a deviation from the Friedman rule in favour of the Fed's current policy.

JEL classification: E31, E41, E52

Keywords: Welfare costs of inflation, flow of funds data, US currency abroad

Executive Summary

More than fifty years after the publication of Bailey (1956), the quest for the correct measurement of the welfare costs of "inflationary finance" continues. Bailey's study focused on the distortions to money demand that arise when agents inefficiently manage their monetary holdings for transaction purposes because of inflation. He argued that inflation acts as a tax on real monetary balances and that it implies welfare costs (the so-called "shoe-leather costs") that are analogous to those of any ordinary excise tax on goods or services.

Many studies have applied Bailey's (1956) methodology to estimate the shoe-leather costs of inflation in the US economy. Most studies (e.g. Lucas, 2000 and Ireland, 2009) use the monetary aggregate M1 (the aggregation of currency and checkable deposits) as a measure of money. However, the data on M1 published by the Fed include all currency in circulation regardless of the country of residence of the holder and, therefore, do not control for foreign holdings of dollars. This distortion may not have been particularly important over most of the century-long sample examined by Lucas (2000). However, official estimates from the US authorities show that starting from the mid-1980s the share of currency abroad has significantly risen and currently accounts for about 60% of total currency in circulation (see US Treasury Department et al., 2006).

The fact that a significant share of the US currency is held abroad should have important implications for the computation of the shoe-leather costs of inflation for two reasons. First, failure to control for the US dollars circulating abroad may lead to overestimating the demand for currency by the domestic agents and, as a result, the shoe-leather costs that agents must bear because of inflation. Second, as noted by Schmitt-Grohé and Uribe (2009), in an economy characterized by strong foreign demand for its domestic currency, the inflation tax is to a large extent borne by foreign rather than domestic residents, which implies transfers of real resources from abroad.

1 Introduction

More than fifty years after the publication of Bailey (1956), the quest for the correct measurement of the welfare costs of "inflationary finance" continues. Bailey's study focused on the distortions to money demand that arise when agents inefficiently manage their monetary holdings for transaction purposes because of inflation.[1] He argued that inflation acts as a tax on real monetary balances and that it implies welfare costs (the so-called "shoe-leather costs") that are analogous to those of any ordinary excise tax on goods or services. Working along the same tradition, Friedman (1969) devised the famous "Friedman rule" prescribing that the optimal quantity of money is given by the level of money demand in correspondence to a zero nominal interest rate.

Earlier studies using Bailey's methodology to quantify the "shoe-leather costs" for the US have produced a relatively broad range of estimates. For instance, an early study by Fischer (1981) estimates the cost of a 10% inflation rate at around 0.3% of US GNP per year. An extensive literature review by Gillman (1995) reports significantly larger estimates for the same inflation rate and concludes that a "conservative" range of estimates lies between 0.85% and 3% of US annual income. Over the past decade, there has been renewed interest in measuring the welfare costs of inflation under the moderate, but still positive inflation rates currently targeted by most central banks. An influential study by Lucas (2000) using annual data covering most of the twentieth century argues that the welfare gains from reducing the annual inflation rate from ten percent to zero percent could be as significant as about 1% of annual GNP in perpetuity. A recent paper by Ireland (2009),

[1] A substantial body of literature has shown that additional sources of inflation-related economic and social costs arise from the inefficient allocation of resources due to increased uncertainty and distortions to relative prices, high risk premia, the interaction between inflation and the tax code, inefficient distraction of resources from production of goods to financial activities, lower capital accumulation and arbitrary redistribution of wealth (see for instance Driffill et al., 1990, and Fischer, 1995).

focusing on post-1980 data, estimates the welfare gains from reducing inflation by ten percentage points at a much lower value (just around 0.25% of annual GDP) and finds that in the current monetary regime eliminating inflation altogether would yield limited benefits at the margin. Evidence from micro household data also lends support to the view that shoe-leather costs are small at low nominal interest rates (Mulligan and Sala-i-Martin, 2000).

Most empirical studies (including Lucas, 2000 and Ireland, 2009) use the monetary aggregate M1 (the aggregation of currency and checkable deposits) as a measure of money. Indeed, M1 represents a close empirical counterpart of the notional monetary balances featuring in the theoretical models of the demand for transaction balances. However, because the official M1 data includes all currency circulating outside banks regardless of the country of residence of the holder, it is affected by non-negligible measurement errors (see Prescott, 1996). This distortion may not have been particularly important over most of the century-long sample examined by Lucas (2000). However, official estimates from the US authorities show that starting from the mid-1980s the share of currency abroad has significantly risen and currently accounts for about 60% of total currency in circulation (see US Treasury Department et al., 2006).

The fact that a sizable part of U.S. currency is held abroad can have important implications for the welfare costs of inflation and for the desirability of eliminating inflation altogether for two reasons.[2] First, failure to control for the US dollars circulating abroad may lead to overestimating the demand for currency by the domestic agents and, as a result, the shoe-leather costs that agents must bear because of inflation.[3] Second, as noted by Schmitt-Grohé

[2] In addition, the fact that a large share of US currency is held abroad can also have implications for the leading indicator properties of money for output and price developments. Aksoy and Piskorski (2006) show that adjusting currency for currency abroad improves its information content for short-term output and inflation developments, thereby lending renewed support to the positive correlation between money and macroeconomic fundamentals documented by Friedman and Schwarz (1963).

