

Macroeconomic Uncertainty and the Demand for Cash in Poland*

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Abstract

We examine the relationship between economic uncertainty and the demand for physical cash, setting our study apart from the extensive literature that focuses on broad monetary aggregates. We use two recently developed uncertainty indices for Poland—based on newspaper coverage and internet searches—spanning nearly 20 years, combined with autoregressive distributed lag (ARDL) models for long-run analysis and threshold regression for short-run investigation. We do not find a stable long-run relationship, but we observe significant nonlinearities in the short-run comovements. Large changes in uncertainty are associated with similar reactions in cash demand, while during “normal times”, this relationship disappears or even reverses in some instances.

Keywords: demand for cash, banknotes, uncertainty, threshold models, nonlinear analysis

JEL Codes: E41, E51, D80

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1 Introduction

Growing global uncertainty has renewed interest in its macroeconomic implications (Bobasu et al., 2024; Claus & Dedewanou, 2024; DeMartino et al., 2024), particularly concerning the demand for money (Choudhry, 2023; Nusair et al., 2024). While the determinants of demand for broad monetary aggregates are well studied, the specific impact of uncertainty on the demand for cash – especially in the form of banknotes – has received comparatively less attention.

Some case studies (Bartzsch et al., 2025; Rösl & Seitz, 2022, 2024) suggest that uncertainty can drive the demand for physical cash, particularly in the aftermath of financial crises. Similarly, Bundesbank (2024) recently presented an extensive descriptive analysis of cash behavior during periods of extraordinary uncertainty, including disruptions related to digital infrastructure, financial system crises, natural disasters, political instability, and exchange rate crises. However, most of these studies examine only narrow time windows immediately following uncertainty shocks affecting the economy. Few studies consider the longer-term and systematic pattern in the uncertainty–cash demand nexus. While most of these studies generally confirm increased cash demand during periods of heightened uncertainty, they remain inconclusive about the existence and direction of this relationship over a longer time window. Our study seeks to address this gap by exploring whether the link between uncertainty and demand for physical cash is episodic (only during periods of heightened uncertainty) or reflects a more persistent economic pattern. We argue that doubts about the cash demand response to changes in uncertainty can be explained by its nonlinear nature.

Using Poland as a case study, we find no evidence of a stable long-run relationship between uncertainty and demand for physical cash. Instead, we show that elevated levels of economic uncertainty (immediately following a shock) are associated with a strong reaction by economic agents to hold more cash (mainly banknotes) as a safe asset. This effect is most pronounced immediately after the shock but diminishes over time. Notably, such behavior is observed only during brief periods of substantial increases in uncertainty. Moreover, we find that this behavior can even reverse during "normal" times, where we document cases of a statistically significant negative relationship between macroeconomic uncertainty and cash demand. To our knowledge, this is the first study to show such nonlinear short-term movements in uncertainty and the demand for physical cash.

To demonstrate the nonlinear nature of the relationship between uncertainty and the demand for physical cash, we employ diverse research methods, including threshold regression models that differentiate periods of high and low uncertainty. As a measure of uncertainty, we use the economic policy uncertainty (EPU)

index, recently calculated for Poland (Białkowski et al., 2025). This news-based measure is well established in the literature and frequently used in empirical studies. Additionally, we use a new internet-search-based measure – the macroeconomic uncertainty index (MUI) developed by Pietrucha and Gulewicz (2025b).

Considering the practical relevance of our research, it is important to note that despite the growing prevalence of digital payments, research on the demand for cash remains both empirically and practically significant. Although electronic transaction volumes continue to increase, physical money still represents a substantial share of total money in circulation. Moreover, until recently, many economies have experienced a paradoxical rise in the share of cash in the economy (measured as a percentage of GDP and broad monetary aggregates). For example, in Poland, the cash-to-GDP ratio increased from 6.4% in 2006 to nearly 11% in 2024, temporarily reaching 12.9% in 2020. The share of cash in M3 increased from 13% to 16%. Only in the case of M1 is it lower – 25.4% in January 2006 and 21.5% in December 2024 (NBP, 2024d). Similar trends are observed in other economies, including the Eurozone (Bundesbank, 2024; Shy, 2023). In the medium term, a full transition from physical cash to a completely cashless economy is neither feasible nor imminent. Major central banks (ECB, 2025) and the European Commission (European Commission, 2023) reaffirm that cash will remain an essential component of the monetary system, coexisting with digital payments and emerging central bank digital currencies.

Choosing Poland as a case study offers several advantages. First and foremost, the Polish zloty is not an international currency and is not commonly used outside of Poland. This limitation poses a significant challenge when estimating demand for money in the United States, the Eurozone, or other regions where currency is widely used beyond national borders. The Polish economy is stable and relatively fast-growing. Although Poland was not directly affected by the war in Ukraine and did not suffer damage to its payment infrastructure, its geographical proximity to the conflict and the resulting political context create considerable uncertainty. On the other hand, Poland is advanced in the transition to electronic payments (in contrast to some European countries where cash remains more dominant), especially mobile payments, with innovations such as the widely used Blik payment system. The adoption of cashless payments in Poland exceeds the EU average, and in certain areas, the country ranks among the leaders (NBP, 2024c). Consequently, Poles are neither at the forefront of electronic payment usage, as seen in countries like Sweden, nor strong advocates of cash, as observed in Germany or Switzerland. Therefore, we believe Poland presents a valuable case study for understanding cash demand.

The structure of the paper is as follows. We begin with a brief review of the literature on the relationship between uncertainty and the demand for money,

acknowledging its limitations, and then present our hypotheses. Section 3 outlines the data and methods used in our analysis. Section 4 presents baseline results for uncertainty, measured by the EPU index and the MUI. In Section 5, we provide additional results. Finally, Section 6 offers a discussion of our empirical findings.

2 Demand for money and uncertainty – literature review

The broad context of our study is the theory and empirics of demand for money. Research on this topic has a long-standing tradition; however, it has been considered less significant in recent years for practical reasons.¹ Consequently, there has been relatively little progress in the theoretical framework since the early 21st century, leaving most foundational studies dated prior to this period.

The foundation of modern money demand theory is rooted in Keynes' liquidity preference theory, which identifies three primary motives for holding money: the transactions motive (driven by the need to make payments in current transactions), the speculative motive (shaped by expectations about future interest rates and asset prices), and the precautionary motive (related to economic uncertainty). Over time, macroeconomic research has largely concentrated on the transactions motive, represented by the Baumol–Tobin model, which was developed independently by Baumol (1952) and Tobin (1956). This model remains central to monetary economics, emphasizing how economic agents optimize money holdings to minimize the costs of holding cash and conducting transactions. Other theoretical frameworks, such as the cash-in-advance model and the shopping-time model, have also emphasised the transactional role of money (Serletis, 2007). The second major approach in money demand theory is the portfolio approach, which originates from Tobin's (1956) article. In this work, he formulated the demand for money for an individual based on assumptions of uncertain expectations and risk aversion. Tobin reinterpreted the Keynesian asset theory of money demand through the lens of portfolio theory, emphasizing the speculative motive. A key feature of Tobin's theory is its explanation of the speculative demand for money, based on the assumption of uncertain expectations and the principle of portfolio diversification (Serletis, 2007).

¹For a long time, discussions regarding the demand for money predominantly focused on its stability, particularly in the context of verifying the conditions necessary for implementing a Friedman-type monetary policy—centered on stabilizing the growth of the money supply. However, the current approach to monetary policy, which is primarily based on interest-rate mechanisms adopted by most central banks, treats the quantity of money as a secondary concern (Walsh, 2017). As a result, demand for money is no longer a focal point for policymakers aiming to stabilize output and inflation. Consequently, interest in studying the demand for money as a prerequisite for monetary-oriented policy has declined.

The precautionary motive, once considered distinct, has largely been incorporated into the transactions motive in most models (Cardim De Carvalho, 2010) and has, as a result, remained outside the scope of empirical research for an extended period. Only a few studies have attempted to revive interest in precautionary demand (Faig & Jerez, 2007; Frenkel & Jovanovic, 1978; Salas, 2025; Sciortino et al., 1987; Telyukova & Visschers, 2013; Whalen, 1966).

