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NBP Working Paper No. 378

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Narodowy Bank Polski
Warsaw 2025

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The authors thank Marcin Bielecki, Adam Czerniak, Paweł Kopiec, Dorota Ścibisz, Piotr Zawadzki, the anonymous referee and participants at the internal NBP seminar for useful comments and discussions. The views expressed herein are those of the authors and not those of the institutions they are affiliated with.

Published by:
Narodowy Bank Polski
Education & Publishing Department
ul. Świętokrzyska 11/21
00-919 Warszawa, Poland
nbp.pl

ISSN 2084-624X

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Abstract

We examine the demand for retail treasury bonds and time deposits in Poland, a typical small open economy with an independent monetary policy. To this end we first employ instrumental variable, OLS and two GMM regressions based on asset demand functions derived from the microfounded household utility maximization model. We find that bonds and deposits are imperfect substitutes with the elasticity of substitution somewhat higher than the US counterpart. Next, we construct an asset aggregate consisting of bonds and deposits and find that it depends negatively on interest rate in Poland consistent with theoretical predictions with the price elasticity being close to the one estimated for the United States. Our findings suggest an effective monetary policy transmission to household assets as well as a need for active bond issuance policy of the government in countries like Poland.

JEL: E43,G11,G23

Keywords: demand for deposits and government bonds, substitutability between bonds and deposits

1 Introduction

Recent years have been exceptionally turbulent for the global economy. Pent-up demand after the COVID-19 pandemic and Russia's invasion of Ukraine triggered a significant rise in inflation, in response to which central banks, including Narodowy Bank Polski (NBP), strongly tightened their monetary policy stance. In line with the NBP interest rate hikes, rates on retail bonds and time deposits have increased significantly, reaching in July 2023 peaks of – respectively – 12.7% (against 2.6% in July 2019) and 5.5% (from 1.5% in July 2019; Figure 1) raising the question about the impact of higher interest on demand for these assets. Over the same period, the share of retail bonds in the sum of time deposits and bonds held by households increased to 21% in July 2023, compared with 7% in July 2019 (Figure 4). At the same time, the interest rate changes and growth in retail bonds were significantly stronger than those of time deposits (Figure 1, Figure 3) pointing to the various sensitivity of these two assets to interest rates. This evidence together with still the relatively low share of bonds in household assets suggest that bonds and time deposits may not be perfect substitutes and factors beyond interest rates influence households' asset allocation decisions.

Against this backdrop, the first goal of this paper is to investigate the substitutability between bonds and time deposits as well as construct their aggregate measure that would account for possible imperfect substitutability between them. The second objective of the study is to estimate sensitivity of the demand for these assets to interest rate in Poland – typical small open economy with bank-based financial system and independent monetary policy. Poland is also quite unique as the government enables direct purchases of retail bonds by households. This focus on individual investor makes it possible to concentrate the analysis on households portfolio choice. To this end we first derive demand functions for these assets from a microfounded household utility maximization model, accounting for their imperfect substitutability. These functions provide us with a regression specification that we estimate via GMM and OLS, applying also the instrumental variable (IV) method. We find that bonds and time deposits are imperfect substitutes, with an elasticity of substitution somewhat higher than that observed in the United States. Additionally, an aggregate of these assets exhibits a negative dependence on interest rates in Poland based on the money-demand type regression, consistent with theoretical predictions and of comparable magnitude to its US counterpart.

This paper is related to two strands of the literature. First, we build on studies that investigated substitutability between various household assets. Early articles on this topic included money in the narrower sense (predominantly M1; Hamburger 1966, Moroney and Wilbratte 1976, Donovan 1977, Feige and Pearce 1977, Boughton 1981a, Belongia and Chalfant 1989) and largely focused on the United States finding imperfect substitution between 'near-money' and M1. Other papers documented that shifts in household asset allocation are associated with changes in deposit rates driven both by shifts in central bank interest rate and in bank margins due to the market power of the latter (Bikker and Gerritsen 2018,Agarwal et al. 2021, Polo 2021). More recent studies, in turn, documented imperfect substitution between broader class of assets in the United States (Christensen and Krogstrup (2016) and Krishnamurthy and Li (2023) who built on the Nagel (2016) model, as well as Drechsler et al. (2017) who put emphasis on the importance of deposit spreads).

The second strand of the literature investigated the money demand function following seminal contributions by Baumol (1952) and Tobin (1956). They pointed to the transaction motive of holding non-interest bearing cash and opportunity cost of keeping it stemming from the presence of an interest-bearing asset. In line with Baumol-Tobin model, empirical studies typically found that real demand for narrow money increased with real output and decreased with the interest rate (for the US see: Meltzer 1963, Lucas 2000, Ball 2001, Funke 2001, Bruggeman et al. 2003, Brand and Cassola 2004, Hamori and Hamori 2008, Ireland 2009, Dreger and Wolters 2010, Lucas Jr and Nicolini 2015, Benati et al. 2021, for Poland see: Lane 1992, Nijsse and Sterken 1996, Buch 2001, Kot 2004, Dreger et al. 2007). Number of papers underlined, however, that in recent decades the stability of this relationship for M1 or M2 aggregates has weakened considerably (Boughton 1981b, Lütkepohl 1993, Bahmani-Oskooee* and Rehman 2005, Teles and Zhou 2005, Lucas Jr and Nicolini 2015, Krishnamurthy and Li 2023). Teles and Zhou (2005) indicate that the regulatory changes in the US in the 1980s and technological advances in finance in the 1990s were two important factors affecting the behaviour of money demand. From the monetary authorities' perspective, a lack of stable empirical link between liquidity measures and their determinants, in particular - interest rate, makes them virtually useless from the policy perspective (Lucas Jr and Nicolini 2015).

Attempts to resolve the empirical breakdown offered alternative liquidity aggregates, including assets previously overlooked, that address different rationale for holding money, in particular – the portfolio motive (Reynard 2004, Teles and Zhou 2005, Lucas Jr and Nicolini 2015). Krishnamurthy and Vissing-Jorgensen (2012) emphasised that treasury bonds as well as bank-created money satisfy the demand for liquidity and safe store of value. Greenwood et al. (2015) prove that these functions are fulfilled particularly well by short-term government bonds. In a more recent study, Krishnamurthy and Li (2023) proposed a new broad liquidity aggregate which helped addressing the money-demand instability and missing money puzzles for the US. Our paper builds on their approach since it conveniently allows to analyse the elasticity of substitution between deposits and bonds as well as the household demand for their aggregate also in a small open economy such as Poland.

While utilizing an approach inspired by Krishnamurthy and Li (2023) to investigate demand for bonds and deposits in Poland, we offer a number of novel elements. First, we adjust the modelling framework to match assets held by households in economies like Poland, where 3-month repo loans are not part of their portfolio. Instead, we model the choice between two types of assets: deposits and government bonds. Second, we build an aggregate of retail bonds based on individual series reported by the Polish Ministry of Finance. Third, we derive regression equations not only from asset-in-utility framework but also show that the same demand functions may be obtained from specification where lower liquidity of some assets is captured by transaction costs in the household budget constraint. Finally, we extend the insights from existing literature to a typical small open economy, where the government offers retail bonds directly to households, showing that it is characterized by somewhat larger degree of asset substitutability and comparable sensitivity to interest rate changes as the United States[1].

The rest of the paper is structured as follows. Section 2 presents derivations of estimable regression equations from the households utility maximization. Section 3 describes data used in the estimations, while section 4 – their results. Section 5 concludes.

[1] It should be noted that our analysis focuses solely on households, whereas Krishnamurthy and Li (2023) also include i.a. institutional investors.

2 Model

We consider a representative household who maximizes lifetime utility U_0:

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, Q_t)$$

where β is a discounting parameter, $u(C_t, Q_t) = \frac{C_t^{1-\gamma_c}}{1-\gamma_c} + \frac{Q_t^{1+\gamma_Q}}{1+\gamma_Q}$ is a period utility function of consumption C_t and an asset aggregate Q_t, γ_c and γ_Q are standard parameters in the constant elasticity of substitution utility function. The assets are aggregated according to the CES function:

$$Q_t = \left((1-\lambda_t) \left(\frac{D_t}{P_t} \right)^{\rho} + \lambda_t \left(\frac{B_t}{P_t} \right)^{\rho} \right)^{\frac{1}{\rho}} \tag{1}$$

where D_t denote nominal time deposits, B_t - retail bonds, P_t - price level, λ_t captures time-varying relative liquidity of bonds and deposits, while ρ measures substitutability between two assets ($\sigma = \frac{1}{1-\rho}$ - elasticity of substitution). When $\rho = 1$, deposits and bonds are perfect substitutes because the elasticity of substitution is infinite. Using asset-in-utility approach follows the literature but it is not necessary - in Appendix B we show that the model exhibiting transaction costs allows to derive the same estimable equations. Households face the following budget constraint:

$$P_t C_t + B_t + D_t + A_t + T_t = R_{t-1}^B B_{t-1} + R_{t-1}^D D_{t-1} + R_{t-1}^A A_{t-1} + I_t$$

where A_t are (relatively illiquid) retail bonds with the highest available maturity , T_t – lump-sum taxes, R_t^i - period returns on i-type asset and I_t - (exogenous) real income. Originally Krishnamurthy and Li (2023) used a general collateral repo and banker's acceptance rates as A_t because of their relative illiquidity in comparison to treasury bills. In Poland such an asset is absent and hence we use retail bonds with the highest available maturity as a relatively illiquid instrument[2]. While selling it before maturity date, the bondholder has to pay a fee that is larger than in case of longer-term bonds[3]. In some cases these fees on the long-term bonds may exceed the interest part and as a result also the principal may be deducted. This cannot occur if the deposit is withdrawn early as it is associated only with interest rate loss.

