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Shoe-leather costs in the euro area and the foreign demand for euro banknotes

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Abstract

We estimate the shoe-leather costs of inflation in the euro area using monetary data adjusted for holdings of euro banknotes abroad. While we find evidence of marginally negative shoe-leather costs for very low levels of the nominal interest rate, our estimates suggest that the shoe-leather costs are non-negligible even for relatively moderate levels of anticipated inflation. We conclude that, despite the increased circulation of euro banknotes abroad, in the euro area the inflation tax is still predominantly borne by domestic agents, with transfers of resources from abroad remaining small.

JEL classification: E41, C22.
Keywords: money demand, welfare cost of inflation, currency abroad, euro

Non-technical summary

The share of euro currency circulating outside the euro area has tended to rise over the past few years and is estimated to have reached 25% (ECB, 2011 and 2013). The widespread circulation of a currency abroad may have implications for the estimation of the "shoe-leather" costs of inflation. These are the inflation-related welfare costs that arise when anticipated inflation – via its impact on the nominal interest rate - increases the opportunity costs of holding money, thereby driving the demand for monetary balances below its optimal level. The traditional way to measure the shoe-leather costs is based on the “welfare triangles” by Bailey (1956), who suggests that such costs can be measured by the area underlying the inverse money demand function representing the lost consumer surplus (net of seigniorage revenues) that could be gained from reducing the positive nominal interest rate to zero.

The reason why widespread circulation of a currency abroad is relevant for the calculation of the shoe-leather costs is because in an economy with foreign demand for its domestic currency, seigniorage revenues are also extracted from foreign residents, which implies transfers of real resources from abroad. When this foreign demand is very large, the inflation tax is to a significant extent borne by foreign rather than domestic residents (see Schmitt-Grohé and Uribe, 2012). Consistently with this observation, an earlier paper of ours (Calza and Zaghini, 2011) used monetary data adjusted for the circulation of US dollars abroad to estimate the shoe-leather costs borne by US residents and estimated them at significantly lower values than most previous studies (e.g. Lucas, 2000 and Ireland, 2009). In addition, we found that the shoe-leather costs become slightly but persistently negative for a fairly broad range of values of the nominal interest rate. The explanation for this finding is that the seigniorage revenues extracted from the foreign holders of US dollars are large enough to offset the consumer surplus losses borne by US domestic residents as a result of the inflation-related distortions to their money demand.

In this paper we replicate the exercise for the euro area and estimate the shoe-leather costs borne by euro area domestic residents using monetary data adjusted for euro banknotes in circulation abroad. The sample period ranges from the introduction of the euro banknotes at the start of 2002 to the end of 2011. Our results show that the shoe-leather costs in the euro area are non-negligible even at moderate levels of the nominal interest rate. While the shoe-leather costs become marginally negative for very low levels of the interest rate, the transfer of resources from abroad is not able to persistently offset the distortionary impact of inflation so that in the euro area the tax on monetary balances continues to be borne predominantly by domestic agents. This result differs from our findings for the US and can be to some extent explained by the relatively wider circulation abroad of US dollars compared to euro banknotes.

As a caveat, it should be noted that we use estimates of the foreign hoardings of euro banknotes based on the net shipments method that may underestimate the true amount of euro banknotes abroad. In addition, it is worth noting that we have focused only on one specific source of inflation-related welfare costs and that policy conclusions may vary when other sources are taken into consideration.

1 Introduction[1]

It is estimated that as much as 25% of the euro currency circulates outside the euro area (ECB, 2011 and 2013). Bartzsch et al. (2013a) estimate that this share could be as high as 45% for the euro banknotes issued in Germany, given the important role of the Deutsche Bundesbank in servicing large banks active in the global currency market. The fact that a significant share of the euro currency circulates abroad may have implications for the calculation of the "shoe-leather" costs of inflation. These are the inflation-related welfare costs arising when agents inefficiently manage their money holdings for transaction purposes because of the tax on monetary balances implied by expected inflation.[2] Bailey's (1956) traditional methodology to compute the shoe-leather costs consists of measuring the area underlying the inverse money demand function, which in turn represents the lost consumer surplus that could be gained by reducing the steady-state nominal interest rate from a positive value to zero. The intuition is that anticipated inflation leads to higher opportunity costs of holding money via its impact on the nominal interest rate, thereby driving the demand for monetary balances below its optimal level.

