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Is There a Portfolio Rebalancing Channel of QE in Latvia?

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Abstract

Portfolio rebalancing is a key mechanism through which central bank asset purchases flatten the yield curve, thus providing additional monetary policy accommodation when conventional policy rate setting is constrained by the effective lower bound. Existing literature provides ample evidence that this channel has played a major role in compressing the long-term interest rates and provided a broad-based easing of financial conditions for firms and households in the euro area. However, this evidence originates from either aggregate euro area or its largest jurisdictions, leaving the effects of the Eurosystem's asset purchases on smaller member states, such as Latvia, unclear. Therefore, we employ a bilateral structural vector autoregression, featuring both aggregate euro area and Latvian blocks, as well as a panel structural vector autoregression with cross-sectional heterogeneity to obtain evidence from both macro-level and bank-level data in order to shed some light on the transmission of QE to the Latvian economy. Our findings suggest that QE led to a compression of sovereign borrowing costs in Latvia and boosted economic activity and prices. At the same time, we also document that the further pass-through to domestic financial conditions was weak owing to limited asset rebalancing by the domestic banking sector in response to the Eurosystem's QE. Instead, we show that Latvian yields were compressed due to direct intervention of the central bank in the bond markets and portfolio readjustment of foreign investors. Our study thus provides additional evidence that the transmission of common monetary policy to the Latvian economy is impaired via the domestic banking sector.

Keywords: quantitative easing, portfolio rebalancing, monetary policy, euro area, Latvia

JEL Codes: C54, E50, E52, E58

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1 Introduction

The Eurosystem has actively deployed large-scale asset purchases since 2015[1] to provide additional monetary policy accommodation as the conventional monetary policy tools were largely constrained by the effective lower bound (ELB) to sufficiently stabilize the path of inflation towards the target. A key aim of quantitative easing (QE) is to compress interest rates at the long end of the term structure and thus bypass the ELB on short-term rates. The compression of long-term rates then results in a broad-based easing of financial conditions for firms and households as these rates are used in the pricing of corporate and mortgage loans. As lower borrowing costs lead to an expansion in credit, the monetary impulse of QE propagates further to an increase in economic activity and inflation.

The main transmission mechanism through which QE flattens the yield curve is the portfolio rebalancing channel (see Vayanos and Vila (2021) for theoretical underpinnings). Since central bank intervention in the bond markets directly affect market equilibrium conditions, asset purchases are able to drive down yields in the targeted segments (labelled as the "local supply" sub-channel in the literature). Additionally, QE removes duration risk from the market, causing price-sensitive investors to readjust their portfolios in order to maintain the desired level of return ("preferred habitat" motive), thus leading to a compression of yields also in the non-targeted segments. Moreover, the portfolio rebalancing mechanism also relieves bank funding constraints as the central bank, by purchasing assets from financial intermediaries, provides them with funds, giving rise to the bank lending channel of QE (Gertler and Karadi (2011), Karadi and Nakov (2021)).

Existing empirical literature provides ample evidence that QE in the euro area, via the portfolio rebalancing, squeezed the sovereign borrowing costs (see Eser et al. (2019), De Santis (2020), Lemke and Werner (2020), Altavilla et al. (2021), Mudde et al. (2021) among others) and trickled down to bank lending rates and incentivised loan creation (Albertazzi et al. (2021),Altavilla et al. (2018), Altavilla et al. (2021)).

However, these studies focus either on the aggregate euro area or its largest jurisdictions, leaving the effects of QE on smaller member states, such as Latvia, ambiguous. Latvia provides an interesting case study due to its highly concentrated banking sector, allowing to gather evidence on the role of bank market power for monetary policy transmission. Establishing evidence on cross-

[1] The Eurosystem announced the Asset Purchase Programme (APP) in January 2015 and the Pandemic Emergency Purchase Programme (PEPP) in March 2020. In this paper, the term asset purchases is used interchangeably with quantitative easing in reference to the APP and the PEPP.

country differences in the pass-through of monetary policy impulses and factors driving them, such as the peculiarities of banking sector, is particularly important for understanding the potential asymmetries and side effects of common monetary policy in the euro area. Current literature on the transmission of the ECB's monetary policy to the Latvian economy suggests that it generates significant real effects, mostly via trade spillovers (see Georgiadis (2015) for the evidence regarding conventional monetary policy shocks, Burriel and Galesi (2018) for unconventional monetary policy shocks and Benecka et al. (2018) for monetary policy shocks generally). However, existing literature suggests that the transmission of common monetary policy via financial channels appears to be limited. For example, Zlobins (2020) also empirically analyses the APP transmission to Latvia using aggregate macroeconomic time series and concludes that under the "first round" of the APP[2] the portfolio rebalancing channel was not activated in Latvia. Benkovskis et al. (2021) studies the transmission of monetary policy measures deployed by the ECB over the period from 2014 to 2020 using individual bank-level data. Their findings suggest that the pass-through of monetary policy measures to lending rates in Latvia has been limited, making them among the highest in the euro area. We contribute to the literature on the transmission of common monetary policy to Latvia by focusing particularly on the financial effects of the Eurosystem's asset purchases, combining approaches to obtain evidence both from aggregate and bank-level data. Also, the passage of time allows to estimate the effects of the APP covering only the relevant sample period and reconsider existing evidence.

Overall, we find robust evidence that QE activated the portfolio rebalancing mechanism in Latvia, but did so differently compared to the aggregate euro area. We show that the flattening of Latvian yield curve was primarily driven by the direct impact of the central bank presence in the bond markets as well as portfolio readjustment of foreign investors. However, we also document that the further pass-through of QE to lending volumes and rates has been weak in Latvia due to limited portfolio rebalancing by the domestic banking sector.

The paper proceeds as follows. Section 2 reviews the relevant literature, while Section 3 describes the empirical framework, data and the identification strategy used in our paper to pin down the effects of the Eurosystem's asset purchases in Latvia. Section 4 presents and discusses the results. Finally, Section 5 concludes.

[2]The ECB announced the APP in January 2015, with purchases starting in March of the same year. Net purchases under the "first round" of the APP ended in December 2018, however, they were soon resumed in September 2019 and lasted until July 2022.

2 Literature Review

As claimed in Rostagno et al. (2019), duration extraction-induced portfolio rebalancing has dominated the ECB's view on how QE is transmitted to the wider economy. Moreover, the literature which documents the experience with QE of central banks, which adopted it prior to the ECB, indeed highlight this mechanism as the main channel through which central bank asset purchases affect the yield curve (see e.g. Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Joyce et al. (2011), Vayanos and Vila (2021)), along with the signalling channel (see Bauer and Rudebusch (2014) and Bhattarai et al. (2015)). In addition to duration extraction, the portfolio rebalancing motive also gives rise to the bank lending channel of QE (see Gertler and Karadi (2011) and Karadi and Nakov (2021)). By participating in asset purchase programmes, banks can relieve their funding constraints by selling bonds to the central bank and re-direct the obtained funds towards lending. Finally, central bank asset purchases directly affect equilibrium conditions in the bond markets for a given maturity. For example, by purchasing 10-year German bonds, QE reduces their supply and leads investors to switch to other bonds with similar maturity, compressing also their yield, but not significantly for other maturities. Hence, this channel has been labelled as the "local supply" sub-channel (D'Amico and King (2013), Froemel et al. (2022)).

Existing empirical evidence on the ECB's QE confirms that the portfolio rebalancing channel indeed has been the main channel through which asset purchases have flattened the sovereign yield curve in the euro area (see Eser et al. (2019), De Santis (2020), Lemke and Werner (2020), Altavilla et al. (2021), Mudde et al. (2021)). Moreover, the literature finds that QE induced a broad-based easing of financial conditions for both firms and households, with a strong pass-through to lending rates and volumes (Albertazzi et al. (2021), Altavilla et al. (2018), Altavilla et al. (2021)). As a result, QE had a sizable macroeconomic impact in the euro area, boosting output and inflation (see Andrade et al. (2016), Garcia Pascual and Wieladek (2016), Hartmann and Smets (2018), Rostagno et al. (2019) Gambetti and Musso (2020), Mandler and Scharnagl (2020)). However, the aforementioned studies focus either on the aggregate euro area or its largest jurisdictions, leaving its effects on smaller member states, such as Latvia, ambiguous.

Therefore, we contribute to the strand of literature documenting the effects of the ECB's monetary policy on Latvia and small jurisdictions of the euro area in general. Existing studies show that the common monetary policy generates comparable macroeconomic effects in Latvia to the aggregate euro area, with most of the impact transmitted via trade channel (Georgiadis (2015), Burriel and Galesi (2018), Benecka et al. (2018)). However, the transmission via financial channels appears to be limited. Zlobins (2020) and Benkovskis et al. (2021) particularly look at the impact of unconventional tools adopted by the ECB since the onset of the ELB and find little evidence that they have lowered Latvian bond yields or bank lending rates. This paper combines econometric approaches to obtain evidence both from aggregate and bank-level data, described in detail in the next section. The passage of time also allows to estimate the models covering only the period when QE was actually deployed, minimising the bias in the estimated parameters.

3 Empirical framework

In this section, we describe our econometric framework to evaluate the effects stemming from the Eurosystem's asset purchases in Latvia. As our baseline model, we employ a bilateral structural vector autoregression (SVAR) with block exogeneity, first introduced by Cushman and Zha (1997) and often used to study monetary policy spillovers from large to small economies (see, e.g. Bluwstein and Canova (2016), Moder (2019) and Zlobins (2020)). Additionally, we use a panel structural vector autoregression with a cross-sectional heterogeneity as in Canova and Ciccarelli (2013) to cross-check the evidence obtained from macro-level data with findings from bank-level data.