[2]This approach allows us to include vast majority of retail bonds in the CES aggregator (on average around 75% of the entire value of bonds).

[3]Currently (as at the end of 2024), these fees amount to 1 PLN for 3-year bonds, 2 PLN for 4-year bonds and 3 PLN for 6- and 10-year bonds (in the case of 3-month bonds, all interest is forfeited).

As a robustness check, we consider an alternative modelling framework in which we do not include long-term bonds as part of bond aggregate and assume that A_t is a variable that is more (not less) liquid than the relatively illiquid aggregate Q_t. This case is discussed in Appendix C assuming A_t to be current deposits. We find that in this alternative setup conclusions remain unaffected, however, interpretation of some parameter estimates is opaque and not directly comparable to those for the United States.

Solving the household maximization problem we obtain the relationship between relative demand for bonds and deposits, interest rates, relative liquidity preference measure (approximated by European stock market volatility index) and shock to relative demand for bonds and deposits ε_t (see Appendix A for derivations):

$$R_t^A - R_t^B = \frac{\lambda_t}{1-\lambda_t}\left(\frac{B_t}{D_t}\right)^{\rho-1}\left(R_t^A - R_t^D\right)\exp\left(\varepsilon_t\right) \tag{2}$$

and after linearization:

$$\ln\left(R_t^A - R_t^B\right) = \gamma_0 + \gamma_R \ln\left(R_t^A - R_t^D\right) + \gamma_{BD}\ln\left(\frac{B_t}{D_t}\right) + \gamma_V \ln\left(VSTOXX_t\right) + \varepsilon_t \tag{3}$$

where $\gamma_{BD} = \rho - 1$. Again, both B_t and D_t might be correlated with the error term, which can be interpreted as an unobserved relative demand shock. Therefore both GMM and OLS are estimated with instrumental variable (IV) method using debt-to-GDP ratio and its natural logarithm (to capture possible non-linearity) as instruments for $\ln\left(\frac{B_t}{D_t}\right)$. These instruments are unlikely to respond to changes of the dependent variable, given that we consider a relative demand shock, which in turn means that endogeneity should not be a concern. Having estimated parameters γ_{BD} and γ_0 we can calculate parameter β_λ and ρ to obtain Q_t, i.e. the asset aggregate, from eq. 1.

Finally, we follow the literature examining money demand in estimating the demand for asset aggregate:

$$\ln\left(Q_t\right) = \kappa_0 + \kappa_R \ln\left(\frac{R_t^A - R_t^D}{R_t^A}\right) + \kappa_Y \ln GDP_t + \varepsilon_t^Q \tag{4}$$

where κ_i are i-type parameters and ε_t^Q are residuals. As we show in Appendix A, eq. 4 is a reduced demand for asset aggregate that can be derived from the theoretical model.

In order to estimate eq. 3 using GMM, following Krishnamurthy and Li (2023) we define the residual as:

$$u_t = \left(R_t^A - R_t^B\right) - \beta_\lambda VSTOXX_t\left(\frac{B_t}{D_t}\right)^{\rho-1}\left(R_t^A - R_t^D\right) \tag{5}$$

and the moment conditions as:

$$\begin{cases} E\left[u_t\right] & = 0 \\ E\left[u_t \frac{Debt_t}{GDP_t}\right] & = 0 \\ E\left[u_t \left(\frac{Debt_t}{GDP_t}\right)^2\right] & = 0 \\ E\left[u_t \left(R_t^A - R_t^D\right)\right] & = 0 \\ E\left[u_t VSTOXX_t\right] & = 0. \end{cases} \tag{6}$$

The inclusion of $\left(\frac{Debt_t}{GDP_t}\right)^2$ besides $\left(\frac{Debt_t}{GDP_t}\right)$ accounts for the possible non-linear relationships and deals with the identification issue, which brings it closer to the IV. We also replace $E\left[u_t \frac{Debt_t}{GDP_t}\right] = 0$ and $E\left[u_t \left(\frac{Debt_t}{GDP_t}\right)^2\right] = 0$ by:

$$E\left[u_t \frac{B_t}{D_t}\right] = 0 \tag{7}$$

for comparison with the OLS regression. Krishnamurthy and Li (2023) explain that the orthogonality conditions in eq. 6 can be understood in terms of underlying unobserved shocks in the following fashion:

$$\left(R_t^A - R_t^B\right) = \beta_\lambda VSTOXX_t \left(\frac{B_t}{D_t}\right)^{\rho-1} \left[\varepsilon_t^D + \left(R_t^A - R_t^D\right) \varepsilon_t\right] + \varepsilon_t^B, \tag{8}$$

where $\varepsilon_t = \varepsilon_t^B - \varepsilon_t^D$ is the relative-demand shock, where ε_t^D is the shock to deposit spread $\left(R_t^A - R_t^D\right)$ and ε_t^B can be interpreted as a measurement error. Additionally all shocks are mean-zero and independent. The combination of eq. 5 and eq. 8 (after applying first-order approximation) yields:

$$u_t = \beta_\lambda VSTOXX_t \left(\frac{B_t}{D_t}\right)^{\rho-1} \left[\varepsilon_t^D + \left(R_t^A - R_t^D\right) \varepsilon_t\right] + \varepsilon_t^B, \tag{9}$$

which we estimate using GMM.

3 Data

We collect quarterly data on Polish retail bonds, household deposits, (real/nominal) GDP and European stock market volatility index (VSTOXX). Due to data availability the sample begins in 2005q1 and ends in 2024q4. Detailed description of the data sources is presented in Table 1.

Table 1: List of variables

Variable	**Description**	**Source**
B_t	nominal value of outstanding Polish retail bonds held by households	Ministry of Finance
D_t	nominal value of outstanding Polish time deposits held by households	Narodowy Bank Polski
R_t^B	average interest rate of Polish retail bonds	own calculations based on Ministry of Finance data
R_t^D	average interest rate of Polish time deposits	Narodowy Bank Polski
R_t^A	average interest rate of Polish retail bond with longest available maturity	Narodowy Bank Polski
$VSTOXX_t$	volatility index implied from EURO STOXX 50 index options	STOXX
GDP_t	nominal gross domestic product of Poland	Statistics Poland
$Debt_t$	debt of central government	Statistics Poland

The main contribution of the paper in the context of data is to construct the aggregate of Polish retail bonds and their interest rates using the granular data published by Ministry of Finance. This gives us a unique opportunity to focus purely on bonds held by households, which along deposits are the main type of households' financial assets. We aggregate the available data on the stock of the outstanding bonds instead of working on disaggregated data due to three reasons. First, the individual series are not available for the whole sample. Second, using them would substantially increase the number of substitution elasticities to be estimated which would have to account also for variety of maturities of both assets. Third, as the data on households' deposits is aggregated, for comparability we prefer bonds to be so as well. The types of bonds issued are described in Table 2.

