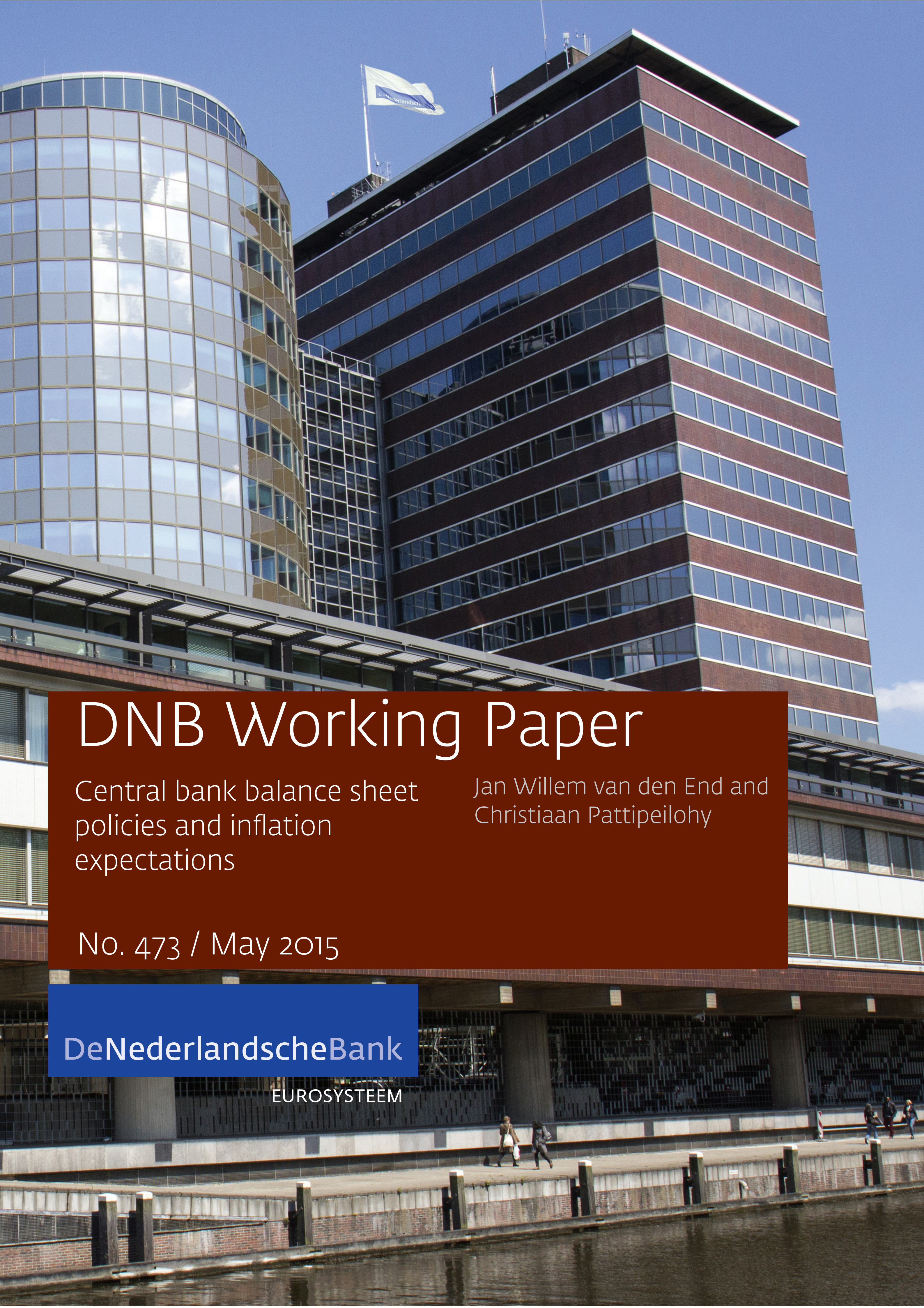

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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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De Nederlandsche Bank NV
P.O. Box 98
1000 AB AMSTERDAM
The Netherlands

Central bank balance sheet policies and inflation expectations*

Jan Willem van den End[a] and Christiaan Pattipeilohy[a]

[a] *De Nederlandsche Bank, the Netherlands*

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Abstract

We analyse the empirical effects of credit easing and quantitative easing on inflation expectations and exchange rates. Both monetary policy strategies are summarised in measures for composition and size of the central bank balance sheet and included in a VAR model. The empirical results show that changes in balance sheet size had positive effects on inflation expectations in Japan, while the effects where negligible in the euro area. By contrast, an increasing balance sheet size is associated with reduced short-term inflation expectations in the US and UK, pointing at negative signalling effects. Shocks to balance sheet size or composition have no substantial effects on long-term inflation expectations in the euro area, US and UK. An expanding balance sheet size is associated with an appreciation of the US dollar and a depreciation of the euro, pound sterling and Japanese yen.

Keywords: central banks and their policies, monetary policy.
JEL classifications: E58, E52.

* *Email addresses*: w.a.van.den.end@dnb.nl (J.W. van den End), c.pattipeilohy@dnb.nl (C. Pattipeilohy). We thank Peter van Els, Jakob de Haan and Richhild Moessner for their comments on a previous version of the paper.

1. Introduction

In this paper we analyse the effects of both quantitative and credit easing policies on inflation expectations and exchange rates. Following Lenza et al. (2010), the former refers to a policy whereby a central bank increases its balance sheet size without changing the composition of central bank assets. By contrast, credit easing policies refer to a change in asset composition, while leaving total balance sheet size unchanged. By engaging in such unconventional monetary policy strategies, the central bank actively uses its balance sheet to influence financial market outcomes and the real economy. This topic is currently of particular relevance for the euro area, as the recent slide of long-term inflation expectations motivated the ECB to announce an active balance sheet policy to steer the inflation rate closer to its policy target of below, but close to 2% (Constâncio, 2014). Moreover, the expansion of the asset purchase program in 2015 has been made conditional on the future path of inflation.

The standard reference with respect to the theoretical impact of monetary policy on inflation expectations is Krugman's analysis of the Japanese experiences in a liquidity trap (1998). Krugman proposes that the ineffectiveness of monetary policy in a liquidity trap essentially boils down to a credibility problem. Using a simple model, he shows this is related to the fact that the long-run money supply - determining the future price level - is fixed. However, if the central bank can commit itself credibly to accept a higher long-run money supply and future price level it can achieve sufficiently low real interest rates to "bootstrap" itself out of the liquidity trap. In this model, inflation expectations adjust simply to ensure consistency between the future price level set autonomously by the central bank and the current price level that is pre-determined. It is easy to see that the central bank can also generate inflation expectations by credibly committing to a higher future price level, by increasing actual inflation. Thus, in this analysis, central bank communication and credibility are crucial in determining inflation expectations.

A possible commitment device to change market expectations can be found in expansions or other modifications to the central bank balance sheet. This can be operationalised by unconventional monetary policy measures, broadly to be categorised as credit easing versus quantitative easing (see Borio and Disyatat, 2010 for a detailed typology).

Quantitative easing (QE) aims at loosening the overall stance of monetary policy, by expanding the size of the central bank balance sheet through an increase of central bank reserves. In addition to the direct effects of asset purchases on bond yields, the theoretical literature broadly distinguishes both portfolio-rebalancing and signalling effects of such policies (see Pattipeilohy et al. (2013) for an overview). Portfolio-rebalancing follows from imperfect asset substitutability, which may be either inherent in asset markets, or could be a consequence of endogenous market failures, for example financial distress. Signalling effects can arise at different levels. One channel often analysed in the literature on balance sheet policies refers to the expected path of short-term interest rates (and hence bond yields). A large scale asset purchase program can reduce bond yields though the portfolio rebalancing channel, as an expansion of base money changes relative asset prices and portfolio durations. This stimulates investments in assets further out along the risk and maturity curve. Moreover, increasing the balance sheet size may also lift confidence and inflation expectations through the signalling channel. It can reinforce the signal of forward guidance by the central bank to keep interest rates low for an extended period. Finally, expansionary monetary policy by expanding the balance sheet size can have spill-overs to foreign exchange markets. By weakening the exchange rate, it can contribute to higher inflation. However, the signalling channel may also work the other way. An expansion of the balance sheet may feed market expectations that the central bank sees downward risks to inflation, which can become self-fulfilling as market participants adjust their inflation expectations downward.

Whereas quantitative easing aims at loosening the overall stance of monetary policy, credit easing targets specific segments of the monetary transmission mechanism, for instance bank lending or specific securities markets. Through targeted lending operations and asset purchases, the central bank can reduce bond yields and credit spreads along the yield curve. This can lower private borrowing costs through the conventional interest rate pass-through channel (by market rates influencing lending rates). As a consequence of these effects, general financial market conditions improve, bolstering economic growth and inflation expectations. By lifting the prospects for economic growth, credit easing may also have an impact on the exchange rate by stimulating capital inflows. Credit easing is conducted by changing the central bank's exposure to different asset classes and, thus alters the composition of central bank asset holdings.

In this paper, we analyse the empirical effects of both quantitative and credit easing on short-term and long-term inflation expectations, in the period 2007-2014. We construct separate metrics for QE and credit easing, based on the balance sheets of the ECB, BoJ, BoE and the Fed. These measures are the size of the balance sheet and the dispersion among different types of assets. To our knowledge, we are the first to control at the same time for both types of balance sheet policies, empirically distinguishing two dimensions of recent central bank balance sheet policies. We include the measures in an unrestricted Vector Autoregressive (VAR) model, to simulate their effects on inflation expectations and exchange rates. VARs are a powerful tool to analyse the interdependence of multiple variables in a system of equations. Moreover, the impulse response functions that can be generated by VARs are simple to construct and straightforward to interpret. We estimate an unrestricted VAR as opposed to a more theory-based structural model as we do not want to impose any restrictions on the dynamics of the system. Rather, in this paper, we led the data speak for itself.