[3] A more practical concern is that, because of potential differences in the behaviour

and Uribe (2009), in an economy characterized by strong foreign demand for its domestic currency, the inflation tax is to a large extent borne by foreign rather than domestic residents, which implies transfers of real resources from abroad.

Thus, the benefits in terms of minor "shoe-leather costs" for domestic agents from reducing inflation must be weighed against the welfare losses associated with the lower transfer of foreign resources and the real appreciation of the foreign claims (implied by the currency holdings abroad). Schmitt-Grohé and Uribe (2009) conclude that, under standard parameter calibrations and assuming that half of the US currency circulates abroad, the optimal policy involves deviations from the Friedman rule and the targeting of positive (not necessarily small) inflation rates.

The purpose of this paper is to present new evidence on the shoe-leather costs of inflation, using monetary data adjusted for the circulation of currency abroad. In order to facilitate comparisons, we closely follow the econometric approach by Ireland (2009) and use the same sample period (1980-2006). To preview our results, we find that adjusting the M1 holdings of domestic agents in order to exclude the holdings abroad leads to a significant reduction in the estimated welfare cost of a ten percent annual inflation rate: around 0.05% of GDP per year, compared to the values ranging between 0.22% and 0.23% reported by Ireland (2009), which were in turn fairly small compared to previous estimates. We also find that for inflation rates below 8%, the shoe-leather costs become even marginally negative as the transfer of real resources from abroad more than offsets the consumer surplus lost by domestic agents because of the inflation-related distortions to their money demand decisions. In particular, welfare costs are minimized at a nominal interest rate of around 5%, thereby justifying a deviation from the Friedman rule in favour of the Fed's current policy of pursuing a small but positive inflation rate.

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of US currency demand from home and foreign residents, the existence of large currency holdings abroad may lead to misspecification of the money demand equations that are required for the application of Bailey's approach (see e.g. Sprenkle, 1993).

The paper is structured as follows. In Section 2 we briefly recall Bailey's approach to the measurement of the welfare cost of inflation. In Section 3 we deal with data issues. Section 4 presents the results of estimates of a double-log and a semi-log money demand function for adjusted US data. Section 5 evaluates the welfare gains from reducing inflation to zero and Section 6 draws some conclusions.

2 Money demand and welfare

Before presenting the empirical results, we briefly recall Bailey's (1956) approach. As a first step, this approach requires the specification of an appropriate long-run money demand relationship. The two functional forms most commonly used are: (1) Meltzer's (1963) log-log function, and (2) Cagan's (1956) semi-log function. The log-log function is specified as:

$$\ln(m) = \ln(A) - \eta \ln(r) \tag{1}$$

where m is the ratio of nominal money M to nominal income Y, r is the nominal interest rate, $A > 0$ is a constant and η denotes the interest rate elasticity in absolute value. Similarly, the semi-log function is as follows:

$$\ln(m) = \ln(B) - \xi r \tag{2}$$

where $B > 0$ is a constant and ξ denotes the absolute value of the interest rate semi-elasticity.

The behavior of the two functions significantly differs under very low levels of the interest rate. In particular, as the interest rate approaches zero, the demand function reaches a finite level under the semi-log specification, while it is asymptote to infinity under the log-log function. This difference in behavior at the zero level has implications for the calculation of the welfare gains from implementing a zero inflation policy or the Friedman rule.

Bailey's measures of inflation-related welfare costs - the so-called "welfare triangles" - are obtained as integrals of the inverse money demand function (i.e. expressed as a function of the nominal interest rate) on the interval $[m(r), m(0)]$. A positive value of the nominal interest rate as a result of expected inflation implies a positive opportunity cost of holding money and leads to the monetary balances of agents falling below their optimal level. Thus, the welfare triangle $w(r)$ measures the consumer surplus lost by agents by inefficiently foregoing the services provided by money in facilitating exchanges because of inflation.

In Lucas's (2000) notation, the welfare triangle (net of seigniorage revenues) can be expressed as follows:

$$w(r) = \int_0^r m(x)dx - rm(r) \tag{3}$$

where $m(x)$ denotes the money demand function. Since the money demand functions (1) and (2) are specified in terms of money to income ratios, the welfare costs represent the fraction of income that living in an economy where the steady state nominal interest rate is r (instead of zero) costs to the agents.[4]

The welfare triangle (3) is correctly specified only under the assumption that money is entirely held by domestic residents. However, in the presence of foreign demand for the domestic currency, the correct specification of the welfare triangle becomes:

$$w(r) = \int_0^r m^h(x)dx - rm(r) \tag{4}$$

where m^h is the demand function for domestic monetary holdings, while m refers to the total amount of money issued (i.e. also including the currency holdings abroad). Indeed, while domestic residents only incur utility losses

[4] Cysne (2009) shows that Lucas's (2000) interpretation of $w(r)$ as the fraction of income foregone by agents because of a steady state non-zero nominal interest rate r, is consistent with Bailey's (1956) original definition.

to the extent that their own demand for monetary services is distorted by inflation, the government obtains seigniorage revenues from the entire amount of money that is issued, regardless of the country of residence of its holders.[5]

It should be noted that the welfare triangles (3) and (4) are derived assuming that money is entirely non-remunerated. Therefore, they provide only an approximation of the "true" shoe-leather costs when some of the deposits included in money are (implicitly or explicitly) interest-rate bearing. Cysne and Turchick (2010) show that, under certain conditions, failure to account for interest-rate bearing deposits may induce some bias in the estimates of the shoe-leather costs.

3 Data issues

Our empirical exercise is based on estimates of the demand for the monetary aggregate M1 adjusted for the circulation of U.S. currency abroad over the sample period 1980:01-2006:04.