Recent discussions about the importance of uncertainty in the demand for money function are primarily empirical in nature. After a long period of neglect, uncertainty is once again receiving considerable attention in various empirical studies and has re-emerged as a key factor influencing the demand for money. This renewed focus is evident in the works of researchers such as (Bahmani-Oskooee & Nayeri, 2020; Bahmani-Oskooee et al., 2021; Bissoondeal et al., 2023; Gan, 2019; Karpetis et al., 2019; Nusair et al., 2024; Thompson & Thompson, 2021). The foundation for empirical research in this area is based on an equation that incorporates essential elements common across different theories of money demand (Serletis, 2007). Generally, this demand for money equation can be written as

$$\frac{M_t}{P_t} = \Phi(R_t, Y_t) \quad (1)$$

where M_t is nominal money balances demanded, P_t is the price index, Y_t is the scale variable relating to activity in the real sector of the economy (a proxy for the number of transactions), and R_t is the opportunity cost of holding money (Serletis, 2007). Some studies also incorporate inflation and exchange rate fluctuations (Barnett et al., 2022; Chen & Valcarcel, 2025; El-Shagi & Zheng, 2022). Numerous studies differ, among other things, in the definition of money used. Both narrow (monetary base, M1) and broad (M2 and M3) definitions of money are used; a few studies consider Divisia-type monetary aggregates. Standard money demand variables are supplemented with proxies for uncertainty. Typically, EPU or measures based on financial uncertainty, such as the volatility index, are used.

Empirical findings on the relationship between uncertainty and money demand remain inconclusive. Some studies suggest that heightened economic uncertainty leads to a short-term decline in money holdings, as individuals hedge against expected inflation by reducing liquidity (Bahmani-Oskooee et al., 2015; Choudhry, 2023; Ivanovski & Churchill, 2019). In contrast, long-run effects indicate that increased uncertainty encourages individuals to hold more cash as a liquidity buffer against economic instability (Bahmani-Oskooee et al., 2016; Ivanovski & Churchill, 2019). Other studies highlight asymmetric responses to changes in uncertainty, that is, different reactions to increases and decreases in uncertainty (Bahmani-Oskooee & Nayeri, 2020; Bahmani-Oskooee et al., 2021).

Nevertheless, findings across different studies are highly heterogeneous. For example, Choudhry (2023) analyzed the impact of EPU on money demand stability in the UK during the interwar period and found a negative relationship. Causality tests confirmed both short- and long-run causality between uncertainty and money demand. Bahmani-Oskooee and Nayeri (2020) provided evidence of asymmetric effects in Japan, where both increases and decreases in policy uncertainty led to higher money demand. Similarly, Hossain and Arwatchanakarn (2020) showed that in New Zealand, an increase in economic uncertainty decreases the demand for money, whereas a decline in uncertainty does not lead to an increase in money holdings.

Further complicating the picture, Nusair et al. (2024) documented nonlinear effects of uncertainty on money demand across Canada, Japan, the UK, and the US. In Canada and the UK, both rising and falling uncertainty negatively impacted money demand in the long term, whereas in the US, uncertainty had a positive effect. In Japan, rising uncertainty increased money demand, whereas declining uncertainty had no significant effect. These inconsistencies highlight the potential role of country-specific structural differences, leading to the conclusion that countries must be examined separately because the effects of uncertainty on money demand vary across nations, as pointed out by Nusair et al. (2024).

Beyond country-specific structural differences, two additional factors may underlie these ambiguous findings. First, uncertainty may affect different components of money demand in different ways, causing potential divergences in the responses of bank money versus physical cash (banknotes) and, consequently, broad aggregates such as M3, narrow aggregates such as M1, and very narrow aggregates such as banknotes in circulation. Second, the nature of uncertainty itself matters. In cases of uncertainty related to the functioning of electronic payment systems (e.g., in the event of a threat of armed conflict) or a financial crisis, an increase in the demand for cash and a decrease in the demand for bank money can generally be expected. However, if the source of uncertainty is macroeconomic imbalance, including high inflation, an escape from both types of money can be expected. Further research is necessary to differentiate the effects of uncertainty across monetary aggregates, economies, and types of uncertainty, because uniform conclusions should not be expected.

Consequently, conclusions based on narrow and broad monetary aggregates provide limited insights when examining the demand for physical cash. This limitation arises because cash typically constitutes only a small fraction of these aggregates—often less than a dozen percent in modern economies—while bank money accounts for the majority of total balances. Therefore, the overall response reflects a combination of different reactions to cash and bank money. Individuals’

behaviors toward physical cash and bank money can vary, particularly during periods of heightened uncertainty. During uncertain times, many individuals prefer to hold cash as a safe asset for precautionary reasons and may choose to reduce their bank money holdings due to concerns about the reliability of the payment infrastructure.

Although the relationship between uncertainty and the demand for broad money has been extensively studied, research specifically addressing how uncertainty affects the demand for physical cash remains limited. The role of standard money demand variables – a proxy for transaction volume and interest rate – is usually confirmed in demand for cash studies, yet the influence of uncertainty may suggest a different dynamic in this relationship. Early studies (Bech et al., 2018; Shirai & Sugandi, 2019) found no significant relationship between uncertainty indices and demand for cash, possibly because the uncertainty measures used failed to capture concerns relevant to banknote holders. In contrast, Rua (2021) showed that in the euro area, uncertainty influences the demand for different banknote denominations, with effects varying depending on the type of uncertainty. Similarly, Seitz et al. (2022) found that precautionary and uncertainty-driven motives play a key role in the demand for cash in France, with large- and medium-denomination notes being particularly sensitive to uncertainty shocks.

Several other econometric studies infer the effects of uncertainty indirectly by analyzing extraordinary events (Cevik, 2020; Claussen et al., 2023; Judson, 2024). Rösl and Seitz (2022, 2024) examined periods of heightened uncertainty, including the Y2K crisis, the 2008 financial crisis, and the early stages of the COVID-19 pandemic across eight major economies. They documented a significant increase in demand for banknotes during these periods. Additionally, Kotkowski (2023) explored the relationship between national cultural traits, such as uncertainty avoidance (based on Hofstede’s framework), and cash circulation trends, suggesting that cultural preferences influence differences in cash demand across countries. Bartzsch et al. (2023) also analyzed cash demand during the COVID-19 pandemic in four major European economies (France, Germany, Italy, and Spain).

In contrast to econometric studies, numerous descriptive case studies examine the behavior of cash in circulation during crises and other events that generate uncertainty. Recently, the 2008 crisis, the Y2K crisis, the pandemic, and the war in Ukraine have been studied extensively. There was a particularly large number of studies on the COVID-19 pandemic, during which money holders significantly increased their precautionary cash holdings in almost all developed countries (Ashworth & Goodhart, 2020; Bundesbank, 2024; Rösl & Seitz, 2022). Rösl and Seitz (2024) added case studies for several developing countries, also confirming an increase in cash use during periods of elevated uncertainty.

Rösl and Seitz (2024) summarize the consequences of different types of

uncertainty for cash in circulation and conclude that, in most cases, the relationship is positive—except for inflation-related uncertainty, where the relationship is negative, especially when inflation is high. The authors of the case study review on international banknote demand during various crises, prepared for the Deutsche Bundesbank (Bundesbank, 2024), draw somewhat more cautious conclusions. While uncertainty typically influences cash demand, its effects on banknote circulation can vary across countries; in fact, there are instances where crises have had little to no discernible impact on banknote circulation.

Another summary of the state of research, based on numerous descriptive case studies, is provided by Bartzsch et al. (2025), who distinguish six distinct types of crises: technological crises, financial system confidence crises, natural disasters, political uncertainty, inflationary crises, and exchange rate crises. They conclude that nearly all forms of crises lead to an increase in cash demand and that such crises often provide valuable explanations for unusual fluctuations in cash circulation. In particular, uncertainty surrounding digital payment infrastructure – such as intensified concerns about the resilience of these systems – induces economic agents to increase their holdings of transaction balances (in the form of smaller-denomination banknotes) as well as non-transaction balances (through larger denominations). Similarly, episodes of political uncertainty or outright political crises tend to create upward pressure on cash demand. Following Russia’s full-scale invasion of Ukraine, demand for cash in Ukraine rose markedly. The conflict also had a noticeable impact on cash demand in neighboring countries, although the magnitude of this effect diminished progressively with increasing geographic distance from the conflict zone.

