Cash and Crises:

No surprises by the virus[*]

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Abstract:

Despite the increasing use of cashless payment instruments, the notion that cash loses importance over time can be unambiguously refuted. In contrast, we show that cash demand increased steeply over the past 30 years. This is not only true on a global scale, but also for the most important currencies in advanced countries (USD, EUR, CHF, GBP and JPY). In this paper, we focus especially on the role of different crises (technological crises, financial market crises, natural disasters) and analyse the demand for small and large banknote denominations since the 1990s in an international perspective. It is evident that cash demand always increases in times of crises, independent of the nature of the crisis itself. However, largely unaffected from crises we observe a trend increase in global cash aligned with a shift from transaction balances towards more hoarding, especially in the form of large denomination banknotes.

JEL: E41, E51, E58

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1. Introduction

Over the past years, there was an intense discussion about restricting or even abolishing cash (see, e. g., Rogoff, 1998, 2016, Agarwal & Kimball, 2015, Sands, 2016). The advocates of such drastic measures typically refer to the fact that cash will become obsolete anyway as electronic payments gain more and more importance. However, as figure 1 shows, global cash in circulation increased enormously since the beginning of the 1990s, and its trend growth became even steeper over time (see also Jobst & Stix, 2017; Bech et al., 2018; Shirai & Sugandi, 2019; Arango-Arango & Suáres-Ariza, 2019, Ashworth & Goodhart, 2020, Rösl & Seitz, 2020).

**Figure 1: Global cash in circulation (US-Dollar billion)**
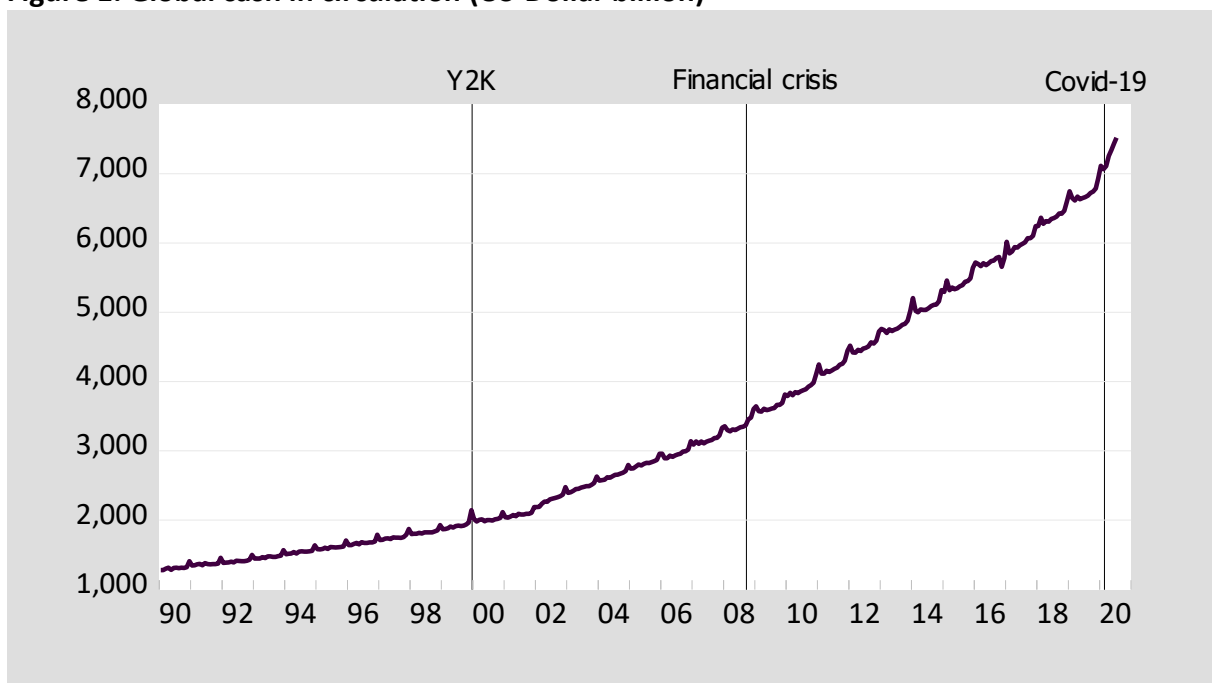
Remarks: Data refer to cash or banknotes in circulation. Countries included are Egypt, Australia, Brazil, China (since 2006), Denmark, Germany (until end of 2001), Euro area (since 2002), United Kingdom, India, Japan, Canada, Norway, Russia, Sweden, Switzerland, South Africa, South Korea, USA; sample period: 1990.01-2020.07. National figures converted in US dollar by using the average exchange rate over the data period. The vertical lines highlight three crises (Y2K 2000, financial crisis October 2008, Covid-19 pandemic). The statistical breaks resulting from the inclusion of the Euro area 2002 and China 2006 were smoothed by simple linear interpolation.

Source: National central banks, IMF.

For the major currencies, growth in cash holdings even exceeded GDP growth in the last decades (see figure 2).

Figure 2: Cash in circulation relative to GDP (in %)
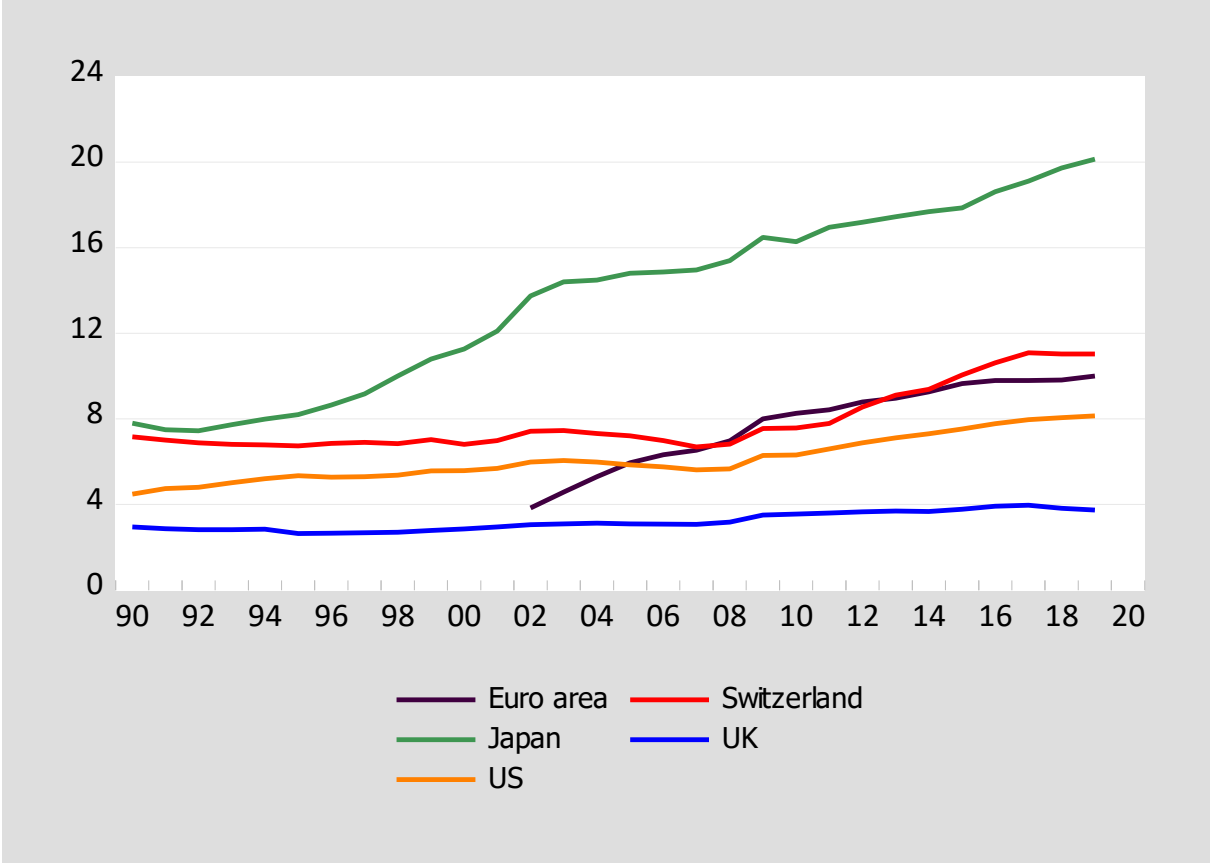

Source: National central banks.

At the current juncture, the Covid-19 pandemic led to an exceptional strong increase of cash demand all around the world (Heinonen, 2020) despite efforts from the retail sector, FINTECH, and the card industry to convince consumers to use electronic payments more intensively (e. g., Beretta & Neuberger, 2020). And, indeed, in many countries cashless payments were more frequently used at the point of sale (see, for instance, Ardizzi et al., 2020, Caswell et al., 2020, Mitchell, 2020). Consequently, other motives of holding cash must have overcompensated this decrease in cash transaction balances. The present paper intends to provide a deeper insight into the motives of cash demand, not only in the wake of the Covid-19 pandemic, but also in times of crises more generally. In addition, it also provides evidence of a trend shift over time towards non-transactional demand for cash.

2. Cash demand in times of crises

Since the early 1990s worldwide inflation rates decreased quite considerably (see figure 3 and Forbes, 2019; Hakkio, 2009; Razin, 2005). The resulting reduction of nominal interest rates and opportunity costs for cash holders alone should have contributed to the increase in global

cash demand during this period (Fujiki, 2019; Haasl et al., 2018; Fish & Whymark, 2015; Deutsche Bundesbank, 1995).

Figure 3: Worldwide inflation since 1990
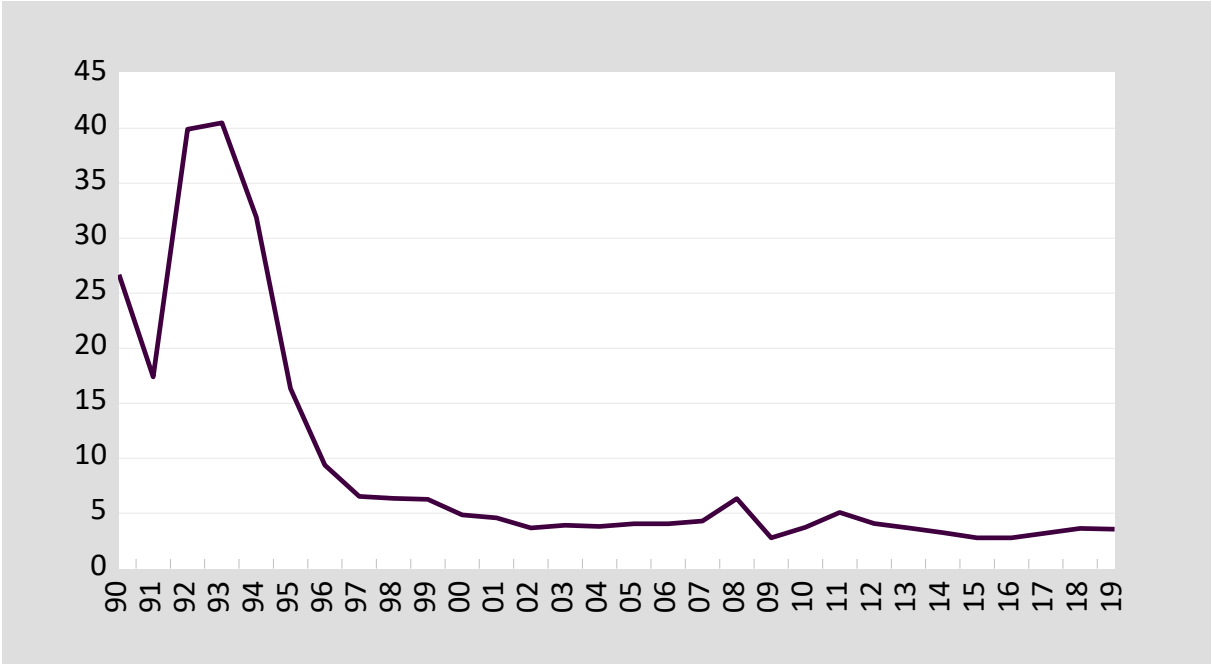
Note: Annual inflation measured by the consumer price index in %.

Source: IMF.