Widespread circulation of a currency abroad can affect the accuracy of Bailey's welfare cost measures since, as noted by Schmitt-Grohé and Uribe (2012), 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. Consistently with this observation, Calza and Zaghini (2011) show for the US that failure to control for the amount of US dollars abroad may lead to overestimating the shoe-leather costs borne by domestic residents. More precisely, using M1 data adjusted for the circulation of US dollars abroad, they obtain significantly lower estimates of the shoe-leather costs than previous studies (such as Fischer, 1995, Gillman, 1995, Lucas, 2000 and Ireland,

[1]We are grateful to three anonymous referees, Edgar Feige and Ruth Judson for a number of interesting and helpful comments. The views expressed in this paper are those of the authors and do not necessarily re‡ect the opinions of Banca d'Italia or the European Central Bank.

[2]See Driffill et al. (1990) and Fischer (1995) for a comprehensive analysis of inflation-related sources of welfare costs (e.g. high-risk premia, the interaction between inflation and the tax code, inefficient distraction of resources from production of goods to financial activities).

2009).[3] In addition, the authors find that in the US the shoe-leather costs are minimized – at *negative* levels – for moderate inflation rates close to the values currently targeted by the FOMC members, rather than for the deflation rate implied by the Friedman rule.

The aim of this paper is to apply Bailey's approach to estimate the shoe–leather costs of inflation for the euro area, using monetary data adjusted for euro banknotes in circulation abroad. In particular, we are interested in assessing whether the foreign demand for euro banknotes is large enough to generate substantial transfers of resources from abroad. To preview our results, we find that on the one hand, the shoe-leather costs in the euro area are non-negligible even at moderate levels of the nominal interest rate; on the other hand, the transfer of resources from abroad, while leading to marginally negative shoe-leather costs of inflation, are not able to offset the distortionary impact of inflation so that the tax on monetary balances stemming from euro area inflation continues to be borne predominantly by domestic agents.

2 Euro banknotes abroad

The empirical exercise is based on estimates of the demand for the narrow monetary aggregate M1 adjusted for the circulation of the euro currency abroad over the period between the introduction of the euro banknotes and coins in 2002 and 2011. Official data on the notional stock of M1 are available at the monthly frequency and on a seasonally adjusted basis from the Statistical Data Warehouse of the ECB. These official data include all currency in circulation, regardless of the country of residence of the holder and, therefore, overestimate the holdings of currency by domestic agents. In order to correct the data for this measurement error, we need an equally long time series of the estimated value of the euro currency circulating abroad.

The ECB publishes monthly estimates of the amount of the euro currency held by non-euro area residents using the shipments-proxy method proposed by Feige (1994, 1997).[4] This method focuses on the cumulated flows of net

[3] In particular, Calza and Zaghini (2011) estimate the costs of a 10% 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.

[4] See ECB (2013). The Federal Reserve Board has also implemented the shipments-proxy method to provide estimates of US dollar circulating abroad in its Flow of Funds Accounts.

shipments abroad of domestic banknotes through the banking sector. In the case of the euro area, total net shipments are given by the sum across the area's member countries of net shipments by monetary and financial institutions (MFIs) to non-euro area countries. According to the data on net shipments, Germany accounts for the largest share (76%) of total net exports of euro banknotes, followed by France (14%) and Italy (6%). The main net importer is Austria, with a negative share of around 30%.

As Figure 1 shows, the estimated amount of euro currency circulating abroad has tended to rise over the past few years. In particular, it increased gradually after the cash change-over in 2002 and then stabilized over the period 2005-2006. The demand for euro currency from abroad significantly increased right after the outbreak of the financial crisis in the summer of 2007 and stabilized again at just below EUR 110 billion after the collapse of Lehman Brothers. However, in 2011 the further deterioration of the financial crisis led to a new increase of shipments of euro notes abroad, probably as a result of the relatively larger deterioration of trust in local currencies in some Eastern and Central European countries (see Beckmann and Scheiber, 2012).

