

Large banknotes

Will the euro go underground?

SUMMARY

Developing countries may hold as much as 25–30% of the \$1.3 trillion OECD currency supply. Although dollar holdings appear to exceed DM holdings by a factor of four, the advent of the euro may change this balance. Indeed, by issuing large-denomination notes of 100, 200 and 500, the European Central Bank appears to be well poised to challenge the dominance of the ubiquitous US \$100 note. However, large-denomination notes are also extremely popular in the OECD underground economy, which appears to hold at least 50% of the currency supply. As a result, the seigniorage revenues obtained by issuing large-denomination notes may be an accounting illusion, substantially or fully offset by losses due to increased tax evasion. Hence, the new European Central Bank may wish to consider policies that discourage underground use of currency, even at the expense of losing out on foreign demand.

— Kenneth Rogoff

Blessing or curse? Foreign and underground demand for euro notes

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1. INTRODUCTION

There has been much discussion of whether the introduction of the euro will diminish the global dominance of the dollar in trade invoicing and in global bond portfolios. But there has been surprisingly little discussion of whether the euro will help Europe capture a larger share of another dollar-dominated market: the global market for a safe, reliable vehicle currency. Dollars are in wide use in Latin America (especially Argentina, where official shipments of dollar notes during the 1990s have exceeded \$40 billion) and in the former Soviet bloc (especially Russia, where official shipments during the 1990s have exceeded \$60 billion). Dollar currency is also dominant in the Middle East (where dollars are typically used to pay guest workers), in parts of Asia and, of course, in the global illegal drugs trade.

On paper, the euro should be an extremely attractive alternative to the dollar. The combined nations of the European Union (EU) are slightly larger than the USA both in terms of gross domestic product (GDP) and in population. Europe is closer geographically to the profitable currency markets of the former Soviet bloc and the Middle East. If the new European Central Bank proves to be as inflation

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averse as its designers intend, the euro inflation rate should be at least as low as that of the dollar. The new euro notes are to be printed using sophisticated modern techniques aimed at discouraging counterfeiting. Last, but not least, the euro is to be issued in large denominations, including 100, 200 and 500 euro notes (\$110, \$220 and \$550 at a dollar/ecu exchange rate of 1.10). Given the apparently overwhelming preference of foreign and underground users for large-denomination bills, the European Monetary Institute's decision to issue large notes constitutes an aggressive step towards grabbing a large share of developing country demand for safe foreign currencies, which we estimate here to be in the range of \$300–400 billion.

Is this a game Europe should want to play? Is this a business in which the USA should seek to preserve its dominance? This paper looks at some of the evidence on world currency demand, and points out some of the policy issues facing monetary authorities in the USA, Europe and Japan. A major question is whether, in attempting to exploit the global demand for large-denomination euro notes, Europe will be facilitating tax evasion and illegal activities at home. If so, the indirect revenue costs of having large quantities of high-denomination notes in circulation might outweigh the seigniorage benefits.

The next section of the paper assesses the murky empirical evidence on who holds the world's currency supply. Legal transactions appear to account for only a small portion of total currency holdings in most countries, but it is difficult to divide the remainder decisively into domestic underground and foreign demand. This is especially the case for the USA, Germany, Japan and Switzerland. We reject the recent assertion by Sprenkle (1993) that up to 80% of all OECD currency is held outside the OECD. Quite the contrary, the evidence suggests that a very large fraction of the OECD currency supply is held domestically, in the OECD underground economy. One of the many pieces of evidence consistent with this hypothesis is the fact that tax levels appear to have a significant positive effect on currency demand. The remaining sections discuss the main policy questions that arise due to currency's mixed usages. What policies might discourage the use of currency in the underground economy without interfering with its value in the legal economy? And if such policies are successful, will they lead to precarious deflation of central banks' balance sheets, weakening their independence and their potential to serve as lenders of last resort? Is it possible that currency's role in helping to shield the underground economy from tax and regulatory authorities is actually helping to provide an essential safety valve? The concluding section summarizes the paper's main findings, and offers some tentative policy conclusions.

Appendices A and B extend the standard transactions-based intertemporal model of money demand to allow for the possibility that high cash balances might help facilitate tax evasion, and illustrate the economics of phasing out large-denomination notes. The resulting model turns out to yield similar positive conclusions to

conventional models that ignore the predominance of the underground economy. Not surprisingly, however, it offers a very different perspective on the net revenue gains from seigniorage and on classic normative questions such as the optimal rate of inflation.

2. EXTERNAL AND UNDERGROUND DEMAND FOR OECD CURRENCIES

To try to understand the potential external and underground demand for the euro, it is helpful to begin by looking at the sources of demand for today's most popular international currencies. The conventional wisdom among central bankers is that the only currencies held abroad in significant quantities are the US dollar, the DM, the yen and the Swiss franc. (For example, Boeschoten (1992) estimates that less than 1% of Dutch currency is circulating abroad.) Of course, there are no hard figures on foreign holdings for any of these currencies. Indeed, except for a small number of consumer surveys, there are no hard numbers on domestic sources of demand, either. True, the central banks know exactly how much currency they have issued, subject to the minor complication that a small, unknown percentage of the currency supply has been lost or destroyed. (We ignore the implications of counterfeiting.) Each central bank also has reasonably hard data on the currency holdings of its domestic banks. While business transactions holdings are more difficult to measure, most estimates suggest that these account for only a very small percentage of total currency holdings; businesses are relatively efficient at cash management. Nor are the holdings of the general public very large, at least according to the limited survey evidence available. The bulk of the OECD currency supply – as we shall see, perhaps 70–80% – must therefore be held either by the domestic underground economy or by developing countries. Unfortunately, it is very difficult to ascertain how much to ascribe to each group. To illustrate the problems, we look first at the case of the USA, which supplies what is almost certainly the world's most widely held currency.

2.1. What can we infer about foreign demand for US dollars?

The supply of US currency outside banks is \$390 billion (8/96). Divided by a population of 263 million, this implies that there is \$1481 in US currency circulating for every man, woman and child in the USA. Put differently, the currency supply is almost \$6000 per four-person family. A survey commissioned by the Federal Reserve Board suggested that, as of 1986, cash holdings by individuals accounted for only 11–12% of the total currency supply. A similar survey in 1995 indicated that this share had dropped to 5%, or \$20 billion: that is, roughly \$300 per four-person family. (See Avery *et al.*, 1987; Porter and Judson, 1996a.) Business holdings do not appear to account for much of the currency supply, either. Sumner (1990) estimates business holdings to be only \$5 billion, while Porter and Judson arrive at a

similar estimate and argue that \$23 billion would be an upper bound.¹ Thus \$350 billion of currency held outside banks is unaccounted for. A small part of this might be explained by systematic underreporting of household holdings in the surveys (though a survey carried out by the Dutch central bank arrived at a similar 10% figure for households' share of total currency holdings: see Boeschoten and Fase (1992)). Some small portion of the currency stock may have been destroyed. Otherwise it seems hard to explain how there can be 96 \$1 bills and \$280 in coin for every four-person family. But these qualifications do not substantially mitigate the basic puzzle.

Figure 1 divides the US currency supply into two components, \$100 bills (the largest denomination now issued) and all other denominations, with both expressed as a ratio to GDP. Overall, despite a decade and a half of rapid financial innovation, the ratio of total currency to GDP has actually risen from 4% in 1981 to 5.3% in 1995. At the same time, \$100 bills now account for over 60% of the total value of the currency supply, up from 39% in 1980. A good part of this rise may be explained by inflation (the CPI, the Consumer Price Index, over this period rose 85%), but the large share of \$100 bills is still remarkable given that they are used only rarely in non-underground US domestic transactions. According to the 1995

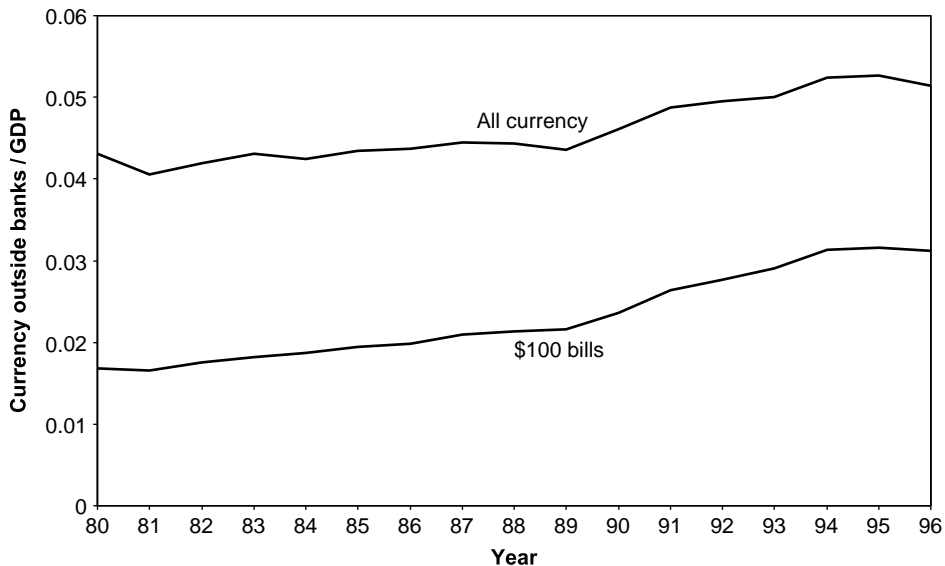


Figure 1. US currency/GDP

Source: US Treasury Department.

¹ If the roughly 3 million retail establishments in the USA each held \$200 in cash for giving change, this would account for only \$6 billion. If all sales were for cash, then adding one day's worth of consumption would bring the total to over \$20 billion, but this is clearly an overestimate, since many transactions are by check or credit card.

Fed survey cited above, consumers average less than one-quarter of a \$100 bill per family. But the outstanding stock is closer to \$36 per family. The growing, but unexplained, appetite for large-denomination bills has become especially striking during the 1990s, with \$100 bills accounting for well over 80% of the total increase in the US currency supply.

Flow data on US currency issuance strongly suggest that a sizeable fraction of all new currency issued in recent years has gone abroad, at least initially. The New York Federal Reserve District, which is the primary supplier of cash to foreign users, has kept records on currency shipments abroad since 1988, by country of destination. These data are still not public, but some characteristics have been published in a *Federal Reserve Bulletin* article by Porter and Judson (1996a). They report that well over \$100 billion in currency has been shipped overseas, with roughly half going to Europe (especially Russia and the former Soviet bloc), 30% to the Middle East and the remainder to Latin America. Kamin and Ericsson (1993) report that shipments of US currency to Argentina from all sources appear to have exceeded \$30 billion. (There is some debate as to whether Argentina has merely served as a transshipment point, though Kamin and Ericsson show that the rise in dollar holdings is consistent with a concomitant fall in real holdings of Argentinian currency.) Shipments to Russia in 1994 and 1995 alone exceeded \$20 billion per year, and the total amount circulating in the former Soviet Union is now thought to exceed \$60 billion. These are, of course, only *reported* outflows, and do not take into account either reflows back into the USA (which are believed to be significant) or unreported outflows.

More insight can be gained by looking at where demand for net new currency originates within the USA. Table 1 provides net currency issuance by Federal Reserve District. The table illustrates two key points. First, the New York Federal Reserve District, despite accounting for only 12% of total personal income, accounted for over 80% of net new cash issued for the years 1974–95 inclusive. Since New York appears to be the primary point of origin for foreign shipments, and since there is no reason to believe that domestic currency demand is an order of

Table 1. Share of currency issued nationally by Federal Reserve District, 1974–95

Federal Reserve	Personal income ^a (%)	\$100 bills issued (%)	All currency issued (%)
New York	12.1	82.8	80.5
Chicago	12.4	13.8	29.0
Atlanta	11.2	-15.9	-34.8
San Francisco	19.6	-9.1	-13.4
All others	54.3	29.4	38.7
Total	100	100	100

^a 1989.

