Spillover effects of Euro Area QE policy

Evidence from the Western African Union*

Giovanni Ricco

École Polytechnique and University of Warwick

Anshumaan Tuteja
University of Warwick

Emmanuele Savini
University of Warwick

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Abstract

This study examines the spillover effects of the European Central Bank's Quantitative Easing (QE) programs on the Western African Economic Monetary Union (WAEMU). The peg of the common currency against the Euro enables us to focus on the trade and financial channels of international transmission. We estimate Bilateral vector autoregression (VAR) models consisting of national macroeconomic and financial data at monthly frequency. Using high frequency identification approach, we study the responses to a structural exogenous QE policy shock. We show that an expansionary shock in the Euro Area results in spillovers to the money market, the stock index and exchange rate with the US dollar. The impact on output and prices is modest, and there is significant heterogeneity in response of member nations. These results are consistent with lack of spillovers through the trade channel.

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1 Introduction

It is widely accepted that Quantitative Easing (QE) policy adopted by major economies, or core economies, played an instrumental role in restoring domestic financial stability and stimulating domestic demand. Yet, several concerns were raised by policy makers of other economies, or periphery economies, about potential negative impact from these policies (Rajan, 2015). This was primarily because depreciation in the currency of core economies dented trade competitiveness, financial market performance and the real economy of peripheries. This debate peaked around the Taper Tantrum episode of 2013 where the potential reversal of QE policy in the US led to negative financial spillovers across global financial markets. The European Central Bank (ECB) also embarked on an expnasive QE program of roughly 2.5 trillion euros beginning in 2015. The sheer size of the program could have led to significant spillovers to economies that are linked to the Euro Area (EA) through trade, exchange rate and financial linkages.

In this paper, we aim to understand the spillovers of QE policy of the ECB on a set of African countries that are part of a monetary union pegged to the Euro. These eight African countries are part of the West African Economic and Monetary Union (WAEMU). Similar to the Euro Area (EA), they use a single currency called the West African Franc of the African Financial Community (CFA Franc). Our research answers the following question: Is there existence of spillovers of QE policy of the Eropean Central Bank on countries outside Europe? We focus on three international channels of policy transmission: first, the demand channel examines the role of change in domestic demand on exports of periphery economies. Second, the exchange rate channel studies the role of changes in exchange rate on trade profile of periphery economies. Third, the financial channel studies the role of financial market integration on spillovers to financial markets of periphery economies. These questions gain significance since unconventional tools have been widely used in the past decade and are part of the standard toolbox of major central banks for countering episodes of enhanced liquidity preference, as happened recently at the onset of the pandemic.

We provide an empirical examination of the above question by combining data

from the Euro Area and WAEMU in a bilateral VAR. The aggregate country level responses are obtained using median country level dynamic response of WAEMU constituents. We identify the QE policy shock using an external instrumental variable (IV) (Stock and Watson, 2008). The methodology relies on constructing an instrument that co-varies *only* with the shock of interest. Following Gürkaynak et al. (2005); Altavilla et al. (2019), we construct an instrument by estimating a factor model on high frequency change in price of financial contracts at different maturities within an event window built around monetary policy decisions. These financial contracts include Overnight Index Swaps (OIS)[1], sovereign bond premium, exchange rates and stock index. To instrument the QE policy shock, we use the QE factor, so named because it loads heavily at medium-long term maturities. In addition, our instrument is orthogonal to information shocks and sovereign bond risk premium. This is done in two stages. In the first stage, before running the factor model, we sieve out the variation in financial market surprises that captures information about economic fundamentals. Miranda-Agrippino and Ricco (2020) show that in the presence of such information, the traditional instrument is likely to be a combination of monetary policy shocks and information effects, and might result in several puzzling dynamic effects in response to a monetary policy shock. Since long-term rates are likely to be impacted more by economic fundamentals as well as respond to QE policy, we consider this an important step. In the second stage, we estimate the factor model on variation in financial surprises that is independent of information effects. We impose restrictions on the factor model such that the factors are orthogonal to each other. Through this process, we obtain a factor that captures QE policy but orthogonal to a factor that loads heavily on sovereign bond risk premium.

Our results from the bilateral VAR show that an expansionary ECB QE policy has a significant impact on domestic variables such as output, prices, exchange rates and

[1]The OIS is a forward agreement between two parties who would like to swap interest payments on a notional amount for a fixed maturity. The only difference between the two payments is that while one depends on the gemoetric mean of the Euro Overnight Interbank Average (EONIA) rate over the duration of the agreement, the other payment is at fixed interest rate. The OIS rate quote refers to the latter.

the stock market. In terms of spillovers, aggregate median response over WAEMU show that an expansionary QE policy leads to a strong impact of the CFA franc against the US dollar and the money market rate. In addition, there is a positive but weak response of output, prices, stock market and trade balance. This is driven by significant heterogeneity in responses of these variables at the country level. For instance, output response is positive and significant for five out of eight members and negative but insignificant for others. The case of trade balance is similar: responses of only two countries are in expected direction while three countries have a negative significant trade balance within the first three months. These results support the view of a strong spillover via the financial channel along with a weak trade channel.

We can interpret our results through the prism of the trilemma. If a decline in EA rates can be viewed as a decline in the prevailing international interest rate, then the trilemma predicts that financial conditions in WAEMU should ease due to capital inflows as a result of ECB policy. Our results provide an indirect confirmation of this as the money market rate declines by 50bps in response to a 100bps decline in the 10 year rate.

The spillover effects of ECB policies has been extensively studied, especially for European countries. This includes papers that examine spillovers for conventional monetary policy (Potjagailo, 2017; Ter Ellen et al., 2020; Corsetti et al., 2021) and unconventional monetary policy (Burriel and Galesi, 2018; Boeckx et al., 2017). Many studies focus on spillover effects to non-Euro Area periphery economies. Falagiarda et al. (2015) documents spillovers to sovereign bond yields of Central European economies. Bluwstein and Canova (2018) find positive spillovers to prices but weak effects on output. There is heterogeneity in spillovers across countries, although they do not find evidence of the exchange rate channel playing a role. In contrast, Moder (2019) find persistent price spillovers to other countries due to non-standard ECB policy.

The papers closest to ours examine the impact of Euro Area monetary policy on periphery economies outside of Europe. Similar to Fratzscher et al. (2016), we find that ECB non-standard policies have a positive spillover effect on financial markets.

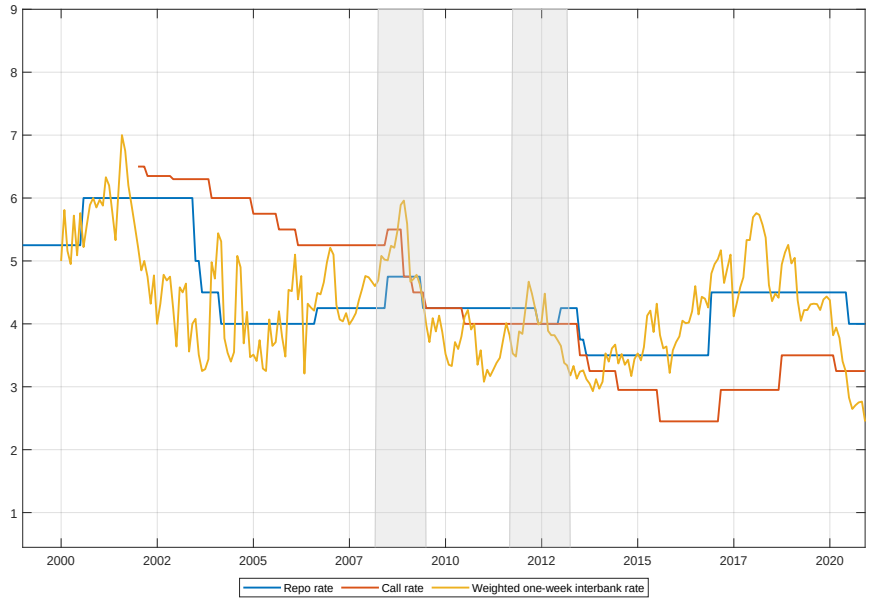
Kearns et al. (2018) study the impact of ECB QE policy on ten year yield of a panel of countries that includes emerging markets from Europe and Latin America. They find the foreign exchange volatility and foreign currency debt to be an important channel for spillovers to the yield. We complement their work by examining the impact of QE policy on a new set of countries and other financial market segments. Ca'Zorzi et al. (2023) study the impact of conventional monetary policy on emerging market economies. They find that EA policy has a weak effect on real GDP, stock prices but a significant impact on export volume. We differ from their study as we focus on QE policy.

The paper proceeds as follows. Section 2 provides descriptive details about WAEMU. Section 3 briefly describe unconventional policy measures of the European Central Bank (ECB) utilized since the Global Financial Crisis. Section 4 describes the various channels of international transmission. Section 5 provides a description of construction of the external instrument for using in the SVAR-IV methodology. Section 6 provides details of the estimation method. Section 7 suggests the results and its discussion. Section 8 concludes the paper with a summary.

