

Ruisi, Germano

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## Global oil price swings: Has their effect on Malta changed over time?

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# CENTRAL BANK OF MALTA WORKING PAPER



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CENTRAL BANK OF MALTA

# Global oil price swings: Has their effect on Malta changed over time?\*

Germano Ruisi<sup>†</sup>

WP/04/2023

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## **Abstract**

This paper develops a two-block Structural Vector Autoregression featuring time-varying parameters and stochastic volatility to estimate the changing spillover of global oil shocks into the Maltese economy during the period that goes from January 2008 to March 2022. The model is estimated by using Bayesian methods and focuses on the effect on Maltese output and prices. The results evidence how Great Recession and COVID-19 pandemic are associated with higher inflation responsiveness. Notwithstanding, the response of energy inflation gradually declines and, as a consequence, the medium-term pass-through from international to domestic energy prices decreases from 1% to virtually zero in response to a shock rising real oil prices by 10%. Finally, the recent surge in global energy prices generated short-lived negative responses in domestic output as a result of the energy subsidies implemented by the Maltese government.

**JEL Classification:** C15, E31, E32, Q43

**Keywords:** Bayesian Structural VAR, time-varying parameters, stochastic volatility, block exogeneity, oil shocks, shock spillover.



# Contents

<b>1</b>	<b>Introduction</b>	<b>4</b>
<b>2</b>	<b>Related literature</b>	<b>6</b>
<b>3</b>	<b>Methodology</b>	<b>7</b>
3.1	A 2-country VAR with time-varying parameters and stochastic volatility . . . . .	7
3.2	Priors . . . . .	9
3.3	Estimation routine . . . . .	11
3.4	Identification strategy . . . . .	13
<b>4</b>	<b>Results</b>	<b>14</b>
4.1	A first look into time-variation . . . . .	14
4.2	Shock transmission into the Maltese economy . . . . .	17
4.3	Pass-through to domestic energy inflation . . . . .	22
4.4	Pass-through to other inflation rates . . . . .	24
4.5	The response of headline HICP inflation . . . . .	26
4.6	Decomposing recent headline inflation fluctuations . . . . .	27
<b>5</b>	<b>Conclusion</b>	<b>29</b>
	<b>Appendix A Data</b>	<b>34</b>
A.1	Maltese variables . . . . .	35
A.2	World variables . . . . .	35
A.3	Maltese HICP weights . . . . .	36
	<b>Appendix B Technical details</b>	<b>36</b>
B.1	Stochastic volatility details . . . . .	36
B.2	Convergence diagnostics . . . . .	37
B.3	The algorithm implementing the zero and sign restrictions . . . . .	38
	<b>Appendix C Response of the world economy to oil shocks</b>	<b>39</b>
	<b>Appendix D Additional results</b>	<b>40</b>
D.1	Response to a 10% oil shock . . . . .	40
D.2	Shipping disruption shocks . . . . .	41

# 1 Introduction

Over the last years the global economy was hit by several macroeconomic shocks of unprecedented magnitude. Above all, the unexpected outbreak of the COVID-19 pandemic and subsequent economic recovery produced an initial deep contraction and a subsequent robust rebound in world economic activity. As a consequence, the falling and then rising global economic outlook produced large swings in oil prices worldwide which influenced the speed of economic recovery especially in oil-importing countries.

The developments on the global oil markets are of high importance to Malta for a number of reasons. First, Malta is a net-oil importer and has been historically heavily dependent on the importation of a variety of fossil fuels, to the extent that almost the entirety of its electricity was produced by heavy fuel oil until 2017 while from liquefied natural gas (LNG) only afterwards. Second, the domestic demand of energy products has been surging as a result of the last decade of remarkable economic activity. Finally, retail energy prices in Malta (e.g., fuels, gas, electricity, etc.) are administered by the government which, over the decades, has been implementing a number of different policies that led to a different transmission of global prices into domestic retail ones.

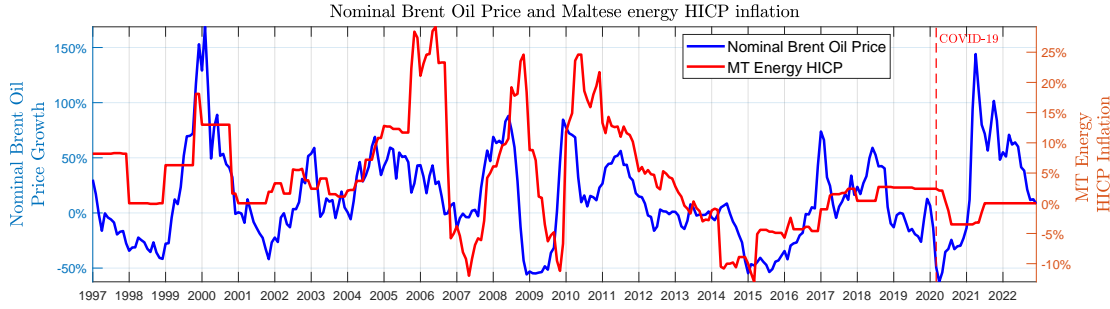


Figure 1: Growth rate of nominal Brent oil price in US dollars (left scale) and Maltese energy inflation (right scale)

Figure 1 aims at better clarify the last point. In blue it shows the year-on-year growth rate of nominal Brent oil price expressed in US dollars, while in red the annual Maltese energy inflation.<sup>1</sup> The chart evidences how, given the high reliance on heavy fuels, Maltese energy inflation appears to have a remarkable degree of comovement with the growth rate of the Brent oil price. Furthermore, the chart can provide a clue into the several energy policies implemented domestically. Specifically, the period that goes from 1997 to 2001 was characterised by more sporadic price changes than the period that stretches between 2002 and 2015. In particular, the figure evidences how during the latter period the government was more reactive to changes in global energy prices. To better clarify this point, in the years of the Great Recession Maltese energy prices showed a tendency to move with oil prices with a lag of a few months. As