To summarize the descriptive case studies, they confirm a strong positive response in the amount of cash in circulation during periods of crisis and other uncertainty shocks. The exception is uncertainty related to high inflation, where the relationship is negative. Economic or political uncertainty increases the demand for cash primarily through a precautionary motive – the need for liquidity during uncertain times. The demand for cash can also result from perceived uncertainty about the ability to freely satisfy payment needs. Another mechanism is flight to quality or flight to safe assets: during periods of increased uncertainty, investors reshape portfolios, moving, among other assets, towards cash.

An important consideration in cash demand research is the role of different banknote denominations. Several studies (Assenmacher et al., 2019; Seitz et al., 2022) emphasize that different motives drive the demand for various denominations, distinguishing between transactional and non-transactional (store-of-value) demand (Zamora-Pérez, 2021). Small-denomination notes are primarily used for transactions, whereas large-denomination notes are often held for hoarding and precautionary

purposes. In international currencies like the US dollar or the euro, foreign demand also influences banknote circulation. During periods of heightened uncertainty, the demand for larger-denomination notes often increases due to their role in medium- and long-term value storage, while short-term precautionary holdings may be driven by concerns over electronic payment system availability during crises, such as armed conflicts (Bundesbank, 2024).

As demonstrated, while descriptive studies provide strong evidence that uncertainty shocks influence demand for cash – at least for certain banknote denominations – systematic econometric research on this topic remains limited. Most existing studies focus on narrow time windows surrounding large shocks affecting the economy, with limited exploration of longer-term trends. To address these gaps, further research is necessary to examine the systematic role of uncertainty in cash demand across different economic contexts, monetary aggregates, and types of uncertainty.

A fundamental open question in current research is whether a stable, long-run relationship exists between uncertainty and cash demand. Another key question is whether the relationship between uncertainty and cash demand, observed in descriptive case studies, occurs systematically during periods of crisis. Furthermore, it remains unclear whether this relationship persists over an extended time window rather than being confined to short intervals around crises. Our basic assumption is that this relationship applies only to periods of heightened uncertainty and is not systematic throughout. Finally, based on the existing literature about the relationship between uncertainty and money demand, we aim to investigate whether a nonlinear relationship exists during periods of both increased and decreased uncertainty.

Consequently in our paper, we investigate the role of uncertainty over a relatively long time window in Poland, considering both the total demand for cash and the demand for individual banknote denominations. Specifically, building on the existing research on estimating the demand for money and cash, we aim to test the following hypotheses:

- H1: There is a stable, positive long-run relationship between uncertainty and the demand for cash.
- H2: The largest increases in uncertainty caused by major crises (the financial crisis, the COVID-19 pandemic outbreak, the Russian invasion of Ukraine) are associated with extraordinary rises in demand for cash.
- H3: The short-term response of demand for cash to changes in uncertainty differs between periods of low and high uncertainty fluctuations.

- H4: The short-term response of demand for cash to changes in uncertainty differs between periods of positive and negative uncertainty changes.

We also assess the sensitivity of the results to changes in uncertainty measures, research periods, and banknote denominations.

3 Data and methods

3.1 Data

Our starting point is the standard demand for money function, where real money demand depends on a measure of economic activity and the interest rate. Choosing a scale variable is not straightforward and involves several challenges. In the demand for money function, the scale variable measures transactions related to economic activity. However, data on the value of economic transactions are usually unavailable. As a result, a proxy must be identified, with income (typically GDP) being the most common, though not ideal, solution. Consumption and related variables are sometimes considered better indicators of changes in transactions associated with economic activity (Serletis, 2007). A limitation of this approach is that the available data are usually reported quarterly, requiring interpolation to convert them into monthly values. Alternatively, other variables serving as proxies for economic activity and reflecting changes in the number of transactions may be used. In our study, we utilized monthly retail sales data, similar to the approach taken by Seitz et al. (2022).

The choice of the variable describing the opportunity cost also requires a brief discussion. The money market interest rate is the most commonly used variable, although some studies use the deposit interest rate. Both options face criticism due to constraints imposed by the zero lower bound on interest rates. The existence of this lower bound may suggest the need to explore other interest rates, including those that are unobservable. For example, the shadow interest rate based on the Asset Purchase Programme of the National Bank of Poland may provide a more comprehensive view of monetary conditions in the context of unconventional policy measures (Hertel et al., 2021). However, these shadow rates are not directly observable nor widely understood by households or small businesses, which raises concerns about their relevance in explaining actual cash-holding decisions. Therefore, we chose a more conventional approach commonly found in the literature and demand for money estimations, similar to the work of Seitz et al. (2022).

The definitions and data sources for our variables are summarized in Table 1. We measure real cash demand using the total cash value in circulation outside the banks, deflated by the consumer price index. Additionally, we consider the demand

for particular low (PLN10 and PLN20) and high (PLN200) banknote denominations for further analysis. The interest rate is proxied by the interest rate on PLN deposits. The level of economic activity is measured by the index of retail sales in constant prices. Our monthly data cover the period 9M2006–9M2024 in the baseline case and 1M2007–9M2024 for analyzing demand for certain denominations. Both the uncertainty indicators and the cash demand variable are available from 1M2004, but reliable data for economic activity before 9M2006 are unavailable.

Table 1: Data sources used in the study

Variable	Remarks	Source
CASH	Cash in circulation outside banks, deflated by CPI	Cash: NBP (2024b); CPI: Statistics Poland (2024)
CASHl	Value of PLN10 and PLN20 banknotes in circulation, deflated by CPI	NBP (2024d)
CASHh	Value of PLN200 banknotes in circulation, deflated by CPI	NBP (2024d)
EPU	Economic Policy Uncertainty index	Białkowski et al. (2025), https://www.policyuncertainty.com/poland_monthly.html
MUI	Macroeconomic Uncertainty Index	Pietrucha and Gulewicz (2025a)
R	Interest rate on PLN deposits – average interest rates on new and renegotiated PLN contracts	NBP (2024a)
SALES	Retail sales of goods in constant prices	Statistics Poland (2024)

The standard model is augmented with uncertainty indicators. We employ two measures of uncertainty. First, EPU, recently calculated for Poland by Białkowski et al. (2025) using the widely adopted methodology developed by Baker et al. (2016). EPU is a news-based uncertainty indicator created by searching databases containing articles from daily newspapers. It is considered one of the most reliable measures of uncertainty and is widely used in economic research, including demand for money modeling.

As an alternative measure, we use the MUI created by Pietrucha and Gulewicz (2025b), which is based on Google Trends data. Internet-search-based indicators were proposed by Bontempi et al. (2021) and Castelnovo and Tran (2017), and recently evaluated by Bontempi et al. (2025). These types of indicators do not rely on press articles reflecting the perception of economic uncertainty by journalists or publicists, but rather on the observations of internet user behavior, which today includes socially and economically diverse groups of individuals (such as households, small businesses, and professionals). One key advantage is that these indicators

capture the spontaneous behavior of a broad group of agents who reveal their interests, concerns, and information needs through search engine activity. This approach also better reflects contemporary channels of information circulation in society compared to traditional press, even accounting for its availability in digital formats. Indicators of this type assume that economic agents, represented by internet users, intensify their online information searches when they are uncertain. Consequently, the number of searches for terms related to specific topics can be treated as proxies for perceived uncertainty. Using Google Trends data, the MUI tracks searches for a set of general macroeconomic "topics" (e.g., inflation, unemployment, stock indices). To construct the MUI, each topic's seasonally adjusted search volumes are aggregated with equal weights to form an index ranging from 0 to 100. Higher MUI values indicate intensified online information-seeking, interpreted here as increased macroeconomic uncertainty.