2 West African Economic Monetary Union

The WAEMU is a monetary union of 8 West African countries established in 1994 that pegs its currency CFA Franc against the Euro. Member states include Benin, Burkina-Faso, Guinea-Bissau, Ivory Coast, Mali, Niger, Senegal and Togo. It aims to promote economic integration and raise living standards among its member nations. The central bank of these eight economies targets inflation to maintain price stability. The bank sets two key policy rates: the minimum interest rate on open market operations, called the call rate for tenders, and an interest rate on the marginal lending window, known as the repo rate. The tenders are issued for weekly and monthly duration and both have the same minimum rate. The two rates are plotted in Figure 1 along with the interbank market rate of one-week maturity. The gray shades reflect the Global Financial Crisis and the Eurozone Debt crisis. As is the case with other economies, policy rates declined over the past two decades. The

Figure 1: WAMU Policy and money market rates



Note: This figure plots the policy rates for WAEMU along with the interbank market rate. The gray shades denote crisis periods of the Global Financial Crisis and the Euro Area debt crisis.

interbank market rate fluctuated around the repo rate throughout the sample period.

The members' trade profiles suggest that they are effectively an agrarian economy with rich resources in petroleum and natural gas. Their main exports are petroleum, crude and agricultural goods while imports include refined petroleum products, motor vehicles and agricultural products. In terms of currency invoicing, six of the eight members of the union (excluding Ivory Coast and Senegal) predominantly trade in Euros (Boz et al., 2020). In the period from 2016-2019, exports invoiced in € stood at an average 75% while share of US dollar invoicing in exports was just 8%. Similarly, import invoicing share was on average about 72% for the € while it is about 11% for the the US dollar. This suggests that the euro is the dominant currency in this monetary union.

Tables 1 and 2 report the top 5 export and import partners for member states of the WAEMU. Among exports, six out of eight members have non-Euro Area countries as their major trading partners. Only Niger has a big export share with the Euro Area. Even though Ivory Coast's major trade partner is Netherlands, the

Table 1: Top export partners for West African economies

Rank	Benin	Burkina-Faso	Ivory coast	Guinea-Bissau	Mali	Niger	Senegal	Togo
1	Bangladesh	Switzerland	Netherlands	India	South Africa	France	Mali	Burkina Faso
	(22.7)	(52.7)	(11.4)	(86.6)	(41.0)	(31.3)	(19.2)	(17.9)
2	India	India	USA	Singapore	Switzerland	Thailand	Switzerland	Benin
	(18.3)	(15.3)	(9.2)	(12.1)	(21.4)	(11.6)	(15.0)	(14.3)
3	Vietnam	Singapore	Vietnam	Portugal	Burkina Faso	Malaysia	India	Ghana
	(10.0)	(7.7)	(6.8)	(0.5)	(6.1)	(11.1)	(8.4)	(7.6)
4	Nigeria	Ivory coast	Germany	Netherlands	Bangladesh	Nigeria	Bunkers	Niger
	(7.9)	(6.3)	(6.4)	(0.3)	(5.8)	(9.5)	(4.5)	(6.4)
5	China	France	France	Panama	Ivory Coast	Mali	Spain	India
	(7.7)	(4.2)	(5.4)	(0.2)	(4.9)	(5.6)	(3.8)	(6.1)
Top 5 Total(%)	66.6	86.2	39.2	99.7	79.2	69.1	50.9	52.3
% Share of EA in Top 5	0	4.8	59.2	0.8	0	45.3	7.5	0

Note: This table reports the top five major export partners of the Western African Economic and Monetary Union (WAEMU). Data presented for latest year as sourced from World Bank: Togo: 2017; Mali: 2017; Guinea Bissau: 2005; Senegal: 2017; Benin: ; Burkina Faso: 2018; Ivory coast: 2018; Niger: 2016. Source: World Integrated Trade Solution

total share is small. Data from imports presents a similar view, though the share of imports from France is moderate to high in all member nations. These observation suggests that demand channel for goods from WAEMU might not be as strong due to weaker trade linkages with the Euro Area. Table 6 and Table 7 in appendix A present the total trade share of WAEMU and non-Euro Area European economies with the Euro Area and confirm this view. Since the exchange rate channel is muted due to a fixed peg with the Euro Area, the major channel likely to impact WAEMU is through financial linkages with the Euro Area and the exchange rate channel that is likely to be effective viz-a-viz non-euro currencies.

3 ECB monetary policy framework: A brief review

The ECB is the monetary authority of the Euro Area and aims to keep inflation stable below but close to 2%. The Governing Council (GC) of the ECB meets once every six weeks to set the policy rate for the Euro Area [2]. In order to make

[2]At its inception in 1999, the GC met every fortnight until November, 2001 when it switched to meeting once on the Thursday of the first full business week of the month. The current frequency

Table 2: Top import partners for West African economies

Rank	Benin	Burkina-Faso	Ivory coast	Guinea-Bissau	Mali	Niger	Senegal	Togo
1	Thailand (14.0)	China (12.7)	China (15.0)	Senegal (40.9)	Senegal (20.5)	France (28.3)	France (12.7)	China (19.6)
2	India (12.1)	Ivory coast (11.5)	Nigeria (12.3)	Portugal (37.2)	China (15.2)	China (16.2)	China (11.1)	France (10.8)
3	Togo (9.3)	France (7.2)	France (10.3)	Thailand (7.0)	Ivory Coast (9.7)	USA (7.8)	Nigeria (8.7)	Japan (5.1)
4	China (7.8)	USA (5.7)	India (4.6)	Netherlands (6.0)	France (7.9)	Nigeria (5.8)	Netherlands (6.5)	Netherlands (5.0)
5	France (7.1)	Russia (5.5)	Netherlands (3.7)	France (3.2)	Germany (3.6)	Thailand (5.8)	India (6.4)	Ghana (4.1)
Top 5 Total	50.3	42.6	35.9	94.3	56.8	63.9	45.4	44.6
Share of EU in Top 5	14.1	16.9	38.9	49.2	20.2	44.3	42.3	35.4

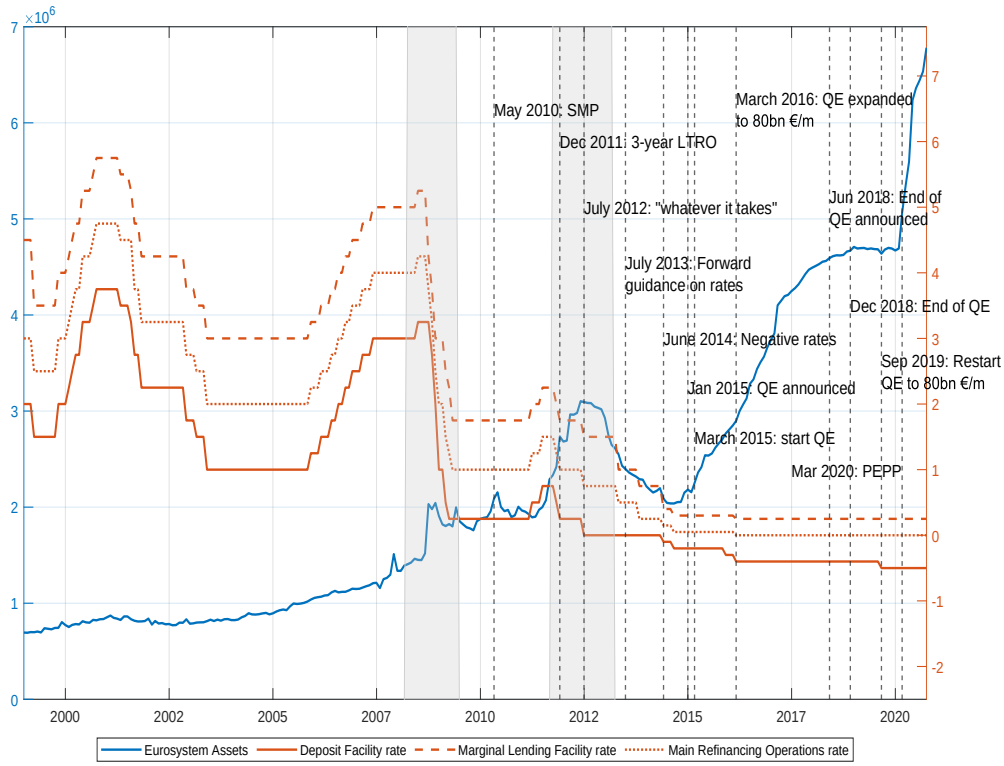
Note: This table reports the top five major import partners of the Western African Economic and Monetary Union (WAEMU). Data presented for latest year as sourced from World Bank: Togo: 2017; Mali: 2017; Guinea Bissau: 2005; Senegal: 2017; Benin: ; Burkina Faso: 2018; Ivory coast: 2018;Niger:2016. Source: World Integrated Trade Solution.

its decision on the policy rate, the ECB uses a "two pillar" strategy of examining the economic and monetary environment as well as their outlook. Based on this assessment, it sets the policy rates for instruments that are part of its operating framework. These include Main Refinancing Operations (MRO) and two standing facilities. The former refers to weekly collateralized open market operations (OMOs) to manage liquidity consistent with the monetary stance. The MRO rate refers to the interest rate paid by counterparties to the ECB on their borrowing in MRO. The latter bounds the MRO rate - the marginal lending facility allows counterparties to borrow overnight from the ECB above their maximum borrowing limit and acts as a ceiling on the MRO rate. The deposit facility allows counterparties to place their funds overnight with the central bank and acts as a floor.