The results show that an increase in balance sheet size (through QE) is associated with declining short-term inflation expectations in the US and UK, which may reflect adverse signalling effects. The effect of a balance sheet size shock on inflation expectations in the euro area is negligible. Japan is the only case with a positive substantial response of inflation expectations to a shock in balance sheet size. The reaction of short-term inflation expectations to a change in balance sheet composition – by which we proxy credit easing policies - show opposite results. In the US and UK, short-term inflation expectations tend to rise after more accommodative credit easing, while this has negligible effects in the euro area and Japan. A shock to composition has no substantial effect on long-term inflation expectations in each of the four economies considered. With respect to the exchange rate effect, we find that an expansion in balance sheet size has a positive impact on the nominal effective exchange rate of the US dollar. The euro, pound sterling and Japanese yen tend to depreciate after a positive size shock. Finally, we find that sterling appreciates following extended credit easing.

The rest of the paper is organised as follows. After reviewing the literature on balance sheet policies in section 2, section 3 describes the data and the metrics we use to measure balance sheet policies. Next, section 4 sets out the empirical model. Section 5 presents the simulation outcomes, which are further discussed and put into perspective in section 6.

2. Literature

The empirical literature on the effects of central bank balance sheet policies is increasing rapidly, as for example documented by Pattipeilohy et al. (2013). Some studies have analysed the effects of such policies on macroeconomic outcomes in the context of VAR models that are also often used to analyse the effects of interest rate policies. For example, Peersman (2011) estimates a structural vector autoregressive (SVAR) model for the euro area focusing on transmission effects of monetary policy measures via the bank credit channel. Gambacorta et al. (2014) specify a panel structural VAR model to estimate the effects of unconventional monetary policy in various countries. Both studies identify expansive balance sheet policies as an increase in base money or total central bank assets.[1] They find that such balance sheet innovations have a qualitatively similar impact on output as changes in the policy rate, whereas the effects on the price level is weaker and less persistent. Weale and Wieladek (2014) estimate a Bayesian VAR to examine the impact of large scale asset purchases on real GDP and inflation in the UK and the US. They find that this QE policy had a statistically significant effect, with

[1] Both Peersman (2011) and Gambacorta et al. (2014) include the variables in (log) levels, assuming implicit cointegrating relationships in the data; however this is not tested and may bias the outcomes due to spurious correlation.

asset purchases of 1% GDP leading to maximum median increases of 0.2 to 0.4% in real GDP and inflation.

Other studies have focussed on the impact of balance sheet policies on financial market variables, often in an event-study framework. As has been noted by Joyce and Tong (2012), the crucial issue in conducting event studies is the choice of the time window used to assess the response of financial market variables. Setting the window too short creates the risk that the impact of policy announcements is not accounted for. However, if the window is set too long factors other than the policy announcement may be at play. Overall, event studies confirm that large scale asset purchases (i.e. QE) by the Fed and Bank of England have substantially reduced government bonds yields and credit spreads (see Williams, 2013 for an overview). These effects stem from the portfolio rebalance and signalling channels. Estimates of the effects of QE on the economy and inflation are more uncertain and range from nil and insignificant, to several percentage points in the US and UK (Cúrdia and Ferrero, 2013; Joyce et al., 2012).

However, only few papers analyse the impact of central bank balance sheet policies on inflation expectations. Ito (2014) investigates in a single equation model whether inflation expectations in Japan are influenced by changes in the central bank's balance sheet. He reports that there is no conclusive evidence that expanding monetary base impacts the formation of inflation expectations. Moessner (2015) analyses the effects of balance sheet policy announcements on market-based measures for inflation expectations using an event study approach. The author finds that the announcement of asset purchase programmes and long-term refinancing operations only have led to a slight increase in long-term inflation expectations. From this she concludes that the ECB's credibility in maintaining price stability in line with its definition has not been harmed by its balance sheet policies.

3. Metrics

In this paper we aim to analyse the effects of both credit and quantitative easing on inflation expectations. For this to be possible, we need to operationalise both dimensions of central bank balance sheet policies empirically. QE is approximated by a metric for total balance sheet size, as is common in the literature on central bank balance sheet policies. As empirical proxy for credit easing we measure changes in the composition of central bank assets. Composition is determined by the dispersion of the distribution of asset holdings. Wide asset dispersion reflects a more accommodative stance of credit easing, as the central bank balance sheet is geared at many market segments at the same time (ceteris paribus). By contrast, small dispersion reflects that the central bank is active in only a limited number of markets which can thus be interpreted as a less accommodative policy stance.

Using these concepts, our definitions of quantitative and credit easing are most closely related to Lenza et al. (2010). In their definition, QE refers to any expansion in the central bank balance sheet which does not alter the composition of central bank assets. By contrast, many other definitions for QE applied in the literature assume that it refers to a balance sheet expansion by purchasing a single asset class, usually government bonds (see eg Ugai, 2006; Benford et al., 2009). This definition implicitly assumes that QE coincides with an increase in portfolio concentration (lower asset dispersion). As a consequence, it is a less suited concept to operationalise empirically, in particular when it is crucial to make a meaningful distinction between quantitative easing and credit easing. Our method, following the definitions given by Lenza et al. (2010), does succeed in attaining this goal. Pure QE increases the balance sheet size, while leaving composition – i.e. asset dispersion – unchanged, whereas pure credit easing ('qualitative easing' in the terminology of Lenza et al. (2010)) only increases asset dispersion while leaving size unchanged. In this setting, the purchase of government bonds can be interpreted as a strategy of quantitative easing, as the balance sheet size increases. However, the relative credit stance is being tightened, as *ceteris paribus* the dispersion of assets decreases.

Both types of central bank balance sheet policies can now be approximated by a single indicator. As noted, we use the total balance sheet size to determine the degree of QE. Size is measured by total assets scaled by GDP.[2] Credit easing, referring to the degree of asset dispersion, is measured by the Herfindahl index (*Hi*) of the distribution of central bank asset holdings. We include the assets on the central bank balance that relate to monetary policy measures, including measures to support the liquidity of financial institutions and to foster market conditions in the financial crisis.[3] The *Hi* statistic is determined for each month in the sample, to construct a time varying. Metric *Hi* is size neutral, since it is normalised by the balance sheet size, as in Equation 1, which specifies the metric for central bank i, with asset x_j, for $j = 1..n$.

$$Hi_j^i = \sum \left(\frac{x_j}{\sum x_j}\right)^2 \qquad (1)$$

Metric *Hi* ranges between 0 and 1. An increase of *Hi* can be interpreted as a decrease in credit easing by the central bank, which reduces its presence to particular market segments. A decline of *Hi* can be associated with an increase in credit easing by a central bank, which expands its exposures to a wider

[2] The model simulations are robust to including an index for nominal balance sheet size.

[3] Source for the balance sheet data is Datastream (which takes the data from central bank reports). We include assets related to programs aimed at supporting individual institutions, such as the Maiden Lane facility of the Fed. We distinguish short term and longer term repo facilities as separate instruments in the composition metric, following Peersman (2011), who sees the ratio between the volumes of main refinancing operations (MROs) and longer-term refinancing operations (LTROs) of the ECB as a reflection of balance sheet composition. We do not make any further distinction between asset holdings in terms of differences in durations.

range of market segments.[4]

Our sample consists of monthly observations in the period 2007:1 to 2014:12. This captures the period in which central banks used unconventional monetary policy measures as policy rates were cut to the zero lower bound (the BoJ already started such policies in the early 2000s). It does not cover the expanded asset purchasing programme of the ECB which started in March 2015. During the sample period, size is negatively correlated with composition metric *Hi* in the balance sheets of the Fed and ECB (Figure 1; note that the scale for *Hi* has been inverted in the graphs). This reflects the fact that both central banks were engaging in quantitative and credit easing at the same time. While the size of the balance sheet increased, both central banks increased asset dispersion, implying a lower value for *Hi*. By contrast, for the BoJ and BoE, the metrics for composition and size are positively correlated.[5] This can be explained by the nature of the balance sheet policy by these two central banks, which primarily conducted QE by purchasing a single assets class (government bonds). As explained above, such a strategy of QE implies that an increase of size and asset concentration go in tandem.

[Insert Figure 1 here]

Generally speaking, the size measure shows two jumps; a small jump in 2008 and a larger jump in 2011-12 (Figures 1.a-d). The former relates to the crisis measures conducted to support market and funding liquidity during the stress conditions following the Lehman collapse. This policy primarily reflected an increase in the degree of credit easing. The Fed aimed at improving liquidity at various market segments, which led to a larger dispersion of its asset composition, as reflected by the sharp increase in the composition measure. In 2008-09 the ECB primarily supported the funding liquidity of banks through extended refinancing operations, which became the most dominant monetary policy instrument and explains the jump of the size and the fall of the composition measure (i.e. higher value of *Hi*). Since 2012, the balance sheet size of the Fed, BoE and BoJ jumped further, in tandem with a decline of the composition measure (i.e. rising value of *Hi*). This reflects the QE policy, which led to an increasing concentration of central bank assets towards government bonds. This contrasts with the ECB balance sheet, which decreased in terms of size and asset concentration (reflecting the repayments of LTROs).

[4] As an alternative composition measure we also applied the rolling Coefficient of Variation of the balance sheet assets; it is highly correlated with the Herfindahl index and shows a similar pattern.

[5] The correlation between the metrics size and composition is -0.39 for the Fed, -0.11 for the ECB, 0.79 for BoJ and 0.93 for BoE.

