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## The spillover of euro area shocks to the Maltese economy

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# CENTRAL BANK OF MALTA WORKING PAPER



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EUROSISTEMA  
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# The spillover of euro area shocks to the Maltese economy\*

William Gatt<sup>†</sup>

Germano Ruisi<sup>‡</sup>

WP/03/2022

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### **Abstract**

This paper develops a two-block Structural Vector Autoregression (SVAR) to estimate the spillover of external shocks to the Maltese economy. The model focuses on five broad macroeconomic shocks hitting the euro area; an aggregate demand shock, two aggregate supply shocks which respectively proxy better overall productivity and more favourable conditions on the global market for oil, a generic monetary policy shock encompassing both conventional and unconventional interventions, and a financial stress shock. The model is estimated using Bayesian methods over a sample that goes from 2003Q1 to 2019Q4 and considers a number of Maltese variables that are representative of both the real and the financial side of the economy. The results point toward a relevant role of the identified shocks in explaining the fluctuations of the Maltese economy with particular regard to the aggregate demand and financial stress shocks. Overall, shocks hitting the euro area are estimated to contribute to around one third of the fluctuations of the Maltese output and prices in the long run.

**JEL Classification:** C11, C32, E32, F41

**Keywords:** Bayesian SVAR, block exogeneity, shock spillover, monetary policy, historical decomposition

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# 1 Introduction

To date there are few studies on the role of foreign shocks on the Maltese economy. [Borg et al. \(2019\)](#) document the impact of several external shocks on the Maltese economy through the lens of a traditional macroeconomic model. They show that foreign demand and oil price shocks can have sizeable effects on local conditions. On the other hand, a euro area monetary policy tightening tends to have a more muted effect owing to an imperfect interest rate pass-through ([Micallef et al., 2016](#)). More recently, [Abela and Rapa \(2021\)](#) study the exchange rate pass-through to domestic inflation. In line with the literature, they find incomplete pass-through that mainly operates via goods prices. While they shed light on the importance of foreign developments on the Maltese economy, a key limitation of these studies is that they derive their results using reduced form methods, and therefore have a limited economic interpretation. Yet, there exist empirical studies which use a structural framework that convey a more interpretable story on economic fluctuations in different sectors. [Gatt and Ruisi \(2020\)](#) study *inter alia* the spillover of immigration on the Maltese economy, focusing on the property market. They find that a foreign housing demand shock accounts for about 33% and 20% of the fluctuations in house prices and real GDP respectively in Malta in the long run. Focusing on the labour market, [Ruisi \(2020\)](#) finds that foreign labour supply shocks account for up to 40% of the fluctuations in GDP, 25% of the fluctuations in the participation rate, and 35% of the fluctuations in the unemployment rate in the long run.

In this paper we shed further light on how external macroeconomic developments of interest can transmit to the Maltese economy. More specifically, we focus on the euro area and we develop a small but rigorous empirical model featuring key macroeconomic variables, and decompose their historical developments as driven by a set of structural shocks. This yields a model that can be used to study broad policy questions relating to euro area developments on the Maltese economy. We then use the model to study the transmission of these shocks to the Maltese economy. Therefore, the contribution of this paper is to quantify the extent to which shocks originating from or hitting the euro area drive fluctuations in the Maltese economy, which is yet undocumented.<sup>1</sup>

We use a structural vector autoregressive (SVAR) model estimated with Bayesian methods to trace the effect of five external shocks on Maltese GDP and inflation. We extend our framework to study the transmission through other relevant variables, such as *inter alia* consumption, investment, exports, labour productivity and household credit. We find that shocks from the euro area account for about 33% of the fluctuations in GDP and inflation in the long run. We use the estimated structural shocks to build a historical decomposition and show that the estimated contributions provide a reliable historical narrative, particularly with regard to Malta’s accession to the EU in 2004 and the subsequent adoption of the euro in 2008. We show that the estimated financial shock that was behind the boom-bust cycle in the euro area between 2006–2010 also significantly contributed to the fluctuations in Malta’s output.

Our work is the first to document the transmission of external shocks to the Maltese economy

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<sup>1</sup>We are unable to use MEDSEA-FIN ([Gatt et al., 2020](#)), a small open economy DSGE model for Malta with rich production technology, trade and financial frictions, as the foreign block is modelled in reduced form and therefore any shocks to foreign variables have no economic interpretation.

in a structural empirical framework. Our findings aid conjunctural analysis and the formation of economic projections as we are able to disentangle the *direct* effect of shocks to the Maltese economy and the *transmission* of shocks to the Maltese economy via the euro area. Our work can also inform the development of theoretical macroeconomic models with the dynamics of the Maltese economy they should replicate, in the spirit of [Christiano et al. \(2005\)](#).

The rest of this paper is structured as follows. In Section 2 we first briefly discuss the literature on the transmission of external shocks to the domestic economy, followed by a detailed discussion of the methodology we use in our work in Section 3. We present the results from the benchmark model in Section 4 and discuss extensions in Sections 5 and 6. Finally, Section 7 concludes.

## 2 Related literature

Our work follows the literature on the transmission of shocks to small or open economies, which typically imposes a ‘small country’ assumption via block exogeneity. [Kim \(2001\)](#) employs a VAR with limited identifying restrictions to study the transmission of monetary policy shocks in the US to output of G-6 countries. He finds that a monetary expansion in the US lowers interest rates and stimulates demand in other countries. [Canova \(2005\)](#) studies the spillover of US shocks to Latin American economies, and finds that monetary policy shocks induce significant fluctuations in these economies. The shock transmits mainly through the interest rate channel rather than the trade channel, and consequently, its transmission is very quick. Other early studies on the international transmission of shocks are [Eichenbaum and Evans \(1995\)](#), [Cushman and Zha \(1997\)](#) and [Faust and Rogers \(2003\)](#). More recently, [Liu et al. \(2014\)](#) find that international demand shocks are important in driving GDP growth and inflation in the UK, and that these shocks became more important near the financial crisis of 2008. [Dedola et al. \(2017\)](#) study the effect of US monetary policy surprises on 36 advanced and emerging economies. Industrial production and real GDP fall while unemployment rises in most countries. They show that the degree of capital mobility and the exchange rate regime adopted are not the key drivers of these spillovers. [Carrillo et al. \(2020\)](#) find that shocks to US aggregate demand, economic policy uncertainty (EPU), monetary policy, productivity, and financial and real costs explain about 75% of the fluctuations in the output gap in Mexico over a horizon of three years.

[Prüser and Schlösser \(2020\)](#) explore how EPU shocks transmit over several euro area countries. While an EPU shock negatively affects GDP, consumption, investment, credit and employment in all countries, the effects are stronger in Greece, Italy, Ireland, Portugal and Spain. These countries are deemed fragile compared to other ‘northern’ countries such as Germany, France and Finland. The effects within all countries were time-invariant over the period 2000–2015. Finally, [Mumtaz and Surico \(2009\)](#) and [Mumtaz et al. \(2011\)](#) are other studies that explore the transmission of international shocks over a large panel of countries. They show that international factors drive a non-trivial share of the variance in GDP and inflation in the UK and in several other countries, respectively.

Although most of the studies of this nature tend to be empirical, there are also contributions using DSGE models. For instance, [Bergholt \(2015\)](#) shows that an estimated small open economy



DSGE model for Canada attributes a considerable share of the forecast error variance of GDP, consumption, investment, inflation, and the trade balance to foreign shocks, proxied by a US model block. These shares rise with the forecast horizon, accounting for close to 75% and 50% of movements in GDP and inflation respectively in the long run. He shows how an intertemporal preference (demand) shock in the foreign economy raises imported inflation in the domestic economy and leads to a drop in investment, consumption and GDP, despite improvements in the trade balance. The latter is partly due to monetary tightening by the domestic central bank, which depresses economic activity. Meanwhile, productivity shocks in the foreign economy lead to increased activity in the domestic economy and lower price pressures, brought about by lower import prices which feeds through the production process. Crucial to these transmission channels is the modelling of international trade in intermediate goods between firms and sectoral producer heterogeneity, which help synchronise co-movements in producer costs and prices across countries and sectors within the same countries.

### 3 Methodology

In this section we present the reduced form model and show how we impose the block exogeneity assumption. We then present the main data used in the estimation, and then discuss how we implement the identification of the shocks of interest.

#### 3.1 The VAR model

The model contains key variables for both the euro area and Malta, and we impose a small-country assumption such that the fluctuations of the Maltese variables do not affect those of the euro area. The model we estimate has the typical VAR representation:

$$Y_t = A + \sum_{l=1}^L B_l Y_{t-l} + U_t \quad (1)$$

for  $t = 1, \dots, T$ . In (1)  $Y_t$  is a  $N \times 1$  vector of endogenous variables while  $Y_{t-l}$  represents lagged values of the latter with  $l = 1, \dots, L$ ,  $A$  is a  $N \times 1$  vector of intercepts while the  $B_l$  matrices have  $N \times N$  dimension and contain the slopes relative to the lagged values of the series entering the autoregression. Finally,  $U_t$  is a  $N \times 1$  vector of reduced form errors that are normally distributed  $U_t \sim N(0, \Sigma)$  and are linked to the structural shocks  $V_t$  via the usual equality  $U_t = A_0 V_t$  where  $V_t \sim N(0, I_N)$ .

More specifically, the model is a two-country VAR with the following representation

$$\underbrace{\begin{bmatrix} Y_t^{MT} \\ Y_t^{EA} \end{bmatrix}}_{Y_t} = \underbrace{\begin{bmatrix} A^{MT} \\ A^{EA} \end{bmatrix}}_A + \sum_{l=1}^L \underbrace{\begin{bmatrix} B_l^{MT} & B_l^{EA \rightarrow MT} \\ \mathbf{0} & B_l^{EA} \end{bmatrix}}_{B_l} \underbrace{\begin{bmatrix} Y_{t-l}^{MT} \\ Y_{t-l}^{EA} \end{bmatrix}}_{Y_{t-l}} + \underbrace{\begin{bmatrix} U_t^{MT} \\ U_t^{EA} \end{bmatrix}}_{U_t} \quad (2)$$

where

$$\underbrace{\begin{bmatrix} U_t^{MT} \\ U_t^{EA} \end{bmatrix}}_{U_t} = \underbrace{\begin{bmatrix} A_0^{MT} & A_0^{EA \rightarrow MT} \\ \mathbf{0} & A_0^{EA} \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} V_t^{MT} \\ V_t^{EA} \end{bmatrix}}_{V_t}. \quad (3)$$

In (2)  $Y_t^{MT}$  is a  $N^{MT} \times 1$  vector of Maltese variables,  $Y_t^{EA}$  is a  $N^{EA} \times 1$  vector of euro area ones while  $Y_{t-l}^{MT}$  and  $Y_{t-l}^{EA}$  are respectively vectors containing their lagged values. It follows that the total number of variables entering the model is  $N = N^{MT} + N^{EA}$ . The vectors  $A^{MT}$  and  $A^{EA}$  are of dimensions  $N^{MT} \times 1$  and  $N^{EA} \times 1$  respectively containing the intercept coefficients, while each of the  $B_l$  matrices contains four blocks. More precisely,  $B_l^{MT}$  is a  $N^{MT} \times N^{MT}$  block containing the slopes relative to the Maltese variables into the Maltese equations while  $B_l^{EA \rightarrow MT}$  contains those relative to the euro area ones and has dimension  $N^{MT} \times N^{EA}$ .  $B_l^{EA}$  is a  $N^{EA} \times N^{EA}$  block containing the slopes relative to the euro area variables into the euro area equations and, finally,  $\mathbf{0}$  is a  $N^{EA} \times N^{MT}$  block of zeros denoting how the Maltese variables do not affect the euro area ones. Finally,  $U_t^{MT}$  and  $U_t^{EA}$  are  $N^{MT} \times 1$  and  $N^{EA} \times 1$  vectors containing the reduced form errors respectively associated with the Maltese and the euro area equations.

Equation 3 shows the link between the reduced and the structural form of the VAR. More precisely,  $V_t^{EA}$  is a  $N^{EA} \times 1$  vector of structural shocks hitting the euro area and spilling into Malta while  $V_t^{MT}$  is a vector of  $N^{MT} \times 1$  structural shocks driving the remaining fluctuations of the Maltese economy. Similar to the  $B_l$  matrices,  $A_0$  contains four blocks. The matrices  $A_0^{MT}$  and  $A_0^{EA \rightarrow MT}$  are  $N^{MT} \times N^{MT}$  and  $N^{MT} \times N^{EA}$  blocks respectively denoting the impact effect of both domestic  $V_t^{MT}$  and foreign  $V_t^{EA}$  shocks into the Maltese economy, while  $A_0^{EA}$  represents how the euro area variables respond on impact to the euro area shocks. Finally,  $\mathbf{0}$  is a  $N^{EA} \times N^{MT}$  block of zeros denoting how any shock hitting the Maltese economy does not spill over to the euro area.

The two blocks of zeros  $\mathbf{0}$  inside the  $A_0$  and the  $B_l$  matrices guarantee the block exogeneity assumption of the euro area block with respect to the Maltese one. By doing so, neither the dynamics of the Maltese variables  $Y_t^{MT}$  nor any other shock hitting the Maltese economy  $V_t^{MT}$  can affect the evolution of the euro area variables.

Our baseline model is a seven-variable Bayesian VAR featuring five variables for the euro area and two variables for Malta. The euro area variables are real GDP growth, HICP inflation, an updated series of the [Krippner \(2013\)](#) shadow policy rate that primarily accounts for a time-varying lower bound of the policy rate ([Krippner, 2020](#)), the real price of oil and the new Composite Indicator of Systemic Stress (CISS) developed in [Chavleishvili and Kremer \(2021\)](#), as a measure of financial stress.<sup>2</sup> This new CISS series we use is an enhanced version of that developed in [Hollo et al. \(2012\)](#) as it puts more weight on situations in which stress becomes more widespread across the various segments of the financial markets (bank and non-bank financial intermediaries, money markets, equities markets, bonds markets and foreign exchange markets) and thus more systemic. The real oil price series is defined as the ratio of the price

---

<sup>2</sup>We do not remove the contribution of developments in Malta's economy from euro area data since the share of Malta in euro area GDP and inflation averages less than 0.1%, owing to Malta's small size. This is extremely unlikely to influence our results.

of oil in euro and the euro area HICP excluding energy. We go over the reasons for this choice in Subsection 3.3 when discussing the identification strategy of the shocks. The choice of the Krippner (2020) shadow rate follows the review of literature and methods used in gauging the effect of unconventional monetary policies contained in Comunale and Striaukas (2017). This enables us to use one single measure to capture the implementation of both conventional and unconventional interventions.<sup>3</sup> For Malta, we include real GDP growth and HICP inflation.<sup>4</sup> We use quarterly data for the period 2003Q1–2019Q4 and we include five lags of each endogenous variable in the system. This allows the effective sample to start in 2004Q2 which is when Malta joined the European Union. Figure 1 shows the data used in the baseline estimation.

The figure clearly shows how the data used in the estimation include the period of protracted economic growth and low inflation in Malta starting from 2013. It also includes the period of higher inflation volatility around the 2007–2009 period driven by the Great Recession and by the developments on the global markets for oil that produced big jumps in oil prices. With regard to the euro area, the data encompasses the years between 2003 and 2007 which is characterised by positive economic growth, the tightening of monetary policy and good conditions on the financial markets. The sample also includes the years of and following the Great Recession characterised instead by a heightened stress on the financial markets and the remarkable implementation of unconventional monetary policies.

In a battery of further estimations we extend the baseline model by including additional variables of interest in order to further explore the transmission channels of the identified euro area shocks to the Maltese economy. Such variables include, but are not limited to, core inflation, a number of interest rates and exports. All data sources and transformations are discussed in Appendix A.

### 3.2 Priors, posteriors and estimation setup

The model in (1) can be compactly written as:

$$\mathbf{Y} = \mathbf{X}\mathbf{B} + \mathbf{U} \quad (4)$$

where  $\mathbf{Y} = [Y_1, \dots, Y_T]'$ ,  $\mathbf{B} = [A, B_1, \dots, B_L]'$ ,  $\mathbf{U} = [U_1, \dots, U_T]'$ , and

$$\mathbf{X} = \begin{bmatrix} 1 & Y'_0 & \dots & Y'_{-L} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & Y'_{T-1} & \dots & Y'_{T-L} \end{bmatrix}.$$

---

<sup>3</sup>Another commonly used measure of shadow rate in the euro area was developed in Wu and Xia (2017). The key results of this work based on the latter do not change and are available upon request. The reason why we choose the shadow rate in Krippner (2020) is its ability to deal with the mentioned time-varying lower bound for the policy rate.