Table 2: Data on retail bonds offered by Polish Ministry of Finance

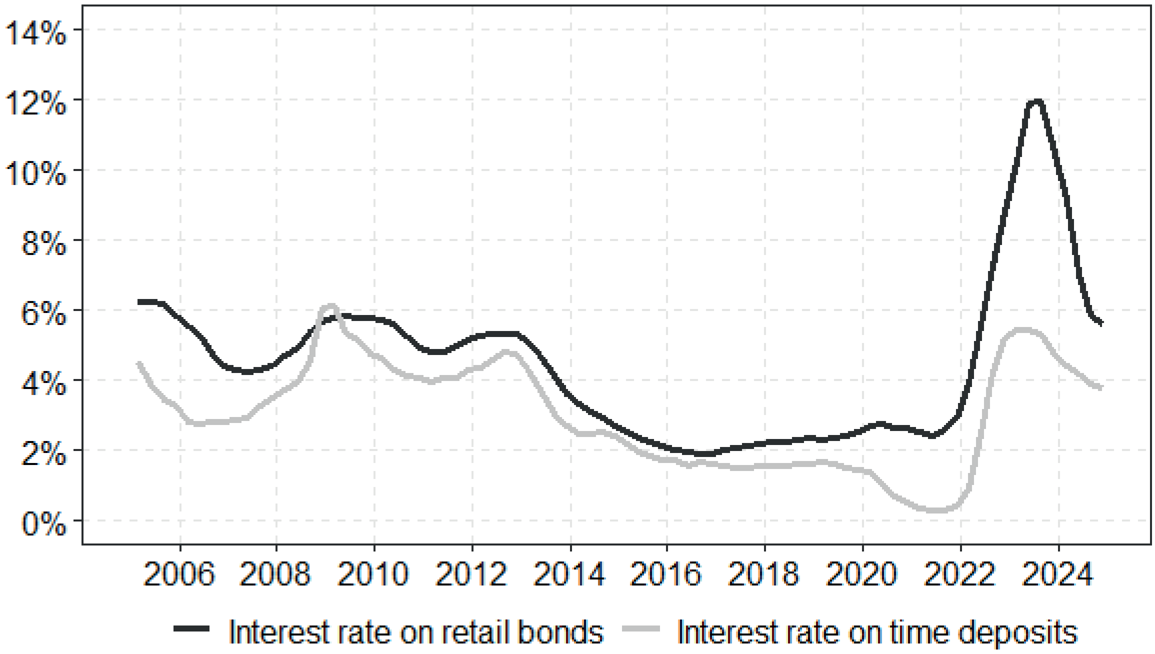
Bond name	**Description**	**Available series (as of December 2024)**
OTS	3-month fixed rate	October 2017 -November 2024
ROR	1-year floating rate	June 2022 - November 2024
DOR	2-year floating rate	June 2022 - November 2024
TOS	3-year fixed rate	August 2022 - November 2024
COI	4-year inflation rate indexed	October 1999 - November 2024
EDO	10-year inflation rate indexed	October 2004 - November 2024
ROS	6-year savings bonds, called *family bonds*, dedicated for beneficiaries of program *Family 500+*	October 2016 - November 2024
ROD	12-year savings bonds, called *family bonds*, dedicated for beneficiaries of program *Family 500+*	October 2016 - November 2024
DOS	2-year fixed rate	June 1999 - August 2020
TOZ	3-year floating rate	May 2012 - July 2022

Source: Ministry of Finance

We aggregate them calculating a weighted average of bonds' interest rate, where the outstanding amounts of each type of bond were used as weights for calculating the weighted average bond interest rate.

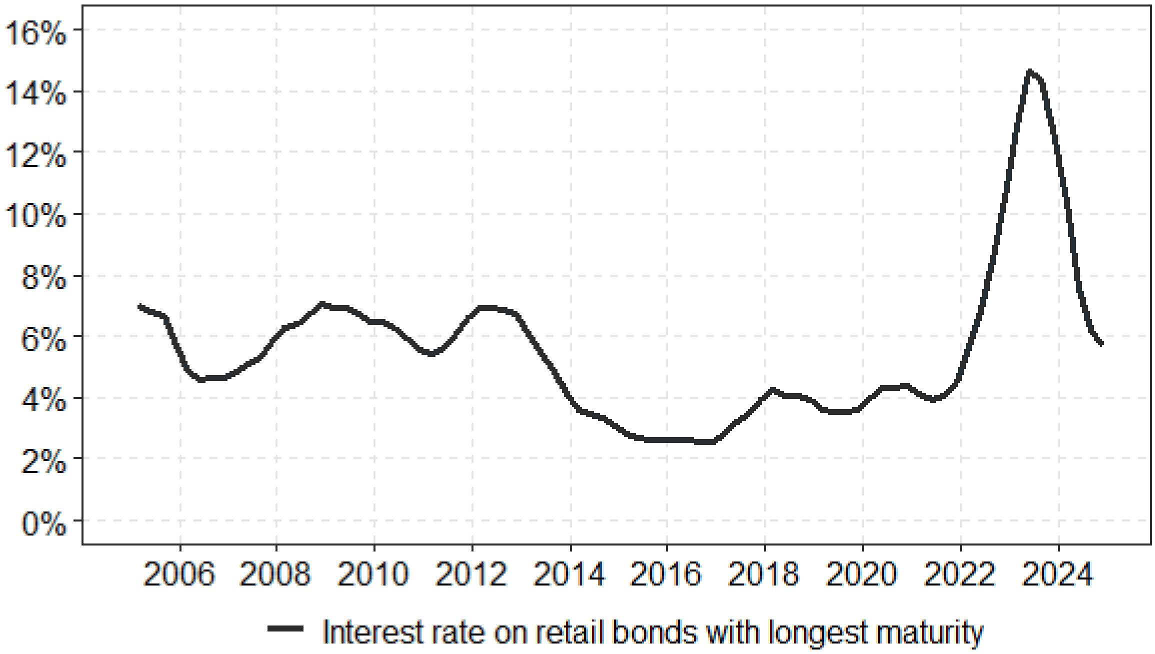
Data on households' deposits used in our analysis are published by NBP. Figure 1 shows that interest rate of retail bonds was higher than deposits' (except for one short period in 2009).

Figure 1: Average interest rates on time deposits and retail bonds held by households



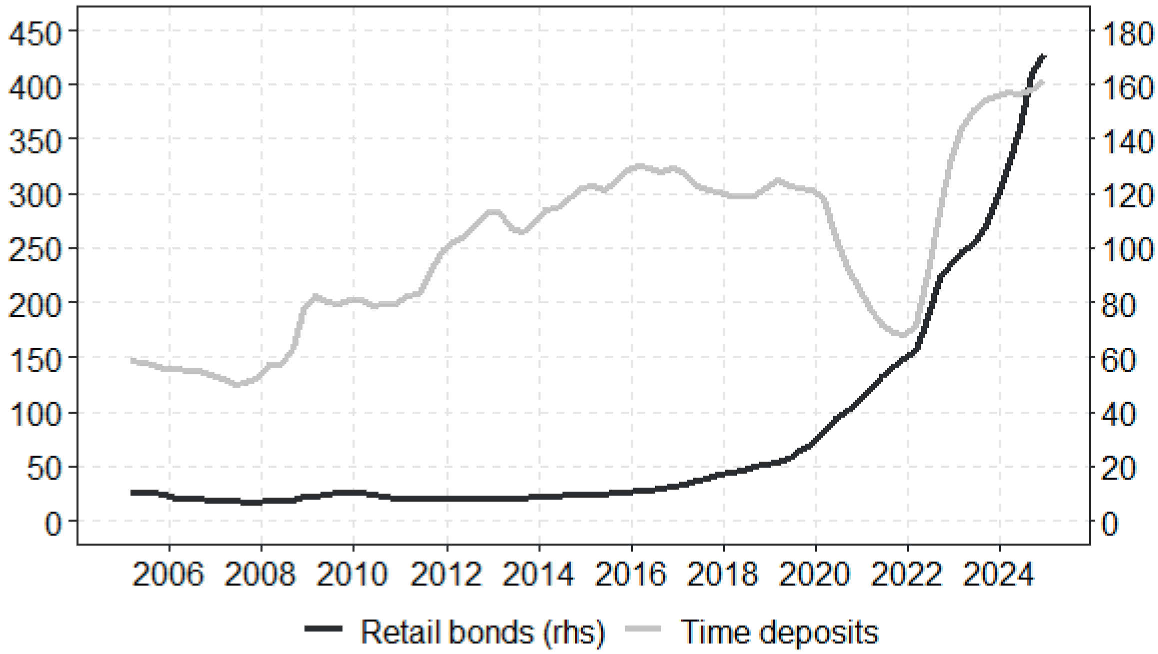
However, the gap has widened significantly in recent years, during which Poland (as well as many other economies) has experienced elevated inflation following the COVID-19 pandemic and the Russian invasion of Ukraine. This widening was to a large extent due to growing interest of long-term, inflation-indexed bonds. In particular, this affected the interest rate of a retail bond with the longest available maturity at given time which is denoted as A_t in our baseline specification (Figure 2).