4. Empirical model

We simulate the effects of central bank balance sheet policies with an unrestricted VAR model. We choose this model because we do not want to impose any ex ante restrictions on the assumed effects of central bank balance sheet policies on inflation expectations, but let the data speak. To this end our measures for composition and size are included in the following VAR model,

$$Y_t = A_0 + B(L)Y_t + C(L)X_t + \mathcal{E}_t \quad (2)$$

Where Y_t is a vector of endogenous variables, X_t a vector of exogenous variables, A_o a vector of intercepts, $B(L)$ and $C(L)$ are matrix polynomials in the lag operator whose order is 2 (based on lag exclusion criteria) and $\mathcal{E}_t$ is the vector of error terms. In addition to the measures for composition and size, vector Y_t contains realised and expected inflation, the exchange rate, output gap and the policy rate as indicator of conventional monetary policy. These variables are common in related studies that analyse the transmission of monetary policy within a VAR framework (see e.g. Peersman and Smets, 2001). The model is estimated with both short-term inflation expectations, based on 1yr/1yr forward inflation indexed swaps, and long-term inflation expectations, based on 5yr/5yr forward inflation indexed swaps. By treating these variables as endogenous, the model captures the reciprocal interaction between realised and expected inflation as well as between price developments and monetary policy.

The exchange rate and the output gap are also included as endogenous variables, as they can be considered as potential transmission channels of balance sheet policies to inflation and inflation expectations.[6] Moreover, the exchange rate may (partly) capture the signalling effects of innovations in balance sheets size, in particular when different central banks would conduct divergent balance sheet policies. As exogenous variables we include the country specific energy price index and VIX index. The latter controls for the influence of financial market stress on inflation (expectations) and monetary policy measures, as in Gambacorta et al. (2014).[7] The exogenous variables influence inflation (expectations) and monetary policy, but are assumed not to be influenced by these factors themselves.

The inflation variables, the output gap and the VIX index are included in levels (based on the criteria that the series are stationary in levels), while the monetary policy variables (i.e. balance sheet size and composition and the policy rate) and the exchange rate are included in first differences, since they are non-stationary in levels. By acknowledging the non-stationarity of the data series our approach differs

[6] We interpolate the quarterly observations for the output gap provided by Oxford Economics to monthly series.
[7] The VIX index captures market expectations of near-term volatility conveyed by the country specific stock index option prices.

from Peersman (2011) and Gambacorta et al. (2014), who estimate VAR models with variables included in (log) levels. Both studies thus allow for implicit cointegration relationships in the data.[8] Compared to these studies, we tend to focus more on the shorter-term effects of central bank balance sheet policies. Moreover, by including first differences we eliminate the risk of finding spurious results - in case no cointegrating relationships are not present in the data - adding to the econometric plausibility of our main findings.

Based on impulse response analysis we assess in the next section to what extent a shock in balance sheet size and composition affects inflation expectations and exchange rates. To identify the shocks we rely on Cholesky decomposition. The motivation to use this simple recursive identification strategy as opposed to a more structural approach is that we want to remain agnostic about the directional impact of balance sheet policies on inflation expectations ex ante. An important reason is that economic theory is ambiguous on the expected signs of the parameters to be estimated. This concerns in particular expectational variables, that can be influenced positively or negatively through signalling effects, as explained in section 1. In this respect, our identification scheme differs from that of Peersman (2011) and Gambacorta et al. (2014), who use zero and sign restrictions to identify the structural shocks. This requires imposing a specific structure on the interdependence between the endogenous variables based on economic theory, which fits better with their focus on longer-term equilibrium effects, as well as the absence of expectational variables in their model set-up.

In the benchmark specification, we assume as an identifying assumption that changes in inflation expectations have an immediate effect on realised inflation and monetary policy. Vice-versa, changes in monetary policy only have a lagged effect on realised and expected inflation, reflecting lags in the transmission process. The reasoning behind the interaction between realised and expected inflation follows from a forward-looking New Keynesian Phillips curve, whereby companies start adjusting their prices immediately following changes in inflation expectations. The VAR allows for the possibility that such adjustments occur in a staggered way, as is the case in most New-Keynesian models. Moreover, in the benchmark specification the market variables, including inflation expectations and exchange rates, are assumed to have a contemporaneous impact on monetary policy measures. By contrast, monetary policy actions only impact market variables with a lag. The reason for this ordering of the variables is twofold. First, this ordering acknowledges that financial markets are forward-looking, as we assume that market variables incorporate future monetary policy measures ahead of the actual implementation of such policies. Thus, we assume that (standard and non-standard) monetary policy shocks are to some extent predictable, e.g. as a consequence of the central bank adhering to a Taylor rule in determining the optimal monetary policy stance. Second, this ordering of

[8] In both Peersman (2011) and Gambacorta et al. (2014) a more explicit assessment of the existence of cointegrating relationships is limited by the relatively short sample available.

variables takes into account that there often exists a lag between announcements of monetary policy measures and their actual implementation. In section 5.5 we test for the robustness of our benchmark results for an alternative ordering scheme of the variables and find that our main results are robust.

The impulse response analysis is used to test the following hypotheses:

i) Increasing balance sheet size shifts (short and long-term) inflation expectations up (i.e. impulse responses have a positive sign);

ii) Increasing balance sheet dispersion – i.e. decline of *Hi* - shifts (short and long-term) inflation expectations up (i.e. impulse responses have a negative sign);

iii) Increasing balance sheet size and dispersion leads to exchange rate depreciation (implying a negative sign of impulse responses following a shock in size and a positive sign of impulse responses following a shock in composition, or *Hi*).

These hypotheses follow from the intended effects of balance sheet policies on inflation expectations and the exchange rate that can work through the channels described in section 1.

5. Outcomes

In this section we analyse how inflation expectations and exchange rates react to a shock in either balance sheet size or composition. A shock is defined as a one standard deviation innovation in the VAR model. This equals a monthly change in balance sheet size and composition measure *Hi* of 5 to 10% approximately (in some cases we saw larger changes in the balance sheets during the sample period).

5.1 Responses of inflation expectations to a shock in size

The impulse responses show that a shock in balance sheet size only has a significant negative effect on short-term inflation expectations in the US and the UK (Figure 2.b-c, left-hand panels). In both countries, an increasing balance sheet size is followed by a (borderline) significant decline in short-term expected inflation over a one to six months horizon. The 12-month cumulative impulse responses of short-term inflation expectations are also negative, mostly in the UK (Figure 2.e). The negative effect on long-term expectations in the US and UK is less persistent (Figure 3.b-c, left-hand panels), while the cumulative responses of long-term inflation expectations are negligible (Figure 2.e). The negative responses of inflation expectations may reflect adverse signalling effects. By changing its balance sheet through unconventional monetary measures, the central bank may feed market expectations that the economy is in bad shape with downside risks for inflation. We also tested for the possibility of reverse causality, i.e. whether increases in balance sheet size are a response to a drop in inflation expectations. The impulse responses show that the response of balance sheet size to a shock in inflation expectations is significantly negative for the US, but only briefly in the first month following the shock, while the response it not significant, or even positive in the other countries. This suggests that negative signalling effects are more likely than an alternative scenario in which the central banks responds to falling inflation expectations.

[Insert Figures 2 and 3 here]

The effects of a shock in balance sheet size on short-term and long-term inflation expectations in the euro area and Japan are positive, but not significant (Figures 2.a, 2.d and 3.a, 3.d, left–hand panels). The cumulative effects in the euro area are negligible (Figure 2.e). Japan is the only country which shows substantial positive cumulative impulse responses of expected inflation after a shock in balance sheet size (Figure 2.e). Short-term and long-term inflation expectations rise around 40-45 basis points after a one standard deviation shock to the size of BoJ's balance sheet.

5.2 Responses of inflation expectations to a shock in composition

In contrast to the response of inflation expectations after a shock in balance sheet size, a shock to composition is associated with rising short-term inflation expectations in the US and UK (Figures 2.b-c, right-hand panels). The negative sign of the impulse responses indicates that a fall in *Hi* - i.e. more credit easing - goes with rising inflation expectations and vice versa. It might indicate that credit easing is effective in improving the conditions for economic growth and inflation. The 12-month cumulative impulse responses of short-term inflation expectations to a shock in balance sheet composition are only substantial for the UK (Figure 3.e).

The response of short-term inflation expectations in the euro area and Japan to a shock in balance sheet composition is not significant (see Figures 2.a and 2.d, right-hand side panels) and negligible in cumulative terms (Figure 3.e). A shock to composition has no significant effect on long-term inflation expectations in each of the four countries (Figure 3, right-hand panels), while the 12-month cumulative impulse responses of long-term inflation expectations are not substantial (Figure 3.e).

5.3 Responses of exchange rates

Surprisingly, a shock to balance sheet size has a positive impact on the nominal effective exchange rate of the US dollar (Figure 4.e, the result is both found for model simulations that include short or long-term inflation expectations). This effect is borderline significant (Figure 4.b, left-hand panel). It indicates that an expansion of the Fed's balance sheet goes with a US dollar appreciation. A potential channel for this effect is that balance sheet expansion signals that monetary policy will remain loose for an extended period of time, which boosts asset prices, investors' confidence and capital inflows. The currency appreciation after a shock in balance sheet size could explain the negative impact of a size shock on inflation expectations in Figure 2.b. In contrast, an expanded balance sheet size of the ECB, BoJ and BoE is associated with a depreciating exchange rate (Figure 4.e) and the effects are (borderline) statistically significant (Figures 4.a and 4.c, left-hand panel). The depreciation of the euro and yen, in tandem with the increase of inflation expectations following a shock in size, indicates that the exchange rate works as a channel through which inflation expectations are influenced in the euro area and Japan.

[Insert Figure 4 here]

A shock in balance sheet composition only has a significant and negative effect on the exchange rate in the UK (Figure 4.c, right-hand panel). The cumulative effect on the pound sterling is also substantial (Figure 4.e). The negative sign of the impulse responses mean that a fall in *Hi* - i.e. more credit easing - goes with a currency appreciation and vice versa. A possible channel for this effect is that credit easing lifts the prospects for economic growth, which stimulates capital inflows. The reaction of the euro, yen and the US dollar to a shock in balance sheet composition is not significant (Figures 4.a-b and 4.d, right-hand panel) and limited in cumulative terms (Figure 4.e).