Figure 2 showcases changes in the above mentioned rates and size of the ECB balance sheet since 1999. The shaded region represents the global financial crisis and the euro-debt crisis. Up-to October 2008, changes in the policy rates were the main instrument and the balance sheet played a supporting role. Following the onset of the global financial crisis, policy rates were slashed by 300 bps in a short span and the policy corridor was also narrowed by 100bps to reduce the volatility of

of meeting at a six week frequency (or twice per quarter) began only in 2015.

Figure 2: ECB policy rates and balance sheet



Note: This figure plots major policy rates for the Euro Area along with the balance sheet of the European Central Bank (ECB). Segmented lines represent major decisions taken by the ECB during the post-crisis period.

market interest rates. This reduced the policy space available for an accommodative monetary stance as the rates neared the zero lower bound. Hence, the ECB decided to utilize the size of the balance sheet more prominently to maintain ample liquidity in the financial system and achieve its growth and inflation objectives.

The figure shows this transition from conventional policies towards unconventional policies by a spike in the balance sheet size in Nov 2008. From 2009, the balance sheet size increases, initially with the intention to ensure smooth functioning of financial markets. Several measures were employed by the ECB under various programmes. Here, we focus on non-standard measures that are associated with bond purchase programs such as direct intervention in the covered bonds market via the Covered Bond Purchase Programme (July 2, 2009 - Jun 30, 2010) [3], the Securities Market

[3]Covered bonds are the key source of funding in Europe and enjoy greater popularity relative to

Program (May 10, 2010-Sep 6, 2012), the Covered Bond Purchase Programme 2 (Nov, 2011 - Oct 31, 2012) and the Outright Monetary Transactions programme (OMT) (Sep 6, 2012 -), which continues to date.

The second set of programmes come under the umbrella term of the Asset Purchase Programme (APP). These were introduced towards the end of 2014 with the aim of achieving the bank's inflation target and improve the pace of economic growth. This led to a more than doubling of the balance sheet to about 5 trillion euros in 2020. Several categories of assets are purchased within the APP under the different programmes: Covered Bond Purchase Programme 3 (CBPP 3) (Oct 20, 2014 - Dec 19, 2018), Asset-backed securities purchase programme (Nov 21, 2014 - Dec 19, 2018), Public sector purchase programme (March 9, 2015 - Dec 19, 2018), Corporate Sector Purchase Programme (CSPP) (June 8, 2016 - Dec 19, 2018).

Another measure frequently employed by the ECB was the Targeted Long Term Refinancing Operations (LTRO). These were first launched in June, 2014 and have been restarted twice in 2016 and 2019. The TLTROs are targeted operations, as the amount that banks can borrow is linked to their loans to non-financial corporations and households. In TLTRO III, similarly to TLTRO II, the interest rate to be applied is linked to the participating banks' lending patterns. The more loans participating banks issue to non-financial corporations and households (except loans to households for house purchases), the more attractive the interest rate on their TLTRO III borrowings becomes. Three year LTROs are also of similar nature. The objective of this programme is also to provide liquidity support to the economy. The ECB continues to use TLTROs during the pandemic to provide support to the economy.

asset backed purchases because of lower credit risk. This is because even if the issuer goes bankrupt, the covered pool is still available to the investors, i.e., the issuer must keep the collateral against which the bonds were issued on their balance sheet. This also ensures that the issuers themselves keep only high quality assets within the cover pool (since they cannot sell them off).

4 Channels of spillovers

We can formulate the international channels of monetary policy transmission from a core economy to a periphery economy based on theoretical models of international trade. These are based on ideas of a standard general equilibrium set up with two countries. Their interaction is conditional on trade patterns, exchange rates and financial integration. In our case, the core economy is the Euro Area and the periphery economy is WAEMU. There are three main channels through which monetary policy shocks in a core economy impact a periphery economy. The trade channel links monetary policy announcements through the change in demand of consumers in the core economy. An expansionary shock is expected to raise incomes via an increase in domestic output. This boosts demand for imports and increases output in the periphery country. The exchange rate channel or the expenditure switching channel relies on the impact of policy shocks on exchange rates to affect changes in demand for goods from the periphery. An expansionary policy shock is likely to depreciate the currency of the core economy and raise prices for periphery goods. This will have a negative effect on their demand in the core economy. The financial channel is based on the idea that monetary policy shocks in the core economy have an impact on valuation of financial assets in periphery economies. For fixed exchange rates, this works through the change in interest rates in peripheries. This is because lower policy rates in the core economy will lead to a decline in interest rates in peripheries for maintaining the fixed exchange rate peg.

We note two important points here. First, under a flexible exchange rate regime, the trade and exchange rate channels work against the other and theoretically, the combined impact on foreign output is ambiguous. But under fixed exchange rate, the impact is only through the trade channel and in the same direction as the impact on domestic output. Since WAEMU follows a pegged exchange rate viz-a-viz the Euro, the exchange rate channel may work to benefit the African countries since the CFA franc automatically depreciates against currencies of other economies, which potentially enhances its trade competitiveness to the extent that it trades in euros. Second, the trade pattern of WAEMU signals the likely weakness in the strength of the trade channel. WAEMU member nations have a low export share with the

Euro Area. While the WAEMU import share is not too low in absolute terms, it is relatively much lower than any non-Euro Area European economy with a fixed exchange rate. Therefore, the spillover of QE policies through the trade channel are not likely to be significant. Hence, the financial channel is likely to be the main link for spillovers.

5 Instrument for Unconventional policy

For the unconventional policy instrument, we utilize high frequency identification where price changes in a short-term futures contract is recorded before and after the monetary policy event conducted by the ECB. Assuming that markets incorporate information about economic fundamentals efficiently prior to the announcement, only unanticipated changes in policy should affect the price of this contract. Therefore, change in price of the contract after the announcement, termed as market surprises, can be treated as a measure of unanticipated monetary policy. The duration of the intra-day event study is designed such that it allows markets to internalize the information provided by the ECB. This approach was initially used by Cook and Hahn (1989); Kuttner (2001) for capturing conventional policy surprises in the US. It was later extended by Gürkaynak et al. (2005); Swanson (2020) to capture the impact of monetary policy on medium-term and long-term expectations about the policy rate using a factor model on yields of forward rates comprising several maturities. These studies show that three factors capture are sufficient to capture the effect of different policy tools of the US Federal Reserve. More importantly, one of the factors captures well the impact of QE policy announcements and decisions. Specific to the Euro Area, Altavilla et al. (2019) exploits the ECB's two steps in communicating its policy decision: the first step is the press release that briefly describes the policy decision. The second step involves a statement by the President of the ECB on the decision taken by the Governing Council along with a Q-and-A session with the media. The timing of these events allows for creation of two windows - press release and press conference - and the QE factor is extracted using the second window.

Recent literature has provided evidence of information effects in the factors. This

is especially important because the reaction of market surprises in yields is similar for negative information about the economy and an expansionary surprise. For example, if the central bank decides to cut rates in order to support a flagging economy, financial markets could infer a possibility of a weaker economy in the next few quarters and yields might decline. *Delphic* forward guidance could be especially important during the press conference window as the ECB president discusses the reasons behind the policy decision through the prism of the "two pillar strategy". Since one of the pillars involves description of the economy and economic outlook, we would like to control for these information effects in our instrument.

We take cognizance of these two strands of literature and modify the approach of Altavilla et al. (2019) to construct our instrument. We differ on following counts. First, we use high frequency data that sums up the surprises in the press release and press conference window. For convenience, we call these surprises occurring in the monetary window. The objective behind this is that the transmission of policy will depend on the total impact of the policy decisions rather than the press conference window. Second, prior to estimating the factor model, we test for the presence of signalling in high frequency surprises of all market surprises. This ensures that the factors are not impacted by any information effects. In order to sieve out the delphic effect and focus on odyssean quantitative easing, we follow (Miranda-Agrippino and Ricco, 2020). Third, we include additional high frequency data for estimating the factor model to incorporate any additional variation that may help in identifying the factors. This includes high frequency price revisions in sovereign bond premia, Euro Area stock indices and exchange rates. We now move to a more detailed account of information effects and the factor model.

