Practice papers

Cash demand in times of crisis

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ABSTRACT

This paper focuses on the role of specific types of crisis (technological crisis, financial market crisis, natural disaster) and their effects on the demand for cash in an international context. As evidence from the last 30 years shows, demand for cash increases during periods of crisis, regardless of the nature of the crisis. The nature of the crisis does, however, determine whether small or large banknote denominations are affected more. This study finds that times of payment uncertainties are associated with increased demand for small denominations, probably reflecting an elevated demand for transaction balances. By contrast, in times of financial crisis or general economic uncertainty, the increased demand for cash is largely the result of consumers taking precautionary actions and building up non-transaction balances; for this reason, there is greater demand for large banknote denominations. This study finds that cash continues to play an important role in crisis management. Whether this function can also be fulfilled by a future central bank digital currency, however, remains to be seen.

Keywords: cash, banknotes, crises, COVID-19

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INTRODUCTION

In recent years there has been intense discussion about restricting the use of cash and even abolishing it altogether.[1] The advocates of such measures typically refer to the 'fact' that cash will become obsolete anyway as electronic payments continue to gain more traction. The truth is, however, that the volume of global cash in circulation has increased enormously over the past 30 years. For the major currencies, growth in cash holdings has even exceeded gross domestic product (GDP) growth in recent decades.[2] On top of this, the outbreak of COVID-19 led to an exceptionally strong increase in the global demand for cash, even in many of the countries where cashless payments were more frequently used at the point of sale, thus creating the so-called

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cash paradox.[3] The present paper aims to provide a deeper insight into cash demand in times of crisis more generally. To this end, the study distinguishes between three different types of crisis and analyses the evolution in demand for both large and small denominations of multiple currencies in specific crisis episodes over the last three decades. At the same time, the study controls for other determinants for holding cash besides crisis-related motives. The findings indicate that cash is an essential element of successful crisis management.

CASH DEMAND IN TIMES OF CRISIS: SOME SPECIFIC EXAMPLES

Since the early 1990s, worldwide inflation rates and opportunity costs for cash holders have decreased considerably.[4] This has helped drive a steep increase in global cash holdings.[5] In such an environment, demand for cash is likely to spike in the event of a crisis as it provides a secure means of payment and at the same time represents the most liquid store of value. To obtain preliminary insights into crisis-related cash demand over the past 30 years, this paper distinguishes three types of crisis with global consequences:

- technological crisis (eg the Y2K crisis);
- financial market crisis (eg the Lehman Brothers insolvency in October 2008); and
- natural disasters (eg the COVID-19 crisis).

For each type of crisis, the study analyses a prominent example from the last 30 years. The authors acknowledge that Y2K could be classified more generally as an uncertainty crisis, given how it originated out of widespread fear of a technological meltdown. Regarding the classification of the COVID-19 pandemic as a natural disaster, this study follows the common judgment.[6] It is worth noting, however, that there are other examples of crisis periods in which cash

demand increased; for example, the tensions in the European Monetary System (EMS) in 1992/93, the (geo-)political crisis after the 9/11 attacks in 2001 and the Euro crisis in 2010/11. In their nature, however, these crises were effectively confidence crises and hence do not differ greatly from the financial market crisis in October 2008. A more detailed analysis of cash demand and crises for single currencies is provided in due course.

Figures 1 and 2, respectively, show the annual growth rates of cash holdings at a global and individual currency level. The latter concentrates on those eight currencies for which the denominational data will be analysed in the section on econometrics.

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 resetting of computer software dates to adjust for the new millennium would lead to a shutdown of key institutions, such as public utilities, as well as disruption to payment systems and cash withdrawals from automated teller machines (ATMs). After the insolvency of Lehman Brothers in October 2008, the resulting financial turmoil in the USA quickly scaled up to a global financial crisis and led to a visible increase in cash demand worldwide (see Figure 1). However, this increase lagged far behind that relating to Y2K, mostly because cash demand increased only in those countries that were affected by the financial crisis. In Japan, for instance, neither overall cash issuance nor single yen denominations showed an unusual increase (see Figure 2, Tables 1 and 2).[7]

With respect to cash demand, it seems that there was a structural difference between the 2008 financial crisis and Y2K crisis. 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 trust in banks
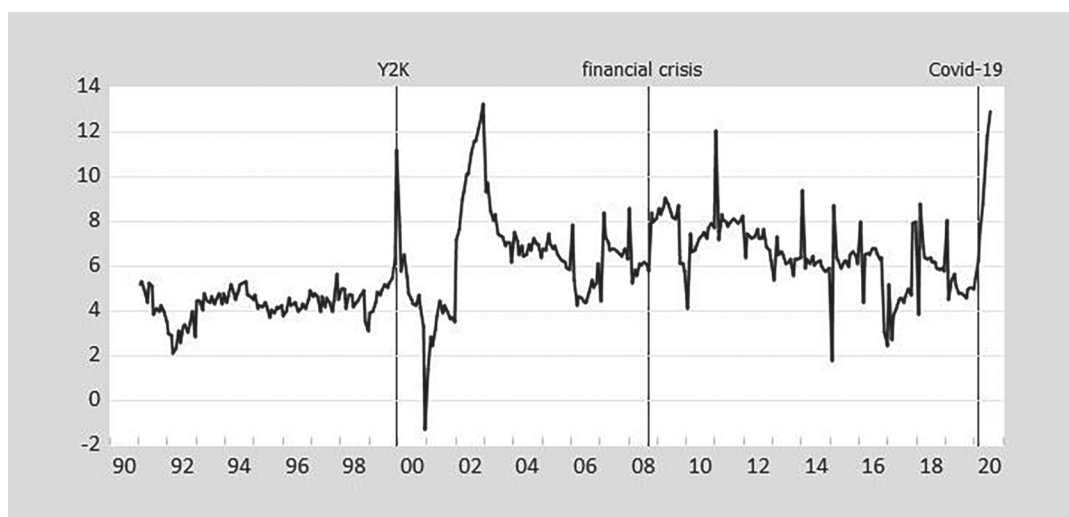
Figure 1: Annual growth rates (%) of 'global' cash, January 1990 to July 2020
Notes: Data refer to cash (banknotes and coins) or banknotes in circulation, depending on availability. Countries included are Australia, Brazil, Canada, China (since 2006), Denmark, Egypt, Euro area (since 2002), Germany (until end of 2001), India, Japan, Norway, Russia, South Africa, South Korea, Sweden, Switzerland, United Kingdom and USA. To eliminate the effect of exchange rate fluctuations, national figures are converted to US dollar values using the average exchange rate over the data period. Statistical breaks resulting from the inclusion of the Euro area 2002 and China 2006 are smoothed by means of simple linear interpolation.
Source: various central banks, IMF.

