



UDK: 336.717.061

DOI: 10.2478/jcbtp-2023-0016

Journal of Central Banking Theory and Practice, 2023, 2, pp. 103-131

Received: 25 February 2022.; accepted: 27 October 2022

Ilona Skibińska-Fabrowska *

Demand for Cash and its Determinants - a Post-Crisis Approach¹

** Department of Insurance and Investments, Faculty of Economics, Maria Curie Skłodowska University, Lublin, Poland and Narodowy Bank Polski, Kraków, Poland*

E-mail:

*ilona.skibinska-fabrowska@
mail.umcs.pl*

Abstract: The use of cashless payment instruments has been on an increase over many years now. At the same time, demand for cash has been on the rise as well and we can observe a particularly high level of growth demand for banknotes during crisis times. The increase in demand for cash known as the "banknote paradox" is a phenomenon observed in many economies. It results from the existence of two streams of demand for cash - transactional and precautionary, and the differences in the directions of their changes from the point of view of the central bank and other entities involved in cash transactions, since it enables the optimization of cash supply management, which allows, on the one hand, to reduce the costs of cash processing and, on the other hand, to improve the effectiveness of monetary policy. This paper estimates the share of the transaction demand for cash with the aggregate demand. The strength and direction of the impact of selected macroeconomic and behavioural factors (uncertainty caused by the Global Financial Crisis and the Pandemic Crisis) on transaction and precautionary demand for cash were also assessed. A novel approach to the problem of demand for cash is based on considering the impact of macroeconomic shocks in the form of crises on the demand for cash.

Keywords: demand for cash, supply of cash, central bank, crisis.

JEL Classification: E41, E47, E51, E52.

¹ The opinions presented in this paper do not constitute the official position of the NBP, but are the author's private opinions.

1. Introduction

For many years, cashless payment instruments have seen an increase in use. At the same time, cash demand has been on the rise as well. We can especially observe high levels of growth demand for banknotes during crisis times - both a financial crisis, like the Global Financial Crisis 2007+, and natural, like the on-going Pandemic Crisis. This increase in the level of banknote circulation, as shown by the results of many studies (Lalouette and Esselink, 2018; Rösl and Seitz, 2021), is connected to non-transactional use of cash, but cash is still an important means of payment (Lalouette and Esselink, 2018). In many countries, this effect has resulted in the growth of banknotes in circulation being higher than the growth of nominal GDP. In the EU, for example, the ratio of banknotes in circulation to nominal GDP growth rose from 7.9% in 2008, to 10.5% in 2018, with the maximum difference in growth dynamics being in 2008 and 2009 (- 100 b.p.).

Changes on the demand for cash (especially for banknotes) and determinants of these changes are important from a central bank point of view. Cash is the retail equivalent of reserves of banks (Bailey, 2009) and is an important determinant of central bank activity. The main aim of monetary policy is to influence the real sphere of the economy by shaping liquidity within the monetary market. To properly fulfil this task, the central bank should anticipate and adequately respond to changes in demand for cash. This practice could be especially important during crisis, when cash is treated as a safe haven and stored.

Central Banks are interested in knowing the structure of demand for banknotes. This interest is especially so with regard to the proportion of banknotes in circulation and that used in everyday transactions. The hoarding of banknotes is important because it is connected with the impact of the power of monetary policy (Assenmacher, Seitz and Tenhofen, 2017). Additionally, if more banknotes are used as stores of value, the demand for cash is less variable. Indeed, in a zero lower bond environment, the alternative cost of using cash decreases. The structure and level of banknotes in circulation is also important from the point of view of other stakeholders such as banks, cash processing firms and commercial outlets. In the scale of the whole economy, cash in circulation generates costs that are estimated to be 1% of a country's total GDP (Shmiedel, Kostova and Ruttenberg, 2012; Álvez Lluberás and Ponce, 2020).

In many countries (in Poland especially), cash is a dominating and hence, very important element of the monetary aggregate. Cash participation in the M1 aggregate is about 20%, in M2 - about 18% and in M3 - about 17.5% (NBP, 2021). Hence, analysing the determinants of level of cash (which is equivalent to the

determinants of the demand for money) is important in the research of monetary aggregate and monetary policy.

The research of demand for cash determinants is also important in the context of acceptance of different means of payments in the retail payment system and the future introduction (or not) of central bank digital currencies.

The research carried out so far on the demand for cash, and in particular on its determinants, took into account macroeconomic factors derived from the Baumol and Tobin model (Baumol, 1952; Tobin, 1956). Among them are GDP, interest rate, and exchange rate. The innovative contribution of the presented research is the inclusion of an additional behavioural factor, which is the uncertainty resulting from macroeconomic shocks related to the financial and economic crisis. An additional value of our work is related to the analysis of the impact of macroeconomic and behavioural factors separately for different denominations of banknotes that represent different types of demand for cash - transactional and precautionary. This is our unique contribution to the development of the financial discipline in its aspect related to the circulation of money in the economy. It also allows the combining of classical theories of money with the concepts of behavioural finance.

1.1. Money, cash, banknotes

The main, basic functions of money are to serve as a universal means of payment and as a storage of value (Duwendag, Ketterer, Kösters, Pohl and Simmert, 1996). Money, so as to perform the function of a store of value, should be stable in value and the purchasing power of money should be constant. The function of money being a universal means of payment is the best realized by monetary aggregate M1, which includes currency in circulation and demand deposits. Normally, the M1 aggregate is not a good means of discerning money as a store of value. Traditionally, the M3 aggregate performs that function better - but sometimes, in special situations, cash is treated by holders as stores of value and therefore is hoarded.

Cash in circulation consists of three components (Zamora-Perez, 2021). Cash:

- held for transaction – retail private transaction at point-of-sale, in vending, ticketing and gaming machines, cross-border shopping;
- stored domestically;
- held as means of payments and as a store of value abroad.

Cash in circulation consists of coins and banknotes. Due to the differences in volumes, only banknotes are analysed and identified with cash. In that approach, banknotes perform the function of being a means of payment or a store of value.

Banknotes, with regard to their function as stores of value, are hoarded. Hoarding is defined as all possible uses of cash, apart from domestic transactions (Assenmacher, Seitz and Tenhofen, 2019). It is difficult to measure the number of banknotes in circulation that are held as means of payments or as stores of value (Lalouette and Esselink., 2018). We can, however, estimate this on the basis of the level of transactions realized in cash. In surveys that Esselik and Hernandez (2017) conducted on a sample of household use of money in 13 countries in Europe, 79% of all transactions were in cash - or 54% of the volume of all type of transactions, but in Spain, Italy and Greece these figures were between 90%, - 70%. Bagnall et al. (2016) discovered in their research that the level of cash payment is determined by the amount of transactions, the demographic characteristics of consummates and the availability and costs of POS. Świecka, Terefenko and Paprotny (2021) present the wide spectrum of determinants of cash payments. They include:

- transaction factors – amount of transaction, place of purchase, types of goods/services that are purchased;
- features of payment instruments – costs of use, security, convenience;
- levels of consumer satisfaction connected with employing a payment instrument;
- consumer demographic factors – age, gender, education level;
- financial knowledge about payment instruments;
- consumer economic factors – income level, wealth;
- other factors – such as anonymity, merchants tendency to acceptance of different payment instruments.