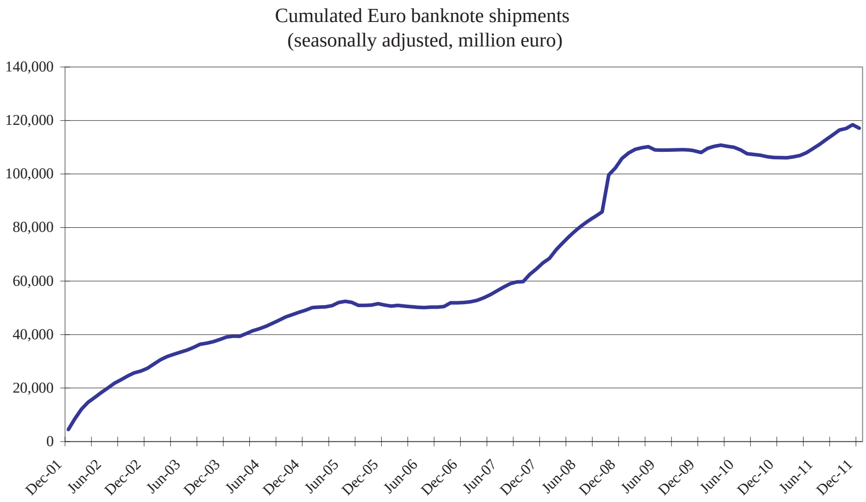

Figure 1. ECB estimates of the euro currency held abroad

At the end of 2011, the estimated share of euro banknotes in circulation outside the euro area amounted to 14% of the total. Nevertheless, ECB (2013) warns that the estimates of euro currency abroad based on the net-shipments approach represent lower bound figures, since MFIs are only one among a number of channels through which euro banknotes are shipped outside the euro area. Indeed, anecdotal evidence suggests that other channels, such as tourism or workers' remittances, are often more important. Overall, ECB (2011, 2013) estimates that the actual share of euro currency abroad could be as high as 25%, with the highest use in the Western Balkans and significant amounts in Russia and in Northern African countries.[5] This figure is broadly consistent with estimates by Bartzsch et al. (2013a, 2013b) showing that around 45% of all banknotes issued by Germany (which accounts for the very large majority of net shipments of euro banknotes outside the euro area) are held by non-euro area residents.

3 Shoe-leather costs and money demand

Before presenting the results of the empirical exercise, we briefly recall Bailey's (1956) approach to measuring the shoe-leather costs of inflation. This approach consist of calculating the integrals of the inverse money demand function (i.e., expressed as function of the nominal interest rate, r) on the interval $[0, r]$, to measure the consumer surplus lost by agents who inefficiently forego monetary services because of anticipated inflation. These welfare triangles are calculated net of seigniorage revenues.

A limitation of the Bailey's methodology is that it follows a partial-equilibrium approach, which does not allow to show how the demand for monetary assets can be endogenously derived as a function of technology and preferences. However, Cysne (2009) show that Bailey's formula can be obtained as an exact general-equilibrium measure of the welfare costs of inflation under the assumption of quasilinear preferences. Cysne (2011) extends this result to an economy with several types of money.

Calza and Zaghini (2011) argue that in the presence of foreign holdings of

[5] Similarly, a recent study by Feige (2012) using the net shipments approach estimates the share of US currency abroad at around 30-37%. However, a study by Judson (2012) using several alternative methods concludes that the actual figure is half or slightly more than half of total US currency. Using various methods, Leung et al. (2010) estimate that between 50% and 70% of the Hong Kong dollar in circulation in 2009 was held abroad.