5.4 Responses of other macro-economic variables

While our study focusses on the impact of balance sheet policies on inflation expectations, most other empirical studies look at the effects of QE and credit easing on realised inflation and output. In our model, the impulse responses of realised inflation to shocks in balance sheet size and composition in most cases have the similar sign as the responses of short-term expected inflation, although the responses of realised inflation are insignificant in most of these cases. The response of the output gap to shocks in size and composition are statistically insignificant for all countries. This suggests that balance sheet policies have had no statistically significant effects on the real economy in the period under review.[9]

5.5 Robustness

5.5.1 Measurement of balance sheet composition

To assess the robustness of the benchmark estimation results presented above, we have re-estimated the VAR-model using a number of alternative specifications.[10] In particular, we are interested to what extent the estimation results are robust for different assumptions with respect to the calculation of our proxy for changes in balance sheet composition. As we rely on a Herfindahl index, it could be the case

[9] The impulse responses of realised inflation and the output gap are not shows graphically, but they are available on request.

[10] As one robustness check not discussed in this paper for the sake of brevity, we have re-estimated the model using the change of industrial production instead of the output gap. The results of these estimations (available upon request) are very much in line with our benchmark estimation results including the output gap.

that our indicator for credit easing depends on the number of different asset classes considered and, thus, on reporting practices. Assuming a central bank's assets are equally distributed among all asset classes, by construction the Herfindahl index would be lower for a central bank reporting more types of assets. Potential measurement errors arising from such factors are to some extent averted, as we do not include the level but rather the change in central bank balance sheet composition in the VAR. However, they cannot be completely excluded, as the amplitude of changes in the Herfindahl index could also be larger for central banks reporting more different asset classes.

[Insert Figure 5 here]

While our benchmark specification of the Herfindahl index is based on the broadest set of disaggregate data publicly available, we re-estimate the model including an alternative Herfindahl index for credit easing based on a very narrow set of asset types. In order to do so, we consider a central bank balance sheet consisting of only three asset classes, i.e. foreign assets, lending to the domestic government and lending to the domestic private sector. For these revised Herfindahl indices we use data from the IMF's International Financial Statistics database. This ensures a higher level of consistency of the calculated indices across countries compared to our benchmark calculations, which are based on national datasets. The disadvantage is that the underlying series are by definition less granular, and, as a consequence, may not identify all relevant policy innovations. The benchmark and revised indices for central bank balance sheet composition are included in Figure 5. As shown in the panels, the correlation between the benchmark and revised Herfindahl indices is very high for the Fed, the Bank of England and the Bank of Japan, whereas the correlation is rather low for the ECB. The main reason for this difference is that, in the first three cases, changes in balance sheet composition were reflected in changes in de central bank's asset allocation between sectors. By contrast, in the case of the ECB, changes in balance sheet composition reflected changes within-sectors (mostly vis-à-vis the banking sector) keeping the allocation between sectors relatively unchanged. As a consequence, such changes in balance sheet composition are not identified using the less granular data.

Figures 6 and 7 summarize how the main estimation results from the revised model compare to our benchmark estimation results. Figure 6 shows the 12-month cumulative impulse responses of a size-shock (Figure 6.a) and a composition shock (Figure 6.b) on long-term inflation expectations. As for the impact of a size shock, the results are largely similar in both models. The same holds for the effects of a composition shock on inflation expectations in the euro area and the US which remain negligible, even though the sign of the estimated effect switched from positive to negative. However, in the revised model, a positive shock to the Herfindahl-index, i.e. reduced credit easing, is now associated with higher inflation expectations in both the UK and Japan, whereas the benchmark model found no impact in the UK and a negative impact in Japan. These revised findings may seem counterintuitive, but can be well understood against the background of differences in the design of the balance sheet policies. As noted in section 3, both in the UK and Japan we find a negative correlation between balance sheet size and the Herfindahl-index. This can be attributed to the fact that, for these two central banks, balance sheet expansions have been pursued largely by purchasing a single asset class, i.e. government bonds. Thus quantitative easing has coincided with lower dispersion of central bank asset holdings, which suggests reduced credit easing according to our methodology. In fact, the narrowly defined composition index fails to distinguish credit easing from QE appropriately, due to the crude disaggregation in the index. As a consequence, the positive impulse response of inflation expectations following a credit easing shock can to some extent be attributed to the effect of central bank balance sheet expansion. This underlines the benefit of our more granular composition index used in the benchmark model.

[Insert Figures 6 and 7 here]

As for the impact on the effective exchange rate, Figure 8 shows that the cumulative impact responses of a size shock are unchanged compared to the benchmark model specification. As for the impact of a composition shock, the results are very similar for the euro area, the US and the UK, but not Japan. Like the impact on inflation expectations, this might reflect an additional exchange rate effect of Japan's quantitative easing policies on the exchange rate, which according to our methodology coincides with reduced credit easing.

An issue related to the one discussed above refers to the calculation of the proxy for balance sheet composition specifically for the ECB. In section 3 we noted that the Herfindahl-indices are based on the part of the balance sheet that relates to monetary policy measures. Whereas for the Fed, BoE and BoJ this broadly coincides with total assets, this is not the case for the Eurosystem, for which monetary policy assets only comprise around 50% of its balance sheet on average in the period under review. By leaving out assets not related to monetary policy (mainly foreign reserves, but also domestic bond holdings in national central banks' investment portfolios) we may underestimate true asset dispersion. At the same time, one might argue that we overestimate asset dispersion in our benchmark specification by distinguishing refinancing operations of different maturities as separate asset classes, whereas in terms of risk-profile (eligible counterparties and collateralization) such operations are fairly similar.

[Insert Figure 8 here]

To assess the relevance of these potential measurement errors, we re-estimate the model including three revised series for asset dispersion for the ECB (Figure 8). For revision 1 we include the non-monetary policy assets as a single asset class and have recalculated the Herfindahl-index over the entire ECB balance sheet. Revision 2 adjusts the benchmark index by treating refinancing operations of all different maturities as a one asset class. Revision 3 combines the adjustments of the two revised series. Figure 9 displays the impulse response functions of a shock to balance sheet composition on long-term inflation expectations and the exchange rate for both the benchmark model and the models with the revised indicators. The outcomes confirm that our benchmark model is robust to these alternative specifications for the Herfindahl index.

[Insert Figure 9 here]

5.5.2 Cholesky ordering

It is well known the impulse response functions from VAR-models can be sensitive to different identification schemes, for example the ordering of the variables in a recursive system, as the one we have estimated. As a simple robustness test, we analyse to what extent our benchmark results are sensitive to different ordering schemes.

We consider one alternative scheme that may be considered plausible from a theoretical perspective. Specifically, we consider an identification scheme that allows for a contemporaneous impact of monetary policy measures on inflation expectations and exchange rates. The rationale for this alternative identification scheme is that financial market variables may not perfectly anticipate future monetary policy innovations. Thus, whereas in the benchmark specification monetary policy measures are anticipated by markets, in the alternative specification monetary policy shocks are unanticipated, and can be interpreted as surprise shocks.

[Insert Figures 10 and 11 here]

The main results of this revised exercised are included in Figures 10 and 11. As in Figures 6 and 7, these graphs show the cumulative 12-month impulse responses of inflation expectations and exchange rates following a shock in balance sheet size and composition for both the benchmark and alternative model specification. As is clear from the charts, the main results for both models are broadly similar, indicating that our results are robust for different ordering schemes.

6 Discussion

We found evidence that balance sheet policies had negligible impact on inflation expectations in the sample period. The exception is Japan, where an increase in central bank balance sheet size increased inflation expectations and led to a depreciation of the yen. The limited sensitivity of inflation expectations to balance sheet policies could be considered a consequence of their anchoring properties, i.e. the fact that inflation expectations do not react to the arrival of news (see for example Galati et al., 2011). As noted in the event-study on ECB measures by Moessner (2015), this can be taken as evidence that the conduct of balance sheet policies has not hampered the credibility of central banks, i.e. it has not impacted the perceived commitment to their inflation target.

However, at the same time, our results suggest that central banks actually aiming to increase inflation expectations may not succeed. Our analysis shows that balance sheet policies by themselves may not prove sufficient to lift inflation expectations significantly. This outcome is in line with theoretical New-Keynesian models, which conclude that QE would only be effective in changing expectations if the central bank succeeds in credibly committing itself to higher inflation by changing its monetary strategy (Eggertson and Woodford, 2003[11]). Indeed, the BoJ's announcement of QE in early 2013 coincided with a revision of its monetary policy strategy, with the BoJ moving from an inflation goal of 1% to an inflation target of 2% (Bank of Japan, 2013). As is confirmed by Kuroda (2015), this change of tack, combined with balance sheet policies, aimed at lifting inflation expectations. By contrast, the ECB, BoE and Fed maintained their traditional inflation targets. This may foster the belief that policy will be tightened as soon as inflation rises, explaining why inflation expectations have not been affected by balance sheet policies. However, the expanded asset purchase program of the ECB which started in 2015 may change this, as the ECB explicitly announced that asset purchases will be conducted until there is a sustained adjustment in the path of inflation.

Finally, it should be noted that our empirical analysis only identifies the actual implementation effect of balance sheet policies on inflation expectations and exchange rates and does not identify any announcement or anticipation effects that could be relevant. However, the event-study by Moessner on the announcement effects of ECB balance sheet policies concludes that such announcement effects have also been negligible in the euro area.