<sup>1</sup>The Brent oil price shows the price of a blend of light-sweet crude oil extracted from the oilfields in the North Sea. Due to its low density and low content of sulphur, the blend is relatively easy to process into petroleum products and, as such, it is used as a benchmark for pricing crude oil in most of the Atlantic basin and internationally.

opposed to that, the period that goes from 2015 onwards was characterised by very sporadic changes in energy prices.<sup>2</sup> More strikingly, after the pandemic broke out in early 2020, the government introduced a number of energy subsidies in order to shelter domestic energy prices from large swings in the global markets. Remarkably, the Maltese government has been keeping retail energy prices fixed since July 2020 with the aim of sustaining the economy through the turbulent pandemic period and subsequent economic recovery.

The implementation of such policies did not only affect energy inflation but the overall one. As shown in [Ruisi \(2022\)](#), the effect of changing energy prices produces two possible effects on Maltese headline inflation: on the one hand a direct effect of increased energy prices, while on the other hand an indirect one caused by the spillover of higher energy prices into other categories of the consumption basket.

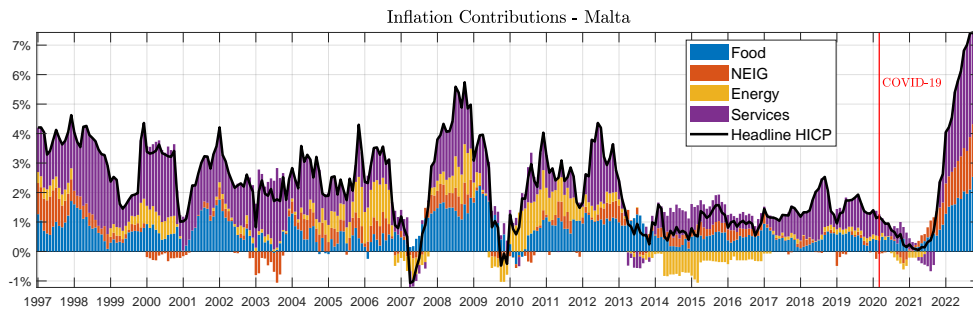


Figure 2: Maltese headline inflation (black solid line) and contributions of the four main sub-indices (coloured bars): food, non-energy industrial goods, energy and services

Figure 2 depicts the Maltese annual headline inflation and decomposes it into contributions of the four main sub-indices: food, non-energy industrial goods, energy and services. While throughout most of the period considered energy inflation appears to relevantly contribute to the fluctuation of the headline index, after the pandemic broke out such a contribution becomes first negligible and then null. Despite this, and despite the implementation of energy subsidies, both headline inflation and its three other sub-indices experienced a sizeable increase in response to the recent oil price swings.

The aim of this study is to improve upon the work carried out in [Ruisi \(2022\)](#). From a methodological standpoint, this work provides the Central Bank of Malta with a tool suitable to assess the evolving spillover of external shocks into the Maltese economy: a 2-country vector autoregressive model featuring time-varying parameters and stochastic volatility. The framework will prove useful in taking account of the continuous structural changes that have been taking place in the domestic economy. From a policy perspective, it aims at deepening the knowledge of the effect of global oil shocks into Malta. The two goals are jointly reached mainly

<sup>2</sup>The Malta-Sicily interconnector that became operational in March 2015 played a remarkable role in further stabilising the cost of energy. The submarine cable linked Malta to the European grid and facilitated the import and export of electricity with the Italian power market. As a result, a smoother matching between demand and supply was allowed.

by comparing most of the new key results with the time-invariant case in [Ruisi \(2022\)](#).<sup>3</sup>

The methodological contribution introduced in this paper allows to more properly gauge the government's response to oil shocks by acknowledging that its energy policies have been differing over time. As such, it is possible to detect how domestic energy prices have responded to changes in global oil prices and how, consequently, these had a time-varying effect on the four main sub-indices in the consumption bundle: food, non-energy industrial goods, energy and services.

The main takeaways are three. First, a certain degree of time-variation is detected in the whole system and, unsurprisingly, this is particularly evident in the case of domestic energy prices. Second, Maltese energy inflation response appears to become flatter over time while the responses of food and services inflation rates appear to be more pronounced in conjunction with two periods of higher volatility on the global oil markets: the Great Recession and the COVID-19 pandemic. Third, the recessionary effect produced by the identified oil shock appears to be longer lived in the 2008-2010 period than in the 2020-2022 one, the former characterised by more frequent changes in domestic energy prices in line with international ones.

The rest of this work is organised as follows. Section 2 outlines the main strands of literature this paper is related to. Subsequently, section 3 describes the modelling effort. In detail, it explains how time-variation in both slopes and volatilities is modelled, it provides an overview of the estimation process and describes the identification strategy. Section 4 comments on the main results by providing a comparison between the time-invariant and the time-varying cases. Finally, section 5 concludes.

## 2 Related literature

The paper mainly refers to three strands of literature as it combines the cross-border transmission of oil shocks with a time-varying framework.