3.1 Structural vector autoregression with block exogeneity

We consider the following SVAR model:

$$A_0 x_t = a_0 + \sum_{j=1}^{p} A_j x_{t-j} + \epsilon_t \tag{1}$$

where a_0 is a vector of constants, A_j is an $m \times m$ array of SVAR coefficients related to the *j-th* lag, x_t for $t = 1, ..., T$ is an $m \times 1$ vector of m variables and ϵ_t denotes the $m \times 1$ vector of residuals with variance-covariance matrix Σ_t. We then impose block exogeneity to ensure that the variables in the Latvian block have no impact on their euro area counterparts by making A_j lower triangular:

$$A_j = \begin{bmatrix} A_{11}^j & 0 \\ A_{21}^j & A_{31}^j \end{bmatrix}, j = 0, ..., p \tag{2}$$

The introduction of block exogeneity effectively implies that both impact matrix A_0 and coefficients A_j with regard to Latvian variables in the block of euro area equations are forced to take a value of 0. Since the model is estimated using Bayesian methods, this is straightforward to implement by setting a 0 prior mean on the corresponding coefficients and by assigning hyper-parameter λ_5, which controls the block exogenous variance, to take a value of 0.001, ensuring that the posterior distribution of these coefficients is centred tightly around 0. In our case, we use an independent normal-Wishart prior distribution, which assumes that the matrix containing VAR coefficients A_j is multivariate normal:

$$A_j \sim N(A_{j0}, \Omega_0) \tag{3}$$

where coefficient mean A_{j0} is an $m \times 1$ vector and Ω_0 is an $m \times m$ diagonal coefficient covariance matrix with variance relating endogenous variables to their own lags given by:

$$\sigma_{ii}^2 = \left(\frac{\lambda_1}{l^{\lambda_3}}\right)^2 \tag{4}$$

where λ_1 is a hyper-parameter that controls the overall tightness, l is the lag considered by the coefficient and λ_3 controls the relative tightness of the variance of lags other than the first one. The variance for cross-variable lag coefficients is given by:

$$\sigma_{ij}^2 = \left(\frac{{\sigma_i}^2}{{\sigma_j}^2}\right)\left(\frac{\lambda_1\lambda_2}{l^{\lambda_3}}\right)^2 \tag{5}$$

where σ_i^2 and σ_j^2 denote the OLS residual variances of an autoregressive model estimated for variables i and j and λ_2 is a hyper-parameter that controls the cross-variable weighting. Finally, the variance for the constant is given by:

$$\sigma_c^2 = {\sigma_i}^2(\lambda_1\lambda_4)^2 \tag{6}$$

where λ_4 is a hyper-parameter governing the exogenous variable tightness. In our case, we specify the prior using standard values for the hyper-parameters, i.e. we set the AR coefficient of the prior to 1, overall tightness λ_1=0.2, cross-variable weighting λ_2=0.99, lag decay λ_3=2 and exogenous variable tightness λ_4=100. Turning to the prior for the residual covariance matrix Σ, we assume that it follows an inverse Wishart distribution:

$$\Sigma \sim IW(S_0, \alpha_0) \tag{7}$$

where S_0 is an $m \times m$ scale matrix for the prior and α_0 is the number of degrees of freedom. S_0 is obtained from individual AR regressions following Karlsson (2012):

$$S_0 = (\alpha_0 - m - 1) \begin{pmatrix} {\sigma_1}^2 & 0 & 0 & 0 \\ 0 & {\sigma_2}^2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & {\sigma_m}^2 \end{pmatrix} \tag{8}$$

where the degrees of freedom are set to $\alpha_0 = m + 2$.

The posterior distribution of the reduced form parameters and the residual covariance matrix is obtained via the Gibbs sampler with a total number of 10 000 iterations with the first 5 000 discarded as burn-in.

In the baseline specification of the model, the euro area block consists of five monthly variables: Real GDP, HICP, Euro Stoxx 50, the EONIA and 10-year benchmark bond yield, while the Latvian block includes the same country-specific counterparts with exception of the EONIA. In order to analyse the transmission mechanism of the ECB's asset purchases to the Latvian economy, we further expand the model with additional variables one-by-one. Regarding the data sample, we estimate the model over the period from January 2015 to November 2021, thus ensuring that the parameters are consistent with the actual deployment of asset purchases in the euro area. Given that the period also includes the acute phase of Covid-19 pandemic (March–July 2020), special attention is needed to treat the impact of these outliers on inference. Lenza and Primiceri (2020) show that the extreme volatility in the data from March to June 2020 has a considerable impact on the parameter estimates and shock volatilities, thus implying serious consequences for identification in the VAR models. In this paper, we follow Carriero et al. (2021), which, *inter alia*, suggests to introduce dummies in the months affected by the pandemic to soak up the excess volatility observed in this period, alleviating the impact of outliers on inference in VARs. Specifically, we include two Covid-19 related dummies as exogenous variables with the first dummy taking the value of 1 in March and April 2020, while the second one - in May, June and July 2020. The lag order is set to 1 and the model includes a constant.

3.2 Panel structural vector autoregression with cross-sectional heterogeneity

In order to obtain robust evidence on the transmission of Eurosystem's asset purchases to the Latvian banking sector, we additionally employ a panel SVAR with a cross-sectional heterogeneity as in Canova and Ciccarelli (2013) and estimate it with Bayesian methods by using the hierarchical prior of Jarocinski (2010). This setup allows to estimate the effects of central bank asset purchases on individual banks which actually participated in the asset purchase programmes. We consider this aspect particularly important because using only aggregate banking sector data in a bilateral SVAR, as described in the previous subsection, could potentially mask the portfolio rebalancing effects among banks due to a significant heterogeneity among them observed in Latvia.

Panel SVAR with a cross-sectional heterogeneity for unit i (with $i = 1, 2, ..., N$) takes the following form:

$$y_{i,t} = A_i^1 y_{i,t-1} + ... + A_i^j y_{i,t-j} + C_i x_t + \epsilon_t \tag{9}$$

where $y_{i,t}$ is an $m \times 1$ vector of m endogenous variables, A_i^1 and A_i^j are an $m \times m$ arrays of SVAR coefficients related the first and *j-th* lag respectively, x_t is an $n \times 1$ vector of n exogenous variables with C_i being $n \times m$ matrix relating the endogenous variables to those exogenous variables. Lastly, ϵ_t denotes $m \times 1$ vector of residuals with variance-covariance matrix Σ_i. Similarly to our bilateral SVAR, we estimate the panel SVAR with Bayesian methods by applying the hierarchical prior of Jarocinski (2010). For convenience, let's stack matrices of SVAR coefficients from equation 9 into vector $\beta_i = (C_i', vec(A_i^1)', ..., vec(A_i^j)')$. It is then assumed that the vectors of SVAR coefficients β_i follow a normal distribution with common mean b and variance Σ_b:

$$\beta_i \sim N(b, \Sigma_b) \tag{10}$$

For parameters in β_i relating endogenous variables to their own lags, the variance is given by:

$$\sigma_{a_{ii}}^2 = \left(\frac{1}{l^{\lambda_3}}\right)^2 \tag{11}$$

The variance for cross-variable coefficients is given by:

$$\sigma_{a_{ij}}^2 = \left(\frac{{\sigma_i}^2}{{\sigma_j}^2}\right)\left(\frac{\lambda_2}{l^{\lambda_3}}\right)^2 \tag{12}$$

Similarly to bilateral SVAR, σ_i^2 and σ_j^2 denote the OLS residual variances of an autoregressive model estimated for variables i and j. In the panel SVAR, the variance is assumed to be common across the cross-sectional units. Therefore, the AR models are estimated by pooling the data of all units, separately for each endogenous variable. Finally, the variance for exogenous variables (including constants) is given by:

$$\sigma_{ci}^2 = {\sigma_i}^2(\lambda_4)^2 \tag{13}$$

λ_2, λ_3 and λ_4 denote the same hyper-parameters as in our bilateral SVAR, controlling the cross-variable weighting, the relative tightness of the variance of lags other than the first one and exogenous variable tightness respectively. Hyper-parameter λ_1 though in this case is estimated from the panel data by imposing an inverse Gamma prior distribution:

$$\lambda_1 \sim IG(s_0/2, \nu_0/2) \tag{14}$$

Following Jarocinski (2010), we make the prior on λ_1 uninformative by setting $s_0 = \nu_0 = 0.001$. Other hyper-parameters governing the prior take standard values, i.e cross-variable weighting λ_2=0.99, lag decay λ_3=2 and exogenous variable tightness λ_4=100. Finally, we use a diffuse prior for the residual covariance matrix Σ_i:

$$\pi(\Sigma_i) \propto |\Sigma_i|^{-(n+1)/2} \tag{15}$$

As in the case of bilateral SVAR, the posterior distribution is obtained using the Gibbs sampler with a total number of 10 000 iterations with the first 5000 discarded as burn-in.

The panel of units included in the model consists of four banks A, B, C and D which have participated in asset purchase programmes by selling their bond holdings to the Bank of Latvia (BoL). For each unit, we include the following set of endogenous variables: QE shock series and 10-year euro area bond yield comprise the monetary policy block, Latvian real GDP and HICP capture the domestic macroeconomic developments and assets sold to the BoL, excess reserves, government debt holdings, lending to non-financial corporations (NFC) and households (HH) characterise the bank-specific developments[3]. The model is estimated over the same sample period as the bilateral SVAR - January 2015 to November 2021 - and includes the same two Covid-19 dummies as exogenous variables to control for the impact of extreme observations on inference. The lag order is set to 1 and the model includes a constant.

[3]All bank-specific variables are obtained from confidential data sets maintained by the BoL.

3.3 Identification strategy

To pin down the effects of the Eurosystem's asset purchases, we follow the approach of Zlobins (2022) and identify the structural QE shock via fusion of high frequency information with narrative sign restrictions of Antolin-Diaz and Rubio-Ramirez (2018). This method allows to simultaneously capture the impact of both conventional and unconventional (the negative interest rate policy (NIRP), forward guidance (FG) and quantitative easing) policy actions from high frequency surprises around the ECB Governing Council events. The explicit consideration of various unconventional tools is particularly important to precisely identify the impact of central bank asset purchases as they have been used in tandem with guidance on the future rate path and rate cuts into negative territory.

In the first step, we gather high frequency reactions of the risk-free yield curve and stock prices around the ECB policy announcements from the Euro Area Monetary Policy Event-Study Database (EA-MPD) of Altavilla et al. (2019). We use the Press Release Window surprises for conventional policy shocks and Press Conference Window reactions for all unconventional policy innovations. Then, we include high frequency surprises into the VAR and ensure that they do not depend on their own lags:

$$m_t = a_0 + \sum_{j=1}^{p} 0 \, m_{t-j} + \epsilon_t \tag{16}$$

where m_t are the high frequency reactions of the 3-month (both in the Press Release and Press Conference Windows), 1-year and 10-year OIS rates and Euro Stoxx 50 to ECB policy announcements. Our choice of the particular OIS maturities is motivated by the evidence from Altavilla et al. (2019) and Rostagno et al. (2021) showing that each instrument targets specific region of the yield curve. For instance, QE predominantly loads on the back-end of the term structure while FG - on medium-term maturities. Regarding the NIRP, we assume that it has the largest impact on short-term rates, similar to conventional policy, but instead of the Press Release, it primarily operates in the Press Conference Window, given the resemblance to FG-type shock. The VAR is estimated on a monthly basis from January 2002 to December 2021 with standard Bayesian techniques by specifying an independent Normal-Wishart prior.[4]

In the second step, we apply traditional sign restrictions as shown in Table 1. All restrictions are imposed to hold on impact only. In addition to identification of conventional and unconventional

[4] We set the AR coefficient of the prior to 0, overall tightness λ_1=0.1, cross-variable weighting $\lambda_2 = 0.5$, lag decay $\lambda_3 = 1$ and block exogeneity shrinkage λ_5=0.001.