Source: Porter and Judson (1996a).

magnitude higher in New York, this evidence supports the view that a considerable fraction of US currency has been shipped abroad. This phenomenon has become even more acute in recent years. Since 1988 the cash office serving New York City has accounted for 97% of net new issuance of \$100 bills. Second, the table indicates that the Atlanta and San Francisco Federal Reserve Districts, in contrast to those in the rest of the nation, have had huge net redemptions of currency. Presumably, this is due in no small part to money laundering by the drugs trade, whose locus has been shifting from Miami and Atlanta to California and Texas in recent years.² These reflows, as Feige (1996) emphasizes, greatly complicate interpretation of the outflow data. Money shipped to Argentina, for example, may be transported to other destinations and then reshipped to the USA. A second implication of the reflow data is that it is somewhat misleading to cite New York's 80% net share as evidence that domestic underground demand is minor compared to foreign demand. Because the Atlanta and San Francisco Feds have large negative shares, the remaining Federal Reserve Districts (excluding New York, Atlanta and San Francisco) actually account for 68% of net issuance.

The above evidence suggests that foreign purchases of currency account for a substantial portion of net new currency purchases, but it is not sufficient to tell us what percentage of the *stock* of US currency is held abroad. A number of recent studies have attempted to tackle this problem, including Sprenkle (1993), Sumner (1994), Feige (1996) and Porter and Judson (1996a, b), with estimates ranging from 30% to 40% at the low end (Feige) to 79% at the high end (Sprenkle). Porter and Judson, whose point estimate is 60%, adopt perhaps the most comprehensive approach. We review their analysis briefly below, since it also helps illustrate how difficult it is to separate out foreign and domestic underground currency demand.

One method considered by Porter and Judson is to compare the changing seasonal patterns of currency demand in the USA and Canada.³ During the 1960s, the estimated currency demand seasonals in the two countries were fairly similar, which seems plausible given that they share similar national holidays and school vacations. Also, Canada and the USA have fairly similar economies and financial service sectors, and issue notes in similar denominations (although Canada also issues a \$1000 bill that today accounts for more than 8% of its currency supply). In recent years, however, the seasonal in US currency demand appears to have sharply dampened, while the Canadian seasonal has remained fairly stable. The seasonal approach assumes that, in the absence of foreign currency holdings, demand for US currency would mirror demand for Canadian currency.

Assuming (1) no foreign demand for Canadian currency and (2) no seasonal

²The Dallas Federal Reserve District (included in 'All others') had net redemptions of -3.6% of total currency issuance over this period, although it was a net issuer of \$100 bills.

³The approach of using the changing seasonal to decompose the components of money demand was suggested by Sumner (1990).

component to the foreign demand for US currency, this implies that an ever-growing share of US currency is held abroad. (Lack of seasonality in foreign currency demand is plausible due to the transactions costs of importing US currency and the fact that a large share of foreign holdings are for hoarding.) Using the seasonal approach, Porter and Judson estimate that the share of US currency held abroad began at 40% in 1960 and rose to 70% by 1995. One difficult technical problem that complicates interpretation of these results is that it is not easy to decompose the changing trends and seasonals across the two countries. A second related approach, which yields similar results, is to take the changing ratio of currency to coin in the two countries (under the assumption that virtually all coins are held domestically).

Approaches that use Canada as a control have drawbacks that may bias the results. For example, it is quite possible that the US dollar has become more popular in the Canadian underground economy since the 1960s, especially given the chronic weakness of the Canadian dollar over the floating rate era. If so, then by treating Canada as a control, one may tend to understate the component of US currency demand that is accounted for by underground demand.

A third approach is the 'biometric method', which takes advantage of the fact that the Federal Reserve maintains separate inflow and outflow data for \$100 bills issued before 1990 versus those issued during or after 1990; beginning in 1990, \$100 notes began to contain an embedded security thread. The approach assumes that all 'marked' (post-1989) notes issued outside the New York office remain in the domestic pool and all marked notes issued in New York go into the foreign pool. Then, by looking at what share of notes recirculating into the non-New York Fed offices are marked, one can form an estimate of what share of the pre-1990s notes have gone abroad. This approach finds that between 66 and 75% of all \$100 bills are in circulation abroad, as are 40–9% of all \$50 bills.

Feige (1996) looks at both direct and indirect evidence. His direct evidence consists of confidential Federal Reserve data (of the type underlying the data in Table 1) together with data filed under the Currency and Foreign Transactions Reporting Act. Under this Act, individuals carrying more than \$10 000 into or out of the country must file declarations (commonly known as 'CMIRs'). CMIR data for 1994 indicate a \$32 billion inflow and a \$39 billion outflow. In all likelihood, both figures are understated, especially outflows, since outbound travellers are not required to pass through customs. Regardless, it is clear that reflows of currency into the USA are quite substantial, so one cannot necessarily assume that virgin currency shipped abroad remains there. Feige also considers some indirect methods similar to those employed by Porter and Judson, but obtains somewhat lower estimates than they do for foreign currency holdings. Overall, his evidence appears to suggest an estimate of foreign holdings of US currency in the region of 35%.

The preceding discussion gives some flavour of the difficulties involved in trying to guess the component of the US currency stock that is held abroad. Some of the very

characteristics of currency that make it so popular in the underground economy and abroad – portability and concealability – make it very difficult to track. In light of the potential estimation biases discussed above, and in light of evidence presented below on other OECD economies, it would seem that the middle-range estimates – implying that 45–50% of USA currency is held abroad – are more plausible than high-end estimates of 60–75%. This would imply that roughly \$200 billion are held by non-residents. As we shall see, such an estimate would still imply a very high underground currency velocity in comparison to most other OECD countries. Even though agents in the USA may well have access to superior transactions technologies,⁴ it seems unlikely that US currency velocity is an order of magnitude greater than in other OECD countries.

2.2. Foreign holdings of yen and DM

However difficult it is to ascertain foreign holdings of dollars, even less information is available for estimating foreign holdings of yen and DM. We look first at the yen, simply because its currency supply forms such a large fraction of the OECD total (at current exchange rates).

2.2.1. Yen. Japan, despite having a population only half that of the USA, has a similar total quantity of currency circulating outside banks, ¥41 720 billion (1 August 1996) or \$382 billion at the August 1996 yen/dollar exchange rate. Moreover, 89% of the total yen money supply is in the form of the ¥10 000, the largest note (source: *International Financial Statistics* and Bank of Japan (BOJ)). The Bank of Japan (1994), however, claims that only a very small share of the total yen currency supply is circulating abroad. Assuming that roughly half the US currency supply is abroad, this claim implies that Japanese citizens hold four times as much currency per capita as US citizens. Although it is notoriously difficult to explain cross-country differences in currency holdings, several arguments for this differential can be given: (1) Low crime allows Japanese to carry around large amounts of currency without risk. (If cash is used heavily by criminals, the overall effect of crime on currency demand is ambiguous; we revisit this question later.) (2) According to Japanese custom, cash is widely used for presents and in many transactions. (3) Japanese inflation has been very low. (4) Credit cards are relatively unpopular in Japan. (5) Automated transactions machines (ATMs) and financial institutions are extremely densely scattered throughout the country. (6) The BOJ substitutes new bills for old ones at a very high rate, maintaining an exceptionally ‘clean’ money supply. This facilitates use in ATMs and ticket machines, and enhances general public acceptance. (7) The

⁴Quirk (1996) argues persuasively that large drug traders have become extremely sophisticated in their money-laundering operations, but this is likely to be much less true for small cash businesses.

BOJ claims that Japanese bills are technically more difficult to counterfeit and, because there are only a relatively small number of denominations, the public is quite familiar with all of them. This also makes counterfeiting more difficult.

According to the BOJ, it has not made massive official currency shipments abroad. International migration of the yen appears to occur mainly via outgoing Japanese tourists and businessmen. There are reports of widespread use of the yen in the Soviet Far East (Bank of Japan, 1994), but there is no hard quantitative evidence. Indeed, there is very little quantitative evidence in general on the issue of foreign holdings of yen.

Should one subscribe to the official view that yen currency holdings abroad are negligible? While detailed micro data are not available, there are reasons to be sceptical. As Figure 2 shows, the ratio of currency to GDP has been rising in Japan, from 7.3% in 1980 to 9.7% in 1995, an even sharper increase than for the USA. The currency/GDP ratio has continued to rise in Japan in recent years even as it has been falling in most other OECD countries, as we shall later confirm. If one were to attribute the entire post-1980 rise in Japan's currency/GDP ratio to foreign holdings, this would suggest that close to 25% of all Japanese currency is held abroad, or \$80 billion at a yen/dollar exchange rate of 127. (Wilson (1992) similarly suggests that the extraordinary rate of currency growth in Japan may be evidence of significant outflows abroad.) This estimate may be treated as a plausible upper bound. However, in the absence of official currency shipment data or detailed surveys on business and consumer holdings, efforts to account for the whereabouts of the yen currency supply remain highly speculative.

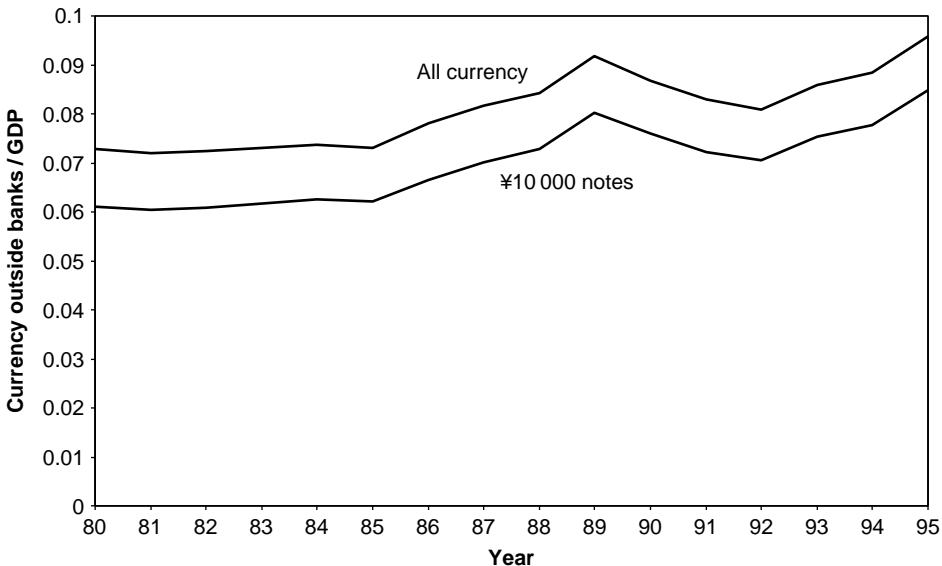


Figure 2. Yen currency/GDP

Source: Bank of Japan.

2.2.2. DM. As Figure 3 shows, Germany has also experienced a rise in its currency/GDP ratio, from 5.7% in 1980 to 6.9% in 1996, again despite rapid evolution of alternative payment mechanisms. As with the USA, the share of the largest bills (DM500 and 1000) in the total money supply has been steadily rising, from 24% to 44%. (Again, this rise is partly explained by cumulative CPI inflation of 54%, though one might have expected it to fall given the relative advantage of modern payments mechanisms in large transactions.) As of 1 August 1996, the total German currency supply amounted to \$1983 per person in value. If all currency outside banks were held by domestic residents, each would have an average of 30 notes including one DM1000 note (\$581 at a DM/dollar rate of 1.72). Although cash is somewhat more common in transactions in Germany than in the USA, the idea that a typical family of four is holding nearly \$8000 in DM seems rather implausible.