The literature focusing on the international spillover of shocks is vast and ever-expanding in a more and more connected global economy. Behind this literature lies the need to quantify the cross-border transmission of shocks taking place internationally. A seminal contribution in the field is represented by [Canova \(2005\)](#) in which the propagation of macroeconomic shocks taking place in the US is studied. The study highlights how Latin American economies are relevantly affected by US monetary policy shocks. Subsequent and reputable contributions in the field are [Bernanke et al. \(2005\)](#) and [Mumtaz and Surico \(2009\)](#) where the effect of unanticipated falls in world short-term rates is estimated. Very closely related to the work here carried out are [Carrillo et al. \(2020\)](#), [Gatt and Ruisi \(2022\)](#) and [Ruisi \(2022\)](#). The first two introduce a similar methodology to the one adopted in this paper: a time-invariant 2-country structural VAR where the spillover of shocks can only take place from the bigger economy to the smaller. The third was recently published as a Central Bank of Malta's policy note and can be seen as the time-invariant version of this work.

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<sup>3</sup>Besides oil shocks, [Ruisi \(2022\)](#) also identifies a macroeconomic disturbance originating in the global shipping industry in order to deal with these specific and recent global supply-chain disruptions which are relevant to Malta. In what follows in this work, however, results related to shipping disruptions are relegated to the appendices for the sake of space.

The literature on oil shocks has experienced a remarkable growth over the last decades. More specifically, the strand on oil VARs can be conventionally assumed to be initiated with the seminal works in [Kilian \(2008\)](#) and [Kilian \(2009\)](#). The first, by means of simple exclusion restrictions, investigates the effect of oil price swings into the American economy. The second refines the first by distinguishing the transmission mechanism of demand and supply shocks taking place on the oil market. Subsequently, more refinements in the field took place with what are now regarded as workhorse oil VAR models, [Kilian and Murphy \(2012\)](#), [Lippi and Nobili \(2012\)](#), [Kilian and Murphy \(2014\)](#) and [Juvenal and Petrella \(2015\)](#) where several other nuances of oil disturbances are introduced, e.g., inventory and speculative demand of oil. Very recent contributions, [Kilian and Zhou \(2020\)](#) and [Kilian and Zhou \(2022\)](#), also deal with the role of the US strategic petroleum reserve in stabilising oil prices as well as that of the real exchange rate as the latter can be a source of oil price fluctuations which is typically denominated in US dollars.

Finally, the third strand of literature this paper is related to is the one dealing with time-varying parameters and stochastic volatility in order to account for the structural changes that gradually take place in the economy. The literature, initiated with [Cogley and Sargent \(2005\)](#) and [Primiceri \(2005\)](#), has seen a number of application to several macroeconomic shocks in order to study their evolving propagation. In the field of oil, notable contributions are [Baumeister and Peersman \(2013b\)](#), [Baumeister and Peersman \(2013a\)](#) where evidence of time-variation is detected and the transmission of shocks is studied. More recently, [Lyu et al. \(2021\)](#) revive the time-varying framework to further study the role of uncertainty on oil price fluctuations.

### 3 Methodology

This section aims at describing the modelling effort. More precisely, it will present how time-variation in the parameters and stochastic volatility are introduced in a 2-country vector autoregressive model as that developed in [Gatt and Ruisi \(2022\)](#) and further employed in [Ruisi \(2022\)](#). Finally, it discusses the estimation procedure and how oil shock identification is implemented.

#### 3.1 A 2-country VAR with time-varying parameters and stochastic volatility

The model in its reduced form contains the same key variables as those in [Ruisi \(2022\)](#) and, as such, the latter are split into two blocks: a world block and a Maltese one. Furthermore, a small-country assumption is imposed, whereby fluctuations in the world economy can affect Malta but not the other way around. The estimated model has the following VAR representation:

$$Y_t = C_t + \sum_{l=1}^L B_{l,t} Y_{t-l} + U_t \quad (1)$$

for  $t = 1, \dots, T$ , with

$$Var(U_t) = \Sigma_t \quad (2)$$

In equation (1)  $Y_t$  is a  $N \times 1$  vector of endogenous variables while  $Y_{t-l}$  represents lagged

values of the latter for the chosen lag length  $l = 1, \dots, L$ .  $C_t$  is a  $N \times 1$  vector of time-varying intercepts while the evolving  $N \times N$   $B_{l,t}$  matrices contain the slope coefficients relative to the lagged values of the series in the autoregression. In equation (2)  $U_t$  is a  $N \times 1$  vector of reduced form errors the variance of which is assumed to be heteroscedastic and equal to  $\Sigma_t$ .

As a 2-country framework, the model in equations (1) and (2) can be analysed more in depth in order to better understand how the block exogeneity assumption is imposed. Specifically, equation (1) can be rewritten as:

$$\underbrace{\begin{bmatrix} Y_t^{MT} \\ Y_t^W \end{bmatrix}}_{Y_t} = \underbrace{\begin{bmatrix} C_t^{MT} \\ C_t^W \end{bmatrix}}_{C_t} + \sum_{l=1}^L \underbrace{\begin{bmatrix} B_{l,t}^{MT} & B_{l,t}^{W \rightarrow MT} \\ \mathbf{0} & B_{l,t}^W \end{bmatrix}}_{B_{l,t}} \underbrace{\begin{bmatrix} Y_{t-l}^{MT} \\ Y_{t-l}^W \end{bmatrix}}_{Y_{t-l}} + \underbrace{\begin{bmatrix} U_t^{MT} \\ U_t^W \end{bmatrix}}_{U_t} \quad (3)$$