In such an environment, it is not surprising that cash will be demanded more intensively especially once a crisis occurs since it provides a secure means of payment and it is at the same time the most liquid store of value. The following figure 4 shows the annual growth rates of global cash and the beginning of three important crises:

1. Technological crisis (Y2K crisis 2000),
2. Financial market crisis (October 2008),
3. Natural disaster (Covid-19 crisis, 2019/20).

**Figure 4: Annual growth rates (%) of global cash**
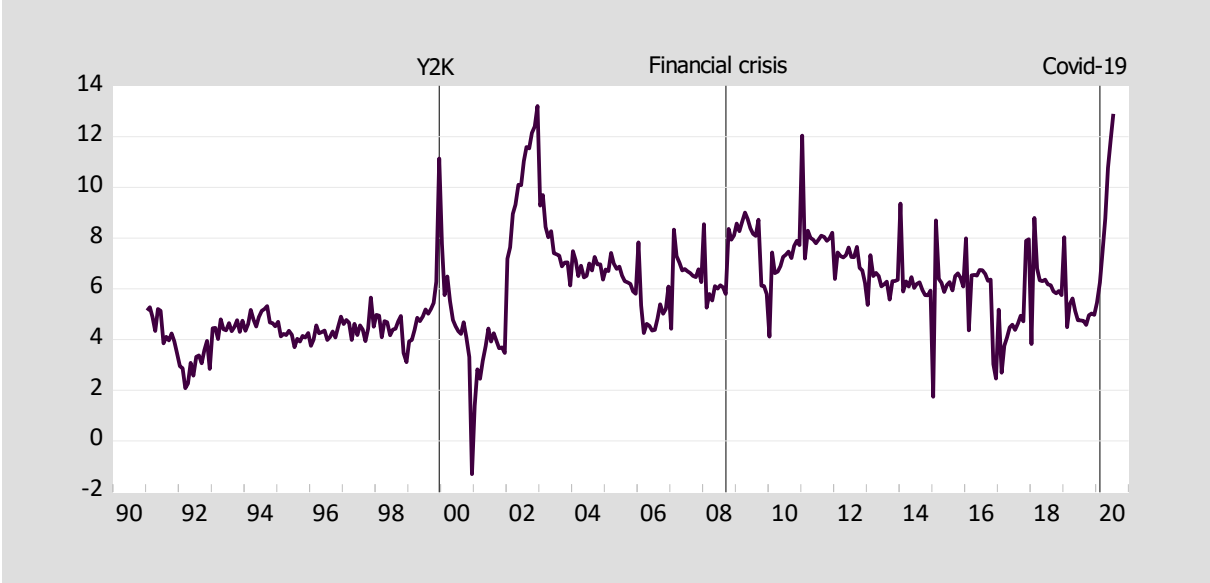
Remarks: Data refer to cash or banknotes in circulation. Countries included are Egypt, Australia, Brazil, China (since 2006), Denmark, Germany (until end of 2001), Euro area (since 2002), United Kingdom, India, Japan, Canada, Norway, Russia, Sweden, Switzerland, South Africa, South Korea, USA; sample period: 1990.01-2020.07. National figures converted in US dollar by using the average exchange rate over the data period. The vertical lines highlight three crises (Y2K 2000, financial crisis October 2008, Covid-19 pandemic). The statistical breaks resulting from the inclusion of the Euro area 2002 and China 2006 are taken out by a simple linear interpolation.

Sources: National central banks, IMF.

2.1 Cash demand during the technological crisis around the turn of the year 2000 (Y2K)

The huge increase in the global demand for cash during the technological crisis around the turn of the year 2000 (Y2K) was caused by heightened uncertainty. At that time, there were fears that the re-setting of computer program dates in order to adjust for the new millennium would have led to a shutdown of important institutions like public utilities, but also the smooth functioning of payment systems and cash withdrawals from ATMs were in question. As shown in the following figure 5, the global surge of cash then was driven by an increased demand for banknotes provided by central banks of large currency areas (US dollar, Deutsche Mark, Great Britain Pound, Japanese Yen and Swiss Francs).

**Figure 5: Annual growth rates (%) of cash in selected countries in %**
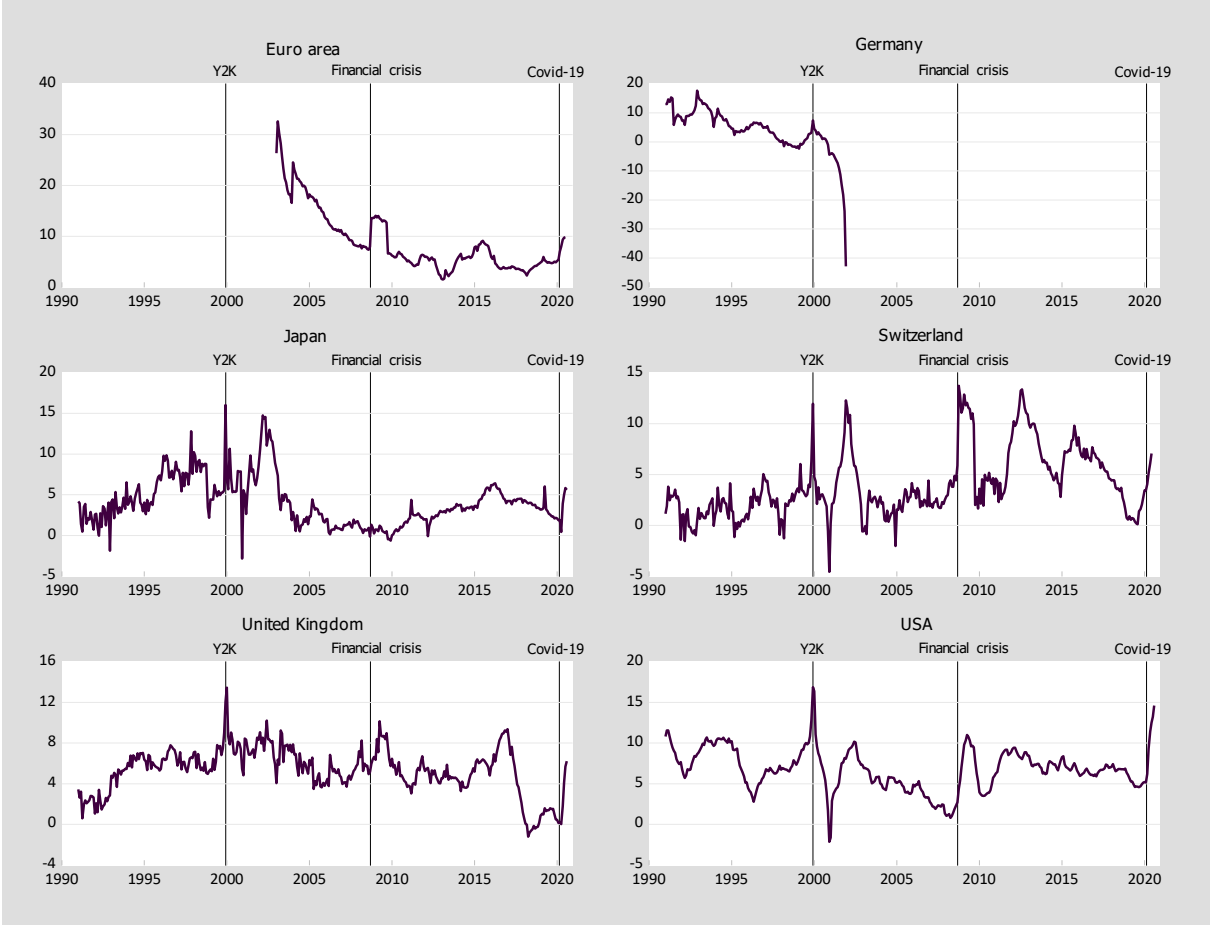
Notes: Data refer to cash or banknotes in circulation.

Source: National central banks.

The marked increase in cash demand around the turn of the millennium was driven by transaction and precautionary motives as well as the desire of money holders to store value.[1] Assuming for simplicity reasons that large denominations of banknotes are predominantly held for hoarding purposes and small denominations for transactions one can make the following rough statements. In the US, both transaction and hoarding motives have probably been equally important during the Y2K crisis. This at least suggests the annual growth rate of the (only) large denomination (USD 100) of 20% in comparison to the respective rate of the small denominations (USD 1-50) of 25% (see figure 6). Judson (2017) attributes this high increase in the USD 100 banknote also substantially to foreign demand for US dollar, further suggesting the importance of non-transaction motives around Y2K.

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[1] In the following, we subsume demand for cash not used for (immediate) domestic transactions as "hoarding".

Figure 6: Annual growth rates (%) of small and large US dollar denominations
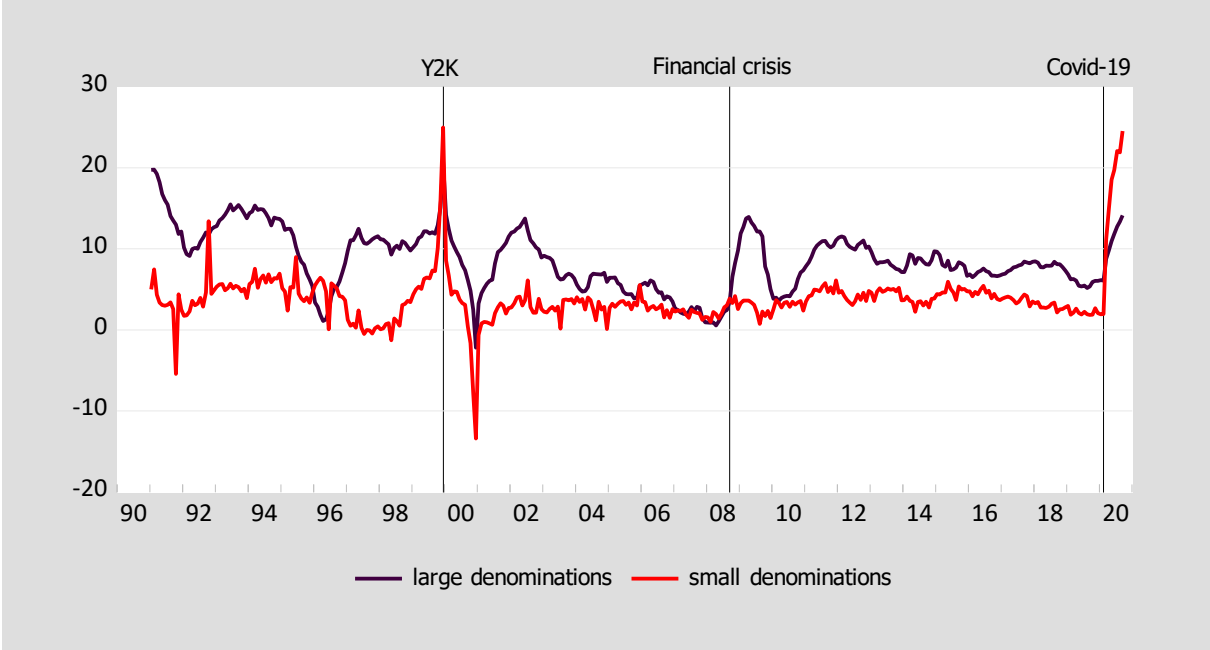
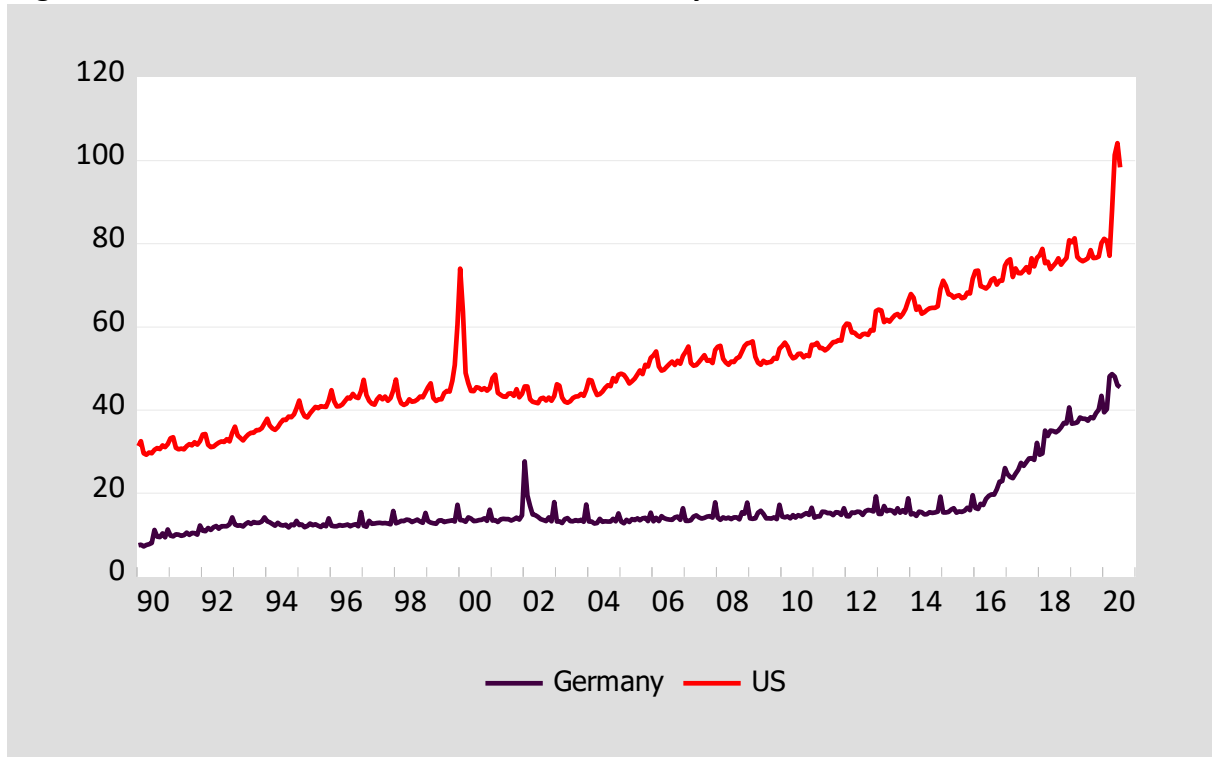Note: Small denominations: USD 1 - 50; large denomination: USD 100.