and the financial system in some countries deteriorated and led to a flight into cash (crisis of confidence). Although it is not uncommon that natural disasters lead to a marked increase in cash demand on a national level,[8] in early 2020, a new type of global crisis affected the world economy and cash demand on a global scale.

The outbreak of COVID-19 led to a deep global recession in 2020, resulting in a stark decrease in turnover at the point of sale, with cash payments decreasing due to fears of virus contagion.[9] At the same time, however, global cash in circulation increased exceptionally (see Figures 1 and 2). Consequently, the main factor behind the increase in cash in circulation in 2020 was non-transactional demand (Sweden is the only country in which the increase in cash demand was only short-lived).[10] Therefore, the following econometric analysis distinguishes between large and small denominations as an indicator of transactional and non-transactional use of cash.

CASH DEMAND FOR LARGE AND SMALL BANKNOTE DENOMINATIONS IN TIMES OF CRISIS

Although the motivations for holding cash in times of crisis will always remain somewhat opaque, the analysis of low-value and high-value banknote denominations may provide some insight into the transaction versus non-transaction motives of cash users. This section examines the long-term relationship between cash, its main determinants (all in levels) and crises. For this purpose, the study augments standard long-term cash demand functions for large and small denominations with crisis-related dummy variables. In the classification of the two groups, at least one denomination per country is treated as a large one.
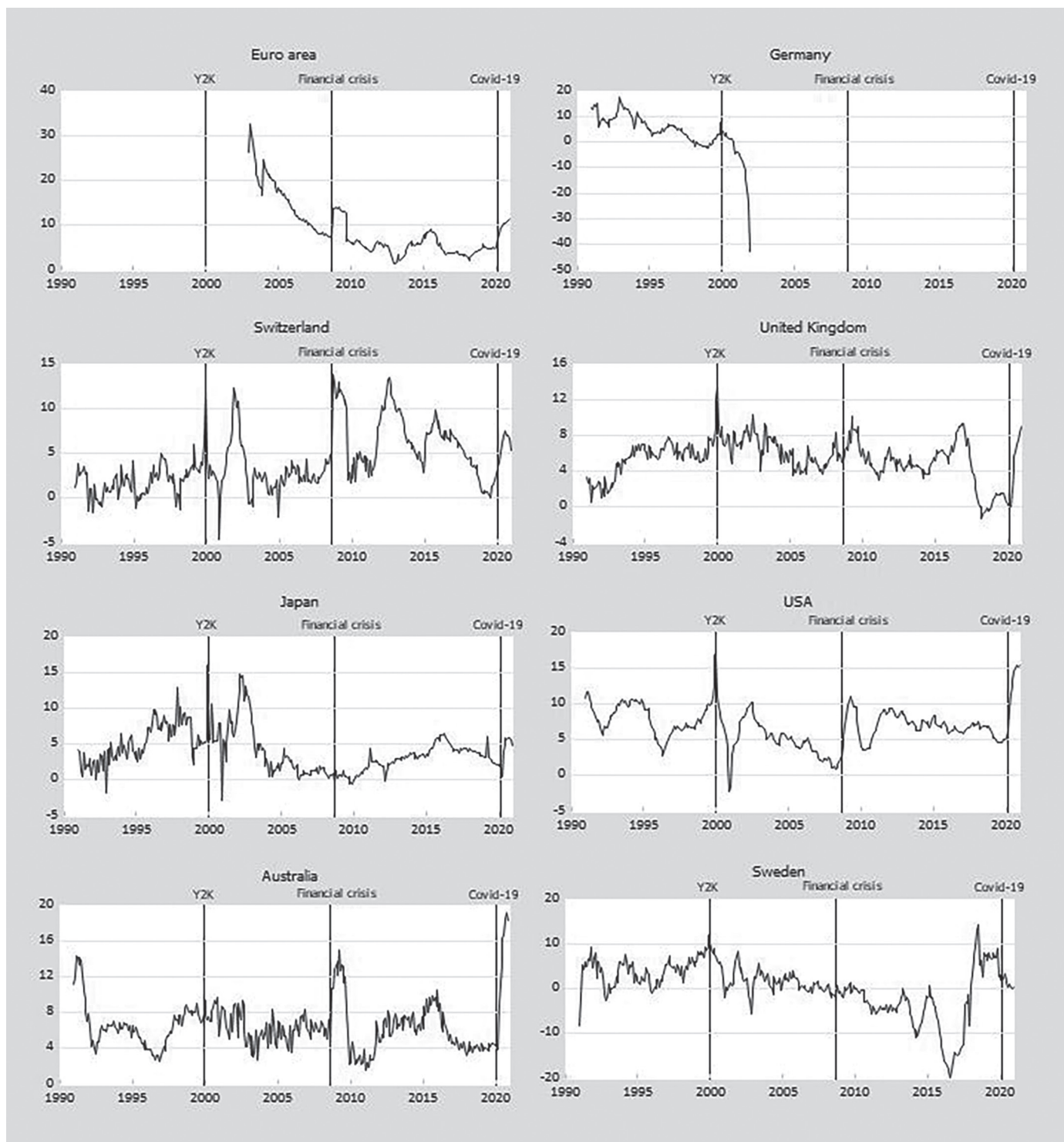
Figure 2: Annual growth in demand for cash in selected countries (%)
Note: Data refer to cash (banknotes and coins) or banknotes in circulation (in value terms).
Source: various central banks.