Official data on M1 referring to end-of-period outstanding amounts are available at a quarterly frequency and on a seasonally adjusted basis from the Federal Reserve Bank of St. Louis Database (FRED). As mentioned earlier, these data include all currency circulating outside banks, regardless of the country of residence of the holder. Therefore, they tend to provide an upward-biased measure of the amount of currency held by domestic agents. In order to correct the data for this source of measurement error, we need an equally long time series of the estimated value of US dollars circulating abroad at a sufficiently high frequency.

A study by Porter and Judson (1996) reviews a number of methods that can be used to estimate the amount of currency circulating abroad. However, most of these methods can be used to generate reliable estimates only at the

[5] This paper focuses on the welfare cost of inflation for the US domestic residents. As a result, the burden of US inflation on the welfare of foreign residents is not explicitly assessed.

annual frequency (e.g. the seasonal methods) or at irregular points in time (e.g. monetary demographic model) or can not go as far back in time as our sample. One exception is the shipments-proxy method proposed by Feige (1994, 1997), which has been officially implemented by the Federal Reserve Board in its Flow of Funds Accounts (Table L.204) to generate quarterly estimates of the amount of US currency held by the rest of the world.

The shipments-proxy method focuses on the net shipments abroad of USD 100 banknotes and is based on three core assumptions: (1) all (or almost all) of the US currency circulating outside the United States is held in the form of USD 100 banknotes; (2) the foreign demand for these banknotes is entirely met by the net shipments abroad from the cash offices of three Federal Reserve branches (New York City, Los Angeles and Miami); and (3) net shipments from these offices for local consumption are assumed to be small, so that their entire issuance of USD 100 banknotes are destined to foreign residents.[6] Thus, the amount of US dollars circulating abroad can be measured by the cumulated net shipments of USD 100 banknotes from these three cash offices.

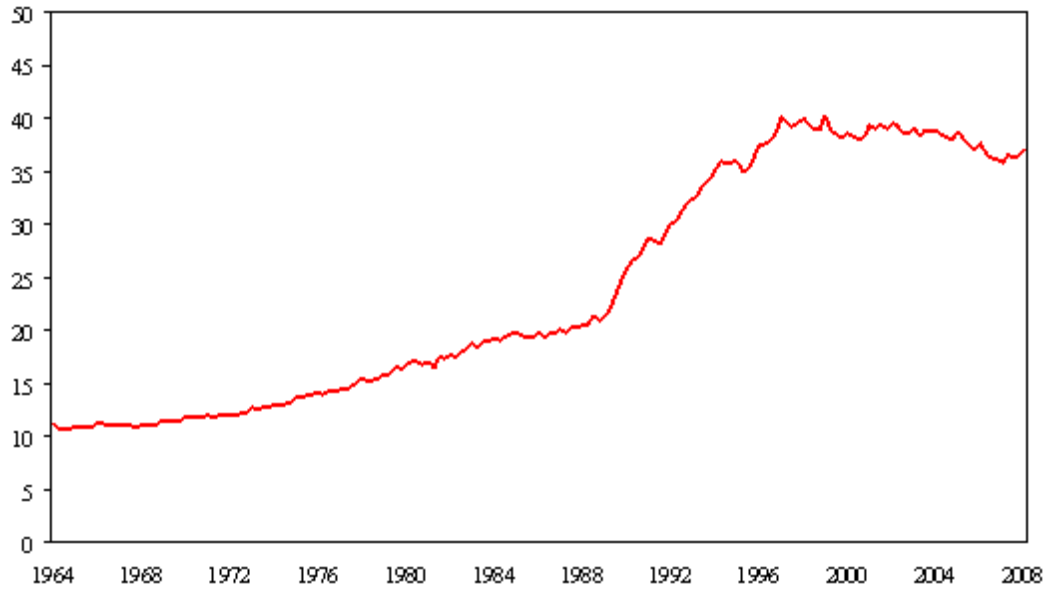
As Figure 1 shows, according to the shipments proxy approach, the share of currency circulating abroad has tended to rise over the past few decades. In particular, it increased gradually over the 1960s and early 1970s and only at a slightly faster pace throughout the second half of the 1970s and most of the 1980s. However, the share of US currency abroad sharply rose between the late 1980s and the second half of the 1990s, mostly reflecting the collapse of the Soviet Union and the breakup of the Communist Bloc as well as episodes of macroeconomic instability in some large Latin American countries. It has since stabilized at just under 40% of the total stock of currency in circulation.

A study by the US Treasury Department, together with the Federal Reserve Board and the US Secret Service (see US Treasury Department et al.,

[6] Only net shipments from the Cash Office of the Federal Bank of New York were initially considered (see Porter and Judson, 1996). Over time, the data have been revised to include net outflows from the cash offices of the other two branches.

2006) noted that in 2005 also significant shares of the USD 20 and USD 50 banknotes were held by foreign residents. This observation suggests that, by focusing only on the USD 100 banknotes, the shipments proxy approach may underestimate the use of US currency abroad. After updating the analysis by Porter and Judson (1996), the study estimated that foreign residents accounted for about 60% of the total value of banknotes in circulation in 2005.

Since for the purpose of the empirical exercise we need time series at a sufficiently high frequency, we use the estimates of the US currency abroad obtained using the shipments proxy approach. Nevertheless, when assessing the results of the exercise, it must be borne in mind that this approach is likely to underestimate the value of US currency abroad.