Figure 2: Interest rates on retail bonds with longest maturity



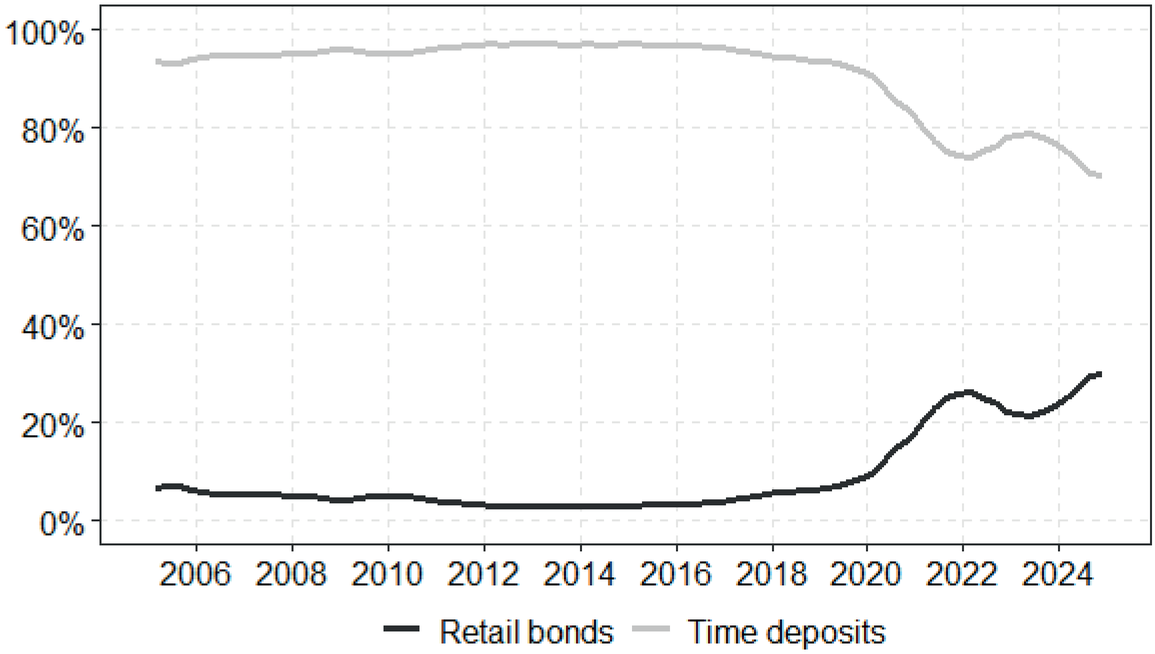
The recent period also saw a considerable increase in popularity of retail bonds, as evidenced in Figure 3.

Figure 3: Stock of time deposits and retail bonds held by households (in PLN billion)



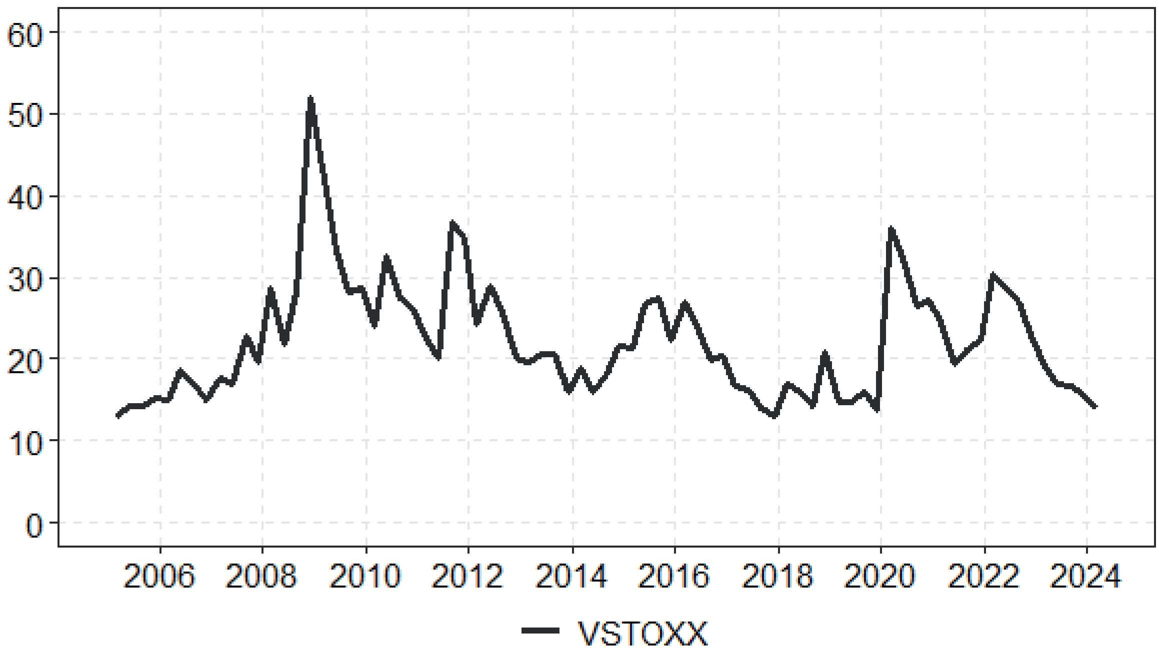
At the same time it should be noted, that even though the stock of time deposit gradually bounced back, the relative share of time deposits in total bonds and deposits held by households markedly declined throughout the years (Figure 4).

Figure 4: Share of time deposits and retail bonds in total bonds and time deposits held by households



Finally, following Nagel (2016) and Krishnamurthy and Li (2023), who utilized CBOE volatility index (VIX) to construct the relative liquidity preference measure λ_t, we use its European counterpart, i.e. the volatility index implied from EURO STOXX 50 index options (*VSTOXX;* Figure 5).

Figure 5: Volatility index implied from EURO STOXX 50 index options



The idea behind using this indicator relies on the fact that bonds are fully guaranteed by the government, while deposits are only covered up to the equivalent of 100,000 EUR. Therefore it is reasonable to assume that during crises a “flight-to-safety” effect occurs, which increases the share for relatively liquid bonds (Beber et al. 2009, Krishnamurthy and Li 2023).

4 Empirical results

The main results regarding the elasticity of substitution between deposits and retail bonds as given by eq. 3 are shown in Table 3.

Table 3: Baseline estimation results in OLS and IV

	Dependent variable: $\ln\left(R_t^A - R_t^B\right)$	
	OLS	IV
$\ln\left(\frac{B_t}{D_t}\right)$	-0.297**	-0.184
	(0.139)	(0.261)
$\ln\left(R_t^A - R_t^D\right)$	1.138***	0.985***
	(0.200)	(0.371)
$\ln\left(VSTOXX_t\right)$	0.608*	0.613**
	(0.321)	(0.320)
constant	-3.021***	-3.287
	(1.047)	(1.006)
Observations	76	
R^2	59.3%	58.0%
Adjusted R^2	57.6%	56.2%
Residual Std. Error	0.410	0.417
F Statistic/Wald test	34.94*** (df = 3; 72)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: the explanatory variable is the logarithm of the spread between: i) the average interest rate of Polish retail bond with the highest maturity and ii) the average interest rate of Polish retail bonds included in the liquidity aggregate. Newey-West standard errors with 4 lags are shown in parentheses

According to the OLS estimation, the parameter γ_{BD} equals -0.3, implying $\rho = 0.7$ or $\sigma \approx 3.33$, and is statistically significant. Moving to the IV approach, we first confirmed the relevance of the instrument. As Table 4 shows, it is strongly correlated with $\frac{B_t}{D_t}$ and the F-statistic is significantly above 10.

Table 4: First-stage regression in IV

	Dependent variable: $\ln\left(\frac{B_t}{D_t}\right)$
$\ln\left(\frac{Debt_t}{GDP_t}\right)$	37.880*
	(20.103)
$\frac{Debt_t}{GDP_t}$	-77.973*
	(39.802)
$\ln\left(R_t^A - R_t^B\right)$	-0.603***
	(0.151)
$\ln\left(R_t^A - R_t^D\right)$	1.820***
	(0.158)
$\ln\left(VSTOXX_t\right)$	0.449*
	(0.244)
constant	65.137***
	(33.917)
Observations	76
R^2	71.2%
Adjusted R^2	69.2%
Residual Std. Error	0.577(df = 70)
F Statistic	34.64*** (df = 5; 70)
Note:	*p<0.1; **p<0.05; ***p<0.01

In the second step, IV regression indicates a slightly higher estimates ($\gamma_{BD} = -0.2$, $\sigma \approx 5.6$) which, however, are statistically insignificant as was also the case for the US (see Krishnamurthy and Li 2023). Finally, we run GMM estimation of the model given by eq. 2 and find GMM results to be broadly consistent with their OLS and IV counterparts (Table 5).

Table 5: Generalized Method of Moments estimation of ρ

	Moment condition based on:	
	OLS	IV
ρ	0.897*	0.872***
	(0.061)	(0.046)
β_λ	0.014***	0.014***
	(0.002)	(0.002)
Observations	80	
p-value of J-test	0.634	0.545
Variation explained	48.9%	49%
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: Newey-West standard errors with 4 lags are shown in parentheses. Variation explained computed as in Krishnamurthy and Li (2023).