Thanks to an important recent study released by the Bundesbank (Seitz, 1995), a great deal more is now known about foreign holdings of DM than was the case a short while ago. Whereas Seitz does not have access to either the kind of household survey data or the international shipment data available for the USA, he is able to apply many of the various indirect methods of Porter and Judson (1996a, b) and Feige (1996) to the German case. For example, Seitz uses Austria as a control in studying the changing seasonality of DM currency demand, in much the same way that Porter and Judson use Canada as a control for the USA. He also compares trend velocity in Germany and Austria. Finally, Seitz takes advantage of the advent of German reunification as a 'natural experiment', and studies the impact on

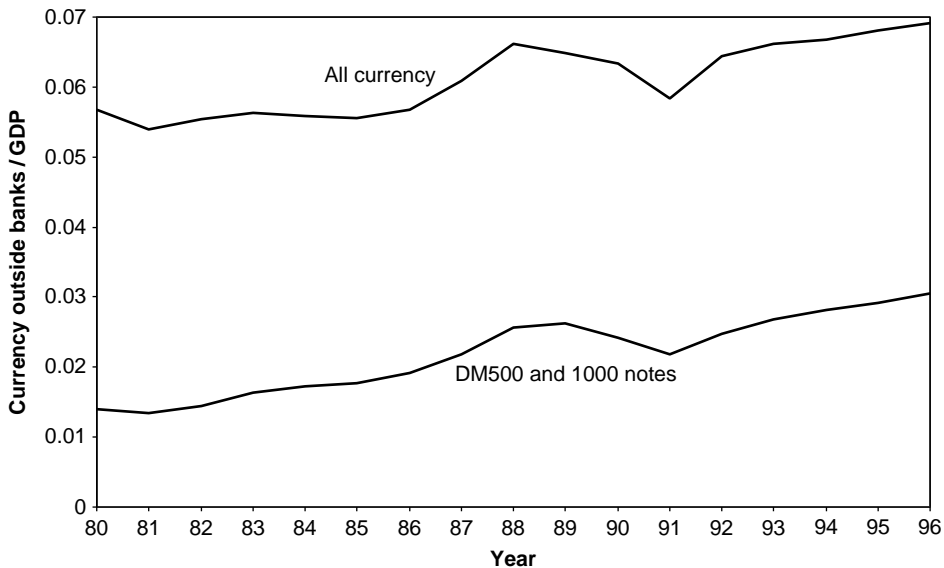


Figure 3. DM currency/GDP

Source: Deutsche Bundesbank.

currency demand. Overall, Seitz concludes that roughly 40% of the German money supply is held abroad, or \$56 billion at a DM/dollar exchange rate of 1.72.

2.3. Currency demand across the OECD countries

How different are the experiences of the USA, Japan and Germany from the experiences of other OECD members? Table 2 gives currency outside banks as a percentage of GDP for the various OECD countries. Remarkably, although Japan, Germany and Switzerland have among the highest currency/GDP ratios, the USA is only about average. However, rising international demand for the dollar, DM and yen may help explain why currency velocity has recently been falling in the USA, Germany and Japan, while it has been stable or rising in other OECD countries. Figures 4a and 4b illustrate this phenomenon over the period 1980–95.

Table 3 ranks the OECD countries in terms of currency per capita. As the bottom entry on the table indicates, average currency holdings in the OECD are \$1571 per capita (\$1293 trillion divided by 823 million people). Suppose that 80% of all OECD currency is indeed co-circulating in developing countries alongside domestic currencies. This would imply that developing countries hold \$1034 trillion of

Table 2. Currency^a to GDP ratio

Country	1995 (%)	1990–5 average (%)
Spain	11.0	10.0
Japan	9.6	8.7
Switzerland	9.1	9.4
Greece	7.2	7.8
Germany	6.9	6.5
Austria	6.1	6.0
Netherlands	5.9	6.4
Portugal ^b	5.8	6.0
Italy	5.5	5.6
Belgium	5.4	5.8
USA	5.3	5.0
Ireland	4.9	4.8
Norway	4.2	4.2
Sweden	4.2	4.5
Australia	4.1	4.0
France	3.4	3.6
UK	3.0	3.0
Canada	3.2	3.2
Denmark	3.2	3.0
Finland	2.3	2.0
New Zealand	1.7	1.5
Iceland	1.1	1.0

^a Currency outside banks.

^b 1994.

Sources: *International Financial Statistics*; central bank bulletins.

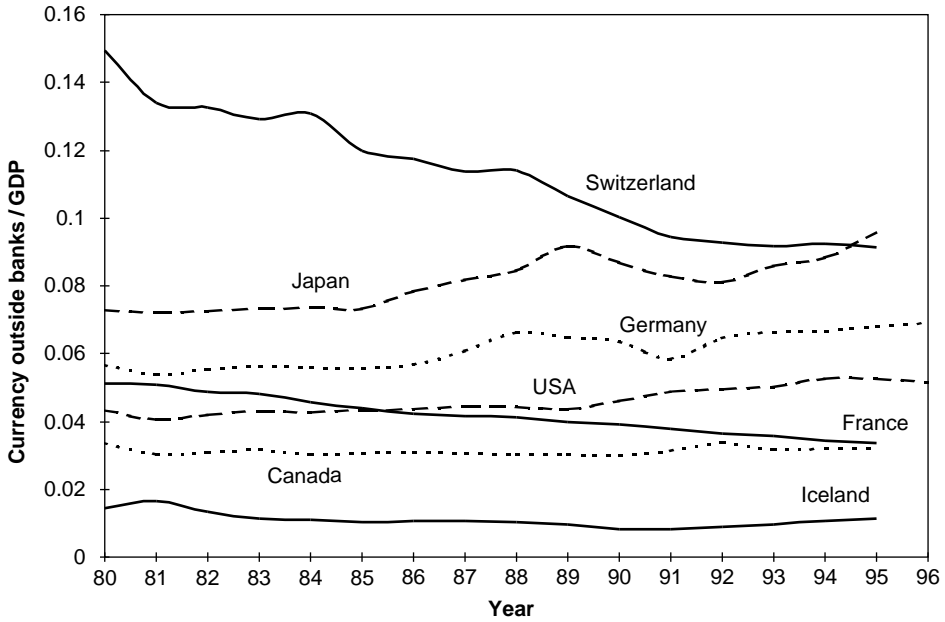


Figure 4a. Currency/GDP

Sources: *International Financial Statistics*; central bank bulletins.

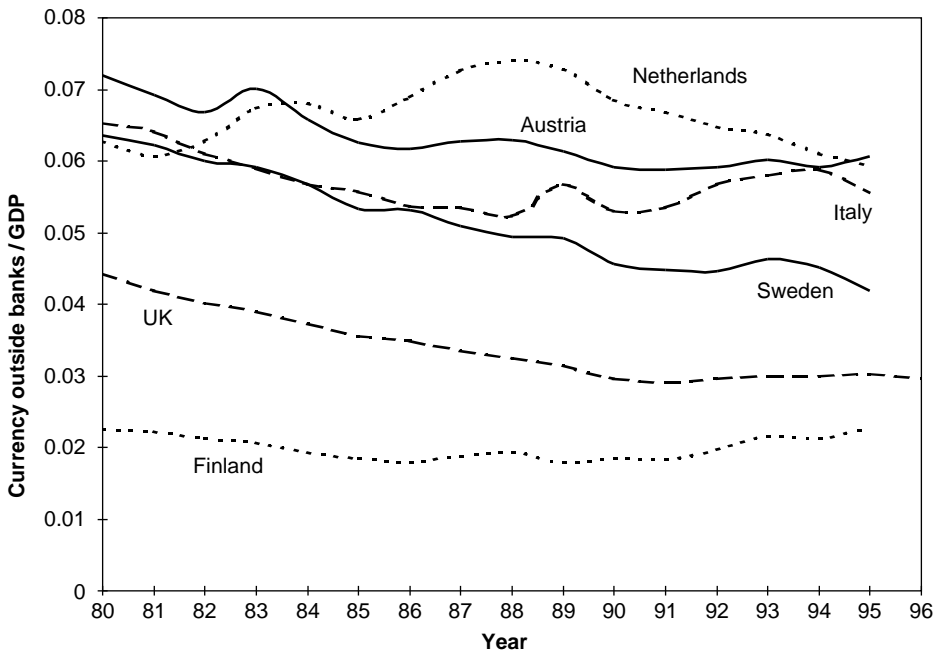


Figure 4b. Currency/GDP

Sources: *International Financial Statistics*; central bank bulletins.

OECD currency. Dividing this figure by the non-OECD population of 4893 billion people, one would conclude that per-capita holdings of OECD currencies are \$211 per person throughout the developing world. It seems utterly implausible that the average four-person family in India and China is holding \$844 in hard currency, or that the difference could be made up by vast per-capita holdings in Russia and the Middle East. Even if one assumes that all yen are held in Japan, and that developing countries hold 25% of the remainder, one comes up with an estimate of \$184 per four-person family, which still seems unlikely. (Haughton (1995) makes a similar argument.) Thus, the conventional wisdom that only three or four currencies are held in any significant quantity abroad seems quite reasonable. The implication is that for most OECD countries – and therefore for most countries in the European Union – the bulk of the currency supply is held domestically.

Presumably the underground economy is a significant factor in why per-capita OECD currency holdings are so high. Unfortunately, for most OECD countries, there have been fairly few studies aimed at exploring this conjecture. An exception is Boeschoten and Fase (1992), who conclude that internal hoarding explains a large fraction of currency holdings in the Netherlands, particularly of large-denomination notes. They attribute this problem in part to the Netherlands' high tax rates. Indeed, large-denomination notes constitute a large share of the currency supply in most

Table 3. Currency per capita outside banks

Country	US dollars (August 1996)
Switzerland	3584
Japan	3048
Belgium	2059
Germany	1983
Austria	1617
Spain	1544
USA	1481
Netherlands	1468
Norway	1283
Sweden	1114
Italy	1066
Denmark	1030
France	850
Australia	821
Ireland	811
Greece	738
Canada	611
UK	575
Finland	565
Portugal	556
Iceland	281
New Zealand	266
OECD average	1571

Source: *International Financial Statistics*.

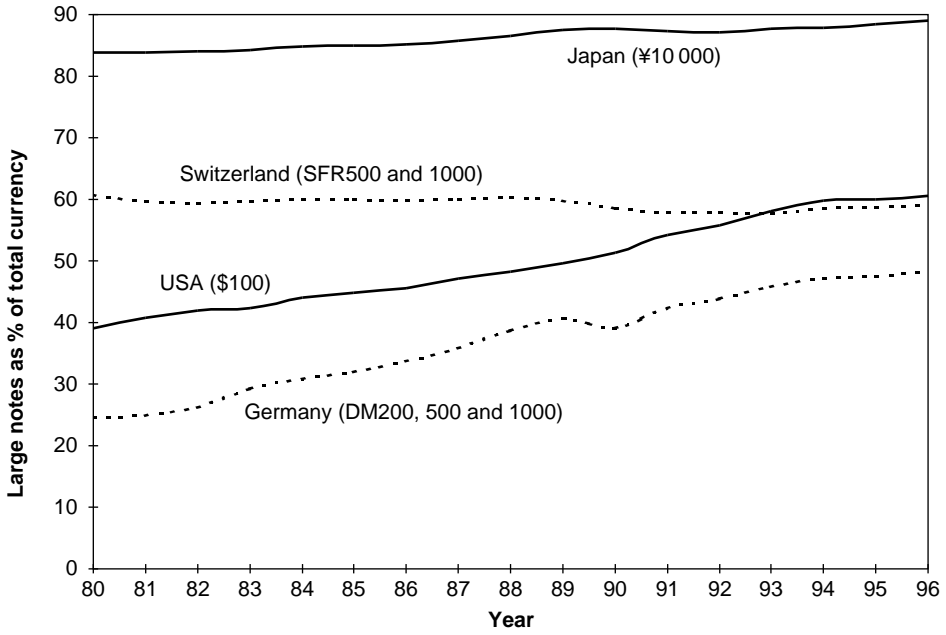


Figure 5a. Share of largest notes in total currency (%)

Source: Central bank bulletins.