Small denominations are those a customer typically gets from ATMs at the current juncture.[11] This helps to correct for the 'bias' with respect to the use of higher denominations at the point of sale when prices rise over time. As traditional potential determinants of cash holdings, the study includes nominal GDP (transactions variable), a short-term (money market) interest rate (opportunity costs variable) and an exchange rate argument (proxy for foreign demand).[12] This captures the most important traditional motives for holding cash and makes it possible to analyse whether the different crises stimulate cash demand on top.

The sample consists of eight currencies (USD, JPY, DEM, EUR, CHF, GBP, SEK and AUD), for which data on individual denominations are available on a monthly basis. 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. From 2002 onwards, the EUR replaces the DEM. The data are unadjusted; therefore, seasonal dummy variables are included. The general estimation equation reads as follows:

$$b_{nt} = \beta_0 + \sum_{i=1}^{4} \alpha_i bn_{t-i} + \beta_1 y_t + \beta_2 i_t + \beta_3 e_t +$$

$$\beta_4 ytk_t + \beta_5 fin_t + \beta_6 \text{cov}_t + \beta_7 x_t + \varepsilon_t$$

where $bn \in \{large, small\}$ is (the log of) large and small banknotes in circulation, respectively (ie two separate relations are estimated — one for large and one for small denominations); y is (the log of) nominal GDP; i is a three-month money market interest rate; e is the (log of the) exchange rate; x represents other deterministic variables like trends (trend),[13] seasonal dummy (s(j), j = 1,2,3,4) or other dummy variables (dum); and ε is the error term. Lagged dependent terms are also taken into account to control for dynamics and serial correlation. The main variables of interest 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 in the period from Q4 2008 to Q1 2009 and *cov* is one in the period from Q1 2020 to Q2(3) 2020, zero otherwise.

Tables 1 and 2 summarise the regression results and Figures 3 and 4 show the growth rates of the corresponding denominational groups.

Significant results are obtained in 31 of the total of 42 crisis cases (see Tables 1 and 2). One denominational group per country is always positively and significantly affected by the crises. Obviously, the nature of the crisis influences which denominations are affected and how (see the explanations below). At least one of the economic determinants of cash holdings (GDP, interest rate, exchange rate) is significant in the equations. Taken together, the serial correlation LM test and the broader Ramsey mis-specification test reveal only minor statistical problems in some cases. At least one test passes the 10 per cent significance threshold. As is usual in econometric analyses, checks are conducted for residual outliers, with impulse dummies included to correct for them. In the present case, this not only helps to obtain better statistical properties, but the additional dummy variables taken into account have economic (crisis) meaning. Specifically, they relate to Y2K (decrease in cash demand in the USA, after the potential problems of Y2K fail to materialise),[14] the Asian and Russian crises (Japan and Switzerland), the introduction of Euro cash (Japan), the 9/11 terrorist attacks (Switzerland, Australia, Sweden) and the EMS crisis (Germany).

With respect to the demand for large banknote denominations, all currencies analysed show a significant crisis-related increase around the millennium except for the DEM, which was to be replaced by the euro shortly afterwards. This general

Table 1: Estimation results for large denominations

	Euro area	USA	Switzerland	Japan	UK	Sweden	Australia	Germany
GDP	–	–	0.07	0.10	0.05	0.18	0.04	–
			(0.03)★★★	(0.03)★★★	(0.03)★★	(0.05)★★★	(0.02)★★★	
Interest rate	–	−0.001	–	−0.003	–	–	−0.002	–
		(0.01)★★		(0.001)★★★			(0.0012)★★	
Exchange rate	0.03	0.02	0.08	–	–	–	–	0.04
	(0.01)★★	(0.01)★★★	(0.02)★★★					(0.02)★
Y2K		0.05	0.05	0.05	0.02	0.04	0.02	0.00
		(0.01)★★★	(0.02)★★★	(0.01)★★★	(0.01)★	(0.02)★★	(0.01)★	−0.01
Fin	0.05	0.02	0.04	−0.00	0.04	0.01	0.01	
	(0.01)★★★	(0.01)★★★	(0.01)★★★	−0.01	(0.01)★★★	−0.01	(0.01)★	
Cov	0.03	0.02	0.02	0.02	0.02	0.04	0.02	
	(0.01)★★★	(0.01)★★★	(0.01)★	(0.01)★	(0.01)★	(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), dum_sea, dum0911	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, dum0911	bn$_{t-1}$, bn$_{t-2}$, bn$_{t-4}$, s(1), s(3), s(4), dum0911	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. R^2	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)	0.80	0.67	0.01	0.00	0.02	0.05	0.00	0.06
Ramsey	0.80	0.85	0.13	0.17	0.24	0.20	0.15	0.29