In equation (3)  $Y_t^{MT}$  is a  $N^{MT} \times 1$  vector of Maltese variables,  $Y_t^W$  is a  $N^W \times 1$  vector of world ones while  $Y_{t-l}^{MT}$  and  $Y_{t-l}^W$  are respectively vectors containing their lagged values. It follows that the total number of variables entering the model  $N$  is equal to  $N^{MT} + N^W$ . The vectors  $C_t^{MT}$  and  $C_t^W$  are of dimensions  $N^{MT} \times 1$  and  $N^W \times 1$  respectively and contain the block-specific time-varying intercept coefficients, while each of the time-varying  $B_{l,t}$  matrices contains four blocks. More precisely,  $B_{l,t}^{MT}$  is a  $N^{MT} \times N^{MT}$  block containing the slopes relative to the Maltese variables into the Maltese equations while  $B_{l,t}^{W \rightarrow MT}$  contains those relative to the world economy and has dimension  $N^{MT} \times N^W$ .  $B_{l,t}^W$  is a  $N^W \times N^W$  block containing the slopes relative to the world variables into the world equations and, finally,  $\mathbf{0}$  is a  $N^W \times N^{MT}$  block of zeros denoting how the Maltese variables do not affect the global ones. Finally,  $U_t^{MT}$  and  $U_t^W$  are  $N^{MT} \times 1$  and  $N^W \times 1$  vectors containing the reduced form errors respectively associated with the Maltese and the world equations.

The model features ten variables with five for each of the two blocks. The world variables are suitable to represent the global economy and how oil prices are formed as well as to identify global oil shocks. The world block contains the growth rates of industrial production and overall consumer price index among all the 38 countries in the Organization for Economic Cooperation and Development. In addition, to be in line with [Ruissi \(2022\)](#), it contains the growth rates of real Brent oil price and the Baltic dry index, the latter being a measure of the global cost of shipping. Finally, the world block contains the ratio between the growth rates of real oil price and Baltic dry index in order to reach shock identification.<sup>4</sup> The Maltese block is highly stylised and contains variables related to output and inflation. Specifically, it features the Central Bank of Malta's business conditions index developed in [Ellul \(2016\)](#) as a measure of output. Moreover, to measure inflation, it features year-on-year growth rates of the four main sub-indices of the harmonised consumer price index: food, non-energy industrial goods, energy and services. The lag length is set to  $L = 1$  and further details on data sources and transformations are in appendix A.<sup>5</sup>

<sup>4</sup>It is important to remind the reader that the inclusion of a series proxying the global shipping cost is necessary to draws a parallel between this work and [\(Ruissi, 2022\)](#).

<sup>5</sup>A criticism on VAR models featuring time-varying parameters and stochastic volatility is the necessity to adopt a limited number of lags for purely computational reasons. [Kilian and Zhou \(2023\)](#), instead, affirm that a large number of lags should be included in a time-invariant oil VAR model in order to accurately identify structural shocks and estimate impulse responses. Differently from the workhorse models in [Kilian and Murphy](#)



As in [Primiceri \(2005\)](#), for each  $t = 1, \dots, T$ , the covariance matrix  $\Sigma_t$  is decomposed through the following triangular reduction:

$$\Sigma_t = A_t^{-1} H_t A_t^{-1'}$$

where  $A_t^{-1}$  are lower triangular matrices with ones on the main diagonal and off-diagonal entries  $a_{i,j,t}$  which are crucial in assessing the cross covariances of the reduced form errors. The diagonal matrix  $H_t$  is time-varying and contains the stochastic volatilities  $h_{n,t}$  for  $n = 1, \dots, N$ .

By grouping slopes and intercepts as  $\beta_t^{MT} = \{C_t^{MT}, B_t^{MT}, B_t^{W \rightarrow MT}\}$  and  $\beta_t^W = \{C_t^W, B_t^W\}$ , the time-varying parameters in  $\beta_t^{MT}$ ,  $\beta_t^W$  and  $A_t$  are assumed to evolve as random walks with normally distributed errors:

$$\beta_t^{MT} = \beta_{t-1}^{MT} + e_t^{MT} \quad \text{Var}(e_t^{MT}) = Q^{MT}$$

$$\beta_t^W = \beta_{t-1}^W + e_t^W \quad \text{Var}(e_t^W) = Q^W$$

$$a_{i,t} = a_{i,t-1} + e_t^a \quad \text{Var}(e_{i,t}^a) = Q_i^a$$

for  $i = 2, \dots, N$ , while the stochastic volatilities evolve as geometric random walks to ensure the positivity of  $h_{n,t}$

$$\ln(h_{n,t}) = \ln(h_{n,t-1}) + e_{n,t}^h \quad \text{Var}(e_{n,t}^h) = Q_n^h$$

for  $n = 1, \dots, N$ .<sup>6</sup>

### 3.2 Priors

The data are collected at monthly frequency and the estimation sample runs from January 1997 to March 2022, thus amounting to 303 monthly observations. As recurrent in time-varying modelling, the overall dataset is split into a training and an effective sample. The training one aims at setting the priors and stretches from January 1997 to December 2007, thus accounting for 131 observations.<sup>7</sup> The effective sample, instead, covers the remaining 171 months and goes from January 2008 to March 2022 and, as such, represents the time span which inference is conducted on, i.e., when time-variation in the spillover of external shocks is estimated. The effective sample is set to start on January 2008 as this date marks the entrance of Malta into the eurozone. By doing so, it avoids to deal with the likely presence of abrupt structural changes

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(2012) and [Kilian and Murphy \(2014\)](#) where variables are expressed in levels or in first differences, the model here developed makes use of year-on-year growth rates. By doing so, the data can (at least partially) contain information dating back 12 months thus making the model less vulnerable to the mentioned critique. Moreover, further estimations with higher numbers of lags were attempted. However, the results were discarded as the highly erratic behaviour of the responses made it impossible to conduct any meaningful inference.

<sup>6</sup>For further details please consult [Appendix B](#).