<sup>4</sup>Alternative variables have been considered with the aim of describing the Maltese economy, i.e., GDP deflator, Producer Price Index, deflator of imported goods, core HICP, etc. These variables do not deliver interesting results and so we do not report them.

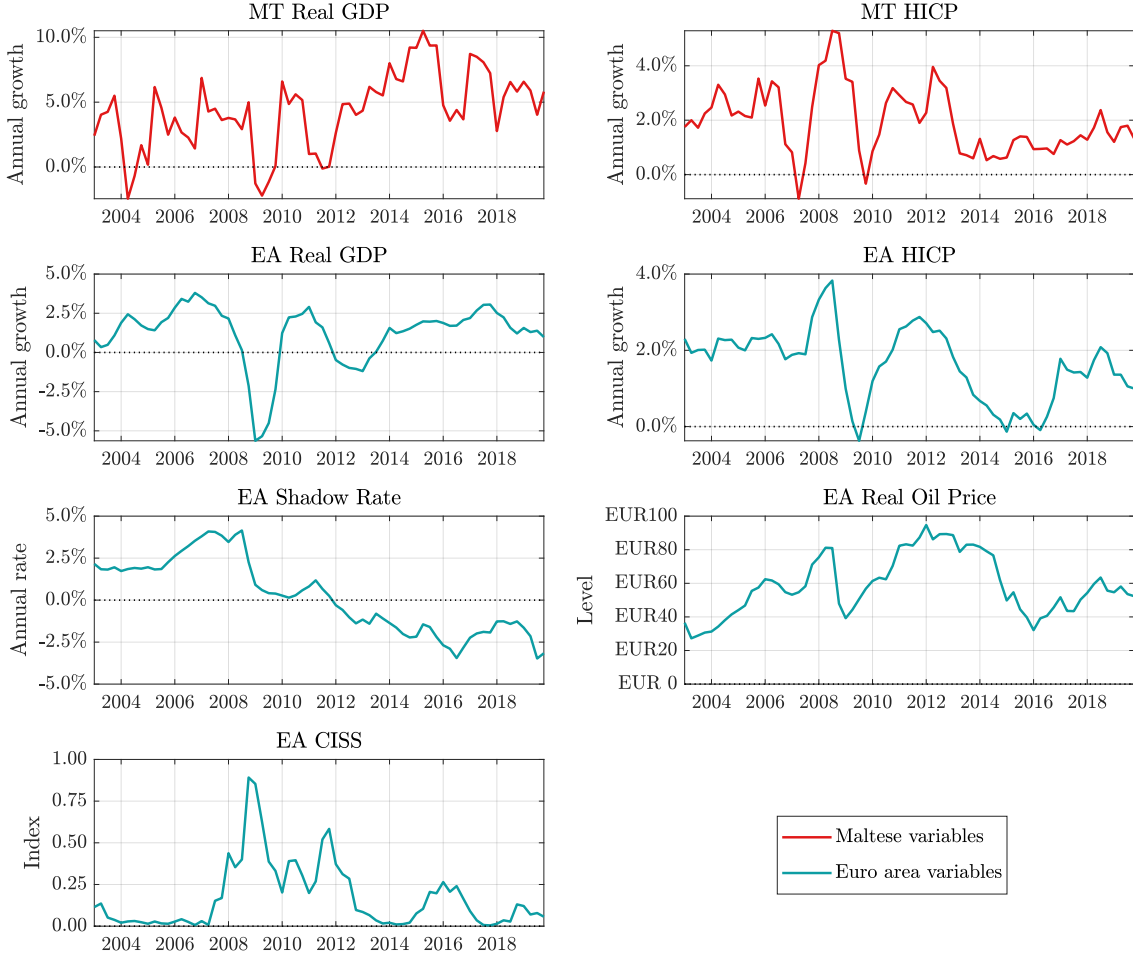


Figure 1: Data used in the VAR

Notes: The figure shows the variables used in the baseline estimation as they enter the VAR. The real oil price and the CISS index are divided by 100. The entire sample covers the 2003Q1-2019Q period while the effective one starts in 2004Q2 because five lags are used in the estimation. The euro area shadow rate goes into negative territory when proxying the conduct of unconventional monetary policies.

For ease of estimation, the model in (4) can be written in vectorised form as

$$\mathbf{y} = (I_N \otimes \mathbf{X})\boldsymbol{\beta} + \mathbf{u} \quad (5)$$

where  $\mathbf{y} = \text{vec}(\mathbf{Y})$ ,  $\boldsymbol{\beta} = \text{vec}(\mathbf{B})$ ,  $\mathbf{u} = \text{vec}(\mathbf{U})$ ,  $\text{vec}()$  is the columnwise vectorisation operator and  $\mathbf{u} \sim N(0, \Sigma \otimes I_T)$ . Define the regression

$$y_{n,t} = \alpha_n + \rho_n y_{n,t-1} + \eta_{n,t} \quad (6)$$

for  $t = 1, \dots, T$  where  $y_{n,t}$  for  $n = 1, \dots, N$  represents each of the variables entering the VAR in (1). In (6)  $\alpha_n$  and  $\rho_n$  respectively represent the intercept and the first autoregressive coefficient

while  $\eta_t$  is an innovation term which is assumed to be normally distributed, i.e.,  $\eta_{n,t} \sim N(0, \sigma_n^2)$ . Define  $\widehat{\rho}_n$  and  $\widehat{\sigma}_n$  as the OLS estimates of the first autoregressive coefficients and standard deviation parameters of the innovations obtained from (6).

The prior for  $\beta$  is assumed to be normally distributed and to follow a structure similar to the Minnesota prior in Litterman (1986) with the only difference that we insert an additional hyperparameter to govern how much we should let the data relative to the foreign block speak regarding their role in influencing the domestic variables. More precisely,  $p(\beta) \sim N(\beta_0, H_0)$  with:

$$\beta_{0,n,j,l} = \begin{cases} \widehat{\rho}_n & \text{if } n = j \text{ and } l = 1, \text{ with } j = 1, \dots, N \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

where the  $\beta_{0,n,j,l}$  refers to the prior mean of the  $l^{th}$  slope coefficient relative to the  $j^{th}$  variable in the  $n^{th}$  equation. The prior variances of the slope parameters are set in the following way:

$$H_{0,n,j,l} = \begin{cases} (\widehat{\sigma}_n \lambda_4)^2 & \text{for the intercept} \\ (\frac{\lambda_1}{l \lambda_3})^2 & \text{if } n = j \\ (\frac{\widehat{\sigma}_n \lambda_1 \lambda_2 \lambda_5}{\widehat{\sigma}_j l \lambda_3})^2 & \text{if } n \neq j \end{cases} \quad (8)$$

where  $H_{0,n,j,l}$  refers to the prior variance of the  $l^{th}$  slope coefficient relative to the  $j^{th}$  variable in the  $n^{th}$  equation. The  $\lambda$  coefficients are the typical Minnesota hyperparameters and are set as suggested in Canova (2007) and widely used in the literature, e.g., Blake and Mumtaz (2017) and Carrillo et al. (2020). Specifically, we set  $\lambda_1 = 0.2$ ,  $\lambda_2 = 0.5$ ,  $\lambda_3 = 1$  and  $\lambda_4 = 10^5$ . As previously mentioned, the additional hyperparameter  $\lambda_5$  governs how relevant the variables of one block are in explaining the fluctuations of the other. Specifically:

$$\lambda_5 = \begin{cases} 1.5 & \text{if } n \in MT_{Equations} \text{ and } j \in EA_{Variables} \\ \rightarrow 0 & \text{if } n \in EA_{Equations} \text{ and } j \in MT_{Variables} \\ 1 & \text{otherwise} \end{cases} \quad (9)$$

The first line in (9) indicates that  $\lambda_5 = 1.5$  when considering the role of euro area variables into the Maltese equations. We obtain this value by minimising the Deviance Information Criterion (Spiegelhalter et al., 2002) associated with the model as shown in Table 2 in appendix B. The second line in (9) indicates that Maltese variables play no role in the euro area equations and that is why  $\lambda_5 \rightarrow 0$  in order to set the prior tightly around a zero mean in such a way to guarantee the block exogeneity assumption of the euro area block with respect to the Maltese one. Finally, the third line in (9) indicates that the prior variance of the slope coefficients is set exactly as in the typical Minnesota prior in all the other cases, i.e., when both  $n$  and  $j$  belong to the same block ( $MT$  or  $EA$ ).

The prior for  $\Sigma$  is distributed as an Inverse Wishart distribution, i.e.,  $p(\Sigma) \sim IW(S_0, \psi_0)$  where

$$S_0 = \text{diag}(\widehat{\sigma}_1^2, \dots, \widehat{\sigma}_n^2, \dots, \widehat{\sigma}_N^2) \\ \psi_0 = N + 1$$

As shown in [Kadiyala and Karlsson \(1998\)](#) the posterior distribution of the VAR slope coefficients conditional on  $\Sigma$  is normal and given by  $p(\beta|\Sigma, \mathbf{X}) \sim N(\beta_1, H_1)$  with

$$H_1 = (H_0^{-1} + \Sigma \otimes X'X)^{-1}$$

$$\beta_1 = H_1(H_0^{-1}\beta_0 + \Sigma^{-1} \otimes X'X\beta_{OLS})$$

where  $\beta_{OLS}$  denotes the OLS estimates of the VAR coefficients expressed in vectorised form. The conjugate prior for the variance-covariance matrix  $\Sigma$  ensures that the associated posterior is distributed as an Inverse Wishart, i.e.,  $p(\Sigma|\beta, \mathbf{X}) \sim IW(S_1, \psi_1)$ , with

$$S_1 = S_0 + (\mathbf{Y} - \mathbf{XB})'(\mathbf{Y} - \mathbf{XB})$$

$$\psi_1 = \psi_0 + T$$

We estimate the model by setting the number of Gibbs sampler iterations in such a way to have a reasonable number of retained draws from the posterior distributions to conduct a meaningful inference. We draw 25,000 vectors of parameter draws and discard the first 20,000 in order to minimise the influence of the initial conditions. In [Appendix B](#) we show that the posterior distributions converge and our inference is conducted on the last 5,000 draws.

### 3.3 Identification strategy

The identification strategy that we adopt aims at identifying seven structural shocks, five for the euro area and two for the Maltese economy. Our approach is based on zero and sign restrictions on the impact responses of variables, summarized in [Table 1](#). As we discuss in the introduction, the aim of this paper is to characterise the transmission of a set of shocks from the euro area to Malta, in part to inform conjunctural analysis and economic projections carried out by the Central Bank of Malta. To this end we identify both euro area and Maltese demand and supply shocks. Since these shocks are orthogonal to each other, we interpret them as a decomposition of ‘euro area wide’ aggregate demand and supply shocks into the *indirect impact*; the component that hits the rest of the euro area and then transmits to the Maltese economy via trade channels, and the *direct impact*; the component of the shock that hits the Maltese economy directly. Therefore, for the euro area we identify a demand shock (EA D), two supply shocks, reflecting productivity (EA S-P) and commodity (EA S-C) push shocks, a monetary policy shock (EA MP) and a financial stress shock (EA Fin). Our identification strategy is similar to that of [Conti et al. \(2017\)](#) and the references therein. The sign restrictions we impose are standard and the full set of restrictions that we include allow us to fully identify the VAR.

The euro area demand shock is meant to capture intertemporal preference shocks in the euro area, and therefore raises output and prices and elicits monetary tightening, while the supply shocks both push output and prices in opposite directions. However, a productivity shock raises the real price of oil through the downward pressure on the general price level, whereas a favourable commodity shock lowers the real price of oil. Consequently, the economy benefits from the more favourable conditions on the global market as a consumer of oil. The response of the real oil price series is, therefore, intended to be purely mechanical in that it helps disentangle

the two supply shocks.

The monetary policy shock is also identified in a standard way and this is achieved by increasing the policy rate and lowering output and prices. This shock is a ‘generic’ monetary policy shock, as our estimation sample covers both conventional and unconventional monetary policy regimes. As previously discussed, we take this approach through the use of the shadow policy rate, which reasonably captures the influence of unconventional monetary policy ([Comunale and Striaukas, 2017](#)) while keeping the system relatively simple.<sup>5</sup>

None of these four shocks has a contemporaneous effect on the indicator of systemic stress as this is a measure of stress that has already materialised in the financial system. For this reason, any shock (other than financial) hitting the economy can only have a delayed effect on it. Finally, a financial shock raises the measure of financial stress and no restriction is imposed on the other euro area variables as in [Hollo et al. \(2012\)](#) and [Chavleishvili and Kremer \(2021\)](#). This combination of zero and sign restrictions allows us to uniquely identify the five euro area shocks.

The two Maltese shocks we identify are simply demand (MT D) and supply (MT S) shocks, which represent catch-all processes that summarise the direct influences of shocks that hit the euro area as a whole, the rest of the world as well as shocks that originate within the Maltese economy. The sign restrictions for these two shocks follow the textbook responses of output and prices. As we discuss above, the small-country assumption implies that none of the Maltese shocks affects the euro area variables, so the responses of euro area variables are all set to zero. On the other hand, the responses of Maltese output and prices to euro area shocks are unrestricted, as they are one of the key objectives we seek to empirically measure in this paper. This setup allows us to decompose an aggregate demand shock into its direct and indirect effects. In [Section 5](#) we also show the full effect of an aggregate demand shock (euro area wide, including Malta) on Maltese variables, since this is also relevant for policymakers.

Since the identification scheme admits block-diagonal restrictions, we use the algorithm of [Rubio-Ramirez et al. \(2010\)](#) to draw the set of structural matrices that satisfy the restrictions at each draw from the posterior distribution of the estimated parameters. For a technical exposition of how the restrictions are implemented please refer to [Appendix B](#).

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<sup>5</sup>Studies on the transmission of monetary policy transmission show that there may be differences between reactions to policy rate changes and reactions to central bank communication (policy shocks and information shocks). See [Jarociński and Karadi \(2020\)](#) and the references therein. This distinction however is beyond the scope of this paper, so we abstract from high frequency variables to capture monetary policy shocks.

Table 1: Identifying restrictions - impact responses

	Variables	MT D	MT S	EA D	EA S-P	EA S-C	EA MP	EA Fin
<b>MT</b>	Real GDP	+	+	?	?	?	?	?
	HICP Inflation	+	−	?	?	?	?	?
<b>EA</b>	Real GDP	0	0	+	+	+	−	?
	HICP Inflation	0	0	+	−	−	−	?
	Shadow Rate	0	0	+	?	?	+	?
	Real Oil Price	0	0	?	+	−	?	?
	CISS	0	0	0	0	0	0	+

Notes: MT and EA denote variables and shocks related to Malta and the euro area respectively. The entries refer to the impact response of a variable  $y_{i,t}$  to a structural shock  $v_{j,t}$ ; ‘+’ indicates  $\partial y_{i,t}/\partial v_{j,t} > 0$  while ‘−’ indicates  $\partial y_{i,t}/\partial v_{j,t} < 0$ , and ‘?’ indicates that no restriction is imposed on that variable.

## 4 Structural analysis

This section is dedicated to the exposition of the main results of the model described in Section 3. Specifically, it starts with a discussion of the structural shocks extracted from the VAR and how they are able to provide a valid narrative of the main driving forces of the fluctuations of the euro area economy. Then, it proceeds with the typical objects of interest in structural VAR analysis, namely responses to the identified shocks and their contribution to the economic fluctuations by means of the forecast error variance decomposition and the historical decomposition.

### 4.1 Estimated structural shocks

We first show the euro area shocks we identify starting from 2004 in Figure 2. As a sanity check we mark the timing of specific events on the relevant shocks, and find that they line up well. For instance, the Great Recession of 2008/9 was driven by negative demand and productivity shocks, as well as by positive commodity and financial stress shocks. In the run up to the Great Recession financial stress shocks were persistently negative, indicating accommodative conditions on the credit market, fuelling the economic boom in the euro area. Commodity shocks were positive as from 2006, and as we show below, were important drivers of the rise in HICP inflation in both the euro area and Malta. The third panel of Figure 2 sheds light on the major developments on the oil market around the Great Recession.<sup>6</sup> On the one hand, the negative shocks from mid-2007 till mid-2008 capture the build-up of unfavourable conditions characterised by the price of a barrel of crude WTI oil going up from \$93 in June 2007 to \$175 in June 2008. On the other hand, the positive shocks in the second half of 2008 reflect the fall in oil prices experienced soon after the beginning of the recession where, notably, a barrel of WTI went down to just \$54 in January 2009.