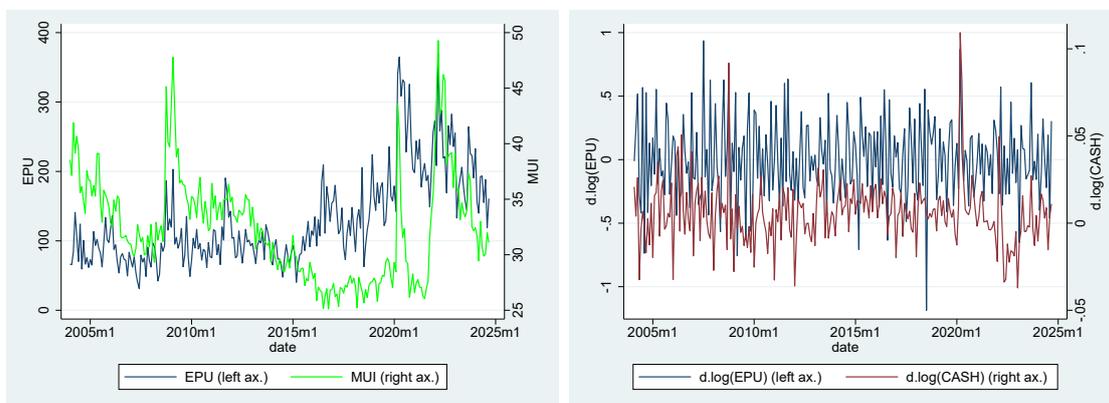


Figure 1: Dynamics of EPU uncertainty measure (left plot) and log changes of EPU and CASH (right plot)

The left plot in Figure 1 illustrates the behavior of the two uncertainty measures. The overall similarity in the short-term dynamics of both measures is weak – both linear and rank correlation coefficients for the monthly growth rates do not exceed 0.25. The EPU and MUI similarly identify periods of sudden increases in uncertainty. The divergence between the two measures occurs primarily at medium and low levels of uncertainty; however, with one exception, the indicators agree that these represent essentially low or medium levels (i.e., they show the underlying picture identically). The exception is the period 2015–2020. The EPU shows a rising trend in uncertainty from 2015 to 2020, whereas the MUI shows sudden jumps in uncertainty only in 2020. Another difference is that the MUI tends to show a more rapid exit from high levels of uncertainty.

However, the low correlation between the two measures is not surprising. The numerous existing measures of uncertainty are indirect methods of measuring highly fuzzy phenomena. The way they are calculated and the data used mean that their

informational value differs, i.e., they capture slightly different aspects of the highly diversified concept of uncertainty (Cascaledi-Garcia et al., 2023). In particular, the specificity of the EPU and MUI constructions means that the former reflects the perception of uncertainty in opinion-forming media, while the latter reflects the general public’s perception of uncertainty. The perception of uncertainty in these two groups may differ. The MUI reflects uncertainty about the state of the economy as seen by the average Polish resident; the EPU reflects the perspective of journalists who probably have better access to information, stronger interpretation skills, and a broader economic and geopolitical perspective, but may be biased and not fully capture the perception of uncertainty in the general public. This diversity in measuring uncertainty reinforces the need to use different measures when examining money demand rather than relying on a single one.

The short-term dynamics of the EPU index and the cash demand indicator are shown in the right plot of Figure 1. It is difficult to identify a clear relationship between changes in cash demand and uncertainty levels. However, the three highest jumps in cash demand—occurring in 10M2008 (financial crisis), 2–3M2020 (COVID-19 pandemic), and 2M2022 (Russian attack on Ukraine)—are always associated with substantial increases in uncertainty. Furthermore, they coincide with the three peaks of the MUI.

The results of the stationarity tests are presented in Table 2. As expected, the cash demand measures and the transaction volume proxy are nonstationary, exhibiting a relatively stable upward trend. The results for the EPU index are somewhat ambiguous, with the augmented Dickey–Fuller test suggesting a unit root. The MUI is stationary according to both tests.

Table 2: Unit root tests

Variable	ADF (Level)	PP (Level)	ADF (Diff)	PP (Diff)
EPU	-1.669	-4.716***	-4.857***	-27.913***
MUI	-2.907**	-3.734***	-5.150***	-18.435***
log(CASH)	-1.513	-0.951	-3.099**	-13.796***
log(CASHl)	-1.455	-1.335	-2.039	-18.752***
log(CASHh)	-0.090	0.763	-3.258**	-11.122***
log(SALES)	-1.468	-1.848	-3.802***	-18.638***
R	-2.155	-1.597	-3.728***	-6.029***

Note: ADF columns contain the test statistics from the augmented Dickey–Fuller test with a constant; PP columns contain the test statistics from the Phillips–Perron test with a constant. Significant estimates are marked with stars (***) $p < 0.01$; ** $p < 0.05$; * $p < 0.1$).

3.2 Methods

Following the literature, we begin the analysis with the ARDL) model:

$$\Delta Y_t = c_0 - \alpha(Y_{t-1} - \boldsymbol{\theta}\mathbf{X}_{t-1}) + \sum_{i=1}^{p-1} \psi_i^y \Delta Y_{t-i} + \sum_{j=0}^{q-1} \psi_j^x \Delta \mathbf{X}_{t-j} + \boldsymbol{\phi}\mathbf{Z}_t + u_t, \quad (2)$$

where Y_t is the log of cash demand and \mathbf{X}_t represents the vector of exogenous variables entering the long-run relationship with cash demand (log sales or the uncertainty index). Vector \mathbf{Z}_t contains regressors affecting the short-term dynamics of cash demand, including the interest rate, the uncertainty index (if it does not enter vector \mathbf{X}_t), and its interactions with major crisis dummies (the financial crisis (10.2008), the COVID-19 pandemic outbreak (3–4.2020), and the Russian invasion of Ukraine (2–3.2022)), as well as seasonal dummies that capture seasonal variation in cash demand.

The model parameters ($c_0, \alpha, \boldsymbol{\theta}, \psi_i^y, \psi_j^x, \boldsymbol{\phi}$) are estimated using the `ardl` function in Stata (Kripfganz & Schneider, 2023). The procedure automatically selects the optimal number of lags p and q according to the Bayesian information criterion. We use the bounds tests developed by Pesaran et al. (2001) to test hypothesis H1 regarding the existence of a long-run relationship.

Because the results obtained from the ARDL models suggest that deviations from the long-run relationships do not significantly explain the short-term dynamics of cash demand, and the ARDL specification lacks the flexibility for an in-depth study of nonlinearities in the short-term dynamics, we subsequently switch to linear and threshold regressions to examine hypotheses H2 and H3. The threshold regression has the following general form:

$$\Delta Y_t = \begin{cases} \delta_{0,1} + \beta_1 \log(UNC_t) + \boldsymbol{\delta}\mathbf{Z}_t^* + \varepsilon_{1,t}, & \text{if } |\Delta \log(UNC_t)| \leq \gamma, \\ \delta_{0,2} + \beta_2 \log(UNC_t) + \boldsymbol{\delta}\mathbf{Z}_t^* + \varepsilon_{2,t}, & \text{if } |\Delta \log(UNC_t)| > \gamma, \end{cases} \quad (3)$$

where UNC_t denotes the uncertainty index, γ is the endogenously selected threshold, and \mathbf{Z}_t^* includes the remaining exogenous variables such as lags of cash demand and sales, the interest rate, interaction terms of the uncertainty index with major crisis dummies, and seasonal dummies. The number of lags for cash demand and sales is taken from the optimal ARDL specification.

We also use nonlinear regressions with higher-order terms for the uncertainty indexes as an alternative way to capture the nonlinearity between uncertainty and cash demand.

To test hypothesis H4 regarding asymmetric reactions to positive and negative changes in uncertainty, we build on the results from the threshold regression models

on the identified regions of high fluctuations of uncertainty with differing impacts on cash demand. We treat the estimated thresholds as exogenous and further divide the region of low fluctuations into two parts, characterized by positive and negative changes in uncertainty. We use a simple linear regression model with interaction terms and dummy variables that define the regions. If the threshold regression does not identify regions with heterogeneous reactions to high and "normal" fluctuations in uncertainty, the procedure simply considers two exogenous regions of positive and negative changes in uncertainty.