the domestic currency, the correct specification of the welfare triangle $w(r)$ becomes:

$$w(r) = \int_0^r m^h(x)dx - rm(r) \tag{1}$$

where $m^h(x)$ denotes the inverse money demand function of domestic residents, r stands for the nominal policy interest rate and $rm(r)$ indicates total seigniorage revenues (including also the revenues stemming from currency holdings abroad). If the money demand functions are specified in terms of money to income ratios, $w(r)$ can be interpreted as the fraction of income foregone by agents because of a steady state non-zero nominal interest rate r.[6]

The key difference compared to the standard specification of the welfare triangles (which assumes that all money is held domestically) regards the distinction between the domestic measure of money ($m^h(x)$) used to compute the inflation-related utility losses and the total aggregate used to calculate the seigniorage revenues ($m(x)$).[7] Indeed, domestic residents incur utility losses only to the extent that their demand for monetary services is distorted by inflation. However, the government obtains seigniorage revenues from the entire amount of money that is issued, regardless of the country of residence of its holders.

It should be noted that the welfare triangle (1) is derived assuming that money is entirely non-remunerated, though the deposits included in money are typically (implicitly or explicitly) interest-rate bearing. Due to unavailability of statistics on the own rate of M1, we maintain this assumption in the empirical analysis. However, Cysne and Turchick (2010) show that, under certain conditions, failure to account for interest-rate bearing deposits may induce some upward bias in the estimates of the shoe-leather costs.[8]

In order to compute the welfare measures, in the next section we estimate the equilibrium money demand equation from euro area domestic residents.

[6] See Lucas (2000). Cysne (2009) shows that this interpretation of $w(r)$ is consistent with Bailey's (1956) original definition.

[7] The standard formula abstracts from foreign holdings of domestic currency and assumes that money is entirely held by the home residents: $m^h(.) = m(.)$.

[8] We assume that the money demand adjusted for currency abroad is entirely used for transactions purposes. However, as noted by an anonymous referee, some of the cash may be hoarded (see Bartzsch et al. 2013a, 2013b), while some of the deposits may be demanded as investment instruments. We are grateful to the referee for pointing this out.

Consistent with the literature (see Sriram, 2001; Duca and vanHoose, 2004), we estimate the relationship in a cointegration analysis framework, in which long-run domestic demand for real balances (m^h) is typically assumed to be a function of a reference interest rate (r) and a measure of the volume of real transactions (y). More precisely, our money demand equation is specified in a semi-logarithmic form:

$$\ln(m^h) = \ln(B) + \beta \ln(y) - \xi r \quad (2)$$

where $B > 0$ is a constant, β is the elasticity with respect to the transaction variable and ξ denotes the absolute value of the interest rate semi-elasticity.

4 Empirical analysis

4.1 Money demand estimates

For the purpose of the estimation, we use monthly seasonally-adjusted data on notional stocks of M1 adjusted for currency abroad sourced from the ECB as our measure of money (m^h). The volume of transactions is measured by GDP sourced from Eurostat and converted from the quarterly to the monthly frequency using the Chow-Lin interpolation procedure based on euro-area industrial production. Both nominal GDP and the monetary data are deflated by the GDP deflator. Two different interest rates are considered: the euro overnight index average (eonia) and the 3-month euro interbank offered rate (euribor). Prior to the crisis, most empirical studies used the euribor rate as a proxy for the ECB policy rate. In the course of the crisis, concerns have emerged about the accuracy and reliability of this rate. Therefore, we also consider the eonia, an effective rate which has been seen in the past as an implicit operational target for the implementation of monetary policy in the euro area.

As a preliminary step, the statistical properties of the variables (both in level and in log format) 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 from January 2002 to December 2011 all the variables can be modelled as I(1) in levels.