<sup>7</sup>Compared with [Ruisi \(2022\)](#), this version extends the sample backwards by including data prior to 2000 in order to increase the size of the training sample. A 131-observation training sample aims at having enough degrees of freedom to confidently set the priors. The monthly data for the business conditions index are approximated as the quarterly year-on-year growth rate of the real gross domestic product.

taking place in the transition from the Maltese Lira to the common European currency.<sup>8</sup>

The priors are set in line with most of the literature and for the time-varying intercepts and slopes it is assumed to be normally distributed:

$$p(\beta_{0|0}^{MT}) \sim N(\beta_0^{MT}, p_{0|0}^{MT})$$

$$p(\beta_{0|0}^W) \sim N(\beta_0^W, p_{0|0}^W)$$

where the prior means are the ordinary least square estimates of intercept and slope coefficients in the training sample while the prior variances are the coefficient covariance matrices.

The variances associated with the law of motion of the parameters are assumed to be drawn from inverse Wishart distributions:

$$p(Q^{MT}) \sim IW(Q_0^{MT}, T_0)$$

$$p(Q^W) \sim IW(Q_0^W, T_0)$$

where the prior degrees of freedom are equal to the training sample size. The prior scales are instead obtained by multiplying the prior parameter variances by the training sample length and by a scaling factor reflecting the uncertainty surrounding the estimation process,  $\tau^{MT} = \tau^W = 3.51^{-4}$ , as suggested in [Cogley and Sargent \(2005\)](#), [Primiceri \(2005\)](#) and [Cogley et al. \(2010\)](#).

A normal prior distribution is also assumed for the off-diagonal lower elements of the  $A_t^{-1}$  matrices. The prior means are obtained from a Cholesky factorisation of the covariance matrix of the reduced form errors, while the variances are set to ten times the absolute values of the prior means as in [Benati and Mumtaz \(2007\)](#). The prior variances have 0.001 as scale parameters while the degrees of freedom are equal to the training sample size.

$$p(a_{i,0|0}) \sim N(a_{i,0}, p_{a_{i,0|0}})$$

and

$$p(Q_i^a) \sim IG(0.001, T_0) \quad \text{for} \quad i = 2$$

$$p(Q_i^a) \sim IW(0.001I_{(i-1)}, T_0) \quad \text{for} \quad i > 2$$

Finally, the prior of each residual variance of the geometric random walk of  $h_{n,t}$  is assumed to be distributed as an inverse gamma as follows:<sup>9</sup>

$$p(Q_n^h) \sim IG(0.001, T_0)$$

---

<sup>8</sup>The time-variation modelled in this framework mainly deals with smooth structural changes.

<sup>9</sup>For a thorough and detailed discussion of how to set priors and initial values with time-varying parameters and stochastic volatility please consult [Blake and Mumtaz \(2017\)](#).

### 3.3 Estimation routine

The model is estimated by setting up a Gibbs sampling routine with 110,000 iterations with a burn-in of 10,000 draws in order to minimise the effect of the chosen initial values. Furthermore, with the aim of minimising the serial correlation across draws, a thinning factor of 100 is employed. This means that 1,000 draws are singled out to approximate the posterior distributions in order to conduct inference.

The flowchart in figure 3 aims at concisely describing how the estimation process is carried out. The estimation process is mainly divided into two parts: one dealing with the two countries' time-varying intercepts and slopes, while the other aiming at estimating the stochastic volatilities.