4 Results

In this section, we present the baseline results of the analysis. First, we focus on the long-run relationships (H1). Then, we examine the asymmetric short-term dynamics, distinguishing between large and moderate changes in uncertainty (H2 and H3). Finally, we consider the asymmetric impact of positive and negative movements in uncertainty (H4).

4.1 Long-run relationships

Table 3 presents the results of the ARDL specifications used to examine the long-run relationship between uncertainty and cash demand and to select the best specification for the short-term dynamics.

Because the MUI is stationary according to unit root tests, we do not include it in the long-run relationship. We do include the EPU index, for which the stationarity tests are ambiguous. In the first two specifications, EPU is included along with the retail sales index in the cointegrating vector. However, according to the bounds tests of Pesaran et al. (2001), no significant relationship is found, which is unsurprising given the very different long-run behavior of cash demand and the uncertainty index. Therefore, in the next two specifications, SALES is considered as the only counterpart of CASH in the cointegrating vector, but the main result remains unchanged. These results clearly reject hypothesis H1 on the existence of a stable, long-run relationship between uncertainty and cash demand.

In the short-run dynamics part, the last specification contains two autoregressive lags with low coefficients that never exceed 0.2, and a statistically significant negative impact of the interest rate. We treat this specification as the starting point for the short-run dynamics analysis.

Table 3: Results of ARDL models for the CASH variable

	(1)	(2)	(3)	(4)
	D.log(CASH)	D.log(CASH)	D.log(CASH)	D.log(CASH)
ADJ				
L.log(CASH)	-0.00116 (0.0102)	0.00433 (0.00824)	-0.00165 (0.00875)	-0.00534 (0.00704)
LR				
L.log(SALES)	0.101 (5.456)	-0.511 (2.232)	0.138 (3.632)	0.643* (0.350)
L.log(EPU)	-0.329 (5.585)	2.066 (3.553)		
SR				
LD.log(CASH)	0.191*** (0.0671)	0.178*** (0.0559)	0.190*** (0.0667)	0.241*** (0.0532)
L2D.log(CASH)	0.196*** (0.0713)	0.122** (0.0537)	0.195*** (0.0709)	
D.log(SALES)	-0.112*** (0.0360)	0.00221 (0.00572)	-0.112*** (0.0358)	0.00343 (0.00574)
D.log(EPU)	0.0120*** (0.00380)	0.00289 (0.00315)	0.0122*** (0.00320)	0.00394 (0.00270)
LD.log(EPU)		0.00893*** (0.00312)		
D.R	-0.0163** (0.00666)	-0.0214*** (0.00532)	-0.0164** (0.00662)	-0.0226*** (0.00532)
D.log(EPU)×Fin_cris		0.138*** (0.0170)		0.137*** (0.0173)
D.log(EPU)×COVID		0.114*** (0.0135)		0.112*** (0.0139)
D.log(EPU)×War		0.0498** (0.0192)		0.0405** (0.0195)
Constant	0.0156 (0.0732)	-0.0199 (0.0590)	0.0189 (0.0643)	0.0437 (0.0518)
Month effects	Yes	Yes	Yes	Yes
Bounds_F	0.116	2.498	0.171	0.400
Bounds_t	-0.114	0.525	-0.188	-0.759
pv_H0_F	0.987	0.190	0.957	0.895
pv_H0_t	0.932	0.981	0.921	0.801
N	214	214	214	214
R ²	0.414	0.645	0.414	0.620

Note: Robust standard errors are in parentheses. Significant estimates are marked with stars (***) $p < 0.01$; ** $p < 0.05$; * $p < 0.1$). ADJ refers to the adjustment coefficient of the long-run relationship; LR refers to coefficients in the long-run relationship; SR refers to coefficients in the short-run adjustments. Bounds_F and Bounds_t denote test statistics from the bounds test for the existence of a long-run relationship by Pesaran et al. (2001). pv_H0_F and pv_H_t are the corresponding p-values for the I(0) case.

The results also reveal a positive but nonlinear relationship between short-term fluctuations in macroeconomic uncertainty and cash demand. In the third specification, we observe a statistically significant positive relationship, indicating that a 1% increase in the uncertainty index is associated with an approximate 0.012% increase in cash demand. However, when controlling for the major crisis periods, the effect weakens by more than half. This raises the key question of whether the results in specifications 1 and 3 are driven solely by periods of increased uncertainty. In the following subsection, we analyze this issue in more detail using threshold regression.

4.2 Short-term dynamics – the asymmetric impact of large and small changes in uncertainty

To analyze the asymmetric impact of short-term fluctuations in uncertainty, we employ threshold and nonlinear regression models. The baseline results for the EPU index are shown in Table 4. The first two columns reproduce the results for the last two ARDL specifications from Table 3 (without the error-correction term) using a simple linear regression model. We observe a strong response of cash demand to jumps in uncertainty during the financial crisis and the COVID-19 pandemic outbreak, with elasticities exceeding 0.1%. However, the effect of the Russian invasion of Ukraine is much smaller and statistically insignificant.²

The threshold regression results are presented in the next two columns of Table 4. The specification without the crisis period dummies confirms that in the case of large jumps in uncertainty (Region 2, defined as $|\Delta \log(EPU_t)| > 0.524$, accounting for approximately 10% of observations), cash demand also moves in the same direction ($\hat{\beta}_2 = 0.0257$). During "normal" times, the reaction is negative but statistically insignificant. However, this effect disappears when controlling for the three crisis periods, as shown in the fourth column. In this case, the two separate regions no longer exist, and the threshold regression model collapses to a simple linear regression. The interaction terms for the major-crisis dummies fully explain the nonlinear effect.

²The reason for this unexpected effect is the delayed reaction of the EPU index to the war that broke out at the end of February 2022. The index value dropped significantly in February and jumped only in March. The reaction of cash demand was immediate, with the huge rise observed in late February.

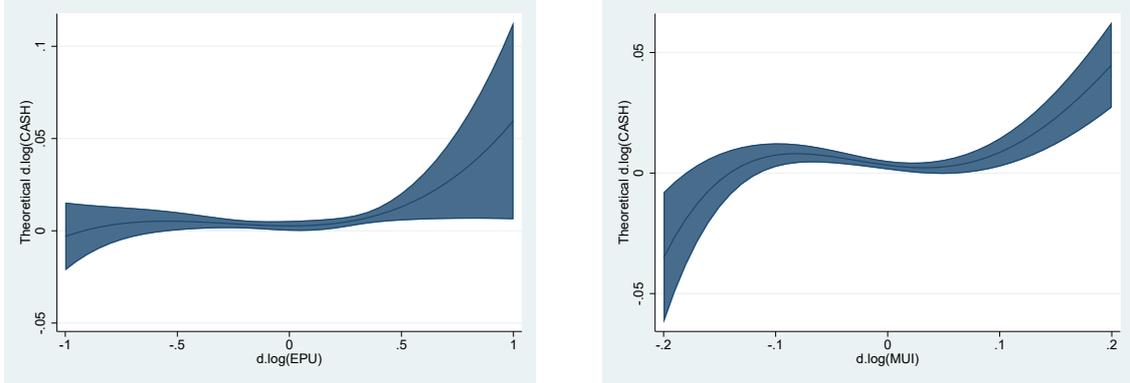
Table 4: Estimates of linear, threshold, and nonlinear regression models for monthly changes in cash demand and the EPU index