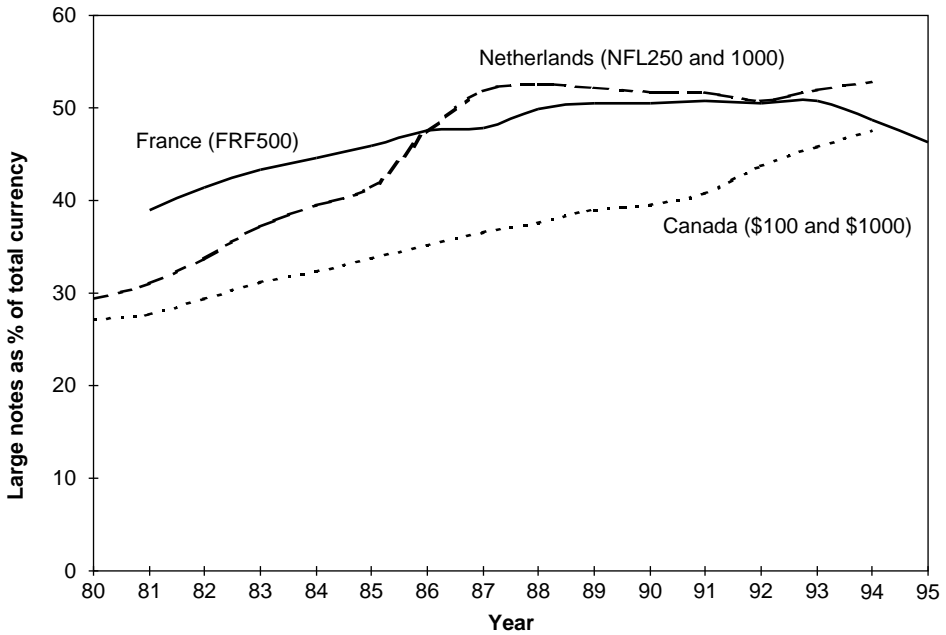


Figure 5b. Share of largest notes in total currency (%)

Source: Central bank bulletins.

countries, as Figures 5a and 5b illustrate. The share of large-denomination notes for France, Switzerland and the Netherlands has been rather flat in recent years, but their levels are still above Germany's. The Swiss franc, of course, is the fourth international currency and, as Figure 5a indicates, a very large share of its total supply is held in large-denomination notes. (There is speculation that many of these notes are held by foreigners in safety deposit boxes in Swiss banks.)

Aside from the high share of large-denomination notes, is there any other evidence consistent with the hypothesis that underground holdings of currency are high throughout most of the OECD? Table 4 looks at the determinants of currency velocity for sixteen OECD countries across annual data for the period 1980–94. The dependent variable is the ratio of nominal GDP to currency (all variables are measured in logs). Consistent with the model of underground currency demand developed in Appendix A, the variables on the right-hand side include the nominal interest rate (an overnight deposit rate) and the ratio of total central government taxes to GDP. Also included is a measure of violent crime based on cross-country United Nations (UN) survey data (see table notes).

Demand equations are notoriously unreliable for any measure of money. Nevertheless, the results are remarkably consistent across countries. The ratio of taxes to GDP, intended as a measure of the incentive to evade taxes, enters with the anticipated negative sign in fourteen of the sixteen countries (in Japan it is negative, but insignificant). (It is well known from the literature on estimating the size of the underground economy that tax levels tend to enter as significant positive variables in currency demand equations: see, for example, Tanzi's (1983) study of the USA.) Crime, on the other hand, enters with a positive (and generally significant) coefficient for fourteen of the sixteen countries. This implies that higher crime rates lower the demand for cash. As we noted earlier, the theoretical effect of a rise in crime on currency demand is ambiguous, since criminals use cash heavily. These results are at least consistent with the view that domestic tax evasion constitutes a major motivation for holding currency.⁵ Of course, direct taxes are only one motivation for evading official detection of transactions. Schneider (1997), in his study of the Austrian underground economy, finds that while direct tax burden is by far the biggest influence on the size of the underground economy, other factors such as regulatory complexity have become more important in recent years.

The possibility of large-scale currency hoarding to evade taxes (especially by small businesses) has long been a concern of tax authorities. According to the US Internal Revenue Service, cash skimming, to reduce reported profits and also to avoid sales

⁵Cross-country panel velocity regressions on the variables in Table 4 do not appear to yield robust results. Institutional and regulatory differences across countries, not captured in the taxes and crime variables, may be too large. Also, although the UN crime data are intended to be comparable across countries, cross-country differences in reporting standards may nevertheless be significant.

Table 4. Tax levels and crime rates as determinants of currency velocity, 1980–94

Country	Explanatory variables (standard errors in parentheses)		
	Nominal interest rate	Taxes/GDP	Violent crime
Australia	2.91 (0.49)	-1.84 (0.16)	-0.08 (0.05)
Austria	1.3 (1.03)	-1.16 (0.31)	0.13 (0.16)
Canada	2.00 (0.54)	-1.28 (0.20)	0.33 (0.05)
Denmark	1.69 (1.31)	-1.55 (0.58)	0.32 (0.12)
Finland	1.28 (0.77)	-0.86 (0.38)	0.50 (0.14)
France	-0.71 (0.54)	-1.82 (0.52)	0.31 (0.09)
Germany	1.65 (1.23)	-0.76 (0.68)	0.23 (0.28)
Greece	-0.37 (1.61)	0.35 (0.12)	1.06 (0.10)
Italy	1.01 (0.63)	-0.32 (0.19)	0.45 (0.08)
Japan	1.76 (1.09)	0.08 (0.11)	0.72 (0.09)
Netherlands	0.71 (1.05)	-0.011 (0.24)	0.58 (0.07)
Norway	0.70 (0.76)	-1.52 (0.20)	0.26 (0.06)
Sweden	0.78 (0.53)	-0.48 (-0.28)	0.48 (0.10)
Switzerland	0.35 (0.52)	-0.24 (0.09)	0.27 (0.05)
UK	1.99 (0.39)	-0.81 (0.19)	-0.40 (0.06)
USA	2.03 (0.56)	-0.68 (0.26)	0.28 (0.08)

^aAll regressions are performed allowing for AR(1) serial correlation using Prais–Whinston transformation.

Sources: Annual data. All variables except crime measures are from *International Financial Statistics*. GDP (line 99a; or if not available, GNP line 99b), nominal interest rates are overnight money market rates (line 60b), currency holdings (line 14a) and government revenue (line 81). Violent crime includes intentional homicide, rape, major assault and robbery (theft with threatened or actual physical harm). Annual data are compiled from the Third, Fourth and Fifth *UN Surveys of Crime Trends and Operations of Criminal Justice Systems*, published online by the UN Crime and Justice Information Network at www.ifs.univie.ac.at/uncjin/mosaic/wcs.html.

taxes, is a very large source of revenue loss (see Gutmann, 1983). A zero rate of return may be attractive if, by holding profits in cash for prolonged periods, an agent has a good chance of sheltering income from detection by tax authorities. The same is obviously true of profits on illegal activities. The problem of tax evasion by small businesses appears to be universal. Indeed, one of the major arguments in favour of value added taxes is that they make it easier to force small businesses to absorb a larger share of the total tax burden.

If, indeed, more than half the OECD currency supply is being held domestically in the underground economy, then the velocity of currency circulation in the underground economy must be substantially lower than in the reported economy. Otherwise, underground OECD output would have to be at least as large as reported OECD GDP. This seems implausible, even for countries such as Italy and Sweden where the underground economy appears to be particularly large, approaching 25% of reported GDP (see Schneider, 1997).

2.4. How much OECD currency is held in non-OECD countries?

Based on the evidence considered so far, can we speculate on the likely order of magnitude for non-OECD holdings of OECD currency? Estimates for the DM suggest that roughly \$50 billion in DM are held abroad, and it seems plausible that a similar quantity of yen is held outside Japan. A middle-range and plausible estimate for US dollars held abroad is \$200 billion. Switzerland has an extraordinarily high currency/GDP ratio, twice the OECD average. However, Switzerland is small so that even if half of Switzerland's currency supply were held abroad, this would account only for another \$12 billion. It seems unlikely that foreign shares of the remaining OECD currencies are terribly large, certainly not larger than 10–15%, or another \$30–45 billion. Thus, a plausible (if admittedly quite speculative) estimate is that developing countries hold roughly 25–30% of all OECD currency – \$300–400 billion – with the US dollar accounting for more than half of the total.

3. SHOULD THE EUROPEAN CENTRAL BANK CATER TO UNDERGROUND AND FOREIGN DEMAND FOR EURO CURRENCY?

At first blush, the large world demand for dollars would seem like a tempting target for promoters of the euro. Today, developing countries appear to hold only about 30% as much in European currencies as they hold in dollars. If the advent of the euro can bring Europe parity, it might imply a one-off shift into euro of \$50–100 billion. Over time, as world demand for all hard currencies grew, Europe would enjoy a higher share of the flow of seigniorage revenues as well. Is this something Europe should be courting aggressively? The USA has taken a very active role in promoting, or at least trying to stabilize, foreign demand for its currency. When the new 'counterfeit-proof' \$100 bill was introduced in 1996, the

Federal Reserve took pains to send auditors to Russia to reassure their 'clients' that no major change was taking place and that old bills would continue to be honoured.

In one important sense, Europe has already fired the first volley. The European Monetary Institute (EMI) has already announced that euro notes will be issued in denominations including 100, 200 and 500 euro. At a euro/dollar exchange rate of 1.10, these correspond to notes of \$110, \$220 and \$550. Given the evidence that US \$100 notes are extremely popular abroad, these large-denomination notes would seem to give Europe an important advantage in competing for the substantial revenues – and perhaps prestige – of the global market for hard currency. \$1 million in \$100 notes fits in a briefcase; \$1 million worth of 500 euro notes could be packed in a purse.

The empirical evidence that we have presented in the preceding section suggests that there may be an important drawback to courting foreign currency demand. The same features that make OECD currencies such as the dollar, mark and yen attractive to foreign underground economies make them attractive to the domestic underground economies as well. If, as we have argued, demand in developing countries accounts for only 25–30% of all OECD currency then, given per-capita OECD currency outstanding of \$1600 per person, it seems likely that the OECD underground economy accounts for as much as 40–50% of the total. The finding that tax burden seems to be an important explanatory variable in currency demand equations tends to support this view.

Here we take up three issues. First, should the new European Central Bank (ECB) be concerned if it knows that 80% of the demand for its product comes from underground and foreign sources? Is facilitating exchange in the underground economy necessarily a bad thing? Second, suppose the ECB (or the US Federal Reserve) were to take measures to inhibit either underground or foreign demand for currency. How much seigniorage revenue would be lost? Are there any important indirect costs? That is, would a sharply reduced currency supply inhibit the central bank's ability to stabilize prices or to serve as a lender of last resort? Third, suppose one accepts the view that the ECB should aim to reduce currency usage by the underground economy, even at the possible cost of reduced supply to foreigners. What concrete steps can be taken to inhibit underground currency usage without significantly inconveniencing legitimate domestic users?

3.1. Is fuelling the underground economy necessarily a bad thing?

If a Colombian drug lord offered a medium-term, zero-interest loan to the US Treasury in return for access to a superior smuggling and hoarding technology, presumably the offer would be refused. Yet such an agreement is implicitly entered when criminals are offered the convenience and anonymity of large-denomination bills. As Feige (1996) points out, currency smuggling is one of the major costs of

drug smugglers, costing them perhaps an amount equivalent to the resources involved in smuggling the product itself. If foreign and domestic criminal activity accounted for the bulk of all currency holdings, then there would be a strong moral case at least to consider ways to restrict currency usage.

However, given the increasing sophistication of criminal laundering operations (see Quirk, 1996), it seems likely that most underground demand for currency comes from agents engaged in otherwise socially productive activities: small businesses, street vendors, moonlighting workers, tradespeople, etc. One might argue that, in circumventing burdensome tax rates and regulations, these agents are helping to make their economies more productive and more efficient. Thus, if currency helps fuel the 'shadow' economy, it is perhaps doing more good than harm. Greasing the wheels of underground commerce can be thought of as an '*n*th-best' policy in a world where political constraints make it difficult to address directly the underlying source of government-induced inefficiencies.

This sympathetic, libertarian view of the underground economy is certainly a legitimate one. But it overlooks some important drawbacks to having a large underground economy. First and foremost, if agents working in the underground economy can evade taxes, it raises the tax burden in the above-ground economy, thereby exacerbating distortions. Standard public finance considerations suggest that efficiency would be promoted by spreading tax burdens more evenly. Second, not all regulation is ill-considered. If a moonlighting worker is avoiding regulations on the handling and disposal of toxic waste, it is not necessarily in the public interest. If apartments being renovated by moonlighting workers do not meet fire and other safety standards, the public may well end up bearing some of the long-run costs. Overall, currency is a dangerously blunt instrument with which to try to mitigate the distortions caused by big government.