Table 1: **Set of traditional sign restrictions used to distinguish monetary policy instruments**

Shock	3-month OIS (Press Release)	3-month OIS (Press Conference)	1-year OIS	10-year OIS	Euro Stoxx 50
CMP	-				+
NIRP		-			+
FG			-		+
QE				-	+
Information		-	-	-	-

monetary policy disturbances, we also control for the effects of information shock following the logic put forth in Jarociński and Karadi (2020) and assuming that the release of central bank information during policy announcements entails a positive co-movement between interest rates and stock prices. However, given that policy shocks of Odyssean nature, induced by different monetary policy tools, move surprises in the same direction, pure sign restrictions alone are insufficient to clearly distinguish the effects of multiple monetary policy instruments. Mechanical orthogonalisation via zero restrictions, on the other hand, would be too restrictive as the ECB has often announced and/or recalibrated several instruments in its toolkit in the same meeting of the Governing Council. Hence, we augment traditional sign restrictions with narrative information about the respective shocks, using the approach of Antolin-Diaz and Rubio-Ramirez (2018), which allows to implement narrative information by placing restrictions on the structural disturbances and historical decompositions in addition to sign restrictions on the impulse response functions and structural parameters, thus sharpening the inference. In particular, we supplement our identification strategy with the following narrative information to tell apart the effects of different monetary policy measures:

Narrative Sign Restriction I. *An expansionary CMP shock took place in November 2011.*

Narrative Sign Restriction II. *For November 2011, the CMP shock is the overwhelming driver of the unexpected movement in 3-month OIS (Press Release Window).*

Narrative Sign Restriction III. *An expansionary NIRP shock took place in June 2014.*

Narrative Sign Restriction IV. *For June 2014, the NIRP shock is the overwhelming driver of the unexpected movement in 3-month OIS (Press conference window).*

Narrative Sign Restriction V. *An expansionary FG shock took place in July 2013.*

Narrative Sign Restriction VI. *For July 2013, the FG shock is the overwhelming driver of the unexpected movement in 1-year OIS.*

Narrative Sign Restriction VII. *An expansionary QE shock took place in January 2015.*

Narrative Sign Restriction VIII. *For January 2015, the QE shock is the overwhelming driver of the unexpected movement in 10-year OIS.*

To sum up, for each of the four monetary policy shocks we identify, we restrict both the sign of the structural disturbance as well as the historical decomposition of the corresponding maturity OIS surprise on which the respective instrument primarily loads. For unconventional instruments - NIRP, FG and QE - the choice of dates is straightforward as the selected Governing Council meetings are the ones in which the respective instruments were first officially announced. For a CMP shock, our choice of the specific date is motivated by the largest recorded easing surprise in 3-month OIS rate (in the Press release window) in the considered sample period and the fact that this conventional policy action was one the last before the ECB switched to a mix of unconventional policy tools, aiding the identification.

Figure A2 shows the obtained QE shock series using our approach and compares it against the updated QE factor of Altavilla et al. (2019)[5]. The figure suggests that our approach generates broadly similar QE shock to the one obtained via the factor rotation approach.

The obtained shock series is then plugged directly into our SVARs, following the "internal instrument" VAR literature (Romer and Romer (2004), Ramey (2011), Barakchian and Crowe (2013), Plagborg-Møller and Wolf (2021)). IRFs to the policy shocks are then generated via Cholesky decomposition by ordering the shock series first as suggested by Plagborg-Møller and Wolf (2021). They also highlight that the "internal instrument" approach produces valid impulse responses even if the instrument is contaminated with measurement errors from other structural shocks, unrelated to the shock of interest. This gives it a clear advantage over the "external instrument" or the proxy SVAR approach of Stock and Watson (2012) and Mertens and Ravn (2013) which requires invertibility to hold. The rest of the endogenous variables are ordered as described in the previous sub-sections for the respective model.

4 Results

Figure 1 shows the baseline results from bilateral SVAR for both aggregate euro area and Latvia. As regards the results for the euro area, impulse responses for all variables have the expected signs - central bank asset purchases push down long-term interest rates and boost stock price valuations. The easing of financial conditions subsequently trickles down to the real economy, increasing output

[5]We use codes from the website of Refet Gürkaynak: http://refet.bilkent.edu.tr/research.html

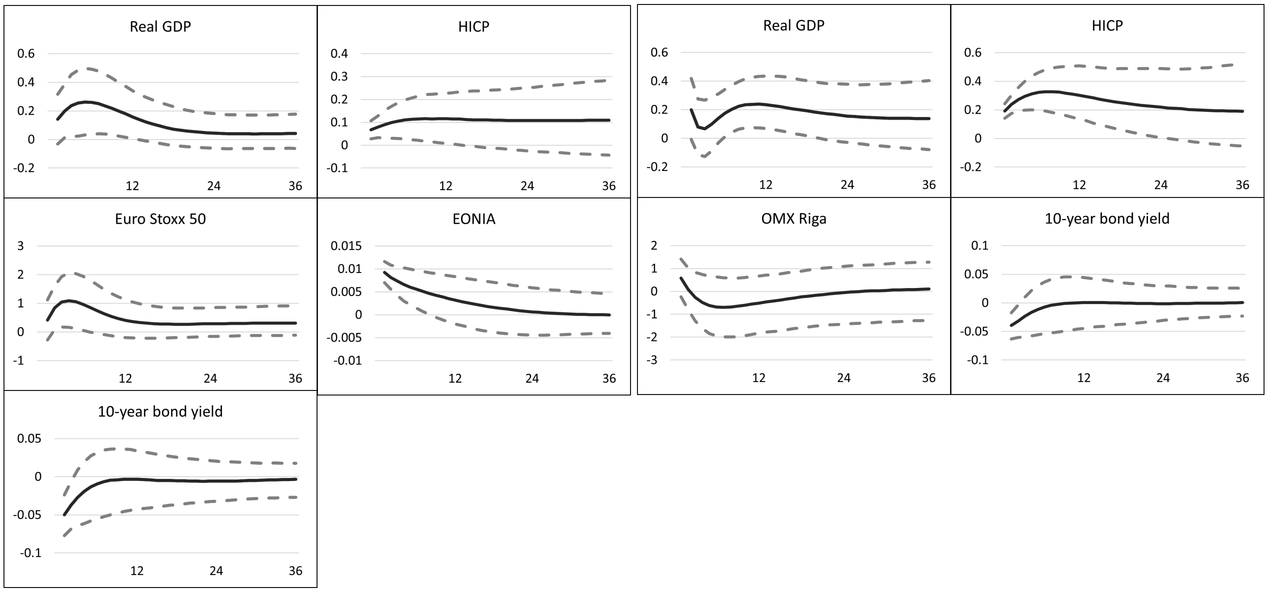
and prices.

Quantitatively, our results on the QE effectiveness in the euro area is in the ballpark of estimates provided by the existing literature. For a better comparison, let us establish the equivalence between the QE impact on the yield curve and volume of purchases as most of the literature focus on the latter. Andrade et al. (2016) compile the evidence from a range of event studies, reporting that the inaugural announcement of the APP in January 2015 worth 10% of GDP lowered the 10-year bond yields by 27-64 bps with a median estimate of 43 bps, roughly implying the elasticity of 4.3 bps per 100 billion euro of purchases. However, model-based estimates in Rostagno et al. (2019), using the term-structure model of Eser et al. (2019), suggest slightly higher effects on the yield curve, reaching a peak of around 100 bps in 2016. Considering the original announcement worth 1140 billion euro and subsequent extensions in December 2015 and March 2016, equal to 360 and 240 billion euro, respectively, this implies the elasticity of 5.7 bps per 100 billion euro. All in all, a QE shock generating a 5 bps drop in 10-year sovereign bond yields is approximately equal to purchases of 100 billion euro or 1% of the 2015 euro area nominal GDP. Existing evidence on the macroeconomic impact of QE in the euro suggest that the Eurosystem's asset purchases, worth 1% of GDP, increase output by 0.1-0.2% and inflation by 0.05-0.1pp, see Garcia Pascual and Wieladek (2016), Lhuissier and Nguyen (2021), Rostagno et al. (2021), Zlobins (2021). Thus, our results reported in Figure 1 fall at the upper range of those estimates. This is likely due to our sample, which also covers the period when the Eurosystem purchased assets under the PEPP. Schnabel (2021) shows that those purchases were more effective in compressing the term premia than the purchases under the PSPP. As a consequence, the macroeconomic impact can also be expected to be slightly larger. The result remains quantitatively and qualitatively robust also when using the QE factor of Altavilla et al. (2019), see Figure A6.

As regards the macroeconomic effects of QE in Latvia, for most variables the impact is similar to the one observed in the euro area. However, the results suggest that QE tend to induce slightly stronger inflationary pressures in Latvia than in the aggregate euro area. Similar findings are also reported in Zlobins (2020), arguing that the strong response of Latvian inflation was driven by QE-induced depreciation of the euro. To cross-check this argument in our setup, we expand the model by including the EUR/USD exchange rate in the euro area block and import prices in the Latvian block. The results in Figure 2 confirm this argument as the strong depreciation of currency in response to central bank asset purchases was reflected in an equal rise in Latvian import prices.

Figure 1: **Baseline results**

(a) Euro area (b) Latvia



Note: Figures show impulse response functions from a bilateral SVAR to the QE shock, normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.

This finding is also in line with the previous literature on exchange rate pass-through to inflation in Latvia, documenting strong impact of exchange rate fluctuations to domestic price formation (see Bitans (2004), Beirne and Bijsterbosch (2011), Comunale (2019) and Ortega and Osbat (2020)).

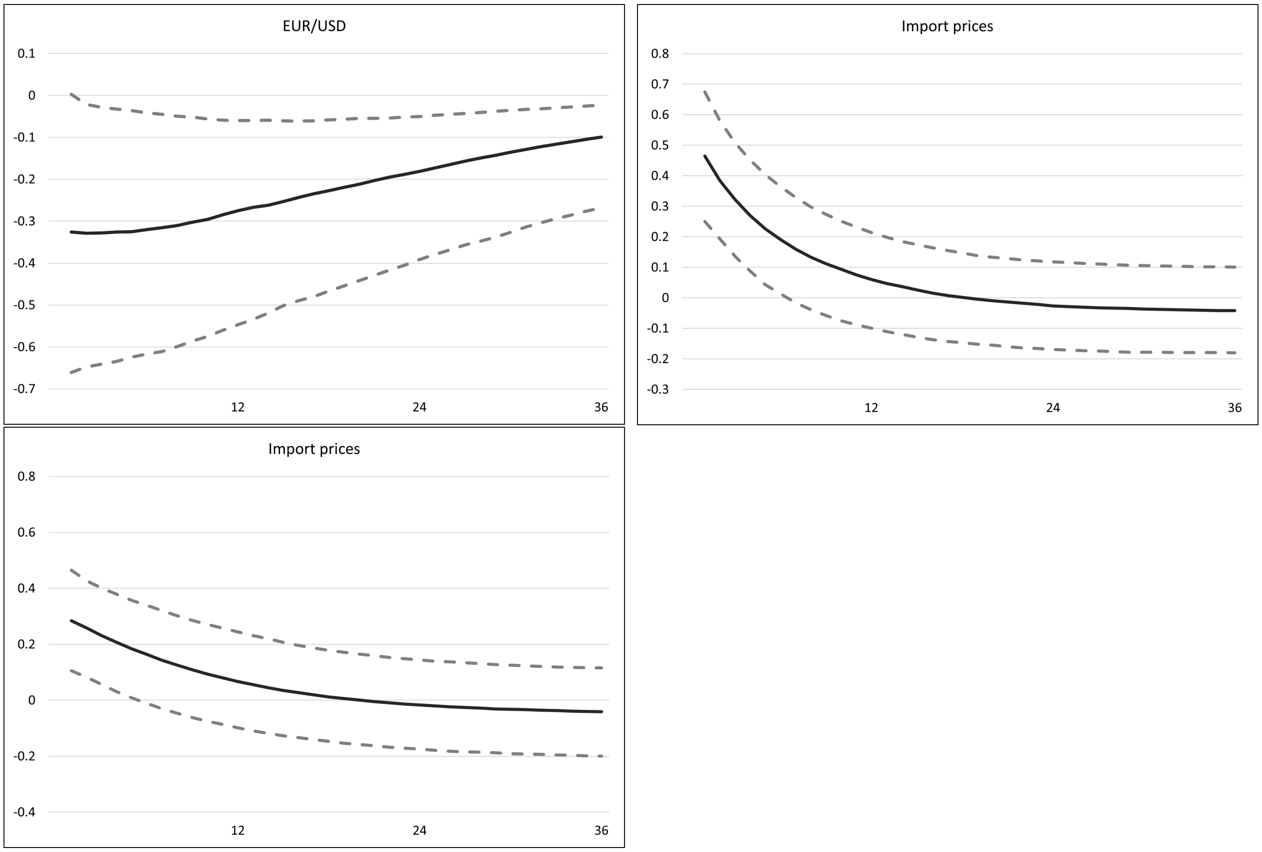
Next, we examine the channels through which the Eurosystem's asset purchases were transmitted to Latvian sovereign yields. Our baseline results in Figure 1 confirm that the QE indeed reduced sovereign borrowing costs in Latvia as 10-year bond yield significantly declines in response to the shock, with the effect being similar in magnitude to the euro area's counterpart. Additional results in Figure 3 show that several factors contributed to the yield curve compression.