The sovereign debt crisis, which started in 2010, lines up with strong and volatile financial stress shocks we estimate for that period, while calm on the financial markets was restored when the ECB’s then-president Mario Draghi famously remarked in 2012 that the ECB will do

<sup>6</sup>Given the identification strategy outlined in Table 1, positive structural shocks are interpreted as more favourable conditions on the global oil market from a consumer’s perspective.



“whatever it takes” to save the euro.<sup>7</sup> After this episode the euro area experienced a period of heightened financial stress, in conjunction with the Greek debt default in June 2015. The plot also illustrates the different magnitudes of the shocks, with financial stress shocks being the most volatile and reaching the highest peaks after the subprime crisis in 2007, the Great Recession and the Greek debt haircut in July 2011.

With regards to the demand shock, the model is able to pick the overall positive demand side developments in the euro area economy prior to the Great Recession. Moreover, the top panel of Figure 2 shows the periods of subdued demand between late 2013 and the beginning of 2015, characterised also by inflation falling below 1%, and this in the context of the Greek sovereign debt default in June 2015. The model is also able to capture the major steps of the ECB’s monetary policy conduct as depicted in the fourth panel of Figure 2.<sup>8</sup> The pre-crisis years are characterised by positive shocks reflecting the increase in interest rates starting from December 2005. These were followed by negative shocks in mid-2007 when interest rates were temporary cut before being raised again for a short period in July 2008 as a response of an increase in headline inflation related to oil price developments. The period that runs from the start of the Great Recession until the ECB reached the zero lower bound (ZLB) of interest rates is initially characterised by negative shocks highlighting how the immediate and quick cut of the interest rates was not enough to really stimulate the economy.

It is only after the beginning of the euro area sovereign debt crisis and the implementation of the first wave of unconventional monetary policies that the structural shocks turn mostly negative. Such policies comprise the ECB’s Securities Market Programme, implying the purchase of government bonds of countries where monetary policy transmission had not been fully effective as a result of excessive market pressures, and the implementation of the two three-year Long-Term Refinancing Operations (LTROs). Subsequently, as the funding situation in the banking sector started to improve the ECB began a process of gradual reduction of the securities accumulated in its balance sheet in order to unwind part of the unconventional policies previously implemented. Finally, in early 2015 the ECB announced the extension of the Asset Purchase Programme (APP) to sovereign bonds in response to the prolonged period of low inflation.<sup>9</sup>

## 4.2 Dynamic responses to euro area shocks

We now explore how the structural shocks we identify propagate through the euro area and spillover to the Maltese economy by looking at the Impulse Response Functions (IRFs) of the endogenous variables.

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<sup>7</sup>Mario Draghi was speaking at the Global Investment Conference in London, on the 26<sup>th</sup> of July 2012.

<sup>8</sup>Given the identification strategy outlined in Table 1, positive structural shocks are interpreted as the implementation of contractionary monetary policies.

<sup>9</sup>For a detailed historical excursus of the ECB’s policies since its inception please refer to the speech held on the 4<sup>th</sup> of May 2018 by Vítor Constâncio, then Vice-President of the European Central Bank, at the Central Bank of Malta with title “Past and future of the ECB monetary policy”.

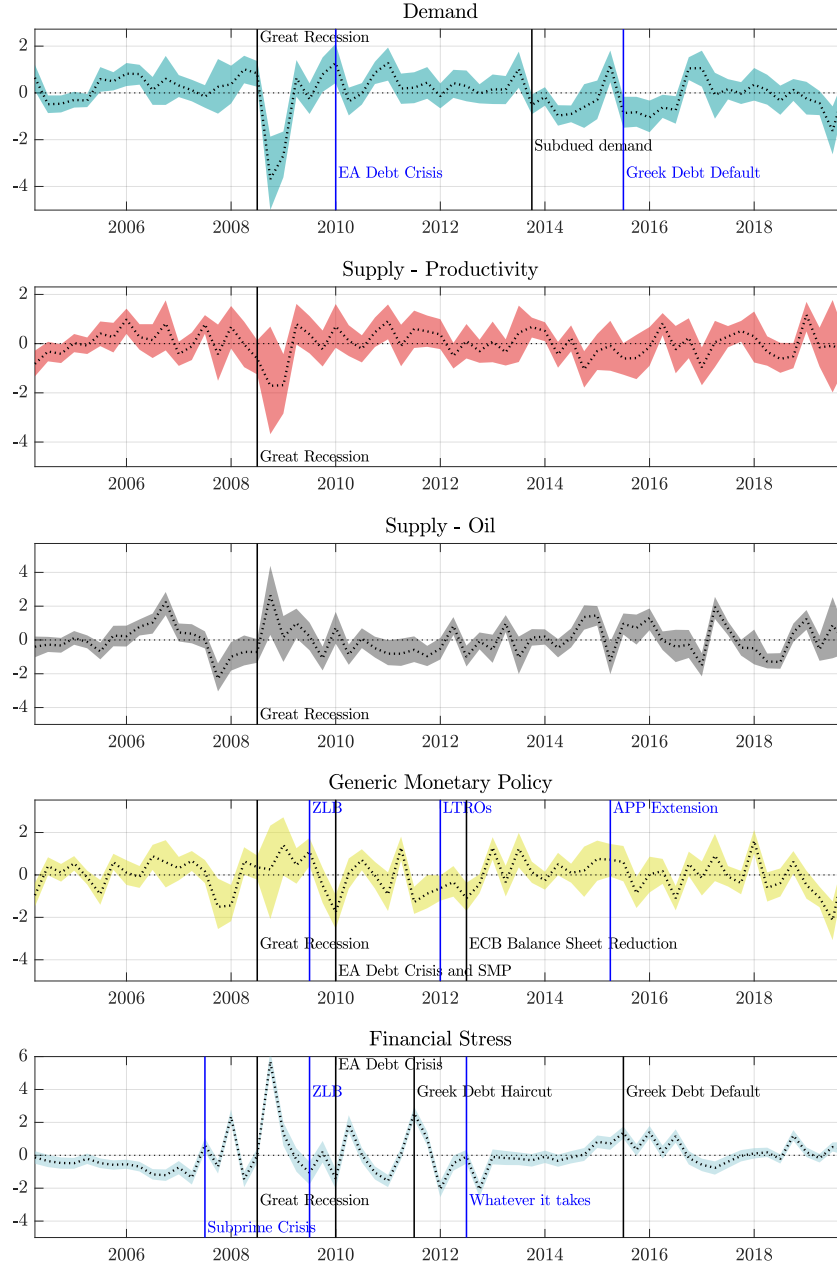


Figure 2: The estimated euro area structural shocks

Notes: The figure shows the median values (dotted lines) and the 68% credible bands (coloured shaded areas) of the estimated structural shocks hitting the euro area economy.

#### 4.2.1 Euro area demand shocks

A euro area demand shock, shown in Figure 3, increases the growth rate of real GDP and prices in the euro area, causing the ECB to raise interest rates. While the response of GDP is relatively short-lived, the inflation and especially the interest rate responses are more persistent. We note

that the interest rate response reflects the ECB's historical upholding of the Taylor principle, as the nominal interest rate rises faster than inflation, raising the real interest rate. The real price of oil does not change by much, while the measure of financial stress rises, but by small magnitudes, following the tightening of the monetary policy stance.

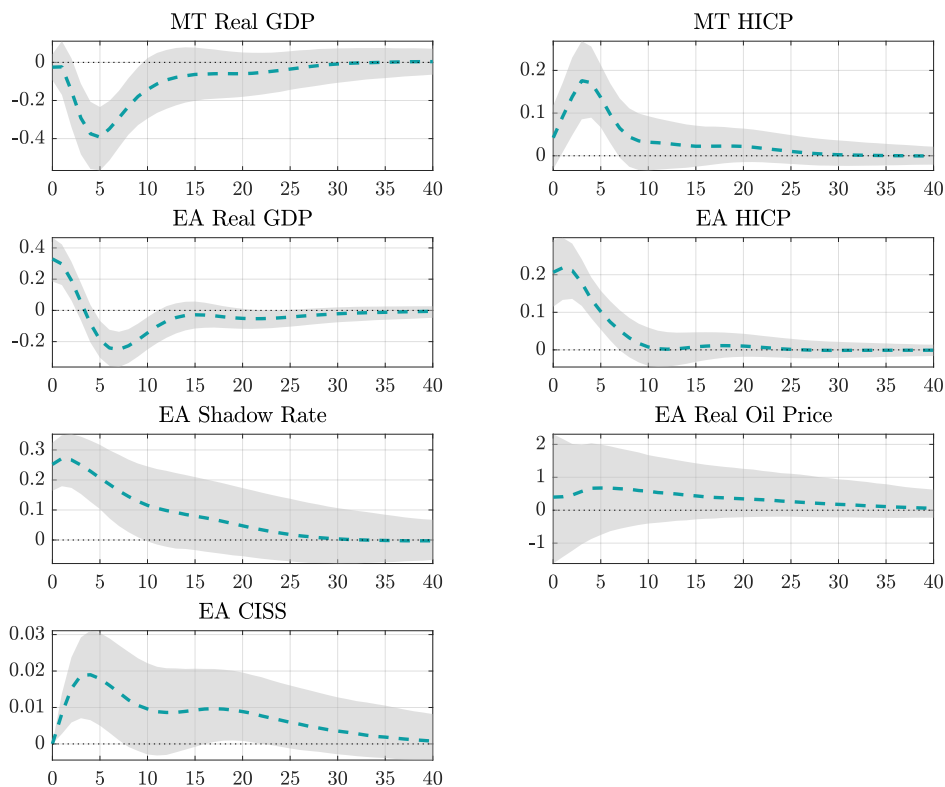


Figure 3: IRFs to a euro area demand shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area aggregate demand shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

The spillovers of this shock into the Maltese economy result in a drop in GDP growth and a rise in inflation. The latter follows a hump-shaped response peaking around a year after the onset of the shock, and reflects the transmission of higher prices in the euro area to Malta through import prices, owing to its openness. The rise in euro area activity is expected to generate positive spillovers to the Maltese economy, but these are dominated by a loss of competitiveness vis-a-vis trade with the euro area and the rest of the world. The response of euro area inflation reaches its peak after one quarter while the peak impact on inflation in Malta occurs after three to four. It is worth noticing that the pass-through is not complete as the two peaks slightly differ, with the peak for Maltese HICP being lower. The downward effect on Maltese GDP fully materialises after five quarters, after which it slowly subsides. These responses are very similar to what [Bergholt \(2015\)](#) documents in an estimated DSGE model for Canada in the wake of a

foreign intertemporal preference shock. We reiterate that, through the identification strategy that we impose, the response of the Maltese variables to this shock reflects only the transmission of this demand shock, and does not feature the response to a direct impact of the shock on the Maltese economy. That response is captured via the Maltese aggregate demand shock (MT D).

To provide evidence for this analysis we resort to a method developed in [Kilian and Lewis \(2011\)](#) and in Figure 4 we decompose the response of real GDP growth in Malta following a euro area aggregate demand shock. The GDP response can be decomposed into the sum of the responses to its own lagged values and the sum of those of all the other variables entering the VAR.<sup>10</sup> The decomposition shows how Malta’s inflation (dark red bars) contributes negatively to the response of the Maltese GDP throughout the entire response horizon.<sup>11</sup> Since local prices react with a lag with respect to prices in the euro area, the contribution of euro area prices to Maltese GDP is positive in the first four quarters of the shock (yellow bars). The delayed pass-through is beneficial in this regard since it temporarily boosts Malta’s relative competitiveness on impact; with GDP growth falling only through the effect of the rise in the ECB policy rate (light blue bars). There is a very slight positive spillover of increased activity in the euro area on impact, likely through higher demand for Malta’s exports, but is very short-lived. Through this exercise we document a previously unknown result that the competitiveness channel operating via import price pass-through takes about a year to take full effect.

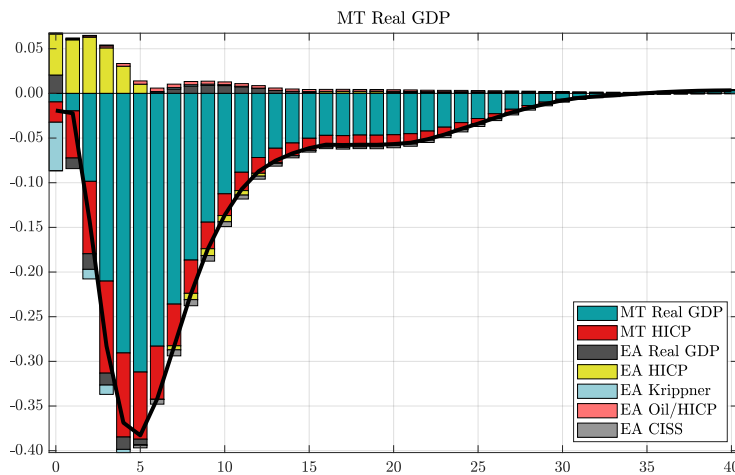


Figure 4: Decomposition of MT real GDP to a euro area demand shock

Notes: The figure shows the median response (solid line) of Maltese GDP to a 1-standard deviation euro area aggregate demand shock while the coloured bars indicate the median contribution of the endogenous variables, based on the method of [Kilian and Lewis \(2011\)](#). Values on the horizontal axis are quarters following the shock, and values on the vertical axis are in percentage point deviations.

[Kilian and Lewis \(2011\)](#) also provide a tool that is suitable in our context to study the

<sup>10</sup>Technical details on its derivation are provided in Appendix C.

<sup>11</sup>The high contribution of the real GDP growth series (teal bars) to its own response is evidence of high persistence of the GDP process itself.

role of inflation in the propagation of this shock. We use this tool to construct a counterfactual scenario in which the increase in euro area inflation is assumed not to spillover to higher domestic inflation and, as a consequence, the response of the latter is completely flat. To do this we feed the model with a sequence of hypothetical shocks to Maltese inflation that exactly offset the contemporaneous and lagged effects of the latter in the reaction of Maltese GDP growth.<sup>12</sup> In Figure 5 we show that the GDP response turns positive in the first few quarters, in line with the short-lived competitiveness channel discussed above and highlighted in Figure 4, reflecting the spillover of demand via exports. In spite of this, the eventual decline in GDP is still present at longer horizons. From a purely technical standpoint, this could be due to the counterfactual not fully shutting off the imported inflationary pressures since we only shut off consumer price growth.<sup>13</sup> It could also reflect the monetary policy tightening that depresses activity, since, given our small country assumption, our counterfactual does not affect monetary policy decisions. We comment more on this further below.

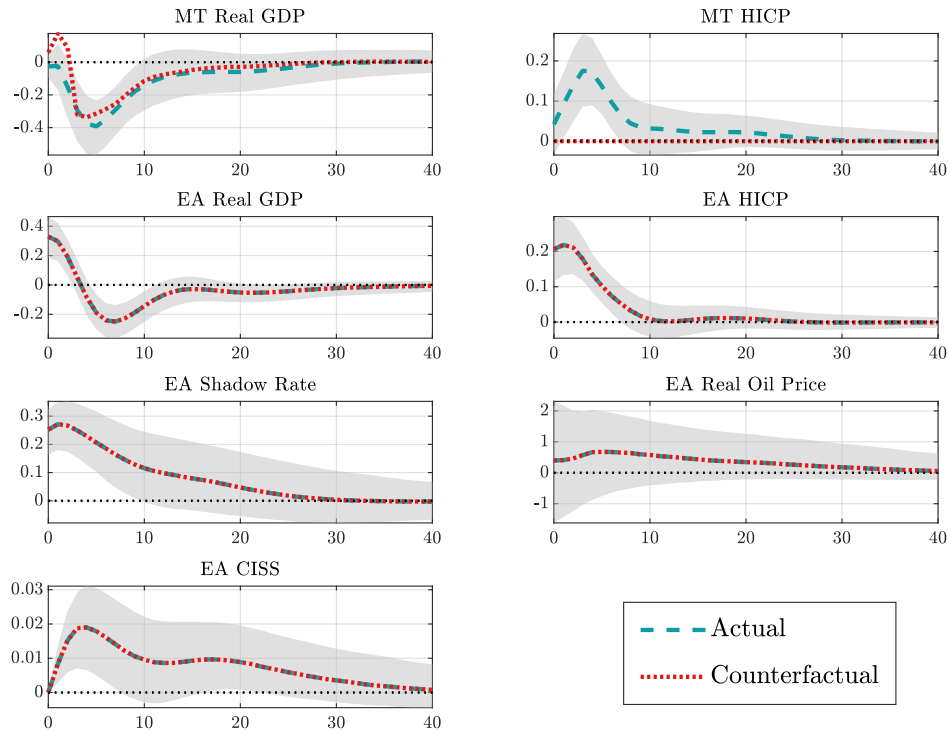


Figure 5: Counterfactual IRFs to a euro area demand shock

Notes: The figure shows the baseline responses (dashed lines and grey shaded areas) to a 1-standard deviation euro area aggregate demand shock and the counterfactual median responses (red dotted lines) under the assumption that Maltese inflation does not react to the shock, based on the method of Kilian and Lewis (2011). Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

<sup>12</sup>We provide a technical discussion of how such a counterfactual is built in Appendix C.