To think more about the implication of summing surprises from both the windows, suppose that surprises for a particular asset were in the same direction in both windows. In this case, there is no change in sign but the total change in yields will have a larger magnitude. If, however, surprises in the asset are in the opposite direction, then using a single window may not be a good indicator for not only the magnitude, but also the sign of the total surprise. We document these two possibilities mentioned above by using OIS yields surprises for seven different maturities. In the

period 2002-2019, there were 191 scheduled monetary policy meetings where both the press release and press conference took place. The first row of table 3 shows the number of events where surprises in press release and press conference window are different in sign. The second (third) row shows the number (percentage) of events where the surprise in the press conference window is greater than the surprise in the press release window. Hence, the sum of the surprises from the two windows will be different in sign from the press release window. Surprisingly, the surprises in the press conference window are greater at least 50% of the time and increase to over 80% at longer maturities.

Table 3: Reversal in sign of surprises in press release and press conference window

	Window	OIS 1M	OIS 3M	OIS 6M	OIS 1Y	OIS 2Y	OIS 5Y	OIS 10Y
Difference	Rel $\neq$ conf [1]	103	103	105	103	98	105	96
in sign	Rel $\leq$ conf	52	66	76	81	80	85	79
		50.5	64.1	72.4	78.6	81.6	81.0	82.3

Notes: This table presents statistics for monetary policy decision events where OIS market surprises in the press release window and the press conference window moved in opposite direction. The first row documents the number of events where OIS surprises differ in sign for the two windows. The second row shows the subset of events (in row one) for which the magnitude of the press release window was less than that of the press conference window, i.e., the sign of the sum of surprise in the two windows is opposite relative to the sign of the press release window. The third row gives this information in percentage terms.

[1] Rel: Press release; Conf: Press conference

A lot of these events happened either on policy announcement days after the financial crisis or during the Euro-zone crisis, probably as a result of markets seeking to understand the direction on the future course of policy. We highlight a few such dates. First, after the January 2009 meeting, a rate cut of 50 bps was announced in the press release. Although this was consistent with expectations as per a Reuters poll, it did reverse the ECB president's claims of a rate pause in the December meeting. This potentially explains the large negative surprise in OIS rates during the press release window. However, OIS rates increased substantially during the press conference window. In the press conference, the president did not make any commitments on the question of quantitative easing. Further, he commented on the need to stay away from a liquidity trap. This may have led to higher rates as the

president suggested that he defines it as a very low interest rate but not zero. This limited the scope of further decline in policy rates in upcoming meetings. Second, after the October 2011 meeting, OIS rates increased during the press release window as well as during the press conference window. The ECB kept rates unchanged, though markets were expecting a rate cut. During the press conference, the ECB president announced the Covered Bond Purchase Program (CBPP2) for alleviating stress in some segments of the markets[4]. This may have reversed some of the safe haven flows and led to an increase in OIS rates at the medium-long end of the yield curve. Hence, the total transmission to financial markets was greater than what is captured by individual windows. To conclude, the above examples highlight that the transmission of the policy may look different by summing up surprises of the two individual windows.

5.1 Signalling Effects

In the first step of creating the instrument, we run regressions of the identified QE factor in the previous section on information about economic fundamentals that is either known to the markets or is disseminated by the central bank. We include additional information on forecasts from private polls. We use two sources to construct our regressors: the first source is the Macroeconomic Projections report published in the last month of every quarter by the ECB/Eurosystem for forecast of real GDP and HICP inflation. It lists out quarterly projections up to seven quarters ahead and yearly projections up to two years ahead. The second source is commercial forecasts from Reuters' polls. They conduct a monthly survey of forecasters for a broader range of variables relative to the ECB. It has two advantages over ECB projections. First, this data is available every month, which is at a higher frequency than quarterly projections of the ECB. Second, it has data on expectations of other important indicators like quarterly projections of the MRO rate up to four quarters ahead, and current year annual projections on industrial production and unemployment rate.

[4]This was not announced in the press release.

We combine the information from public and commercial forecasts to create our informationally robust instrument. Since ECB forecasts are available at lower frequency than Reuters' polls, we use a dummy variable that takes the value one to indicate the end of month in every quarter where the ECB forecast is released. The ECB data enters the regression with an interaction with the dummy. This is akin to splitting the sample according to the dummy and running two regressions with different regressors. The first sub-sample will include events where ECB published its macro-projections report and we run a regression on forecasts and revisions of ECB and well as the commercial forecasters. The second sub-sample represents events where the ECB does not publish its forecasts and the regressors include only commercial forecasts and revisions. In addition, we include a dummy variable and interact it with regressors for events which had a strong impact on market surprises. We believe these days are consistent with non-linear effects on the market due to a variety of reasons that include change in communication style and/or policy stance. For instance, in November 2002, the ECB discussed the possibility of a rate cut in the future during the press conference for the first time. In August 2011, the ECB discussed their expectations from fiscal authorities in the context of the Eurozone debt crisis.

Note that we have many variables that are likely to have similar information. So, we employ the Least Absolute Shrinkage and Selection Operator (LASSO) Tibshirani (1996) for selection of a subset of regressors that will be used in the final equation. In essence, the estimator is an L_1 penalized linear regression that combines the minimization of residual sum of squares with a penalty on the coefficients. Variables that do not have explanatory power are shrunk to 0 due to the penalty. The selected variables are then used in the following Ordinary Least Squares (OLS) regression equation:

$$
\begin{aligned}
\text{HF Surprises}_m =& \alpha_0 + \sum_{j=0}^{1} \beta_j F_m^{pvt} x_{h+j} + \sum_{j=0}^{1} \gamma_j \Big(F_m^{pvt} x_{h+j}^{pvt} - F_{m-1}^{pvt} x_{h+j}^{pvt} \Big) \\
&+ d_1\{i=1\} \Big[\sum_{j=0}^{1} \delta_j F_m^{cb} x_{h+j} + \sum_{j=0}^{1} \zeta_j \Big(F_m^{cb} x_{h+j} - F_{m-1}^{cb} x_{h+j} \Big) \Big] \\
&+ d_2\{i=1\} \Bigg\{ \sum_{j=0}^{1} \mu_j F_m^{pvt} x_{h+j} + \sum_{j=0}^{1} \nu_j \Big(F_m^{pvt} x_{h+j}^{pvt} - F_{m-1}^{pvt} x_{h+j}^{pvt} \Big) \qquad (1) \\
&+ d_1\{i=1\} \Big[\sum_{j=0}^{1} \chi_j F_m^{cb} x_{h+j} + \sum_{j=0}^{1} \psi_j \Big(F_m^{cb} x_{h+j} - F_{m-1}^{cb} x_{h+j} \Big) \Big] \Bigg\} \\
&+ d_2\{i=1\} + \sum_{k=0}^{n} \psi_k controls_{k,m} + MPI_m \qquad (2)
\end{aligned}
$$

where h is the year and j is the forecast horizon, HF Surprises$m$ is the market surprise, x^p is the selected forecast variable from LASSO for $p \in \{ECB, pvt\}$, d_1 denotes the dummy for ECB's publication of macro projections and d_2 denotes the dummy for events that we believe had non-linear effects. MPI_m is the monetary policy instrument. Generally, x= {HICP,GDP} but Reuters' also contains data for x^{pvt} = {HICP,GDP,MRO,IIP,unemployment rate}. HF Surprises$_m$ includes market surprises from an array of financial markets. We take data from risk-free Overnight Index Swap (OIS) rate at varying maturities[5], i.e., 1 month, 3 months, 6 months, 1 year, 2 years, 5 years and 10 years [6], sovereign bond premium at two year, five year and ten year maturity, stoxx50 index and euro exchange rates against the US dollar, British pound and the Japanese yen. Among regressors, we use fixed horizon forecasts that are constructed by taking the weighted sum of fixed event projections, as in Dovern et al. (2012). We exclude some forecasts of longer horizons due to lack of data availability. This happens, for instance, with the ECB's two years ahead projection where only one data point is available per year. Hence, we have up to seven quarters ahead and up to one year ahead forecasts for the ECB, and up to three quarters ahead and current year forecasts for the Reuters' polls. The revisions data are then derived from the above constructed forecast series by taking the difference

[5]The contract does not involve exchange of principal and does not entail any credit risk. Hence, the swap rate reflects expectations about the policy rate during the maturity of the forward agreement. This makes it is an extremely popular and widely bought instrument in Europe.

[6]Since data for 5 years and 10 years maturity is not available before July, 2011, we use the German 5 and 10 year rates during that period.

between the current meeting forecasts with the previous meeting forecasts. We also include end of day Composite Indicator of Systemic Stress (CISS) and lagged end of day value of crude oil commodity index as additional controls.