First, as suggested by the response of CDS spread, the Eurosystem's asset purchases significantly lowered the credit risk premia of Latvian bonds. We argue that the presence of central bank in the sovereign bond markets effectively provides a backstop for investors, lowering their risk perception and demands for premia (see Broeders et al. (2022)). However, the presence of a central bank in the market, coupled with strong demand by foreign investors, resulted in scarcity in the available universe of Latvian bonds. The impulse responses of two commonly used measures of liquidity conditions - CDS-bond basis and bid-ask spread - show that liquidity conditions in the Latvian bond market deteriorate after the central bank embarked on asset purchases[6]. Schlepper et al. (2017) also

[6] A decrease in CDS-bond basis indicates a deterioration in liquidity while for bid-ask spread the opposite is true.

Figure 2: **Exchange rate channel**

(a) Euro area (b) Latvia



Note: Figures show impulse response functions from a bilateral SVAR to the QE shock, normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.

empirically documents that the APP-induced scarcity had an adverse impact on liquidity conditions in the German Bund markets, while Ferdinandusse et al. (2020) provides theoretical underpinnings of scarcity effects arising from QE.

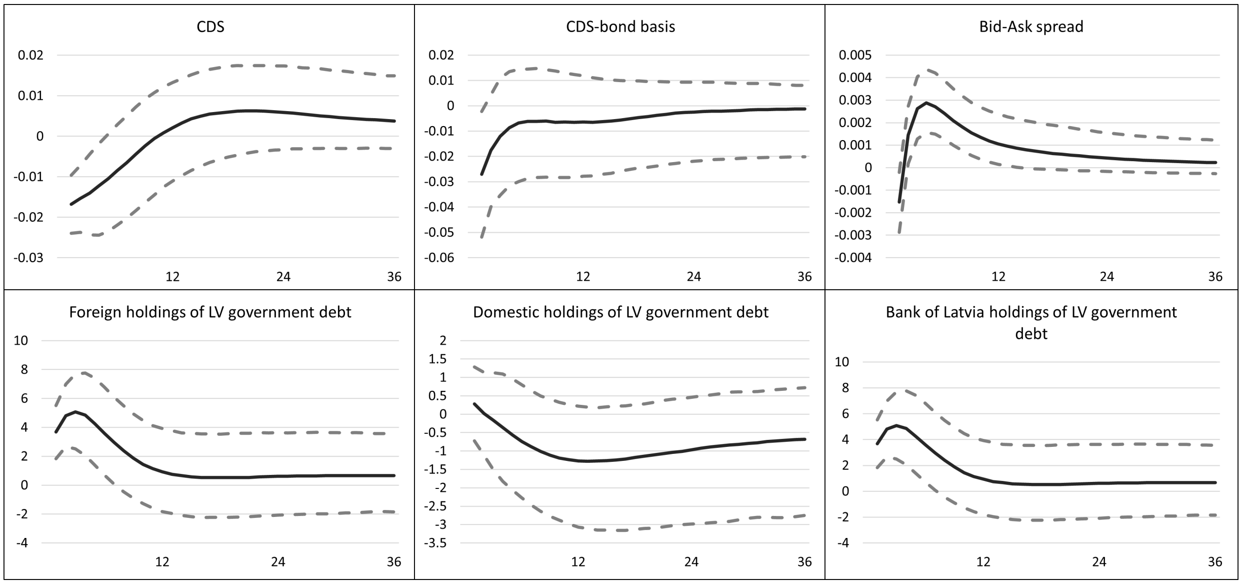
Second, the impulse responses in the second row of Figure 3 suggest that Latvian yields were compressed due to direct impact of central bank asset purchases via the local supply sub-channel as well as portfolio readjustment of foreign investors. In particular, both the BoL and foreign investors increase their holdings of Latvian government debt, while the share held by domestic private agents decreases (although statistically insignificantly) in response to the QE shock [7].

In addition, results in Figure 4 suggest that there was minimal asset rebalancing by the domestic banking sector as neither its aggregate government debt holdings nor excess reserves react significantly to the QE shock. If anything, our results suggest that Latvian banks swapped do-

[7] Figure A5 in the Appendix confirms that the share of government debt held by the domestic banking sector has substantially declined in the QE period.

Figure 3: **Transmission to sovereign yields**

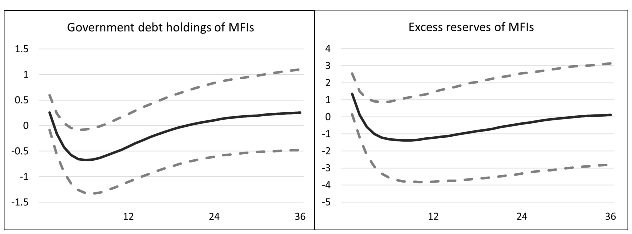
Latvia



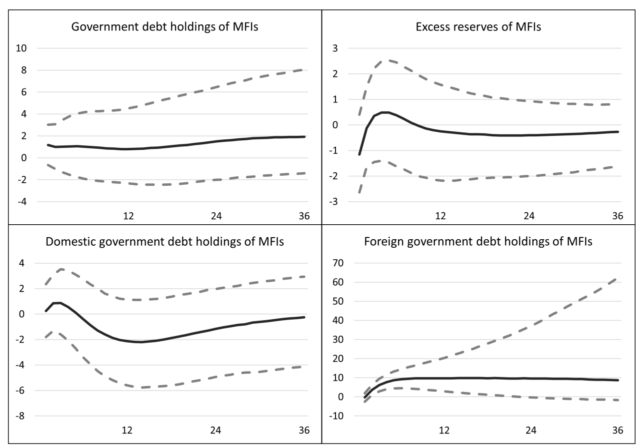
Note: Figures show impulse response functions from a bilateral SVAR to the QE shock, normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.

Figure 4: **Transmission via banking sector (I)**

(a) Euro area



(b) Latvia

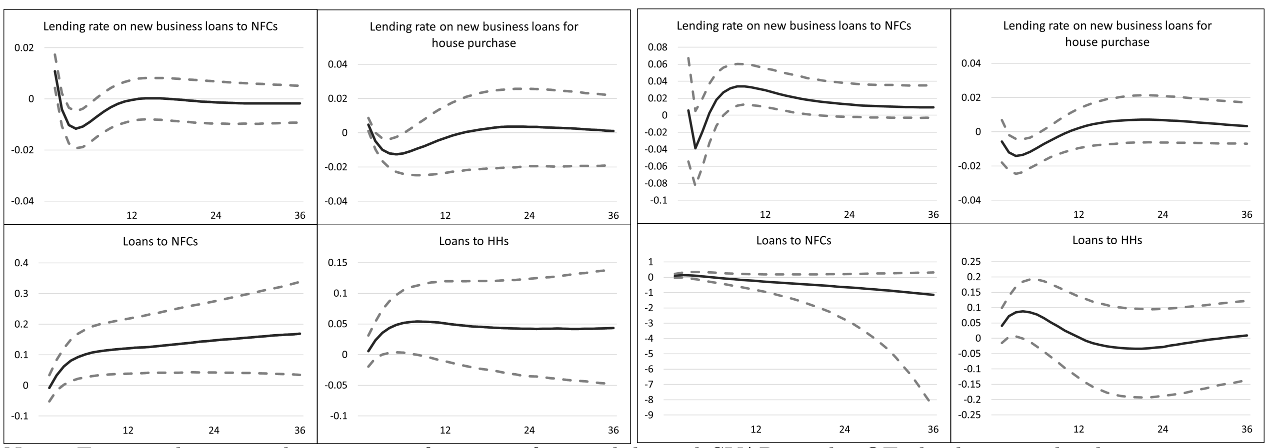


Note: Figures show impulse response functions from a bilateral SVAR to the QE shock, normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.

mestic bonds with foreign counterparts in their bond portfolios in response to QE. Such banking sector behaviour substantially differs from the developments observed in the euro area. As the impulse responses in the Panel (a) show, banks in the euro area actively participated in the asset purchase programmes by selling their bond holdings to the Eurosystem's central banks which, in turn, led to an increase in excess liquidity. Thus, the compression in sovereign borrowing costs via the portfolio rebalancing mechanism could effectively trickle down to bank lending rates and incentivise new loan creation in the euro area, as evidenced by our results in Figure 5. Contrary to the euro area though, our results document limited pass-through of QE to both lending rates and volumes in Latvia. As shown by impulse responses in panel (b), financing conditions eased to some extent only for households, while no statistically significant effects can be observed with respect to firms, further corroborating the evidence of impaired monetary policy transmission via the domestic banking sector. Benkovskis et al. (2021) arrives at similar conclusions using individual bank-level data, showing that the pass-through of monetary policy measures to lending rates has been limited in Latvia over the period from 2014 to 2020, leaving them persistently higher than in other jurisdictions of the monetary union.

Figure 5: **Transmission via banking sector (II)**

(a) Euro area (b) Latvia



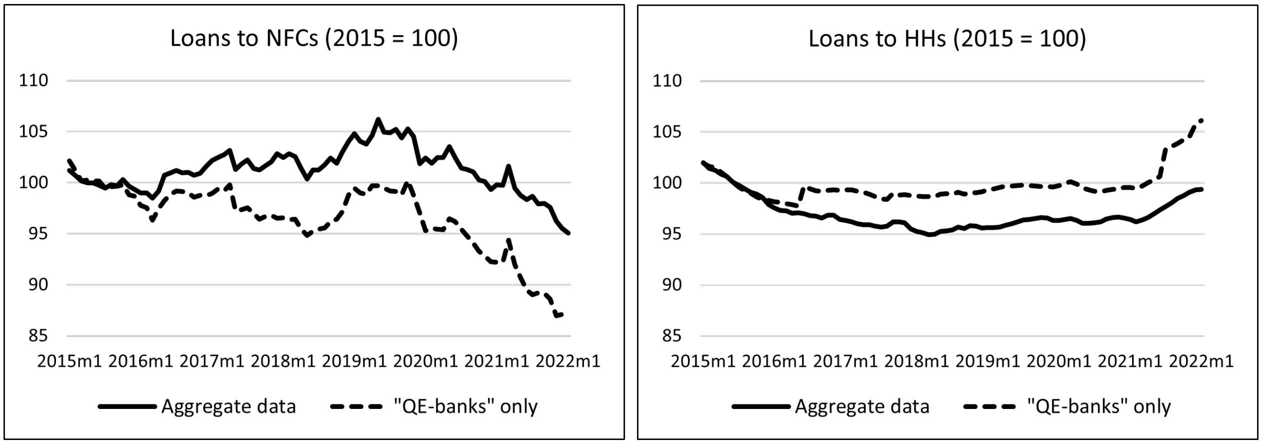
Note: Figures show impulse response functions from a bilateral SVAR to the QE shock, normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.