<sup>13</sup>We also experimented with other price measures, such as the Producer Price Index, but did not obtain meaningful results which can be used to shed further light on the issue.

Finally, in order to further explore the transmission channel of the euro area demand shock, we show in Figure 6 the IRFs of a set of additional relevant Maltese variables.<sup>14</sup> Firstly, the hump-shaped response of inflation is broad-based, as reflected in a very similar response in core HICP inflation. Foreign demand for Maltese goods and services initially rises, leading to a short-lived rise in Malta's total exports, although exports to the euro area are static, implying that it is exports to the rest of the world that rise. This is likely explained by a lower relative price for Maltese exports relative to that of the rest of the euro area in the first few periods of the shock, although there is considerable uncertainty around this rise in exports. Foreign demand then declines together with drop in euro area GDP, explaining the hump-shaped decline of Maltese GDP growth. Growth in investment follows a similar path, while consumption growth experiences a long contraction, although there is considerable uncertainty about this path throughout the horizon. Again, these are in line with the dynamics following an intertemporal preference shock in the foreign economy documented in [Bergholt \(2015\)](#).

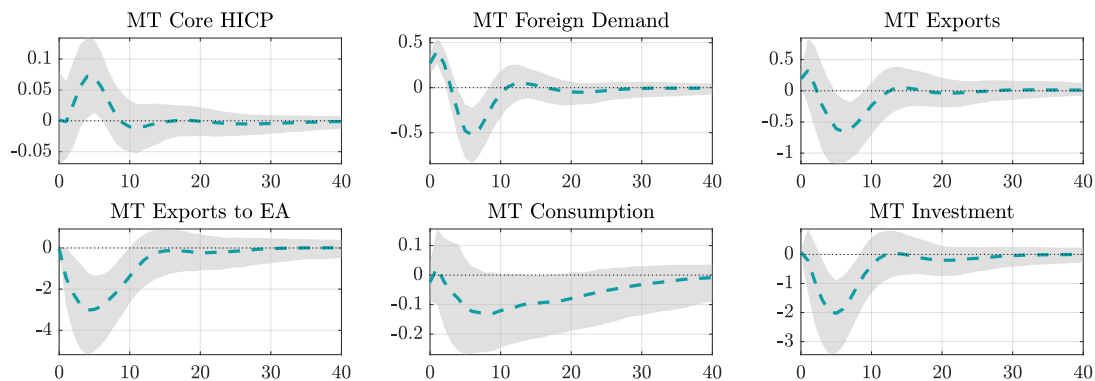


Figure 6: Additional IRFs to the euro area demand shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area demand shock. All variables enter the VAR in yearly growth rates. Values on the horizontal axis are quarters following the shock, while values on the vertical axis denote deviations from the baseline in percentage points.

In sum, the transmission of a positive euro area aggregate demand shock appears to be largely unfavourable to the Maltese economy, as positive demand spillovers are dominated by a loss in competitiveness due to imported price pressures.

#### 4.2.2 Euro area aggregate productivity shocks

We now turn to productivity shocks in the euro area. The interpretation of this shock is broad since we do not distinguish between labour and capital productivity in our model. Productivity shocks in the euro area generate a rise in GDP and a fall in prices that lasts about a year, while

<sup>14</sup>The impulse responses shown in Figure 6 are obtained by including a variable at a time into the Maltese block in (2). A relatively similar approach is used by [Gertler and Karadi \(2015\)](#) to gauge the transmission mechanism of their identified monetary policy shock on a number of additional variables without making the model proliferate in terms of parameters to be estimated. In our case the Maltese block is no longer fully identified but this does not affect the euro area block. The inclusion of an additional variable at a time is implemented also in all the extensions relative to the other identified shocks.

monetary policy does not respond (see Figure 7). These responses are standard. Meanwhile, the real price of oil rises on account of the drop in HICP inflation, which we use to deflate the oil price series. The CISS indicator rises slightly but the response is surrounded by high uncertainty. The transmission to the Maltese economy leads to higher economic activity and lower price pressures, although we estimate considerable uncertainty around the responses for the Maltese economy. Furthermore, the shock feeds into the Maltese economy with a delay, reaching a peak impact about 4 periods after the onset. In Figure 9 (top row) we show that the shock raises both labour and total factor productivity in Malta, although again the responses are surrounded by high uncertainty. The rise in Maltese GDP appears to be driven by a rise in exports through a competitiveness channel, which is a recurring finding in this paper. Historically, movements in import prices tended to play an important bearing on Maltese economic activity.

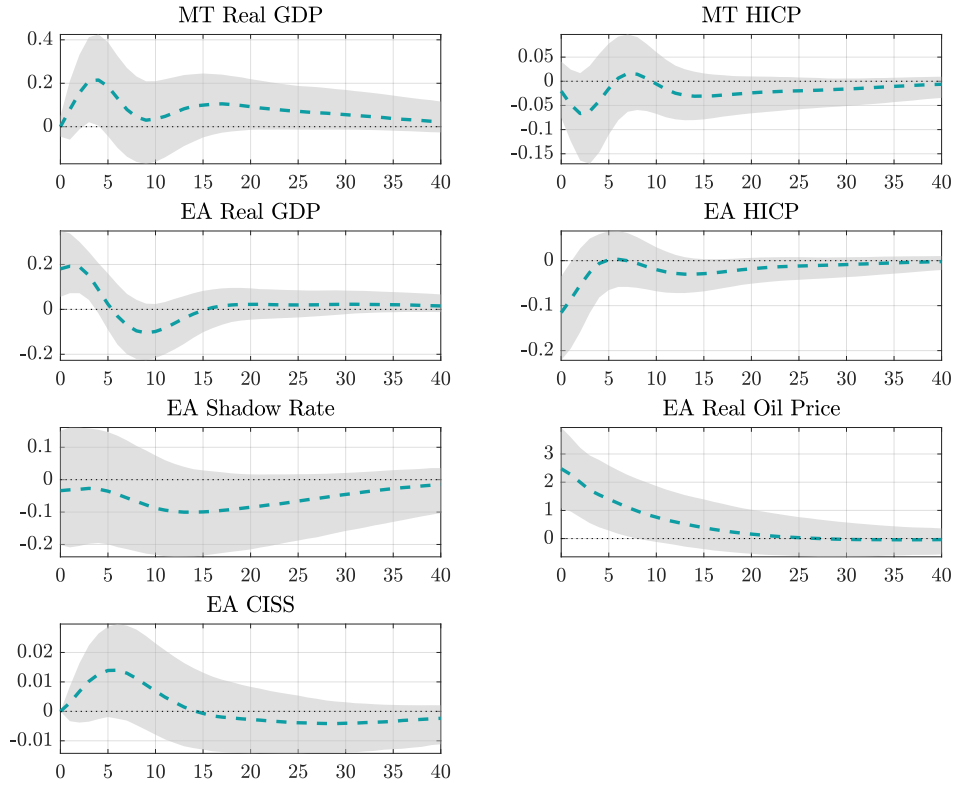


Figure 7: IRFs to aggregate supply shock - productivity

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area aggregate supply - productivity shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

#### 4.2.3 Euro area commodity price shocks

The next shock we discuss is a commodity price shock, which we interpret as reflecting conditions in the oil market that the euro area takes as given. We model the shock as a favourable development in the oil market that leads to lower nominal and real oil prices on impact. Figure

8 shows that the shock generates a persistent decline in real oil prices that drives an expansion in euro area economic activity while lowering pressure on consumer prices. The ECB does not react to this shock, given that although such commodity price shocks can have a sizeable effect on HICP inflation in the short term, the shocks tend to be transitory and therefore do not affect the medium term outlook for inflation. Financial stress in the euro area is not affected by this shock. The transmission to the Maltese economy results in downward pressure on consumer prices that is delayed and again appears to reach full impact after about 3–4 quarters.

The finding that although the shock lowers euro area price pressures immediately, the effect on Maltese GDP is muted at very short horizons can appear somewhat puzzling. A possible explanation for this is the fact that Malta negotiated forward oil purchase agreements during a considerable period in our sample, and was thus shielded from oil price swings, favourable or otherwise. Consequently, the shock only affects Maltese prices indirectly through slower growth in consumer import prices from the euro area and possibly other trading partners that similarly benefit from lower oil prices. Yet, it did not affect production prices and therefore had no effect on output. A possible explanation for the puzzling negative response of GDP in the medium term is the fact that most of the favourable shocks on the oil markets take place during periods of declining global economic activity. As a consequence, such a GDP decline matches the medium term lower trade activity that Malta engages, as we show in Figure 9. The response of the additional variables in this figure shows that Maltese exports, besides experiencing a medium term decline, experience an upward pressure in the very first quarters following the shock. Additionally, labour and total factor productivity initially do not react but then fall roughly two years into the shock. From a timing perspective, this fall coincides with the rebound in Maltese HICP inflation and, to a lesser extent, with the decline in exports. These are in line with the dip in GDP growth, which we attribute to the general international economic conditions under which a commodity price decline occurs.



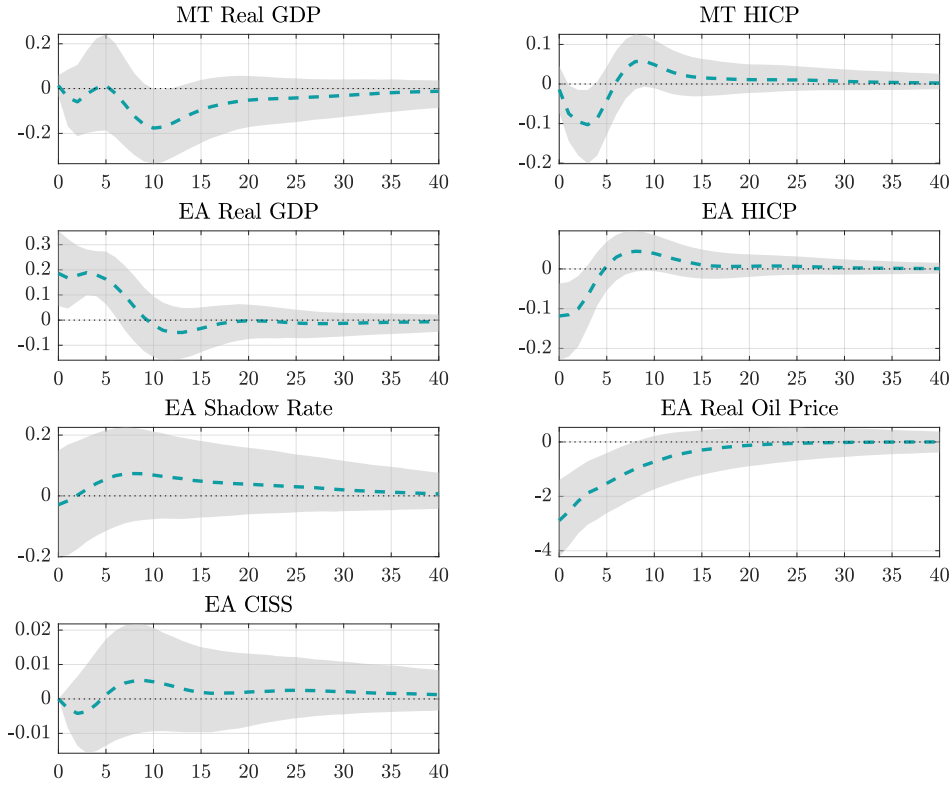


Figure 8: IRFs to aggregate supply shock - oil

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area aggregate supply - oil shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

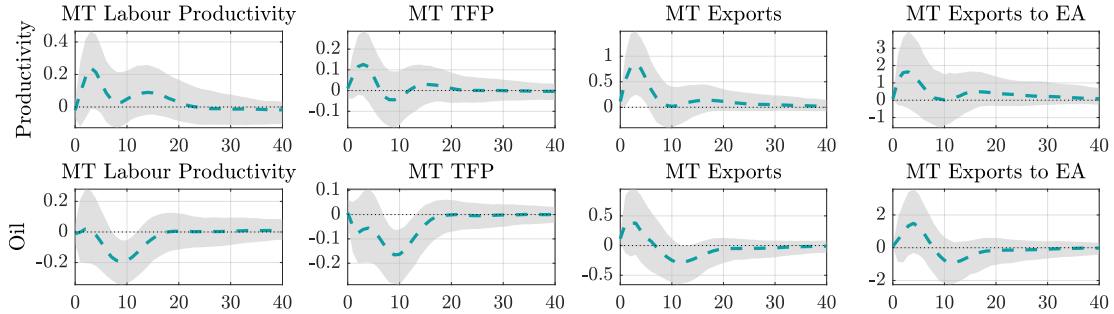


Figure 9: Additional IRFs to aggregate supply shock - productivity (top row) and oil (bottom row)

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area aggregate supply shock (both productivity and oil). Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection.

#### 4.2.4 Euro area generic monetary policy shocks

As discussed in our identification strategy above, we model a broad monetary policy shock that captures both conventional and unconventional monetary policies through the use of a single measure: the shadow policy rate. While we acknowledge that these two policy implementations might have different effects on euro area variables and also different transmission channels, in this paper we provide a ‘first-pass’ at studying the reaction of the Maltese economy to unanticipated movements in the ECB policy rate.

In Figure 10 it is shown how a one-standard deviation shock translates to about a 10 basis point rise in the policy rate in our estimation. An unanticipated contractionary policy leading to a rise in the ECB policy rate decreases output and price growth in the euro area, and has virtually no impact on the real price of oil. The result of a positive response of the financial stress indicator after about a year after the shock hits is explained by the overall less favourable conditions on the credit markets following a monetary tightening. However, as our sample covers periods of both conventional and unconventional monetary policies, we refrain from discussing further the behaviour of the stress indicator as the two kinds of monetary policies are likely to exert a different effect on the financial system.

A contractionary monetary policy shock transmits to the Maltese economy through lower pressure on consumer prices on impact, by a magnitude that is close to the impact on euro area HICP inflation, and with a slightly delayed peak response. Notably, this is the only shock in our model that generates an immediate movement in prices. Although the shock is contractionary in the euro area, we observe evidence of a somewhat upward pressure on Maltese GDP, despite the wide impulse response credible bands. This is in line with other findings we report above, in which a competitiveness channel dominates lower euro area export demand, leading to a higher output growth.

We take a further look at the effects of the shock on other Maltese variables in Figure 11. An unanticipated monetary policy tightening of 10 basis points raises both lending and deposit interest rates in Malta, albeit with a delay, peaking at also around 10 basis points after about a year. The same considerations are drawn for the 10-year government bond but this seems to be in line with the response of the 10-year German bund rate as the sovereign spread does not appear to widen significantly. Finally, the overall response of the Financial Conditions Index (FCI)<sup>15</sup> and Maltese core inflation (HICP excluding energy) does not appear to be significantly different from zero at all horizons.

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<sup>15</sup>See [Borg and Micallef \(2018\)](#) for a discussion on the methodology behind the FCI.