[11] Joyce et al. (2012) mention that the theory of Eggertson and Woodford implies that the private sector faces no credit restrictions and is rational (it sees the assets held by the government and by the central bank as indistinguishable from their own assets). Then any swap of assets with the central bank cannot change anything. According to Joyce et al. the representative agent assumption is a strong one, as is the assumption of perfect substitutability between assets, while it is debatable whether this last assumption holds even in unstressed financial markets but it is very questionable in the wake of a financial crisis where markets are not operating smoothly.

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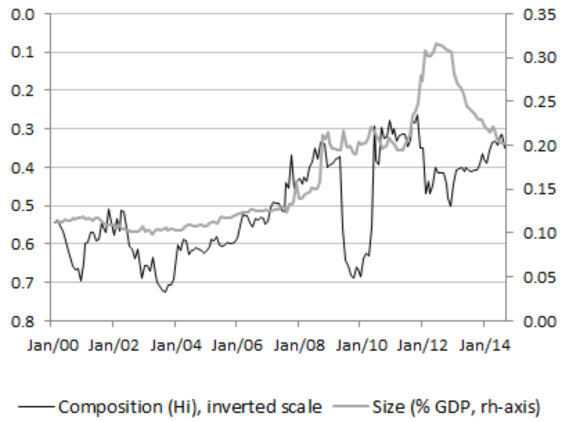
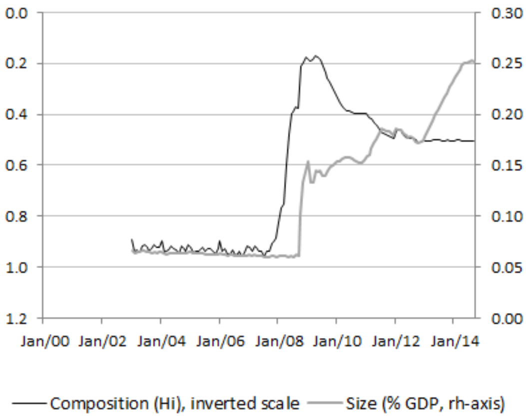
Figure 1. Size and composition

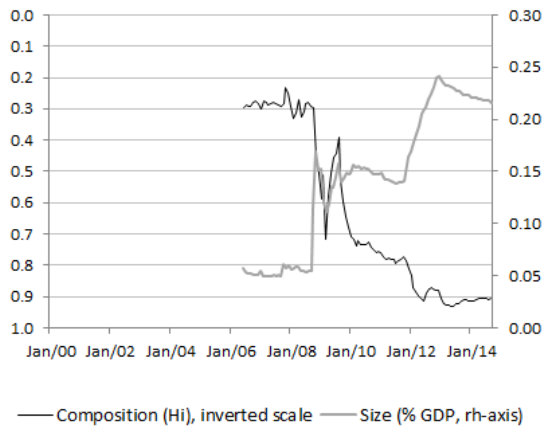
1a. ECB balance sheet



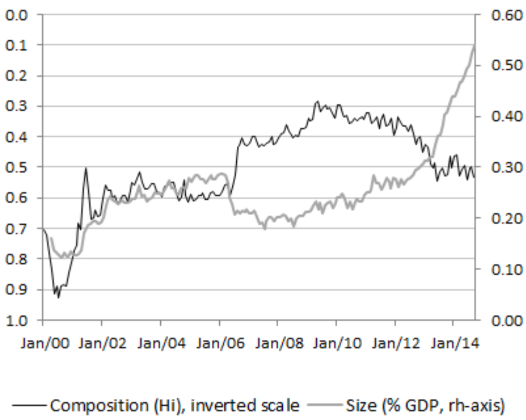
1b. Fed balance sheet



1c. BoE balance sheet



1d. BoJ balance sheet



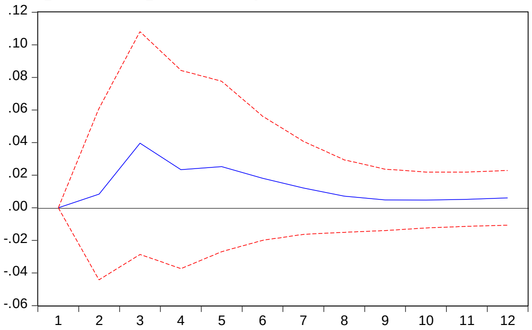
Source: Authors' own calculation based on Datastream

Note: Size is measured by total assets scaled by GDP. Composition is measured by the Herfindahl index (*Hi*) of the distribution of central bank asset holdings. The *Hi* statistic is determined for each month in the sample, to construct a time varying, rolling dispersion measure. Metric Hi is size neutral, since it is normalised by the balance sheet size and ranges between 0 and 1. An increase of *Hi* can be interpreted as a decrease in credit easing by the central bank, which reduces its presence to particular market segments. A decline of *Hi* can be associated with an increase in credit easing by a central bank, which expands its exposures to a wider range of market segments.

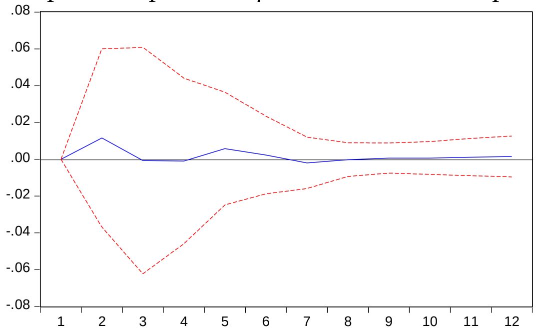
Figure 2. Impulse responses of short-term inflation expectations to shock in size and composition

2a. Euro area

Response expected inflation to shock size

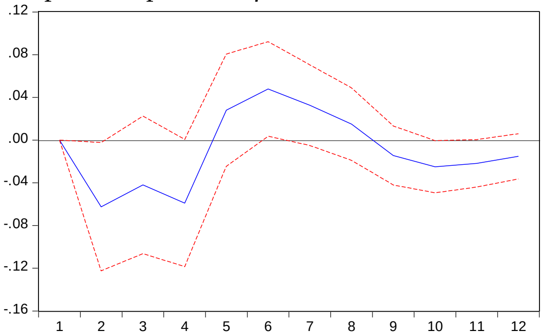


Response expected inflation to shock composition

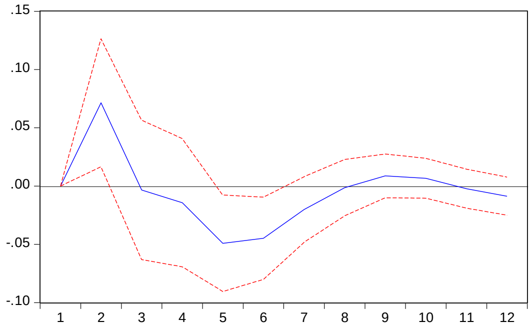


2b. US

Response expected inflation to shock size

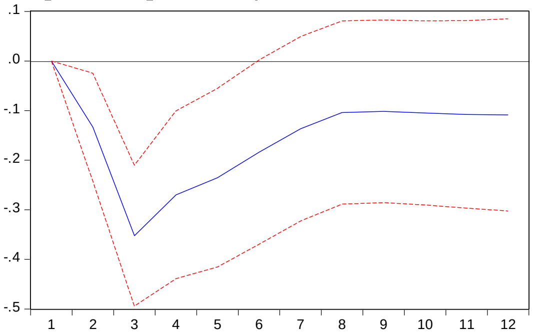


Response expected inflation to shock composition

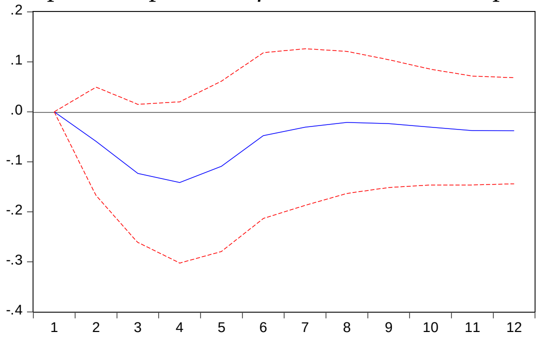


2c. UK

Response expected inflation to shock size

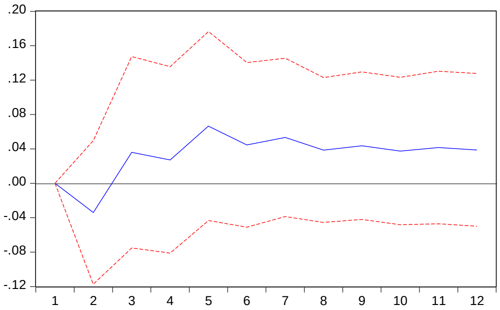


Response expected inflation to shock composition

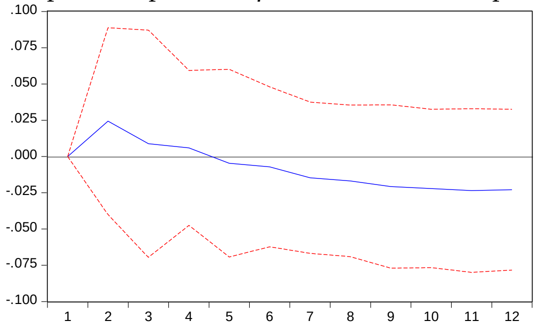


2d. Japan

Response expected inflation to shock size



Response expected inflation to shock composition

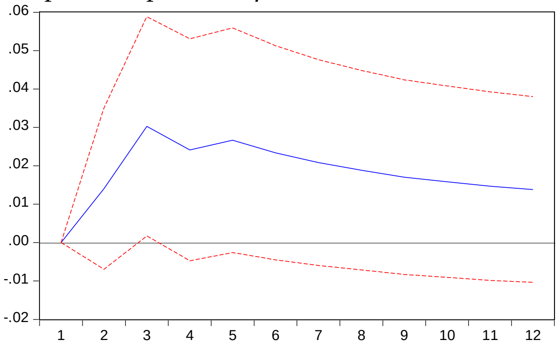


Note: Shock is defined as a 1 standard deviation innovation in the VAR model. Number of months on horizontal axis.
Source: Authors' own calculations