However, a valid concern regarding our results is the use of aggregate lending data - the significant heterogeneity among banks, not all of which have participated in the asset purchase programmes, could potentially mask the portfolio rebalancing effects. We address this point by (I) using aggregate time series only of those banks which actually sold assets to the BoL under the auspices of the APP/PEPP and (II) in the next subsection, we employ bank-level data to track the propagation of the QE innovation at individual bank level.

Figure 6 compares the lending dynamics of banks participating in the asset purchase dynamics against the aggregate lending time series. A simple eye-balling exercise does not provide any straightforward conclusions - while lending to households has been more active by the "QE-banks", the opposite can be observed with respect to loans granted to firms.

Figure 6: **Lending dynamics: "QE-banks" vs. aggregate data**

Latvia

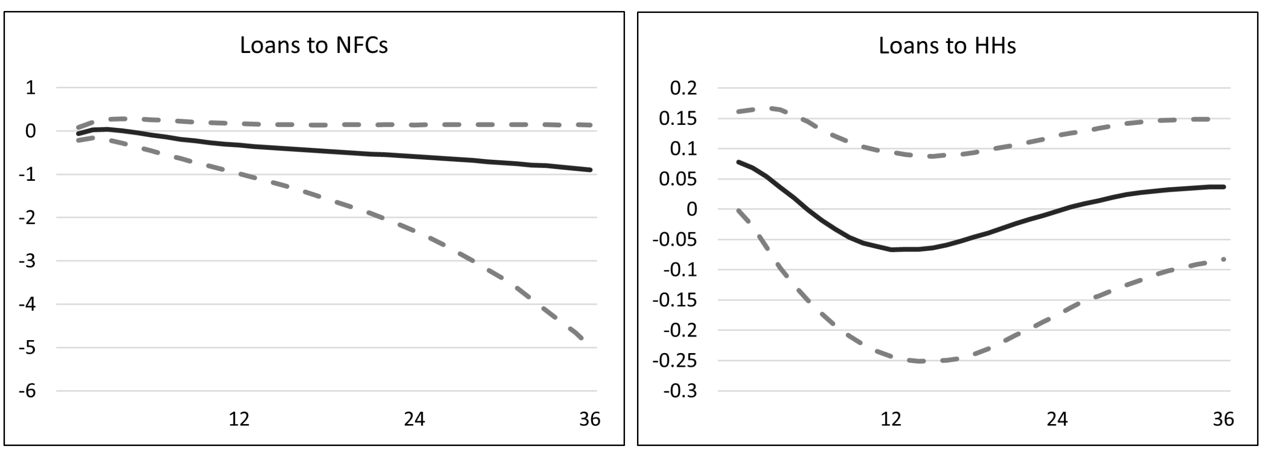


Note: Figures show lending dynamics to firms and households in Latvia over the period from January 2015 to January 2022. The solid line shows the aggregate lending data while the dashed line - a sum of loans granted by banks participating in the APP/PEPP.

However, the impulse responses in Figure 7 confirm that QE has had a limited impact on bank lending in Latvia as even the banks, which took part in the asset purchase programmes, did not channel the obtained funds towards new loan creation. Thus, in the next subsection we further investigate how Latvian banks responded to QE by employing individual bank-level data.

Figure 7: **Results for the "QE-banks" only**

Latvia



Note: Figures show impulse response functions from a bilateral SVAR to the QE shock, normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.

4.1 Bank-level evidence

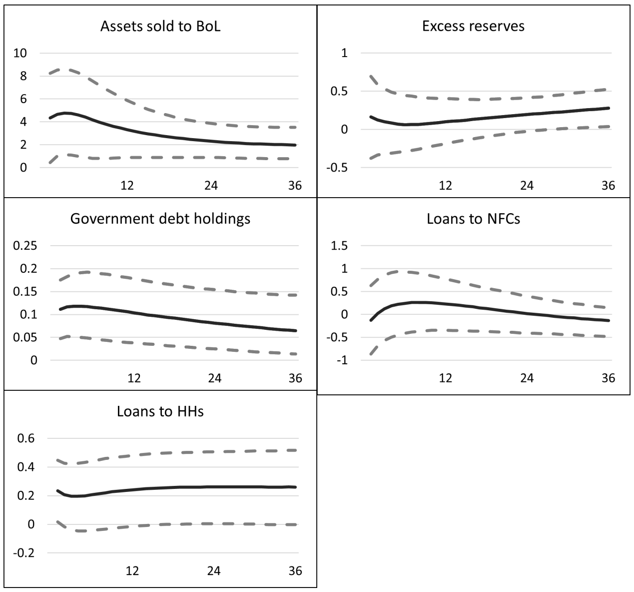
In this subsection we focus particularly on those Latvian banks which participated in the APP/PEPP and how did QE affected their asset structure. Therefore, we make use of a panel SVAR, as described in Section 3.2, to pin down the effects of the Eurosystem's asset purchase programmes at individual bank level. In total, five Latvian banks have participated in the APP/PEPP operations, but one bank only sold assets to the BoL once and in a relatively small amount, thus we do not include it in our further analysis. However, the banks included in our analysis represent the Latvian banking sector rather well as they cover more than 80% of total industry assets by the end of our sample period (see Figure A4).

In general, the bank-level results in Figure 8 confirm our findings from aggregate-level data that QE has had rather limited effects on bank lending in Latvia. We find robust and statistically significant evidence for only one bank (bank D) that the funds from sale of assets to the BoL were channelled towards lending to NFCs. Moreover, bank-level results demonstrate that even those banks, which participated in the QE operations, reinvested the obtained funds in the purchase of debt securities instead of new loan creation as government debt holdings increase in response to the QE shock for all banks except the one which did increase lending. The results are also broadly in line with the "QE-intensity" of banks, as shown in Figure A3, since bank D engaged in QE operations much more heavily than its competitors. Moreover, these findings complement those of Ryan and Whelan (2021) which shows that banks in the euro area actively managed excess reserves obtained via QE, in particular by adjusting security holdings rather than just fully turning them into loans. They argue that a negative DFR, which has been used alongside QE, created a disincentive for banks to hold excess reserves and thus motivated them to pass on these costs to other banks primarily via purchase of debt securities. However, both Albertazzi et al. (2021) and Altavilla et al. (2021) document that, despite this disincentive, QE in the euro area trickled down to bank lending rates and increased credit flows to the private sector.

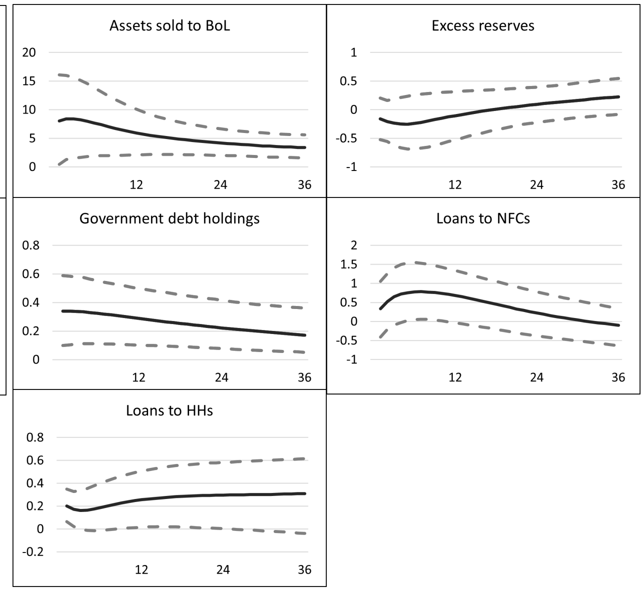
What could explain the limited pass-through of central bank asset purchases to loan market conditions in Latvia? For example, Fatouh et al. (2021) finds that QE also in the UK had a relatively limited impact on bank lending to NFCs. They highlight two factors which have contributed to such outcome. First, large corporations substituted bank loans with bond issuance as QE led to compression not only in sovereign bond yields but also their corporate counterparts via the portfolio rebalancing mechanism, making this source of financing more attractive for large firms. Second, the

Figure 8: **Bank-level results**

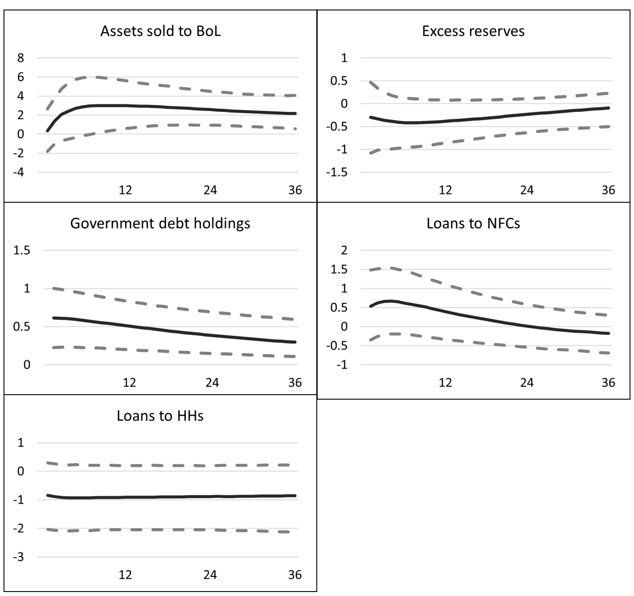
(a) Bank A



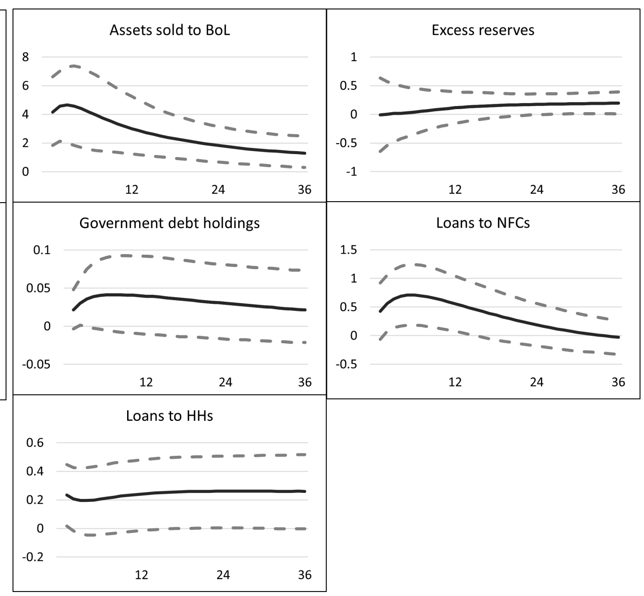
(b) Bank B



(c) Bank C



(d) Bank D



Note: Figures show impulse response functions from a panel SVAR to the QE shock, normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.

risk weight regime of Basel III on capital induces banks to favour mortgages over loans to SMEs as such loans require higher provisions. In addition, Basel III encourages bond holding as government debt securities can be used as a collateral, thus providing a motive for reinvesting the obtained funds from the central bank into purchase of government bonds rather than new credit creation.