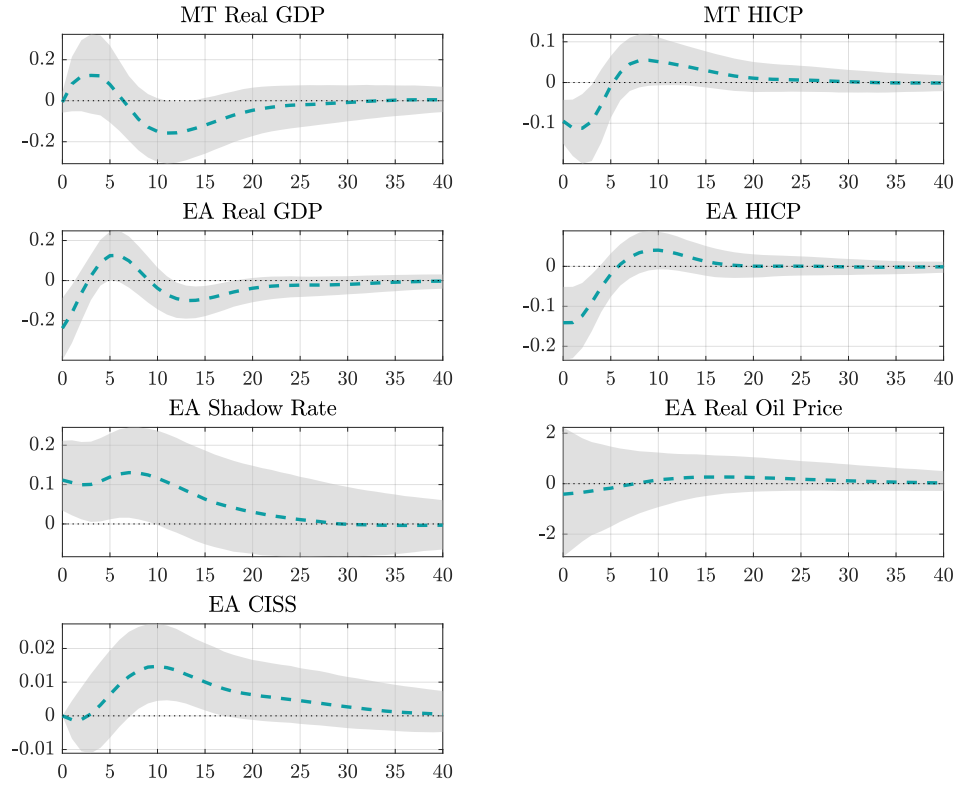


Figure 10: IRFs to generic monetary policy shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area generic monetary policy shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

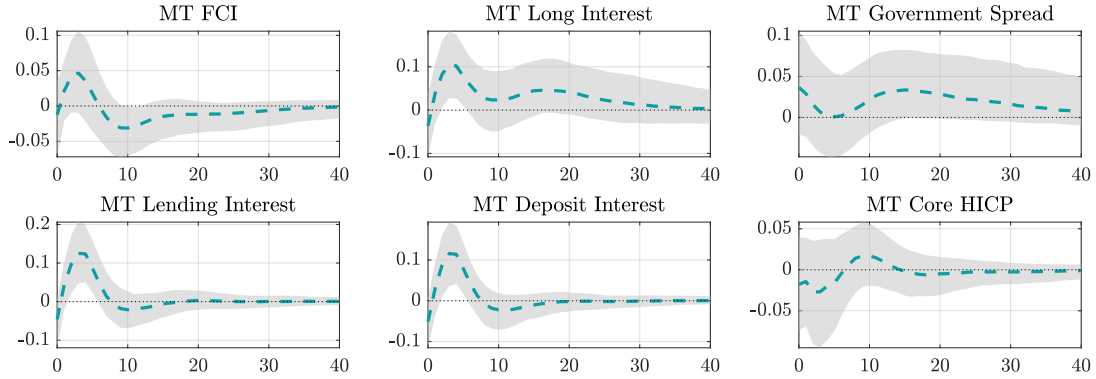


Figure 11: Additional IRFs to generic monetary policy shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area generic monetary policy shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection.

#### 4.2.5 Financial shocks in the euro area

The final euro area shock in our model is the financial shock, a shock which raises the indicator of systemic risk. Recall from the identification strategy in Table 1 that the impact responses of the variables are unrestricted and purely data-driven as in a (lower) Cholesky decomposition, with the CISS index ordered first. Figure 12 shows that a typical financial shock has adverse effects on the euro area economy, causing output to drop for several quarters. The impact on inflation, although also negative, is much more muted. The real oil price also falls as a result of the lower economic activity and in line with the experience of the Great Recession. The VAR model captures the typical monetary policy response which lowers the policy rate in a bid to stimulate the economy.

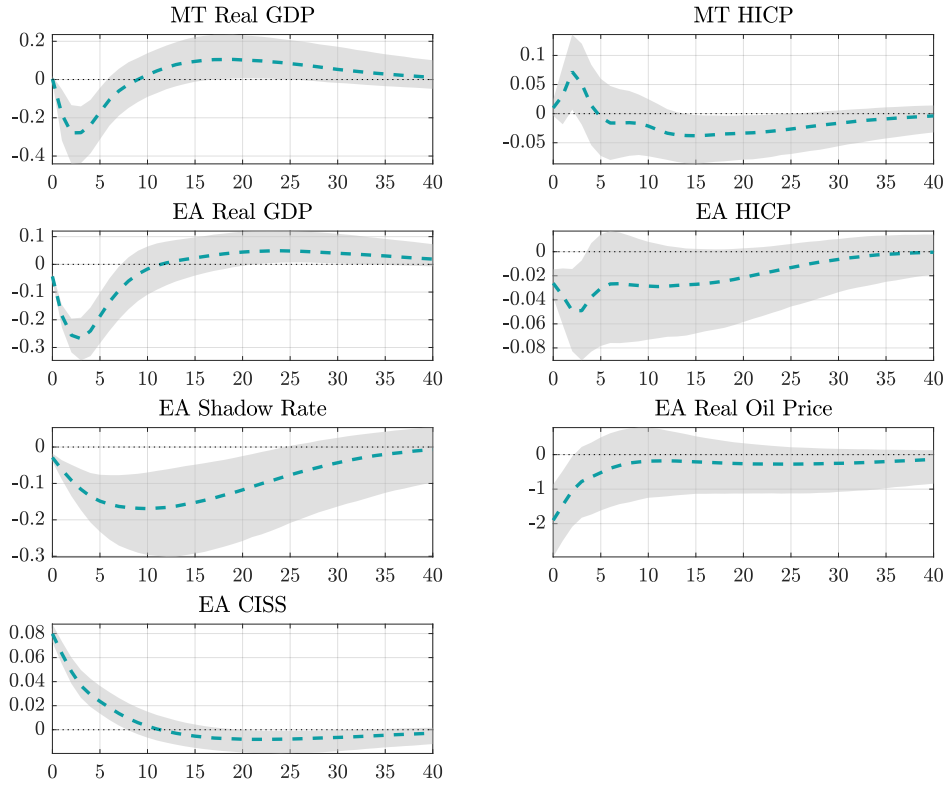


Figure 12: IRFs to a financial stress shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area financial stress shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

This shock also spills over to the Maltese economy, lowering output growth by similar magnitudes. Although the effect on inflation is initially positive, is it also largely muted, as in the euro area. Our analysis shows that a financial shock typically transmits across the euro area and Malta quickly, and reaches its maximum impact within a few quarters in both economies.<sup>16</sup>

<sup>16</sup>The responses relative to the financial stress shock in this subsection, as well as the results relative to the

In Section 6 we show that this financial shock has a global component and is not necessarily specific to the euro area.

In order to better understand the transmission of this shock to the Maltese economy we trace the dynamic responses of a selection of variables that are relevant for the real and the financial side of the economy. Figure 13 shows how a financial shock exerts a negative effect on Maltese investment and exports. Consumption growth immediately declines but then experiences a rebound thus indicating how, during times of heightened financial turbulence, consumption plans might be postponed. Finally, with regard to the financial side of the economy, the lending rate and household credit growth experience a decline as depicted by their hump-shaped responses. In addition, the gap between Maltese and German government 10-year bond yields widens, indicating that Malta’s risk premium reacts more strongly during periods of financial stress.<sup>17</sup>

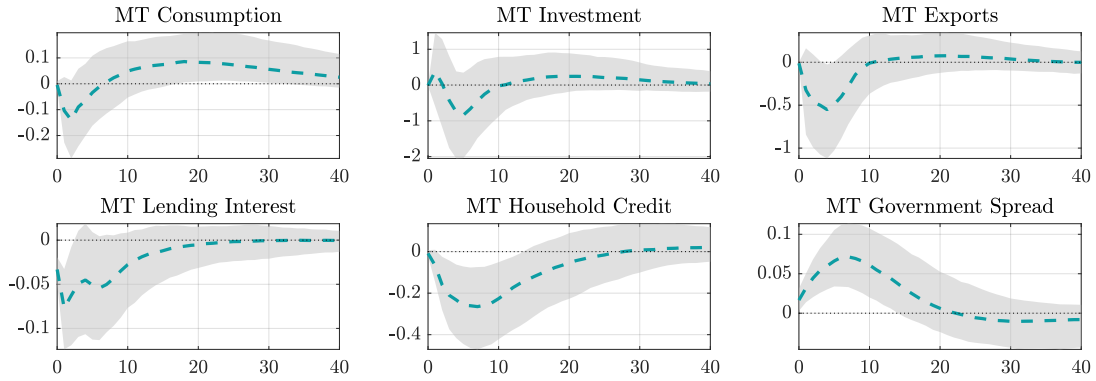


Figure 13: Additional IRFs to a financial stress shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area financial stress shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection.

### 4.3 Forecast error variance decomposition

To better understand the average relative importance of euro area shocks at different horizons, we show the Forecast Error Variance Decomposition (FEVD) of the structural shocks in Figure 14. This figure shows the share of the unexpected fluctuations of the endogenous variables around their long term trend. A significant proportion of euro area GDP, inflation and the shadow rate is driven by aggregate demand shocks, at both short and long-term horizons. Aggregate productivity and commodity supply shocks are the next most important drivers of euro area GDP and prices. Financial shocks, besides driving most of the fluctuations in the financial stress indicator, played an important role in shaping developments in the ECB shadow rate,

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same shock in the following subsections, need to be treated with some caution as they are representative of an *average* response. More precisely, financial stress shocks are known to exert highly non-linear effects on the economy, for example, with a higher GDP response when stress conditions are already high or with an asymmetric response between positive and negative shocks.

<sup>17</sup>For the sake of space we do not depict the response of the Maltese financial condition index. The latter, by construction, negatively and heavily loads on the CISS index and therefore, not surprisingly, shows a negative hump-shaped behaviour in response to a financial stress shock in the euro area thus indicating a worsening in the financial conditions in Malta.

particularly at longer horizons. Through this we further confirm that our model captures both conventional and unconventional monetary policy shocks.

Among the euro area shocks, aggregate demand and financial shocks were, on average, the highest contributors to movements in Maltese GDP growth, with roughly equal impact on GDP within a year of the shock, while productivity shocks were the next most important sources of variation. Over longer-term horizons, however, aggregate demand shocks in the euro area had the highest contribution to movements in GDP growth in Malta. Meanwhile, commodity price and monetary policy shocks played a weaker role in driving domestic GDP. On the other hand, euro area demand and, to a lesser extent, monetary policy shocks were the strongest drivers of HICP inflation out of the five euro area shocks, with commodity shocks ranking as the third most important. Collectively, the five euro area shocks accounted for about a third of fluctuations in Malta’s GDP growth and inflation rates at a ten-year horizon.

#### 4.4 Decomposing recent economic history

Using the estimated structural VAR, we decompose the business cycle component of euro area and Maltese variables into the contribution from the structural shocks we identify as their drivers. Figure 15 shows the impact of euro area shocks on the fluctuations of real GDP growth and HICP inflation for the euro area and Malta, as well as the shadow policy rate. The fluctuations of these variables are around their long term trend, which is implicitly estimated within the VAR. Focusing on the euro area variables first, we show that the financial shock played a major role in driving euro area GDP both before, during and after the financial crisis of 2008. These findings are in line with the estimates derived through the lens of the ECB’s New Area Wide Model II, a DSGE model with rich macro-financial linkages (Coenen et al., 2018). That model also assigns a lot of importance to financial shocks as driving factors over the same period. In our model financial shocks contributed positively to GDP growth and HICP inflation, driving the ECB policy rate up. Indeed, our estimates imply that favourable financial shocks in the period 2005–2008 contributed to keep the ECB policy rate about 100 basis points higher, while at the peak of the Great Recession they contributed to the downward pressure on GDP growth by 2%. Demand and supply shocks were also key drivers of euro area variables, as expected, with demand shocks in particular driving a substantial share of the movements in the ECB shadow rate. With specific reference to the growth of real GDP in the upper left panel of Figure 15, demand shocks are estimated to contribute negatively during the Great Recession, to contribute positively during the partial recovery of 2010 and 2011 and then, to again exert a downward pressure during the economic slowdown between 2012 and 2014.

The lower left panel of Figure 15 shows how the model is particularly precise in estimating the sources of fluctuations of the euro area shadow rate and, therefore, in explaining to which economic developments the ECB has been responding to when implementing its monetary policies. The years preceding the Great Recession are characterised by an increase in interest rates driven by the evidence of strong demand-driven growth but also by the build-up of financial imbalances. The picture, therefore, clearly shows how at that time conventional monetary policies were used as a tool to respond to such imbalances in what was then referred to as ‘leaning against the wind’ which is a precautionary move to curb the possible arise of future turmoil on

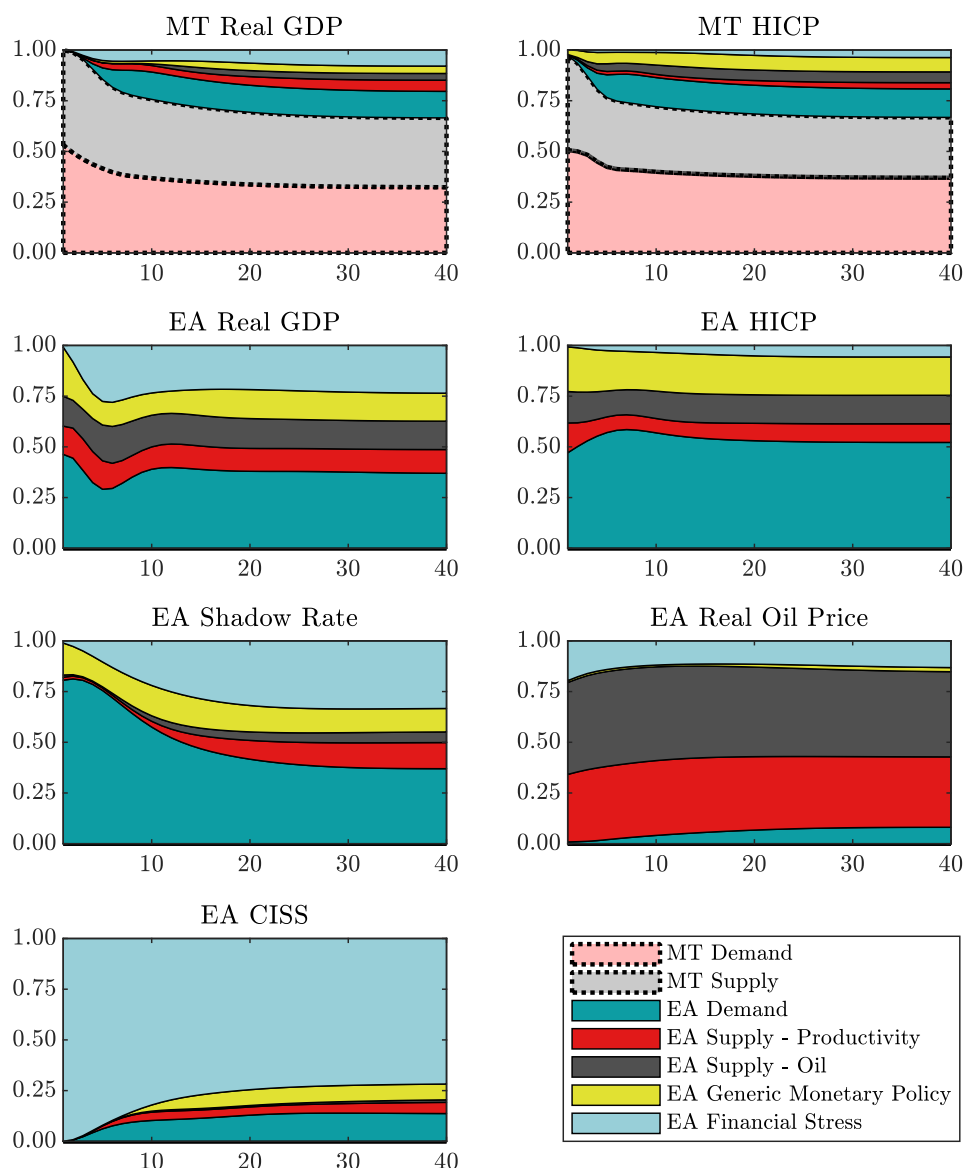


Figure 14: Forecast error variance decomposition

Notes: The figure shows the forecast error variance decomposition of the variables entering the VAR over a horizon of up to 40 quarters and obtained by means of the median draw across the identified sets. The coloured areas represent the portion of forecast error variance explained by the identified shocks at each horizon.

the financial markets. The picture also captures how, in 2008, the ECB increased its reference rate as a reaction to oil price developments that brought headline inflation to 4%. Such a decision was then immediately reversed as soon as the Great Recession started to unfold and the ZLB was reached. It also explains how the two policy rate increases in April and July 2011 were driven by evidence in recovery in demand and economic growth slightly above 2%. Such policy rate hikes were subsequently reverted and, in addition, accompanied by further expansionary unconventional monetary policies starting from 2012 (LTROs and APP extension) in response

to a weakening demand that eventually protracted till late 2017.