1.2. Determinants of demand for cash

Demand for cash can be defined as household desire and non-financial enterprises state of cash resources (Duwendag et al., 1996). In recent years, the “paradox of banknotes” has been observed in many economies. This phenomenon means that the demand for cash (especially high nominated banknotes) increases, while the use of cash in transactions decreases (Zamora-Perez, 2021; Bailey, 2009). Indeed, Deutsche Bundesbank estimates that less than 10% of all banknotes circulate in transaction (Deutsche Bundesbank, 2016). In Japan, hoarded banknotes are about 40% of the total volume of cash in circulation (Fujiki & Tomura, 2017).

In many countries, demand for banknotes is stimulated by using them abroad, especially as stores of value (Judson, 2017). Movement of banknotes abroad is difficult to measure because there is no legal mechanism for the monitoring of private transfers (migrant workers) outside the banking system. Bartzsch, Rösl and Seitz (2013) researched foreign demand for euro banknotes in Germany. They found that 60% of the cumulated net issuance of banknotes was hoarded outside Germany. In the 1990s, Deutsche Bundesbank estimated that 30-40% of all deutsche marks were circulated abroad (ECB, 2003). Engert, Fung and Segendorf (2019), by way of survey, discovered that in countries (like Sweden) where domestic banknotes are used only inside the country, the level of cash in circulation decreases or stays stable (the Danish situation). The National Bank of Poland suggested that their knowledge about the use of Polish banknotes as stores of value abroad was still very small and that they did not know if foreign workers employed Polish banknotes as a store of value so this possibility complicated the estimations of demand for cash in Poland (NBP, 2020).

In the literature, many reasons for the high demand for cash are described (Lalouette et al., 2021). Some are connected with the financial system. These include:

- the lack of possibilities of collecting savings in credible institutions,
- the level of development of the payment system infrastructure and possibilities of realizing payments using different means of payment, not only cash,
- financial system stability and past crises.

Using cash as means of payments is still popular in spite of the appearance of new, modern, digital technologies and instruments of payments (Wong, Lau and Yip, 2020; Świecka et al., 2021). Transaction demand for cash and their determinants were described by Baumol and Tobin (Baumol, 1952; Tobin, 1956). Accordingly, optimal cash balance (demand for cash in transaction) is determined by:

- scale of transaction which is connected with output level in the whole economy. This is especially true in the case of demand for low denomination banknotes (ECB, 2003);
- cost of using cash or different payment instruments, and
- risk - which is measured by nominal interest rate.

Nominal or real interest rates are the result of inflation level. The ECB has observed (ECB, 2003) that in countries afflicted with high inflation, the average

legacy banknote values² are lower than in countries experiencing low inflation and low interest rates.

The possibilities of using cash as payment instruments are one of main determinants of demand for banknotes (Alonso et al., 2018). Here, the demand is connected with access to cash (number and availability of ATM and bank branches), regulation (limitation of the transaction amount realised by cash), macroeconomic environment (unemployment rate, inflation rate), cultural factors (shadow economy, corruption) and digitalization (access to internet and mobile banking).

Use of cash for precautionary or speculative purposes is determined by uncertainty (Miller and Orr, 1966; Tobin, 1958) and opportunity costs (ECB, 2003). Uncertainty is related with future levels of interest rate and future cost of portfolio adjustments. Factors determining precautionary and speculative demand have positive (output, private consumption, retail sales) or negative (opportunity cost) impacts.

Some determinants of using cash are connected with habits and levels of financial education and financial inclusion (Klapper and Singer, 2014; Newman, Tarp and van den Broeck, 2014). In conditions of low interest rates (zero-lower bound), cash becomes more attractive as a medium of payment and wealth storage, because the opportunity cost of hoarded banknotes decreases (Liñares -Zegarra & Willeson, 2021; Assenmacher et. al., 2017).

Based on the considerations on the nature and determinants of the demand for cash, the following hypotheses are formulated:

H1: The demand for cash is constantly growing and its dynamics are higher than the dynamics of GDP, which indicates that it is not solely a demand for money for transaction purposes.

H2: Demand for cash is determined by macroeconomic factors such as nominal GDP, nominal exchange rate and nominal interest rate, but the strength of their influence varies for different denominations of banknotes.

² Average legacy banknote value is the relation between total cash value in circulation and total number of banknotes in circulation.

1.3. Crisis - demand for and supply of cash

In the XXI century, the global economy was affected by two serious financial and, consequently, economic crises. The first was the Global Financial Crisis (GFC) that began in 2007 and started to have impact in the autumn of 2008, after the Lehman Brothers bankruptcy spread to the entire world's financial markets. The second crisis is connected with the SARS-CoV-2 pandemic. It started in the early spring of 2020 and it is still being felt. Both crises affected not only the financial market and the real economy, but also the supply and demand for cash.

In order to counteract the effects of the crises, the central banks of many countries put into practice expansionary monetary policies (Kozińska, 2022). Thus, both during the GFC and during the Pandemic Crisis, the first action taken by central banks was to decrease the interest rate to levels near zero (unless it was already at this level, as with the EBC interest rate before the Pandemic Crisis). That meant changes in the opportunity cost of hoarded banknotes, which is one of the determinants of demand for cash.

Another important factor affecting demand for cash was increase uncertainty. During GFC, uncertainty was connected with the destabilization of financial sector, especially the bank sector. Many banks had problems with liquidity and decline in customer confidence. In spite of the European system of deposit guarantee, in the first phase of crisis, customer confidence was weak as low levels of guarantee were offered in many member-nations.

The on-going Pandemic Crisis has little direct connection with the global financial system and banking sector. It is the result of unpredictability of the further development of the epidemic and its impact on the economy. In the crisis, however, doubts about possibilities of transmission of the disease through banknotes or credit cards appeared. As a reaction, central banks were quick to inform the population of the low probabilities of infection by this way.

Restrictions introduced during the Pandemic Crisis (isolation, lock downs etc.), however, have had impact on the increase of e-commerce and the popularisation of cashless means of payment (especially by using Internet, mobile banking, credit cards). These factors have influence on the transaction demand for cash (Maniszewski, 2021; Dannenberg, Fuchs, Riedler and Wiedeman, 2020).

During both the Global Financial and Pandemic crises, demand for banknotes saw increase (Assenmacher et al., 2017), but only large denomination banknotes were/are being hoarded. Franses and Kippers (2007) studied the denominational

structure of the Euro as used in transactions. They found that non-denomination is preferred in everyday transactions. It should be noted that research undertaken by Bissoondeal, Kargolou and Binner (2019) shows that the use of unconventional measures of monetary policy during the GFC would have been more effective if money was not being hoarded.

In connection with the study of crises impact on the demand for cash, two hypotheses are formulated:

H3: Crises affect the demand for cash, but only with regard to some denominations in a significant way.

H4: The impact of the Pandemic Crisis on the demand for cash due to the higher level of uncertainty associated with it is greater than that of the Global Financial crisis.

2. Research

2.1. Methodology

In the current literature, we can find two main currents of analysis. One is connected with the estimation of transaction and precautionary demand for cash (banknote use as means of payment and hoarded banknotes) from figures of whole cash in circulation. The second aims to construct a model that describes the force and direction of impact of different determinants of demand for cash. It is worth noting that in all studies, demand for cash is analysed in separate groups of banknotes – low, medium and high denominations. Such an approach avoids dealing with the substitution effects connecting with the withdrawal and the introduction in circulation of different denominational banknotes (Assenmacher et al., 2017). Additionally, low denomination banknotes are rather more often used to realize transactions, but high denomination banknotes are usually hoarded. However, some denomination banknotes (middle, in Poland, the 50 and 100 zloty bank notes) are used to realize transaction and are also hoarded, thus, these are analysed separately.