	Lin. reg. D.log(CASH)	Lin. reg. D.log(CASH)	Thresh. reg. D.log(CASH)	Thresh. reg. D.log(CASH)	Nonlin. reg. D.log(CASH)
Main					
LD.log(CASH)	0.215*** (0.0722)	0.207*** (0.0736)	0.189** (0.0744)	0.207*** (0.0712)	0.203** (0.0791)
L2D.log(CASH)	0.149** (0.0603)	0.0924** (0.0443)	0.150*** (0.0509)	0.0924** (0.0429)	0.155*** (0.0548)
D.log(SALES)	-0.110 (0.0815)	0.000820 (0.0393)	-0.106* (0.0604)	0.000820 (0.0380)	-0.0864 (0.0571)
D.R	-0.0183** (0.00720)	-0.0224*** (0.00587)	-0.0233*** (0.00646)	-0.0224*** (0.00568)	-0.0213*** (0.00704)
D.log(EPU)	0.0110** (0.00449)	0.00379 (0.00246)		0.00379 (0.00238)	-0.0000850 (0.00464)
D.log(EPU) × Fin_cris		0.137*** (0.00390)		0.137*** (0.00377)	
D.log(EPU) × COVID		0.112*** (0.00962)		0.112*** (0.00930)	
D.log(EPU) × War		0.0419 (0.0393)		0.0419 (0.0380)	
[D.log(EPU)] ²					0.0257* (0.0145)
[D.log(EPU)] ³					0.0315* (0.0182)
Region 1					
D.log(EPU)			-0.00301 (0.00297)		
Region 2					
D.log(EPU)			0.0257*** (0.00744)		
Month effects	Yes	Yes	Yes	Yes	Yes
Threshold			0.524	–	
<i>N</i>	216	216	216	216	216
<i>R</i> ²	0.388	0.620	0.474	0.620	0.447
BIC			-1816.8	-1881.7	

Note: Robust standard errors are in parentheses. Significant estimates are marked with stars (***) $p < 0.01$; (**) $p < 0.05$; (*) $p < 0.1$).

Alternatively, the nonlinear nature of the relationship is also captured by the nonlinear regression model, which augments the standard linear regression with higher-order terms, as shown in the last column of Table 4. The theoretical relationship between uncertainty and cash demand from the nonlinear regression

model is illustrated in the left panel of Figure 2. It confirms that the positive relationship mainly occurs during sharp rises in uncertainty.



Note: The shaded areas represent the 95% confidence intervals.

Figure 2: Theoretical relationships between the uncertainty indexes and cash demand from the nonlinear regression models

The analogous results for the MUI are presented in Table 5. They confirm the large reaction of cash demand during the major crisis periods, with the strongest impact observed during the Russian invasion of Ukraine. These results support our hypothesis H2. However, what is much more important from the perspective of understanding the nature of this relationship is that the threshold model with interaction terms still identifies two regimes: a weak positive impact of uncertainty on cash demand ($\hat{\beta}_1 = 0.038$) during periods with larger fluctuations of uncertainty ($|\Delta \log(MUI_t)| > 0.0749$, accounting for approximately 16% of cases), and a stronger negative relationship ($\hat{\beta}_2 = -0.066$) during "normal" times. These nonlinearities are also captured by the quintic regression model presented in the last column, illustrated in the right panel of Figure 2.

In both cases, the results for EPU and MUI show a relatively consistent pattern and provide evidence of different responses of cash demand during periods of high and low uncertainty changes. In the former case, we observe a statistically significant positive effect—that is, uncertainty increases cash demand. This relationship persists even after controlling for major crises in recent years. In the latter, the response is either absent or, surprisingly, negative. These results support our hypothesis H3.

It should also be noted that the MUI-based models generally fit the data better than those with the EPU indicator. For example, the coefficient of determination for the threshold regression model without interaction terms is 0.525 for MUI and 0.474 for EPU. The difference is slightly smaller when accounting for crisis interaction terms: 0.646 and 0.620, respectively. Additionally, the Bayesian information criterion clearly favors the specifications with the MUI.

Table 5: Estimates of linear, threshold, and nonlinear regression models for monthly changes in cash demand and MUI

	Lin. reg. D.log(CASH)	Lin. reg. D.log(CASH)	Thresh. reg. D.log(CASH)	Thresh. reg. D.log(CASH)	Nonlin. reg. D.log(CASH)
main					
LD.log(CASH)	0.236*** (0.0723)	0.273*** (0.0819)	0.267*** (0.0746)	0.283*** (0.0716)	0.271*** (0.0838)
L2D.log(CASH)	0.164*** (0.0589)	0.0867* (0.0459)	0.135*** (0.0490)	0.0971** (0.0406)	0.100* (0.0518)
D.log(SALES)	-0.0851 (0.0566)	-0.0287 (0.0514)	-0.00542 (0.0473)	-0.00140 (0.0450)	0.0455 (0.0457)
D.R	-0.0192*** (0.00687)	-0.0231*** (0.00638)	-0.0167*** (0.00605)	-0.0197*** (0.00538)	-0.0164** (0.00694)
D.log(MUI)	0.0848** (0.0359)	0.000451 (0.0170)			-0.0592** (0.0261)
D.log(MUI) × Fin_cris		0.360*** (0.0190)		0.333*** (0.0250)	
D.log(MUI) × COVID		0.199*** (0.0431)		0.186*** (0.0418)	
D.log(MUI) × War		0.404*** (0.0301)		0.393*** (0.0357)	
[D.log(MUI)] ²					0.622*** (0.234)
[D.log(MUI)] ³					6.482*** (1.400)
[D.log(MUI)] ⁴					-14.52*** (3.495)
Region 1					
D.log(MUI)			-0.0311 (0.0224)	-0.0661*** (0.0216)	
Region 2					
D.log(MUI)			0.161*** (0.0397)	0.0380* (0.0212)	
Month effects	Yes	Yes	Yes	Yes	Yes
Threshold			0.0963	0.0749	
<i>N</i>	216	216	216	216	216
<i>R</i> ²	0.433	0.618	0.525	0.646	0.596
BIC			-1838.9	-1886.3	

Note: Robust standard errors are in parentheses. Significant estimates are marked with stars (*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$).

4.3 Short-term dynamics – the asymmetric impact of positive and negative changes in uncertainty

In this subsection, we test hypothesis H4 by examining whether cash demand responds differently to positive versus negative movements in uncertainty, while accounting for the potential differences in response to high and low changes in uncertainty identified earlier. The results are presented in Table 6. The table shows the responses for the baseline region of declining uncertainty and the difference in response for the region of rising uncertainty, represented by the coefficient of the interaction term between the uncertainty index and a dummy variable for the rising uncertainty region.

Table 6: Impact of positive and negative changes in uncertainty on cash demand

	Lin. reg. D.log(CASH)	Lin. reg. D.log(CASH)
Baseline region (declining unc.) D.log(UNC)	D.log(EPU) < 0 0.00578 (0.00556)	-0.0749 < D.log(MUI) < 0 -0.0834* (0.0469)
Rising uncertainty region D.log(UNC) × ID _r	D.log(EPU) ≥ 0 0.00782 (0.00852)	0 < D.log(MUI) < 0.0749 0.0494 (0.0795)
High fluctuations region D.log(UNC) × ID _r		D.log(MUI) ≥ 0.0749 0.122** (0.0537)
<i>N</i>	216	216
<i>R</i> ²	0.627	0.647

Note: The table reports the estimated slopes for the uncertainty indexes across regions. ID_r is the dummy variable for a region specified in the table. Results for other regressors are omitted for brevity, because they are similar to those reported for the fourth model in Tables 4 and 5. Standard errors are in parentheses. Significant estimates are marked with stars (***) $p < 0.01$; ** $p < 0.05$; * $p < 0.1$).

In both cases, the coefficient for the rising uncertainty region is not statistically significant, indicating no significant difference in cash demand reactions to positive versus negative changes in uncertainty. Therefore, the results do not support hypothesis H4. The statistically significant coefficients in the second column for the declining uncertainty region and the high fluctuations region confirm the asymmetry in reactions to large and "normal" changes in uncertainty discussed in the previous subsection.

5 Additional results

We conduct two additional analyses. First, we investigate nonlinearities in the short-term relationships within subsamples. Second, we analyze the demand for specific banknote denominations: low denominations (PLN10 and PLN20), which are used more frequently for transactional purposes, and high denominations (PLN200), which are more convenient for thesaurization purposes.

5.1 Analysis in subsamples

In this subsection, we split the sample roughly in half: the first part covers the period 10M2006–12M2015, while the second covers 1M2016–9M2024.