We now turn to our key question of interest: how important were the euro area shocks in driving recent business cycles in Malta? While all the euro area shocks were important drivers of economic activity, the financial shock is very prominent throughout most of the sample period. From 2005, the shock exerted upward pressure on euro area GDP growth, which also spilled over to the Maltese one. During the financial crisis of 2008-09, the shock significantly contributed to the decline in output in both the euro area and in Malta, the latter primarily through a big drop in export demand. Financial shocks continued to exert downward pressure on Maltese GDP up until the end of 2012, after which a period of calm was restored following the strong intervention of the ECB, partly through the promise of expansionary policies for an extended period of time and lifted economic activity (Rostagno et al., 2019, 2021). Once again, the favourable contribution to euro area GDP growth passed through to the Maltese economy, contributing to the rising GDP growth as from 2013 onward.

Supply shocks from the euro area, particularly commodity shocks, were also important drivers of HICP inflation in Malta, and the delayed pass-through from euro area to Maltese price pressures can be seen in the diagram, with the same dynamics for inflation in Malta as the euro area occurring with a slight delay. Demand shocks from the euro area also contributed to the Maltese business cycle. Despite contributing to the strong decline in euro area output following the financial crisis, these demand shocks did not transmit directly to lower economic activity in Malta. Rather, euro area demand shocks contributed most notably during the sovereign debt crisis some years later, and then again during the pick-up in the euro area more recently. Monetary policy shocks also contributed to the dynamics in Maltese inflation, especially in the periods after the crisis during which several non-standard measures were implemented.<sup>18</sup>

By construction, Maltese shocks play no role in driving euro area GDP and inflation.<sup>19</sup> The contributions of euro area shocks became more significant close to Malta's EU accession, and continued to rise following euro adoption, as expected given the transition to full economic and monetary integration.<sup>20</sup>

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<sup>18</sup>Due to the broad identification of monetary policy shocks that we employ in this paper, we cannot delve into deeper discussions of which and whether any one particular non-standard measure had greater influence than the rest. We leave this discussion for future research.

<sup>19</sup>In Appendix D we show also a full decomposition of the Maltese fluctuations obtained by including the contribution of the Maltese demand and supply shocks.

<sup>20</sup>As part of our robustness tests, we re-estimate the VAR using data starting from 2001Q1 in order to better capture the effect of euro area shocks prior to EU accession. The results shown in Appendix D confirm that the magnitudes of the contributions become larger as the Maltese economy became more integrated with the EU.



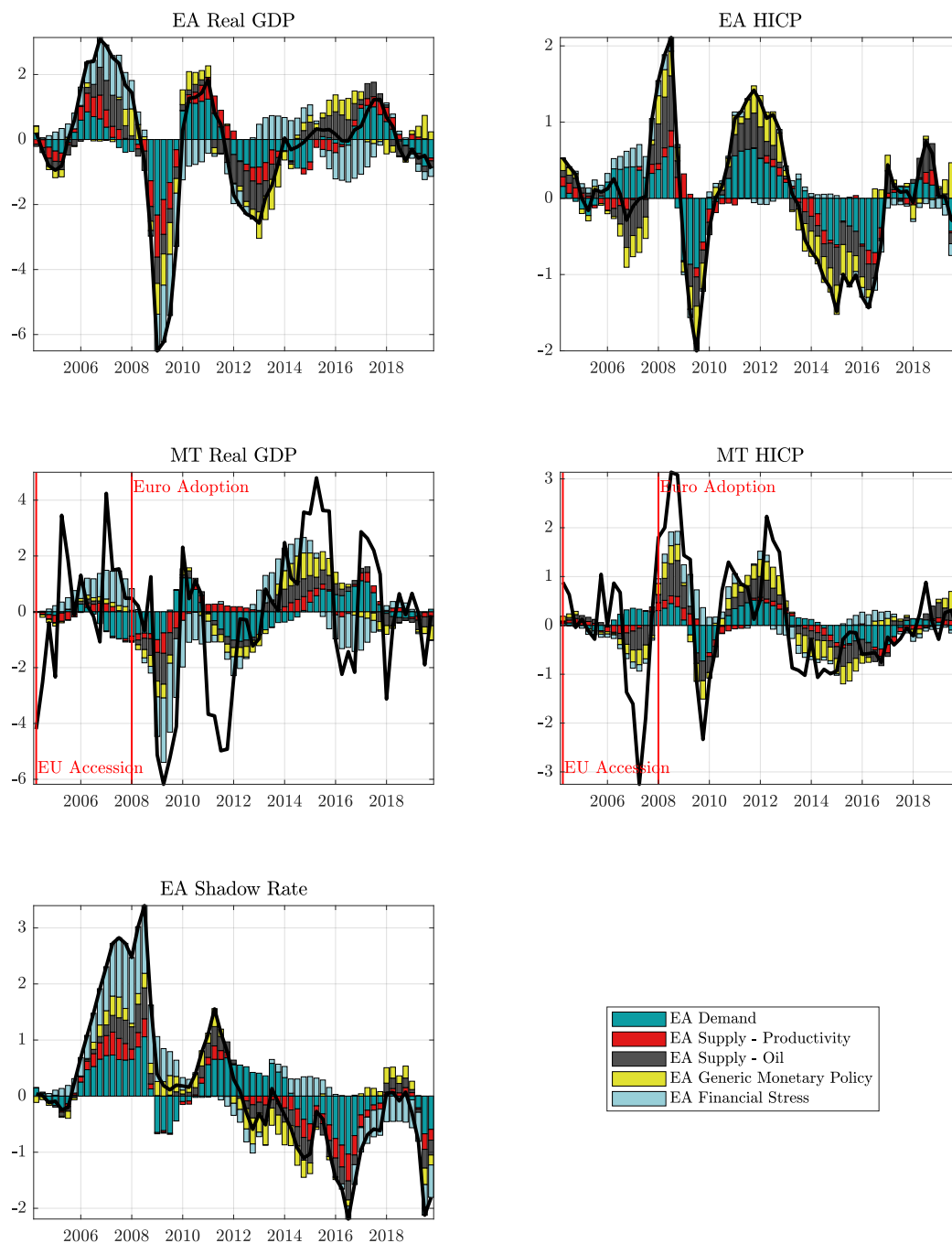


Figure 15: Historical decomposition - contribution of the identified shocks

Notes: The figure shows the contribution of the identified structural shocks hitting the euro area (coloured bars) and affecting the fluctuations of the Maltese and euro area real GDP growth and HICP inflation rates, and the shadow rate. The actual data minus the contribution of the VAR-identified trend components is in black. The shadow rate is in percentage points, while all other variables in percentage. The calculation of the contribution of the identified shocks is based on the mean of the distribution of all historical decompositions obtained from the retained draws.

## 5 A euro area aggregate demand shock

We estimate another version of the VAR where we identify only one shock, an aggregate demand shock, which captures the effect of the euro area demand and Maltese demand shocks jointly. The identifying restrictions are that the shock raises euro area GDP growth, euro area inflation, the ECB shadow rate, Maltese GDP growth and Maltese inflation on impact. The response of oil prices is unrestricted, while the CISS index is restricted to a zero impact response. The responses of the endogenous variables, both euro area and Maltese, are also of interest to policymakers.

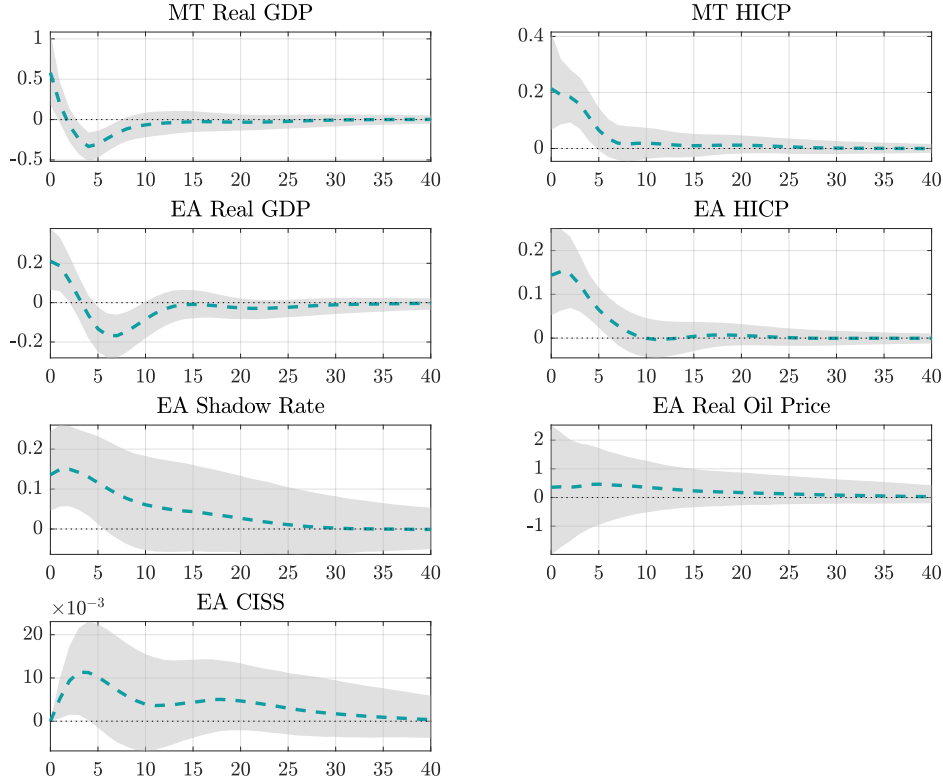


Figure 16: IRFs to a euro area *aggregate* demand shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area wide aggregate demand shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

As in the case of a euro area demand shock, an *aggregate* shock also raises euro area GDP growth and inflation on impact, which is accompanied by an increase in the policy rate (Figure 16). The shock also leads to an immediate increase in Maltese GDP and price growth, which we refer to as the *full effect* of the shock. Therefore, while the *direct effect* of the shock leads to a boom in the Maltese economy, the *transmission* of this shock (the indirect effect, measured through the euro area demand shock) leads to slower output growth and higher prices through competitiveness channels. The response of Maltese variables in Figure 16 show the combined

impact of the direct effect and the transmission of this shock.<sup>21</sup>

We also show in Appendix E.1 that an aggregate demand shock leads to increased economic activity across a lot of sectors, as growth in consumption, investment and exports rises on impact. However the effects are relatively short-lived, likely due to price pressures dampening demand after a few quarters, as reflected in the reversal of foreign demand growth about a year into the shock.

## 6 Controlling for global factors

The shocks that we estimate could include elements that are both specific to the euro area but also be more global in nature. Although our results are still informative about the dynamics of the euro area and Maltese economies in the wake of these shocks, we estimate another version of our SVAR after including US output, prices and a measure of financial stress for the US economy. These variables proxy global dynamics and therefore to some extent control for global shocks.<sup>22</sup>

The implementation details are discussed in Appendix E.2. Figure 17 shows in red the responses compared with those obtained in Section 4 in grey. For comparability both sets of IRFs are calculated as a response to a one-standard deviation shock. Overall, the responses appear broadly similar to those in Section 4, both for Malta and for the euro area, but some differences arise when controlling for US economic activity. First, the credible regions tend to be wider, indicating higher uncertainty in the estimates which cross the zero line more often, suggesting how the effect of the shocks is softened. Second, with regard to the financial stress shock, it is interesting to notice how the negative effect on the euro area GDP growth is dampened significantly. This provides evidence that a significant element of the euro area financial shock has a global component. Once the financial stress shock is purged of this, the negative effect on economic activity is reduced. Third, the peak effect of an euro area demand shock on the Maltese variables is reduced. Once the demand shock becomes more euro area-specific, the peak responses of Maltese GDP and inflation stand at around -0.26% from -0.4% and 0.09% from 0.18%, respectively. However, the key results from the benchmark VAR remain largely unchanged.

Finally, in Appendix E.2 we also document slight changes in the forecast error variance decomposition of the Maltese economy in response to the identified shocks. The long-run variance decompositions for the two Maltese variables moves from 33% to 28% for the real GDP growth and from 33% to 36% for the HICP inflation. This result demonstrates how, once global factors are taken into account, Malta's GDP becomes slightly less influenced by euro area fluctuations while, conversely, inflation becomes more sensitive to the latter.

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<sup>21</sup>In fact, we check and confirm that the IRFs for Maltese variables can be qualitatively approximated very well as the sum of the IRFs under the euro area and Maltese demand shocks from the benchmark VAR estimates.

<sup>22</sup>Data sources and transformations are discussed in Appendix A

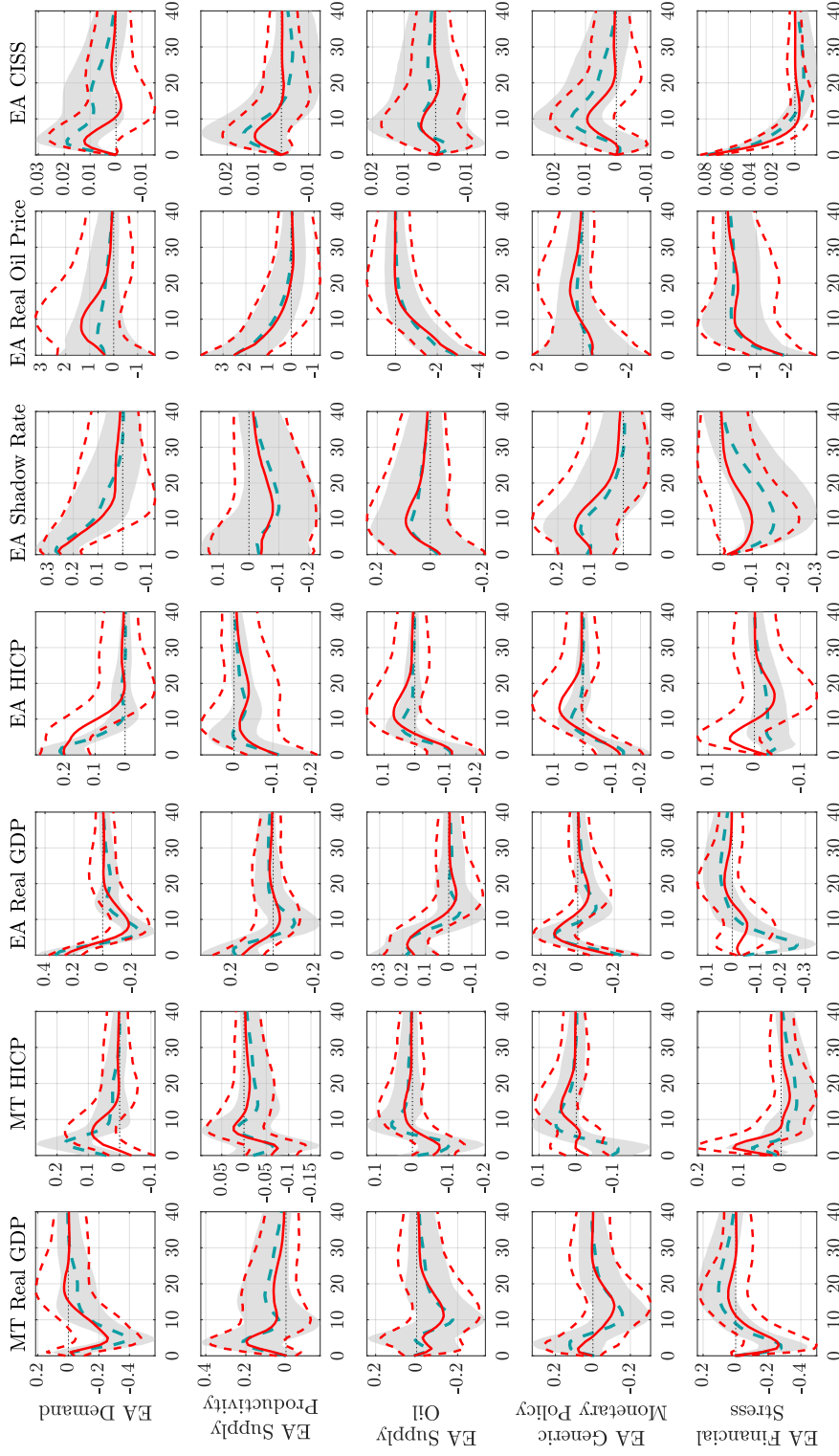


Figure 17: Impulses responses with and without US variables

Notes: The figure shows the median responses across the identified sets and the 68% credible bands, to a 1-standard deviation shock in the baseline model. The baseline response are characterised by black dashed lines and grey shaded areas while those stemming from the model in E.1 in red. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations. Each row shows the effect of each identified shock on the endogenous variable which are organised by column.