Following Krishnamurthy and Li (2023) we use moment conditions that closely relate to the OLS regression, as well as a variation ensuring comparability with IV estimation. The first approach yields $\rho = 0.9$ ($\sigma = 10$) and the latter $\rho = 0.87$ ($\sigma \approx 7.7$). In both cases we find ρ to be statistically different from 1. As the number of moment conditions is higher than the number of parameters ($\beta_\lambda$and ρ), we test the validity of the over-identifying restrictions using the standard Sargan-Hansen J-test. We found the good fitness of the model to the data as indicated by large p-values of corresponding J-tests.

Summing up evidence on the substitutability of assets, based on GMM, IV and OLS estimations we conclude that the elasticity of substitution between retail bonds and time deposits in Poland is substantially larger than 1, but not larger than 10. Consequently, these assets are relatively good, although imperfect substitutes, while relative changes in their interest rates to a large extent translate into rebalancing of household portfolio. Given the levels of asset aggregates and interest rates near the end of our sample, i.e. as of 2024 Q1 (in order to avoid negative bond spread), this implies that an increase in retail bond interest rate by 25 bp ceteris paribus leads to a portfolio rebalancing from deposits to bonds by 76.2 bn PLN, i.e. 19.3% of time deposits. Comparing our results with Table 1 in Krishnamurthy and Li (2023) we find a somewhat larger coefficient on deposit rate spread (c.a. 1 in our case vs 0.5 in Krishnamurthy and Li 2023) and comparably significant $VSTOXX$ (0.6 in our case vs 0.5/0.7 in Krishnamurthy and Li 2023). The former result is actually desired – Krishnamurthy and Li (2023) notice that one should expect the coefficient to be around one, which is true in our case. The latter may indicate relatively similar "flight-to-safety" effect in Poland in comparison with the US.

We use estimated values of parameters $\beta_\lambda$and ρ from GMM specification to calculate Q_t, i.e. the asset aggregate that accounts for imperfect substitutability between bonds and deposits. In next step, we estimate demand equation for this aggregate of assets given by eq. 4 using OLS. This regression is in fact application of Baumol-Tobin model to an estimated CES asset aggregate. The estimation results are presented in Table 6.

Table 6: Estimation results where the explanatory variable is the asset aggregate Q

	Dependent variable: $\ln(Q)$
$\ln\left(\frac{R_t^A - R_t^D}{1+R_t^A}\right)$	-0.227***
	(0.052)
$\ln(GDP_t)$	-0.072
	(0.174)
$\ln(VSTOXX_t)$	-0.374***
	(0.054)
constant	0.218
	(2.343)
Observations	76
R^2	60.7%
Adjusted R^2	59.1%
Residual Std. Error	0.157 (df = 75)
F Statistic	38.66*** (df = 3; 75)
Note:	*p<0.1; **p<0.05; ***p<0.01

Note: Newey-West standard errors with 4 lags are shown in parentheses

Our main finding is that a 1% increase in the deposit premium leads (ceteris paribus) to a 0.2% decrease in demand for the aggregate of time deposits and retail bonds relative to GDP. Given the variable values at the end of our sample, i.e. as of 2024 Q4, this means that an increase in deposit rate by 1 p.p. ceteris paribus leads to a drop in asset aggregate demand by 5.4%. Qualitatively, it is an intuitive outcome that is consistent with theoretical predictions, which indicate that new bonds and time deposits are attractive after an interest rate increase. Quantitatively, in turn, the findings indicate a relatively low elasticity of the asset aggregate as compared with elasticity of substitution between deposits and retail bonds. A plausible explanation for this pattern lies in heterogeneity across households in both portfolio composition and optimization behaviour. First of all, still majority of Polish households hold neither bank deposits nor retail bonds.[4]. Moreover, wealthier households tend to hold substantially more bonds than less affluent ones[5]. If the wealthier also adjust their portfolios more actively in response to changes in interest rates, they are likely to exhibit greater elasticity of substitution between bonds and deposits. At the same time, if poorer households display limited responsiveness to interest rate changes, the aggregate elasticity of demand for interest-bearing assets could be lower.

[4]According to The Association of Financial Companies in Poland (ZPF) and Research Institute for Economic Development of Warsaw School of Economics study, in Q3 2023 (latest available data), 55.1% of Polish households held (at least part of) their savings in cash compared to 39.5% using bank deposits and 8.4% picking retail bonds, see: https://zpf.pl/ponad-polowa-polakow-trzyma-oszczednosci-w-gotowce-juz-zaplacili-wysoki-podatek-inflacyjny/

[5]According to Narodowy Bank Polski study, in 2016 (latest available data), the wealthiest decile of households held 1309 m PLN in bonds, 10% o the average wealth households - 240 m PLN, while the poorest decile held virtually none, see: https://nbp.pl/wp-content/uploads/2022/11/bzgd_2016_en.pdf

4.1 Robustness

In order to verify the robustness of the results we estimate eq. 3 and 4 with alternative specifications. As far as the former regression is concerned, first we limit the sample to assets with maturities of up to 2 years. The results from IV, OLS and GMM estimations are presented in Tables 7-8 and point to higher elasticity of substitution that cannot be statistically distinguished from perfect substitution.

Table 7: Robustness check: bonds with the maturity up to 2Y

	Dependent variable: $\ln\left(R_t^A - R_t^{B2Y}\right)$	
	OLS	IV
$\ln\left(\frac{B_t^{2Y}}{D_t^{2Y}}\right)$	-0.117	-0.163
	(0.183)	(0.298)
$\ln\left(R_t^A - R_t^{D2Y}\right)$	1.770***	0.603***
	(0.315)	(0.048)
$\ln\left(VSTOXX_t\right)$	0.731*	-0.738*
	(0.420)	(0.415)
constant	-0.320	-0.347
	(1.800)	(1.781)
Observations	74	
R^2	60.3%	60.3%
Adjusted R^2	58.6%	58.9%
Residual Std. Error	0.802	0.802
F Statistic/Wald test	35.5*** (df = 3; 70)	35.3*** (df = 3; 70)
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: Newey-West standard errors with 4 lags are shown in parentheses

Table 8: Robustness check: bonds with the maturity up to 2Y - GMM

	Moment condition based on:	
	OLS	IV
ρ	0.893	1.076
	(0.198)	(0.148)
β_λ	0.019	0.0137**
	(0.014)	(0.017)
Observations	80	
p-value of J-test	0.630	0.744
Variation explained	60.6%	66.9%
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: Newey-West standard errors with 4 lags are shown in parentheses. Variation explained computed as in Krishnamurthy and Li (2023).

This outcome indicates that the imperfect substitution outcome in our baseline scenario can be attributed to the presence of bonds with longer maturity (predominantly inflation-indexed bonds). This conclusion is rather expected and intuitive given the nature of both assets and is further confirmed when estimating eq. 3 using only inflation-indexed bonds. In that case the obtained elasticity of substitution is lower than in the baseline results and indicates to imperfect substitution (Table 9).

Table 9: Robustness check: inflation-indexed bonds - GMM

	Moment condition based on:	
	OLS	IV
ρ	0.596***	0.633***
	(0.053)	(0.127)
β_λ	0.015***	0.020**
	(0.003)	(0.10)
Observations	80	
p-value of J-test	0.176	0.005
Variation explained	54.5%	41.5%
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: Newey-West standard errors with 4 lags are shown in parentheses. Variation explained computed as in Krishnamurthy and Li (2023).

Second, as *VSTOXX* index is known for its relatively large volatility we estimate our models using monthly averages of *VSTOXX* (instead of end-of-quarter values) and find that the estimated coefficients and their significance remain broadly unchanged (Table 10-11)[6].

[6] We also replace *VSTOXX* by using calculated coefficient of variation for Polish WIG index. The obtained results remain virtually unchanged.

Table 10: Robustness check: using smoothed VSTOXX

	Dependent variable: $\ln\left(R_t^A - R_t^B\right)$	
	OLS	IV
$\ln\left(\frac{B_t}{D_t}\right)$	-0.356**	-0.275
	(0.149)	(0.257)
$\ln\left(R_t^A - R_t^D\right)$	1.145***	1.035***
	(0.206)	(0.353)
$\ln\left(VSTOXXsmooth_t\right)$	0.568**	0.540*
	(0.271)	(0.291)
constant	-2.970	-3.069
	(0.933)	(0.903)
Observations	76	
R^2	59.8%	59.1%
Adjusted R^2	58.1%	57.5%
Residual Std. Error	0.407	0.411
F Statistic/Wald test	35.7*** (df = 3; 72)	28.03*** (df = 3; 72)
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: Newey-West standard errors with 4 lags are shown in parentheses. VSTOXX smoothed by using a quarter average instead of end-of-quarter values.