Source: Board of Governors of the Federal Reserve System.

Domestic demand for US dollar cash was also boosted by a steep increase in vault cash of US commercial banks (see figure 7). In principle, this was also observed in Germany at that time although to a much lesser degree. Vault cash of German banks at the end of the year showed a typical increase of about 2 billion DEM before Y2K, but in December 1999 these additional cash stocks were nearly doubled.[2]

The Y2K effect on overall cash demand in Japan was less pronounced than in the US with growth rates of well over 15% (see figure 5). However, the denominational breakdown was different. At the end of year 1999, the annual growth rate of the only large Japanese banknote denomination (Yen 10,000) stood at 18%, heavily exceeding the growth rates of the small denominations (Yen 5,000 – 500) of 5% (see figure 8).

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[2] The increase in vault cash of German banks since 2015 is predominantly due to negative interest rates on central bank deposits with the Eurosystem.

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Figure 7: Vault cash of banks in the US and Germany

Notes: US: US dollar billion; Germany: Euro billion.

Source: Federal Reserve System; Deutsche Bundesbank.

Figure 8: Annual growth rates (%) of small and large Japanese Yen denominations
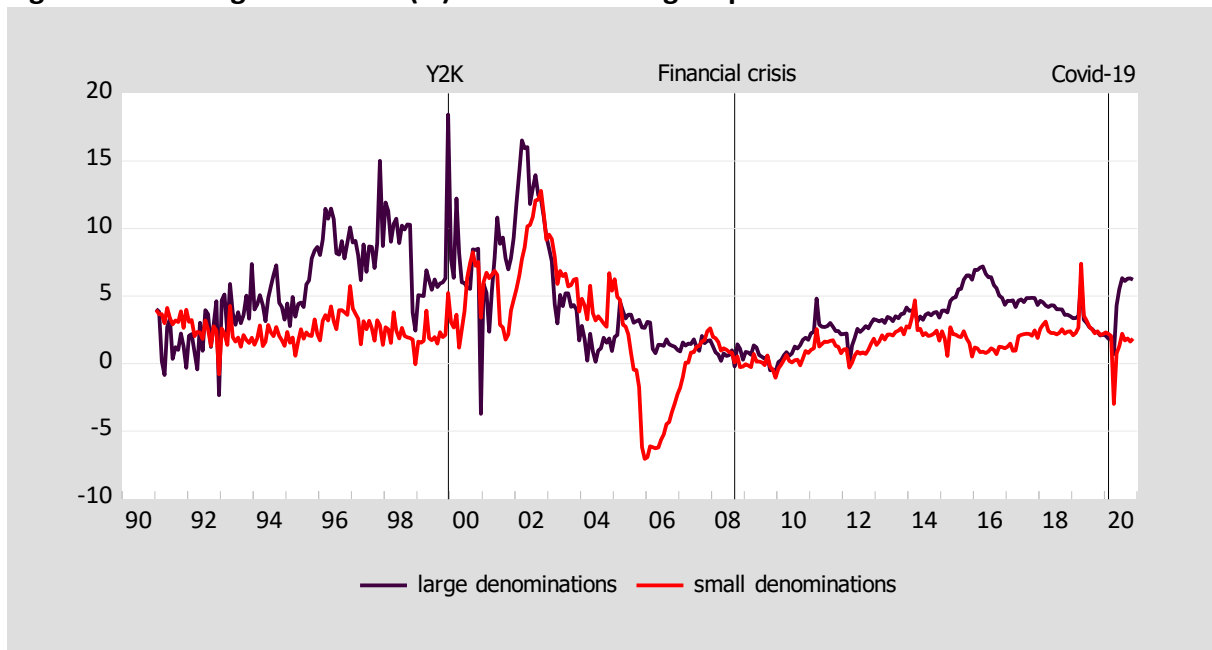
Note: Small denominations: JPY 500 – 5,000; large denomination: JPY 10,000.

Source: Bank of Japan.

Therefore, and in tendency, one can assume that hoarding motives were the main drivers of the strong increase in cash issues in Japan around Y2K. However, one should take into account that it is not unusual in Japan to pay in stores by using Yen 10,000 banknotes.

Hoarding of Swiss Francs was obviously the main motivation behind the considerable increase in CHF banknotes at the end of 1999 (annual growth rate 12%, see figure 5). Especially the larger denominations (CHF 200, 500 and 1,000) were heavily in demand with an annual growth rate of 14% that exceeded the already unusual high rates of previous years (see figure 9).[3] Similar growth rates of high denominations occurred around the 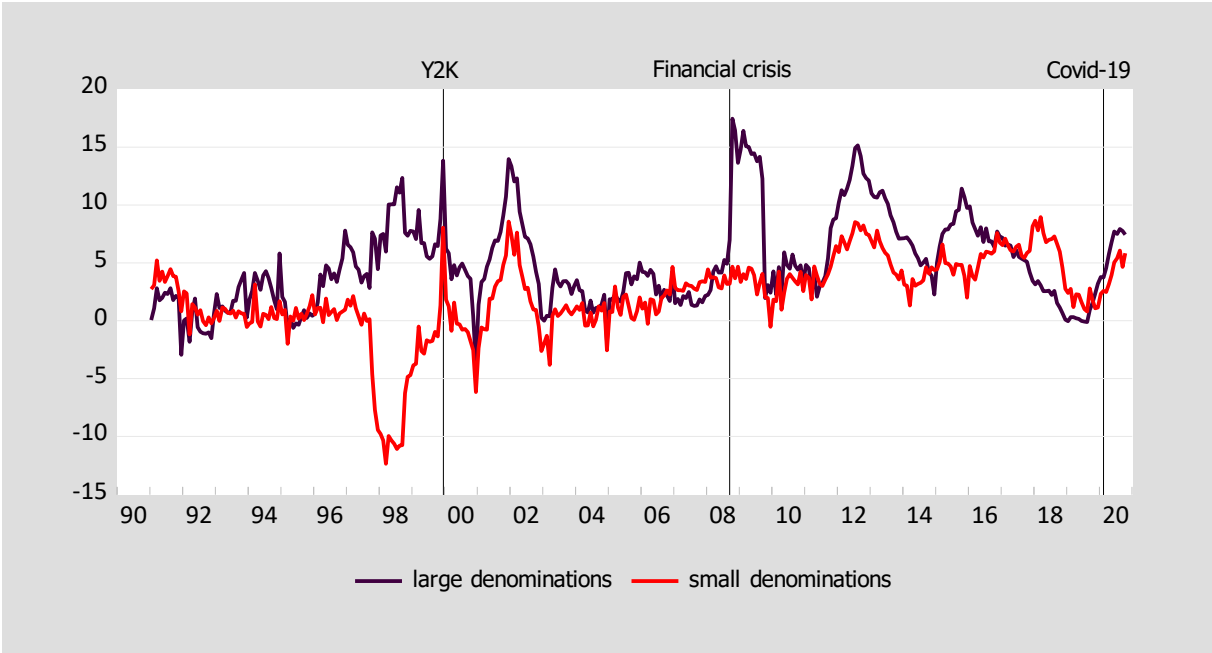terrorist attacks of September 11, 2001. Once again, foreign demand played a significant role at that time (see Assenmacher et al., 2019).

Figure 9: Annual growth rates (%) of small and large Swiss Francs denominations

Note: Small denominations: CHF 5, 10, 20, 50, 100; large denominations: CHF 200, 500, 1,000.
Source: Swiss National Bank.

In the United Kingdom, too, the demand for British pounds surged enormously in the wake of Y2K with a growth rate of well over 12% at the end of 1999 (see figure 10) and which remained at a fairly high level afterwards. One year before, it stood at just 5%. As foreign demand for GBP is very limited, the steep increase in the demand for GBP banknotes reflect domestic demand. As figure 10 shows, this increase in cash demand was nearly exclusively driven by the small denominations, with annual growth rates of 20%. Thus, in the UK, transactions balances in cash increased due to precautionary and uncertainty reasons.

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[3] Demand for large denominations of Swiss Francs was already high since mid-1990s when foreign demand increased due to uncertainties with respect to the introduction of the Euro/abolishment of the DEM as of 1.1.1999 (see for instance Assenmacher et al., 2019).

Figure 10: Annual growth rates (%) of small and large GBP denominations
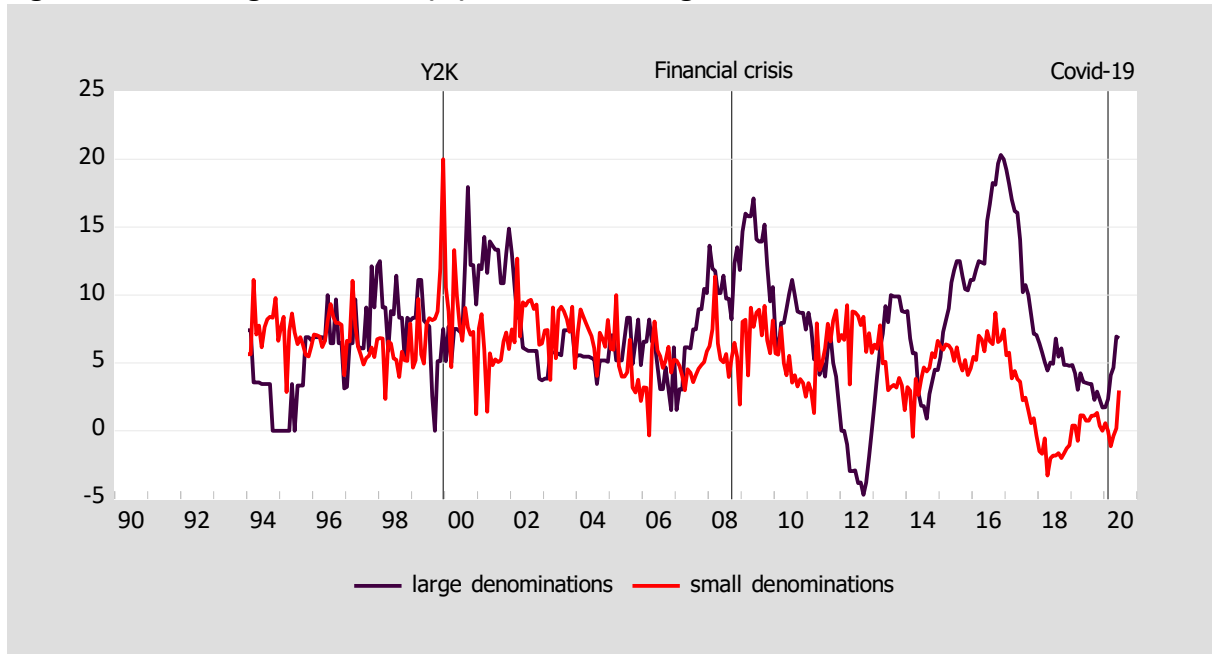
Note: Small denominations: GBP 5, 10, 20; large denomination: GBP 50.