5.2 Factor model

After obtaining informationally robust market surprises, we estimate a factor model. A detailed description of the factor model is in appendix B. In brief, there are three steps. The first step is to use a Principal Components Analysis for reducing the dimension of surprises. This gives us four factors. The second step is to identify elements of a unique orthonormal rotating factor that enables a structural interpretation. This is achieved by imposing restrictions on the factor model, which is standard in the monetary literature since Gürkaynak et al. (2005). We obtain three factors that have a high loading on OIS rate surprises with differing maturities and a fourth factor, named risk factor, that loads heavily on sovereign bond premium at different maturities, but has near zero loadings on OIS rates. The QE factor loads heavily on *medium-long term* OIS yield surprises. Due to the orthonormal property of the rotating factor, the QE factor is orthogonal to the risk factor. In the third step, we normalize the QE factor such that it's unit represents one standard deviation change in OIS 10 year rate.

6 Estimation Methodology

6.1 Data

We utilize a combination of macro and financial variables from the Euro Area. The output measure is proxied by the Index of Industrial Production (IIP) while the Harmonized Index of Consumer Prices (HICP) is the indicator of prices. The Nominal Effective Exchange Rate (NEER), a trade weighted average of all major partners of Europe, is utilized for examining the impact on the exchange rates. To measure the impact on trade, we include exports and imports. The stock market index STOXX

50 helps to evaluate the response of financial asset prices. We also include interest rates at the medium-term maturity and long-term maturity to understand the impact on bond markets. In addition, we have two measures for financial conditions: first, the 3 month Euro interbank offered rate (Euribor) and second, the composite index of systemic stress.

For the spillovers to WAEMU, we utilize data from various sources. There are three variables that are country specific variables and four variables which are common to WAEMU. Beginning with country specific variables, for the output measure, we include seasonally adjusted industrial production and seasonally adjusted consumer price index as a measure for prices[7]. The trade data on exports and imports is sourced from the Direction of Trade Statistics (DOTS) database of the IMF. For common variables, we include the CFA Franc exchange rate to the US dollar, the call rate for tenders as a measure of short term policy rate, the average monthly money market rate and the stock index.

We also add exogenous variables in the VAR to control for global economic and financial conditions. To capture global economic activity, we proxy measures for world output and world prices using industrial production and prices in the OECD.

All data sources and transformations are in table 8 of appendix A. The sample length of the data is from Jan, 2005 - Dec, 2019.

6.2 Methodology

In the estimation of VAR using frequentist approach, the number of parameters required to be estimated increases with the lag length and limits precision. In contrast, the Bayesian VAR model improves on the frequentist approach by incorporating apriori information about the data. For the purpose of this paper, we use a BVAR with a Normal Inverse Wishart prior. In particular, we use the fact that time series properties of macroeconomic variables is a random walk with drift. The tightness parameter is optimized using Giannone et al. (2015). For an in-depth exposition on

[7]Seasonal adjustment is done using census X-12 method.

BVARs and their advantages, see Miranda-Agrippino and Ricco (2019).

The identification in a VAR model requires exclusion restrictions on the contemporaneous relationships between variables in the model. The model has an instrumental variable interpretation in the sense that linear combinations of innovations act as an IV for identifying structural parameters (Stock and Watson, 2012). However, contemporaneous restrictions can be considered subjective. In this paper, we instead follow the "external" instruments approach (developed by Stock and Watson, 2008; Merterns and Ravn, (2012). It utilizes information from outside the VAR model to create instrumental variables. Suppose the relationship between structural shocks (ε_t) and the reduced form innovations (u_t) is given by $\varepsilon_t = A_0 u_t$ where A_0 represents these contemporaneous relationships. Then, the standard assumptions for use of an external instrument (z_t) in order to identify the shock ε_t^{mp} is given by:-

$$\mathbb{E}(\varepsilon_t^{mp}.z_t') \neq 0$$

$$\mathbb{E}(\varepsilon_t^{mp}.z_t') = 0$$

The first condition is the instrument relevance: the instrument must be contemporaneously correlated with the structural shock. The second condition relates to instrument exogeneity, i.e., the instrument must be contemporaneously uncorrelated with other structural shocks. Subject to these conditions, the IV allows identification of causal effects of the QE policy shock. The steps for operationalizing this approach are in appendix C.

For estimation of spillovers using the VAR model, we utilize a bilateral model, i.e., we include another country along with the Euro Area. The monetary shock is identified within the system and its transmission to the second country is examined. We construct aggregate responses using the "median-median" approach following Degasperi et al. (2020). Here, we briefly discuss the steps. For each Gibbs sampler iteration from every African country's estimated Bilateral VAR, we store the median response at each horizon. We then pick the median among iterations to construct the median-median response and confidence bands.

7 Results

7.1 Monetary policy instrument

Tables 4 and 5 present evidence for signalling in market surprises. Among OIS rates, LASSO shrinks a large number of coefficients to zero. It selects a combination of data on MRO rate, real GDP, HICP, risk and interaction of our dummy for seven dates with some variables as well. For the short-medium term OIS rates, revision in MRO rates is relevant. For medium-term maturities, the interaction with revision in one quarter ahead HICP is important. The R^2 is highest for OIS one month and three month rate. For other market surprises, the LASSO drops majority of the variables. The R^2 is in the range of 5%-10%. Overall, this suggests that OIS surprises do contain signalling effects. This is despite the fact that the EU regularly provides an update on the central bank's projection of the economy and holds a press conference after every meeting of the Governing Council. Our results conform with Cieslak and Schrimpf (2019) who show that 65% of ECB event dates have a pre-dominant role for information shocks.

Figure 3 shows the time series plot of the informationally robust QE factor. We also plot an additional time series from a factor model that was estimated on market surprises without any information cleaning, i.e., without the first step in our instrument construction. The segmented lines depict important policy decisions of the ECB during the post-crisis period. The time series plots additionally highlights the 10 biggest surprises in the informationally robust QE factor (in orange segmented lines). Eight out of ten big jumps are recorded in the post-crisis period. Two of these jumps coincide with QE policy announcements. The first date is January 2015, when QE was announced and resulted in the largest negative surprise in the QE factor. The second date is June 2018, when the end of QE was announced. Yet, this was a dovish event because the ECB simultaneously announced to keep the policy rate unchanged "at least through the summer of 2019". Hence, it reflects the forward guidance on the policy rate.

Table 4: Projection of market surprises on forecasts and revisions

	OIS 1M	OIS 3M	OIS 6M	OIS 1Y	OIS 2Y	OIS 5Y	OIS 10Y
Unemp_t	-0.640		-2.549				
	(1.687)		(1.888)				
Δ MRO_q	-2.994	-3.730	-8.208**				
	(3.437)	(3.060)	(3.754)				
Δ MRO_{q+1}	-0.090						
	(2.536)						
Δ MRO_{q+2}	-0.621						
	(1.612)						
Δ GDP_{q+3}	-7.404*	-4.289					
	(4.070)	(6.419)					
Oil price	-0.012*	-0.011	-0.007			-0.016	
	(0.006)	(0.008)	(0.011)			(0.015)	
$\Delta\text{GDP}^{ECB}_{q+1}$	0.295						
	(3.842)						
$\Delta\text{GDP}^{ECB}_{q+3}$	-2.716						
	(3.776)						
$\Delta\text{GDP}^{ECB}_{q+6}$	8.023						
	(5.994)						
$\Delta\text{HICP}^{ECB}_{q+4}$	-2.863**						
	(1.239)						
$\Delta\text{GDP}^{ECB}_{t}$	-0.530		-0.413				
	(0.718)		(0.962)				
d_2*ΔIP_t	-10.400***	-3.670***	-8.279***				
	(2.257)	(1.060)	(0.598)				
d_2*MRO_q	-1.713*						
	(1.012)						
$\text{d}_2\Delta$*GDP_q	-14.318*						
	(8.049)						
d_2*Risk	-11.666**						
	(5.400)						
d_2*Unemp_t		14.041***					
		(2.713)					
HICP^{ECB}_{q}		0.093					
		(1.173)					
HICP^{ECB}_{t}		0.208	0.452				
		(1.220)	(0.299)				
d_2*IP_t		-0.420	-1.770***				
		(0.298)	(0.336)				
d_2*MRO_{q+1}		-1.012***	-0.324				
		(0.372)	(0.278)				
d_2*HICP_{q+1}		14.321***	25.402***	44.457***	40.166***	25.580**	
		(2.234)	(1.764)	(14.542)	(14.620)	(9.896)	
d_2*Oil price		-0.047***					
		(0.016)					
ΔGDP_t			-3.887**				
			(1.912)				
ΔMRO_{t+3}			3.108				
			(2.510)				
ΔGDP_q			11.958***			9.117*	5.138
			(4.141)			(4.926)	(3.723)
ΔGDP_{q+1}			-6.474			-9.994***	
			(3.974)			(3.766)	