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 (at least at the 10 per cent level) lagged endogenous or deterministic variables; dum_us: dummy variable for the extraordinary decrease in banknotes in 2000.1 in the USA; dum0911: dummy variable for positive outlier in the last two quarters of 2001; dum_sea: dummy variable for positive outlier in 1997.4; dum_ja: dummy variable for positive 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 test.

development seems to hold also roughly for the demand for small denominations at that time. In the case of the USD, CHF, GBP, JPY and DEM, all estimates are significant, whereas the results for the AUD and SEK are positive, but not significant. The highest percentage increases are found in the case of the USD, CHF and JPY. Hence, one can tentatively conclude that the drastic increase in global cash at end of the last century was caused by the desire to hold additional trans-action balances as well as non-transaction balances (see also Figures 3 and 4). Clearly, the public prefers physical money when con-fidence in the technological infrastructure deteriorates or uncertainty about its proper functioning increases. Cash is by nature a stabilising factor in times of rising doubts about the robustness of the digital infrastruc-ture comparable to fears about instabilities of power grids.[15]

During the financial crisis in 2008/09, the overall picture of crisis-related cash demand was somewhat different from the situation around the millennium. As already men-tioned, overall cash demand only increased
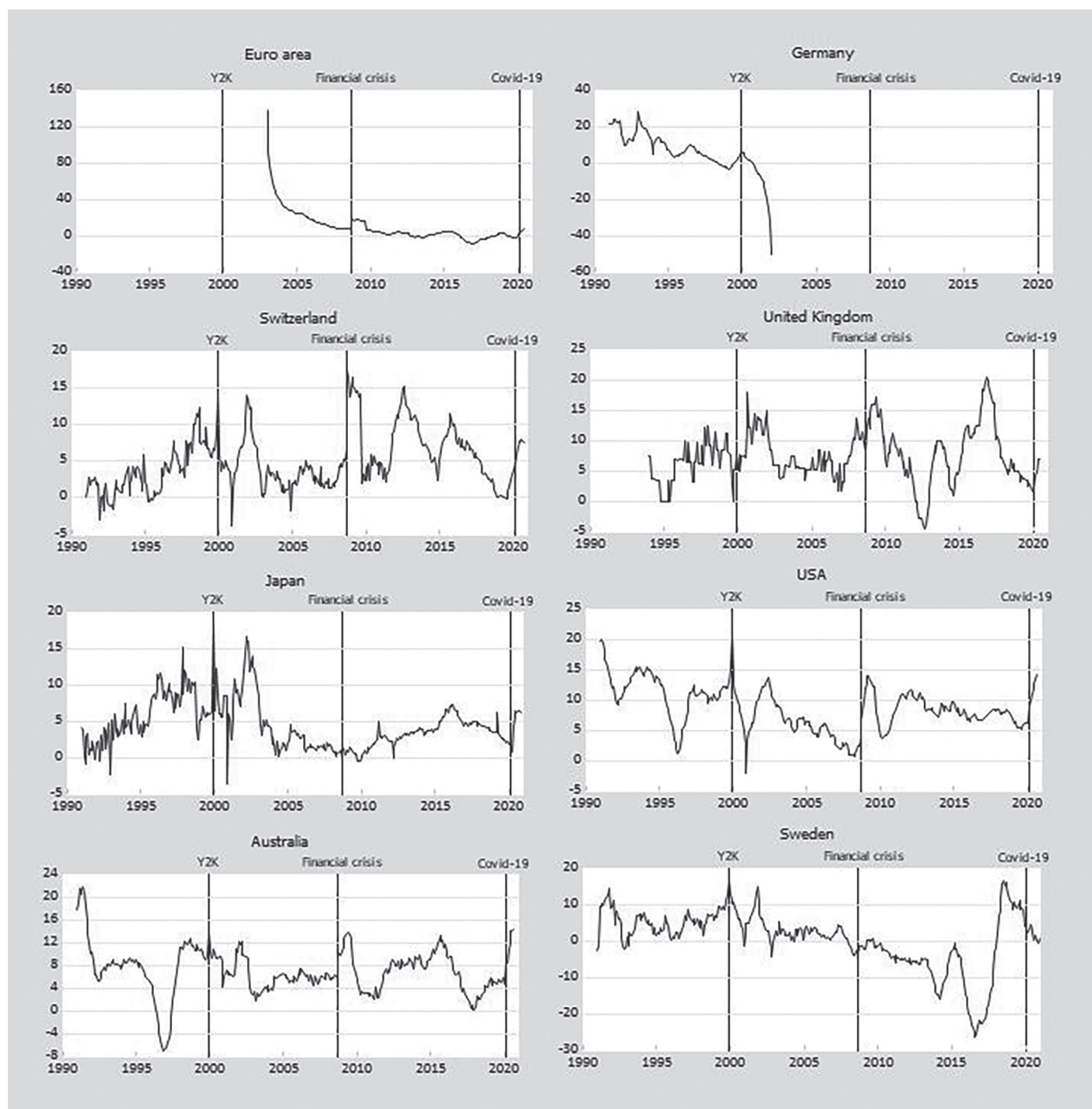
Figure 3: Annual growth rates of large denominations in selected countries (%)
Notes: Large denominations: USD 100; JPY 10,000; DEM 200, 500, 1,000; EUR 200, 500; CHF 200, 500, 1,000; GBP 50; SEK 10,000; 1,000; 500; AUD 100.
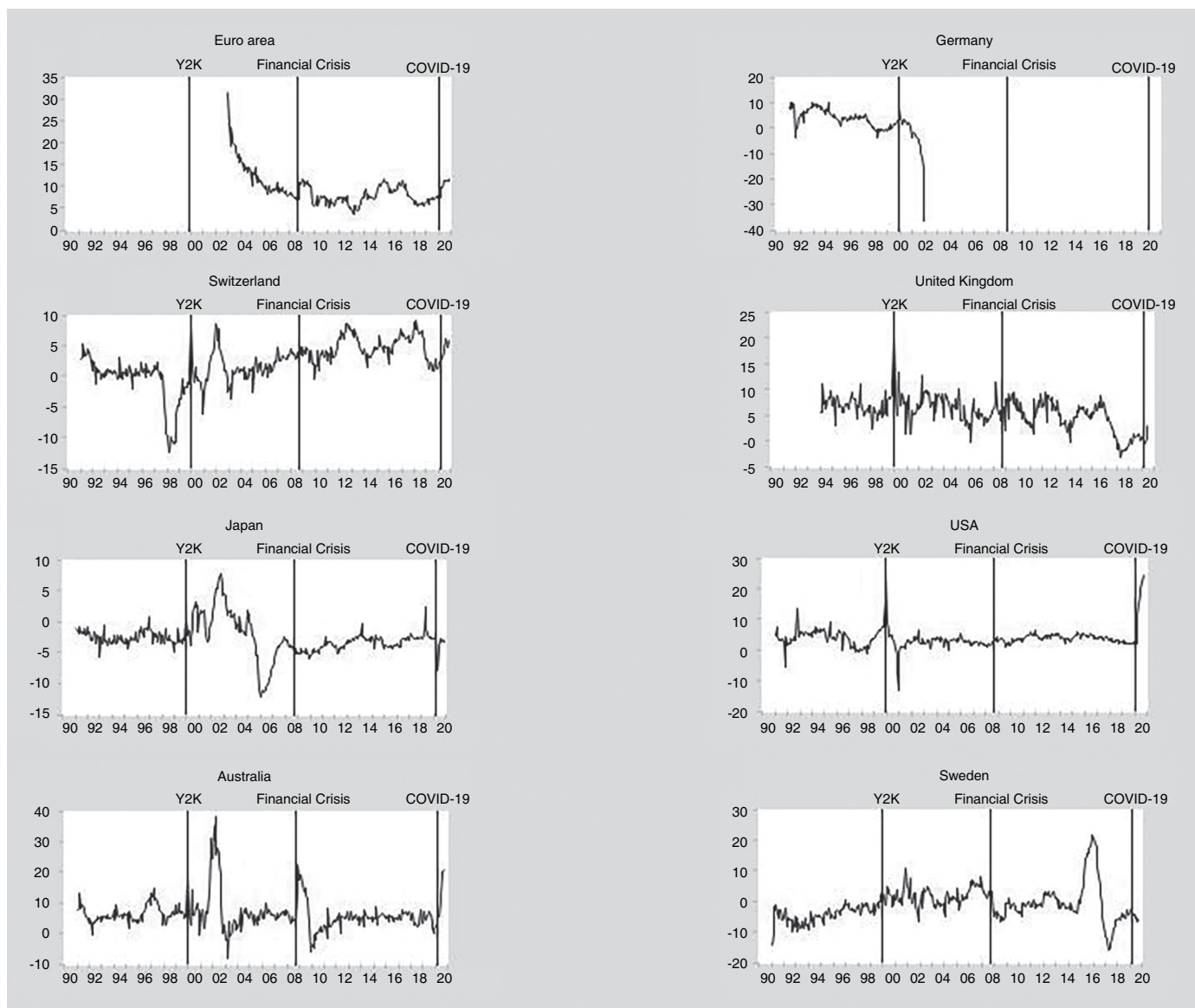Source: various central banks.

Figure 4: Annual growth rates of small denominations in selected countries (%)
Notes: Small denominations: USD 1, 2, 5, 10, 20, 50; JPY 500, 1,000, 2,000, 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; 200; AUD 5, 10, 20, 50.
Source: various central banks.

notably in those countries that were affected by the financial crisis. Hence, it is not surprising that cash demand was boosted quickly and promptly especially in the USA, the euro area, the UK, Switzerland and Australia, but not in Japan (see Figure 2). Japan — which was largely insulated from the financial turmoil around 2008/09 — had no significant increase in cash demand, neither for large nor small denominations. Another exception is Sweden: it seems that in this country, the decline in cash in circulation started to intensify after the financial and economic crisis at the end of the first