Source: Bank of England.

Although the European Monetary Union was established on 1 January 1999, national banknotes and coins of member states remained in circulation for three more years. In what follows, we concentrate on the Deutsche Mark (DEM), the most important European currency at that time. Quite naturally, also the demand for DEM banknotes increased markedly at the end of the millennium (see figure 11). Small DEM denominations (DEM 5 – 100) usually used for transaction purposes showed a yoy growth of well over 8% being even higher than the growth rate of large DEM denominations (DEM 200 – 1000) of 6½%.[4]

What is remarkable is the parallel movement of the annual growth rates of small and large DEM denominations since 1997. This suggests that foreign demand for German banknotes played no important role anymore around Y2K. This was, of course, completely different at times of previous international crises such as the gulf war (1991), the breakdown of the former Soviet Union and the opening-up of Eastern Europe and during the crisis of the European Monetary System in 1992/93.[5] This might also at least partly explain why the large CHF denominations were so heavily in demand at the end of 1999. Over the next two years (2000/01), DEM banknotes were (together with all the other "national denominations of the

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[4] Figure 11 also shows that the growth rates of the large DEM denominations reached almost 30% during the EMS crisis 1992/93. See also the econometric evidence in section 3.

[5] See figure 11 and the econometric analysis in section 3 as well as Seitz (1995).

Euro") steadily returned to the Deutsche Bundesbank to be exchanged for the first series of Euro banknotes.

Figure 11: Annual growth rates (%) of small and large Deutsche Mark denominations
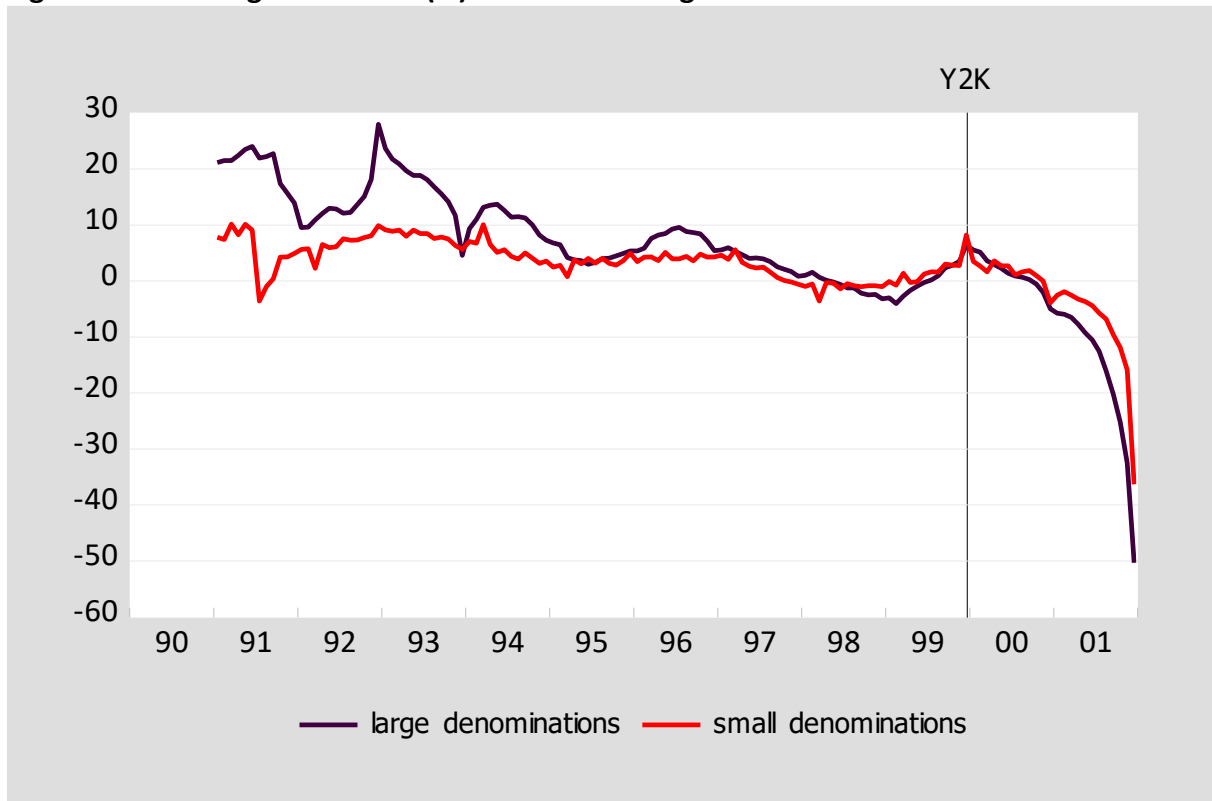
Note: Small denominations: DEM 5, 10, 20, 50, 100; large denominations: DEM 200, 500, 1.000.

Source: Deutsche Bundesbank.

As a first result, the analysis of small and large denominations of banknotes of important currencies indicates that the drastic increase in global cash at end of the last century was caused by the desire to hold additional transaction balances as well as hoarding. Hereby, not only the US dollar banknote issuance rocketed, but also all the other major currencies (DEM, CHF, JPY, GBP) were heavily in demand.

Although it is hard to quantify exactly the different motives of holding additional cash around Y2K is has to be acknowledged that the public obviously seeks for physical money once the confidence in the technological infrastructure deteriorates (technological crisis).[6] Insofar, cash is by nature a stabilising factor at times of raising doubts about the robustness of the digital infrastructure.[7]

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[6] For the advantages of "physical" money see Ruberton et al. (2016).

[7] Such considerations can also be conferred on instabilities of power grids. In the US, those problems quite often occur during the hurricane season and lead to an increase in demand for cash even in regions that are not directly affected by the hurricane itself, see for instance Cheney & Rhine (2006) and Smith (2014).

2.2 Cash demand in the course of the financial crisis (2008/09)

After the insolvency of Lehman Brothers in October 2008, the resulting financial turmoil in the US quickly scaled up to a global financial crisis which led to a visible increase in cash demand (see figure 5). However, this increase was way behind its rate around Y2K mostly because the banknote issuance in China in Q4/2008 was hardly affected by the financial crisis.[8] A similar picture was observed in Japan where neither overall cash issuance nor single Yen denominations showed an unusual increase (see figures 5 and 8).

Obviously, there was a structural difference between the financial crisis 2008 and Y2K with respect to cash demand. Around the millennium, doubts of the public about the solidity of the digital infrastructure predominantly fostered the demand for cash. After the collapse of Lehman Brothers, however, the global trust in banks and the financial system deteriorated and led to a flight into cash (crisis of confidence). Hence, it is not surprising that cash demand was boosted quickly and promptly especially in the US where the financial crisis originated (see figure 4). This time, however, hoarding was clearly the main motive behind the demand for US banknotes as the growth rate of the only large denomination (USD 100) went up quickly in October 2008 reaching a peak of almost 14% in April 2009.[9] Against the background of the approaching Great Recession, the demand for small US dollar denominations (USD 1 – 50) increased only moderately at that time (see figure 6).

A very similar development took place in the Euro area where overall cash issuance increased by an annual growth rate of around 14% (see figure 4). As in the US, it was predominantly large denominations that drove overall Euro banknotes in circulation with an annual growth rate in October 2008 of 17% (see figure 12).

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[8] The annual growth rate of total cash in China in Q4/2008 and Q1/2009 was 11% and 10%. This might look high by international standards but is in fact a continuation of an overall slowdown process since cash growth rates in the previous three quarters were even higher: 16% (Q1/2008), 12% (Q2/2008) and 11% (Q3/2008).

[9] A similar growth rate of the 100 US dollar banknote was also seen after the terrorist attacks in September 2001, see figure 6. In both instances, also foreign demand for US dollar notes should have contributed to this enormous increase in US cash demand (Judson, 2017, ch. II).

Figure 12: Annual growth rates (%) of small and large Euro banknote denominations
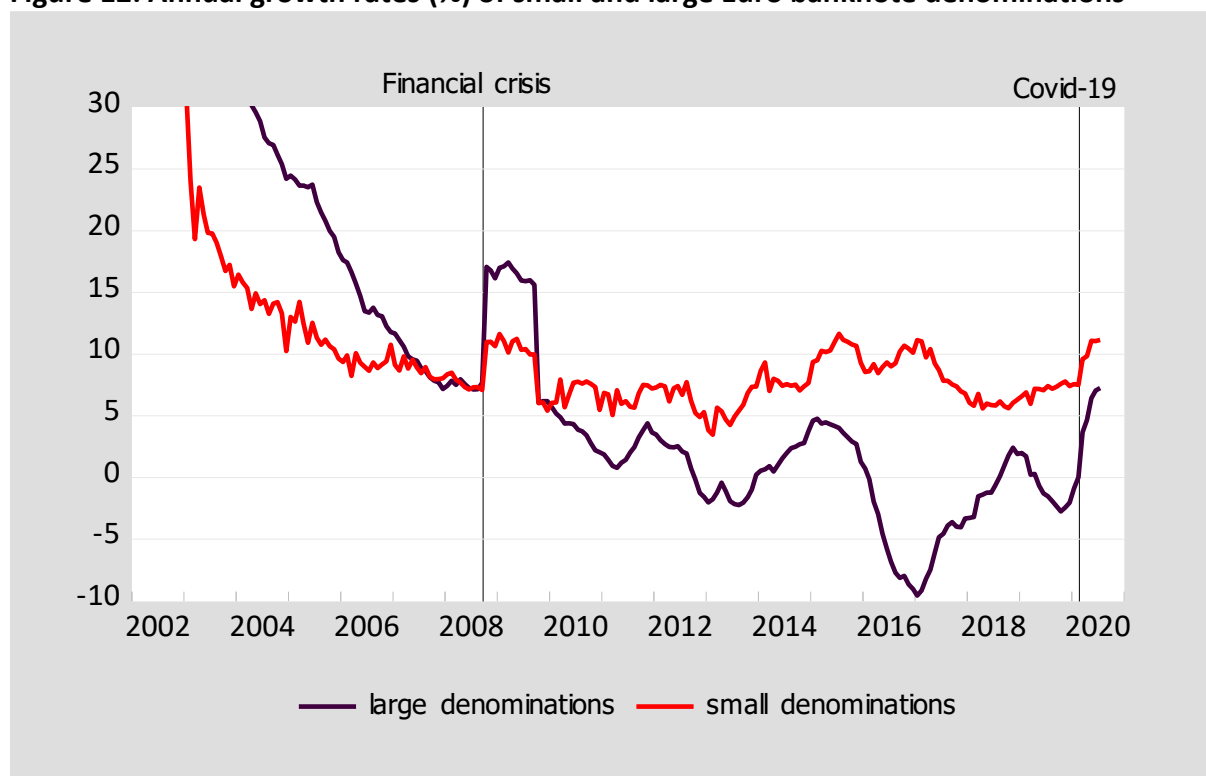
Note: Small denominations: EUR 5, 10, 20, 50, 100; large denominations: EUR 200, 500.

Source: European Central Bank.

It is safe to say that hoarding was the main motive for cash withdrawals at that time as money holders within and outside the Euro area increased their Euro banknote holdings sharply.[10] This becomes evident as the €500 Euro banknote issuance of the Deutsche Bundesbank nearly skyrocketed in October 2008. The Bundesbank provides almost alone all the Euro banknotes circulating outside the Euro (Deutsche Bundesbank, 2016).[11]

The banknote issues of the Swiss Franc (CHF) also increased sharply in October 2008, by 13.7% against the previous year – a growth rate that even exceeded the expansion rate at Y2K (see figure 5). As in the US and the Euro area, especially the large denominations (CHF 200 – 1,000) with a respective growth rate of more than 17% were heavily in demand whereas small denominations (CHF 5 – 100) were at that time growing at a rate of only 4,7%, not different

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[10] See ECB (2020a, ch. 2.5) for estimates of Euro banknotes circulating outside the Euro area. According to Bartzsch et al. (2019) there is also a permanent influence of the financial crisis in Q4/2008 of the Euro banknote circulation in Germany.