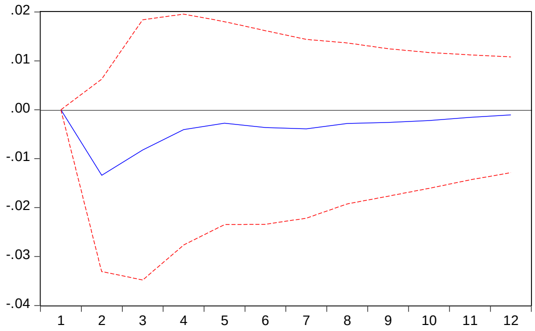
Figure 3. Impulse responses of long-term inflation expectations to shock in size and composition

3a. Euro area

Response expected inflation to shock size

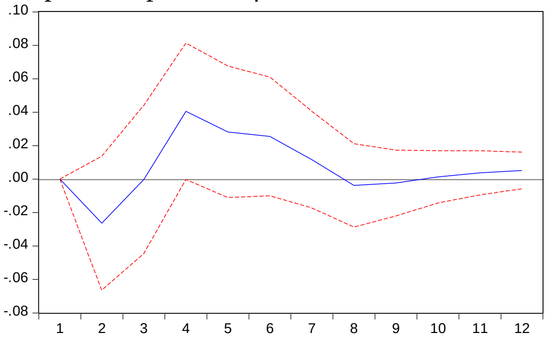


Response expected inflation to shock composition

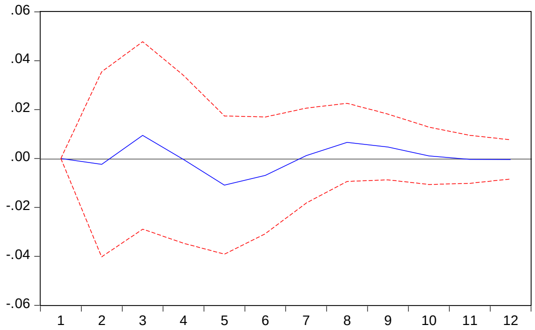


3b. US

Response expected inflation to shock size

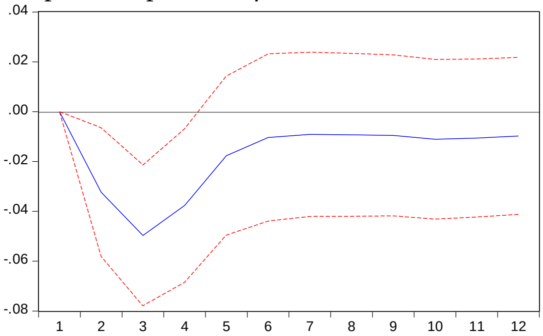


Response expected inflation to shock composition

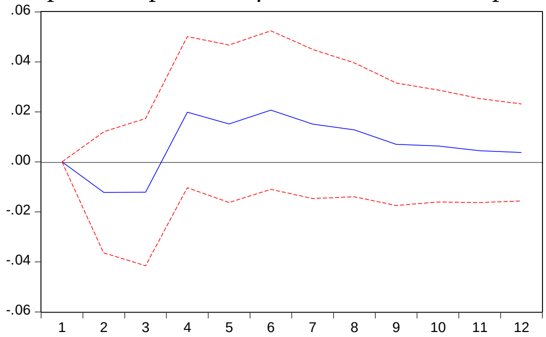


3c. UK

Response expected inflation to shock size

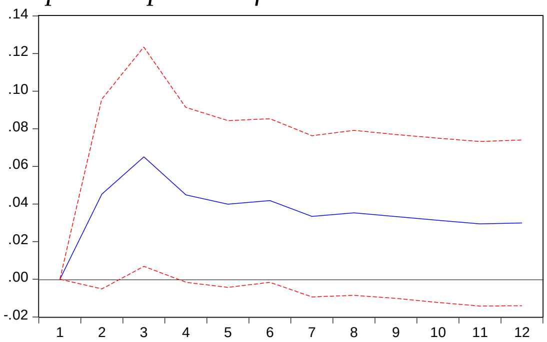


Response expected inflation to shock composition

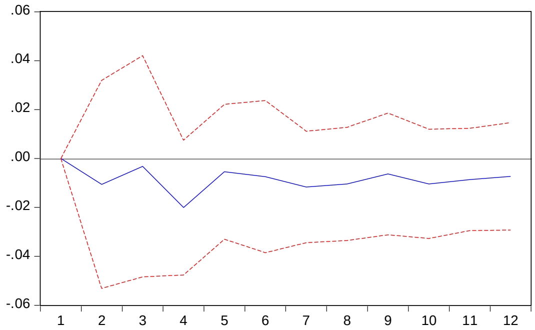


3d. Japan

Response expected inflation to shock size



Response expected inflation to shock composition

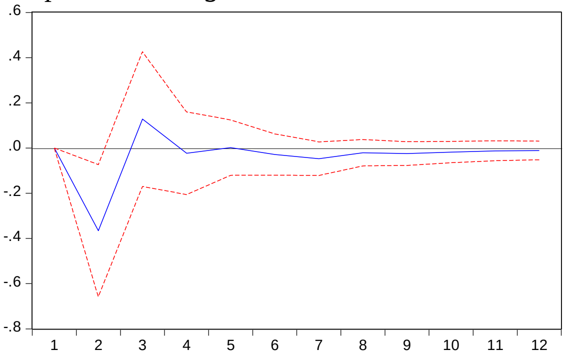


Note: Shock is defined as a 1 standard deviation innovation in the VAR model. Number of months on horizontal axis.
Source: Authors' own calculations

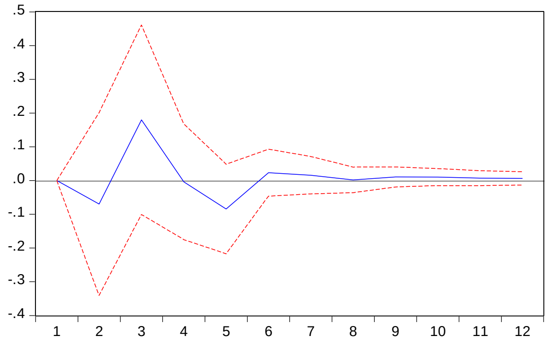
Figure 4. Impulse responses of exchange rate to shock in size and composition, including long-term inflation expectations in the VAR model