Table 11: Robustness check: using smoothed VSTOXX in GMM

	Moment condition based on:	
	OLS	IV
ρ	0.897*	0.874***
	(0.065)	(0.047)
β_λ	0.014***	0.014***
	(0.002)	(0.002)
Observations	80	
p-value of J-test	0.778	0.52
Variation explained	48.5%	48.6%
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: Newey-West standard errors with 4 lags are shown in parentheses. VSTOXX smoothed by using a quarter average instead of end-of-quarter values. Variation explained computed as in Krishnamurthy and Li (2023).

Finally, we test for the number of lags in the HAC estimator which also does not alter our conclusions (Table 12-13).

Table 12: Robustness check: different length of HAC lags

	Dependent variable: $\ln\left(R_t^A - R_t^B\right)$	
	12 lags	16 lags
$\ln\left(\frac{B_t}{D_t}\right)$	-0.297*	-0.297*
	(0.152)	(0.150)
$\ln\left(R_t^A - R_t^D\right)$	1.138***	1.138***
	(0.197)	(0.198)
$\ln(VIX_t)$	0.608	0.608*
	(0.379)	(0.351)
constant	-3.021	-3.021
	(1.200)	(1.254)
Observations	76	
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: OLS method used.

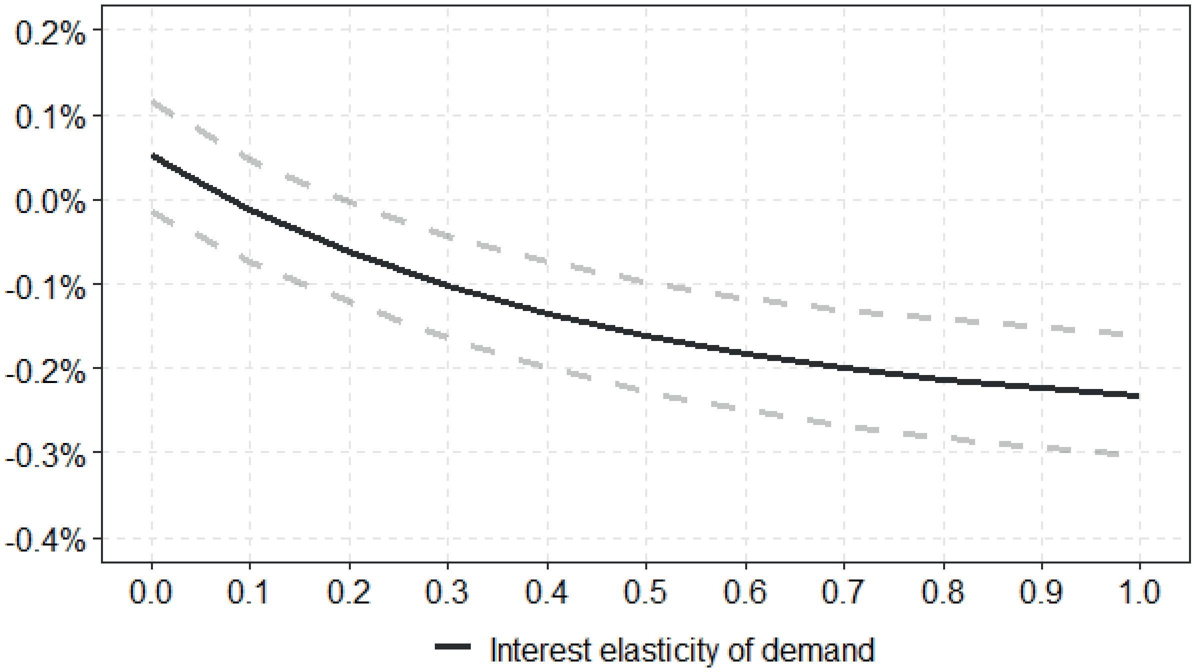
Table 13: Robustness check: different length of HAC lags - GMM

	Moment condition based on:			
	OLS		IV	
	12 lags	16 lags	12 lags	16 lags
ρ	0.897*	0.872***	0.873***	0.89**
	(0.049)	(0.043)	(0.04)	(0.042)
β_λ	0.013***	0.013***	0.014***	0.015***
	(0.002)	(0.001)	(0.002)	(0.002)
Observations	80			
p-value of J-test	0.554	0.526	0.371	0.362
Variation explained	49.4%	49.6%	48.8%	47.1%
Note:	*p<0.1; **p<0.05; ***p<0.01			

Note: Variation explained computed as in Krishnamurthy and Li (2023).

Moving to the second regression, i.e. the one based on eq. 4, we verify to what extent the results from the first stage affect the demand for the asset aggregate that accounts for imperfect substitutability between time deposits and retail bonds. Therefore, we follow an agnostic approach, where we consider the true value of parameter ρ as an unknown and we estimate the set of regressions allowing retail bonds and deposits to be anything from perfect substitutes to fully inelastic. Figure 6 shows that the value of the elasticity of demand (γ_{BD}) decreases with higher ρ.

Figure 6: Interest rate elasticity of demand for interest-bearing, less liquid than narrow money, assets depending on the value of parameter ρ



Note: The dashed lighter lines indicate the 95% confidence interval.

However as long as our assets are not nearly completely inelastic we find that the elasticity is negative and significant, which indicates the robustness of our results from the second stage regression.

Finally, we find that a number of changes to model specifications presented in appendices B and C do not alter the main conclusions, even though interpretation of some parameters changes. More specifically, Appendix B discusses the framework in which the asset aggregate Q_t do not enter the utility function. Instead, deviations in the structure of assets give rise to transaction costs. Under this assumption, we derive the same equation as eq. 7 which we transform to an estimable model in section 2. In Appendix C, in turn, we assume that the asset aggregate Q_t consists of less (not more as in our baseline model) liquid assets as compared to A_t. Under this framework we associate Q_t with retail bonds and time deposits, while A_t - with current deposits. This assumption does not affect the main results on substitutability between retail bonds and time deposits and demand for the asset aggregate, even though it slightly alters the interpretation of the estimated parameters.

To sum up we found alternative approaches to produce results broadly consistent with the baseline outcome. The important exception in this regard is the specification of the first step regression where we use bonds with maturities of up to 2 years and find evidence for perfect substitutability of bonds and deposits. This indicates that bonds with longer maturities are key drivers of the conclusion about imperfect substitution from our baseline approach.

5 Conclusions

To sum up, in this paper we investigated the demand for treasury bonds and deposits in Poland in a two-stage approach. First, we used IV, OLS and two GMM estimations based on microfounded asset demand equations to find that retail bonds and time deposits in Poland are imperfect substitutes. Depending on the method, the elasticity of substitution between these assets is estimated to be between 3 and 10 which is a somewhat larger than its US counterpart. This result implies that relative interest rate changes, e.g. driven by borrowing needs by the government, have substantial impact on household asset allocation.

Second, using the estimated elasticity of substitution we constructed an asset aggregate consisting of retail bonds and deposits. Based on Baumol-Tobin-like model we find that it depends negatively on interest rate in Poland. The estimated parameter is hence consistent with theoretical predictions and its value is closed to the one found for the United States. Relatively stronger elasticity of substitution between bonds and deposits as compared to responsiveness of their aggregate to interest rate changes may reflect household heterogeneity in portfolio composition and optimization behavior.

The results, that have turned out to be robust to multiple modifications, enhance understanding of asset substitutability and the impact of monetary policy on household financial decisions in emerging markets pointing to a substantial impact of interest rates, and therefore also central bank actions, on household asset holdings. More specifically, they suggest that by affecting interest rates on time deposits, changes in monetary policy stance transmit to asset holdings as strongly as in the developed market such as the US. Second, given high asset substitutability, relative changes in interest rates on bonds and time deposits can have large portfolio rebalancing effects. This calls for active bond issuance policy by government aimed at keeping bond yields attractive for households and preventing from an abrupt rebalancing of household portfolio. Furthermore, this result suggests potential risks of fiscal dominance for high levels of public debt. In such environment the central bank may find difficult to increase interest rates if they lead to a strong selloff in government bonds by households.