Source: Federal Reserve Bank St. Louis

Figure 1. Estimated share of US currency circulating abroad (percentage)

When dealing with monetary data, it is also important to control for the effect on households' checkable deposits of the wide use of retail deposit sweep programs. As noted by Anderson (2003), since January 1994 US banks use software programmes that "sweep" funds from demand deposits (that are subject to statutory reserve requirements) to money market deposit accounts (a type of savings accounts and, therefore, subject to a zero percent reserve ratio) at the end of each business day in order to economize on their statutory reserve requirements. The sweep movements performed by banks involve only re-classifications of the balances in their customers' accounts rather than shifts in the demand for money from economic agents. Therefore, in

order to understand the money demand behavior of US households, one needs to add the estimated amount of transaction deposits involved in the retail sweep programs to the holdings of checkable deposits reported in the official monetary statistics. In this paper we use the estimates of transaction deposits affected by the retail sweep programs by Cynamon et al. (2006),[7] used in previous empirical money demand studies (e.g. Dutkowsky and Cynamon, 2003; Ireland, 2009; Calza and Zaghini, 2010).

In addition, for the purpose of computing the money income ratio, the volume of transactions is measured by seasonally adjusted data on GDP sourced from the Bureau of Economic Analysis. Data on income and money are in billion dollars. The interest rate is the period average of the rate of return on the three-month Treasury bill, sourced from the Federal Reserve Board, and is expressed in percentage points.

As a final point, note that in his analysis of US data over the period 1900-1994, Lucas (2000) argues that the log-log functional form provides a superior description of the historical behavior of US money demand and a more precise calculation of the welfare costs of inflation, particularly at low interest rates. However, this claim is disputed by Ireland (2009), who argues that the superior performance of Lucas's log-log function mainly reflects its ability to fit the data from some rather different and specific periods (the post-WWII years, the peak of the Great Inflation and the "missing money" episode) that are less relevant to explain the behavior of money demand in the current monetary regime. In support of his hypothesis, Ireland (2009) provides econometric evidence showing that the post-1980 data are better described by a semi-log function.

As mentioned earlier, these authors use M1 data unadjusted for currency abroad. However, the inclusion of foreign holdings of US dollars in the data can potentially lead to misspecifications of the money demand curve and

[7] The data can be downloaded from a webpage dedicated to the issue of the effect of sweep programs maintained by these three authors (http://www.sweepmeasures.com/data.html).

affect the reliability of the estimated welfare measures. In order to investigate this issue, Figure 2 plots the ratio of money to GDP against the interest rate from 1980 to 2006, using both original M1 and M1 adjusted for currency holdings abroad, together with fitted values from Ireland's (2009) preferred semi-log specification.

Ireland's (2009) estimated money demand curve describes fairly well the money/income ratios based on the unadjusted data over the entire horizon. However, neither its curvature nor its position allows it to accurately describe the same ratios when the monetary data are adjusted for currency abroad. Not surprisingly, as the interest rate reaches zero, the satiation point of money demand for the adjusted data is lower than the unadjusted observations.

Interestingly, Figure 2 seems to suggest that the money demand equation based on data adjusted for currency holdings abroad should be less interest-rate elastic than Ireland's (2009) estimated semi-log equation. This is not consistent with expectations by some authors that, because foreign residents hold US currency mostly as a store for value or as a parallel medium of exchange (particularly in countries with unstable currencies or underdeveloped financial systems), the developments in currency circulation abroad should not be closely related to changes in US macroeconomic variables. For instance, Sprenkle (1993) argues that the effect of foreign demand for currency on total transactions demand for money can be captured by a constant.

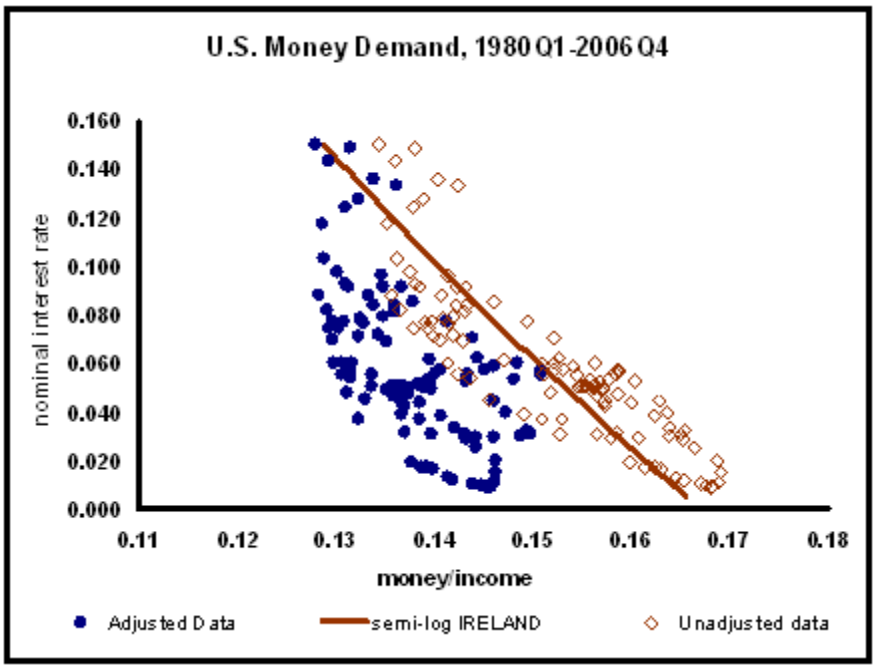


Figure 2 Adjusted and unadjusted US money demand

By contrast, some theoretical models (e.g. Obstfeld and Rogoff, 1996) predict that the use of foreign currency should be a function of inflation differentials between the country of issuance and the foreign country in which the currency is held. Based on these models, the demand for currency from abroad should be fairly interest rate sensitive and, therefore, the demand for monetary aggregates that include foreign holdings of currency may appear to be relatively elastic to interest rate movements. In particular, the significant increase in demand for US dollars from abroad over the past few decades may have been triggered by the shift to a regime of low and stable inflation rates in the US after the Great Inflation.