Table 2: Estimation results for small denominations

	Euro area	USA	Switzerland	Japan	UK	Sweden	Australia	Germany
GDP	0.31	–	0.02	0.05	–	0.17	0.08	0.2
	(0.07)★★★		(0.01)★★	(0.03)★		(0.05)★★★	(0.04)★★	(0.07)★★★
Interest rate	−0.01	−0.001	–	–	−0.003	–	–	–
	(0.002)★★★	(0.001)★★			(0.001)★★★			
Exchange rate	–	–	–	–	–	–	–	–
Y2K		0.11	0.03	0.02	0.02	0.01	0.03	0.02
		(0.01)★★★	(0.01)★★★	(0.01)★	(0.01)★★★	−0.02	−0.02	(0.01)★★
Fin	0.03	−0.01	0.01	−0.00	0.02	−0.02	0.05	
	(0.01)★★★	−0.01	−0.01	−0.01	(0.01)★	(0.01)★	(0.02)★★★	
Cov	0.04	0.03	0.01	0.01	0.01	−0.00	0.04	
	(0.01)★★★	(0.00)★★★	(0.01)★	−0.01	−0.01	−0.01	(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_sea, dum0911	$bn_{t−1}$, s(1), s(4), dum_ja	$bn_{t−1}$, dum_ja	$bn_{t−1}$, $bn_{t−4}$, s(1), s(4), trend, dum0911	$bn_{t−1}$, $bn_{t−2}$, s(1), s(4), dum0911	$bn_{t−1}$, 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. R^2	0.99	0.99	0.99	0.99	0.99	0.9	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	0.07	0.69	0.00	0.08	0.01	0.00	0.78
Ramsey	0.15	0.27	0.01	0.47	0.25	0.23	0.69	0.01

Notes: Small denominations: USD 1, 2, 5, 10, 20, 50; JPY 500, 1,000, 2,000, 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; 200; AUD 5, 10, 20, 50. GDP: nominal GDP; interest rate: 3-month money market interest rate; exchange rate: euro–dollar exchange rate; x: additional significant (at least at the 10 per cent level) lagged endogenous or deterministic variables; dum_us: dummy variable for the extraordinary decrease in banknotes in 2000.1 in the USA; dum_sea: dummy variable for outlier in 1997.4; 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. LM(4): p-value of Breusch-Godfrey serial correlation LM test up to lag 4; Ramsey: p-value of Ramsey RESET test.

decade of the 21st century (see Figure 1). The second difference to the situation around Y2K is that this time the stockpiling of non-transactional balances was clearly the main motive behind the demand for large denominations of USD, EUR, CHF and GBP. Concretely, crisis-related demand for high-value banknotes increased strongly (between 2 and 5 per cent) and significantly in these countries during the financial crisis, as shown in Table 1.

By contrast, crisis-related demand for small denominations was quite limited at that time, indicating that transactional motives should have played only a minor role. This overall assessment seems to hold although the demand for small euro denominations increased significantly during the financial crisis, as shown in Table 2. However, as 30–50 per cent of all euro banknotes issued circulate outside the euro area,[16] non-transactional motives among foreign cash holders might still be the dominant factor. In less stable foreign countries, the €50 and €100 banknote (and sometimes even the €20 banknote) may well be considered

large banknotes (in value) compared with national currencies.

Regarding the demand for cash during the COVID-19 pandemic, interesting international similarities show up again. All countries analysed were heavily hit by the SARS-CoV-2 virus in the first half of 2020 and the demand for high banknote denominations increased significantly everywhere, roughly in the region of 2–4 per cent (see Table 1) which also supports results found previously for Australia[17] and Japan.[18] Concerns regarding future tax increases might have played a role in this respect, but the crisis-induced flight to physical cash can also be explained by precautionary motives and psychological factors.

In addition, a notable significant crisis-related rise in the demand for small denominations can also be detected for some currency areas, notably the USD, the EUR, the CHF and the AUD, where demand increased up to 4 per cent (see Table 2). However, as these countries went into lockdowns and shutdowns in the first half of 2020, one should be careful not to over-emphasise the transactional motive too much. Rather, this development might reflect precautionary motives as commercial banks in these countries also quickly increased their vault cash.[19] For the US dollar, the euro and the Swiss franc, again, foreign non-transactional demand provides another partial explanation. It seems that AUD are also in demand outside Australia for non-transactional purposes.[20] Moreover, findings from the Reserve Bank of Australia's Consumer Payment Surveys reveal that the major reason why Australians hold cash outside their wallets is for use in emergencies.[21] Finally, the results may also be due to the fact that the AUD50 banknote was included in the small category.[22] However, this is not the case for the USD.

Note that the overall results would not change much if one were to refer to real rather than nominal cash balances as inflation is already accounted for in the estimation equation by using *nominal* GDP as a determinant of cash demand. For convenience, however, *real* total cash holdings as well as real large and small denominations for three selected currency areas, namely the euro area, the USA and Switzerland, are provided in the appendix. Evidently, the general conclusions remain valid even if the crisis-related spikes are more subdued.