The ARDL models confirm the baseline finding of no long-run relationship between uncertainty and cash demand (see Table A1 in the appendix). The results for the short-term dynamics are presented in Table 7, where we consider the EPU index in the first two columns and the MUI in the subsequent columns. For both measures, we observe a strong reaction of cash demand to jumps in uncertainty during major crises. However, evidence for the further impact of uncertainty on cash demand outside these crises is weak. Specifically, for the EPU index in the second subperiod and the MUI in both subsamples, no evidence of any impact — even linear — is found. For the EPU index in the first subperiod, we observe a nonlinear impact: a small positive reaction of cash demand to larger movements in uncertainty and a moderate negative relationship during "normal" times. This pattern mirrors the scheme identified for the MUI in the full sample (Table 5). Regarding model fit, we do not confirm the finding from the full sample that the MUI better captures the impact of uncertainty on cash demand; in fact, in the first subsample, the model with the EPU index fits the data considerably better.

We also examined the hypothesis of asymmetric reactions to positive and negative changes in uncertainty. Consistent with the full sample, we find no support for this hypothesis in the subsamples. Detailed results are available upon request.

Table 7: Threshold models in subsamples

	Thresh. reg. 2006–15 UNC = EPU	Thresh. reg. 2016–24 UNC = EPU	Thresh. reg. 2006–15 UNC = MUI	Thresh. reg. 2016–24 UNC = MUI
main				
LD.log(CASH)	0.196*** (0.0678)	0.287** (0.116)	0.147** (0.0718)	0.448*** (0.0743)
L2D.log(CASH)	0.142** (0.0595)	0.00220 (0.0716)	0.118* (0.0716)	-0.0819 (0.0660)
D.log(SALES)	0.0859** (0.0428)	-0.0588 (0.0396)	0.0786* (0.0420)	-0.0921** (0.0380)
D.R	-0.0145* (0.00792)	-0.0302*** (0.00790)	-0.00908 (0.00836)	-0.0294*** (0.00763)
D.log(UNC) × Fin_cris	0.132*** (0.00438)	0 (.)	0.336*** (0.0266)	0 (.)
D.log(UNC) × COVID	0 (.)	0.0951*** (0.0110)	0 (.)	0.194*** (0.0274)
D.log(UNC) × War	0 (.)	0.0412 (0.0451)	0 (.)	0.481*** (0.0317)
D.log(UNC)		0.00350 (0.00339)	0.00741 (0.0237)	-0.0209 (0.0170)
Region 1				
D.log(UNC)	-0.0313** (0.0141)			
Region 2				
D.log(UNC)	0.00522* (0.00282)			
Month effects	Yes	Yes	Yes	Yes
Threshold	0.186	–	–	–
N	111	105	111	105
R^2	0.659	0.701	0.623	0.751
BIC	-957.2	-898.3	-955.3	-917.6

Note: Robust standard errors are in parentheses. Significant estimates are marked with stars (***) $p < 0.01$; ** $p < 0.05$; * $p < 0.1$).

5.2 Results for different banknote denominations

The long-run analysis of the demand for low- (PLN10 and PLN20) and high-denominated banknotes is shown in Table A2 in the appendix. It shows a lack of a stable long-run relationship between uncertainty and cash demand.

The results for the asymmetric relationships in the short-run dynamics are shown in Table 8. Regarding the reaction to jumps in uncertainty caused by

major crises, the pattern is similar to that of total cash demand. Interestingly, the reaction of the demand for PLN200 banknotes is stronger compared to PLN10 and PLN20 banknotes, especially during the financial crisis (0.174 vs. 0.016 for the EPU index and 0.473 vs. 0.089 for the MUI). During "normal" times, we observe a mild but statistically significant negative relationship between uncertainty and cash demand for both uncertainty measures (the threshold model identifies two separate regions for the MUI, but in both regions, the coefficients are negative and the difference between them is not statistically significant). In the case of PLN200 banknotes, which are used more often for thesaurization purposes, nonlinearities are not observed, although the threshold model identifies two regions for the MUI. The difference in reactions between these two regions is not statistically significant. For all denominations considered, the MUI better captures the impact of uncertainty on cash demand.

We also investigated potential differences in reactions to positive and negative changes in uncertainty and found no statistically significant differences. Detailed results are available upon request.

However, we emphasize that, in the case of Poland, the effects on banknote denominations should be interpreted with caution due to significant changes in the usage of individual denominations. These changes stem from inflationary processes during the period under review, which led to substantial substitution between banknote types. PLN 10–20 banknotes are gradually being phased out and are no longer available in most ATMs. The PLN 200 banknote, on the other hand, no longer serves primarily as a store of value (it is roughly equivalent to a EUR 50 banknote). The presented results are likely heavily influenced by substitution effects among the banknotes.

Table 8: Threshold models for different banknote denominations

	Thresh. reg. D.log(CASHl) UNC = EPU	Thresh. reg. D.log(CASHl) UNC = MUI	Thresh. reg. D.log(CASHh) UNC = EPU	Thresh. reg. D.log(CASHh) UNC = MUI
main				
L.log(CASHh)			0.282*** (0.105)	0.392*** (0.0977)
L2.log(CASHh)			0.142*** (0.0489)	0.157*** (0.0463)
D.log(SALES)			-0.0112 (0.0624)	-0.0538 (0.0716)
D.R	-0.00931* (0.00482)	-0.00822* (0.00495)	-0.0195*** (0.00645)	-0.0174*** (0.00633)
D.log(UNC) × Fin_cris	0.0157*** (0.00421)	0.0886*** (0.0284)	0.174*** (0.00426)	0.473*** (0.0329)
D.log(UNC) × COVID	0.0556*** (0.00555)	0.165*** (0.0289)	0.115*** (0.0151)	0.180*** (0.0590)
D.log(UNC) × War	-0.0126 (0.0468)	0.513*** (0.0402)	0.0337 (0.0791)	0.779*** (0.0612)
D.log(UNC)	-0.00407* (0.00247)		0.00257 (0.00341)	
Region 1				
D.log(UNC)		-0.0483*** (0.0179)		-0.00458 (0.0278)
Region 2				
D.log(UNC)		-0.0198 (0.0235)		0.0277 (0.0308)
Month effects	Yes	Yes	Yes	Yes
Threshold	–	0.0978	–	0.0978
N	212	212	210	210
R^2	0.565	0.661	0.562	0.632
BIC	-1881.2	-1923.5	-1726.8	-1753.0

Note: Robust standard errors are in parentheses. Significant estimates are marked with stars (***) $p < 0.01$; ** $p < 0.05$; * $p < 0.1$).

6 Discussion and conclusion

Building on the existing literature on money demand and descriptive case studies examining the impact of uncertainty on cash demand, our study aimed to analyze the long-run nature of the relationship between uncertainty and cash demand. We also sought to determine whether episodes of strong money demand responses during periods of heightened uncertainty, reported in case studies, are systematic.

The main conclusions of our study are as follows. ARDL models, assuming a linear relationship, do not confirm the existence of a stable, long-run association between uncertainty and cash demand in Poland. Therefore, we found no evidence supporting hypothesis H1.

While such a relationship does appear in the short term, it is primarily driven by several episodes of exceptionally high uncertainty. When controlling for these episodes, the significance of uncertainty's impact diminishes. However, a closer examination using threshold regression shows that the assumption of linearity cannot be maintained. We identify two regimes for both uncertainty measures (EPU and MUI): first, periods of medium and low uncertainty fluctuations, during which money demand either does not respond or responds negatively to changes in uncertainty; and second, periods of high uncertainty changes, during which money demand responds positively to changes in uncertainty.

These patterns can explain the diverse results found in the few econometric studies to date (Rua, 2021; Seitz et al., 2022). Generally, the more a study's sample includes episodes of elevated uncertainty fluctuations, the greater the likelihood of observing a positive, significant relationship. Only by considering the nonlinearity of this relationship can the role of uncertainty in cash demand be fully understood.

Conversely, our findings align with previous descriptive case studies that focus on the narrow time window immediately after uncertainty shocks (Bartzsch et al., 2025; Rösl & Seitz, 2024). These studies generally agree that during periods of increased uncertainty, demand for cash increases. This supports our confirmed hypothesis H2. Indeed, our results show that during such periods, a positive relationship between uncertainty and physical cash demand exists. However, we show that these findings should not be generalized to periods of moderate or low uncertainty fluctuations. Evidently, a threshold exists beyond which rising uncertainty triggers a response from economic agents. During normal times, small fluctuations in uncertainty do not elicit a positive response in cash demand. Thus, our results suggest a potential path for reconciling previously diverse findings from descriptive case studies and econometric analyses.