[11] Euro banknotes being held outside of the Euro area are almost exclusively provided by the Deutsche Bundesbank, see Bartzsch et al. (2013a, b) and Uhl & Bartzsch (2017).

to those of previous months (see figure 9). Again, foreign demand for large CHF banknotes played a significant role during the financial crisis (Assenmacher et al., 2019).[12]

In the United Kingdom the growth rate of overall cash went from 4.9% in August 2008 up to 10.2% in April 2009 (see figure 5) before it started to normalize afterwards. The annual growth rates of the large denomination (GBP 50) reached a peak of 16% in March 2009, after starting to rise steadily from October 2008 onwards. Therefore, it seems reasonable to assume that also in the UK hoarding motives should have been of major importance as the domestic financial industry was strongly affected by the financial crisis.

The analysis above clearly shows that right from the outbreak of the financial crisis in October 2008 cash was heavily in demand. Although global growth rates of cash were not as high as they had been at the start of the millennium (Y2K), the declining trust in banks led to a comparably stronger cash demand in those countries where the financial crisis hit especially hard. The steep increase in high denomination banknotes in circulation suggests that hoarding was the overriding motive in this respect. And, once again, central banks provided banknotes in a perfectly elastic way in order to stabilize the overall situation.

2.3 Cash demand during the Covid-19 pandemic (2019/20)

The outbreak of Covid-19 led to a drastic downturn of the world economy during 2020 resulting in a stark decrease in turnover at the point of sale (see Auer at al., 2020; Chen et al., 2020). In addition, due to fears of virus contagion cash payments decreased (Cevik, 2020).[13] However, at the same time global cash in circulation increased exceptionally (see figure 4).[14] Regarding the demand for small and large banknote denominations, interesting international differences emerge. In the US (see figure 6) as well in the Euro area (see figure 12) annual growth rates of small denominations exceeded those of large denominations in mid-2020 whereas the opposite was true for CHF and JPY banknote issues (see figures 8 and 9). The exceptionally strong increase of small US dollar denominations (22% in August 2020) probably reflect predominantly domestic demand as the huge increase in vault cash of US commercial

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[12] Such a development was observed already shortly after the terrorist attacks of 11 September 2001 when the demand for high value CHF banknotes increased massively, see figure 9.

[13] This happened despite the fact that banknotes do not carry viruses very well in contrast to authorization devices for electronic payments. If this had been the case, numbers of infections would have been much higher, see Auer et al. (2020), Beermann (2020), Caswell et al. (2020), Panetta (2020).

[14] According to Heinonen (2020), on a global scale annual growth rates of cash stood mid 2020 by just under 13% compared to almost 5% in July 2019

banks at the same time suggests (see figure 7).[15] In general, US banks usually stockpile cash quite significantly if a natural disaster happens, as, for instance, after the Superstorm Sandy struck the Northeastern United States in October 2012 or prior to the anticipated landfall of hurricane "Irma" in September 2017.[16]

Figure 13: Annual growth rate (%) of €200 banknote issues
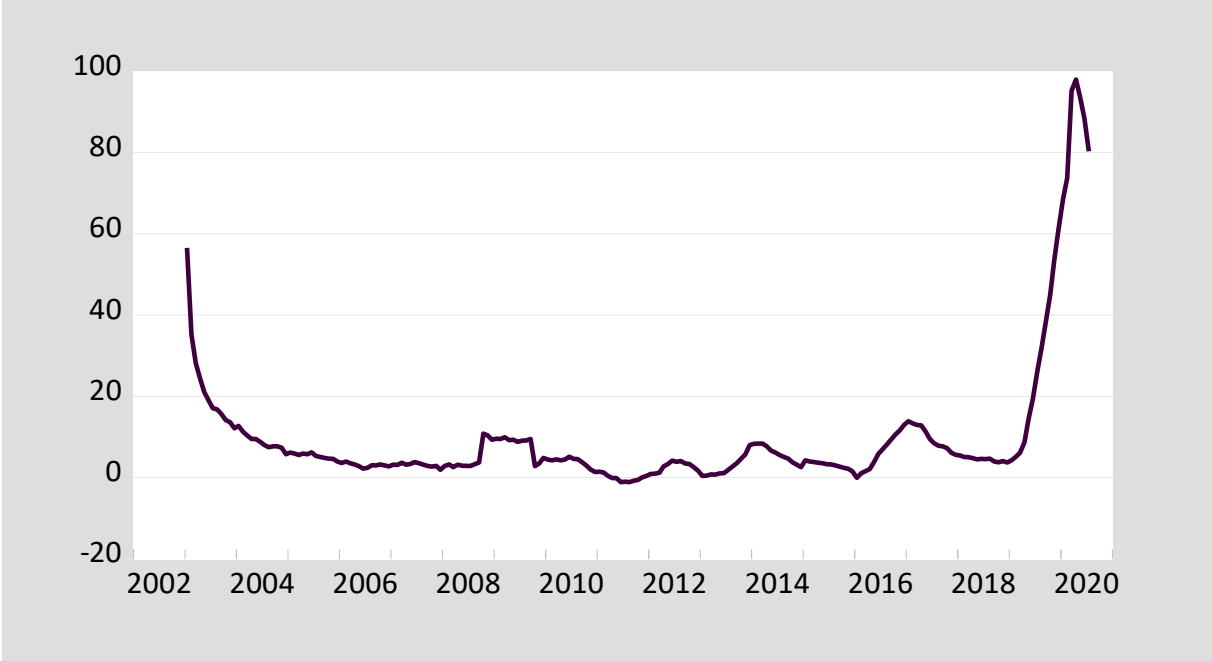
Source: European Central Bank.

The Covid-19 pandemic also boosted Euro banknotes in circulation. By denomination, the €200 banknote showed the highest annual growth rate of up to 98% in April 2020 (see figure 13). However, one has to bear in mind that the formerly highest denomination (€500) was still withdrawn from circulation in 2020. Consequently, the growth rate of both large denominations (€200 and €500) taken together stayed only at 7% in mid-2020 and well behind the rate of the small denominations (€5 – €100) of 11% (see figure 12). This implies that during the Covid-19 crisis hoarding of small Euro banknote denominations must have intensified.

At least at first sight, demand for Japanese Yen banknotes appeared to be quite different after the outbreak of the Covid-19 pandemic. As shown in figure 8, the demand for the (only) large Yen denomination (JPY 10,000) increased considerably in the first half of 2020 (at 6% against the previous year) whereas small denominations showed average growth rates of only slightly

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[15] The annual growth rate of large US dollar denominations in August 2020 was 13½%.

[16] See the program of the Board of Governors of the Federal Reserve System "Disaster Preparedness and Recovery Resources", https://www.frbsf.org/cash/federal-reserve-role-cash-distribution/cash-product-office/meeting-demand-currency-disaster-video/ and Spicer (2017).

over 1% during this period. However, and as already mentioned, one should not forget that the highest Yen denomination is also used for day-to-day transactions. Nonetheless, overall growth of Yen banknotes spiked markedly since the outbreak of Covid-19 but by far less than in previous crises (see figure 5).[17]

Figure 14: Annual growth rates (%) of British Pounds cash in circulation
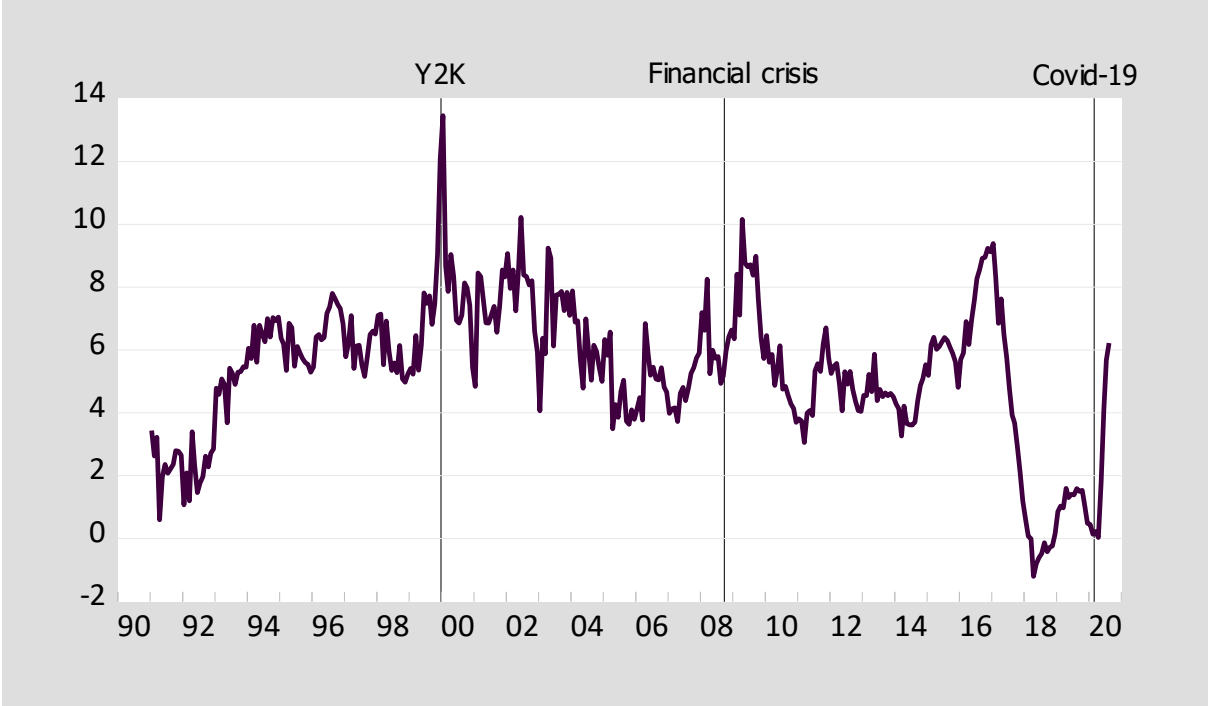
Source: Bank of England.

Banknote issues of the Swiss National Bank also increased steeply during the first half of 2020 (see figure 9). The growth of large denominations was considerably stronger than that of the smaller ones, indicating that the demand from abroad for CHF for hoarding purposes was also substantial.

The demand for GBP was also heavily boosted by Covid-19 (see figure 14). It seems that this process was probably driven by the smaller and the large denominations. Unfortunately, however, the Bank of England does not publish up-to-date data on cash by denomination. Even in Scandinavian countries like Denmark, Sweden and Norway, the Covid-19 outbreak seems to have stimulated cash demand. In these countries, cash payments declined in the last

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[17] By international standards (e. g. as a share of GDP), cash in circulation in Japan is comparatively high as interest rates and inflation rates are low for decades. In addition, criminal activities with respect to cash are not very widespread in Japan. Consequently, the share of currency in circulation to nominal GDP was in the mid-1990 between 6% and 8% and increased afterwards to a level of over 20% in 2018/19, see Fujiki (2019).

decade considerably reflecting former policy measures that – at least partly – aimed at reducing cash use (see figure 15).

Figure 15: Cash in Scandinavian countries (billion national currency)
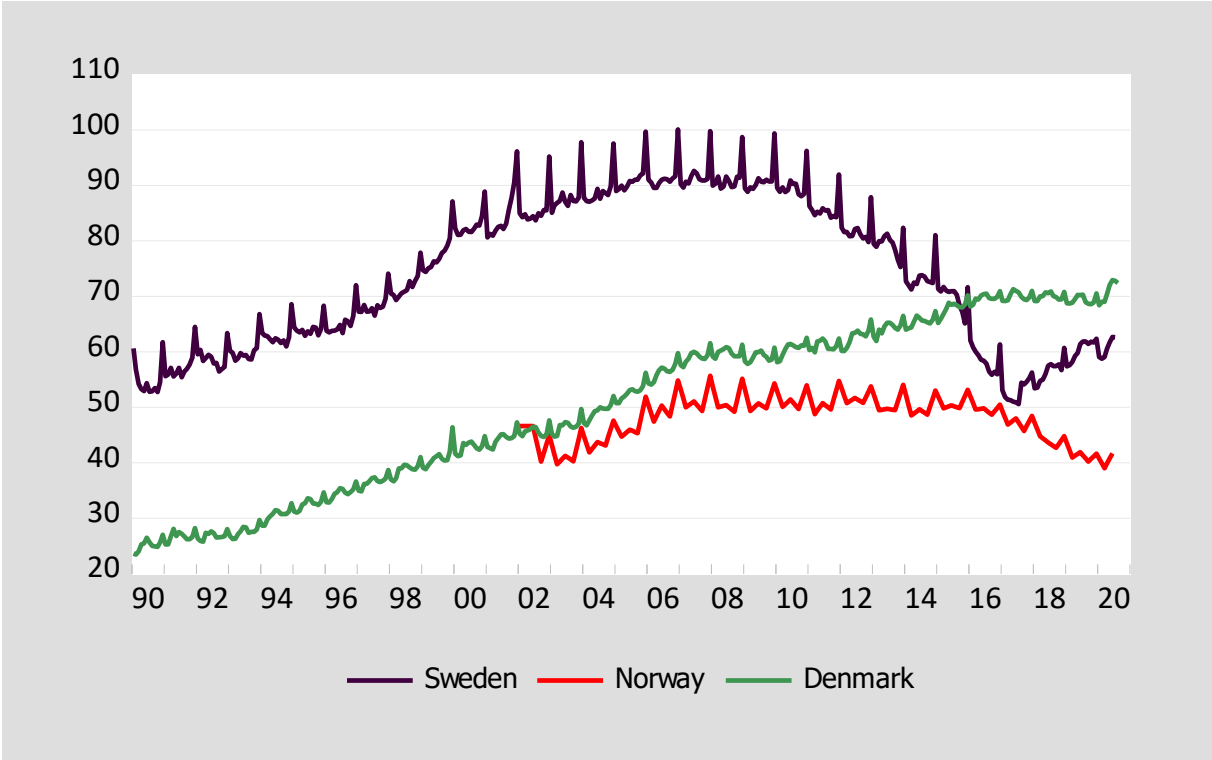
Source: National central banks, IMF.