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Appendix A Key derivations in the baseline model

In order to solve the optimization problem of the representative household we specify the Lagrangian:

$$\mathscr{L}_t = \mathbf{E}_t \sum_{k=0}^{\infty} \beta^{t+k} \{u(C_{t+k}, Q_{t+k}) + ...$$
$$... + \mu_{t+k}[P_{t+k}C_{t+k} + B_{t+k} + D_{t+k} + A_{t+k} + T_{t+k} + ...$$
$$... - R^B_{t+k-1}B_{t+k-1} - R^D_{t+k-1}D_{t+k-1} - R^A_{t+k-1}A_{t+k-1} - I_{t+k}]$$

first order conditions are:

$$\frac{\partial \mathscr{L}_t}{\partial C_t} = u_C + \mu_t P_t = 0 \tag{1}$$

$$\frac{\partial \mathscr{L}_t}{\partial D_t} = u_Q \frac{\partial Q_t}{\partial D_t} + \mu_t - \beta \mathbf{E}_t \mu_{t+1} R^D_t = 0 \tag{2}$$

$$\frac{\partial \mathscr{L}_t}{\partial B_t} = u_Q \frac{\partial Q_t}{\partial B_t} + \mu_t - \beta \mathbf{E}_t \mu_{t+1} R^B_t = 0 \tag{3}$$

$$\frac{\partial \mathscr{L}_t}{\partial A_t} = \mu_t - \beta \mathbf{E}_t \mu_{t+1} R^A_t = 0 \tag{4}$$

Combining eq. 2 and 3 with 4 we get:

$$-u_Q \frac{\partial Q_t}{\partial B_t} = \beta \left(R^A_t - R^B_t\right) \mathbf{E}_t \mu_{t+1} \tag{5}$$

$$-u_Q \frac{\partial Q_t}{\partial D_t} = \beta \left(R^A_t - R^D_t\right) \mathbf{E}_t \mu_{t+1} \tag{6}$$

dividing eq. 6 by 5:

$$\frac{\frac{\partial Q_t}{\partial D_t}}{\frac{\partial Q_t}{\partial B_t}} = \frac{R^A_t - R^D_t}{R^A_t - R^B_t}$$

assuming for estimation purposes shocks to asset-specific demand in aggregate Q: $Q_t = \left((1-\lambda_t)\left(\frac{D_t}{P_t}\right)^{\rho} \exp\left(\varepsilon^D_t\right) + \lambda_t \left(\frac{B_t}{P_t}\right)^{\rho} \exp\left(\varepsilon^B_t\right)\right)^{\frac{1}{\rho}}$ and substituting partial derivatives we obtain:

$$\frac{1-\lambda_t}{\lambda_t} \frac{\exp\left(\varepsilon^D_t\right)}{\exp\left(\varepsilon^B_t\right)} \left(\frac{D_t}{B_t}\right)^{\rho-1} = \frac{R^A_t - R^D_t}{R^A_t - R^B_t} \tag{7}$$

after re-arranging:

$$R_t^A - R_t^B = \frac{\lambda_t}{1-\lambda_t}\left(\frac{B_t}{D_t}\right)^{\rho-1}\left(R_t^A - R_t^D\right)\frac{\exp\left(\varepsilon_t^B\right)}{\exp\left(\varepsilon_t^D\right)}$$

taking natural logarithm:

$$\ln\left(R_t^A - R_t^B\right) = \ln\left(\frac{\lambda_t}{1-\lambda_t}\right) + (\rho-1)\ln\left(\frac{B_t}{D_t}\right) + \ln\left(R_t^A - R_t^D\right) + \varepsilon_t^B - \varepsilon_t^D$$

denoting $\sigma = \frac{1}{1-\rho}$ the price (interest rate) elasticity substitution between bonds and deposits, $\varepsilon_t = \varepsilon_t^B - \varepsilon_t^D$ the shock to relative demand for deposits and bonds and assuming as in Krishnamurthy and Li (2023) that time-varying changes in the relative demand for bonds and deposits is proportional to sentiment changes as described by VSTOXX index: $\frac{\lambda_t}{1-\lambda_t} = \beta_\lambda VSTOXX_t$ we obtain the following equation:

$$\ln\left(R_t^A - R_t^B\right) = \ln\left(\beta_\lambda\right) + \ln\left(VSTOXX_t\right) + (\rho-1)\ln\left(\frac{B_t}{D_t}\right) + \ln\left(R_t^A - R_t^D\right) + \varepsilon_t,$$

which gives the eq. 3 in the main text.

Having estimates of parameters ρ and β_λ we can calculate Q_t from eq. 1. Then, assuming the functional form of the utility:

$$u(C_t, Q_t) = \frac{C_t^{1-\gamma_c}}{1-\gamma_c} + \frac{Q_t^{1+\gamma_Q}}{1+\gamma_Q}$$

we can use eq. 1 to obtain:

$$C_t^{-\gamma_c} + \mu_t P_t = 0 \tag{8}$$

and from eq. 2 and 4:

$$u_Q \frac{\partial Q_t}{\partial D_t} + \mu_t - \frac{\mu_t}{R_t^A} R_t^D = 0$$

taking into account the utility functional form:

$$Q_t^{\gamma_Q + (1-\rho)}\left(1-\lambda_t\right)\left(\frac{1}{P_t}\right)^{\rho}\exp\left(\varepsilon_t^D\right) D_t^{\rho-1} = -\mu_t\left(1 - \frac{R_t^D}{R_t^A}\right)$$

substituting eq. 8 into this equation we get:

$$Q_t = \left[\left(1 - \frac{R_t^D}{R_t^A}\right) C_t^{-\gamma_c}\left(\frac{D_t}{P_t}\right)^{1-\rho}\frac{1}{1-\lambda_t}\exp\left(-\varepsilon_t^D\right)\right]^{\frac{1}{\gamma_Q + (1-\rho)}}$$

which after linearization gives:

$$
\begin{aligned}
\ln (Q_t) = & \frac{1}{\gamma_Q + (1-\rho)} \ln (\beta_{\lambda Q}) - ... \\
& ... + \frac{1}{\gamma_Q + (1-\rho)} \ln \left(\frac{R_t^A - R_t^D}{R_t^A} \right) + \frac{-\gamma_c}{\gamma_Q + (1-\rho)} \ln C_t + ... \\
& + \frac{1-\rho}{\gamma_Q + (1-\rho)} \ln \left(\frac{D_t}{P_t} \right) + \frac{1}{\gamma_Q + (1-\rho)} \ln (VSTOXX_t) + \frac{1}{\gamma_Q + (1-\rho)} \varepsilon_t^D
\end{aligned}
$$

this equation can be reduced to the eq. 4 estimated in Krishnamurthy and Li (2023) from the main text with parameters: $\kappa_0 = \frac{1}{\gamma_Q+(1-\rho)} \ln (\beta_{\lambda Q})$, $\kappa_R = \frac{1}{\gamma_Q+(1-\rho)}$, $\kappa_Y = \frac{-\gamma_c}{\gamma_Q+(1-\rho)}$, ignoring deposit and VSTOXX terms and assuming that consumption is proportional to GDP.

Appendix B Transaction cost model

This appendix presents the alternative derivation of model equations using transaction costs specification and utility drawn only from consumption:

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t)$$

where:

$$Q_t = \left((1-\lambda_t) \left(\frac{D_t}{P_t} \right)^{\rho} + \lambda_t \left(\frac{B_t}{P_t} \right)^{\rho} \right)^{\frac{1}{\rho}}$$

subject to the budget constraint:

$$P_t C_t + B_t + D_t + \frac{\zeta}{2} \left(\nu \frac{B_t}{D_t} - 1 \right)^2 + A_t + T_t = R^B_{t-1} B_{t-1} + R^D_{t-1} D_{t-1} + R^A_{t-1} A_{t-1} + I_t$$

which implies that while trading in less liquid assets, households have to pay linear time-varying transaction costs.