Our results confirm the conclusions from descriptive case studies and hypothesis H2 derived from them, but they do not support extrapolation of these conclusions to a longer time window. Instead, we demonstrate that the short-term reaction of cash demand to changes in uncertainty varies between periods of low and high uncertainty movements, confirming our hypothesis H3. Moreover, our results suggest that during normal times, this response may be negative. This last finding may be somewhat surprising, although several studies have pointed to the negative impact of uncertainty on various monetary aggregates, often including bank money (Bahmani-Oskooee et al., 2015). However, it is difficult to extrapolate this reasoning

to cash, because the most obvious reaction mechanism primarily concerns bank account balances; i.e., heightened uncertainty may reduce bank deposits and cause a flight to cash. Nevertheless, a similar negative coefficient was also reported by Rua (2021), who used data up to 2019, essentially before the significant increase in uncertainty from 2020. In our view, a reliable explanation for this result requires further investigation.

Following numerous recent publications on money demand, we also examined whether cash demand responds differently to positive and negative movements in uncertainty. We found no evidence supporting this type of asymmetry and thus reject our hypothesis H4.

Somewhat surprisingly, we were unable to establish a stable, positive relationship between cash demand and transaction volume measures in either the long or short run. The presented results use retail sales in constant prices as the transaction volume measure, but we repeated the estimations using real GDP series disaggregated to a monthly frequency, with similar findings. However, we note two issues. First, we estimate demand for cash, which constitutes only a small percentage of total money demand. It is not easy to translate theoretical relationships derived for total money demand to the context of cash demand. Especially with the growth of electronic payments, substitutions between components of money demand may occur. Second, we examine a study period characterized not only by significant changes in payment habits but also by notable GDP volatility. During crises, cash may behave differently from total money demand. Periods of GDP decline may coincide with increased cash demand for precautionary reasons.

Additionally, our results reaffirm the role of the opportunity cost, in the form of interest rates, when modeling money demand, as documented in numerous previous empirical studies and postulated in theoretical models. However, in light of ongoing discussions about the surprising behavior of physical cash demand in recent years—such as its inertia or even growth in some countries—this result deserves particular emphasis. It indicates that the unexpected behavior of cash demand, despite the growing importance of electronic payments, is primarily due to the loose monetary policies conducted until approximately 2022 in most countries, as confirmed by the results presented in Liñares-Zegarra and Willeson (2021) and other studies. Our results further show that the effects of loose and unconventional monetary policies were supported in the short run by uncertainty shocks.

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A Additional tables

Table A1: Results of ARDL models in subsamples

	(1) D.log(CASH) 2006-15	(2) D.log(CASH) 2006-15	(3) D.log(CASH) 2016-24	(4) D.log(CASH) 2016-24
ADJ				
L.log(CASH)	0.00432 (0.0151)	0.00410 (0.0159)	0.00943 (0.0123)	0.0190* (0.00986)
LR				
L.log(SALES)	-2.307 (9.570)	-1.975 (9.326)	3.572 (3.866)	1.960*** (0.653)
L.log(EPU)	2.507 (8.843)		-0.578 (1.120)	
SR				
D.log(SALES)	0.104** (0.0444)	0.00809 (0.00772)	-0.121*** (0.0422)	-0.127*** (0.0425)
LD.log(SALES)			-0.0849*** (0.0308)	-0.0882*** (0.0308)
L2D.log(SALES)			-0.0849*** (0.0321)	-0.0876*** (0.0325)
D.log(EPU)	0.00321 (0.00384)	0.00610* (0.00340)	0.00545 (0.00463)	0.00456 (0.00409)
LD.log(EPU)	0.00966** (0.00376)			
D.R				
D.log(EPU)×Fin_cris	0.00130 (0.00750)	0.00406 (0.00772)	-0.0425*** (0.00646)	-0.0426*** (0.00646)
D.log(EPU)×COVID			0.0904*** (0.0166)	0.0903*** (0.0167)
D.log(EPU)×War			0.0759*** (0.0184)	0.0762*** (0.0184)
Constant	-0.0531 (0.140)	-0.0871 (0.146)	0.0709 (0.0913)	0.00581 (0.0764)
Month effects	Yes	Yes	Yes	Yes
Bounds_F	4.589	3.256	7.883	11.09
Bounds_t	0.286	0.258	0.767	1.922
pv_H0_F	0.0203	0.168	0.0006	0.0004
pv_H0_t	0.960	0.958	0.984	0.999
N	109	109	105	105
R ²	0.708	0.664	0.756	0.756

Note: Robust standard errors are in parentheses. Significant estimates are marked with stars (***) $p < 0.01$; (**) $p < 0.05$; (*) $p < 0.1$). ADJ refers to the adjustment coefficient of the long-run relationship; LR refers to coefficients in the long-run relationship; SR refers to coefficients in the short-run adjustments. Bounds_F and Bounds_t denote test statistics from the bounds test for the existence of a long-run relationship by Pesaran et al. (2001). pv_H0_F and pv_H_t are the corresponding p-values for the I(0) case.

Table A2: Results of ARDL models for banknotes of different denominations

	(1) D.log(CASHl)	(2) D.log(CASHl)	(3) D.log(CASHh)	(4) D.log(CASHh)
ADJ				
L.log(CASHl)	0.00770 (0.00955)	-0.00278 (0.00974)		
L.log(CASHh)			-0.0101* (0.00534)	-0.00808* (0.00485)
LR				
L.log(SALES)	-0.398 (0.807)	-0.556 (2.839)	1.351*** (0.344)	1.623*** (0.358)
L.log(EPU)	1.422 (1.737)		0.379 (0.325)	
SR				
LD.log(CASHl)	-0.182*** (0.0697)			
D.log(SALES)	0.00306 (0.00293)	-0.00155 (0.00276)	-0.00180 (0.0397)	-0.0328 (0.0415)
LD.log(SALES)			-0.123*** (0.0344)	-0.140*** (0.0348)
D.log(EPU)	-0.0110*** (0.00226)	-0.00619** (0.00247)	0.00381 (0.00351)	0.00324 (0.00330)
D.R				
	-0.00699 (0.00450)	-0.00855* (0.00467)	-0.0204*** (0.00656)	-0.0181*** (0.00652)
D.log(EPU)×Fin_cris	0.0194 (0.0149)	0.0155 (0.0156)	0.181*** (0.0211)	0.181*** (0.0209)
D.log(EPU)×COVID	0.0645*** (0.0120)	0.0595*** (0.0126)	0.111*** (0.0193)	0.104*** (0.0194)
D.log(EPU)×War	0.0111 (0.0175)	-0.00793 (0.0173)	0.0246 (0.0241)	0.0330 (0.0244)
LD.log(CASHh)			0.326*** (0.0549)	0.289*** (0.0573)
L2D.log(CASHh)				0.137** (0.0589)
Constant	0.00728 (0.0196)	0.0137 (0.0205)	-0.0318** (0.0135)	-0.0230* (0.0125)
Month effects	Yes	Yes	Yes	Yes
Bounds_F	8.920	1.165	2.670	2.893
Bounds_t	0.806	-0.285	-1.885	-1.666
pv_H0_F	0.0001	0.658	0.160	0.222
pv_H0_t	0.991	0.906	0.313	0.418
<i>N</i>	210	210	210	210
<i>R</i> ²	0.627	0.588	0.610	0.620

Note: Robust standard errors are in parentheses. Significant estimates are marked with stars (***) $p < 0.01$; ** $p < 0.05$; * $p < 0.1$). ADJ refers to the adjustment coefficient of the long-run relationship; LR refers to coefficients in the long-run relationship; SR refers to coefficients in the short-run adjustments. Bounds_F and Bounds_t denote test statistics from the bounds test for the existence of a long-run relationship by Pesaran et al. (2001). pv_H0_F and pv_H_t are the corresponding p-values for the I(0) case.