Continued: Projection of market surprises on forecasts and revisions

	OIS 1M	OIS 3M	OIS 6M	OIS 1Y	OIS 2Y	OIS 5Y	OIS 10Y
Risk			-1.156				
			(1.402)				
$\Delta\text{HICP}^{ECB}_{q+6}$			1.951				
			(2.225)				
$d_2{*}\Delta\text{GDP}^{ECB}_{q+6}$			-46.118*				
			(25.097)				
$d_2{*}\Delta\text{GDP}_{q+1}$			19.108				11.817
			(14.984)				(7.709)
HICP_{q+1}						-0.562	-0.468
						(0.597)	(0.435)
HICP^{ECB}_{q+3}						0.968**	
						(0.417)	
ΔHICP_{q+2}							0.904
							(2.048)
GDP_t							-0.408
							(0.256)
ΔHICP_t							4.729
							(3.139)
ΔGDP_{q+2}							-8.264*
							(4.896)
$\Delta\text{GDP}^{ECB}_{q}$							1.837
							(2.744)
HICP^{ECB}_{q+6}							0.753***
							(0.257)
$\Delta\text{HICP}^{ECB}_{q+3}$							1.492
							(1.782)
$d_2{*}\ \Delta\text{GDP}^{ECB}_{q+5}$							-86.425***
							(20.280)
Constant	0.890**	0.661	0.450	0.139	-0.078	1.360	0.763
	(0.441)	(0.564)	(0.756)	(0.283)	(0.316)	(1.526)	(0.684)
Adjusted R^2	0.44	0.26	0.27	0.10	0.068	0.093	0.15
R^2	0.48	0.30	0.33	0.11	0.07	0.12	0.20
Observations	197	197	197	197	197	197	197

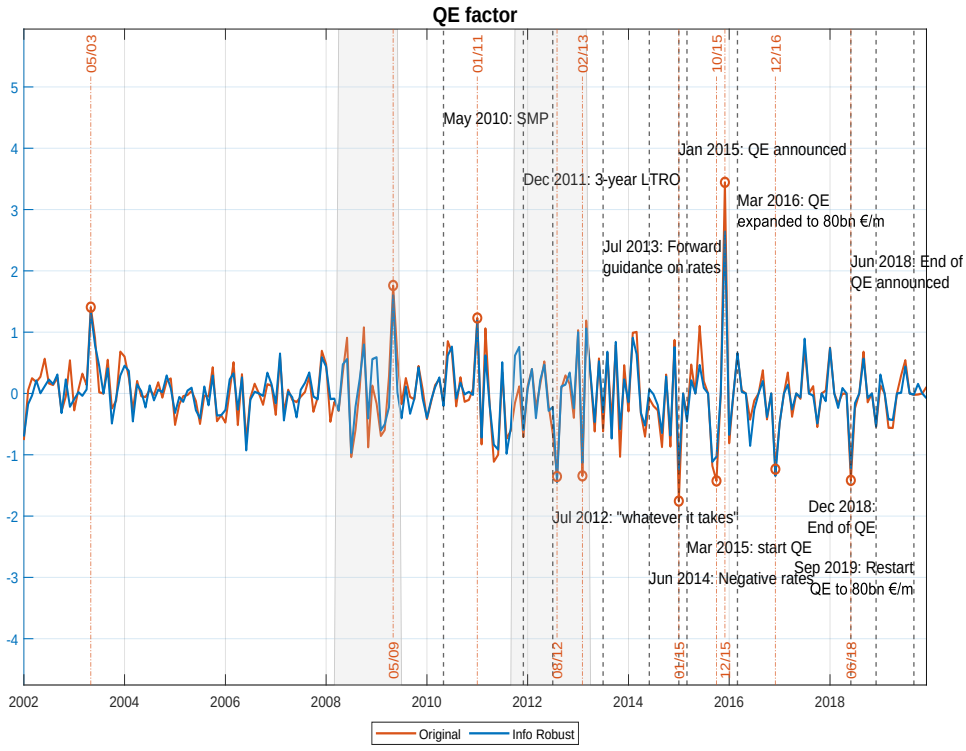
Notes: This table reports results for regression of OIS market surprises at different maturities on a select number of ECB and Reuters' forecasts data based on LASSO. The dummy variable d_2 takes the value one for dates where we believe market participants reacted to a potential change in ECB communication style. Sample length is Nov, 2002-Dec, 2019. *p<0.1, **p<0.05,***p<0.01. Standard errors in parentheses.

Table 5: Projection of market surprises on forecasts and revisions

	2 year sov bond spread	5 year sov bond spread	10 year sov bond spread	EUR GBP	EUR JPY	EUR USD	STOXX 50
$HICP_q$	0.813***	0.979***					
	(0.294)	(0.350)					
d_2*$\Delta HICP_{q+1}$	-24.312*						
	(13.698)						
ΔMRO_q		-4.375					0.924***
		(3.070)					(0.251)
Risk		2.227					
		(1.485)					
IP_t				-0.018			
				(0.017)			
ΔGDP_q				0.472*			
				(0.268)			
Oil price				-0.001		-0.002	
				(0.001)		(0.001)	
GDP^{ECB}_{q+7}				0.200*	0.347**	0.274*	
				(0.108)	(0.137)	(0.147)	
ΔGDP^{ECB}_{q}				0.856**			
				(0.330)			
ΔGDP^{ECB}_{q+5}				-1.496**			
				(0.756)			
$\Delta HICP_{q+2}$					0.508***	0.705***	
					(0.183)	(0.188)	
d_2*IP_t							-0.190**
							(0.074)
d_2*MRO_{q+1}							0.651**
							(0.317)
Constant	-1.615***	-2.302***	-0.022	0.056	-0.075**	0.071	-0.077*
	(0.481)	(0.660)	(0.333)	(0.081)	(0.035)	(0.098)	(0.046)
Adjusted R^2	0.048	0.050	0.000	0.066	0.058	0.083	0.075
R^2	0.058	0.064	0.000	0.094	0.068	0.097	0.089
Observations	197	197	197	197	197	197	197

Notes: This table reports results for regression of OIS market surprises at different maturities on a select number of ECB and Reuters' forecasts data based on LASSO. The dummy variable d_2 takes the value one for dates where we believe market participants reacted to a potential change in ECB communication style. Sample length is Nov, 2002-Dec, 2019. *p<0.1, **p<0.05,***p<0.01. Standard errors in parentheses.

Figure 3: Time series plot of Informationally robust QE factor



Note: This figure plots the time series of two factors. The original factor (in orange) is constructed via a factor model without the first step of removing signalling effects from market surprises. The Info robust factor is constructed using the two step procedure explained in section 5. Segmented lines display important events in QE announcements by the ECB. The orange segmented lines display the ten largest surprises in the QE factor.

7.2 Bilateral VAR results

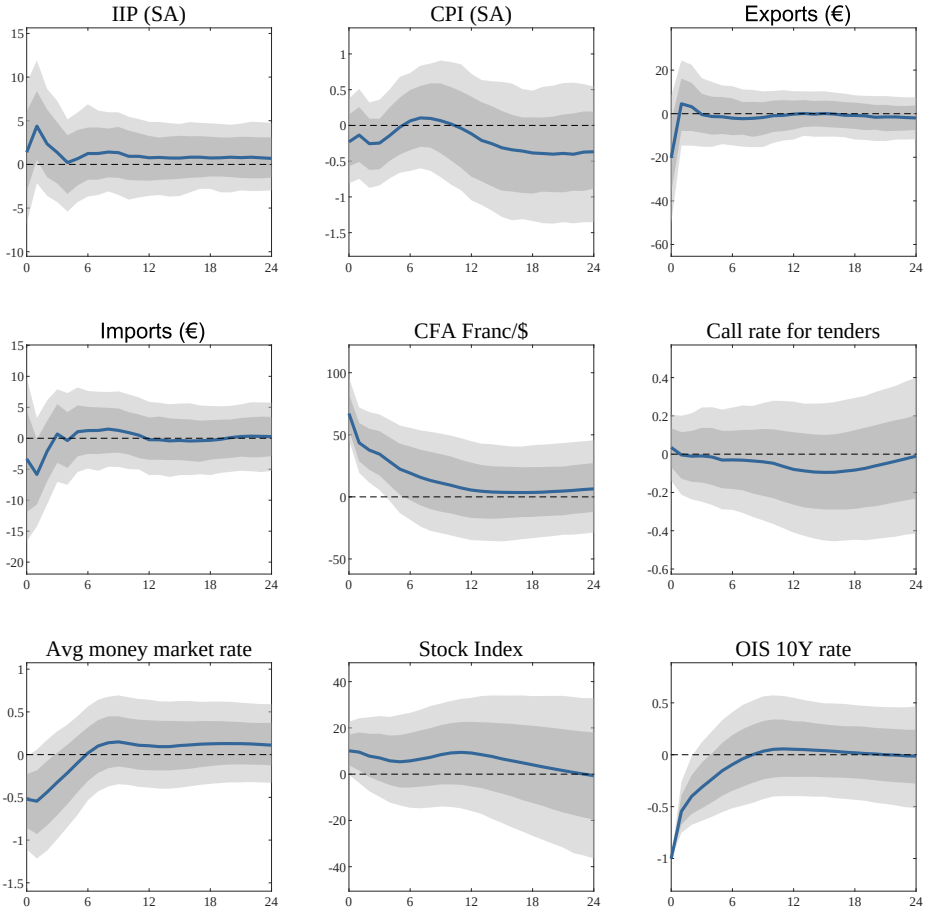
Figure shows the median-median responses of WAEMU countries to an expansionary QE policy shock in the Euro Area. The 68% and 95% confidence bands are in light gray and dark gray shades respectively. Industrial production response is positive and weakly significant. It peaks to about 5% one year after the initial shock. Inflation increases gradually to about 1% in six months and dies out wihin one year. Compared with responses of the Euro Area (figure 6 in appendix D), these effects are similar for production, weaker for prices and less persistent. In terms of trade, the impact on imports declines by 5% points as expected. However, surprisingly, exports decline in response to an expansionary shock in the short run and are flat after three months. Coming to financial variables in the WAEMU, the CFA franc depreciates against the