Researches concentrated on separating the different types of demand for cash have transaction demand for banknotes as the starting point. There are many methods of estimating transaction demand. Assenmacher et al. (2017), Rösl and Seitz (2021) and Engert et al. (2017) propose estimation by comparison with a

benchmark³. The main difficulty in applying this approach is finding benchmark countries. Otani and Suzuki's (2008) proposed method assumes that the structure of banknote denominations is stable. Accordingly, all deviations, especially increases in the structure of high denomination banknotes, are effects of an increase in hoarding. The problem in this type of estimation is choosing the base year (benchmark year) in which banknote structure is "clear" of atypical demand. Further weaknesses are connected with not including the impact of inflation, output level changes or changes in consumer behaviour and their preferences in choosing means of payments. Others methods of estimating transaction demands are:

- lifespan methods (Assenmacher, Seitz and Tenhofen, 2019). These assume that low denomination banknotes used as means of payments have shorter lifespans than hoarded banknotes. By using data about the lifespan of low denomination banknotes, we can estimate the whole demand for cash as means of payments in all denominations;
- seasonal approaches (Assenmacher et al., 2019; Otani and Suzuki, 2008). These assume that hoarded demand is stable and all deviation are the effects of seasonable changes in demand for means of payment (esp. low denomination banknotes).

Models are constructed through applying linear regression (Assenmacher et al., 2017; Rösl and Seitz, 2021). Estimations of model-explained determinants of demand for cash are connected with choosing appropriate independent variables. The spectrum of these, unfortunately, is not very extensive. In all researches, real or nominal GDP is included. The variables representing opportunity costs of cash are usually interest rate (risk-free rate as 10-year bonds) or retail bank deposit rate. In most models, nominal exchange rate is included partially as opportunity cost representation and partially as influence of foreign demand.

2.2. Data

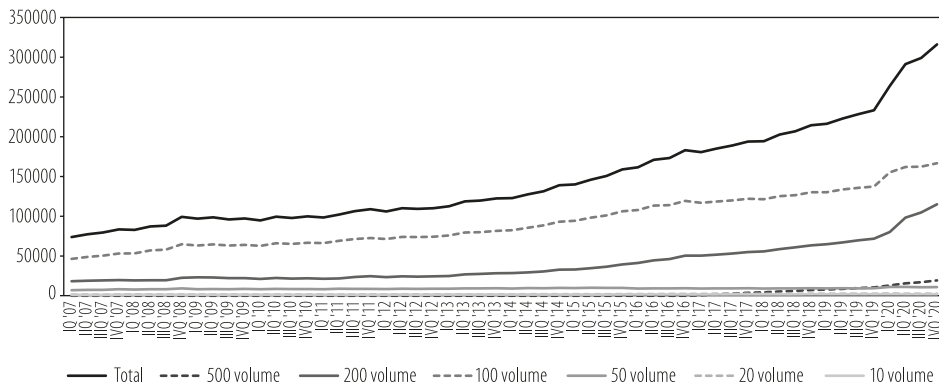
After a period of high inflation (in 1990s), in 1995, in Poland, the process of denomination was realized. Five denominations of banknotes (10, 20, 50, 100 and 200 zloty) and eight denominations of coins were introduced into circulation. Initially, due to their availability in ATMs, 10, 20, 50 and 100 zloty dominated banknotes in circulation, and the 200 zloty banknote was used less often. In 2017,

³ Benchmark is demand for cash in countries similar in cash aspects to countries covered by the study, but without the hoarded cash phenomenon.

the 500 zloty banknote appeared in circulation. At the same time, the 200 zloty became more popular (as it started to be distributed by ATMs). In this research, we concentrate only on banknotes as the main part of cash in circulation. The problem of demand of coins, especially of low denomination, is also very interesting and it can be the subject of other research.

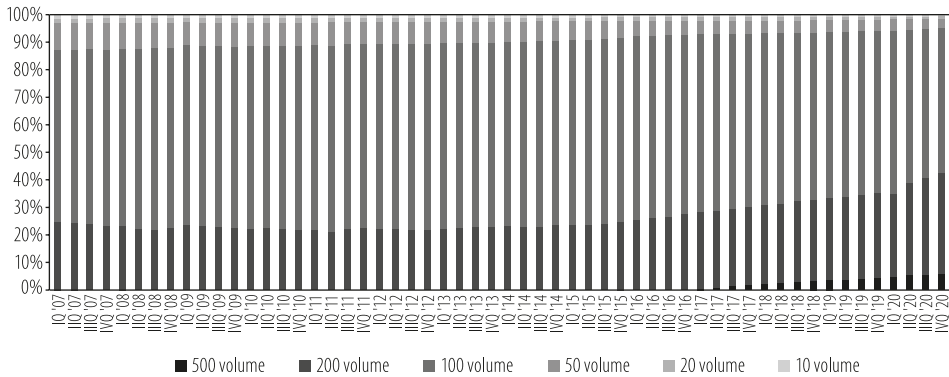
Data about volume of banknotes in circulation has been published by the National Bank of Poland since 2007. However, only information about global volumes and number of banknotes is provided. No information is available on differentiation in cash use in transaction and storing. Fig. 1 and 2 present information about level and structure of cash in circulation in Poland in the years of 2007 to 2020.

Figure 1: Banknotes in circulation – volume



Source: NBP, 2021

As indicated in the supplied figures, the value of cash in circulation was enhanced in the analysed period - from about 74 to 316 billion zloty (according to the current exchange rate, from 19 to 68 billion euro). Wherein the value of 10, 20 and 50 zloty in circulation were stable, that of 100, 200 and 500 zloty increased. If we analyse the structure of the banknotes in circulation, we can observe the increasing participation of 200 and 500 zloty (high denomination) bank notes and a notable stability of the 100 zloty bank note. At the same time, the participation of low denomination banknotes (10 and 20) and 50 decreased. Preliminary analysis allows us to conclude that high denomination banknotes, normally used as stores of value, had an increasing role in circulation, while the share of 10 and 20 banknotes in total low denomination banknotes and that of the 50 zloty banknote normally used as means of payment declined.

Figure 2: Banknotes in circulation – structure

Source: NBP, 2021

In Table 1, we present descriptive statistics of the dynamic volume of banknotes (year to year). In the analysed period of time, the mean increase of banknotes in circulation was about 11.2%. It is worth underlining that the maximum was above 35%. The mean dynamic of the 200 zloty bank note was higher – 15.2% (with maximum of above 60%). In contrast, the mean dynamic of low denomination banknotes was low – about 5%. Furthermore, the mean dynamic of the 50 zloty bank note was very low (2.8%), which can mean that the role of that denomination, both as means of payment and as a store of value, was decreasing. Of note, the mean dynamic of the 100 zloty bank note is nearly equal to the mean of total volume, which complicates the interpretation of the role of that denomination.