## 7 Conclusion

In this article we document the spillover and relative importance of euro area shocks to the Maltese economy. We develop a two-block structural VAR model estimated using Bayesian methods and identified using a mix of zero and sign restrictions. We show that the identified structural shocks and their contributions to the fluctuations of the euro area and Maltese economy line up with a series of events. Our identification strategy allows us to identify separately the effect of a shock via its direct effect on the Maltese economy, as well as via its transmission through the euro area.

We also document that financial shocks around the Great Recession and later during the euro area debt crisis were important drivers not only of euro area output but also had sizeable effects on Maltese GDP growth. In addition, the results indicate how a competitiveness channel has an important bearing on Maltese output. Monetary policy shocks also had a considerable impact on Maltese output and inflation. In the long run, euro area shocks collectively drive around a third of the fluctuations of GDP and consumer price growth in Malta, reflecting the integration into economic and monetary union.

This work therefore serves an important contribution as it quantifies the spillovers of the euro area economy to the Maltese economy, which were previously undocumented. Future work will focus on a more detailed investigation of the other shocks in the model, especially monetary policy shocks, to disentangle the specific role and transmission of conventional and unconventional monetary policies in the Maltese economy.

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## Appendix A Data

This appendix describes the data series and transformations used in this work. Unless otherwise indicated, the data series are collected at quarterly frequency.

### A.1 Maltese variables

**Real gross domestic product:** year-on-year growth rate of real gross domestic product. Source: National statistics Office (NSO).

**HICP inflation:** year-on-year growth rate of the quarterly measure of the overall Harmonised Index of Consumer Prices. The quarterly measure was obtained by averaging the three monthly observations composing each quarter. Source: NSO/Eurostat.

**Core HICP inflation:** year-on-year growth rate of the quarterly measure of the harmonised index of consumer prices that excludes energy and food. The quarterly measure was obtained by averaging the three monthly observations composing each quarter. Source: NSO/Eurostat.

**Foreign demand:** year-on-year growth rate of the index of foreign demand for Malta. Source: ECB Technical Assumptions (2020Q3 data vintage).

**Real total exports:** year-on-year growth rate of real total exports. The latter have been calculated as the difference between total nominal exports and special purpose entities nominal exports divided by the exports deflator. Source: Central Bank of Malta (CBM).

**Real exports to the euro area:** year-on-year growth rate of real exports to the euro area. The latter have been calculated as nominal exports to the euro area divided by the exports deflator. Source: Eurostat and CBM.

**Real consumption:** year-on-year growth rate of consumption divided by consumption deflator. Source: NSO and CBM.

**Real investment:** year-on-year growth rate of investment divided by investment deflator. Source: NSO and CBM.

**Total factor productivity:** year-on-year growth rate of total factor productivity. Source: CBM.

**Labour productivity:** year-on-year growth rate of real gross domestic product divided by total number of hours worked. Source: CBM.

**Financial conditions index:** year-on-year growth rate of the index of financial conditions for Malta developed in [Borg and Micallef \(2018\)](#). Source: CBM.

**Real long-term interest rate:** 10-year government bond yield for Malta minus the year-on-year growth rate of the retail price index. The latter measure has been transformed into quarterly frequency by averaging the three monthly observations composing each quarter. Source: NSO and CBM.

**Sovereign spread:** 10-year government bond yield for Malta minus 10-year German Bund yield. Source: CBM and ECB SDW.

**Real lending interest rate:** nominal household lending rate minus the growth rate of the retail price index. The latter measure has been transformed into quarterly frequency by averaging the three monthly observations composing each quarter. Source: NSO and CBM.

**Real deposit interest rate:** nominal deposit rate minus the year-on-year growth rate of the retail price index. The latter measure has been transformed into quarterly frequency by averaging the three monthly observations composing each quarter. Source: NSO and CBM.

**Real household credit:** year-on-year growth rate of nominal household credit divided by consumption deflator. Source: NSO and CBM.

## A.2 Euro area variables

**Real gross domestic product:** year-on-year growth rate of gross domestic product at market prices (Euro area 19) divided by gross domestic product deflator at market prices (Euro area 19). Source: European Central Bank Statistical Data Warehouse (ECB SDW).

**HICP inflation:** year-on-year growth rate of the quarterly measure of the overall Harmonised Index of Consumer Prices. The quarterly measure was obtained by averaging the three monthly observations composing each quarter. Source: ECB SDW/Eurostat.

**Shadow rate:** Quarterly measure of the Krippner (2020) shadow rate for the euro area. The quarterly measure was obtained by averaging the three monthly observations composing each quarter. Source: Leo Krippner's website <https://www.ljkmfa.com/>.

**Real oil price:** Seasonally adjusted oil price in EUR (oil price in USD divided by USD to EUR nominal exchange rate) divided by a seasonally adjusted measure of the harmonised index of consumer prices that excludes energy only. The quarterly measure of this HICP index was obtained by averaging the three monthly observations composing each quarter. Source: Central Bank of Malta data and ECB SDW/Eurostat.

**Composite index of systemic stress:** Quarterly measure of the new composite indicator of systemic stress for the euro area (Chavleishvili and Kremer, 2021). The quarterly measure was obtained by averaging the three monthly observations composing each quarter. Source: ECB SDW.

## A.3 USA variables

**Real gross domestic product:** year-on-year growth rate of real gross domestic product at constant prices, billions of chained 2012 Dollars. Source: Federal Reserve Bank of St. Louis - Federal Reserve Economic Data (FRED).

**HICP inflation:** year-on-year growth rate of the quarterly measure of the overall Harmonised Index of Consumer Prices for all items for the United States (Index 2015=100). The quarterly measure was obtained by averaging the three monthly observations composing each quarter.

Source: FRED.

**Composite index of systemic stress:** Quarterly measure of the new composite indicator of systemic stress for the United states ([Chavleishvili and Kremer, 2021](#)). The quarterly measure was obtained by averaging the three monthly observations composing each quarter. Source: ECB SDW.

## Appendix B Technical details

### B.1 Choice of the $\lambda_5$ hyperparameter

This appendix shows how the value of 1.5 is the one that minimises the deviance information criterion when considering a fine grid of possible values for  $\lambda_5$  that goes from 1 to 2.

Table 2: Choice of the  $\lambda_5$  hyperparameter

$\lambda_5$	1.0	1.1	1.2	1.3	1.4	<b>1.5</b>	1.6	1.7	1.8	1.9	2.0
DIC	290.79	290.94	290.22	289.87	289.82	<b>287.91</b>	289.87	289.54	288.88	288.08	289.90

Note: DIC refers to the Deviance Information Criterion

### B.2 Convergence diagnostics

This appendix shows the convergence diagnostics relative to the model presented in Section 3. As suggested in ([Primiceri, 2005](#)), in order to assess the satisfactory performance of the algorithm, the 20th-order autocorrelation of the retained draws is employed. The red vertical lines separate the autocorrelations of the intercept and slope coefficients in 1, i.e.,  $A$  and  $B$ , from those of the variance-covariance matrix  $\Sigma$ .

Figure B.1 shows how all the autocorrelations of the retained draws lie within the  $[-0.2, 0.2]$  interval. Independently of the high dimensionality of the model, the algorithm performs in a satisfactory way and the draws are nearly independent. As such, the latter can be used to conduct meaningful inference.

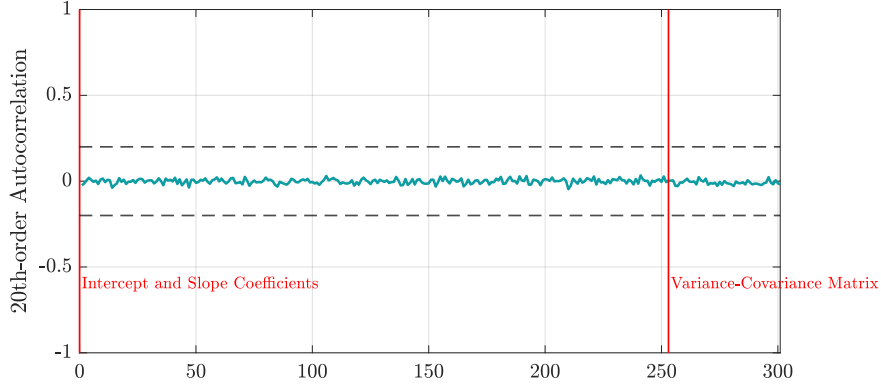


Figure B.1: 20<sup>th</sup> order autocorrelation of the retained draws

### B.3 The algorithm implementing the zero and sign restrictions

In order to trace the propagation of the shocks identified in Table 1 we implement the following procedure. Recall the link between reduced form errors and structural shocks  $U_t = A_0 V_t$  and the restrictions in table 1. This means that the relation in 3 can be further expanded as:

$$\underbrace{\begin{bmatrix} \underbrace{\begin{bmatrix} u_{t,RGDP}^{MT} \\ u_{t,HICP}^{MT} \end{bmatrix}}_{U_t^{MT}} \\ \underbrace{\begin{bmatrix} u_{t,RGDP}^{EA} \\ u_{t,HICP}^{EA} \\ u_{t,Interest}^{EA} \\ u_{t,Oil}^{EA} \\ u_{t,CISS}^{EA} \end{bmatrix}}_{U_t^{EA}} \end{bmatrix}}_{U_t} = \underbrace{\begin{bmatrix} \underbrace{\begin{bmatrix} a_{0,1,1}^{MT} & a_{0,1,2}^{MT} \\ a_{0,2,1}^{MT} & a_{0,2,2}^{MT} \end{bmatrix}}_{A_0^{MT}} & \begin{bmatrix} ? \end{bmatrix}_{(2 \times 5)} \\ [0]_{(5 \times 2)} & \underbrace{\begin{bmatrix} \begin{bmatrix} a_{0,1,1}^{EA} & a_{0,1,2}^{EA} & a_{0,1,3}^{EA} & a_{0,1,4}^{EA} \\ a_{0,2,1}^{EA} & a_{0,2,2}^{EA} & a_{0,2,3}^{EA} & a_{0,2,4}^{EA} \\ a_{0,3,1}^{EA} & ? & ? & a_{0,3,4}^{EA} \\ ? & a_{0,4,2}^{EA} & a_{0,4,3}^{EA} & ? \end{bmatrix} & \begin{bmatrix} ? \end{bmatrix}_{(4 \times 1)} \\ \underbrace{\begin{bmatrix} ? \end{bmatrix}_{(1 \times 4)}}_{A_0^{EA}} & \begin{bmatrix} a_0^{5,5} \end{bmatrix} \end{bmatrix}}_{A_0} \end{bmatrix} \underbrace{\begin{bmatrix} \underbrace{\begin{bmatrix} v_{t,D}^{MT} \\ v_{t,S}^{MT} \end{bmatrix}}_{V_t^{MT}} \\ \underbrace{\begin{bmatrix} v_{t,D}^{EA} \\ v_{t,S}^{EA} \\ v_{t,Oil}^{EA} \\ v_{t,MP}^{EA} \\ v_{t,FIN}^{EA} \end{bmatrix}}_{V_t^{EA}} \end{bmatrix}}_{V_t}$$

In order to obtain a factorisation satisfying the equation above we implement the following algorithm once past the burn-in stage:<sup>23</sup>

1. Draw  $\Sigma$  from its posterior distribution in (3.2) and compute its Cholesky decomposition  $P$  such that  $PP' = \Sigma$
2. Draw  $X_{MT} \sim N(0, I_{N_{MT}})$  and get  $Q_{MT}$  such that  $Q_{MT}R_{MT} = X_{MT}$ , i.e., an orthogonal matrix  $Q_{MT}$  that satisfies the QR decomposition of  $X_{MT}$  with the diagonal of  $R_{MT}$

<sup>23</sup>This algorithm can be seen as an extension of that developed in Uhlig (2005) and Rubio-Ramirez et al. (2010). For similar applications see also Jarocinski (2010), Gambacorta et al. (2014), Perez Forero (2015). The formalisation of the problem into such a block-diagonal version allows not to necessarily use the more computationally intensive algorithm developed in Arias et al. (2018). The results based on the latter do not present major differences and are available upon request.

normalised to be positive. The matrix  $Q_{MT}$  has the uniform Haar measure.

3. Draw  $X_{EA_1} \sim N(0, I_{N^{EA_1-1}})$  and get  $Q_{EA_1}$  such that  $Q_{EA_1} R_{EA_1} = X_{EA_1}$ , i.e., an orthogonal matrix  $Q_{EA_1}$  that satisfies the QR decomposition of  $X_{EA_1}$  with the diagonal of  $R_{EA_1}$  normalised to be positive. The matrix  $Q_{EA_1}$  has the uniform Haar measure.
4. Draw  $X_{EA_2} \sim N(0, I_1)$  and get  $Q_{EA_2}$  such that  $Q_{EA_2} R_{EA_2} = X_{EA_2}$ , i.e., an orthogonal matrix  $Q_{EA_2}$  that satisfies the QR decomposition of  $X_{EA_2}$  with the diagonal of  $R_{EA_2}$  normalised to be positive. The matrix  $Q_{EA_2}$  has the uniform Haar measure.
5. Build the  $N \times N$  matrix:

$$Q_{(N \times N)} = \begin{bmatrix} Q_{MT} & [0]_{(2 \times 4)} & [0]_{(2 \times 1)} \\ [0]_{(4 \times 2)} & Q_{EA_1} & [0]_{(4 \times 1)} \\ [0]_{(1 \times 2)} & [0]_{(1 \times 4)} & Q_{EA_2} \end{bmatrix}$$

6. Obtain the candidate draw  $A_0 = QP$ . If  $A_0$  satisfies the restrictions in table 1 then keep it otherwise discard it and return to step 1.

## Appendix C IRF decomposition and counterfactual IRFs

This appendix describes how to derive the IRF decomposition and the counterfactual IRFs presented in Section 4 following the method of [Kilian and Lewis \(2011\)](#).

### C.1 IRF decomposition

Consider the model in 1

$$Y_t = A + B_1 Y_{t-1} + \dots + B_L Y_{t-L} + A_0 V_t$$

premultiply both sides of the equation by  $A_0^{-1}$  and ignore the intercept as it does not play any role in the shock transmission

$$A_0^{-1} Y_t = A_0^{-1} B_1 Y_{t-1} + \dots + A_0^{-1} B_L Y_{t-L} + V_t$$

Then add  $Y_t$  on both sides and rearrange in order to have

$$Y_t = (I - A_0^{-1}) Y_t + A_0^{-1} B_1 Y_{t-1} + \dots + A_0^{-1} B_L Y_{t-L} + V_t$$

and collect the structural slope coefficients in such a way to define

$$\mathcal{B} = [(I - A_0^{-1}), A_0^{-1} B_1, \dots, A_0^{-1} B_L]$$

The contribution of variable  $i$  to the response of the Maltese GDP  $y_{MT}$  at horizon  $h$  to a euro area aggregate demand shock  $S_{AD}$  taking place at time  $t = 0$  is given by:

$$d_{y_{MT},i,h} = \sum_{m=0}^{\min(L,h)} \mathcal{B}_{y_{MT},mN+i} \theta_{i,S_D,h-m} \quad h = 0, 1, 2, \dots; \quad i = 1, \dots, N$$

where  $\theta_{i,S_D,h-m}$  is the  $i, S_D$  element of the  $N \times N$  impulse coefficient matrix  $\theta$  at horizon  $h-m$  as defined in [Luetkepohl \(2011\)](#).