At first glance, these factors appear to be a credible explanation for a limited pass-through of QE to bank lending in Latvia. However, banks in the euro area were able to pass the monetary impulse to firms and households despite being subject to the same regulatory framework. Betz and Santis (2022) argue that the CSPP - part of the APP - induced issuance of bonds by large corporations in the euro area and this substitution eased financing conditions for SMEs as well as it created a spare capacity in bank balance sheets. However, in Latvia such rebalancing towards corporate bonds *en masse* has not been observed, providing a potential explanation for the observed differences in lending dynamics. Still, we believe that the real reasons for a limited pass-through of QE to financial conditions in Latvia are different. Both Neuenkirch and Nöckel (2018) and Albertazzi et al. (2021) emphasise increased risk-taking by European banks in a low interest rate environment. They show that banks in the euro area actively engaged in a search for yield in response to QE and low policy rates, granting loans to SMEs and riskier firms, to keep their profit margins. As regards Latvian banks, Benkovskis et al. (2021) shows that they were able to charge higher interest rates *vis-à-vis* their euro area counterparts, limiting the need to take on higher risk via lending to firms and households. Therefore, we conclude that the high market power of Latvian banks, coupled with peculiarities inherent in Basel III regulatory framework discussed above, have contributed to limited transmission of the Eurosystem's asset purchases to domestic financial conditions.

5 Conclusions

This paper provides a comprehensive investigation of how the Eurosystem's asset purchases - deployed over the period from 2015 to 2021 - have propagated to Latvian economy, with a particular focus on QE's financial effects via the portfolio rebalancing mechanism. To that end, we have employed a set of empirical frameworks, namely a bilateral SVAR, featuring both the aggregate euro area and the Latvian block, and a panel SVAR with cross-sectional heterogeneity, allowing us to obtain evidence from both macro-level and bank-level data.

Our findings suggest that QE led to a compression of sovereign borrowing costs in Latvia and boosted economic activity and prices. The results indicate that several factors contributed to a flatter yield curve of Latvian bonds. First, QE lowered the credit risk premia as the entry of the central bank into sovereign bond markets effectively provided a backstop for investors. Second, the presence of the central bank directly affected equilibrium conditions in the Latvian government bond market, thereby driving down yields via the local supply sub-channel. Additionally, we find evidence of portfolio readjustment by foreign investors towards Latvian bonds, contributing to their yield compression.

However, in stark contrast to the euro area, we find that further pass-through of QE to domestic financial conditions was weak due to limited asset rebalancing by the Latvian banking sector - a result obtained from both aggregate and bank-level data. Our analysis reveals that even those banks which did participate in QE operations reinvested the obtained funds from the central bank in the purchase of debt securities rather than used them for new loan creation. We argue that several circumstances have contributed to such outcome in Latvia. QE being used in tandem with negative policy rates created a disincentive for banks to hold excess reserves and thus motivated them to quickly convert excess liquidity into holdings of debt securities. This was further reinforced by Basel III regulatory framework, which encourages banks to hold government bonds as they can be used as a collateral. Still, the euro area banks have been subject to the same conditions and yet were able to pass on the monetary impulse of QE to firms and households. The literature has emphasised increased risk-taking by European banks in the QE era as a means to protect their profit margins. For Latvian banks, though, the low interest rate environment has not posed such a challenge as they have been able to charge higher interest rates *vis-à-vis* their euro area counterparts, limiting the need to take on higher risk via lending to firms and households.

To sum up, this paper contributes to the literature on the transmission of common monetary policy to Latvia, with a particular focus on QE as the main unconventional tool used by the Eurosystem at the ELB. The passage of time allows to estimate its effects over the relevant sample period and reconsider existing evidence. While our study documents a significant impact of QE on the Latvian economy, the transmission of common monetary policy could be further facilitated via the domestic banking sector.

References

Albertazzi, U., B. Becker, and M. Boucinha (2021). Portfolio rebalancing and the transmission of large-scale asset purchase programs: Evidence from the Euro area. *Journal of Financial Intermediation 48*(C).

Altavilla, C., M. Boucinha, S. Holton, and S. Ongena (2021). Credit Supply and Demand in Unconventional Times. *Journal of Money, Credit and Banking 53*(8), 2071–2098.

Altavilla, C., M. Boucinha, and J.-L. Peydró (2018). Monetary policy and bank profitability in a low interest rate environment. *Economic Policy 33*(96), 531–586.

Altavilla, C., L. Brugnolini, R. S. Gürkaynak, R. Motto, and G. Ragusa (2019). Measuring euro area monetary policy. *Journal of Monetary Economics 108*, 162–179.

Altavilla, C., L. Burlon, M. Giannetti, and S. Holton (2019). Is there a zero lower bound? The effects of negative policy rates on banks and firms. Working Paper No. 2289, ECB.

Altavilla, C., G. Carboni, and R. Motto (2021). Asset Purchase Programs and Financial Markets: Lessons from the Euro Area. *International Journal of Central Banking 17*(70), 1–48.

Andrade, P., J. Breckenfelder, F. De Fiore, P. Karadi, and O. Tristani (2016). The ECB's asset purchase programme: an early assessment. Working Paper No. 1956, ECB.

Antolin-Diaz, J. and J. F. Rubio-Ramirez (2018). Narrative sign restrictions for SVARs. *American Economic Review 108*(10), 2802–2829.

Barakchian, M. S. and C. Crowe (2013). Monetary policy matters: Evidence from new shocks data. *Journal of Monetary Economics 60*(8), 950–966.

Bauer, M. D. and G. D. Rudebusch (2014). The signaling channel for Federal Reserve bond purchases. *International Journal of Central Banking 10*(3), 233–289.

Beirne, J. and M. Bijsterbosch (2011). Exchange rate pass-through in central and eastern european eu member states. *Journal of Policy Modeling 33*(2), 241–254.

Benecka, S., L. Fadejeva, and M. Feldkircher (2018). Spillovers from Euro Area Monetary Policy: A Focus on Emerging Europe. Working Paper No. 2018/04, Latvijas Banka.

Benkovskis, K., O. Tkacevs, and K. Vilerts (2021). Interest Rate Spreads in the Baltics and the Rest of the Euro Area: Understanding the Factors behind the Differences. Discussion Paper No. 2021/02, Latvijas Banka.

Betz, F. and R. A. D. Santis (2022). ECB Corporate QE and the Loan Supply to Bank-Dependent Firms. *International Journal of Central Banking 18*(2), 107–148.

Bhattarai, S., G. B. Eggertsson, and B. Gafarov (2015). Time consistency and the duration of government debt: A signalling theory of quantitative easing. Working Papers No. 21336, NBER.

Bitans, M. (2004). Pass-through of exchange rates to domestic prices in east european countries and the role of economic environment. Working Paper No. 2004/04, Latvijas Banka.

Bluwstein, K. and F. Canova (2016, September). Beggar-Thy-Neighbor? The International Effects of ECB Unconventional Monetary Policy Measures. *International Journal of Central Banking 12*(3), 69–120.

Broeders, D., L. de Haan, and J. W. van den End (2022). How QE changes the nature of sovereign risk. Working Paper No. 737, DNB.

Burriel, P. and A. Galesi (2018). Uncovering the heterogeneous effects of ECB unconventional monetary policies across euro area countries. *European Economic Review 101*(C), 210–229.

Canova, F. and M. Ciccarelli (2013). Panel vector autoregressive models: a survey. Working Paper No. 1507, ECB.

Carriero, A., T. E. Clark, M. Marcellino, and E. Mertens (2021). Addressing COVID-19 outliers in BVARs with stochastic volatility. Working Paper No. 21-02, Federal Reserve Bank of Cleveland.

Comunale, M. (2019). An investigation of the exchange rate pass-through in the baltic states. Discussion Paper No. 13, Bank of Lithuania.

Cushman, D. O. and T. Zha (1997, August). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics 39*(3), 433–448.

De Santis, R. A. (2020). Impact of the Asset Purchase Programme on euro area government bond yields using market news. *Economic Modelling 86*(C), 192–209.

D'Amico, S. and T. B. King (2013). Flow and stock effects of large-scale treasury purchases: Evidence on the importance of local supply. *Journal of Financial Economics 108*(2), 425–448.

Eser, F., W. Lemke, K. Nyholm, S. Radde, and A. L. Vladu (2019). Tracing the impact of the ECB's asset purchase programme on the yield curve. Working Paper No. 2293, ECB.

Fatouh, M., S. Markose, and S. Giansante (2021). The impact of quantitative easing on uk bank lending: Why banks do not lend to businesses? *Journal of Economic Behavior Organization 183*(C), 928–953.

Ferdinandusse, M., M. Freier, and A. Ristiniemi (2020). Quantitative easing and the price-liquidity trade-off. Working Paper No. 2399, ECB.

Froemel, M., M. Joyce, and I. Kaminska (2022, May). The local supply channel of QE: evidence from the Bank of England's gilt purchases. Working paper No. 980, Bank of England.

Gagnon, J., M. Raskin, J. Remache, and B. Sack (2011). The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases. *International Journal of Central Banking 7*(1), 3–43.

Gambetti, L. and A. Musso (2020). The effects of the ECB's expanded asset purchase programme. *European Economic Review 130*.

Garcia Pascual, A. I. and T. Wieladek (2016). The European Central Bank's QE: A new hope. Discussion Paper No. DP11309, CEPR.

Georgiadis, G. (2015). Examining asymmetries in the transmission of monetary policy in the euro area: Evidence from a mixed cross-section global VAR model. *European Economic Review 75*(C), 195–215.

Gertler, M. and P. Karadi (2011). A model of unconventional monetary policy. *Journal of Monetary Economics 58*(1), 17–34.

Hartmann, P. and F. Smets (2018). The first twenty years of the European Central Bank: Monetary policy. Working Paper No. 2219, ECB.

Jarocinski, M. (2010). Responses to monetary policy shocks in the east and the west of Europe: a comparison. *Journal of Applied Econometrics 25*(5), 833–868.

Jarociński, M. and P. Karadi (2020). Monetary policy surprises – the role of information shocks. *American Economic Journal: Macroeconomics 12*(2), 1–43.

Joyce, M. A. S., A. Lasaosa, I. Stevens, and M. Tong (2011). The Financial Market Impact of Quantitative Easing in the United Kingdom. *International Journal of Central Banking 7*(3), 113–161.

Karadi, P. and A. Nakov (2021). Effectiveness and addictiveness of quantitative easing. *Journal of*

Monetary Economics 117, 1096–1117.

Krishnamurthy, A. and A. Vissing-Jorgensen (2011). The effects of quantitative easing on interest rates: Channels and implications for policy. *Brookings Papers on Economic Activity 42*(2), 215–287.

Lemke, W. and T. Werner (2020). Dissecting long-term bund yields in the run-up to the ECB's public sector purchase programme. *Journal of Banking Finance 111*.

Lenza, M. and G. E. Primiceri (2020). How to estimate a VAR after March 2020. Working Paper No. 2461, ECB.

Lhuissier, S. and B. Nguyen (2021). The dynamic effects of the ECB's asset purchases: a survey-based identification. Working Paper No. 806, Banque de France.