An alternative explanation of the finding of a reduced interest rate sen-

sitivity of adjusted money demand relates to possible compositional changes as a result of the adjustment for currency abroad. In fact, the exclusion of currency held by foreigners increases the share of deposits in the adjusted monetary aggregate.[8] Consistent with most of the shoe-leather cost literature, we have assumed that money is entirely non-remunerated, though some checkable deposits are interest rate bearing (see Cysne and Turchick, 2010). To the extent that deposits are remunerated, the increase in the opportunity cost of holding them following a rise in inflation should be lower than for the currency holdings. Thus, the monetary aggregate also including the holdings of currency abroad (in which the share of deposits is lower) may appear relatively more sensitive to changes in nominal interest rates than the aggregate including only the currency held at home.

4 Empirical estimates

The computation of the welfare triangle (4) requires estimates of the equilibrium money demand function of domestic agents $m^h(r)$. In the previous section we showed that the equilibrium money demand equation estimated by Ireland (2009) cannot satisfactorily account for domestic monetary developments when data adjusted for US dollars abroad are used. Thus, in this section we present the results of the cointegration analysis based on the adjusted data.

Equilibrium money demand relationships are conventionally estimated in a cointegration analysis framework (see Sriram, 2001; Duca and van Hoose, 2004). As a preliminary step, the statistical properties of the variables are examined using standard unit root tests (augmented Dickey-Fuller and Phillips-Perron) as well as the KPSS stationarity test. The results - not reported for the sake of brevity - suggest that over the sample period considered all the relevant variables can be modelled as I(1) in levels.

[8] We are grateful to a referee for indicating this possible explanation.

In order to facilitate the comparison with Ireland's (2009) results, we also use the Philips-Ouliaris (1990) residual-based cointegration tests. These tests are conducted by applying the Phillips-Perron Z_ρ and Z_t unit root tests to the residuals of the equilibrium equations (1) and (2), estimated using a standard OLS regression. Under the null hypothesis ($\rho = 1$) the residuals contain a unit root and the equation fails to represent a cointegrating relationship. Table 1 presents the test statistics Z_ρ and Z_t under both the log-log and the semi-log functional specifications. The covariance matrix is estimated using Newey and West's heteroscedasticity and autocorrelation-consistent estimator for different values of the truncated lag q (which indicates the number of autocorrelation lags in the error term to be considered when estimating the covariance matrix).

The results of the tests provide evidence of cointegration at the 10% significance level for the semi-log specification for values of the truncated lag greater than 5 for Z_ρ and greater than 6 for Z_t (see Table 1). By contrast, the tests reject the null hypothesis of cointegration for the log-log specification, regardless of the number of residual autocorrelation lags considered.

Hence, we find that adjusting the monetary aggregate for foreign holdings of currency does not alter the evidence provided by Ireland (2009) against the log-log specification, but somewhat weakens his evidence in favour of the semi-log specification, specifically by rendering it more sensitive to the specification of the dynamics of the error term.

Based on the outcome of the cointegration analysis, in the rest of the paper we focus on the semi-log specification and estimate the equilibrium relationship between the ratio of money to GDP and the nominal interest rate using three alternative single-equation estimators: (1) the Engle and Yoo's (1991) "three-step" approach to the Engle-Granger OLS estimator; (2) the Autoregressive Distributed Lag Modelling (ARDL) approach by Pesaran and Shin (1999); and (3) the dynamic OLS method by Saikkonen (1991).[9]

[9] The lags of the ARDL estimates as well as the lags and leads of the dynamic OLS

Table 1.Phillips-Ouliaris Contegration Test

(A) Log-Log Model

$$\ln(m^h) = k - \eta \ln(r)$$

$\widehat{k}$	$\widehat{\eta}$	$\widehat{\rho}$	q	Z_ρ	Z_t
2.1066	0.041	0.9362	4	−13.9310	−2.6761
			5	−14.9251	−2.7673
			6	−15.7742	−2.8429
			7	−16.0992	−2.8713
			8	−16.0344	−2.8657

(A) Semi-Log Model

$$\ln(m^h) = k - \xi r$$

$\widehat{k}$	$\widehat{\xi}$	$\widehat{\rho}$	q	Z_ρ	Z_t
−1.9342	0.8396	0.9197	4	−15.1024	−2.8583
			5	−16.2142	−2.9533
			6	−17.2789*	−3.0416
			7	−17.6670*	−3.0732*
			8	−17.6980*	−3.0757*

Note: * denotes statistical significance at the 10% critical level. The panels show the estimated equations using OLS regressions; the slope coefficient $\widehat{\rho}$ from an OLS regression of the error term on its own lagged values, and the Phillips-Ouliaris statistic for $\rho = 1$ corrected for autocorrelation in the residual with the Newey-West procedure for various values of the lag truncation parameter q. The 90% critical values are –17.0 for Z_ρ, –3.07 for Z_t.