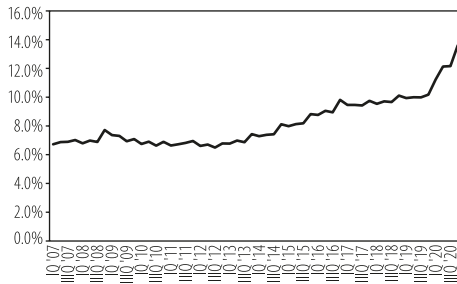
Table 1: Descriptive statistics – cash in circulation dynamic

variable	Descriptive statistics				
	sample	Mean	Min	Max	Sd
Total	54	0.112031	-0.024298	0.354344	0.074987
500	14	1.167919	0.465772	5.269396	1.252904
200	54	0.152002	-0.087743	0.601680	0.138427
100	54	0.095644	-0.014267	0.221931	0.057800
50	54	0.028084	-0.073461	0.211408	0.059783
20	54	0.050976	-0.051607	0.170440	0.046243
10	54	0.042750	0.004178	0.074868	0.014260

Source: Author's own calculations

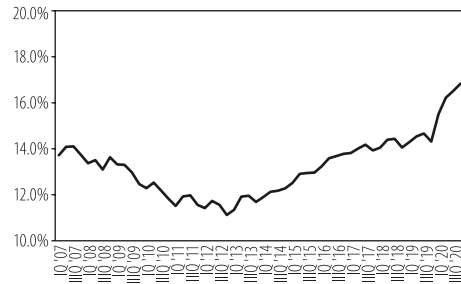
To identify changes in demand for cash, two ratios are used. The first is the measure of volume of banknotes in circulation as compared to GDP (Fig. 3). The second measure is the volume of banknotes in circulation to broad money (M3 – Fig. 4). A similar approach was used by Zamora-Perez (2021) to identify the demand for banknotes in the euro area. We can see from the figures that the cash to GDP ratio had systematically increased, from 6.88% to 13.6% (Fig. 3). Taking into account the above-presented interpretation of the structure of banknotes in circulation, it can be concluded that the use of banknotes as a means of storing value was increasing. This is confirmed by the analysis of cash to M3 ratio – in the first period (2007 – 2013), which was decreasing, and in the second period (from 2013) when it was increasing (Fig. 4).

Figure 3: Cash to GDP ratio



Source: author's own calculations.

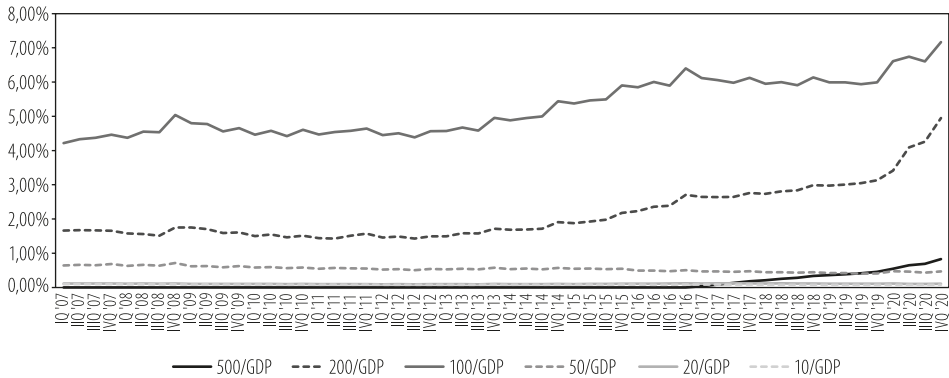
Figure 4: Cash to M3 ratio



Source: author's own calculations

The presented calculations allows to verify hypothesis 1 that demand for cash is increasing faster than nominal GDP. This relationship has confirmation in the supplied data.

It is interesting to observe the cash to GDP ratio as calculated for different denominations of banknotes (Fig. 5). We find that the ratios had increased for high denomination banknotes and the 100 zloty bank note, but for low denominations and the 50 zloty banknote, this was stable. This confirms, in the light of the quantitative theory of money, that low-denomination notes are used for transaction purposes, but high-denomination notes are used as stores of value.

Figure 5: Cash to GDP ratio – banknotes by denomination

Source: author's own calculations.

The cash to GDP ratio calculated for different denominations therefore allows the verification of the statement contained in hypothesis H1 - that increase of demand for cash is not solely connected with transaction purposes.

2.3. Variables

To verify the hypothesis H3 and H4, several variables were chosen. All were treated as independent variables. The dependent variable was demand for cash - as measured as volume of banknotes in circulation.

Gross Domestic Product, as a measure of the size of the national economy, is an important factor affecting cash demand. On the basis of the quantitative theory of money, GDP is the main determinant of transactional demand for cash. The size of the economy affects the number and volume of transactions. Demand for cash as a means of value (transactional demand) is strongly connected with the size of trade. There are, however, many another factors that determine the use of cash in transactions (such as payment habits, structure of the financial system, financial instruments, etc.).

A country's nominal exchange rate explains the part of demand for cash as a means of value - from abroad and domestically. Depreciation is usually connected with decrease of demand for domestic currency banknotes. In contrast, appreciation positively affects demand for currency from abroad. Most foreign transactions in Poland are settled in euros, so the 'zloty-euro' exchange ratio is used in the described models.

Interest rate is the main component of cash hoarded cost. The level of interest rate determines the structure of monetary aggregates, especially M1 (cash and short-term deposits). In countries (such as Poland) with financial systems that are dominated by the banking sector, the household bank deposit interest rate is the most appropriate tool for estimating demand for cash.

Both the Global Financial Crisis and the Pandemic Crisis had significant impacts on the economy and the financial system. Destabilisation of the financial system and the economy as a whole and the resulting uncertainty could be important factors influencing the level of hoarded cash. During crises, confidence in the banking sector decreases and households hoard cash as they are afraid of problems with the availability of cash. Uncertainty connected with the future situation also prompts the hoarding of cash as a safe financial asset. Table 2 lists all the independent variables.

Table 2: Independent variables

Variable	Definition	Direction of impact
GDP	Gross Domestic Product in quarterly nominal value	"+"
Exchange Rate	Nominal exchange rate zloty/euro	"+"
Interest rate	Household bank deposit interest rate	"_"
Crisis	The occurrence of a crisis – variables	"+"

2.4. Models

2.4.1. Estimation of transaction and precautionary demand for cash

To estimate demand for cash as a means of value (transactional demand), different approaches are adopted (Schmiedel, Kostova and Ruttenberg, 2012). There are two methods that are used most often. The first was proposed by Otani and Suzuki (2008). This approach assumes that structure of cash in circulation in transactional use is stable, and all deviations are connected with changes in hoarded money. This is especially true with regard to high denomination banknotes.

To verify hypothesis

H1: The demand for cash is constantly growing and its dynamics are higher than the dynamics of GDP, which indicates that it is not a solely a demand for money for transaction purposes.

Two models are used. The starting point for analysis was the structure of banknotes in circulation in IQ2007. This was the time before the GFC when the financial system (and economy) was in equilibrium. The structure of banknotes in circulation as of 31-03-2007 was, therefore, accepted as a benchmark. The estimation was prepared for the following groups of banknotes:

- first – high denomination banknotes – 500 and 200 zloty,
- second -- 100 zloty banknote,
- third –50 zloty banknote,
- fourth –20 zloty banknote, and
- fifth –10 zloty banknote.

The listed structures are presented in Table 3.

Table 3: Structure of banknotes in circulation as of IQ2007

Group of banknotes	500&200	100	50	20	10
Share	24.686	62.695	9.519	1.685	1.415

Source: Author's own calculations

In the next step, the obtained hypothetical structure was used to calculate the volume of each denomination in the assumed real total banknote volume. The following formula was employed in the estimation:

$$ED_{it} = s_i * TD_t$$

where:

ED_{it} - estimated demand for i denomination banknote in t time

s_i - i - denomination banknote share in IQ2007

TD_t - total demand for banknotes in t time.