Mandler, M. and M. Scharnagl (2020). Estimating the effects of the Eurosystem's asset purchase programme at the country level. Discussion Paper No. 29/2020, Deutsche Bundesbank.

Mertens, K. and M. O. Ravn (2013). The dynamic effects of personal and corporate income tax changes in the United States. *American Economic Review 103*(4), 1212–1247.

Moder, I. (2019, October). Spillovers from the ECB's Non-standard Monetary Policy Measures on Southeastern Europe. *International Journal of Central Banking 15*(4), 127–163.

Mudde, Y., A. Samarina, and R. Vermeulen (2021, January). Spillover effects of sovereign bond purchases in the euro area. Working Paper No. 706, DNB.

Neuenkirch, M. and M. Nöckel (2018). The risk-taking channel of monetary policy transmission in the euro area. *Journal of Banking & Finance 93*(C), 71–91.

Ortega, E. and C. Osbat (2020). Exchange rate pass-through in the euro area and eu countries. Occasional Paper No. 241, ECB.

Plagborg-Møller, M. and C. K. Wolf (2021). Local projections and VARs estimate the same impulse responses. *Econometrica 89*(2), 955–980.

Ramey, V. A. (2011). Identifying government spending shocks: It's all in the timing. *The Quarterly Journal of Economics 126*(1), 1–50.

Romer, C. D. and D. H. Romer (2004). A new measure of monetary shocks: Derivation and implications. *American Economic Review 94*(4), 1055–1084.

Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, S. G. A., and J. Yiangou (2019). A tale of two decades: the ECB's monetary policy at 20. Working Paper No. 2346, ECB.

Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, and A. Saint Guilhem (2021). Combining negative rates, forward guidance and asset purchases: identification and impacts of the ECB's unconventional policies. Working Paper No. 2564, ECB.

Ryan, E. and K. Whelan (2021). Quantitative easing and the hot potato effect: Evidence from euro area banks. *Journal of International Money and Finance 115*.

Schlepper, K., R. Riordan, H. Hofer, and A. Schrimpf (2017). Scarcity effects of QE: A transaction-level analysis in the Bund market. Discussion Paper No. 06/2017, Deutsche Bundesbank.

Schnabel, I. (2021). Asset purchases: from crisis to recovery. Speech at the Annual Conference of Bank of Latvia on "Sustainable Economy in Times of Change". Available at: https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210920~ae2c7412dc.en.html.

Stock, J. H. and M. W. Watson (2012). Disentangling the channels of the 2007-09 recession. *Brookings Papers on Economic Activity 43*(1), 81–156.

Vayanos, D. and J. Vila (2021). A Preferred-Habitat Model of the Term Structure of Interest Rates. *Econometrica 89*(1), 77–112.

Zlobins, A. (2020). Country-level effects of the ECB's expanded asset purchase programme. *Baltic Journal of Economics 20*(2), 187–217.

Zlobins, A. (2021). On the time-varying effects of the ECB's asset purchases. Working Paper No. 2021/02, Latvijas Banka.

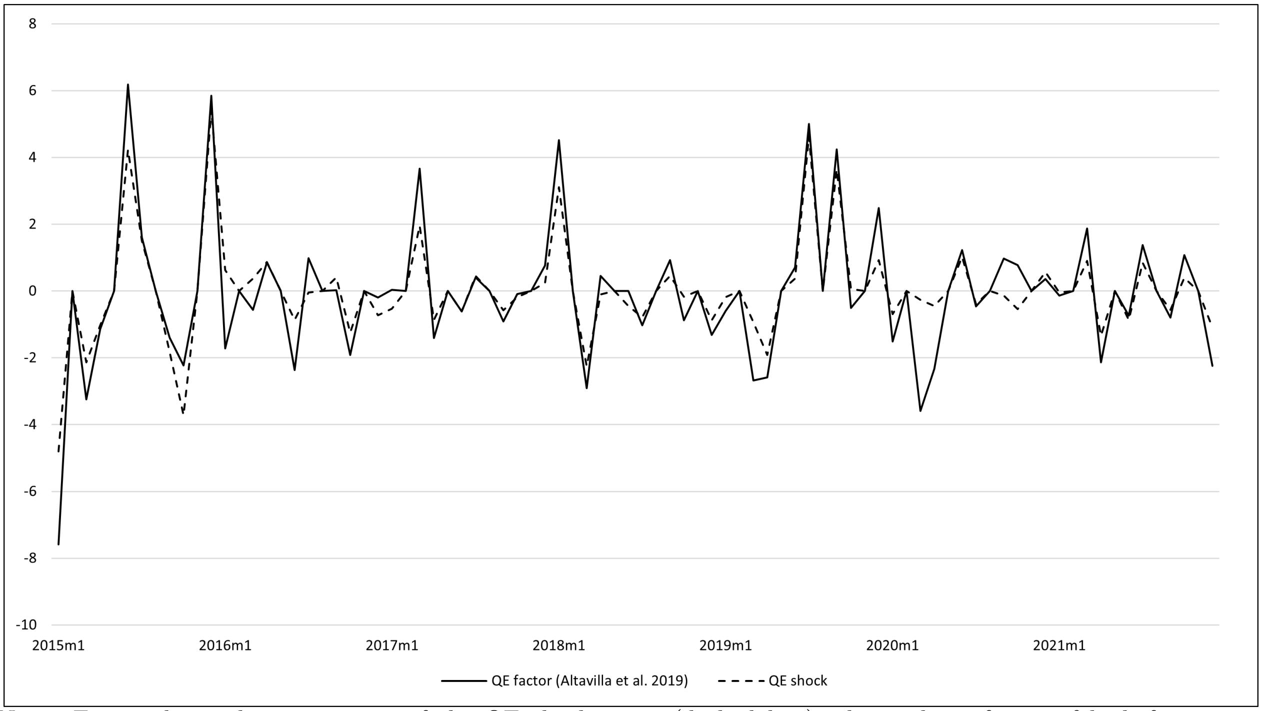
Zlobins, A. (2022). Into the universe of unconventional monetary policy: State-dependence, interaction and complementarities. Working Paper No. 2022/05, Latvijas Banka.

Appendix

Table A1: **Dataset description**

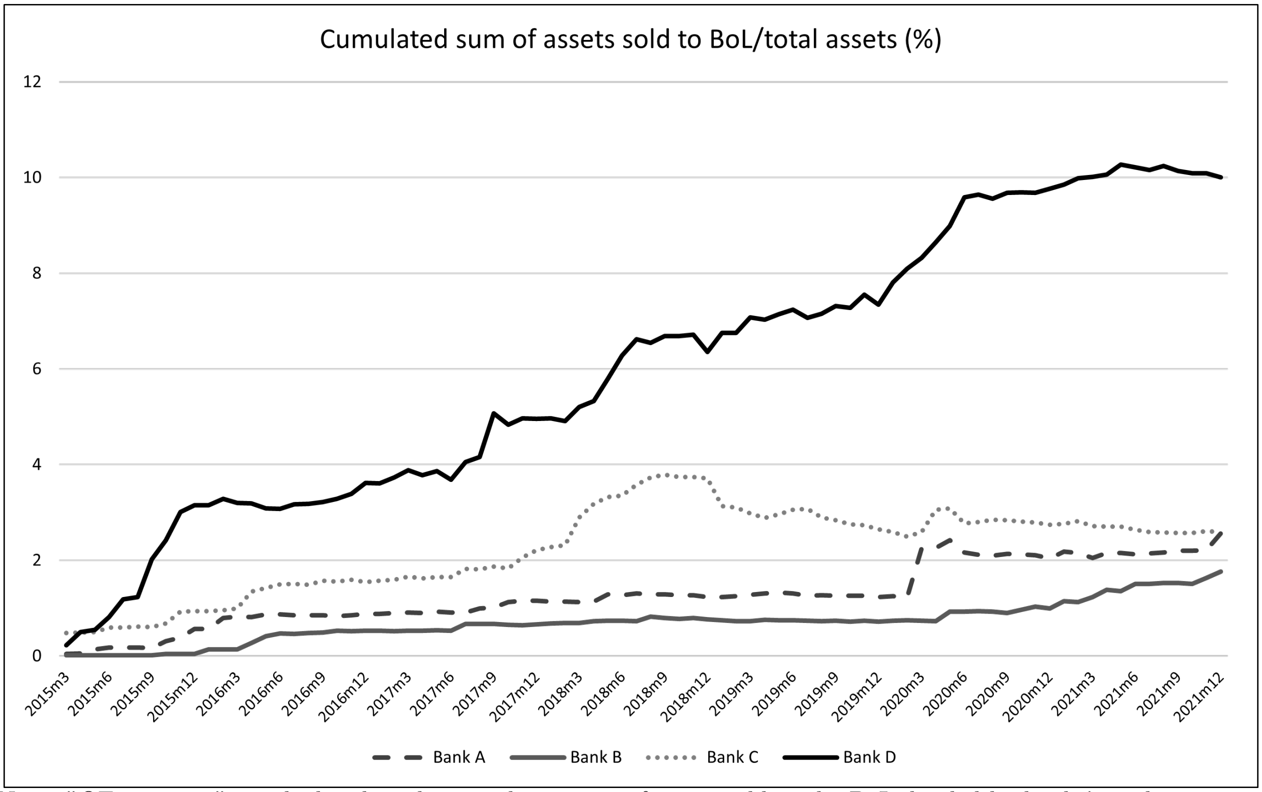
Block	Variable	Description	Data source
Baseline model - euro area	Real GDP	Real GDP index. 2015=100. Monthly series are obtained by performing the Litterman temporal disaggregation procedure using the industrial production index as indicator series.	Author's calculations based on the Eurostat data
	HICP	All-items HICP. 2015=100.	ECB
	Euro Stoxx 50	Dow Jones Euro Stoxx 50 price index.	ECB
	EONIA	Money market interest rate.	Eurostat
	10-year bond yield	10-year government benchmark bond yield.	ECB
Baseline model - Latvia	Real GDP	Real GDP index. 2015=100. Monthly series are obtained by performing the Litterman temporal disaggregation procedure using the industrial production index as indicator series.	Author's calculations based on the Eurostat data
	HICP	All-items HICP. 2015=100.	ECB
	OMX Riga	Nasdaq OMX price index.	Nasdaq
	10-year bond yield	EMU convergence criterion bond yield.	Eurostat
Transmission - exchange rate	EUR/USD	Monthly average value of the euro per US dollar.	Eurostat
	Import prices	Unit value index of imports from all countries of the world. 2015=100.	Eurostat
Transmission - sovereign yields	CDS	5-year credit default swap.	Bloomberg
	CDS-bond basis	The series are calculated as the difference between the 5-year CDS and the spread of 10-year Latvian bond yield over the 10-year OIS rate.	Author's calculations based on the Bloomberg data
	Bid-Ask spread	Bid-Ask spread for the 10-year Latvian bond yield.	Bloomberg
	Foreign holdings of LV government debt	Share of total government debt held by non-residents.	BoL
	Domestic holdings of LV government debt	Share of total government debt held by residents other than the BoL.	BoL
	BoL holdings of LV government debt	Share of total government debt held by the BoL.	BoL
Transmission - banking sector	Government debt holdings of MFIs	Government debt securities held by the MFIs excluding the ECSB.	ECB, BoL
	Excess reserves of MFIs	Excess reserves of MFIs excluding the ECSB.	ECB, BoL
	Lending rate for NFCs	Lending rate for non-financial corporations as defined for cost of borrowing purposes.	ECB
	Lending rate for HHs	Lending rate for households and non-profit institutions serving households for house purchase excluding revolving loans and overdrafts, convenience and extended credit card debt.	ECB
	Loans to NFCs	Loans to non-financial corporations. Outstanding amounts at the end of the period (stocks), total maturity.	ECB
	Loans to HHs	Loans to households and non-profit institutions serving households for house purchase. Outstanding amounts at the end of the period (stocks), total maturity.	ECB
Bank-level data	Assets sold to the BoL	Cumulative sum of government debt securities sold to the BoL.	BoL
	Excess reserves	Excess reserves held at the BoL.	BoL
	Government debt holdings	Euro denominated government debt securities held by the MFI.	BoL
	Loans to NFCs	Loans to non-financial corporations. Outstanding amounts at the end of the period (stocks), total maturity.	BoL
	Loans to HHs	Loans to households and non-profit institutions serving households for house purchase. Outstanding amounts at the end of the period (stocks), total maturity.	BoL