SUMMARY AND CONCLUSIONS

This paper has analysed the role of different types of crisis (technological crises, financial market crises, natural disasters) and their effect on the demand for cash in an international context in an exemplified manner. Besides the three crises considered explicitly (Y2K, financial crisis 2008/9, COVID-19), the study identifies other periods of crisis from the past 30 years that stimulated cash holdings over and above traditional transactional and non-transactional determinants. As the evidence presented in this paper has shown, cash demand (over the past 30 years, at the very least) has always increased in such times of crisis. This study also finds that although the flight to cash itself is independent of the nature of the crisis, the type of crisis does however determine which denominations — ie large or small banknotes — are most affected. In times of pronounced payment uncertainties, the crisis-related demand for small banknotes is stimulated, probably reflecting an increased demand for transaction balances. In times of uncertainties with respect to the financial and/or general economic situation (also possibly driven by natural disasters), large banknote denominations were in comparatively greater demand, indicating a crisis-related need for non-transaction balances. As central banks usually provide cash in a perfectly elastic way, one can also conclude that cash, as the only form of central bank money for the general public up to

now, plays an important role in successful crisis management.[23] Whether this will be equally true for future central bank digital currencies remains an open question. In a broader context, these findings also point to the need to examine the role of cash in contingency planning in the context of prolonged outages in digital payment systems.[24]

ACKNOWLEDGMENTS

REFERENCES

(1) Rogoff, K. S. (2016) 'The Curse of Cash', Princeton University Press, Princeton and Oxford.
(2) Ashworth, J. and Goodhart, C. A. E. (2020) 'The surprising recovery of currency usage', *International Journal of Central Banking*, Vol. 16, pp. 239–277.
(3) Zamora-Pérez, A. (2021) 'The paradox of banknotes: understanding the demand for cash beyond transactional use', *European Central Bank, Economic Bulletin* 2/2021, pp. 121–137.
(4) Forbes, K. J. (2019) 'Has globalization changed the inflation process?', BIS Working Paper No. 791, available at: https://www.bis.org/publ/work791.pdf (accessed 27th April, 2022).
(5) Fish, T. and Whymark R. (2015) 'How has cash usage evolved in recent decades? What might drive demand in the future?', *Bank of England, Quarterly Bulletin* Q3, available at: https://www.bankofengland.co.uk/quarterly-bulletin/2015/q3/how–has–cash–usage–evolved–in–recent–decades–what–might–drive–demand–in–the–future (accessed 27th April, 2022).
(6) Nussbaum C. G. and Mason, C. M. (2020) 'COVID-19 pandemic is a natural disaster for purpose of a contractual force majeure provision, says Southern District of New York', available at: https://www.nixonpeabody.com/ideas/articles/2020/12/21/covid19–pandemic–is–a–natural–disaster (accessed 27th April, 2022).
(7) Rösl, G. and Seitz, F. (2021) 'Cash and crises: no surprises by the virus', IMFS Working Paper No. 150, available at: https://www.imfs-frankfurt.de/fileadmin/user_upload/IMFS_WP/IMFS_WP_150_web.pdf (accessed 27th April, 2022).
(8) CashEssentials (2021) 'The resilience of cash before, during, and after Hurricane Ida', available at: https://cashessentials.org/the-resilience-of-cash-before-during-and-after-hurricane-ida/ (accessed 27th April, 2022).
(9) Tamele, B., Zamora-Pérez, A., Litardi, C., Howes, J., Steinmann, E. and Todt, D. (2021) 'Catch me (if you can): assessing the risk of SARS-CoV-2 transmission via euro cash', ECB Occasional Paper No. 259, available at: https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op259~33b180d450.en.pdf (accessed 27th April, 2022).
(10) Heinonen, A. (2020) 'Banknote developments at the global level — before and after the outbreak of COVID-19', *Currency News, Special Report*, Vol. 18, No. 9, pp. 10–12.
(11) Amromin, G. and Chakravorti, S. (2009) 'Whither loose change? The diminishing demand for small-denomination currency', *Journal of Money, Credit and Banking*, Vol. 41, pp. 315–335.
(12) Assenmacher, K., Seitz, F. and Tenhofen, J. (2019) 'The demand for Swiss banknotes: some new evidence', *Swiss Journal of Economics and Statistics* Vol. 155, article 14, available at: https://sjes.springeropen.com/articles/10.1186/s41937-019-0041-7 (accessed 27th April, 2022).
(13) Judson, R. (2017) 'The future of cash in crisis and calm: demand for US dollar banknotes', paper presented at International Cash Conference, 26th–27th April, 2017, in: Deutsche Bundesbank (ed.) 'War on Cash: Is There a Future for Cash?', Seiters, Frankfurt am Main, pp. 200–249, available at: https://www.bundesbank.de/resource/blob/710118/6bab368611007785b02fbb008f368cf7/mL/war-on-cash-data.pdf (accessed 27th April, 2022).
(14) Judson, ref. 13 above.
(15) Cheney, J. S. and Rhine, S. L. W. (2006) 'How effective were the financial safety nets in the aftermath of Katrina?', Payment Cards Center, Federal Reserve Bank of Philadelphia Discussion Paper, available at: https://www.philadelphiafed.org/-/media/frbp/assets/consumer-finance/discussion-papers/HurricaneKatrinaJan06.pdf (accessed 27th April, 2022).
(16) European Central Bank (2020) 'The international role of the euro', June, ch. 2.5, available at: https://www.ecb.europa.eu/pub/pdf/ire/ecb.ire202006~81495c263a.en.pdf (accessed 27th April, 2022).
(17) Guttmann, R., Pavlik, C., Ung, B. and Wang, G. (2021) 'Cash demand during COVID-19', *Reserve Bank of Australia, Bulletin*, March, available at: https://www.rba.gov.au/publications/bulletin/2021/mar/pdf/cash-demand-during-covid-19.pdf (accessed 27th April, 2022).

(18) Yoshizawa, K., Maehashi, K., Yanagihara, H., Kadogawa, Y. and Inada, M. (2021) 'Developments in banknotes in circulation since the start of the pandemic', *Bank of Japan Review*, December, available at: https://www.boj.or.jp/en/research/wps_rev/rev_2021/data/rev21e06.pdf (accessed 27th April, 2022).