In Sweden, especially the large denominations (SEK 10,000, 100, 500) were in strong demand. This intensified a trend which already started in 2017 (see figure 16). In contrast, small denominations continued their decline which already began in 2015.

Taken together, our analysis reveals that global cash demand increased substantially due to the Covid-19 pandemic. The availability of means of payment surely played a role with respect to the increase in the demand for small denominations. However, the main factor behind the increase in cash in circulation seems to be hoarding for different reasons. Concerns of future tax increases might play a role, but also precautionary motives and the crisis-induced flight to physical cash due to psychological reasons.

Figure 16: Large and small denominations in Sweden (SEK billion)
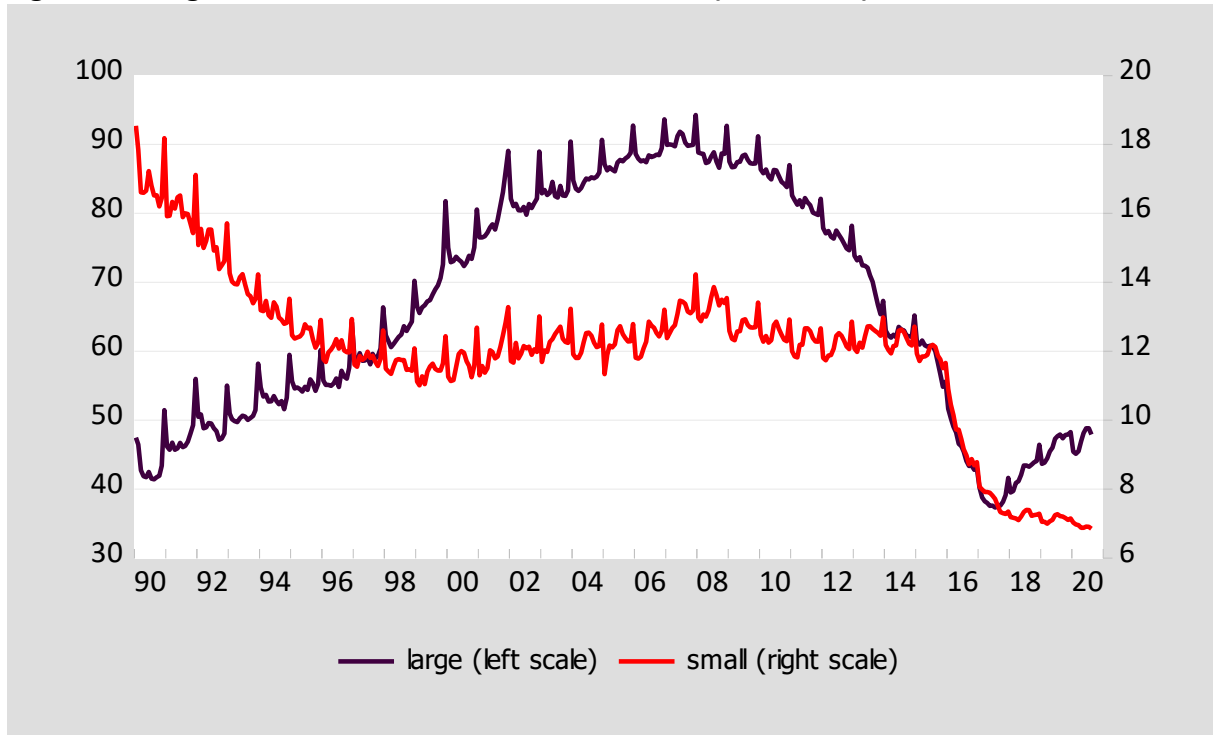
Note: Small denominations SEK 5; 10; 20; 50; 100; large denominations: SEK 10,000; 1.000; 500.

Source: Sveriges Riksbank.

3. Some econometric exercises

In this section, we examine the long-term relationship between cash, its main determinants and crises. For that purpose, we augment standard long-run cash demand functions for small and large denominations with crisis-related dummy variables. As traditional potential determinants of cash holdings we include GDP (transactions variable), a short-term (money market) interest rate (opportunity costs variable) and an exchange rate argument (proxy for foreign demand) (see, e. g., Assenmacher et al, 2019).

Our sample consists of eight currencies for which we have denominational data: USD, JPY, DEM, EUR, CHF, GBP, SEK, AUD.[18] The sample is quarterly and ranges from the beginning of the 1990s until the third quarter of 2020. For the DEM, the sample ends in Q4/2000 due to the approaching cash changeover. Our data set is unadjusted; therefore, we include seasonal dummy variables. The general estimation equation reads as follows

(1) $\qquad bn_t = ß_0 + ß_1 y_t + ß_2 i_t + ß_3 e_t + ß_4 ytk_t + ß_5 fin_t + ß_6 cov_t + ß_7 x_t + \varepsilon_t,$

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[18] Flannigan & Staib (2017) find that the demand for the AUD 100 banknote strengthened since the global financial crisis 2008.

where $bn \in \{large, small\}$ is (the log of) large and small banknotes in circulation, respectively, y is (the log of) nominal GDP, i is a 3-month money market interest rate, e is the (log of the) exchange rate, x stands for other deterministic variables like trends (trend),[19] seasonal dummy (s(i), i=1,2,3,4) or other dummy variables (dum) and ε is the error term. The main variables of interest on which we concentrate predominantly in what follows, are ytk, fin and cov. These represent impulse dummy variables for the Y2K crisis, the financial crisis and the covid-19 crisis. $Y2K$ is one in Q4/1999, fin is one from Q4/2008 – Q1/2009 and cov is one from Q1/2020 – Q2(3)/2020, zero otherwise. Tables 1 and 2 summarize the results.

Table 1: Estimation results for large denominations

	Euro area	US	Switzer-land	Japan	UK	Sweden	Australia	Germany
GDP	-	-	***	***	**	***	**	-
Interest rate	-	**	-	***		-	**	***
Exchange rate	**	***	***	-	-	-	-	-
Y2K		0.05 (0.01)***	0.05 (0.02)***	0.05 (0.01)***	0.02 (0.01)*	0.04 (0.02)**	0.02 (0.01)*	0.00 (0.01)
Fin	0.05 (0.01)***	0.02 (0.01)***	0.04 (0.01)***	-0.00 (0.01)	0.04 (0.01)***	0.01 (0.01)	0.01 (0.01)*	
Cov	0.03 (0.01)***	0.02 (0.01)***	0.02 (0.01)*	0.02 (0.01)*	0.02 (0.01)*	0.04 (0.02)**	0.02 (0.01)***	
x	bn_{t-1}, bn_{t-4}, s(2), s(4)	bn_{t-1}, bn_{t-2}, s(1), s(4), dum_us, trend	bn_{t-1}, s(3), s(4)	bn_{t-1}, bn_{t-2}, s(1), s(4), dum_ja	bn_{t-1}, bn_{t-4}, s(1), s(3), s(4)	bn_{t-1}, bn_{t-2}, s(1), trend	bn_{t-1}, bn_{t-2}, bn_{t-4}, s(1), s(3), s(4)	bn_{t-1}, bn_{t-2}, s(4) dum_de
Sample	03.1-20.3	90.3-20.3	90.2-20.3	90.3-20.3	94.1-20.2	93.1-20.3	91.1-20.3	90.3-00.4
Adj. R²	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
SE	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
LM(4)	0.83	0.67	0.01	0.00	0.02	0.04	0.00	0.07
Ramsey	0.83	0.85	0.07	0.15	0.21	0.17	0.33	0.08

Notes: Large denominations: USD 100; JPY 10,000; DEM 200, 500, 1,000; EUR 200, 500; CHF 200, 500, 1,000; GBP 50; SEK 10,000; 1,000; 500; AUD 100. GDP: nominal GDP; interest rate: 3-month money market interest rate; exchange rate: Euro-dollar exchange rate (US, Euro area), effective exchange rate (Switzerland); x: additional significant variables; dum_us: dummy variable for the extraordinary decrease in banknotes in 2000.1 in the US; dum_ja: dummy variable for outliers in 1997.4 and 2002.1-2002.2 in Japan; dum_de: dummy variable for an outlier during the EMS crisis in 1992.4 in Germany. Standard errors in brackets below coefficients; ***(**,*): 1 (5, 10) % level of significance; LM(4): p-value of Breusch-Godfrey serial correlation LM Test up to lag 4; Ramsey: p-value of Ramsey RESET misspecification test.

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[19] A significant deterministic trend in the case of the US is also present in Judson (2017), ch. V.

Table 2: Estimation results for small denominations

	Euro area	US	Switzer-land	Japan	UK	Sweden	Australia	Germany
GDP	***	-	**	*	-	***	**	***
Interest rate	***	**	-	-	***	-	-	-
Exchange rate	-	-	-	-	-	-	-	-
Y2K		0.11 (0.01)***	0.03 (0.01)***	0.02 (0.01)*	0.06 (0.01)***	0.01 (0.01)	0.03 (0.02)	0.02 (0.01)**
Fin	0.03 (0.01)***	0.02 (0.01)	0.01 (0.01)	-0.00 (0.01)	0.02 (0.01)*	-0.02 (0.01)*	0.05 (0.02)**	
Cov	0.04 (0.01)***	0.09 (0.01)***	0.01 (0.01)**	0.01 (0.01)	0.01 (0.01)	-0.00 (0.01)	0.04 (0.02)**	
x	bn_{t-1}, bn_{t-2}, bn_{t-3}, s(3)	bn_{t-1}, bn_{t-2}, s(1), s(2), s(4), dum_us	bn_{t-1}, bn_{t-4}, s(1), s(4), dum_swi	bn_{t-1}, s(1), s(4), dum_ja	bn_{t-1}, bn_{t-4}, s(1), s(4), trend	bn_{t-1}, bn_{t-4}, s(1), s(3), trend	bn_{t-1}, bn_{t-2}, s(1), s(4)	bn_{t-1}, s(1), trend
Sample	02.4-20.3	90.3-20.3	91.1-20.3	90.2-20.3	94.1-20.2	93.1-20.3	90.3-20.3	91.1-00.4
Adj. R²	0.99	0.99	0.99	0.99	0.99	0.90	0.99	0.99
SE	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01
LM(4)	0.01	0.54	0.64	0.00	0.06	0.09	0.15	0.70
Ramsey	0.12	0.02	0.04	0.07	0.22	0.20	0.36	0.01

Notes: Small denominations: USD 1 – 50; JPY 500 – 5,000; DEM 5, 10, 20, 50, 100; EUR 5, 10, 20, 50, 100; CHF 5, 10, 20, 50, 100; GBP 5, 10, 20; SEK 5; 10; 20; 50; 100; AUD 5 − 50. GDP: nominal GDP; interest rate: 3-month money market interest rate; exchange rate: Euro-dollar exchange rate; x: additional significant variables; dum_us: dummy variable for the extraordinary decrease in banknotes in 2000.1 in the US; dum_swi: dummy variable for outlier in 1997.4 in Switzerland; dum_ja: dummy variable for outliers in 1997.4 and 2002.1-2002.2 in Japan. Standard errors in brackets below coefficients; ***(**,*): 1 (5, 10) % level of significance.