Figure A2: **Comparison of the QE shock series**



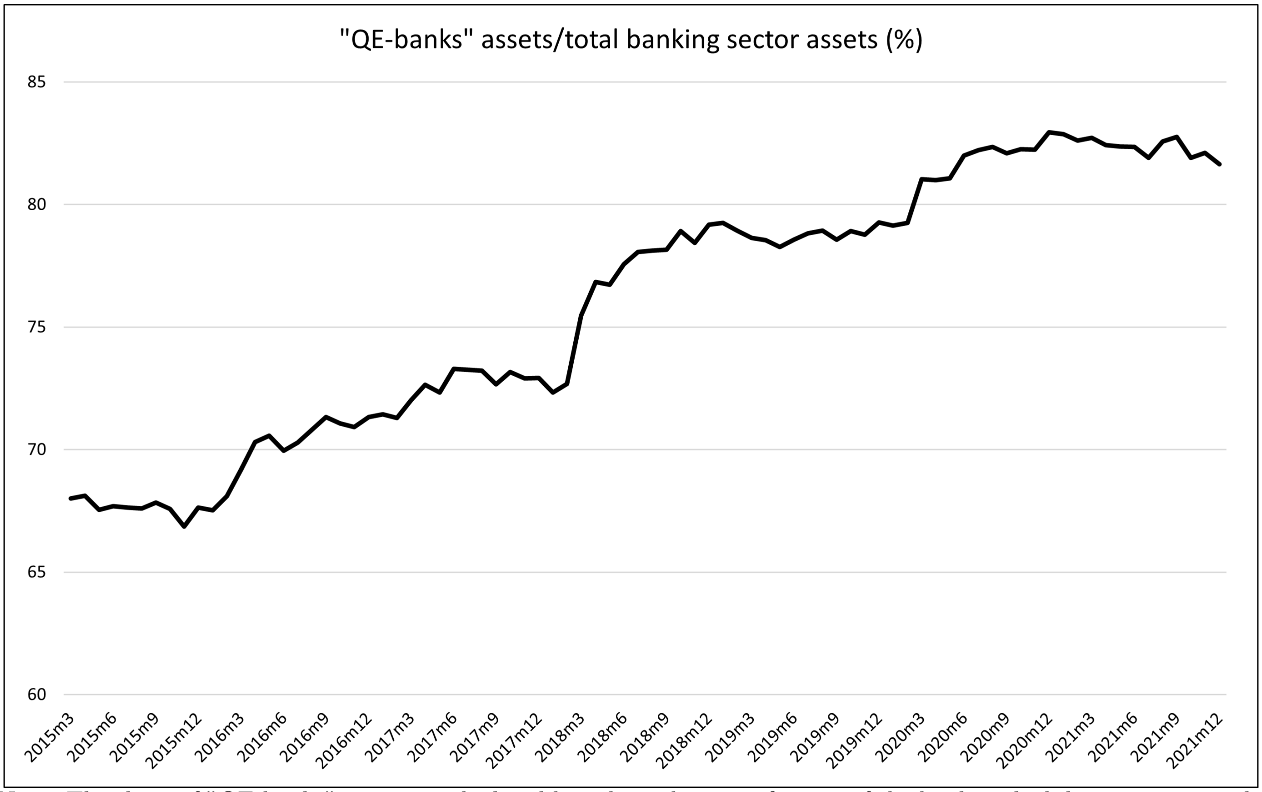
Note: Figure shows the comparison of the QE shock series (dashed line), obtained via fusion of high frequency information with narrative sign restrictions, with the QE factor of Altavilla et al. (2019) (solid line).

Figure A3: **"QE-intensity" of banks**



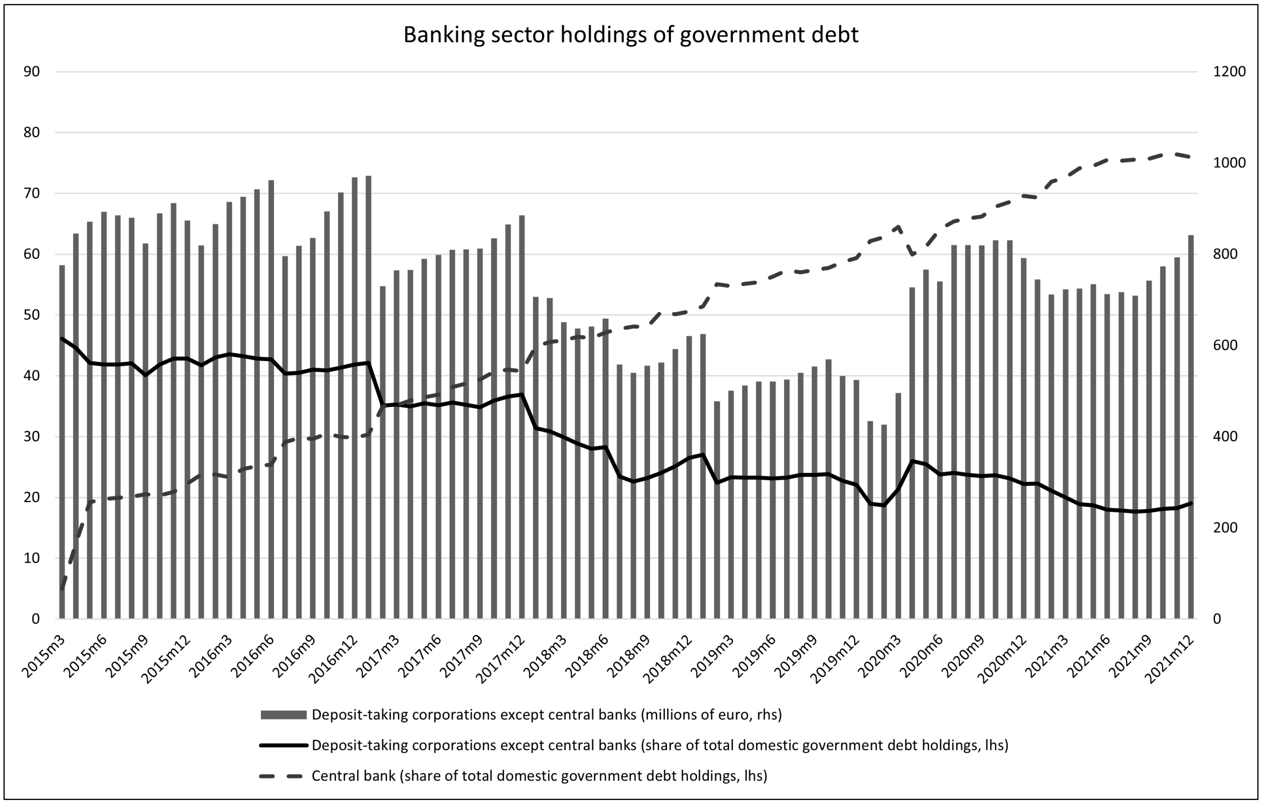
Note: "QE-intensity" is calculated as the cumulative sum of assets sold to the BoL divided by banks' total assets in the respective month.

Figure A4: **The share of "QE-banks" assets**



Note: The share of "QE-banks" assets is calculated by taking the sum of assets of the banks, which have participated in the QE programmes, and dividing by the total assets of the Latvian banking sector. We adjust the total assets series by removing the assets of those banks which have ceased to exist or have been liquidated in the considered sample period.

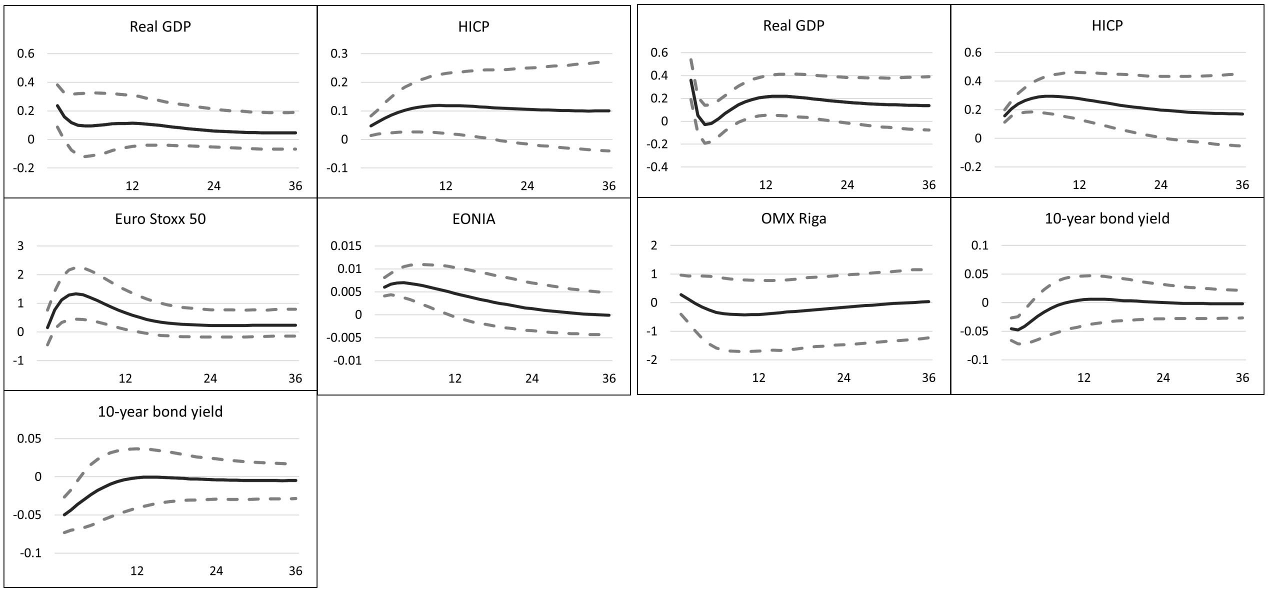
Figure A5: **Share of Latvian government debt held by the BoL and banks**



Note: Figure shows the evolution of Latvian government debt holdings in the QE period.

Figure A6: **Robustness check - using QE factor of Altavilla et al. (2019)**

(a) Euro area (b) Latvia



Note: Figures show impulse response functions from a bilateral SVAR to the asset purchase shock, identified using the QE factor of Altavilla et al. (2019), normalised to generate a 5 bps drop in the euro area 10-year bond yield. The solid line shows the median response while the dashed region denotes the 68% credible sets.