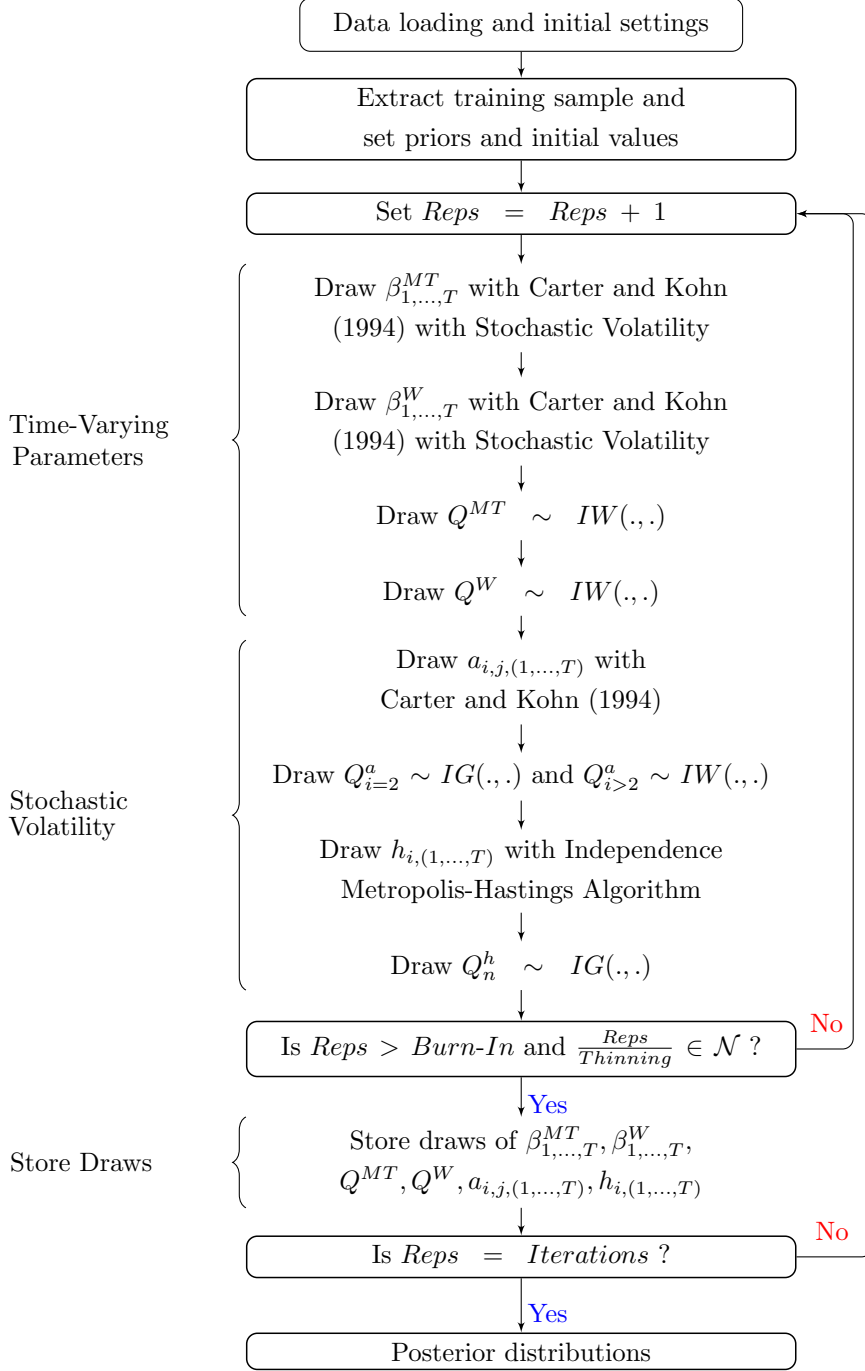


Figure 3: Flowchart of estimation routine

The routine starts with data loading and initial settings (lag length, training sample length, number of Gibbs iterations, etc,...). Then it continues with the separation of the estimation sample into effective and training sample, the latter being necessary to set up both priors and initial values. Subsequently, the core of the routine starts. The loop begins by drawing from the posterior distributions of the histories of the time-varying parameters for both Malta and

the world economy and then it draws from the posteriors of the covariance matrices of the two laws of motions. The first of these two steps is achieved by means of the [Carter and Kohn \(1994\)](#) algorithm which accounts for stochastic volatility in the observation equation.<sup>10</sup> Then the routine deals with the time-varying covariance matrix. Initially, it draws the off-diagonal elements of the  $A_{0,t}^{-1}$  matrices by means of the base [Carter and Kohn \(1994\)](#) algorithm while, subsequently, it estimates the volatilities contained in  $H_t$  by using an independent Metropolis-Hastings algorithm.<sup>11</sup> Finally, once past the burn-in period, the routine stores one draw every one hundred. Appendix B shows how the chain successfully converged thus making it possible to conduct inference.

### 3.4 Identification strategy

As typically assumed in structural VARs, the reduced form errors  $U_t$  are linked to the structural ones  $V_t$  via the equality

$$U_t = A_{0,t}V_t \quad (4)$$

Noticeably, the  $A_{0,t}$  matrix is time-varying while equation (4) can be explored further as

$$\underbrace{\begin{bmatrix} U_t^{MT} \\ U_t^W \end{bmatrix}}_{U_t} = \underbrace{\begin{bmatrix} A_{0,t}^{MT} & A_{0,t}^{W \rightarrow MT} \\ \mathbf{0} & A_{0,t}^W \end{bmatrix}}_{A_{0,t}} \underbrace{\begin{bmatrix} V_t^{MT} \\ V_t^W \end{bmatrix}}_{V_t} \quad (5)$$

Equation (5) shows the link between the reduced and the structural form errors of the VAR. More precisely,  $V_t^W$  is a  $N^W \times 1$  vector of structural shocks hitting the world economy 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. Similarly to the  $B_{l,t}$  matrices, the time-varying  $A_{0,t}$  matrices contain four blocks. The matrices  $A_{0,t}^{MT}$  and  $A_{0,t}^{W \rightarrow MT}$  are  $N^{MT} \times N^{MT}$  and  $N^{MT} \times N^W$  blocks respectively denoting the impact effect of both domestic  $V_t^{MT}$  and foreign  $V_t^W$  shocks into the Maltese economy, while  $A_{0,t}^W$  represents how the global variables respond on impact to the global shocks only. Finally,  $\mathbf{0}$  is a  $N^W \times N^{MT}$  block of zeros denoting how any shock hitting the Maltese economy does not spill over to the global economy.

The two blocks of zeros  $\mathbf{0}$  inside the  $A_{0,t}$  and the  $B_{l,t}$  matrices guarantee the block exogeneity assumption of the world economy 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 fluctuations of the world variables.

The identification of the global oil shock is reached by means of sign restrictions imposed on impact ([Canova and Paustian \(2011\)](#)) and is implemented on each month of the effective sample, i.e., from January 2008 till March 2022. As the oil shock is assumed to take place in the global economy, the identification strategy is applied only to the  $A_{0,t}^W$  block while  $A_{0,t}^{W \rightarrow MT}$  is let

<sup>10</sup>See [Blake and Mumtaz \(2017\)](#) for a detailed explanation.

<sup>11</sup>For the sake of space, the parameters relative to the posterior distributions are not reported. However, they can be consulted in [Blake and Mumtaz \(2017\)](#).

unrestricted to let the model trace the spillover into the Maltese economy.<sup>12</sup> The identification strategy of the global oil shock is outlined in table 1 and is exactly the same as the one adopted in Ruisi (2022):<sup>13</sup>

	OECD IP	OECD CPI	BDI	Real Oil	Real Oil/BDI
Oil	—	+	?	+	+

Notes: 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.