## C.2 Counterfactual IRFs

In order to build a counterfactual in which the response of  $y_{MT}$  to a euro area demand shock  $S_D$  is purged of the effect of the Maltese inflation  $\pi_{MT}$  it is necessary to feed the model with a sequence of hypothetical shocks to  $y_{MT}$  that exactly offset the contemporaneous and lagged effects of including the Maltese inflation in the Maltese GDP reaction function. The sequence of shocks is obtained as:

$$\epsilon_{y_{MT},h} = -\mathcal{B}_{y_{MT},S_D} x_{S_D,h} - \sum_{m=1}^{\min(L,h)} \mathcal{B}_{y_{MT},mN+S_{EA}} z_{S_{EA},h-m} \quad h = 0, 1, 2, \dots$$

where  $x_{i,0}$ , with  $i = 1, \dots, N$ , denotes the contemporaneous response of variable  $i$  to the euro area aggregate demand shock. The counterfactual impact response of variable  $i$  after the shock took place is given by:

$$z_{i,0} = x_{i,0} + \frac{\theta_{i,y_{MT},0} \epsilon_{y_{MT},0}}{\sigma_{S_D}}$$

where  $\sigma_{S_D}$  is the standard deviation of the aggregate shock. It follows that it is possible to recursively generate the horizon  $h > 0$  values of  $x_{i,h}$

$$x_{i,h} = \sum_{m=1}^{\min(L,h)} \sum_{j=1}^N \mathcal{B}_{i,mH+j} z_{i,h-m} + \sum_{j<i} \mathcal{B}_{i,j} x_{j,h} \quad j = 1, \dots, N$$

Finally, the values of  $x_{i,h}$  allow to recursively obtain the counterfactual responses  $z_{i,h}$  as follows:

$$z_{i,h} = x_{i,h} + \frac{\theta_{i,y_{MT},h} \epsilon_{y_{MT},h}}{\sigma_{y_{MT}}}$$

## Appendix D Additional figures

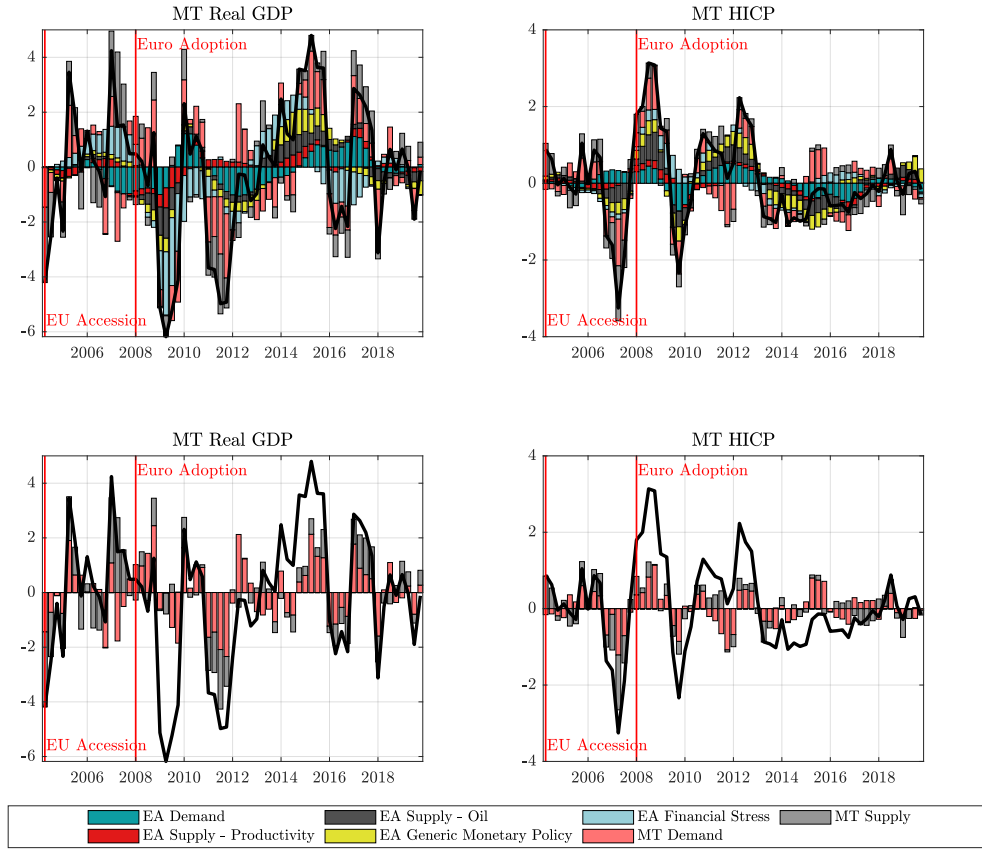


Figure D.1: Historical decomposition - contribution of the identified shocks

Notes: The figure shows the contribution of all the identified structural shocks (coloured bars) and affecting the fluctuations of the Maltese and euro area real GDP growth and HICP inflation rates. Specifically, the black dashed lines represent the actual data minus the contribution of the VAR-identified trend components. The calculation of the contribution of the identified shocks is based on the mean of the distribution of all historical decompositions obtained from the retained draws.

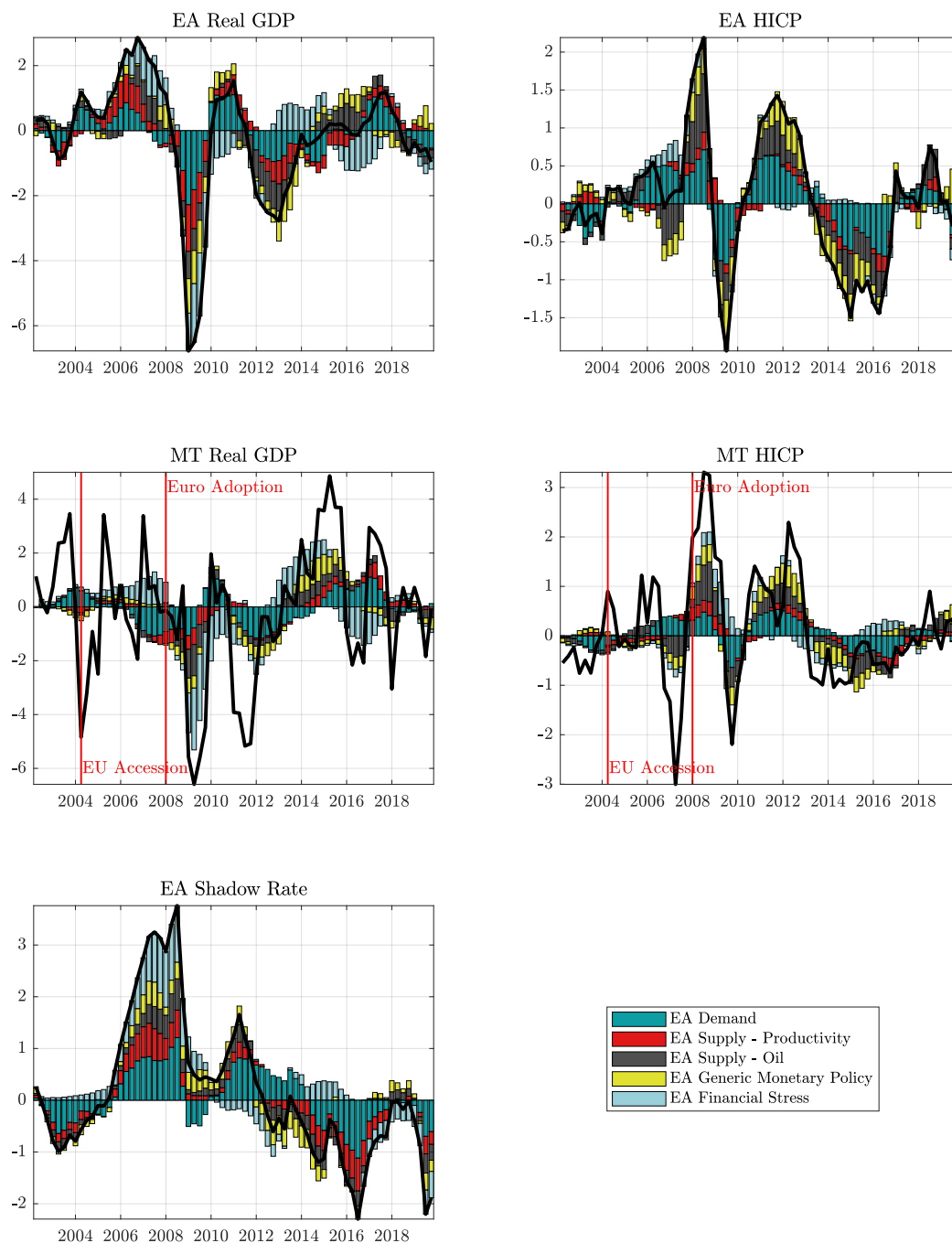


Figure D.2: Historical decomposition - contribution of the identified shocks (2001–2019)

Notes: The figure shows the contribution of the identified structural shocks hitting the euro area (coloured bars) and affecting the fluctuations of the Maltese and euro area real GDP growth and HICP inflation rates, and the shadow rate. Specifically, the black dashed lines represent the actual data minus the contribution of the VAR-identified trend components. The calculation of the contribution of the identified shocks is based on the mean of the distribution of all historical decompositions obtained from the retained draws.



## Appendix E Additional extensions

### E.1 A euro area wide aggregate demand shock

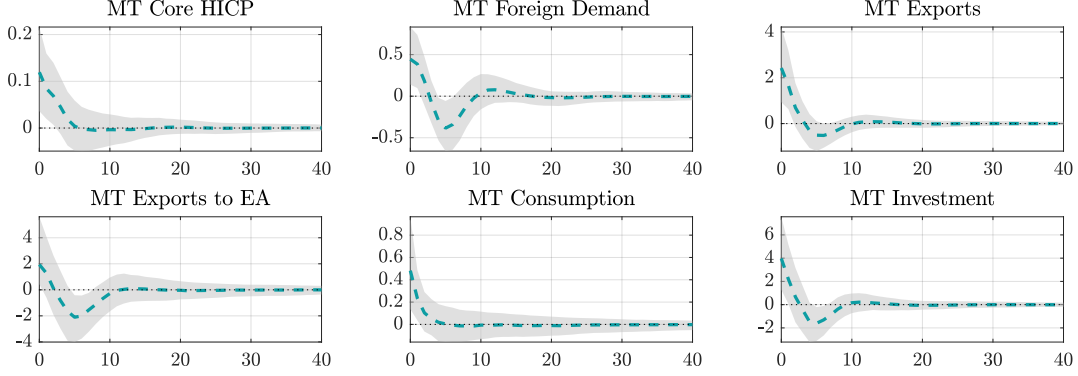


Figure E.1: Additional IRFs to the euro area aggregate demand shock

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area aggregate demand shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection.

### E.2 Adding US variables to the VAR

This appendix shows how the results in Section (4) change when we add exogenous variables related to the US economy to control for global activity. The model in 1 is now given by:

$$Y_t = A + \sum_{l=1}^L B_l Y_{t-l} + \sum_{l=1}^L C_l Z_{t-l} + U_t \quad (\text{E.1})$$

for  $t = 1, \dots, T$ . In (E.1)  $Z_{t-l}$ , with  $l = 1, \dots, L$ , are  $M \times 1$  vectors containing lagged values of the exogenous variables with the latter being US real GDP growth, HICP inflation and CISS index. Moreover, the  $N \times M$  matrices  $C_l$  contain the slope parameters associated with the US variables.

The setup outlined in Section 3 remains broadly unchanged with the only difference that a conjugate prior for the slopes in  $C_l$  is imposed in order to guarantee a certain degree of shrinkage.<sup>24</sup> By defining  $c$  each entry of the slope matrices, the prior is assumed to be normally-distributed, i.e.,  $p(c) \sim N(c_0, V_0)$ , and is imposed in a Minnesota-style way as follows:

$$c_{0,n,m,l} = 0 \quad \text{for any } n = 1, \dots, N \quad m = 1, \dots, M \quad l = 1, \dots, L \quad (\text{E.2})$$

where  $c_{0,n,m,l}$  refers to the prior mean of the  $l^{th}$  slope coefficient relative to the  $m^{th}$  US variable

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<sup>24</sup>The role of such a prior is of fundamental importance in this context as each equation in E.1 has now 51 regressors compared to a sample with time length equal to 63 (from 2004Q2 to 2019Q4). This model, therefore, estimates 406 parameters when considering all the equations in the autoregression as well as the variance-covariance matrix of the residuals.

in the  $n^{th}$  equation. The prior variances of the slope parameters are set in the following way:

$$H_{0,n,m,l} = \left( \frac{\widehat{\sigma}_n \lambda_1 \lambda_2 \lambda_6}{\widehat{\sigma}_j l^{\lambda_3}} \right)^2 \quad (\text{E.3})$$

where  $H_{0,n,m,l}$  refers to the prior variance of the  $l^{th}$  slope coefficient relative to the  $m^{th}$  variable in the  $n^{th}$  equation. The  $\lambda$  coefficients are set as in Section 3. The additional hyperparameter  $\lambda_6$  governs how relevant the US variables are in explaining the fluctuations of the Maltese and euro area ones. We set  $\lambda_6$  to 2.5 as this value minimises the deviance information criterion (Table 3).<sup>25</sup>

Table 3: Choice of the  $\lambda_6$  hyperparameter

$\lambda_6$	2.0	2.1	2.2	2.3	2.4	<b>2.5</b>	2.6	2.7	2.8	2.9	3.0
DIC	237.23	238.19	237.38	237.27	237.00	<b>236.86</b>	237.22	237.13	237.29	238.34	238.46

Note: DIC refers to the Deviance Information Criterion

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<sup>25</sup>The DIC associated with a tight prior ( $\lambda_6 = 0.01$ ) yields a DIC of 288.61 which is, not surprisingly, close to those found in Table 2. In addition, a very loose prior ( $\lambda_6 = 10^5$ ) raises the DIC to 308.07 thus indicating a worse fit.

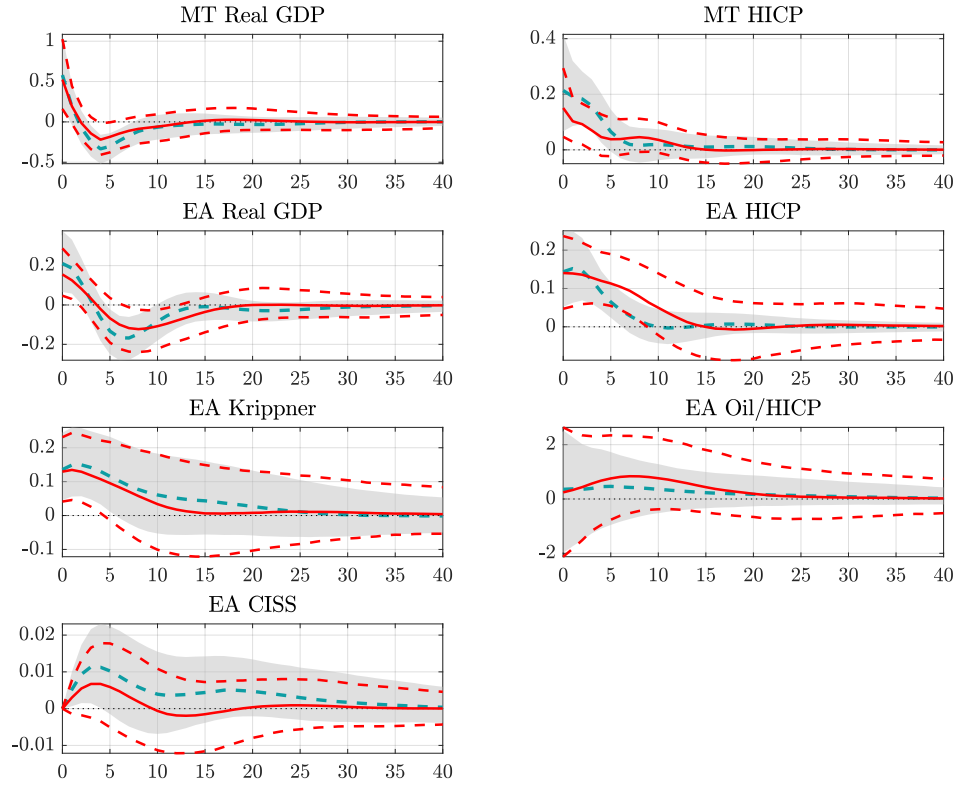


Figure E.2: IRFs to a euro area wide aggregate demand shock with US variables

Notes: The figure shows the median responses across the identified sets (dashed lines) and the 68% credible bands (shaded areas), to a 1-standard deviation euro area wide aggregate demand shock. Values on the horizontal axis are quarters following the shock. The values on the vertical axis are percentage point deviations from the baseline projection for all variables except for the oil price and the CISS, which are in absolute deviations.

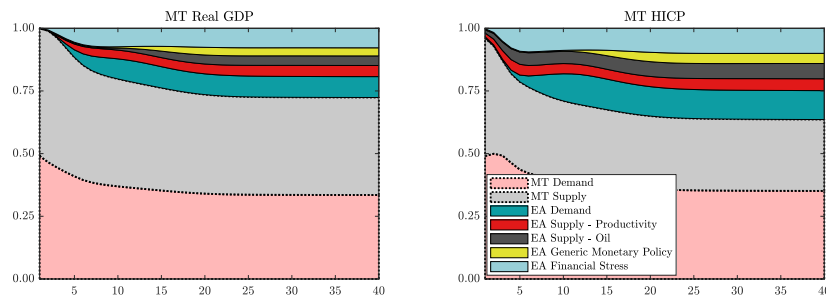


Figure E.3: Forecast error variance decomposition with US variables

Notes: The figure shows the forecast error variance decomposition of the Maltese variables entering the VAR described in E.1 over a horizon of up to 40 quarters and obtained by means of the median draw across the identified sets. The coloured areas represent the portion of forecast error variance explained by the identified shocks at each horizon.