Promoting currency usage by foreigners would seem to be a clearer issue. Legal and tax systems in many developing countries are an order of magnitude more oppressive than in most OECD countries. The efficiency gains from promoting the parallel dollar economy may greatly outweigh other considerations. Dollarization may also be efficiency enhancing because many developing countries lack the institutional and legal infrastructure to achieve any measure of price stability. On the other hand, one can also argue that this policy is paternalistic, and that dollarization greatly exacerbates the problems of authorities in regularizing economic activity. Seigniorage is an important source of tax revenue in many developing countries, and its loss (perhaps) forces the authorities to resort to even more distortionary taxes. Moreover, not all foreign underground activity is productive; the Russian Mafia and Latin America's drug kings also appear to be heavy users of dollars.

In the ensuing discussion, we will take an agnostic view, and assume that the OECD central banks care about foreigner currency holders only because they provide an important source of seigniorage.

3.2. Direct and indirect costs of allowing a sharp decrease in the currency supply

Assuming for the moment that the ECB can indeed find effective measures to reduce sharply the underground use of its currency, what would the likely consequences be?

3.2.1. Lost seigniorage versus lost direct tax revenue. The most obvious costs are fiscal. With a lower currency base, the ECB would enjoy much lower seigniorage profits. In this section, I argue that by fuelling the underground economy, currency has negative effects on the collection of direct taxes, and these indirect revenue losses may substantially offset the loss that the government suffers by giving up the underground economy's seigniorage business.

Table 5 contains recent figures for OECD countries for Cagan's (1956) measure of seigniorage, the real value of money creation:

$$\text{Seigniorage} = \frac{M_t - M_{t-1}}{P_t} \quad (1)$$

Here, M is the stock of money, P is a price index and t refers to a time index. As

Table 5. Real revenues from currency creation

Country	1995 (% of GNP)	1990–5 average (% of GNP)
Japan	0.80	0.34
Greece	0.73	0.82
Spain	0.53	1.07
Ireland	0.49	0.28
Belgium	0.40	0.01
Austria	0.37	0.32
Germany	0.33	0.48
Portugal	0.31	0.34 ^a
Finland	0.29	0.12
USA	0.26	0.41
New Zealand	0.18	0.06
UK	0.18	0.13
Denmark	0.17	0.15
Australia	0.16	0.25
Iceland	0.12	0.09
Italy	0.12	0.34
Norway	0.12	0.22
Switzerland	0.11	0.10
Canada	0.09	0.12
France	0.05	0.03
Netherlands	0.01	0.06
Sweden	-0.02	0.09

^a 1990–4.

one can see, seigniorage is not trivial by any means. During the first half of the 1990s, it averaged 0.48% of GDP for Germany and 0.41% of GDP (or more than \$30 billion per year) for the USA.

Arguably, a more appropriate definition of seigniorage in the present context is the ‘central banker’s’ definition, which is the annual savings from being able to float interest-free debt. For most countries, similar orders of magnitude for the 1995 seigniorage are obtained using either approach.⁶ For example, if the average interest rate on US debt is 7% then, with currency supply of \$400 billion, one obtains a seigniorage estimate of \$28 billion. If half of the US currency is held abroad, this means that the USA is earning \$15 billion per year from foreigners.

Suppose that, by accident or by design, the USA were to lose its domestic and underground foreign currency business. Its seigniorage profits would drop precipitously by perhaps 75% or more. Suppose further that the underground economy is 5–10% of GDP (in line with estimates for the USA by Tanzi (1983) and Feige (1996)), and that forgone taxes (including taxes for old-age retirement programmes) amounted to 4% of GDP. This estimate is consistent with official Internal Revenue Service estimates of forgone tax revenue due to the underground economy (see Gutmann, 1983). If eliminating currency use by the underground economy brought 5% of the underground economy ‘above ground’, the revenue gain would substantially offset the drop in seigniorage. This estimate is not implausible, since presumably some spectrum of the underground economy must be close to indifference between reporting and not reporting income (due to the deadweight evasion costs to non-reporting). Of course, if making currency less attractive to the underground economy also leads to even a marginal drop in unproductive criminal activity, the savings on law enforcement costs could also be quite significant. Since the underground economy in the USA is generally considered small relative to Europe’s (see Schneider, 1997), the potential tax gains in Europe are relatively larger.

In the appendices to this paper, the idea that currency may be useful in transactions, especially large-denomination bills, is formalized. The analysis shows that, even if underground transactions constitute a large share of total demand for currency, standard positive results on demand for money and price level determinacy go through (except that tax rates become an important explanatory variable in money demand). Normative conclusions, however, may be sharply altered. For example, the literature on the optimal quantity of money stemming from Friedman (1969) is completely oblivious to the fact that most currency is held by agents either

⁶The present value of the ‘central banker’s’ definition of seigniorage is the same as what one gets using equation (1), except that it is smaller by an initial term, M_{t-1}/P_t . (This equivalence is demonstrated on p. 537, fn. 26 of Obstfeld and Rogoff, 1996). The difference, of course, is that the central banker’s definition assumes that the principal of the ‘loan’ will be paid back someday, whereas the academic’s preferred version is more cynical (since the government can default by inflating).

evading taxes or engaged in unproductive illegal activities (for a recent survey, see Mulligan and Sala-i-Martin (1997)).

3.2.2. Will a sharp reduction in real balances compromise the ability of the central bank to stabilize prices or to serve as a lender of last resort?

If dispensing with large-denomination notes leads to a precipitous drop in real currency balances, will this complicate the tasks of the central bank? This question has relevance beyond the scope of issues considered here. Regardless of how currency is restructured, central banks are likely to face ever-increasing difficulty in maintaining their monopoly on currency-like devices as electronic alternatives proliferate. Eventually, even the OECD central banks' most solid customers, the home and foreign underground economies, are going to find alternatives.

It is well known that a central bank can stabilize prices even if the non-bank public ceases to use currency entirely (e.g., Wallace, 1983). As long as banks use central bank money (in electronic form) for liquid reserves, and as long as there is a well-defined demand for bank liabilities, then the central bank can use its control of aggregate liquidity to stabilize prices. Indeed, this is essentially how central banking is practised today in the industrialized countries.

If the OECD governments were forced to buy back the entire supply of currency held by the public, it *would* be expensive. Germany would have to issue new interest-bearing debt equal to almost 7% of GDP, while Japan would have to issue debt of almost 10% of GDP, assuming they wished to keep prices stable. (Under the Maastricht Treaty, Germany would have to bear the cost of buying back its original currency share even after the European Central Bank was established. Implicitly, the sharing provisions for negative seigniorage are different from the sharing provisions for positive seigniorage. The latter is divided up according to a treaty-determined revenue-sharing formula; the former is divided up according to each country's share of the initial pre-conversion money stock.)

Having to buy back the currency supply would certainly take the shine off many central bank balance sheets, as Table 6 indicates. Should the effect on central banks' balance sheets of mass currency repurchases be of any great concern? One issue is that, if its operating profits (from government bond interest) are reduced too sharply, the central bank may no longer have enough revenues to cover its operating expenses (note that Table 6 includes non-interest-bearing gold reserves).⁷ This seems like a rather mundane issue, but if the central bank had to request funds for operating revenues each year from the government, its independence might be

⁷The Bank for International Settlements (1996) calculates the percentage decline in seigniorage that can be tolerated by major central banks before revenues will no longer be sufficient to cover operating costs. According to their calculations, the Bundesbank can absorb an 86% decline in operating revenues, but the Bank of France can absorb only a 54% decline. For related calculations, see Boeschoten and Hebbkink (1996).

seriously compromised. Based on the figures in Table 6, this does not appear to be a decisive problem for Europe.

A more vexing question is whether a sharp drop in currency demand might compromise a central bank's ability to serve as a lender of last resort. Ultimately, the central bank's capacity to sterilize emergency lending is limited by its assets. For example, if the Federal Reserve wants to serve as a lender of last resort to IBM, it will open its discount window to banks lending to IBM. But it will also sterilize these loans using open market operations, to the extent that IBM's financial troubles did not lead to an aggregate rise in demand for base money. The central bank does not have to sterilize, of course, and can allow some inflation. But if the currency base shrinks, this option becomes less attractive. Loosely speaking, the smaller the base of real base money demand, the more inflation that any given level of increase in central bank money will cause.

The problem of sharply reduced central bank balance sheets is a serious one, but as Table 6 indicates, most OECD central banks would still have substantial resources even after buying back their entire currency supply. This would clearly be the case for the ECB.

Table 6. Currency as a fraction of market value of total central bank assets^a

Country	End-1995
Japan ^b	0.83
Canada	0.76
USA	0.65
Germany ^b	0.57
Spain	0.48
Australia	0.46
Belgium	0.46
Austria	0.42
Netherlands ^b	0.40
UK	0.35
Switzerland	0.33
Ireland ^b	0.32
France	0.30
Italy	0.27
Sweden	0.26
Norway	0.22
Denmark	0.19
Finland	0.19
Portugal	0.18
Greece	0.15
New Zealand	0.14
Iceland	0.09

^a Gold reserves are measured at market value.

^b End-1994.

Source: Central bank annual reports.

3.3. Private substitutes for currency

If the government were to withdraw large-denomination notes, would private substitutes not fully supplant the functions of currency? The modern case for retaining public monopoly of currency is that the government is a very efficient provider. Currency costs governments very little to produce and, in principle, the taxpayer benefits from the revenues generated. If private competitors are allowed to compete with the government, they will be willing to bear large costs in setting up their payments systems, provided they can gather a share of the government's profits. From a social point of view, these set-up and maintenance expenditures are wasteful unless the private money is superior in some dimensions to the public money.⁸ This argument has some force, but it should not be decisive. If facilitating the use of private money speeds up the rate of innovation in transactions technologies, the long-run efficiency gains may more than compensate for the initial costs involved in setting up new private currency substitutes.

Government currency has an anonymity feature that differentiates it sharply from media such as ATMs and credit cards. It is this anonymity that makes large-denomination notes so useful to the underground economy. Government regulation of private currency substitutes may be needed to limit their use in illegal activities. Such regulation has costs, but these are not likely to be as important as the benefits. Humphrey *et al.* (1996) put the cost of the current payments system of the USA at 2–3% of GDP. Increased efficiency in this sector is therefore valuable, but probably less important than controlling the size of the underground economy, including illegal activities.

3.4. Exchange rate stability

If the euro and the dollar do co-circulate in many countries, will the resulting instabilities from currency substitution not lead to instability in the euro/dollar exchange rate? If, indeed, half of all demand for these two currencies comes from abroad, international substitution between them may lead to massive swings in money demand for the euro and the dollar. In principle, this will not be a problem if the ECB uses the interest rate as its instrument, but it could be a very serious problem if the ECB targets money. Even using an interest rate target, it is still possible for massive money demand shifts to create major technical problems in interpreting data. This is one possible reason why Europe might prefer to be cautious, at least initially, in promoting use of the euro abroad.

Even if Europe actively courts foreign demand, it is not obvious that the euro can break the dollar's strong position in developing countries. The literature on

⁸See Lacker (1996) for a model of this issue and a survey of the literature.

co-circulating currencies suggests that there are likely to be multiple equilibria (e.g., Matsuyama *et al.*, 1993), in some of which both the euro and the dollar co-circulate in developing countries, and in some of which one currency is dominant. In such situations, history and initial conditions can be important determinants of the equilibrium. The euro may also suffer because the physical currency will initially be new and unfamiliar. The foreign public may not be able easily to distinguish counterfeits and, if so, this will reduce acceptance for an extended period.

4. REDUCING THE USEFULNESS OF CURRENCY TO THE UNDERGROUND ECONOMY

Though the arguments are complex, it would appear that on balance the new ECB, and indeed all OECD central banks, should strongly consider policies aimed at reducing currency's usefulness in underground transactions. This may be an uphill battle, especially considering that the strict anti-inflationary statutes of the ECB will otherwise make currency more attractive.