Table 1: Identifying sign restrictions on the World Economy - Impact responses

The strategy aims at capturing a broad oil shock by focusing only on the adverse effect that it causes on the global economy: a depressing effect on output, a rise in overall prices and in real oil as well as a rise in the real oil/BDI ratio.<sup>14</sup>

## 4 Results

This section aims at presenting the main results. It will start by providing an initial evidence of time-variation in parameters, volatilities and oil price response. Then, it will delve into a more structural analysis by presenting how the responses of the Maltese variables to the identified oil shocks have changed over time and will look into the specific economic reasons from a historical perspective. Subsequently, further emphasis on energy and headline inflation is put to further investigate the role of the two.<sup>15</sup>

### 4.1 A first look into time-variation

A first way to provide evidence of the presence of time-variation is to look at the main parameters of interest: slopes and volatilities.

<sup>12</sup>Please refer to appendix D.2 to see the identification strategy that accounts also for disturbances taking place in the shipping industry.

<sup>13</sup>The ratio between real oil price and Baltic dry index was crucial in Ruisi (2022) to distinguish disturbances taking place in the global oil market from those in the shipping industry.

<sup>14</sup>As already outlined and acknowledged in section 2, the literature on oil shocks has widened in the last decades and has encompassed several disturbances that take place on the global oil markets. The workhorse models tend to distinguish oil shocks mainly related to supply, demand, speculative demand and demand of inventories as each of them would transmit to the economy in specific way. This work, for simplicity, aims at gauging the effect of a generic shock of interest to the Maltese case: a recessionary one accompanied by a general increase in global prices.

<sup>15</sup>The responses of the world economy to the oil shock are highly stylised and, for the sake of space, most of them are presented in Appendix C.



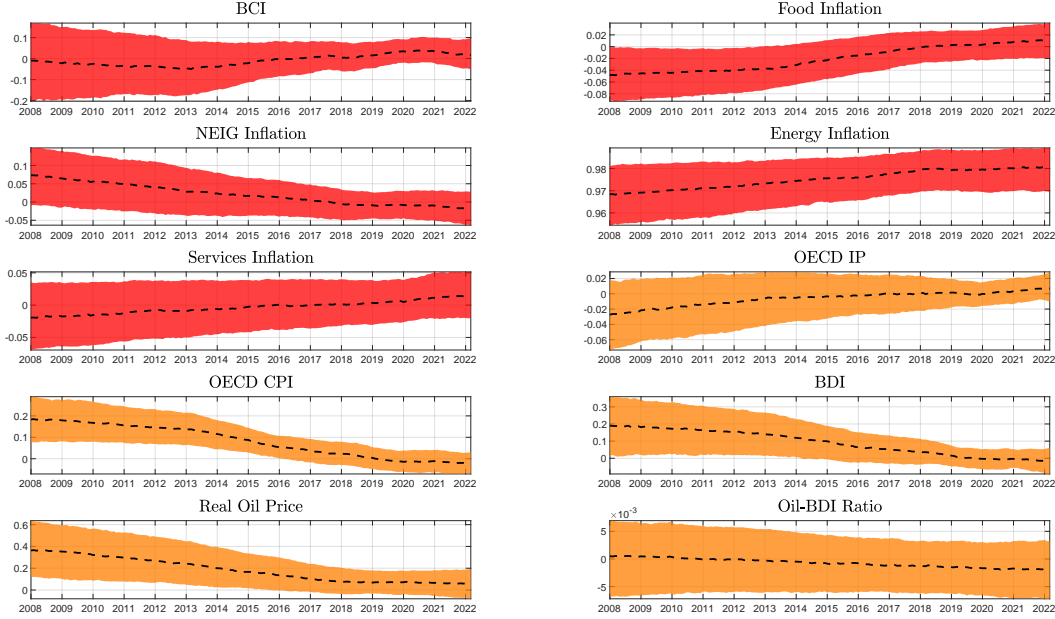


Figure 4: The estimated time-varying slopes relative to the energy equation

Notes: The figure shows the median values (black dashed lines) and the 16<sup>th</sup> and 84<sup>th</sup> percentiles (shaded areas) of the posterior distributions relative to the time-varying slope coefficients associated with the first lag of Maltese (red) and world (orange) variables into the energy equation.

Figure 4 shows the posterior distributions of the slopes in the Maltese energy inflation equation and how they have changed over time.<sup>16</sup> The charts provide a clear illustration of how energy inflation in Malta has become more and more disconnected from fluctuations in the other variables in the autoregression.<sup>17</sup> Specifically, while the slope relative to its own lag has increased from about 0.97 to 0.98, all the other slope coefficients have shown the tendency to gradually decline and tending towards very small values, especially after 2018. An interesting case to put emphasis on is the slope relative to real oil price: positive prior to 2016 while not significantly different from zero afterwards.

<sup>16</sup>For the sake of space, the slopes relative to the other nine equations are not shown. However, they are all available upon request.

<sup>17</sup>It is important to emphasise that these parameters cannot be used to detect causality. The reason being that they are in reduced form and, as such, no identification strategy is operational in this stage.