US dollar and is in line with the depreciation of the Euro against the US dollar. The call rate for tenders shows an insignificant response. The average money market rate decreases on impact by about 1% point but this effect dissipates after six months. The stock market index rises by about 10% on impact and declines gradually over a two year period. This suggests that the financial channel is very effective for these economies. Our findings are in line with Bluwstein and Canova (2018); Moder (2019), who find weak effects of QE policy for non-EA European periphery economies. We also confirm the presence of a potential financial channel from EA to periphery economies, in line with Fratzscher et al. (2016). While capital flows to WAEMU member nations are not a significant percentage of GDP, it is possible that presence of foreign banks may be a mechanism for the existence of this channel.

7.3 Country wise results

We now turn to examining country level median responses of member nations of WAEMU. Figure 5 show the responses of members for country specific variables. Heterogeneity in country results explains our weak results in the aggregate. Industrial production response is positive for Benin, Ivory Coast and Togo, and positive but insignificant for Guinea Bissau and Mali. The response of the other three member nations is negative and insignificant. Coming to prices, responses are positive on impact for four member nations with differing degrees of persistence. With the exception of Ivory Coast, responses of all other members is insignificant. We now turn to variables on trade. For exports, only Guinea Bissau and Togo benefit from the external shock to WAEMU, but this is only in the short run and weakly significant. Similarly, import responses are negative only for three out of eight member nations. Our results are consistent with the literature on Euro Area that finds heterogeneous effects of non-standard monetary policies (Bluwstein and Canova, 2018; Moder, 2019).

Figure 4: Median-median response of WAEMU countries



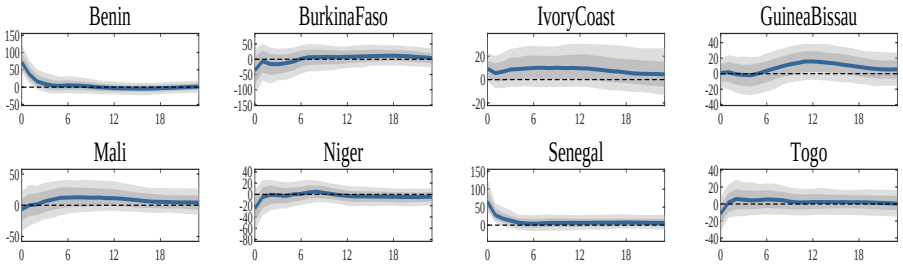
Notes: Median-median impulse responses for WAEMU to an expansionary QE policy shock using informationally robust instrument. The shock is normalised to induce a 1% point decrease in the EA 10 year rate. Sample: 2005:1-2019:12. Dark and light shaded areas represent 68% and 90% posterior coverage bands respectively.

8 Conclusion

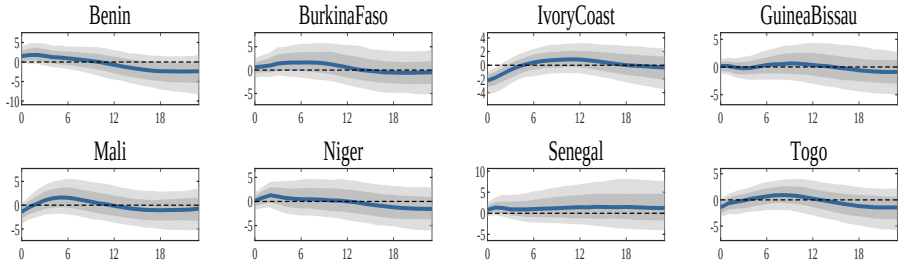
This paper examines the international transmission of QE policy of the Euro Area to the African grouping of Western African Economic and Monetary Union. We consider three channels of transmission: the trade channel, the exchange rate channel and the financial channel. While the block is similar to other non-Euro Area European countries in terms of the dominant currency being the Euro, it differs from them due to significantly lower trade openness with the Euro Area. This has implications for the channels through which Euro Area policy spillovers are likely to occur. In particular, the trade channel and exchange rate channel are likely to have lower significance for the WAEMU. We therefore expect the financial channel be more relevant.

We examine this empirical question using a Bilateral VAR consisting of macroeconomic aggregates from the Euro Area and WAEMU member nations. The causal effect of the QE policy shock is identified using an external instrument that contains high frequency movements in medium-long term maturities. Our findings show that different segments of financial markets in these African nations respond strongly to an exogenous QE shock in the Euro Area, especially in the short run. Hence, the financial channel is an important channel for spillovers to these African nations. Our results also point towards modest pass-through of QE policy for output and prices, with significant heterogeneity among member nations. This may point towards the weakness of trade and exchange rate channel, which is consistent with the fact that the exchange rate regime is fixed and trade shares with the Euro Area are low.

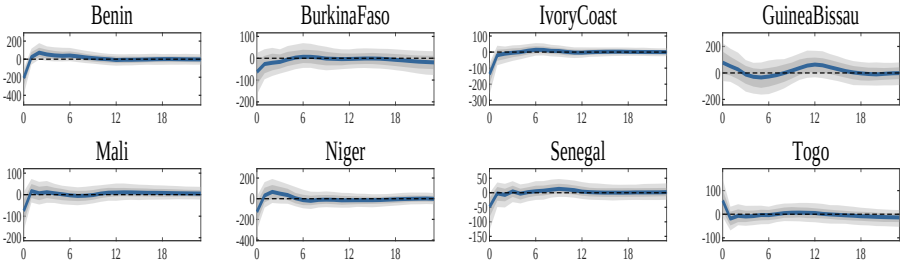
Figure 5: Median responses by WAEMU member nations



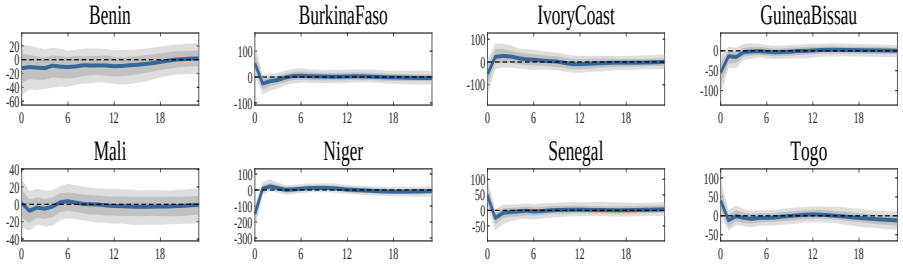
(a) Industrial Production



(b) Consumer Price Index



(c) Exports



(d) Imports

Notes: Country level median impulse responses to an expansionary QE policy shock using informationally robust instrument. The shock is normalised to induce a 1% point decrease in the EA 10 year rate. Sample: 2005:1-2019:12. Dark and light shaded areas represent 68% and 90% posterior coverage bands respectively.

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A Tables

Table 6: Trade share of WAEMU with Euro Area

	Exports				Imports			
	2016	2017	2018	2019	2016	2017	2018	2019
Benin	5.8	3.9	2.4	2.7	25.4	21.3	19.2	20.4
Burkina Faso	5.5	4.4	5.4	4.2	22.7	26.7	19.7	22.7
Ivory coast	36.2	37.1	32.5	35.0	28.6	34.0	26.0	24.3
Guinea-Bissau	1.7	0.0	1.0	26.8	51.1	56.4	60.3	55.7
Mali	2.1	2.0	3.4	2.5	20.8	21.1	21.4	18.5
Niger	32.6	12.0	14.5	12.0	35.2	21.2	27.7	23.2
Senegal	12.0	12.7	12.9	10.9	35.8	32.6	29.5	39.9
Togo	7.2	8.1	8.6	8.5	26.3	25.2	22.2	23.9

Note: This table presents statistics on the share of trade of WAEMU member nations with the Euro Area.