The obtained results were subsequently compared to the observed volume for each banknote. Because the 500 zloty banknote was introduced in circulation in 2017, the assumption that it represents hoarded demand was made. The second assumption was that a combined treatment demand existed for the 200 and 500 zloty banknotes. The results of the structure estimation are presented in Figs. 6-10. Deviation on estimation was calculated as follows:

$$Dev_{it} = \frac{ED_{it} - OD_{it}}{ED_{it}}$$

where:

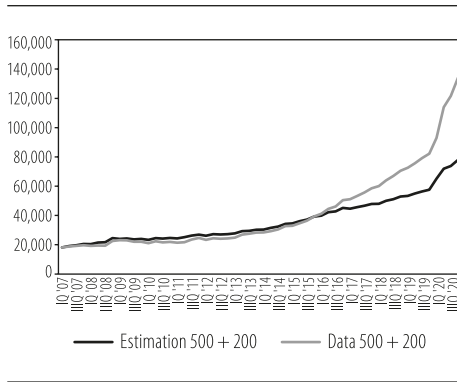
Dev_{it} - deviation of estimation for i denomination banknote in t time

ED_{it} - estimated demand for i denomination banknote in t time

OD_{it} - observed demand for i denomination banknote in t time.

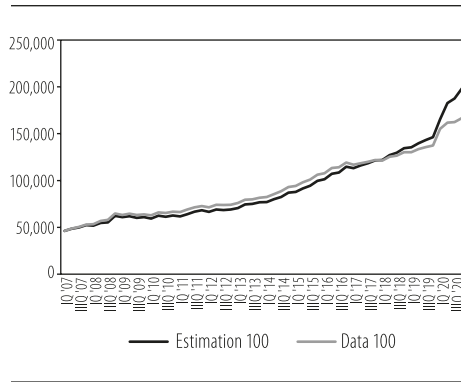
Deviation estimated and observed demand are presented in Fig. 11.

Figure 6: Estimated demand - banknotes 500 & 200 zloty



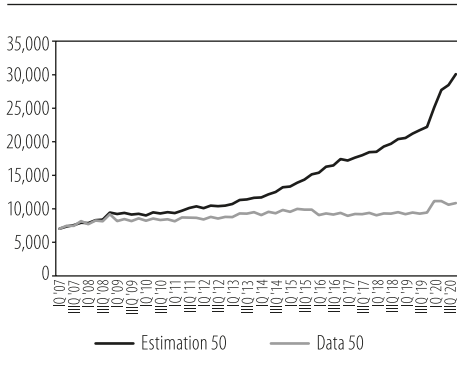
Source: Author's own calculations

Figure 7: Estimated demand - banknote 100



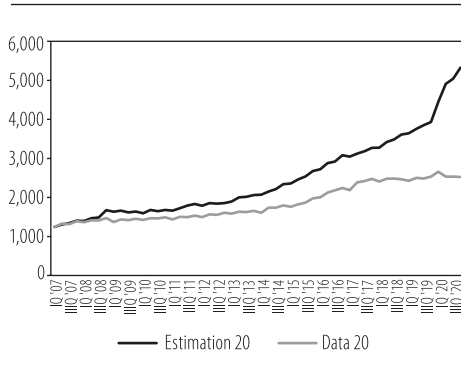
Source: Author's own calculations

Figure 8: Estimated demand - banknote 50



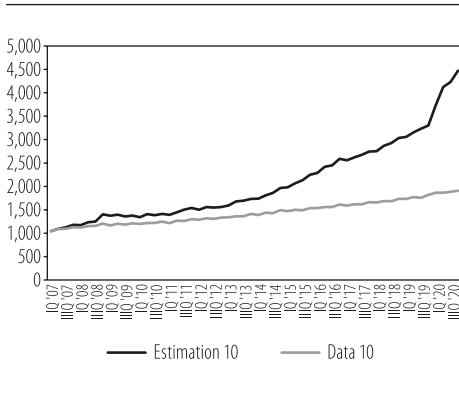
Source: Author's own calculations

Figure 9: Estimated demand - banknote 20



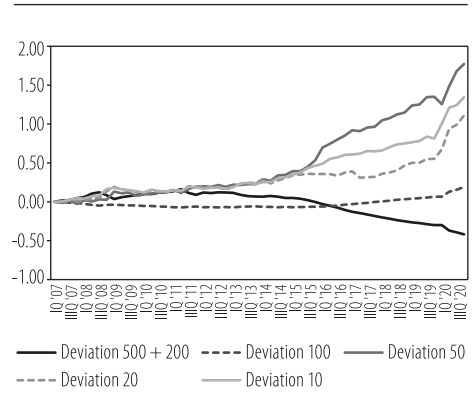
Source: Author's own calculations

Figure 10: Estimated demand - banknote 10



Source: Author's own calculations

Figure 11: Deviation – estimated vs. observed demand



Source: Author's own calculations

The estimation carried out with this method confirms the conclusions flowing from the assessment of the structure and dynamics of demand for banknotes. We found that the observed demand for low denomination banknotes (as used in transactions: 10, 20 and 50 zloty) was lower than estimated demand. Hence, the demand for banknotes as means of payment decreased in the analysed periods. We also found that the observed demand for banknotes of 500 and 200 zloty was higher than estimated. Thus, the demand for banknotes for use as a store of value increased in the analysed periods. In the case of the 100 zloty banknote, we did not notice significant differences between observed and estimated demand.

The second of the applied methods of estimating the transaction demand for cash uses the frequency rate of return. Frequency rate of return is the quotient of a volume of banknotes lodged at the central bank by banks and other entities in the last four quarters, to the average volume of banknotes in circulation in an analogous period of time. A similar approach was used by Anderson (1977) and Assenmacher et al. (2017). It is based on the assumption that low denomination banknotes are usually used only in transactions. Therefore, the frequency rates of return of such denominations are typical for whole cash use and serve as measures of volume of use. We can, thus, calculate the transactional demand for cash using the frequency return ratio of low denomination banknotes. The National Bank of Poland has published frequency return ratios from 2016 onwards in yearly periods. The published frequency return ratios for banknotes are presented in Table 4.

Table 4: Frequency return ratio

Year	10	20	50	100	200	500
2016	1.00	1.20	2.30	1.00	0.72	0.00
2017	0.90	1.40	2.10	0.90	0.74	0.30
2018	0.82	1.35	2.05	0.89	0.72	0.16
2019	0.76	1.27	2.10	0.85	0.67	0.10
mean	0.870	1.305	2.138	0.910	0.713	0.140

Source: Author's own calculations

The estimation of total demand for banknotes was calculated using the following formula:

$$\sum \frac{OD_{it} * frr_{it}}{frr_n}$$

where:

OD_{it} - observed demand for i denomination banknote in t time

frr_{it} - frequency return ratio for i denomination banknote in t time

frr_n - mean frequency return ratio for the chosen denomination.

By using the mean frequency return ratios for 10, 20 and 50 zloty banknotes, we estimated total demand for banknotes in circulation, and compared this with the published data. Because the function of cash circulation dramatically changed in the last few years (NBP, 2018), we have estimated the demand for banknotes in the years between 2016 and 2020. The results of research are presented in Table 5.