4a. Euro area

Response exchange rate to shock size

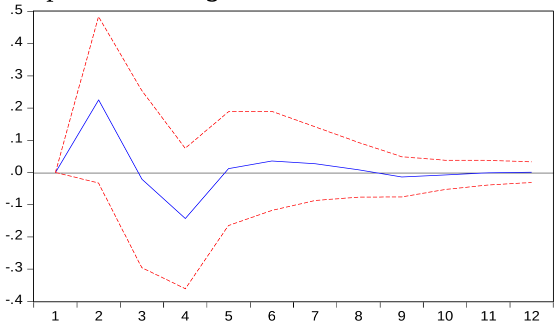


Response exchange rate to shock composition

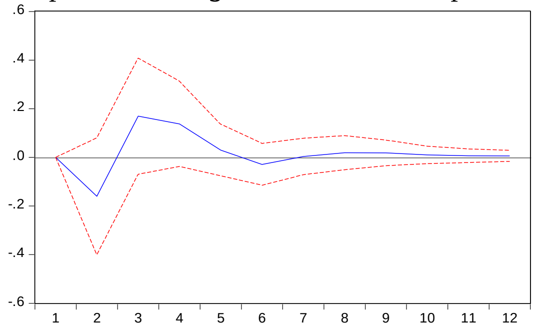


4b. US

Response exchange rate to shock size

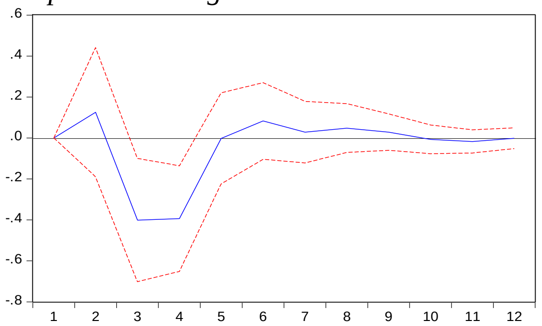


Response exchange rate to shock composition

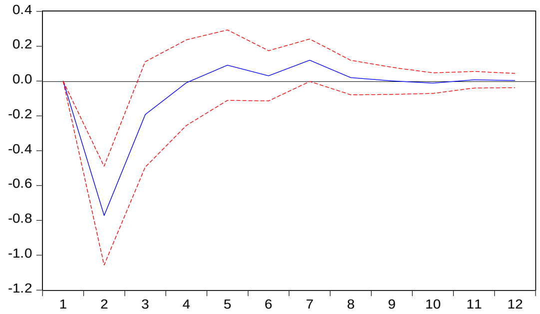


4c. UK

Response exchange rate to shock size

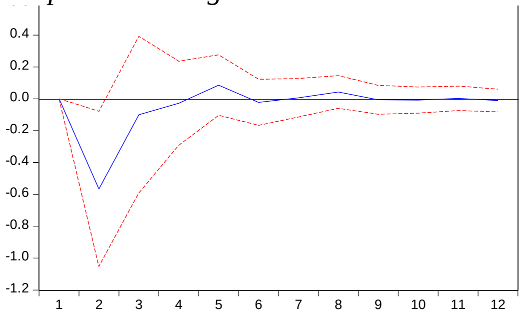


Response exchange rate to shock composition

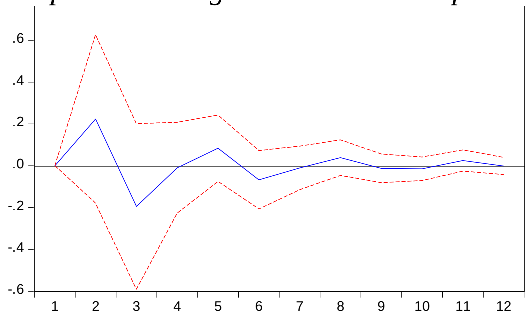


4d. Japan

Response exchange rate to shock size

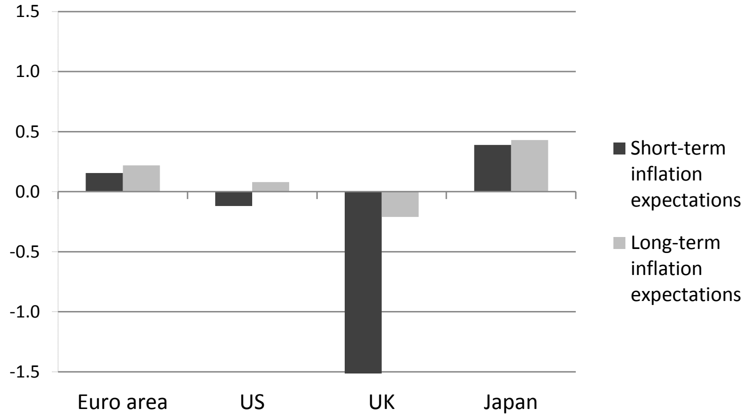


Response exchange rate to shock composition



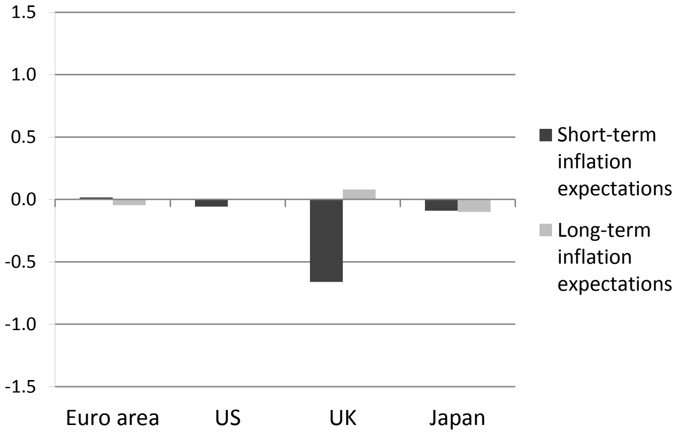
Note: Shock is defined as a 1 standard deviation innovation in the VAR model. Number of months on horizontal axis.
Source: Authors' own calculations.

Figure 2.e Cumulative impulse response of inflation expectations to shock in size, %-points



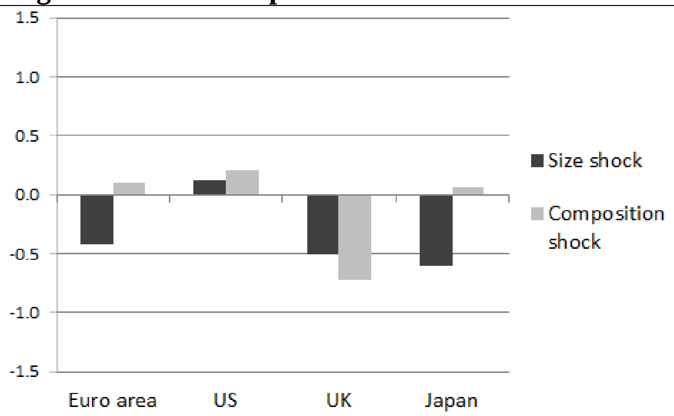
Note: 12-month cumulative impulse responses.
Source: Authors' calculations.

Figure 3.e Cumulative impulse response of inflation expectations to shock in composition, %-points



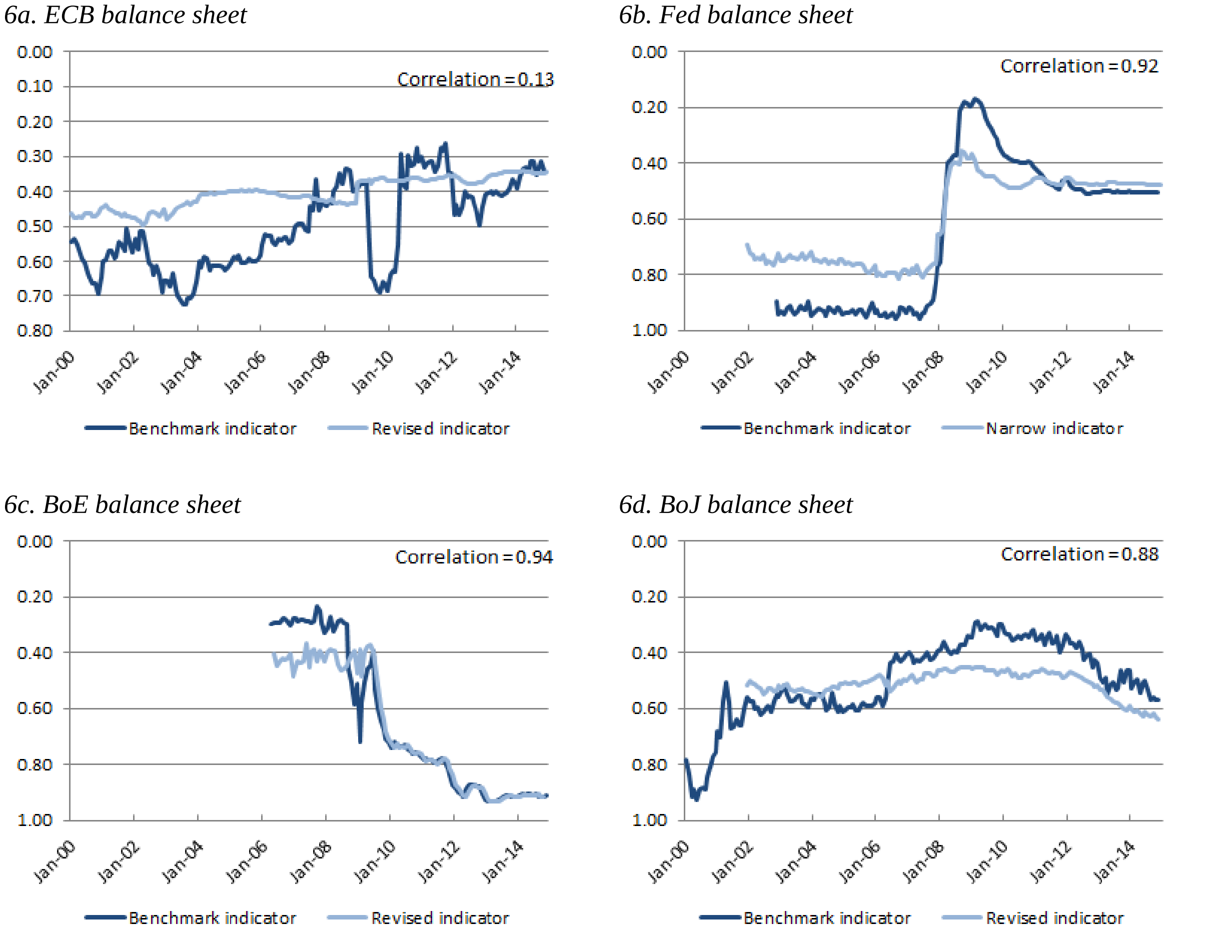
Note: 12-month cumulative impulse responses.
Source: Authors' calculations.

Figure 4.e Cumulative impulse response of nominal effective exchange rate (change of index), including long-term inflation expectations



Note: 12-month cumulative impulse responses.
Source: Authors'

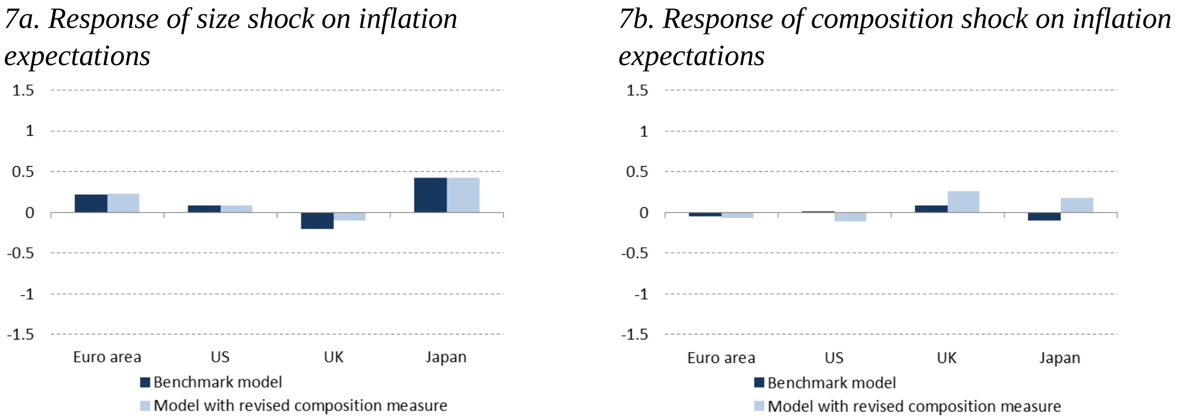
Figure 5. Revised Herfindahl index



Note: Size is measured by total assets scaled by GDP. Composition is measured by the Herfindahl index (*Hi*) of the distribution of central bank asset holdings. The revised Herfindahl index is based on a very narrow set of asset types (foreign assets, lending to the domestic government and lending to the domestic private sector). The revised Herfindahl indices are based on data from the IMF's International Financial Statistics database which are transposed using a harmonised procedure.