The estimated long-run interest rate coefficients are statistically significant at the conventional levels, regardless of the estimation procedure used. The signs and magnitude of the coefficients are in all cases consistent with the interpretation of the cointegrating vectors as equilibrium money demand relationships. [10]

estimates are selected using the Schwartz Information Criterion.

[10]The estimates are robust to the extension of the sample period up to 2009 Q1. In

Regardless of the estimator considered, the estimated semi-elasticities are significantly lower than the values between 1.8 and 1.9 reported by Ireland (2009) using a sample period covering the same time span. This confirms the evidence in Figure 2 that the adjustment for foreign holdings of currency leads to a relatively lower interest rate sensitivity of money demand.

Table 2. Estimated long-run interest rate coefficients

$\ln(m^h) = \ln(B) - \xi r$		
	$\widehat{B}$	$\widehat{\xi}$
EY(2)	0.1446	0.8468^{***} (0.15)
ARDL(2)	0.1449	0.8796^{*} (0.46)
DOLS(4,4)	0.1413	0.4486^{**} (0.22)

Note: Standard errors in parenthesis. *, **, *** denote statistical significance at the 10%, 5% and 1% critical levels, respectively. EY denotes the Engle and Yoo's (1991) three-step Engle and Granger procedure, ARDL the autoregressive distributed lag model by Pesaran and Shin (1999), and DOLS the dynamic OLS by Saikkonen (1991). The number of lags (and leads for DOLS) in levels used are specified next to the estimator. Newey-West standard errors for ARDL and DOLS. B calibrated as in Lucas (2000) to equal average value over sample period of $me^{\xi r}$.

5 Adjusted welfare costs

The coefficients in Table 2 define the horizontal position and curvature of the money demand function adjusted for currency abroad $m^h(r)$ and must be substituted in the first term of (4) to estimate the consumer surplus lost

addition, the recursive estimates of the interest rate coefficients are relatively stable.

by US agents because of a non-zero nominal interest rate. However, in order to compute the seigniorage revenues, we also need to substitute the value of the parameters of total money demand $m(r)$ in the second term of (4). For this purpose, we rely on the results of Ireland (2009), who estimates a semi-log specification that accurately describes the long-term developments of total M1.

Figure 3 shows the shoe-leather costs net of total seigniorage revenues for different levels of the nominal interest rate obtained by combining: (a) the various estimates of $m^h(r)$ reported in Table 2, with (b) a selected specification of $m(r)$ from Ireland (2009).[11] A general observation is that the calculations are rather robust to the choice of estimator for $m^h(r)$. The results obtained using the Engle and Yoo procedure and the ARDL estimator are almost identical and only slightly different from those obtained using DOLS.

The shoe-leather costs are convex in the nominal interest rate and, interestingly, for values below $r = 11\%$ the function lies below the x-axis. Assuming a steady-state real interest rate of 3% (a value broadly consistent with estimates of the natural interest rate by Laubach and Williams, 2003, over the sample period considered), $r = 11\%$ is equivalent to an inflation rate of 8%. Thus, our estimates suggest that the shoe-leather costs associated with inflation rates below 8% are not only small, but actually slightly negative. The costs are minimized at -0.05% of annual GDP for $r = 5\%$, which implies a steady-state inflation rate of 2%.

This result is consistent with Schmitt-Grohé and Uribe's (2009) observation that, when the share of US dollars circulating abroad is very large, optimal policy may involve deviations from the Friedman rule and the targeting of positive inflation rates. Nevertheless, the estimates show that when

[11] Ireland (2009) considers several lags for his estimate of the parameters. In this exercise, we use the values obtained using the DOLS(4,4) estimator ($\widehat{\xi} = 1.8261, \widehat{B} = 0.1689$). The estimates of the welfare costs are robust to the use of the different specifications reported by the author.

expected inflation exceeds 8%, the shoe-leather costs turn positive and increase rather steeply.

Negative values of the shoe-leather costs are not intuitive, but can be explained by the existence of substantial foreign demand for US dollars. In fact, in a closed economy and assuming that money provides utility-enhancing liquidity services, the shoe-leather costs are non-negative and increase with the steady-state inflation rate. However, in the presence of large demand for domestic currency from abroad, the shoe-leather costs can become negative if, for some levels of inflation, the disutility to domestic agents stemming from positive inflation is more than offset by the associated transfer of resources from abroad. In other words, the loss to domestic agents because of the money demand distortions is more than compensated by the seigniorage revenues from foreign holders of US dollars.

In order to illustrate more in details the effect of the inflation tax on foreign holders of US currency, Figure 4 reproduces the welfare triangle function based on the DOLS estimates already shown in Figure 3 (labelled "baseline"), together with a function obtained under the counterfactual of no foreign demand for US dollars. In practice, we estimate this shoe-leather cost function by substituting $m^h(r)$ for $m(r)$ in the second term of (4). This is equivalent to treating the US as a closed economy and focusing only on the seigniorage revenues that the government extracts at home (instead of total seigniorage revenues) to compute the welfare costs of inflation. For comparison purposes, we also include the estimated welfare triangle function based on monetary data unadjusted for foreign holdings (computed using the elasticities in Ireland, 2009).