There are many institutional ways to try to tackle the problem of underground currency use, and it may take considerable study and experimentation to determine the best one. Our contention, however, is that a simple and relatively unobtrusive first step would be to remove large-denomination notes from circulation. Large-denomination notes are increasingly rare in legal transactions, having generally been replaced by credit and debit cards, cheques, and other more modern transaction media. The demand for large-denomination notes comes mainly from agents interested in storing or transporting very large sums of currency; such agents tend to be involved in the underground economy.⁹ The idea of withdrawing large-denomination notes from circulation is hardly novel. In the early 1980s, the US Internal Revenue Service placed the removal of \$100 and \$50 bills on its 'wish list' of the most desirable tax enforcement measures (see Gutmann, 1983).

One cannot guarantee that this policy will have even a marginal effect on tax evasion (though as we have argued, tax evasion is so rampant that only a marginal effect would be needed to justify the policy from a revenue standpoint). One cannot even guarantee that underground currency use would drop dramatically. If it did not, the policy would not have any significant direct revenue cost, save for the small extra cost of printing ten 50 euro notes in place of every 500 euro note. Even this cost might be mitigated by reduced counterfeiting, since the economics of counterfeiting give a considerable incentive to focus mainly on the largest-denomination note.

⁹Van Hove and Vuchelen (1996) also emphasize that large-denomination notes are really needed only by agents planning to store or physically transport large sums of cash.

There is the possibility that the underground economy will find a private substitute for large-denomination notes, and that the only effect will be for the government to lose seigniorage revenue. This extreme outcome seems unlikely, since any private alternative will probably carry much greater credit risk. It will also be difficult to replace the complete anonymity of cash.

There are certainly alternative policies that one might consider, aimed at achieving the same end. One can, for example, make it more difficult to launder cash by prohibiting the payment of cash in large transactions – an idea that has already been implemented in some countries in Europe.

Many other imaginative policies are also possible. For example, the central bank can periodically require that people trade in all their large-denomination notes for new ones, and force any individuals turning exceptionally large cash holdings to register with the authorities. The US Treasury could have – perhaps should have – done this when it issued the new off-centre \$100 bill in 1996. India implemented such a policy in 1978, when ultimately 13% of its notes were never redeemed (see Thomas, 1992). Current plans are to begin switching new euro notes for existing national currency notes three years after the start of EMU. This switch provides a golden opportunity for Europe simultaneously to eliminate large-denomination notes, and to force hoarders of large amounts of currency to identify themselves to the authorities. The idea should at least receive serious consideration.

5. CONCLUSIONS

Over the past two decades, despite major innovations in transactions technology, the supply of OECD currency has actually grown as a share of OECD GDP. There is strong evidence that a major reason for this surprising trend is that a large and growing share of OECD currency – probably well over 50% – is held in the domestic OECD underground economy. A wide range of evidence appears to support this conclusion, including the fact that currency demand seems to be positively related to tax burdens in most OECD countries. Another piece of evidence is the high demand for the largest-denomination notes. Despite the increasing convenience of modern technologies for large transactions, and despite some survey evidence indicating that businesses and consumers do not report significant holdings of large-denomination notes, over 60% of the OECD money supply is held in the form of notes equivalent to \$100 or more. A good fraction of the remainder is held in notes equivalent to \$50 or more.

There seems little question that underground demand greatly inflates OECD central bank balance sheets, and that without underground demand seigniorage revenues would be dramatically lower. This paper argues, however, that the revenue benefits obtained by catering to the currency needs of the underground economy may well be an accounting illusion. When one takes lost tax revenue into account, the net benefits to governments' balance sheets are likely to be quite small and

perhaps negative. If removing the convenience of large-denomination notes helps induce even a small percentage of underground activities to be reported, the revenue gains could easily outweigh any seigniorage costs. This is likely to be true even if developing country holdings of OECD currency, which presently constitute perhaps 25% of the total, dropped dramatically as well. (Changes that discourage the use of the domestic underground economy are likely to discourage its use in the foreign underground economy as well.) Note that our revenue calculation would be strengthened if one took into account potential savings on law and tax enforcement costs. The best way to reduce underground currency usage is not entirely clear. Eliminating large-denomination notes, or placing reporting requirements on them, seems like a good place to start.

By all appearances, the decision to issue large-denomination euro notes was aimed at accommodating the DM bloc countries (Germany, the Netherlands, Austria and Belgium). At the end of 1996, these were the only European Union countries issuing notes equivalent to 200 euro or higher. It is surely no coincidence that the fifteen planned denominations of the euro closely match the fifteen existing denominations of the DM. Issuing large-denomination notes certainly makes sense from the point of view of maximizing demand for the new currency. After all, the large-denomination countries in Europe tend to have the highest currency/GDP ratios. As we have just argued, however, this logic is ill-considered.

True, it is possible that the elimination of 100, 200 and 500 euro notes would have little effect on the overall demand for euro currency, with agents simply substituting into smaller bills. This seems unlikely, however, given that \$1 million worth of 500 euro notes can be stored in a large purse, while £1 million in 50 euro notes would take a large suitcase. The ECB might also seriously consider urging national authorities to require identification and reporting of agents attempting to convert quantities of national currencies into euro.

An important contrary viewpoint must be acknowledged. Some may view the ability of agents to shift economic activities underground as an important safety valve in a region where taxes and regulation are high. According to this viewpoint, the underground economy is basically an important resource. If large-denomination notes drastically facilitate production in the tax-evading sector, the contrary viewpoint is that this is a good thing. Providing large-denomination notes may be thought of as an n th-best policy that mitigates other distortions. Indeed, the ECB's strict anti-inflation statutes should be applauded because they reduce the one tax that governments can currently levy on the underground economy.

The above contrary viewpoint is a legitimate one, and it has undeniable libertarian appeal. But, on balance, it is difficult to agree with it. First and foremost, the inability of the government to tax the underground economy increases taxes and distortions in the legal economy. Second, promoting the tax-favoured status of currency-intensive businesses is an extremely arbitrary way to reduce taxes. Surely a

policy of free trade and factor mobility within Europe provides a more sensible and efficient safety valve against high taxes. Moreover, the low-inflation policies of the new ECB already make currency use by the underground economy relatively attractive. It is not wise or necessary to enhance this attractiveness any further by issuing large-denomination notes.

Perhaps an ideal policy is one that allows the ECB to expand foreign demand for its currency while discouraging its use in the underground economy. There may be clever devices for achieving this. But the benefits of curtailing the convenience of currency for the underground economy may be sufficient to justify such a policy, regardless of its implications for foreign demand.

Finally, we note that the logic of this paper probably applies to the US dollar as well, even if over half of all dollars are held by foreigners. The popularity of the \$100 bill, which Europe appears to want to emulate, may well be a mixed blessing.

Discussion

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Why did the European Monetary Institute (EMI) decide that the new European Central Bank (ECB) will issue 500 ecu notes? The simple answer is that we have DM1000 notes and the EMI followed the example of the Bundesbank. Ken Rogoff's paper has the merit of showing that the decision on which size notes to issue is not irrelevant. But should we agree with his conclusion that the ECB should not issue 500 ecu notes because the availability of banknotes of this size facilitates tax evasion and other illegal transactions?

As Rudi Dornbusch pointed out during the Panel discussion, people who use cash for illegal transactions look for a balance between value (a DM1000 note takes up very little space) and anonymity (if only drug dealers use DM1000 notes then the anonymity is gone). This suggests that, if there is a discontinuity in the size of banknotes issued (say 5, 10, 20 and 500), pooling becomes more difficult and only those individuals who use large banknotes for legal purposes (e.g., travellers who wish to travel light) will use them. This may be better than not issuing large-denomination banknotes at all. The ECB instead plans to issue a continuum of banknotes: 5, 10, 20, 50, 100, 200, etc.

When large-denomination banknotes are not available, people find other ways to carry out underground transactions: not providing large denominations may cause only a small inconvenience to the underground economy. Italy offers an interesting experiment. A large-denomination banknote has been issued by the Banca d'Italia

since the early 1970s: the ITL100 000 note. However, because of inflation, the purchasing power of this banknote has fallen by a factor of ten between 1970 and today. Therefore, it is as if a large-denomination banknote had been withdrawn by the Banca d'Italia, which never issued denominations in excess of ITL100 000 lire. Estimating a simple money demand function for the ITL100 000 note, one discovers that in the early part of the sample, the 1970s, the only variable on the right-hand side that appears to be significant in the regression is 'crime' – an estimate of the yearly value of crime-related transactions. This variable, however, drops out of the regression in the second part of the sample, the 1980s and early 1990s. This finding is consistent with the view that, as long as the purchasing power of the ITL100 000 note was relatively high, it was indeed used by the underground economy. But when its value fell, the Italian underground economy found other ways to carry out its transactions: for example, bearer treasury bills became a common instrument. Eliminating large-denomination banknotes may cause only a minor nuisance to the underground economy.

The fact that the European Commission has already chosen the drawings for the new ecu banknotes does not mean that in four years' time they will all need to be issued. This paper suggests that it may be a good idea to think through the issues once more.

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Kenneth Rogoff argues that, by issuing large-denomination euro notes of 100, 200 and 500, the European Central Bank will challenge the US Federal Reserve as the leading purveyor of currency to unstable developing countries, to tax-evaders (or to people working in the underground economy) and to criminals throughout the world. Rogoff concludes that it is not a good policy for the European Central Bank to issue large-denomination notes because this helps (or stimulates) the underground economy, including criminal activities such as drug dealing. Moreover, the euro will be vastly used outside its currency domain, and it will be a real competitor to US dollar notes. He therefore suggests that it might be a better idea *not* to bring out large-denomination notes with the potential results that the shadow economy will shrink (perhaps by 10%), that fewer euro currency notes may be held abroad, and that less currency may be used for criminal activities. Furthermore, he argues that the use of cash is 'out' for normal (legal) transactions. Against these findings I have the following four objections:

1. A theoretical approach to using the elimination of large-denomination notes as an efficient instrument to fight crimes and/or to reduce the shadow economy is missing. The author's main argument is that, if large-denomination notes are not printed, this will have a considerable negative effect on underground and criminal activities: that is, it will reduce the underground

economy (and possibly other criminal activities) because the use of cash is much less attractive. In my opinion this conclusion is not convincing because the author does not analyse the reasons why people evade taxes or work in the underground economy. Research in Europe and North America shows that the major reasons for working in the underground economy are the high direct and indirect tax burden (including social security payments, which, at least in Europe, are treated as an additional tax due to the insecurity of getting a pension in the future) and overregulation of the economy (at least in most European countries). Most transactions in the underground economy are undertaken with cash because cash transactions do not leave traces for the tax authorities. (See, e.g., Frey and Pommerehne, 1984; Frey and Weck-Hannemann, 1984; Feige, 1989; Schneider, 1994a, 1997.)

The abolition of large-denomination notes will hardly reduce the incentives to work in the underground economy (or to evade taxes) because the major causes are not tackled at all by this policy measure. The only effect will be that the transaction costs of working in the underground economy or evading tax will rise because people will have to use smaller-denomination notes. This might 'drive out' a few people at the margin of the underground economy, but the effect will be rather small. Hence, Rogoff should develop a more convincing theoretical approach or a more decisive argument, such that an increase in transaction costs is really an efficient means to fight tax evasion or to substantially reduce the underground economy.

2. The review of the empirical analysis of using cash for various purposes is incomplete. There exists a large literature on estimating the size and development of the shadow economy in Europe and in the USA (see, e.g., Frey and Pommerehne, 1984; Frey and Weck-Hannemann, 1984; Feige, 1989; Schneider, 1994a, 1997; Aigner *et al.*, 1988; Clovland, 1984.) The latest empirical results on the size of the shadow economy using the currency demand approach are shown in Table 7. Taking the results on the size of the underground economy for the latest available year, 1994, it can be seen that Italy (25.8%), Spain (22.3%), Belgium (21.4%) and Sweden (18.3%) have the largest shadow economies. In the mid-group are Norway (17.9%), Denmark (17.6%), Ireland (15.3%), Canada (14.6%) and France (14.3%). At the lower end are the Netherlands (13.6%), Germany (13.1%), the UK (12.4%), the USA (9.4%), Austria (6.8%) and Switzerland (6.6%). From Table 7 it can also be seen that the increase in size of the shadow economy over time is quite remarkable. Whereas in 1960 the shadow economy accounted for less than 5% of GNP in the investigated countries, in 1994 (excluding the USA, Austria and Switzerland) it accounted for over 10% of GNP.