Source: Authors' calculations based on national data sources and IMF International Financial Statistics.

Figure 6. Robustness analysis: 12-month cumulative impulse responses of size and composition shock on long-term inflation expectations

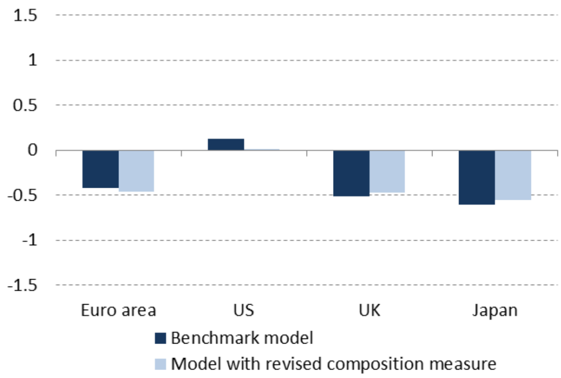


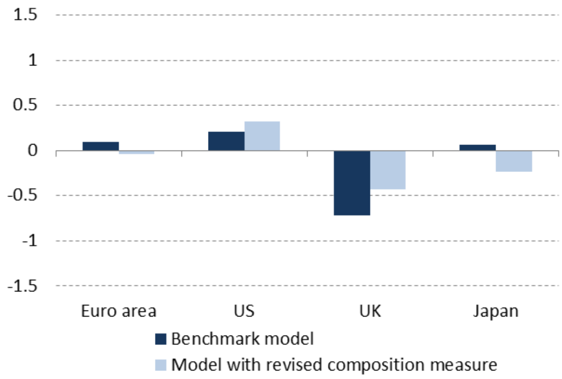
Note: 12-month cumulative impulse responses.

Source: Authors' own calculations.

Figure 7. Robustness analysis: 12-month cumulative impulse responses of size and composition shock exchange rate

8a. Response of size shock on exchange rate *8b. Response of composition shock on exchange rate*

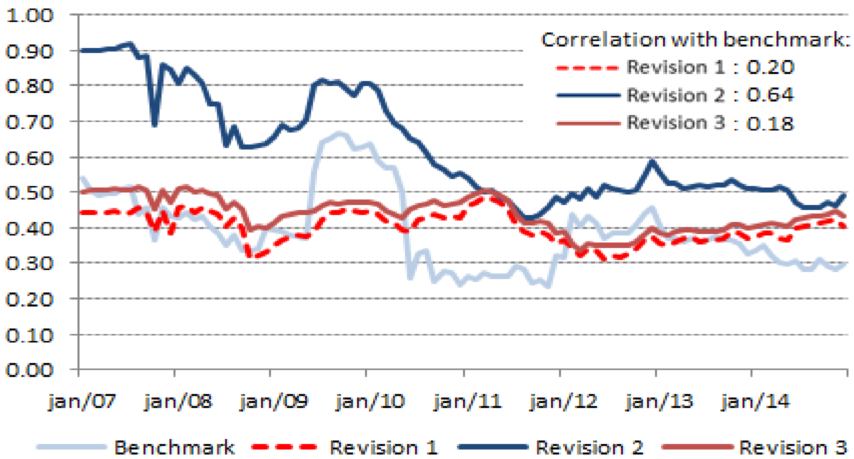




Note: 12-month cumulative impulse responses.

Source: Authors' own calculations.

Figure 8: Revised series for balance sheet composition ECB

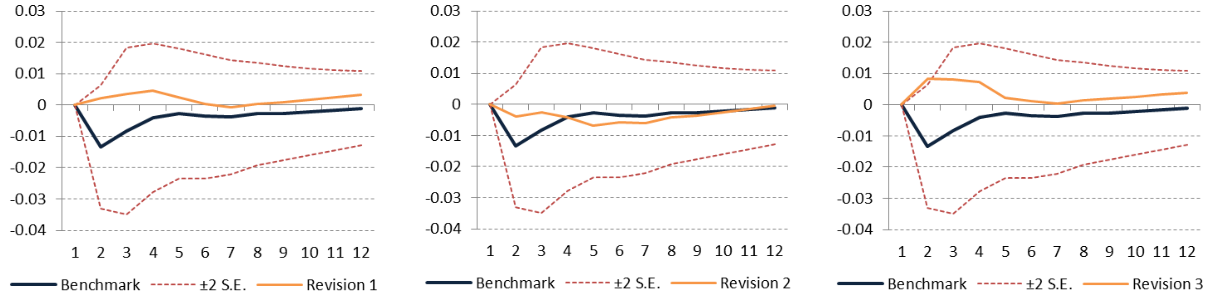


Note: To assess the relevance of potential measurement errors, the model is re-estimate including three revised series for asset dispersion for the ECB. Revision 1 includes the non-monetary policy assets as a single asset class and have recalculated the Herfindahl-index over the entire ECB balance sheet. Revision 2 adjusts the benchmark index by treating refinancing operations of all different maturities as a one asset class. Revision 3 combines the adjustments of the two revised series.

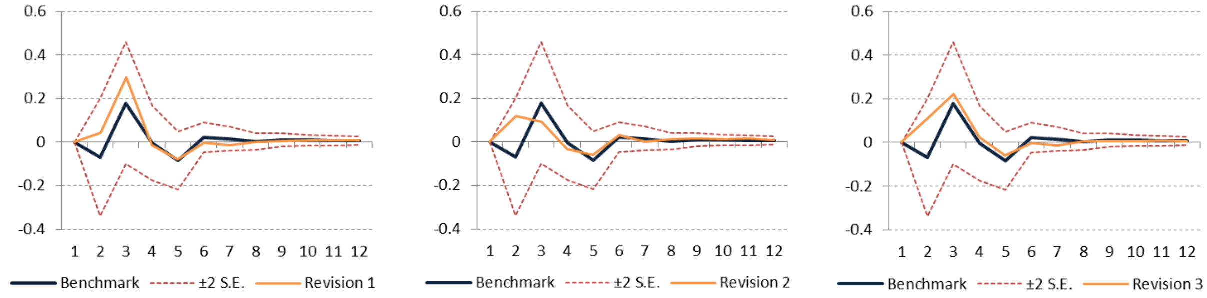
Source: Authors' own calculations based on ECB-data.

Figure 9. Robustness analysis: Impulse responses with revised composition indices ECB

10a. Response of 5 yr inflation expectations to shock in composition



10b. Response of exchange rate to shock in composition (based on model for long-term inflation expectations)

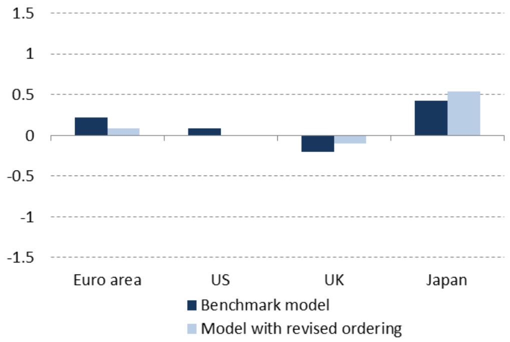


Note: Shock is defined as a 1 standard deviation innovation in the VAR model. Number of months on horizontal axis.

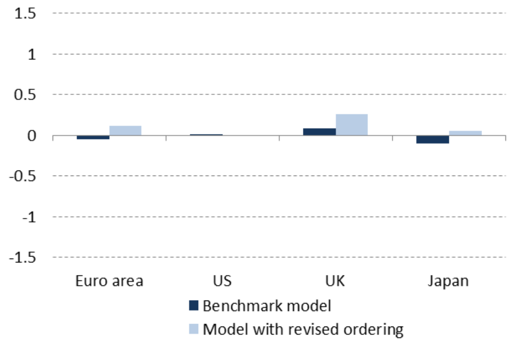
Source: Authors' own calculations.

Figure 10. Robustness analysis: 12 –month cumulative impulse responses of long-term inflation expectations with revised variable ordering

11a. Response of size shock on inflation expectations



11b. Response of composition shock on inflation expectations

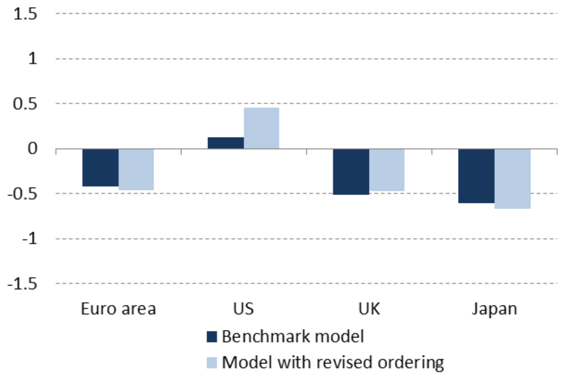


Note: 12-month cumulative impulse responses.

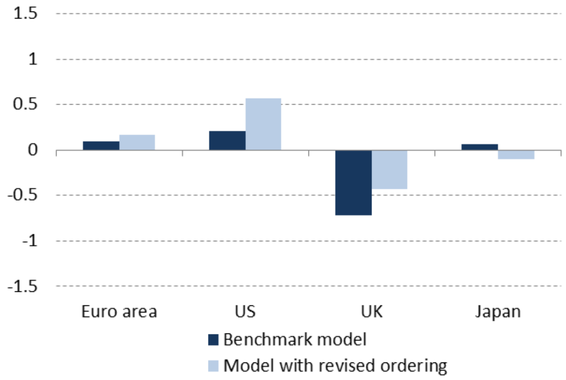
Source: Authors' own calculations

Figure 11. Robustness analysis: 12-month cumulative impulse responses of exchange rate with revised variable ordering

12a. Response of size shock on exchange rate



12b. Response of composition shock on exchange rate



Note: 12-month cumulative impulse responses.

Source: Authors' own calculations

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