The estimation carried out with this method allows establishing the transaction demand. To ascertain this, we used the mean frequency return ratio for low denomination banknotes, as these are probably used as means of payment and, hence, represent transaction demand. We found that using the mean frequency return ratio for the 10 zloty banknote produces a result above the observed demand. Because we know that observed demand contains transaction demand and demand for banknotes as store of value, this estimation is considered false. It is an interesting observation that the mean frequency return ratio for the 10 zloty banknote (which is obviously a transactional banknote) turned out to be the best predictor of transaction demand. An interesting direction of research could be to explain the reasons for this state of affairs.

Table 5: Estimation of demand for banknotes as compared with observed demand

Year	Estimated demand	Observed demand	Observed – estimated demand	Observed/estimated demand (%)
10 zloty frequency return ratio 0.870				
2016	236 359.38	182 975.21	-53 384.17	77.41
2017	230 930.55	193 950.16	-36 980.39	83.99
2018	242 902.18	214 402.97	-28 499.22	88.27
2019	285 587.48	233 356.10	-52 231.38	81.71
2020	210 696.30	316 044.44	105 348.15	150.00
20 zloty frequency return ratio 1.305				
2016	157 572.92	182 975.21	25 402.29	116.12
2017	153 953.70	193 950.16	9 996.46	125.98
2018	161 934.79	214 402.97	52 468.18	132.40
2019	167 945.90	233 356.10	65 410.21	138.95
2020	140 464.20	316 044.44	175 580.25	225.00
50 zloty frequency return ratio 2.138				
2016	96 202.41	182 975.21	86 772.79	190.20
2017	93 992.79	193 950.16	99 957.38	206.35
2018	98 865.45	214 402.97	115 537.52	216.86
2019	102 535.39	233 356.10	130 820.71	227.59
2020	85 757.09	316 044.44	230 287.36	368.53

Source: Author's own calculations

Using the mean frequency return ratio for the 20 and 50 zloty banknotes produced results below the observed demand. The observed differences could be treated as demand for banknotes as store of value. We found that the volume of hoarded banknotes (demand for banknotes as store of value) increased, especially in 2020, in the period of the Pandemic Crisis. This is consistent with the results of other research (Zamora-Perez, 2021).

Both approaches allowed for a positive verification of the hypothesis H1 indicating that the observed increase of demand for cash is the result of hoarded banknotes, as the demand for banknotes as means of payment is lower than the entire observed demand for cash.

2.4.2. Regression

A regression analysis was applied to verify hypothesis

H2: Demand for cash is determined by macroeconomic factors such as nominal GDP, nominal exchange rate and nominal interest rate, but the strength of their influence varies for different denominations of banknotes.

The inclusion in the model of variables illustrating the impact of crises on the demand for money also allowed for the verification of subsequent hypotheses.

H3: Crises affect the demand for cash, but only with regard to some denominations in a significant way.

and

H4: The impact of the Pandemic Crisis on the demand for cash due to the higher level of uncertainty associated with it, is greater than that of the global financial crisis.

The general formula of the regression model is the following:

$$DV = \beta_0 + \beta_1 IV + \varepsilon_i$$

where:

DV is a dependent variable vector reflecting factors influencing demand for banknotes.

IV is an independent variables vector reflecting demand for banknotes.

B is a coefficient estimate for the independent variable.

ε_n is a random variable.

Regression analyses were prepared for all banknotes (cash) and for separate denominations. Four groups of banknotes were analysed:

- first – high denomination banknotes – 500 and 200 zloty.
- second – 100 zloty banknotes.
- third – 50 zloty banknotes.
- fourth – the low denomination banknotes of 20 and 10 zloty.

This segmentation was decided because we assumed that only high denomination banknotes are hoarded. Moreover, the 500 zloty banknote was introduced

to circulation later than the other banknotes. As we also adopted the notion that low denomination banknotes represent transactional demand, these can be grouped together for analysis. Of note: banknotes of 100 and 50 zloty could not be uniquely assigned to either hoarded or transactional demand.

OLS regression results are presented in Table 6.

Table 6: OLS regression analysis results

Variables	Denomination of banknotes			
	500&200 zloty	100 zloty	50 zloty	20&10 zloty
GDP	1.313*** (0.182)	0.944*** (0.098)	0.274*** (0.057)	0.601*** (0.061)
Exchange rate	1.197** (0.421)	0.979*** (0.226)	0.241* (0.133)	0.329* (0.140)
Interest Rate	-7.236*** (1.044)	-3.747*** (0.560)	-0.210 (0.330)	-2.535*** (0.348)
GFC	0.112*** (0.030)	0.037* (0.016)	0.008 (0.010)	0.028*** (0.010)
Pandemic Crisis	0.185*** (0.043)	0.027 (0.023)	0.033* (0.014)	-0.010 (0.015)
F statistic	139.564***	192.812***	31.373***	172.382***
R square	0.97	0.98	0.87	0.97

*p<0.1; ** p<0.01; *** p<0.001

Source: Author's own calculations

To construct this regression model, we use three numeric independent variables (GDP, exchange rate and interest rate) and two variables that take into account the impact of crises – the Global Financial Crisis and the Pandemic Crisis. For all denominations, except the 50 zloty banknote, R square is above 97%. For the 50 zloty banknote, the value is above 87%. All models largely explain the volatility of demand.

We found that for all denomination groups, two variables (GDP and exchange rate) had statistically significant impact on demand. The weakest impact of GDP variables was for banknote 50 and the strongest for the combined 500 and 200 zloty banknote group. The impact of exchange rate was strongest for high denomination banknotes (the combined 500 and 200 zloty banknotes, and the 100 zloty banknote). Since the exchange rate explains the hoarded demand from abroad, the results indicate that high denomination banknotes are hoarded. The impact of interest rate is very interesting. There is not a statistically significant impact on the 50 zloty banknote. On the other denominations, for this variable,

impact is statistically significant and very strong - especially on the high denominations. As evidenced in the table, the Global Financial Crisis had impact on demand for high denominations (500&200) and for low denominations (20&10). In contrast, the impact on the 100 zloty banknote was not strong. The situation was different in the case of the Pandemic Crisis. Here, the impact was statistically significant and strong only for high denominations and was notably weak for 50 zloty banknotes.

The conducted analyses allowed for a positive verification of hypotheses H2, H3 and H4. Macroeconomic factors such as nominal GDP, nominal exchange rate, and nominal interest rate determine demand for cash. However, some of these determinants have statistically significant and strong influence only for high denomination banknotes. This represents demand for cash as a store of value. The effects of the Global Financial Crisis and the Pandemic Crisis proved statistically significant only for high denominations, but the impact was weak. However, it should be noted that the impact of the Pandemic Crisis on these denominations was stronger. Moreover, while the GFC determined demand for low denomination banknotes, the Pandemic Crisis had little effect on them.

3. Findings and discussion

The conducted research allowed for the identification of many interesting results. These concern the nature of the demand for banknotes - transactional or hoarded, and the factors determining the demand for various denominations of banknotes. Our results correspond with the results of the researches of other authors (ECB, 2003; Bailye, 2009).