Table 1.Phillips-Ouliaris Contegration Test

$\ln(m^h) = \ln(B) + \beta \ln(y) - \xi r$

(A) Eonia

$\widehat{\beta}$	$\widehat{\xi}$	$\widehat{\rho}$	q	Z_ρ	Z_t
3.2953	6.3573	0.7653	4	-26.702^{**}	-3.717^{**}
			5	-28.051^{***}	-3.806^{***}
			6	-29.883^{***}	-3.924^{***}
			7	-30.514^{***}	-3.964^{***}
			8	-31.636^{***}	-4.034^{***}

(B) Euribor

$\widehat{\beta}$	$\widehat{\xi}$	$\widehat{\rho}$	q	Z_ρ	Z_t
3.6337	6.2845	0.8032	4	-22.273^{*}	-3.498^{*}
			5	-22.790^{*}	-3.534^{**}
			6	-23.885^{**}	-3.610^{**}
			7	-24.264^{**}	-3.636^{**}
			8	-24.626^{**}	-3.661^{**}

Note: *, ** and *** denotes statistical significance at the 15%, 10% and 5% critical level, respectively. The panels show the estimated coefficients using OLS, 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. Critical values as in Case 3, Tables B.8 and B.9 of Hamilton(1994).

Based on the results of the cointegration analysis, we focus on the specification using the eonia rate and proceed to estimate the equilibrium relationship between the real monetary balances (adjusted for currency abroad), the real transaction variable and the nominal interest rate using three alternative estimators: (1) Engle and Yoo's (1991) "three-step" approach to the Engle-Granger estimator, (2) the dynamic OLS (DOLS) method by Saikkonen (1991) and (3) the generalised least squares (GLS) estimator corrected as in Choi et al (2008).

Table 2. Estimated long-run interest rate coefficients

	$\ln(m^h) = \ln(B) + \beta \ln(y) - \xi r$	
	$\widehat{\beta}$	$\widehat{\xi}$
EY(1)	3.2949*** (0.001)	6.0446*** (0.822)
DOLS(4,4)	3.5133*** (0.074)	6.1936*** (0.215)
GLS(1)	2.2208*** (0.301)	5.0109*** (0.513)

Note: Standard errors in parentheses. *, ** and *** denotes statistical significance at the 10%, 5% and 1% critical levels, respectively. Number of lags (and leads for DOLS) in levels are reported next to the estimator. The lag specification of the models (as well as of the leads in the case of the dynamic OLS) is based on the Schwarz and Hannan-Quinn Information Criteria.

We then test for the existence of an equilibrium money demand relationship using the residual-based cointegration tests by Philips-Ouliaris (1990). These tests are conducted by applying the Phillips-Perron Z_ρ and Z_t unit root tests to the residuals of the equilibrium equation (2) estimated with OLS (with the test statistics computed for different values of the truncated lag q in the Newey-West estimator of the error covariance matrix). Under the null hypothesis ($\rho = 1$) the residuals contain a unit root and the equation fails to represent a cointegrating relationship. The results of the tests provide evidence of cointegration at the conventional significance levels for the specification using the eonia (at the 5% significance level for values of the truncated lag q equal to or greater than 5 and at the 10% level for $q = 4$). The evidence of cointegration is slightly weaker (at the 10% critical level for $q \geq 5$) when the euribor rate is used instead. Nevertheless, the results of the analysis are overall supportive of the hypothesis of cointegration.

The estimated long-run coefficients for both the scale variable and the interest rate are statistically significant at the conventional levels, regardless of the estimation procedure used. In addition, the signs of the coefficients are consistent with the interpretation of the cointegrating vectors as equilibrium money demand relationships.[9] The estimated coefficients tend to be consistent across estimators, suggesting that the results are fairly robust to the choice of econometric methodology. The application of Nyblom tests for

[9] In the rest of the exercise the value of the intercept B is calibrated as in Lucas (2000) so that it equals the average value over the sample of $my^\beta e^{-\xi r}$.

parameter constancy of the cointegrating vector as extended to cointegrated systems by Hansen and Johansen (1999) suggest that the long-run parameters are fairly stable over the sample period considered.[10] In the rest of this paper, we will use the DOLS estimates for the computation of the welfare measures.