This specification results in the following Lagrangian

$$\begin{aligned} \mathscr{L}_t = \mathbf{E}_t \sum_{k=0}^{\infty} \beta^{t+k} \{ & u(C_{t+k}) + \mu_{t+k} \\ & [P_{t+k} C_{t+k} + B_{t+k} + D_{t+k} + \frac{\zeta}{2} \left(\frac{Q_{t+k}}{Q} - 1 \right)^2 + A_{t+k} + T_{t+k} + ... \\ & - R^B_{t+k-1} B_{t+k-1} - R^D_{t+k-1} D_{t+k-1} - R^A_{t+k-1} A_{t+k-1} - I_{t+k}] \} \end{aligned}$$

first order conditions are:

$$\frac{\partial \mathscr{L}_t}{\partial C_t} = u_C + \mu_t P_t = 0 \tag{9}$$

$$\frac{\partial \mathscr{L}_t}{\partial D_t} = \mu_t - \mu_t \zeta \frac{\partial Q_t}{\partial D_t} \left(\frac{Q_t}{Q} - 1 \right) - \beta \mathbf{E}_t \mu_{t+1} R^D_t = 0 \tag{10}$$

$$\frac{\partial \mathscr{L}_t}{\partial B_t} = \mu_t - \mu_t \zeta \frac{\partial Q_t}{\partial B_t} \left(\frac{Q_t}{Q} - 1 \right) - \beta \mathbf{E}_t \mu_{t+1} R^B_t = 0 \tag{11}$$

$$\frac{\partial \mathscr{L}_t}{\partial A_t} = \mu_t - \beta \mathbf{E}_t \mu_{t+1} R^A_t = 0 \tag{12}$$

Combining eq. 10 and 11 with 12 we get:

$$\mu_t - \mu_t \zeta \frac{\partial Q_t}{\partial B_t}\left(\frac{Q_t}{Q} - 1\right) = \mu_t \frac{R_t^B}{R_t^A} \tag{13}$$

$$1 - \zeta \frac{\partial Q_t}{\partial B_t}\left(\frac{Q_t}{Q} - 1\right) = \frac{R_t^B}{R_t^A}$$

$$-\zeta \frac{\partial Q_t}{\partial B_t}\left(\frac{Q_t}{Q} - 1\right) = \frac{R_t^B - R_t^A}{R_t^A}$$

and analogously:

$$-\zeta \frac{\partial Q_t}{\partial D_t}\left(\frac{Q_t}{Q} - 1\right) = \frac{R_t^D - R_t^A}{R_t^A}$$

this gives:

$$\frac{\frac{\partial Q_t}{\partial B_t}}{\frac{\partial Q_t}{\partial D_t}} = \frac{R_t^A - R_t^B}{R_t^A - R_t^D}$$

given:

$$\frac{\partial Q_t}{\partial B_t} = \left((1-\lambda_t)\left(\frac{D_t}{P_t}\right)^{\rho} + \lambda_t \left(\frac{B_t}{P_t}\right)^{\rho}\right)^{\left(\frac{1}{\rho}-1\right)} \lambda_t \left(\frac{B_t}{P_t}\right)^{\rho-1}$$

$$\frac{\partial Q_t}{\partial D_t} = \left((1-\lambda_t)\left(\frac{D_t}{P_t}\right)^{\rho} + \lambda_t \left(\frac{B_t}{P_t}\right)^{\rho}\right)^{\left(\frac{1}{\rho}-1\right)} (1-\lambda_t) \left(\frac{D_t}{P_t}\right)^{\rho-1}$$

we obtain:

$$\frac{\lambda_t}{(1-\lambda_t)}\left(\frac{B_t}{D_t}\right)^{\rho-1} = \frac{R_t^A - R_t^B}{R_t^A - R_t^D}$$

which is the same (before adjusting for relative demand shocks) as eq. 7.

Appendix C Alternative asset structure

In this Appendix we present an alternative specification of the model which differs from the baseline in that it assumes that the asset aggregate Q_t is less (instead of more as in the baseline) liquid than the asset A_t. The former includes now also long-term bonds together with bonds of shorter maturity and time deposits while the latter represents current deposits. As a consequence households derive now disutility from holding the asset aggregate: $u(C_t, Q_t) = \frac{C_t^{1-\gamma_c}}{1-\gamma_c} - \frac{Q_t^{1+\gamma_Q}}{1+\gamma_Q}$. This change does not affect most of derivations presented in Appendix A. The main adjustment occurs in eq. 7 which now takes the form:

$$\frac{1-\lambda_t}{\lambda_t}\frac{\exp\left(\varepsilon_t^D\right)}{\exp\left(\varepsilon_t^B\right)}\left(\frac{D_t}{B_t}\right)^{\rho-1} = \frac{R_t^D - R_t^A}{R_t^B - R_t^A}$$

This adjustment of eq. 7 guarantees that interest rate spreads are positive and all variables in the equation can be logged. As a consequence in the first step of this approach we estimate the equation of the form:

$$\ln\left(R_t^B - R_t^A\right) = \gamma_0 + \gamma_R \ln\left(R_t^D - R_t^A\right) + (\rho - 1)\ln\left(\frac{B_t}{D_t}\right) + \gamma_V \ln\left(VSTOXX_t\right) + \varepsilon_t \quad (14)$$

Table 8 presents the results of this estimation given by OLS and IV. Knowing that now we consider assets included in the aggregate Q_t to be less liquid than the asset A_t, hence deriving disutility, we obtain coefficients with the opposite sign in comparison to our baseline results. This in turn might cause some interpretational difficulties. To build some intuition one can consider it to be negative of those from the baseline approach. The values of the estimates are indeed close to be a mirror reflection of their counterparts in Table 3. Taking that distinction into consideration we conclude, that the elasticity of substitution in the case of OLS is: $\sigma \approx 3$ and result yielded from IV is somewhat larger - $\sigma \approx 4.33$ (we find instruments used in IV to be relevant, as evidenced by high value of F statistic; Table 2). In both cases we find imperfect substitutability. GMM results are presented in Table 3 and lead to similar conclusions.

Table 1: Baseline estimation results in OLS and IV - alternative asset structure

	Dependent variable: $\ln\left(R_t^B - R_t^A\right)$	
	OLS	IV
$\ln\left(\frac{B_t}{D_t}\right)$	0.330**	0.231***
	(0.050)	(0.074)
$\ln\left(R_t^D - R_t^A\right)$	0.512***	0.504***
	(0.064)	(0.097)
$\ln\left(VSTOXX_t\right)$	0.040	-0.001
	(0.098)	(0.103)
constant	-0.549	-0.721
	(0.501)	(0.654)
Observations	80	
R^2	83.3%	80.0%
Adjusted R^2	82.7%	79.3%
Residual Std. Error	0.189	0.206
F Statistic/Wald test	126.6*** (df = 3; 76)	67.63*** (df=3; 76)
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: the explanatory variable is the logarithm of the spread between: i) the average interest rate of Polish retail bonds and ii) the average interest rate of current deposits. Newey-West standard errors with 4 lags are shown in parentheses

Table 2: First-stage regression in IV - alternative asset structure

	Dependent variable: $\ln\left(\frac{B_t}{D_t}\right)$
$\ln\left(\frac{Debt_t}{GDP_t}\right)$	-0.344
	(0.939)
$\frac{Debt_t}{GDP_t}$	4.150
	(2.664)
$\ln\left(R_t^B - R_t^A\right)$	1.815***
	(0.135)
$\ln\left(R_t^D - R_t^A\right)$	-0.635***
	(0.121)
$\ln\left(VSTOXX_t\right)$	-0.245*
	(0.136)
constant	-0.262***
	(1.874)
Observations	80
R^2	82.8%
Adjusted R^2	81.6%
Residual Std. Error	0.364 (df = 74)
F Statistic	71.21*** (df = 5; 74)
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 3: Generalized Method of Moments estimation - alternative asset structure

	Moment condition based on:	
	OLS	IV
σ	8.247	2.941***
	(0.123)	(0.118)
β_λ	0.152***	0.415***
	(0.053)	(0.137)
Observations	80	
p-value of J-test	0.642	0.322
Note:	*p<0.1; **p<0.05; ***p<0.01	

Note: Newey-West standard errors with 4 lags are shown in parentheses

Similarily, the second-stage equation now takes the following form:

$$\ln\left(Q_t\right) = \kappa_0 + \kappa_R \ln\left(\frac{R_t^D - R_t^A}{R_t^A}\right) + \kappa_Y \ln GDP_t + \varepsilon_t^Q \tag{15}$$

It is worth reiterating that despite following the money demand literature, our aggregate in this case should not be interpreted as a typical money aggregate given the nature of the asset considered. Importantly, we now consider the demand for asset aggregate Q_t that is relatively less liquid than the another asset held by households (A_t). Once again our findings turn out to be similar to those in baseline results as they only differ by the sign (Table 4). In this alternative specification a 1% increase in the deposit premium leads (ceteris paribus) to a 0.13% increase in demand for the aggregate of time deposits and retail bonds relative to GDP. Summing up, we conclude that alternative asset specification does not alter the main conclusions of the paper on substitutability between retail bonds and time deposits and demand for the asset aggregate, even though it slightly affects interpretation of the estimated parameters.

Table 4: Estimation results where the explanatory variable is the asset aggregate Q - alternative asset structure

	Dependent variable: $\ln(Q)$
$\ln\left(\frac{R_t^D - R_t^A}{1+R_t^A}\right)$	0.131***
	(0.024)
$\ln(GDP_t)$	0.446***
	(0.109)
$\ln(VSTOXX_t)$	-0.575***
	(0.044)
constant	-5.519***
	(1.492)
Observations	80
R^2	92.1%
Adjusted R^2	91.8%
Residual Std. Error	0.099 (df = 75)
F Statistic	291.2*** (df = 3; 75)
Note:	*p<0.1; **p<0.05; ***p<0.01

Note: Newey-West standard errors with 4 lags are shown in parentheses nbp.pl