Our first and main fundamental finding is that demand for banknotes has increased and this growth rate is higher than the GDP dynamics. This indicates that the demand for cash is not a demand for the notes for transaction purposes. This is confirmed by our research on estimating the size of the transaction demand. We found that the observed transaction demand (demand for low denomination banknotes - 10&20 and 50 zloty) throughout the entire period of the analysis increased more slowly than the estimated transaction demand for these denominations. However, the works of Engert et al. (2019) and Lallouette et al. (2021) indicate that in countries where the currency is local, its volume in circulation decreases during crises. Our research does not support this conclusion. According to the results of our analysis, during the time period researched, the observed hoarded demand for high denomination banknotes (500 and 200) increased faster than the estimated path of growth.

In order to verify the obtained results, we conducted a study using a different method of estimating the transaction demand. By doing so, we established that in the years of 2016 – 2020, observed demand for banknotes was higher than estimated transaction demand for banknotes. A notably large difference was found in 2020. Presumably, this was caused by the Pandemic Crisis. The study of factors determining the size of the demand for banknotes confirms this assumption. Other researchers have come to similar conclusions (Lallouette et al., 2021).

The second stage of the study of the demand for banknotes was an attempt to estimate the strength and direction of the impact of selected factors. We saw that nominal GDP is one of several factors that the impact on demand for all denominations is very strong. This result is expected and described by other authors. As a result of his research, for example, Zamora-Perez (2021) discovered that growth of demand for euro banknotes is higher than growth of GDP. This outcome suggests that there are other determinants of demand for banknotes than the development of economic activity.

The same case is with nominal exchange rate. The impact of this factor is strong and statistically significant for all denominations. Other researchers have obtained similar results (Bahmani-Oskooee, Halicioglu and Bahmani, 2017; Nyumuah, 2018). At the same time, it should be noted that the described factors have the strongest effect on high denominations and 100 zloty banknotes, which represent hoarded demand. The impact upon low denominations and 50 zloty banknotes is statistically significant too, albeit weaker. This means that despite the conclusions of the quantitative theory of money that GDP growth affects the number of transactions in the economy and transaction demand for banknotes, GDP growth has a stronger impact on hoarded demand. Because the nominal exchange rate is connected with demand for cash as a store of value, the effect on high denominations and 100 zloty is stronger than that upon low denominations and 50 zloty banknotes.

Against the backdrop of low interest rates, the opportunity cost of holding cash decreases. This outcome is one of the reasons for the increasing demand for cash, which has become a store of value to a greater extent, (Zamora-Perez, 2021; Ragot, 2014; Ball, 2012). The analysis of the influence of interest rate on the demand for banknotes leads to interesting conclusions. This variable is connected with the alternative cost of cash. We saw that the interest rate impact on demand for each denomination is very strong, but the strongest effect is on high denominations and low denominations. We can interpret this observation as follows: low interest rates mean low alternative costs of hoarded cash, so demand for high denominations increases. In the context of low interest costs, interchangeability between

cash and deposit is strong, and households more often use banknotes than cashless instruments in transactions. Hence, the demand for low denominations increases as well.

The influence of interest rate on the demand for 50 zloty banknotes, however, was not statistically significant. This observation leads to the conclusion that this banknote has a different nature than high denominations (hoarded) and low denominations (transaction). If we analyse the variables effect on the demand for 50 zloty banknotes for the considered time period, we find that only nominal GDP and nominal exchange rate and the Pandemic Crisis have statistically significant impact on this. Thus, a significant difference between the employment and treatment of this banknote exists to that of the other denominations. The 50 zloty banknote, therefore, cannot be treated as high denomination nor as low denomination. This leads to the conclusion that despite the high degree of explaining the variability of demand by the regression model, there are other variables, not included in the study, influencing this demand.

An important element of our research is the taking into account of the impact of uncertainty related to two crises – the Global Financial Crisis and the Pandemic Crisis, as a behavioural factor, and their effect on demand for banknotes. We discovered that the GFC had weak impact (but statistically significant) on demand for high denomination and low denomination banknotes. This result is different from expectations, because in literature, we found researches that describe only a strong positive impact on high denominations (Assenmacher et al., 2017). With regard to the Pandemic Crisis, we noted that it has a strong and statistically significant impact only on the demand for high denominations. The specific situation during the on-going pandemic gives explanations to that observation. The situation that has given rise to this effect is that the lockdown in the economy has limited the possibility of in-person shopping and strongly activated Internet trade with on-line means of payment. Thus, transaction demand during the Pandemic Crisis has been stable. A similar observation has been made by other researchers (Auer, Cornelli and Frost, 2020). Overall, according to our study results, hoarded demand for high denominations is strongly affected by interest rate, nominal exchange rate and nominal GDP, and the direct impact of crises upon this was rather weak. In contrast, transaction demand for low denominations is affected mainly by interest rates and nominal GDP. It should be noted that the nominal exchange rate and the GFC effect were rather weak.

4. Conclusion

Our research shows the important role of cash in modern economy. Despite the popularization of modern cashless payment instruments, the demand for cash continues to grow. This is because cash is used as a store of value. As a result, despite the decline in the demand for transactional money, the global demand for money grows. Our research also shows an increasing share of cash in relation to GDP and in monetary aggregates. In our opinion, this means that cash is still an important element of the financial system that central banks should take into account in monetary policy pursuit.

Factors influencing the volume of demand for money described on the basis of the quantitative theory of money are not fully reflected in the research results. Nominal GDP has the strongest impact on the demand for high-denomination notes that are not used for transaction purposes. It is surprising that the impact of the crises on the demand for money is weak. It can be assumed that this is related to the good condition of the domestic financial sector, which is highly trusted. However, further research is required to confirm this hypothesis.

It is also worth noting that while the factors determining the demand for high and low denomination notes are statistically significant, the determinants of the demand for medium denomination notes are not fully researched and require a further in-depth study.

Our research allowed to verify the findings regarding macroeconomic factors influencing the demand for money, resulting from both classical theories of money and earlier empirical research. Our unique contribution to the current state of knowledge is the separation of the aggregate stream of money demand into transaction demand, into low denomination and hoarded banknotes, into high denomination banknotes and building a separate regression model for each of them. These models indicated a diversified strength of the impact of macroeconomic factors on various types of demand.

Our original contribution to the development of finance is to include the behavioural factor in the form of uncertainty behaviour among determinants of cash demand and to examine the strength and direction of its impact on precautionary and transactional demand. Our research allowed to conclude that there is a significant difference between the strength of influence of the factors determining transactional demand and precautionary demand, which implies that they should be treated as independent streams.

The application value of our research is related to the indication of the growing demand for high-denomination notes in periods of uncertainty, with no significant impact on the demand for low-denominations. This points to the structure of the banknote stocks that central banks should hold. The willingness of central banks to immediately meet the growing demand for banknotes is one of the conditions for maintaining the stability of the financial system, which is one of the key tasks of modern monetary authorities.