4.2 Shoe-leather costs of inflation

After substituting the estimated parameters into (1) and solving the integral, the welfare cost measure for a given level of r takes the following form[11]:

$$w(r) = \frac{\widehat{B}}{\widehat{\xi}} y^{\widehat{\beta}-1} \left(1 - e^{-\widehat{\xi} r}\right) - rm(r) \tag{3}$$

When the elasticity of money with respect to the transaction variable (β) is statistically different from one (as is the case in our estimates), a value of the transaction variable must be specified so as to calculate the welfare costs (Gillman, 1995). In order to ensure that the welfare calculations at different inflation levels are time-independent, the level of the transaction variable is usually set at its average value over the sample period.[12] Before presenting the results it should be mentioned as a caveat that the sample period for the analysis covers a period in which anticipated inflation and nominal interest rates remained at relatively low levels. For instance, the eonia averaged 2.2%. Therefore, the estimated shoe-leather function may be less appropriate to assess the welfare impact of high inflation and nominal interest rates.

The continuous line in Figure 2 shows the shoe-leather costs net of total seigniorage revenues as a function of the nominal interest rate. As usual,

[10] The null hypothesis of the tests—which are respectively based on the mean (Mean) and the maximum (Sup) of a weighted LM-type statistics over the sample period—is the joint stability of the parameters of the cointegrating vector. The Mean and Sup test statistics yield 0.26 (p-value =0.33) and 1.14 (p-value=0.17), respectively. The distributions of the tests are bootstrapped using 1,000 replications. The computations are performed using the program Structural VAR, version 0.19, by Anders Warne (downloadable from www.texlips.hypermart.net/svar)

[11] Note that in order to compute the seigniorage revenues, we also need to substitute in (1) the parameters of $m(r)$, the money demand estimated over the same time period for the whole M1 (i.e. including currency abroad). DOLS coefficients are used in the paper, but results are robust to the estimation method employed.

[12] The results are not affected when alternative reference values are used.

the shoe-leather costs are convex in the nominal interest rate and increase rather steeply for values of the steady-state nominal interest rate r above 2%. At the same time, the shoe-leather cost function is rather flat at around 0% for values of r within the [0,1] interval.[13] While the function lies below the x-axis for some points within this interval – thereby, signalling negative shoe-leather costs – the deviations from zero are very limited in size.

These results for the euro area somewhat differ from those in Calza and Zaghini (2011), who provide evidence of small but persistently negative shoe-leather costs in the US for values of the nominal interest rate up to 11%. In the case of the US, the negative shoe-leather costs can be explained by the fact that in the presence of substantial foreign demand for the US dollars, the consumer loss because of the inflation-related money demand distortions is more than compensated by the seigniorage revenues extracted from the foreign holders of US dollars.

Our results suggest that in the euro area, where foreign demand for the euro currency (as a proportion of the total aggregate) is still significantly lower than in the US, the seigniorage revenues extracted from foreign residents are significant enough to drive the shoe-leather costs function below zero for a narrow range of values of the interest rate, but not large enough to offset in a meaningful way the disutility to euro area agents stemming from positive inflation. In order to illustrate this result, the dotted line in Figure 2 represents the shoe-leather costs under the counterfactual of no foreign demand for euro banknotes.[14] The relatively limited gap between the two lines in Figure 2, which provides an estimate of the amount of resources transferred from abroad, suggests that in the euro area the inflation tax continues to be borne almost entirely by the domestic agents. The estimated shoe-leather costs do not significantly change when the dataset is extended to include data for 2012 and early 2013.

These estimates can also be used to illustrate the impact of the financial

[13]The steady-state nominal interest rate can be translated into the equivalent inflation rate, provided that an estimate of the natural rate of interest is available. Mésonnier and Renne (2007) estimate that the natural rate of interest in the euro area was very low - at around 0.5% - just before the crisis, suggesting that values of the nominal interest rate within the [0,1] interval may be close to a zero inflation regime.

[14]This counterfactual is equivalent to treating the euro area as a closed economy and focusing only on the seigniorage revenues extracted from domestic residents home (instead of total seigniorage revenues) to compute the shoe-leather costs of inflation. In practice, we estimate this shoe-leather cost function by substituting $m^h(r)$ for $m(r)$ in the second term of (1).

crisis on the shoe-leather costs in the euro area. Between the introduction of the euro banknotes in 2002 and the start of the crisis in the summer of 2007, the eonia rate averaged about 2.7%, equating to a shoe-leather cost of 0.08% of annual GDP in perpetuity. At the peak of the crisis, the eonia rate stood at 4.3% and the corresponding shoe-leather cost rose to 0.22% of the euro area's output per year. As a result of a number of policy interventions, the eonia rate fell by the end of 2009 below 0.4%, therefore implying shoe-leather costs close to nil.