By definition, an advantage of the currency demand approach is that one is able to calculate roughly how much currency will be used for activities in the underground economy. Furthermore, there is some knowledge of how much currency is used for legal cash transactions and how much currency is used abroad. So Rogoff could have calculated how much currency is used in the underground economy and

Table 7. Size of the shadow economy applying the currency demand

Country	Author(s)	Size of the shadow economy (% of official GNP)							
		1960	1965	1970	1975	1978	1980	1990	1994
Austria	Schneider (1997)	0.4	1.2	1.8	1.9	2.6	3.0	5.1	6.8
Belgium	Hove and Vuchelen (1994)	–	7.8	10.4	15.2	–	16.4	19.6	21.4
Canada	Karoleff <i>et al.</i> (1993)	–	–	–	5.8–7.2	–	10.1–11.2	–	14.6
Denmark	Schneider (1986)	3.8–4.8	5.0–6.3	5.3–7.4	6.4–7.8	6.7–8.0	6.9–10.2	9.0–13.4	17.6
France	Barthelemy (1989)	–	–	3.9	–	6.7	6.9	9.4	14.3
Germany	Kirchgässner (1983)	2.0–2.1	3.6–4.3	2.7–3.0	5.5–6.0	8.1–9.2	10.3–11.2	11.4–12.0	13.1
Ireland	Boyle (1982)	–	–	4.3	6.9	–	8.0	11.7	15.3
Italy	Contini (1989)	–	8.4	10.7	–	–	16.7	23.4	25.8
Netherlands	Broesterhuizen (1989)	–	–	4.8	–	–	9.1	12.9	13.6
Norway	Lundager and Schneider (1986)	1.3–1.7	3.2–4.1	6.2–6.9	7.8–8.2	9.6–10.0	10.2–10.9	14.5–16.0	17.9
Spain	Lafuente (1989)	–	–	–	–	18.0	–	21.0	22.3
Sweden	Lundager and Schneider (1986)	1.5–1.8	3.7–4.6	6.8–7.8	10.2–11.2	12.5–13.6	11.9–12.4	15.8–16.7	18.3
Switzerland	Weck-Hannemann <i>et al.</i> (1986)	1.2	1.6	4.1	6.1	6.2	6.5	6.9	6.6
UK	Matthews and Rostagi (1985)	–	–	2.0	6.5	7.8	8.4	10.2	12.4
USA	Tanzi (1983)	2.6–4.1	2.5–3.8	2.6–4.6	3.5–5.2	3.7–5.3	3.9–6.1	5.1–8.6	9.4

Notes: A dash means that no value exists for this period for this country. Only a crude comparison of the size of the shadow economy between the different countries can be done because of (1) different tax variables; (2) different specifications of the dependent variable and estimation equation; and (3) different assumptions about the velocity of currency.

Sources: For the currency demand approach, see references in the text. The values for the years 1990 and 1994 for Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, UK and USA are calculated by Schneider (1997).

the residual of the currency for other criminal activities, such as drug dealing. Such a calculation could be done for both the US dollar and the German mark. This would shed some light on whether the abolition of large-denomination bills would reduce the size of the underground economy.

3. There is a missing link between the underground and the official economy. Various studies have shown that there is a strong interaction between the underground and the official economy. (Compare, e.g., Neck *et al.*, 1989; Schneider and Neck, 1993; Schneider, 1994b.) First, people work in the underground economy only because the official economy is overburdened with regulation. A trader working in the official economy is too expensive. On the other hand, at least 70% of all income earned in the underground economy is spent again in the official economy, so that this additional purchasing power is a strongly stabilizing factor in the official economy.

For example, it has been estimated that the underground economy in Austria was worth roughly 200 billion Austrian Schillings in 1994, of which 140 billion are spent again in the official Austrian economy. Hence, if the Austrian underground economy were considerably reduced (assuming that the author's suggestion not to print large-denomination notes works efficiently) then Austria would suffer from a considerable recession. People would not work more in the official economy because the reasons for their working in the underground economy would not have been tackled at all. People would either work even more in the underground economy or take more leisure.

4. The use of 'hard' currencies abroad. It is difficult to evaluate what domestic and foreign effects the dollar (or, in the future, the euro) really has if it is widely used outside the own currency domain. I am not aware of any study that estimates the costs and benefits for the US dollar of its being used as a 'hard currency' in Argentina or Russia. What effect does this have on the US economy, what costs and benefits are involved, and will these costs and benefits change if large-denomination notes are reduced? There might be a trade-off between using hard currencies (like the dollar or the German mark) in developing or other countries, which have severe problems in stabilizing their own currency, and the illegal activities that might also result. One could argue that this is a kind of development aid from hard currency countries to soft currency countries because individuals in the latter will learn to use hard currencies, and that eventually soft currency countries will turn into hard currency countries when they see the advantages. As long as it has not been convincingly shown that the use of money abroad has severe disadvantages for the home country, it can be argued that large-denomination notes should be allowed.

General discussion

In Rudi Dornbusch's opinion, the analysis of the interaction between crime and

demand for cash was reminiscent of the Chicago tradition of the 1960s and 1970s. He was also reminded of Mundell's monetary theory of empires, which postulated that the potential for seigniorage may have been a crucial incentive for holding on to large empires. Moving on to the specifics, he thought that even though the cash holdings of the Japanese yen seem stunningly large, these may well be domestic rather than foreign. Given the high price stability, the low return on bank deposits and the relative absence of street crime in Japan, households prefer to hold cash rather than bank deposits. Second, eliminating large-denomination notes was futile, and likely to inconvenience only honest people, as long as the private sector could supply perfect substitutes for illegal purposes. For instance, large-denomination unsigned travellers' cheques had been common currency in Hollywood in the past. Third, large-denomination banknotes are convenient to store and transport, but are relatively illiquid. This trade-off must be incorporated in the analysis.

He went on to propose methods for estimating the different components of the demand for dollars. Foreign demand that is induced by hyperinflations could be estimated, for instance, by assuming that the entire reduction in the demand for real balances in hyperinflationary countries is substitution towards the dollar. The countries concerned, namely Argentina, Russia and Israel, and the timing of their hyperinflationary episodes, were well known. This would provide an upper estimate for such a demand. When it came to the domestic demand, he wondered if there was a seasonal pattern in the use of large-denomination notes. If so, one could further improve the estimates of foreign versus domestic holding of such notes. Finally, he speculated that modern technology, in particular the ability to 'bug' and then monitor the flow of large-denomination notes, might provide new ways to check illegal activity.

Robert McCauley felt that the paper was written from a somewhat parochial American perspective, and had missed some significant differences between Europe and the USA. First, large cash holdings in Europe could be a consequence of the relatively safe environment in European cities, rather than large-denomination notes being a contributory cause of criminal activity. Second, in the European case, seigniorage will be lower as the launch of the new European currency will involve a call-in of existing currency notes. The USA was careful to avoid a call-in of old notes when new \$100 bills were launched. He too speculated on the possibilities afforded by new technology. The advent of the electronic purse and the growing ability of the private sector to generate close substitutes for cash meant that governments may soon lose their monopoly of issuing large-denomination banknotes.

Olivier de Bandt added that money is increasingly laundered through credit cards and other sophisticated methods rather than banknotes. Furthermore, when it comes to choosing denominations, removing large denominations is unlikely to reduce black market activity as substitution to smaller denominations is almost costless. Rudi Dornbusch felt that, instead of abolishing large-denomination notes,

one could restrict their use by imposing reporting requirements for large cash transactions.

Hans Genberg wondered if counterfeiting of banknotes was sensitive to the denomination in which they were issued. Stefan Gerlach pointed out that counterfeiting costs would vary systematically across denominations and, moreover, these costs would be borne by the public at large. He thought that pooled data on currency demand – pooled across countries and time periods – would yield additional information about the incentives to hold money.

Hélène Rey argued that large-denomination euro notes are unlikely to be perfect substitutes for dollar notes. Criminals' demand for currency may be quite heterogeneous and, further, currency substitution models indicate that there is considerable hysteresis in currency holdings. Richard Portes felt that the possibility of currency substitution introduces complications for monetary policy and, therefore, merited greater attention. Olivier Blanchard wondered if criminals with European currency holdings will convert to the dollar before the euro is launched. If so, would this affect the demand for money in the run-up to the launch?

Georges de Ménil stressed that it was important to appreciate the reasons for large unofficial sectors in some countries. For instance, one has to ask why half the Ukrainian GDP is generated in the unofficial sector. In his opinion, it was the enormous amount of regulatory intervention and bureaucratic red tape that generated and supported illegal transactions. If so, law enforcement and the correction of these economy-wide imperfections were better approaches than focusing on the choice of currency denominations.

APPENDIX A. THE THEORY OF CURRENCY DEMAND AND TAX EVASION

Although the empirical literature on currency demand has long recognized the importance of currency use in the underground economy (e.g., Feige, 1979; Tanzi, 1983), standard theoretical treatments of money demand and optimal inflation taxation have remained curiously oblivious to this possibility.¹⁰ For positive results, the distinction between legal and illegal or tax-avoiding transactions may be secondary, but this is certainly not the case for normative questions such as the optimal level of money growth and inflation. This appendix presents a simple modification of a standard transactions cost model that accounts for the potential role of currency in tax evasion.

A1. A transactions-based model of currency demand with tax evasion

Consider a small, open economy in which the domestic currency is the sole legal tender. The representative individual is endowed each period with y units of output and can borrow and

¹⁰ E.g., Sidrauski (1967) (money in the utility function), Lucas and Stokey (1987) (cash-in-advance constraint), Kiyotaki and Wright (1989) (matching model), or Sims (1994) (transactions costs).

lend at the world real interest rate r . The agent has a utility function given by

$$U = \sum_{s=t}^{\infty} \beta^{s-t} u(c_s) \quad (\text{A1})$$

where c is consumption in period s , $\beta < 1$ is the time discount factor, and $u' > 0$, $u'' < 0$. The individual is endowed each period with gross real income y . However, due to trading frictions, a portion of this income dissipates in production so that net pre-tax income in period t is given by

$$y[1 - v(M_t^i/P_t, y)] \quad (\text{A2})$$

where M_t^i denotes the individual's holdings of currency at time t (for now we will ignore the distinction between notes of differing denominations), and P_t is the money price level. The function $v(M/P, y)$ has the properties that $v'(\cdot) < 0$, $v''(\cdot) > 0$, $\lim_{M/P \rightarrow \infty} v(M/P, y) = 0$, and $v(0) < 1$. Thus currency is helpful in reducing the transactions costs associated with exchange, but it is not absolutely essential. This is, of course, a variant of the well-known money-in-the-utility-function approach, in which demand for money is rationalized as being derived from an underlying transactions technology.¹¹ In interpreting this model, it is not necessary to view currency as being the sole mechanism for effecting payments, provided there is no perfect substitute in all transactions. For example, the individual may use cheque accounts on which bank intermediaries hold currency reserves, so that the demand for currency is a derived one.

In addition to receiving income, the agent also faces a proportional tax on earned income (y) at notional rate τ . (For simplicity, we assume that interest income is not taxed.) The tax rate is notional in that the agent can reduce his or her effective tax rate by holding a higher level of real balances M/P . The idea is that using currency helps avoid detection of income by the tax authorities.¹² Thus the net real taxes paid by the individual are

$$\tau g(M_t^i/P_t, y) \quad (\text{A3})$$

where $g(0) = 1$, $g'(\cdot) < 0$, $g''(\cdot) > 0$, and $\lim_{M/P \rightarrow \infty} g(M/P, y) \geq 0$. (Obviously, we do not need to think of every individual as engaging in tax evasion, but thinking of the representative agent as wearing two hats is a useful shortcut to analysing a more heterogenous economy.) In addition to paying a tax proportional to income, the individual receives a lump-sum nominal transfer of $\Delta M_t \equiv M_t - M_{t-1}$, where ΔM_t is the increase in the per-capita money supply. Thus holding currency facilitates avoiding income taxes, but does not affect the individual's ability to accept lump-sum transfers from the government.