References:

1. Alonso, J., Ganga, H., Belio, J.L., Martin, A., Miron, P., Plata, C.T., Rubio, A., Santos, A., Burke, J.V. (2018). The use of cash and its determinants. BBVA Research.
2. Álvez, M., Lluberas, R., & Ponce, J. (2020). The cost of using cash and checks in Uruguay. *Journal of Central Banking Theory and Practice*, 9(2), 109-129.
3. Anderson P. (1977), Currency in use and in hoards, *New England Economic Review*, March/April, 21-30.
4. Assenmacher, K., Seitz, F. Tenhofen, J. (2017). The use of large denomination banknotes in Switzerland. International Cash Conference 2017 - War on Cash: Is there a Future for Cash? 25 - 27 April 2017. Island of Mainau. Germany. <https://www.econstor.eu/handle/10419/162917>. dostępnia 10.08.2021.
5. Assenmacher, K., Seitz, F., Tenhofen, J. (2019). The demand for Swiss banknotes: some new evidence. SNB Working Papers 2/2019.
6. Auer, R., Cornelli, G., Frost, J. (2020). Covid-19. cash. and the future of payments. *BIS Bulletin* No 3.
7. Bagnall, J., Bounie, D., Huynh, K., Kosse, A., Schmidt, T., Schuh, S., Stix, H. (2016). Consumer cash usage: a cross-country comparison with payment of the diary survey date. *International Journal of Central Bank* No 12. pp. 1 – 62.
8. Bahmani-Oskooee, M., Halicioglu, F., Bahmani, S. (2017), Do exchange rate changes have symmetric or asymmetric effects on the demand for money in Turkey?, *Applied Economics*, 49:42, pp. 4261-4270.
9. Ball, L. (2012), Short-run money demand, *Journal of Monetary Economics* 59, pp. 622–633.
10. Bailey, A. (2009, December). Banknotes in Circulation–Still Rising. What Does this Mean for the Future of Cash?. In Speech at the Banknote 2009 Conference, Washington DC (Vol. 6).
11. Bartzsch, N., Rösl, G., Seitz, F. (2013). Estimating the foreign circulation of banknotes. *Economics Letters* 119. pp. 165 – 167.
12. Baumol, W. J. (1952). The Transactions Demand for Cash: An Inventory Theoretic Approach. *The Quarterly Journal of Economics* 66 (4). pp. 545–556.
13. Bissoondeal, R.K., Karoglou, M. and Binner, J.M. (2019). Structural changes and the role of monetary aggregates in the UK. *Journal of Financial Stability* 42. s. 100 – 107

14. Dannenberg, P., Fuchs, M., Riedler, T. and Wiedeman, C. (2020). Digital Transition by COVID-19 Pandemic? The German Food Online Retail. *Journal of Economic and Human Geography. Special Issue: The Geography of the COVID-19 Pandemic* vol. 111. Issue 3.
15. Deutsche Bundesbank (2016). Cash as a means of payments and store of value. Annual Report 2015.
16. Duwendag, D., Ketterer, K.H., Kösters, W., Pohl, R. and Simmert, D.B. (1996). Teoria pieniądza i polityka pieniężna. Poltex. Warszawa.
17. European Central Bank (2003). The demand for currency in the euro area and the impact of the euro cash changeover. *Monthly Bulletin* pp. 39 – 51.
18. Engert, W., Fung, B., Segendorf, B. (2019). A tale of two countries: Cash demand in Canada and Sweden. Staff Discussion Papers. No 2019-7. Bank of Canada.
19. Esselink, H. & Hernandez L. (2017). The Use of Cash by Households in the Euro Area. *ECB Occasional Paper* No 201.
20. Franses, P.K. & Kippers, J. (2007). An empirical analysis of euro cash payments. *European Economic Review* 51. pp. 1985 – 1997.
21. Fujiki, H. & Tomura, H. (2017). Fiscal cost to exit quantitative easing: the case of Japan. *Japan and the World Economy* 42. 1–11. <https://doi.org/10.1016/j.japwor.2017.02.003>.
22. Judson, R. (2017). The Death of Cash? Not So Fast: Demand for U.S. Currency at Home and Abroad. 1990-2016. International Cash Conference 2017 - War on Cash: Is there a Future for Cash? 25 – 27 April 2017. Island of Mainau. Germany
23. Klapper, L. & Singer, D. (2014). The Opportunities of Digitizing Payments. The World Bank Development Research Group. Better Than Cash Alliance. and the Bill & Melinda Gates Foundation, prepared for the G20 Global Partnership for Financial Inclusion.
24. Kozińska, M. (2022). CEE EU Central Banks' Policy during the First Wave of COVID-19. *Journal of Central Banking Theory and Practice*, 11(3), 5-32.
25. Lalouette, L. & Esselink, H. (2018). Trends and developments in the use of euro cash over the past ten years. *ECB Economic Bulletin* 6/2018.
26. Lalouette, L., Zamora-Pérez, A., Rusu, C., Bartzsch, N., Politronacci, E., Delmas M., Rua, A., Brandi, M., Naksi, M. (2021). Foreign Demand for Euro Banknotes. *ECB Occasional Paper* No. 2021/253.
27. Liñares-Zegarra, J. & Willeson, M. (2021). The effects of negative interest rates on cash usage: Evidence for EU countries. *Economics Letters* 198.
28. Maniszewski, M. (2021). Konsumpcja w pandemii. <https://pie.net.pl/wp-content/uploads/2021/05/PIE-Konsumpcja-w-pandemii.pdf>. (access 20.10.2021).

29. Miller, M. H. & Orr, D. (1966). A Model of the Demand for Money by Firms. *The Quarterly Journal of Economics* 80 (3). 413–435
30. Narodowy Bank Polski (2018). Report on Cash Circulation in Poland in 2018. <https://www.nbp.pl/en/publikacje/inne/cash-circulation-2018.pdf> (access 16.10.2021).
31. Narodowy Bank Polski (2020). Imigranci w polskiej gospodarce – raport z badań ankietowych. Warszawa.
32. Narodowy Bank Polski (2021). Statystyka monetarna i finansowa. https://www.nbp.pl/home.aspx?f=/statystyka/pieniezna_i_bankowa/m3.html (access 16.10.2021).
33. Newman, C., Tarp, F. and van den Broeck, K. (2012). Social Capital. Network Effects And Savings In Rural Vietnam. WIDER Working Paper 2012/039 Helsinki: UNU-WIDER.
34. Nyumuah, F.S. (2018), The Impacts of Interest Rate and Exchange Rate Volatilities on the Demand for Money in Developing Economies, *International Journal of Economics and Finance*; Vol. 10, No. 3.
35. Otani, A. & Suzuki, T.(2008). Background to the High Level of Banknotes in Circulation and Demand Deposits. *Bank of Japan Review Series* 08-E-5, Bank of Japan.
36. Ragot, X. (2014), The case for a financial approach to money demand, *Journal of Monetary Economics* 62 pp. 94–107.
37. Rösl, G. & Seitz, F. (2021). Cash and crisis: no surprises by the virus. Institute for Monetary and Financial Stability. *Working Paper Series* No. 150.
38. Schmiedel, H., Kostova, G., Ruttenberg W. (2012). The social and private costs of retail payment instruments. A European perspective. *EBC Occasional Paper* No 137.
39. Świecka, B., Terefenko, P., Paprotny, D. (2021). Transaction factors' influence on the choice of payment by Polish consumers. *Journal of Retailing and Consumer Services* No 58.
40. Tobin, J. (1956). The Interest-Elasticity of Transactions Demand For Cash. *The Review of Economics and Statistics* 38 (3). 241–247.
41. Tobin, J. (1958). Liquidity Preference As Behavior Towards Risk. *Review of Economic Studies* 25. 65–86.
42. Wong, T. L., Lau, W. Y., & Yip, T. M. (2020). Cashless payments and economic growth: Evidence from selected OECD countries. *Journal of Central Banking Theory and Practice*, 9(s1), 189-213.
43. Zamora-Perez, A. (2021). The paradox of banknotes: understanding the demand for cash beyond transactional use. *ECB Economic Bulletin*. Issue 2/2021..