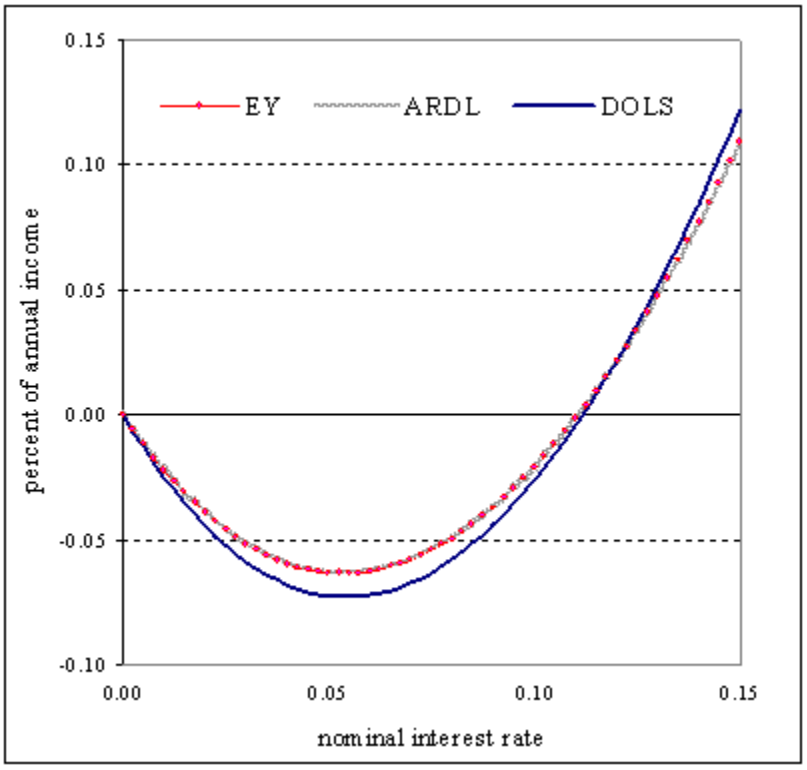


Figure 3. Shoe-leather costs for different estimates of m^h

The difference between our baseline function (blue, solid) and that obtained under the counterfactual of zero foreign demand for US dollars (red, dashed) provides information on the magnitude of the inflation tax on foreign residents. As expected, under the counterfactual scenario, the shoe-leather costs are non-negative and, consistent with the Friedman rule, are minimized for $r = 0$. However, for relative high levels of the nominal interest rate, the functions under the baseline and counterfactual scenarios converge as the utility losses to domestic agents from rising inflation increasingly offset the transfer of real resources from abroad. The shoe-leather cost based on unadjusted data (grey, dotted) are higher, suggesting that failure to account for

circulation of US dollars abroad leads to a non-negligible overestimation of the welfare costs of inflation arising from money demand distortions.

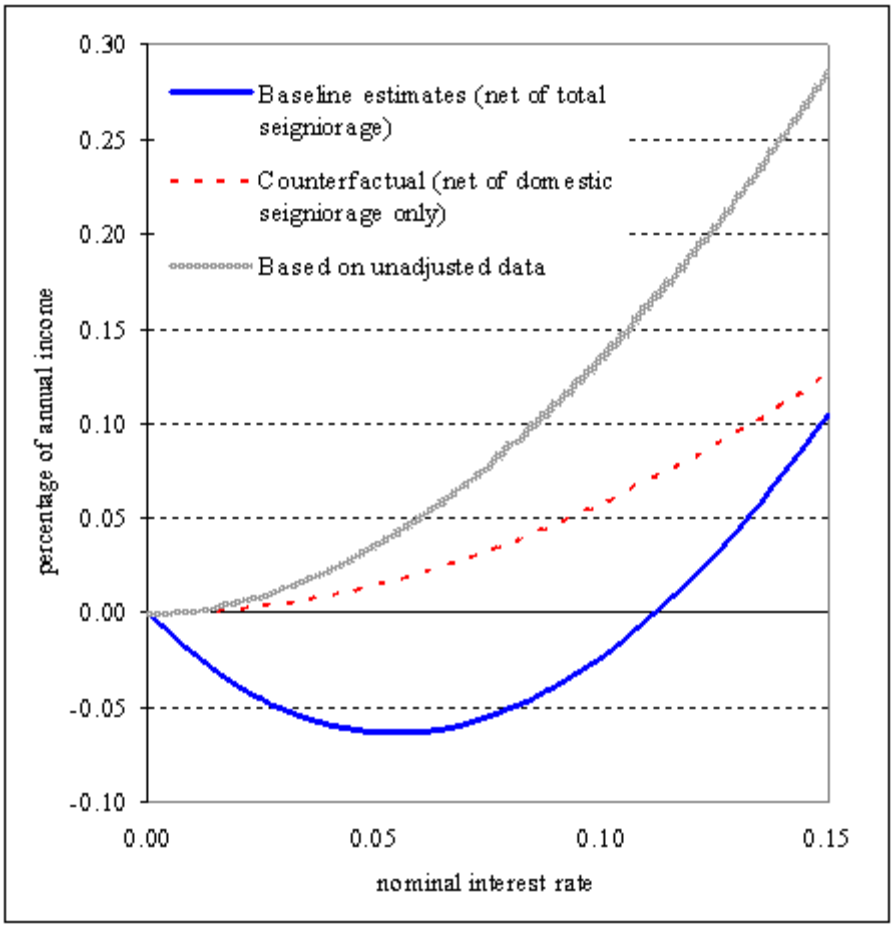


Figure 4. Shoe-leather costs using different data and assumptions for seigniorage revenues

How do our results compare with previous studies? Earlier studies typically report the cost of a steady-state 10% inflation rate and the welfare gains

from shifting from that state to one in which prices are stable. Assuming a natural real rate of interest of 3%, the shoe-leather cost of steady-state 10% inflation rate is equivalent to that of $r = 13\%$. Based on the empirical analysis reported in Figures 3 and 4, we estimate it at about 0.05% of annual income per year.