(19) See Rösl and Seitz, ref. 7 above, Figure 7.

(20) Finlay, R., Staib, A. and Wakefield, M. (2019) 'Where's the money? An investigation into the whereabouts and uses of Australian banknotes', *Australian Economic Review*, Vol. 53, pp. 22–34

(21) Caddy, J., Delaney, L. and Fisher, C. (2020) 'Consumer payment behaviour in Australia: evidence from the 2019 Consumer Payments Survey', Reserve Bank of Australia, Research Discussion Paper 2020-06, available at: https://www.rba.gov.au/publications/rdp/2020/pdf/rdp2020-06.pdf (accessed 27th April, 2022).

(22) Guttmann *et al.*, ref. 17 above.

(23) Ruberton, P. M., Gladstone, J. and Lyubomirsky, S. (2016) 'How your bank balance buys happiness: the importance of "cash on hand" to life satisfaction', *Emotion*, Vol. 16, pp. 575–580.

(24) See, eg Khiaonarong, T., Leinonen, H. and Rizaldy, R. (2021) 'Operational resilience in digital payments — experiences and issues', IMF Working Paper WP/21/288, available at: https://www.imf.org/en/Publications/WP/Issues/2021/12/10/Operational-Resilience-in-Digital-Payments-Experiences-and-Issues-510393 (accessed 27th April, 2022).
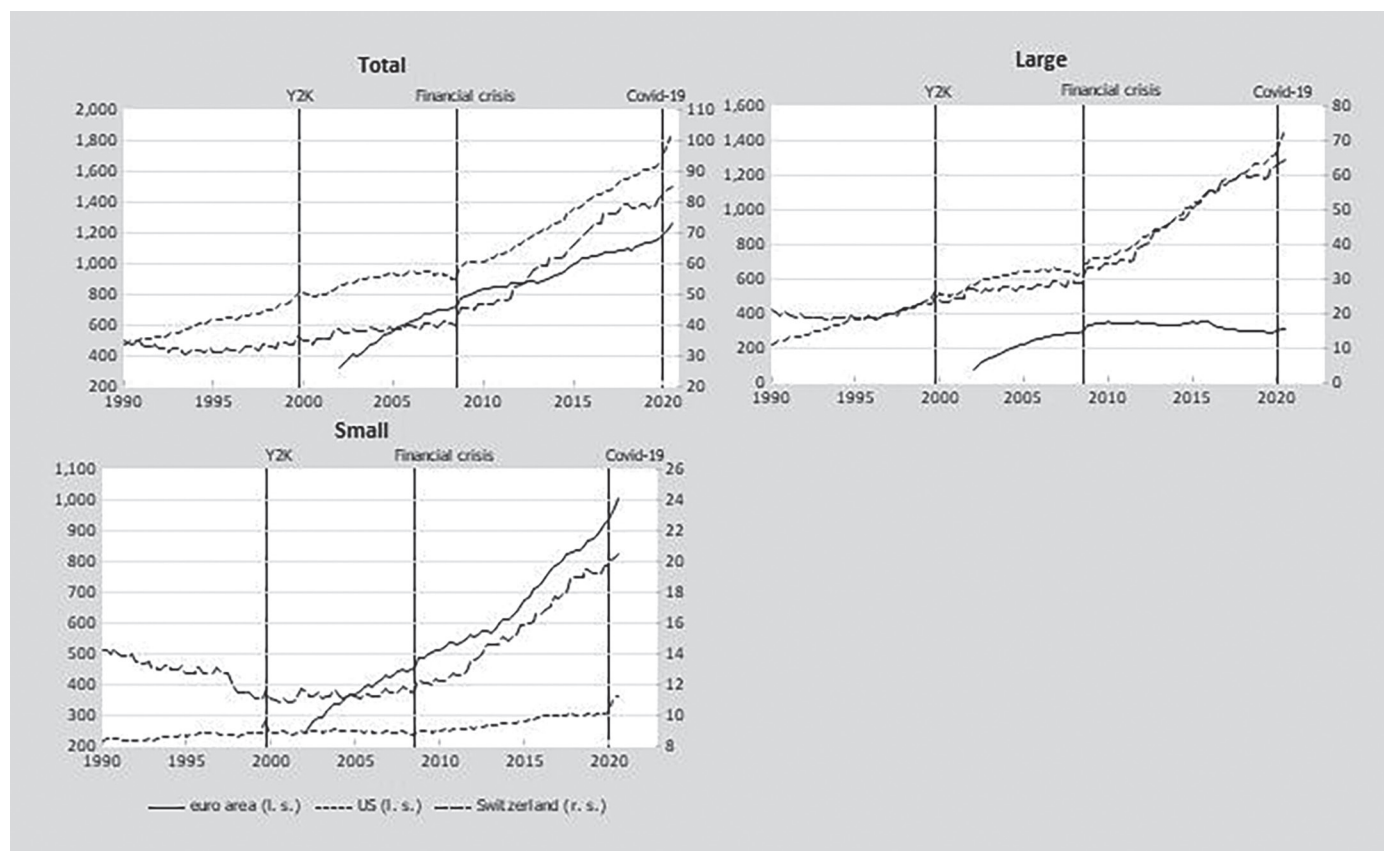
APPENDIX

Figure A1: Real cash balances in selected currency areas
Notes: Billions of national currency. Nominal balances deflated by the consumer price index.
Source: various central banks.