Table 7: Trade share of non-Euro Area economies with Euro Area

	Exports				Imports			
	2016	2017	2018	2019	2016	2017	2018	2019
Bulgaria	47.0	45.1	47.6	46.4	45.5	44.3	44.3	43.0
Croatia	54.9	53.3	56.3	55.4	60.7	60.0	59.6	61.2
Czech Rep.	65.1	65.2	65.6	65.0	60.1	59.2	58.2	58.0
Denmark	38.1	36.5	37.4	36.4	48.0	46.8	47.8	47.4
Hungary	59.2	58.5	58.7	59.3	59.7	58.4	57.1	56.2
Norway	44.0	44.8	46.5	43.5	34.6	33.3	34.0	32.3
Poland	56.5	57.0	57.8	57.5	58.6	58.2	56.8	56.0
Romania	55.1	56.1	56.8	56.4	55.1	53.7	53.3	52.5
Sweden	40.9	40.9	41.5	40.3	51.9	52.4	51.0	51.5
Switzerland	34.9	36.6	37.9	37.6	45.5	48.8	49.7	49.5
UK	41.8	42.1	41.5	41.1	43.9	44.8	45.3	42.7

Note: This table presents statistics on the share of trade of non-Euro Area economies with the Euro Area.

Table 8: Data sources

Variable	Sources	Log	RW
EA variables			
Industrial Production	Eurostat	•	•
Consumer Price Index	Eurostat	•	•
Nominal Effective Exchange Rate	ECB SDW		•
Exports	ECB SDW		•
Imports	ECB SDW		•
Stock Market Index (Euro STOXX 50)	Bloomberg	•	•
OIS Rates	Bloomberg		•
Euribor 3 month	ECB SDW		•
Financial Stess (CISS)	ECB SDW		•
EA 10 Year Benchmark Yield	Bloomberg		•
OECD IP	OECD	•	•
OECD CPI	OECD	•	•
WAEMU variables			
Industrial Production	BCEAO	•	•
Consumer Price Index	BCEAO	•	•
Exports	BCEAO	•	•
Imports	BCEAO	•	•
Avg money market rate	BCEAO		•
Call rate	BCEAO		•
Exchange rate	IMF IFS		•
Stock price	Bloomberg	•	•

B Instrument construction

We utilize fourteen market surprise series from the Euro Area Monetary Policy Database (Altavilla et al., 2019). These surprises are seven Overnight Index Swap (OIS) rates at varying maturities, i.e., 1 month, 3 months, 6 months, 1 year, 2 years, 5 years and 10 years [8], three sovereign bond premium surprises of two year, five year and ten year maturities, three exchange rates of the Euro against the US dollar, British pound and Japanese yen, and stock index surprises.

Let X_{IR} denote the matrix of $(T \times 14)$ data on which to fit the factor model:

$$X_{IR} = F\Lambda + \varepsilon$$

where F is the matrix of common latent factors, Λ is the matrix of factor loadings and ε is the idiosyncratic error. The matrix Λ is not unique since for any orthonormal matrix M, the factor model can be written as:

$$X_{IR} = F.M.M'.\Lambda + \varepsilon \implies X_{IR} = \tilde{F}\tilde{\Lambda} + \varepsilon \tag{3}$$

Hence, to provide a structural interpretation to the factors in $\tilde{F}$, it is important to identify M. Since the Cragg and Donald test (1997) suggests there are 4 factors that appropriately capture the variation in the data. Hence, 16 restrictions are required to identify the parameters of the orthonormal matrix up to sign. Let $_{.j}$ denote the j_{th} column of any matrix. The first ten restrictions come from orthonormality:

1. Orthogonality

$$M'_{.1}M_{.2} = 0, M'_{.1}M_{.3} = 0, M'_{.1}M_{.4} = 0 M'_{.2}M_{.3} = 0, M'_{.2}M_{.4} = 0, M'_{.3}M_{.4} = 0 \tag{4}$$

[8] Since data for 5 years and 10 years maturity is not available before July, 2011, we use the German 5 and 10 year rates during that period.

2. Normalization to unit length

$$M'_{.1}M_{.1} = 1, M'_{.2}M_{.2} = 1, M'_{.3}M_{.3} = 1, M'_{.4}M_{.4} = 1$$

Four zero restrictions are placed on the OIS rates:

1. Three restrictions on the OIS 1 month rate surprise:

$$U'_{.2}\Lambda_{.1} = 0, U'_{.3}\Lambda_{.1} = 0, U'_{.4}\Lambda_{.1} = 0$$

2. The fourth factor does not load onto the 10 year OIS rate surprise:

$$U'_{.4}\Lambda_{.7} = 0$$

Finally, the last two restrictions are that the third factor and fourth factor have the smallest variance in the pre-crisis period. This minimization is subject to the above constraints and provides elements up to a sign. We therefore normalize the factors $\tilde{F}$ such that a unit increase in the conventional factor, FG factor, QE factor and risk factor are equivalent to a unit increase in OIS1M rate, OIS2Y rate, OIS10Y rate and 10 year bond spread.

C Steps for using external IV approach

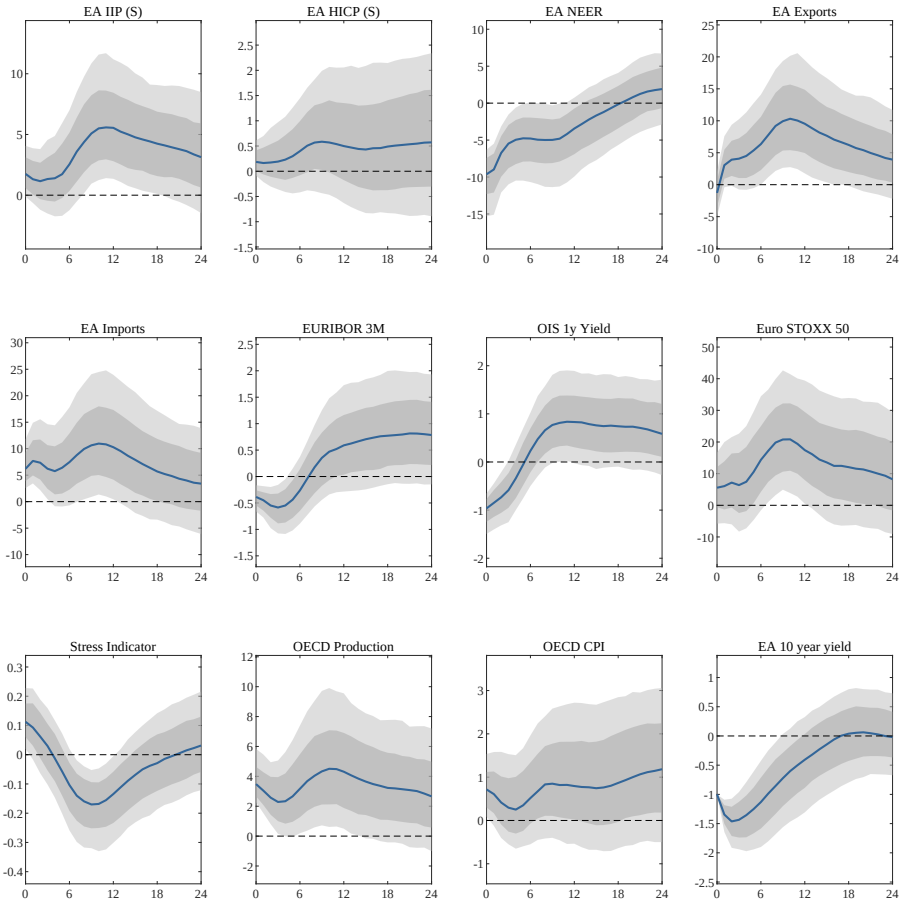
Assuming that the shock of interest is ordered first, estimation of the monetary policy shock is done in three steps:-

1. Estimate the VAR model and obtain the residuals ($\hat{u_t}$).
2. In order to obtain elements of the column of the matrix (A_0^{-1}), say a_1, regress $\hat{u_t}$ on z_t.
3. Take the ratio of regression coefficients obtained from step 2 with the coefficient a_{11}.
4. Choose a normalization.

In order to transmit a unit shock in the system, we normalize such that a_{11}=1.

D Results for Euro Area

Figure 6: Median response of Euro Area countries



Notes: Median impulse responses for Euro Area to an expansionary QE policy shock using informationally robust instrument. The shock is normalised to induce a 1% point decrease in the EA 10 year rate. Sample: 2005:1-2019:12. Dark and light shaded areas represent 68% and 90% posterior coverage bands respectively.