In order to measure the welfare gains from moving from a 10% inflation rate in the steady-state to a policy of price stability, Table 3 reports the difference between the shoe-leather costs at $r = 13\%$ and those at $r = 3\%$ using our different estimates. According to these calculations, the welfare gains would be very limited, at around 0.1% of GDP in perpetuity regardless of the estimator employed. This figure is a fraction of the estimates reported in Gillman's (1995) survey (ranging between 0.85% and 3%) and in Lucas' (2000) study (1%), and is also significantly lower than the more moderate estimates by Fischer (1981) and Ireland (2009) (0.3% and around 0.20-0.22%, respectively).

In addition, the comparison between the welfare losses at $r = 5\%$ and $r = 3\%$ suggests that, as far as shoe-leather costs are concerned, there would be no gains (actually, a very small welfare loss) from implementing a zero inflation policy instead of the 2% inflation rate currently targeted by FMOC members (Federal Reserve Board, 2009).[12] This result is not surprising since, as Figure 3 shows, the shoe-leather costs are minimized for $r = 5\%$.

The results of the exercise are almost unchanged when we re-run the estimates using a sample extended to include the latest data available (2009Q1). Extending the sample by more than two years may be potentially important since it implies that an additional episode of very low nominal interest rates (after that of 2002-2004) and of financial crisis can be included in the analysis.[13] In practice, including data from the most recent period of financial

[12] Feldstein (1997) has argued that the welfare gains from moving to price stability can be substantial even at low inflation levels, when sources of welfare losses other than shoe-leather costs (notably, the interaction between inflation and the tax system) are considered.

[13] Note that although ending in 1994, also Lucas (2000) analysis could include an episode

crisis does not affect the conclusions.

Table 3. Welfare gains from inflation reduction

	EY	ARDL	DOLS
$w(0.13) - w(0.03)$	0.102%	0.101%	0.114%
$w(0.05) - w(0.03)$	−0.012%	−0.012%	−0.014%

Note: Values expressed in percentage points of GDP.

Model specifications as in Table 2.

Overall, our results suggest that the fact that a significant share of US currency is held abroad has important implications for the computation of the shoe-leather costs of inflation for domestic citizens. After adjusting the M1 data for the estimated holdings of currency abroad, we obtain significantly lower estimates of the welfare costs of inflation than in previous studies, even though our calculations probably err on the high side because of two factors: (1) we use estimates of the holdings of US dollars abroad that are believed to underestimate the true amount of US currency abroad, and (2) we assume that the deposits included in M1 are entirely not remunerated, which may lead to overestimating the distortions to money demand caused by inflation.

6 Concluding remarks

Many studies have applied Bailey's (1956) methodology to estimate the shoe-leather costs of inflation in the US economy (i.e. the welfare costs that arise from inflation-related distortions to money demand). These studies typically use the monetary aggregate M1 as a measure of money. However, the data on M1 officially published by the Fed includes all currency in circulation

of very low interest rates. Indeed, over more than 10 years from 1934 to 1946 the nominal interest rate was on average below 1%.

regardless of the country of residence of the holder and, therefore, do not control for foreign holdings of dollars. Yet, foreign demand for US currency is substantial and, according to the US authorities, accounts for more than half of total currency in circulation (US Treasury Department et al., 2006).

The fact that a significant share of the US currency is held abroad should have important implications for the computation of the welfare costs of inflation for two reasons. First, it implies that the inflation tax may be to a large extent borne by foreign rather than domestic residents. Secondly, failure to control for currency circulating abroad may lead to overestimating the distortions to money demand from domestic residents. Both factors are likely to translate into an overestimation of the shoe-leather costs borne by US residents.

This paper presents new estimates of the shoe-leather costs of inflation in the US using M1 data adjusted for the circulation of currency abroad over the sample period 1980-2006. The adjustment is performed using the estimated holdings of US dollars by the rest of the world provided by the Federal Reserve Board in its Flow of Fund Accounts. We find that the money demand is less sensitive to interest rate changes when the data are adjusted for US dollars abroad. While theoretical arguments and measurement issues may contribute to explaining it, this is clearly an area that requires further investigation before any firm conclusions can be drawn.

Using a semi-log money demand specification as in Ireland (2009), we estimate the welfare cost of a 10% annual inflation rate at just 0.05% of GDP per year in perpetuity and the welfare gains from moving from 10% inflation to price stability at about 0.1% of annual GDP. The latest figure is smaller than the value reported by Ireland (2009), which was in turn significantly below most previous estimates (such as Fischer, 1981, Gillman, 1995, and Lucas, 2000).

In addition, our results suggest that the shoe-leather costs are minimized (and become even marginally negative) for inflation rates close to the values

currently targeted by the FOMC members, thereby justifying a deviation from the Friedman rule in favour of the Fed's present policy.

Of course, the finding that the estimated shoe-leather costs are relatively small does not imply that the welfare costs of inflation are negligible. Indeed, some authors (e.g. Dotsey and Ireland 1996, Feldstein, 1997) have argued that, since Bailey's partial equilibrium approach focuses only on one specific source of inflation-related distortions, it may significantly underestimate the true cost of inflation. In particular, Feldstein (1997) has suggested that the welfare gains from moving to price stability can be substantial even at low inflation levels, when sources of welfare losses other than shoe-leather costs (notably, the interaction between inflation and the tax system) are considered.

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