In nearly all the estimates, the results of the visual inspection in section 2 are confirmed. This is true with respect to the general influence of the crisis, but also with respect to (relative and absolute) magnitudes. All the crisis variables are highly positive significant except Y2K for the small denominations in Sweden and the large denominations in Germany, the financial crisis for large denominations in Sweden, small denominations in Switzerland and the US and for both denominational groups in Japan and the Corona crisis for the small denominations in Japan and Sweden. We get significant results in 31 of our total of 42 crisis cases. One denominational group per country is always positively affected by the crises. Obviously, the nature of the crisis influences which denominations are affected and how. At least one of the economic determinants of cash holdings – GDP, interest rate, exchange rate – is significant in the equations. The statistical properties of the relationships are satisfactory: Taken together, the serial correlation LM test and the broader Ramsey mis-specification test do not reveal

serious problems. The additional dummy variables taken into account have economic significance: They are related to Y2K (decrease in cash demand in the US, after the potential problems of YTK have not materialized, see Judson, 2017, chs. II and V), the Asian and Russian crises (Japan and Switzerland), the introduction of Euro cash (Japan) and the EMS crisis (large denominations Germany).

We find the strongest crisis influence for the case of the small denominations in the US, which increased by 11 and 8 percent, respectively, during the Y2K (see also Judson, 2017, 233) and the Covid-19 crisis. Given the additional determinants of cash demand, the following observations can be made with respect to the individual crises: In the fourth quarter of 1999 (Y2K), the large denominations in the US, Switzerland and Japan as well as the small denominations in the US and the UK increased most. During the financial crisis, mainly the large denominations were affected, especially in the Euro area, Switzerland and the UK. However, an exceptional high increase in the demand for small denominations can be detected in Australia. The Corona crisis stimulated cash holdings of large denominations particularly in Sweden and to a lesser extent in the Euro area and those of small denominations in the US, the Euro area and Australia. Thus, and in general, the consideration of other motives for holding cash does not render the significant crisis-related influence obsolete.

4. The trend in banknote hoardings

There is overwhelming evidence that in the course of the three crises analyzed (Y2K, financial crisis, Covid-19), cash demand increased substantially. However, such single events do not necessarily change the overall trend in cash in circulation or that of single banknote denominations. Figure 17 shows that the absolute increase in large denominations of selected international currencies (USD, DEM/EUR, JPY, CHF, GBP, SEK, AUD) clearly outpaced that of small denominations.

Figure 17: Small and large banknote denominations in circulation international
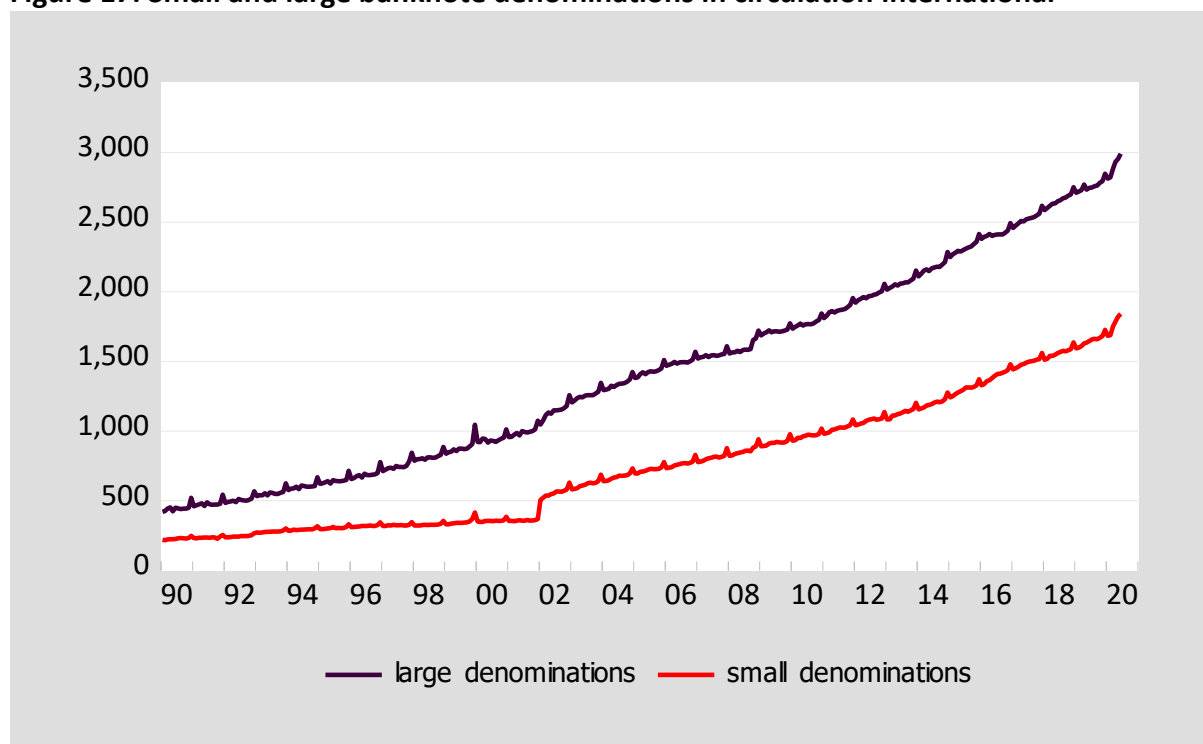
Note: Data refer to the following banknotes in circulation: USD, DEM/EUR, JPY, CHF, GBP, SEK, AUD. Large denominations: USD 100; JPY 10,000; DEM 200, 500, 1,000; EUR 200, 500; CHF 200, 500, 1,000; GBP 50; SEK 10,000; 1,000; 500; AUD 100; small denominations: USD 1 – 50; JPY 500 – 5,000; DEM 5, 10, 20, 50, 100; EUR 5, 10, 20, 50, 100; CHF 5, 10, 20, 50, 100; GBP 5, 10, 20; SEK 5; 10; 20; 50; 100; AUD 5 – 50. National currencies converted into USD by using the average exchange rate of the national currency versus the US dollar over the data period. GBP monthly data for 3/2020 – 6/2020 estimated by multiplying the share of small and large GBP denominations in overall GBP banknotes in circulation in 2/2020 by overall GBP banknotes in circulation.

Source: National central banks.

Against the background of the decreasing use of cash for day-to-day transactions (see, e. g., ECB, 2020b), this suggests that holding cash for non-transactional purposes gained momentum over time. However, the substantial increase in large banknote denominations was not distributed equally over the currencies analyzed. At the beginning of the sample period (1990), it was the Japanese Yen that accounted for almost 60% of all large banknote denominations followed by USD (28%), DEM (8%), and CHF (3%). The other currencies (GBP, SEK, AUD) were of negligible importance (see table 3). While the latter is still true today, an enormous shift towards the US dollar took place over the past 30 years. Nowadays, well over half of the value of all (recorded) large banknote denominations are in USD, the Japanese Yen has currently a share of 32%, which is still considerable and higher than the share of the Euro (13%).

Table 3: Volumes and shares of small and large banknote denominations

Small denominations of national currencies in USD billion							
End of month	USD	JPY	DEM/EUR	CHF	GBP	SEK	AUD	Sum
Jan 90	116.2	36.8	50.6	8.7	-	2.4	5.7	220.3
Dec 95	159.6	47.7	75.8	10.1	27.3	1.7	8.7	330.9
Dec 99	214.7	53.8	84.2	9.5	39.4	1.6	12.6	415.9
Dec 05	213.6	64.7	417.0	9.5	52.0	1.7	18.1	776.6
Dec 10	237.1	64.6	613.9	11.0	65.5	1.7	24.1	1017.8
Dec 15	297.4	69.6	875.3	13.9	83.4	1.5	30.0	1371.3
Jun 20	388.7	70.7	1237.4	16.6	88.7	0.9	37.8	1840.9

Share of national currency in total small denominations							
	USD	JPY	DEM/EUR	CHF	GBP	SEK	AUD	Sum
Jan 90	52.7%	16.7%	22.9%	4.0%	-	1.1%	2.6%	100.0%
Dec 95	48.2%	14.4%	22.9%	3.1%	8.3%	0.5%	2.6%	100.0%
Dec 99	51.6%	12.9%	20.2%	2.3%	9.5%	0.4%	3.0%	100.0%
Dec 05	27.5%	8.3%	53.7%	1.2%	6.7%	0.2%	2.3%	100.0%
Dec 10	23.3%	6.3%	60.3%	1.1%	6.4%	0.2%	2.4%	100.0%
Dec 15	21.7%	5.1%	63.8%	1.0%	6.1%	0.1%	2.2%	100.0%
Jun 20	21.1%	3.8%	67.2%	0.9%	4.8%	0.0%	2.1%	100.0%

Large denominations of national currencies in USD billion							
End of month	USD	JPY	DEM/EUR	CHF	GBP	SEK	AUD	Sum
Jan 90	118.5	245.8	33.3	12.8	-	6.2	3.9	420.4
Dec 95	241.5	369.7	68.6	15.0	5.2	7.9	6.8	714.7
Dec 99	386.2	536.8	75.2	20.7	6.9	10.7	8.8	1,045.2
Dec 05	545.0	651.2	255.9	24.1	10.5	12.1	12.0	1,510.8
Dec 10	704.6	678.8	385.8	30.9	16.2	11.4	16.3	1,844.0
Dec 15	1,082.2	819.4	414.5	45.3	20.8	7.3	24.7	2,414.2
Jun 20	1,532.7	952.6	386.5	52.4	30.1	6.4	30.7	2,991.3

Share of national currency in total large denominations							
	USD	JPY	DEM/EUR	CHF	GBP	SEK	AUD	Sum
Jan 90	28.2%	58.5%	7.9%	3.0%	0.0%	1.5%	0.9%	100.0%
Dec 95	33.8%	51.7%	9.6%	2.1%	0.7%	1.1%	1.0%	100.0%
Dec 99	36.9%	51.4%	7.2%	2.0%	0.7%	1.0%	0.8%	100.0%
Dec 05	36.1%	43.1%	16.9%	1.6%	0.7%	0.8%	0.8%	100.0%
Dec 10	38.2%	36.8%	20.9%	1.7%	0.9%	0.6%	0.9%	100.0%
Dec 15	44.8%	33.9%	17.2%	1.9%	0.9%	0.3%	1.0%	100.0%
Jun 20	51.2%	31.8%	12.9%	1.8%	1.0%	0.2%	1.0%	100.0%

Note: Large denominations: USD 100; JPY 10000; DEM 200, 500, 1,000; EUR 200, 500; CHF 200, 500, 1,000; GBP 50; SEK 10,000; 1,000; 500; AUD 100; small denominations: USD 1 - 50; JPY 500 – 5,000; DEM 5, 10, 20, 50, 100; EUR 5, 10, 20, 50, 100; CHF 5, 10, 20, 50, 100; GBP 5, 10, 20; SEK 5; 10; 20; 50; 100; AUD 5 – 50. National currencies converted into USD by using the average exchange rate of the national currency versus the US dollar over the data period. GBP data for 1/1999 – 12/1992 not available. GBP monthly data for 3/2020 – 6/2020 estimated by multiplying the share of small and large GBP denominations in overall GBP banknotes in circulation in 2/2020 by overall GBP banknotes in circulation.

Source: National central banks.

At the beginning of the 1990s, the US dollar accounted for half of all small denominations in our sample (53%), outweighing the shares of DEM (23%), JPY (17%), and CHF (4%). The dynamics in the demand for US dollar in the following three decades concentrated mostly on large denominations in part also reflecting a strong foreign demand (see, e. g., Judson, 2017).

The latter is also true for the demand for Swiss Francs banknotes (Assenmacher et al., 2019), whereas the stark increase in large JPY banknote denominations was almost exclusively driven by an increase in domestic demand (Otani & Suzuki, 2008). Hence, the relative share of small denominations provided by other countries went up considerably. At the current juncture, the Euro comprises 67% of all (recorded) small denominations. This is due to two effects. Firstly, the inclusion of the Euro area in the data sample at the beginning of 2002 led to a notable shift in the DEM/EUR time series (see figure 17) and secondly, the growth rates of small Euro banknote denominations were relatively high by international comparison (nearly 500% over 18 ½ years). Nonetheless, the US dollar share in "global" small denominations is still well over 20%, followed by all other currencies with shares less than 5% (see table 3).