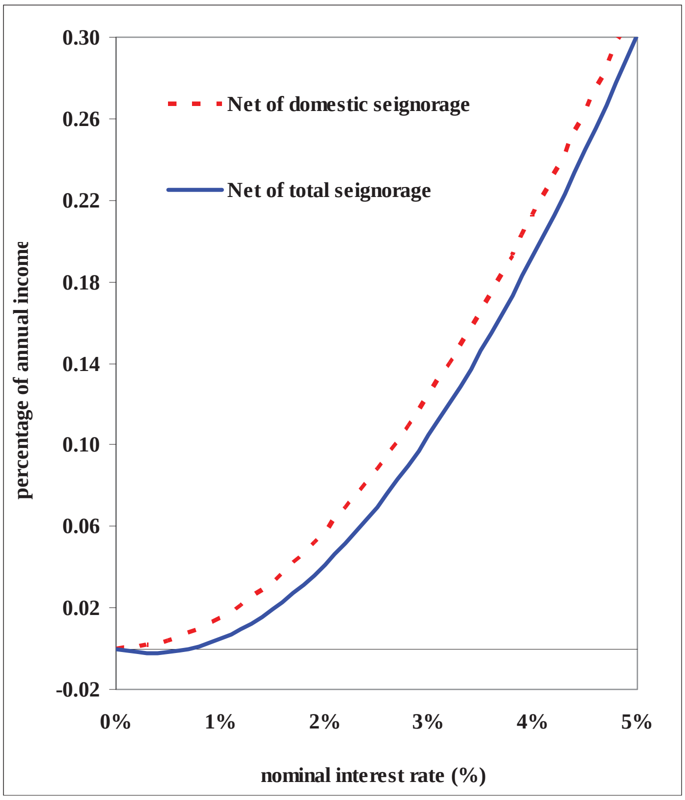

Figure 2 Estimated shoe-leather costs

5 Concluding remarks

This paper presents estimates of the shoe-leather costs of inflation in the euro area using M1 data adjusted for the circulation of currency abroad over the sample period between the introduction of the euro banknotes in 2002 and 2011. Our results suggest that the adjusted shoe-leather costs of inflation in the euro area are non-negligible even for levels of the nominal interest rate that are relatively modest. Although we find evidence of marginally negative shoe-leather costs for the nominal interest rate in the restricted interval between 0% and 1%, our results are not as striking as those in Calza and Zaghini (2011) for the US, who show that the shoe-leather costs of inflation in the US are persistently and more significantly negative for a much broader interval of values of the nominal interest rate (up to 11%).

This difference between the euro area and the US can be mainly explained by the relatively wider circulation abroad of US dollars compared to euro banknotes. Indeed, the widespread circulation of US dollars abroad implies large transfers of real resources from foreign residents, which more than compensate for the consumer losses borne by domestic agents because of inflation-related money demand distortions. While the circulation of euro banknotes abroad has risen since their introduction, it is not yet so large as to significantly offset the distortionary impact of inflation on the monetary holdings of euro residents.

Our results suggest that, as far as the shoe-leather costs of inflation are concerned, the results for the euro area may not be qualitatively different from those obtained under the assumption of a closed economy. As a caveat, it should be noted that we use estimates of the foreign hoardings of euro banknotes that may underestimate the true amount of euro banknotes abroad. In addition, it is worth noting that we have focused only on one specific source of inflation-related welfare costs and that policy conclusions may vary when other sources are taken into consideration.

Future research should try to assess the robustness of our findings to estimates of foreign holdings of euro currency obtained using different methods (such as those used for US dollars by Porter and Judson (1996) and for euro banknotes issued in Germany by Bartzsch et al., 2013a and 2013b).

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