Our assumptions on the transactions and tax evasion technology imply that the individual's budget constraint can be written in money terms as

$$P_t b_{t+1}^i + M_t^i = P_t(1+r)b_t^i + M_{t-1}^i + P_t y[1 - v(M_t^i/P_t, y) - \tau g(M_t^i/P_t, y)] - P_t c_t + \Delta M_t \quad (\text{A4})$$

¹¹ The formulation is the same as Sims (1994), except that he posits the transactions savings as being proportional to consumption rather than income. Since income and consumption are proportional here, this distinction is not important for present purposes. Taken literally, one can think of cash here as being needed in production (for stocking cash registers, for giving change, for purchasing intermediate goods and for paying wages).

¹² A more sophisticated approach would be to have the individual's income y be private information, with currency a mechanism for concealment.

where b_{t+1}^i denotes the individual's holding of real bonds, and M_t^i his or her money holdings at the end of period t .

The first-order conditions for individual utility maximization (of (A1) subject to (A4)) imply

$$u'(c_t) = \beta(1+r)u'(c_{t+1}) \quad (\text{A5})$$

and

$$\frac{1}{P_t} u'(c_t) \left[1 + v' \left(\frac{M_t}{P_t y} \right) + \tau g' \left(\frac{M_t}{P_t y} \right) \right] = \frac{1}{P_{t+1}} \beta u'(c_{t+1}) \quad (\text{A6})$$

where we have dropped i superscripts. Equation (A5) is the standard consumption/Euler equation,¹³ while equation (A6) determines the allocation of income between money and consumption. Combining (A5) and (A6) yields

$$-v' \left(\frac{M_t}{P_t y} \right) - \tau g' \left(\frac{M_t}{P_t y} \right) = 1 - \frac{P_t}{P_{t+1}(1+r)} = \frac{i}{1+i} \quad (\text{A7})$$

which, given our assumptions on v' and g' , implies a standard demand function for real balances, increasing in y , and decreasing in the nominal interest rate i .¹⁴ The one important difference, however, is that money demand also depends positively on the marginal tax rate.

To see the implications of the model more clearly, it is helpful to consider the specific functional forms

$$g(M/Py) = \exp - \frac{1}{\eta} (M/Py) \text{ and } v(M/Py) = a \exp - \frac{1}{\eta} (M/Py),$$

where $0 < a < 1$. In this case, (A7) reduces to

$$\frac{M_t}{P_t} = \eta y \left\{ \log \frac{1}{\eta} (a + \tau) - \log \left(\frac{i}{1+i} \right) \right\} \quad (\text{A8})$$

A2. A digression on price-level determinacy

Before proceeding, it is important to pause to ask about price-level determinacy in this model. If τ is exogenous and M grows at a constant exogenous rate, then an analysis of price-level determinacy parallels that for a standard money-in-the-utility-function model.¹⁵

¹³ A nuance here, however, is that although the individual's gross income is constant, his or her income net of taxes and transactions costs fluctuates depending on his or her holding of real balances.

¹⁴ The nominal interest rate i is defined as

$$1+i = \frac{P_{t+1}}{P_t} (1+r)$$

¹⁵ See also Obstfeld and Rogoff (1983) and Obstfeld and Rogoff (1996), chapter 8.

Specifically, equation (A7) can be rewritten

$$m_{t+1} = (1 + \theta)(1 + r)m_t \left[1 + v' \left(\frac{m_t}{y} \right) + \tau g' \left(\frac{m_t}{y} \right) \right] \quad (\text{A9})$$

where $m \equiv M/P$ and $\theta = (M_{t+1} - M_t)/M_t$. Our assumptions on the transactions and tax evasion technologies imply that this difference equation has a single stationary state with $m > 0$, but the equation also admits speculative bubble paths. Paths where real money balances grow without bound can be ruled out by a transversality argument. Hyperinflationary paths where real balances fall to zero, however, cannot be ruled out without making an assumption that the government offers to back the currency fractionally with real resources (although the fractional backing can be arbitrarily small and need not be certain). Implicit in this analysis is the assumption that the government endogenously varies government spending to maintain a constant notional tax rate τ and a constant money growth rate θ . Otherwise, if τ varies endogenously, the analysis becomes more complicated, though the price level is still determinate under plausible conditions.

A3. Optimal rate of steady-state money growth

Assume that when the notional tax rate is τ , real revenues to the government are $\tau y f(M_t/P_t, y)$, where $f(M/P, y) \leq g(M/P, y)$. The two functions are equal in the case where tax evasion does not consume any real resources so that the public's cost of paying taxes equals the government's revenue. In general, even if $f(M/P, y) = g(M/P, y)$, Ricardian equivalence does not hold here. The notional tax rate affects the demand for money, which in turn affects the real resources dissipated in transactions. Correspondingly, raising the steady-state rate of money growth will raise receipts from direct taxes, since, in general, steady-state real balances fall as inflation rises: that is, denoting steady-state real balance as $\bar{m}(\theta)$, $\bar{m}'(\theta) < 0$.

These observations have implications for the two standard exercises in the analysis of money demand. First, the usual optimal rate of money growth arguments suggest that the higher are real balances, the lower are transactions costs and the higher is welfare. If, however, there is a wedge between government tax revenue and the private cost of paying taxes [$f(M/P, y) < g(M/P, y)$] then this may no longer be the case. The optimal level of inflation will then also depend on the properties of the function $g(M/P, y) - f(M/P, y)$, since higher real balances may increase the deadweight costs of tax evasion.

Second, standard calculations of the optimal seigniorage revenue-maximizing rate of inflation (as in Cagan, 1956) ignore the fact that net revenues to the government from direct taxation may be decreasing in M/P and, therefore, *rising* in the rate of inflation.¹⁶ In the present model, total steady-state government revenues are given by

$$\theta \bar{m}(\theta) + \tau y f \left[\frac{\bar{m}(\theta)}{y} \right] \quad (\text{A10})$$

¹⁶This is the opposite of Tanzi's (1977) result. Tanzi emphasizes that tax levels are often nominally sticky, and therefore a rise in inflation may curtail the real value of government tax revenues. Dixit (1991) argues that the Tanzi effect disappears if tax rates are appropriately indexed. The same is true here, but only if there are no deadweight costs to tax evasion.

Differentiating with respect to θ yields the first-order condition

$$\bar{m}(\theta) + \theta \bar{m}'(\theta) + \tau f' \left[\frac{\bar{m}(\theta)}{y} \right] \bar{m}'(\theta) = 0 \quad (\text{A11})$$

or

$$\theta = - \frac{\bar{m}(\theta)}{m'(\theta)} - \tau f' \left[\frac{\bar{m}(\theta)}{y} \right] \quad (\text{A12})$$

Standard analyses (e.g., Obstfeld and Rogoff, 1996, ch. 8) focus only on the first term on the right-hand side of (A12). However, since the second term is unambiguously positive (recall $f' < 0$), allowing for tax evasion as in this model unambiguously raises the revenue-maximizing rate of inflation at any given level of τ . The potential empirical significance of this effect is discussed in the text.

APPENDIX B. EXTENSION TO MULTIPLE DENOMINATIONS OF CURRENCY

The preceding analysis treated currency as homogeneous, but the empirical evidence suggests that for most countries, large-denomination notes are used disproportionately in the underground economy. An extension of the model to allow for multiple currency denominations illustrates a natural way that net direct tax revenues might be raised without necessarily raising either steady-state inflation or prices.

In this appendix, we extend our model to allow for two different denominations of currency, 1 and 2. Think of currency 1 as \$20 bills and currency 2 as \$100 bills. The numeraire currency is 1, and the exchange rate of currency 1 for currency 2 is S (units of currency 1 required to purchase a unit of currency 2). We will initially assume that the government fixes the exchange rate at \bar{S} by trading the currencies in unlimited quantities as necessary. (Obviously, in the example of \$100 and \$20 bills, the official exchange rate is 5.) As we shall see, the unofficial exchange rate can deviate from the official exchange rate if the government ceases to print new \$100 bills in an effort to remove them gradually from circulation.

If the denominations were perfect substitutes in all uses then, of course, the public would willingly accept them in whatever ratio the government chose. If, however, the two currencies are not perfect substitutes (say, because denomination 1 is a more suitable size for most transactions or because smugglers find denomination 2 lighter and more convenient for making bulk currency shipments) then the central bank must allow the relative supplies of the two currencies to be demand determined if it wishes to fix S at the face-value exchange rate. For convenience, we model this imperfect substitutability in an extreme way, so that currency 1 alone is useful for reducing transactions costs in legal transactions, and currency 2 alone is useful in tax evasion.¹⁷ Nothing important in the analysis below would be changed by

¹⁷ In the traditional currency denomination literature (e.g., Manski and Goldin, 1987), the demand for different-denomination notes depends on the distribution of transaction sizes in the economy. Here we abstract from this issue.

modifying these assumptions so that either currency could be used for either purpose, provided that tax evasion was relatively currency-intensive. Denote $P_{1,t}$ as the price level at time t in terms of currency 1, and $P_{2,t}$ as the price level in terms of currency 2. Because both currencies are legal tender, purchasing power parity must hold so that

$$P_{1,t} = S_t P_{2,t} \tag{B1}$$

or, as long as S_t is fixed at \bar{S} ,

$$P_{1,t} = \bar{S} P_{2,t} \tag{B2}$$

Given our assumptions, the individual's period budget constraint (A3) is replaced by

$$P_{1,t} b_{t+1}^i + M_{1,t}^i + S_t M_{2,t}^i - P_{1,t}(1+r) b_t^i - (M_{1,t-1}^i + S_t M_{2,t-1}^i) = P_{1,t} y [1 - v(M_{1,t}^i/P_{1,t} y) - \tau g(M_{2,t}^i/P_{2,t} y)] - P_{1,t} c_t + \Delta M_{1,t} + S_t \Delta M_{2,t} \tag{B3}$$

where the numeraire is currency 1. The first-order consumption/Euler condition (A5) remains the same, but the other first-order condition (A6) is replaced by the two conditions

$$\frac{1}{P_{1,t}} u'(c_t) \left[1 + v' \left(\frac{M_{1,t}}{P_{1,t} y} \right) \right] = \frac{1}{P_{1,t+1}} \beta u'(c_{t+1}) \tag{B4}$$

and

$$\frac{1}{P_{2,t}} u'(c_t) \left[1 + \tau g' \left(\frac{M_{2,t}}{P_{2,t} y} \right) \right] = \frac{1}{P_{2,t+1}} \beta u'(c_{t+1}) \tag{B5}$$

Combining the three first-order conditions, (B4), (B5) and (A5), with the purchasing power parity relationship (B1) implies

$$1 = \frac{v' \left(\frac{M_{1,t}}{P_{1,t} y} \right)}{\tau g' \left(\frac{M_{2,t}}{S_t P_{1,t} y} \right)} \tag{B6}$$

Given τ , (B6) determines the relative supplies of the two moneys needed to fix the exchange rate at face value \bar{S} . Then, given a path for M_1 , one can think of the currency-1 price level P_1 being determined by (A5) and (B4) in the usual way, with (B6) determining the requisite supply of M_2 . Of course, the analysis is more complex if the government does not adjust spending to achieve budget balance (as we assume for simplicity here), since tax revenues, money growth and expenditures are all related through the government budget constraint. We will not attempt an analysis of the general case here.

What happens when, as suggested in the text, the government phases out currency 2 by ceasing any printing of new notes, offering to redeem any old ones for currency 1 at the face-value exchange rate? The official exchange rate \bar{S} now provides a floor for the value of currency 2 in terms of currency 1, but (since there is only one-way exchange), it does not provide a ceiling. There can be an appreciation, since currency 2 is more efficient for tax evasion and its supply is now limited. Thus, initially, there is the possibility that phasing out the large-denomination currency will actually raise the value of existing notes, perversely giving hoarders a capital gain. This effect is probably small, however, compared to the long-

term revenue gain. It can also be mitigated by adopting a more elaborate phase-out scheme (e.g., specifying that after a certain interval all redemptions of \$100 bills will have to be registered with the government).

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