Although the issuance of small Euro banknote denominations was extremely high since 2002, the observed overall shift of global demand towards higher banknote denominations is not in question (see figure 17 and table 3). Nevertheless, the share of large denominations in total Euro banknotes in circulation is decreasing continuously since 2002 (see figure 18). As is shown in the appendix, this is no contradiction. It depends on the absolute changes of large and small denominations, the growth rate of large denominations and the total banknotes in circulation. Consequently, such a share carries no information about the relative trends in small and large banknotes denominations. And it also does not provide any hints regarding possible shifts in motives of holding cash over time. However, as small denominations have also increased substantially, especially since the financial crisis 2008, it seems that these bills are more and more used for non-transaction purposes, too, both at home and abroad.

Figure 18: Share of large denominations in total banknotes in circulation
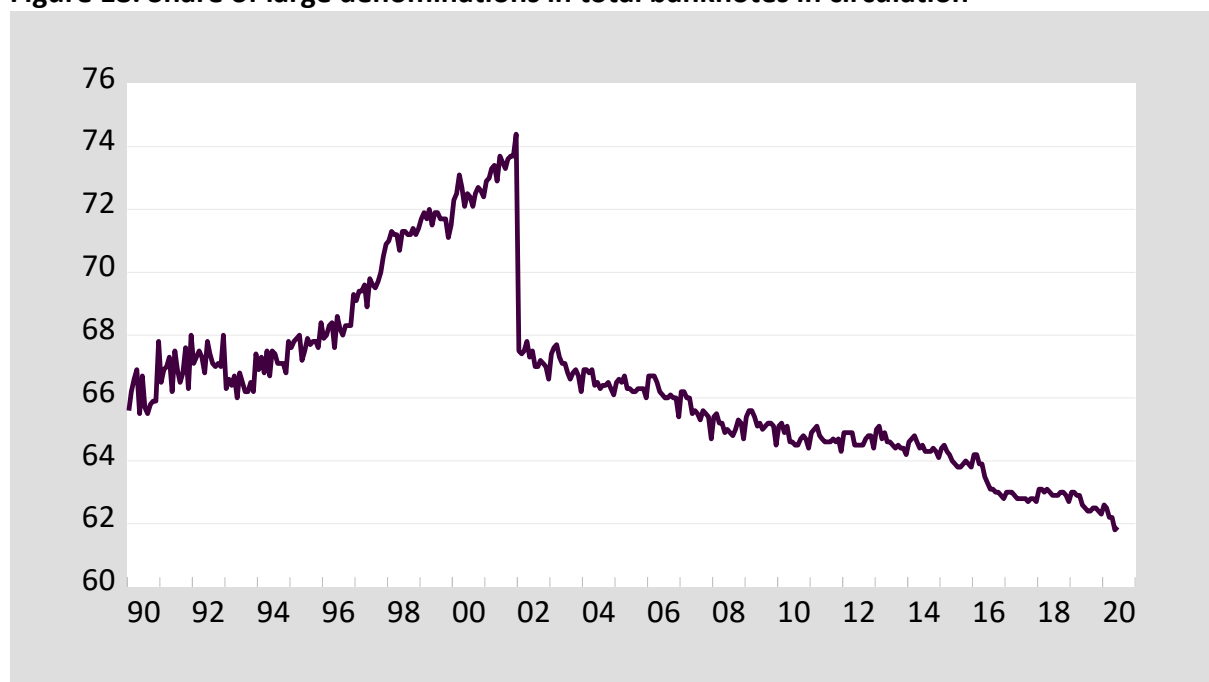
Note: See table 3.

Source: European Central Bank.

5. Summary and conclusions

Despite the increasing use of electronic payments worldwide, the notion that cash loses importance over time in general can be clearly refuted. The observed increase in global cash in circulation over the past 30 years cannot be attributed to cash issues of developing countries that might overcompensate a supposed reduction in cash demand in more technologically advanced economies. To the contrary, the overall development was strongly driven by the traditional "hard currency" central banks in an environment of declining interest and inflation rates. And especially in times of severe crises, an additional stimulus to cash arose. Hereby, it does obviously not matter what kind of crises occurs. Money holders tend to demand more cash in technological crisis such as Y2K as well as during times of doubts about the stability of the financial system (2008/9). In addition, the same is true for natural disasters like hurricanes and the current Covid-19 crisis. However, regarding the motives behind the increase in global cash demand we observe a shift from transaction balances towards more hoarding, especially in the form of large denomination banknotes. However, up to now, the crisis-related increase in the demand for cash did not change the trend in cash in circulation. It remains to be seen whether this is also true for the current Covid-19 crisis. First analyses

reveal that at least payment patterns might have changed permanently (see Alfonso et al., 2021; Ardizzi et al., 2020; Jonker et al., 2020)

In normal times, some emphasize the alleged inefficiency, inconvenience and costly provision of cash. Against the background of our analysis, however, cash seems to play an important part in successful crisis management. The sheer possibility of having access to cash reduces uncertainty during a crisis and can be interpreted as a special kind of public insurance service. Of course, such an insurance provided by the central banks generates moral hazard. Nevertheless, one should have a critical view on suggestions and political actions that aim at restricting the use of cash and making cash unattractive.[20] Once payments in cash reach a critical lower level, it becomes unattractive for retailers to accept and for banks to supply and offer the possibility to deposit banknotes and coins. An alarming example in this direction is Sweden, which came in the past years already quite close to this lower threshold. The latest actions of official authorities to reverse this trend speaks for itself (see for instance Ingves, 2020).

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[20] For a broader discussion on the pros and cons of cash, see Krüger & Seitz (2017), Kap. 7 and Rösl & Seitz (2015).

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Annex

The aim of the annex is to demonstrate that the ratio of large denominations in total banknotes in circulation does not contain any information about the trends of large and small denominations over time if total banknotes also increase over time.

A.1. Definition:

L(t) = Large banknote denominations at time t

S(t) = Small banknote denominations at time t

X(t) = L(t) + S(t) = Total banknotes in circulation at time t

$l(t) = \dfrac{L(t)}{X(t)}$ = share of large denominations in total banknotes in circulation at time t

The change in the share of large denominations in total banknotes over time is

$$\frac{dl(t)}{dt} = \frac{\frac{dL(t)}{dt}}{X(t)} - \frac{L(t)}{X(t)} \cdot \frac{\frac{dX(t)}{dt}}{X(t)}$$

with

$\dfrac{\frac{dL(t)}{dt}}{X(t)}$ = change in large denominations relative to total banknotes in circulation over time,

$\dfrac{L(t)}{X(t)}$ = share of large denominations in total banknotes in circulation,

$\dfrac{\frac{dX(t)}{dt}}{X(t)}$ = growth rate of total banknotes in circulation.

A.2. Different scenarios

A.2.1. Total banknotes remain constant, large denominations increase over time

If total banknotes remain constant, $\frac{dX(t)}{dt} = 0$, an increase in large denominations, $\frac{dL(t)}{dt} > 0$, leads directly to an increase in the share of large denominations of total banknotes in circulation: $\frac{dl(t)}{dt} = \dfrac{\frac{dL(t)}{dt}}{X(t)} > 0$.

A.2.2. Total banknotes, large denominations and the share of large denominations increase

In an environment of rising total banknotes in circulation, $\frac{dX(t)}{dt} > 0$, the share of large denominations in total banknotes in circulation increases, $\frac{dl(t)}{dt} > 0$, if:

$$\frac{\frac{dL(t)}{dt}}{X(t)} > \frac{L(t)}{X(t)} \cdot \frac{\frac{dX(t)}{dt}}{X(t)}$$

In other words, the change in large denominations relative to total banknotes in circulation, $\frac{\frac{dL(t)}{dt}}{X(t)}$, has to be greater than the share of large denominations in total banknotes, $\frac{L(t)}{X(t)}$, times the growth rate of total banknotes in circulation, $\frac{\frac{dX(t)}{dt}}{X(t)}$.

A.2.3. Total banknotes and large denominations increase, but the share of large denominations decreases

Consequently, in an environment of rising total banknotes in circulation, $\frac{dX(t)}{dt} > 0$, the share of large denominations in total banknotes in circulation decreases, $\frac{dl(t)}{dt} < 0$, if:

$$\frac{\frac{dL(t)}{dt}}{X(t)} < \frac{L(t)}{X(t)} \cdot \frac{\frac{dX(t)}{dt}}{X(t)}$$

Is it possible that large denominations increase faster than small denominations, whereas the share of large denominations in total banknotes in circulation still decreases? The answer is yes! For this to happen, the following conditions must hold:

$\frac{dl(t)}{dt} < 0$ and at the same time $\frac{dL(t)}{dt} > \frac{dS(t)}{dt}$.

From $\frac{dl(t)}{dt} < 0$ we get $\frac{dL(t)}{dt} < L(t) \cdot \frac{\frac{dX(t)}{dt}}{X(t)}$ and, as $\frac{dX(t)}{dt} = \frac{dL(t)}{dt} + \frac{dS(t)}{dt}$, one obtains the following condition:

$$\frac{dL(t)}{dt} + \frac{dS(t)}{dt} > \frac{\frac{dL(t)}{dt}}{L(t)} \cdot X(t)$$

The sum of absolute changes of large and small denominations has to be higher than the growth rate of large denominations times total banknotes. To illustrate such a scenario, we mirror approximate figures for large and small denominations of "global" banknotes in circulation as observed from January 2002 – June 2020, see figure 17.

Table A1: Simulation

t	L(t)	S(t)	X(t)	dL/dt	dS/dt	dL/dt + dS/dt	[(dL(t)/dt)]/L(t)*X(t)	L(t)/X(t)
1	1000	500	1500				333	66.7%
2	1222	666	1888	222	166	388	343	64.7%
3	1444	832	2276	222	166	388	350	63.4%
4	1666	998	2664	222	166	388	355	62.5%
5	1888	1164	3052	222	166	388	359	61.9%
6	2110	1330	3440	222	166	388	362	61.3%
7	2332	1496	3828	222	166	388	364	60.9%
8	2554	1662	4216	222	166	388	366	60.6%
9	2776	1828	4604	222	166	388	368	60.3%
10	2998	1994	4992	222	166	388	370	60.1%

Figure A1: Graphs to simulation
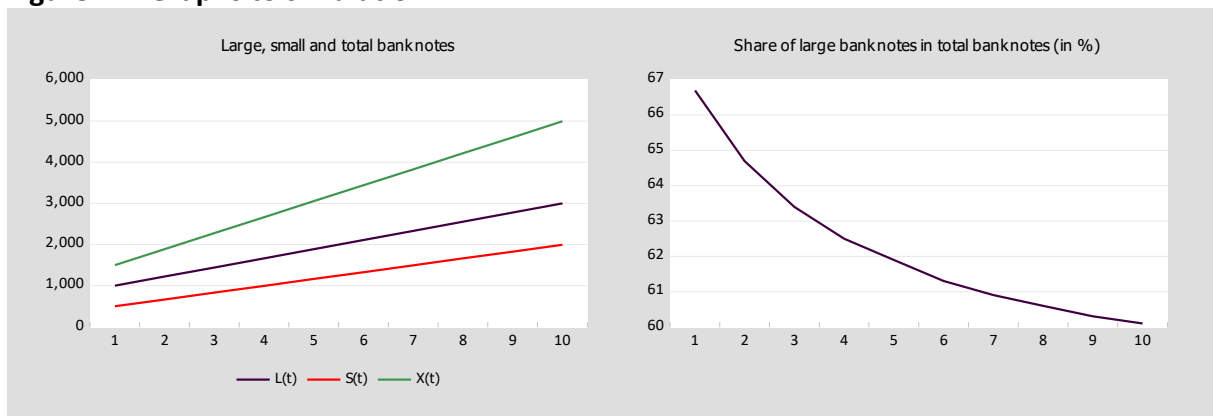
A.2.4. Results

A trend increase in large banknote denominations and hence a possible increase in banknote hoarding is not a contradiction to an observed decline in the share of large denominations in total banknotes in circulation. In addition, it is also not uncommon that the absolute increase in large denominations is higher than the increase of the small ones, but the share of large denominations in total banknotes in circulation decreases over time. Thus, a declining share of large denominations over time contains per se no information on trend changes of large denominations. Of course, these considerations apply also to small denominations.