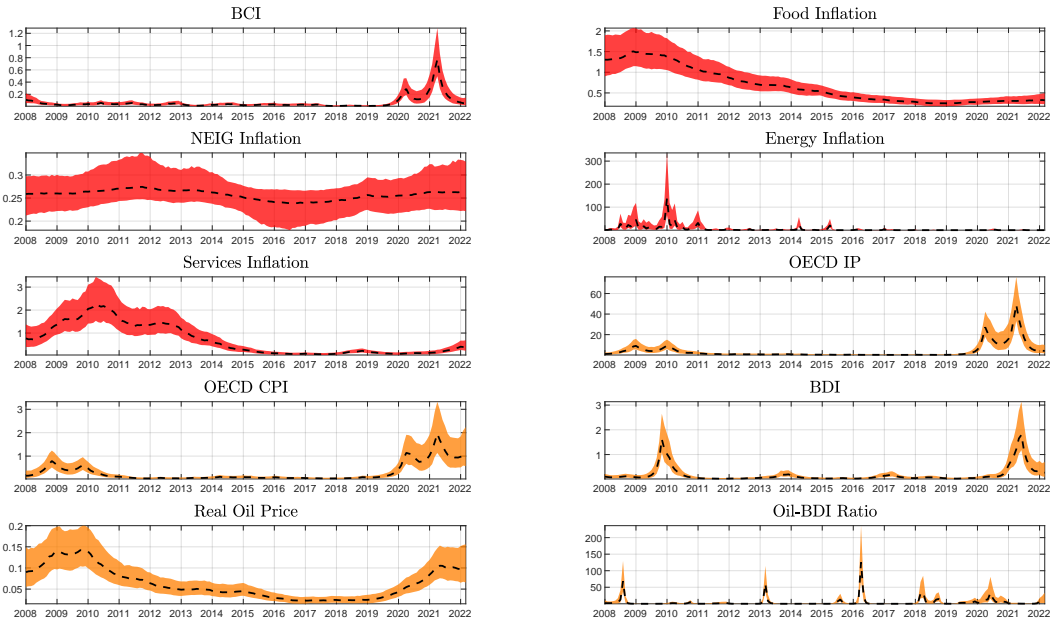


Figure 5: The estimated stochastic volatilities

Notes: The figure shows the median values (black dashed lines) and the 16<sup>th</sup> and 84<sup>th</sup> percentiles (shaded areas) of the posterior distributions relative to the stochastic volatilities associated with Maltese (red) and world (orange) variables.

The detection of time-variation in the system can be further implemented by looking at the stochastic volatilities in figure 5. The charts clearly illustrate how the model is able to capture reasonably well the variable and time-specific degree of volatility in the vector autoregression. In general, higher volatilities tend to be found during the Great Recession and the COVID-19 period for both the Maltese and the world economies. Notable exceptions are the case of Maltese output during the Great Recession and energy inflation over the recent years which experienced very low volatility. Overall, figures 4 and 5 shed light on how energy prices (and, therefore, energy inflation) have recently become not responsive to developments in the world economy as a result of the government's policies aiming at curbing inflationary pressures.

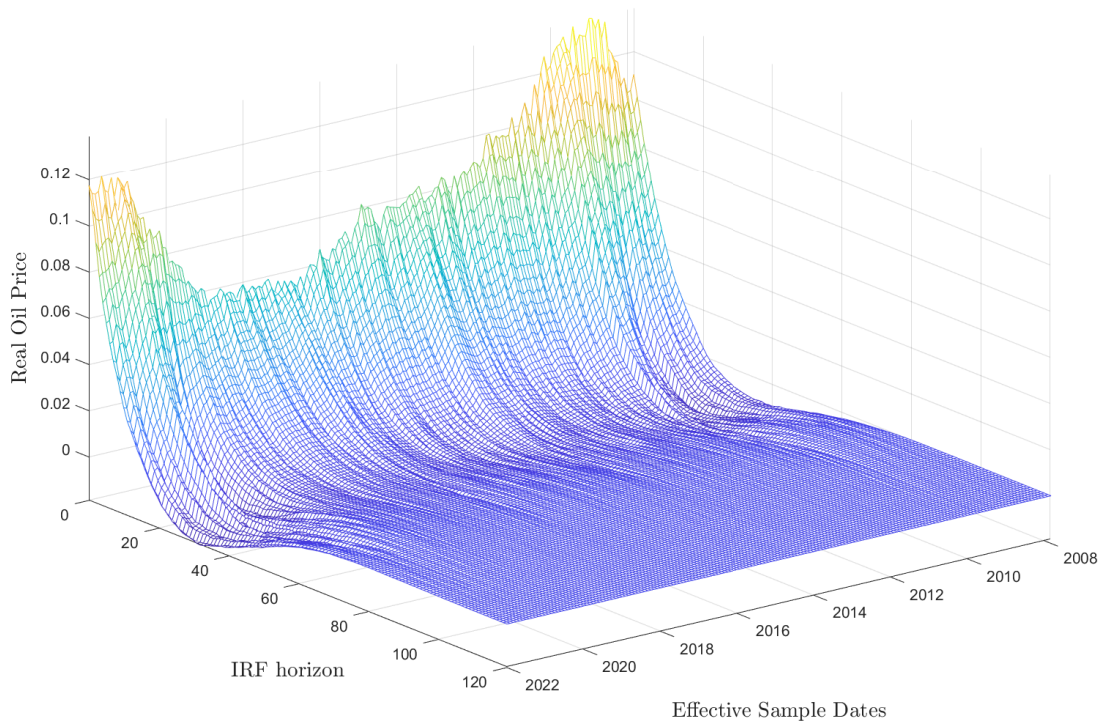


Figure 6: Time-varying response of real Brent oil price growth to an oil shock

Notes: The figure shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Finally, figure 6 provides a first look into time-varying responses by depicting the reaction of real oil price growth to a one standard deviation shock.<sup>18</sup> Despite being highly stylised, the chart conveys relevant information as it is able to trace how impact responses ranged between about 6% and 13% and reached peak values during the two mentioned periods characterised by higher oil volatility.

## 4.2 Shock transmission into the Maltese economy

This subsection aims at showing the changing transmission of the identified oil shock into the Maltese economy. Specifically, figures 7 to 11 compare the time-invariant responses of the Maltese variables with the time-varying ones.<sup>19</sup> The left panels depict the median responses and the

<sup>18</sup>It is important to emphasise that, being a model with stochastic volatility, the shock standard deviation is evolving over time as well.

<sup>19</sup>This exercise also aims at further validating the goodness of the model and its eligibility to conduct further policy analyses at the Central Bank of Malta. By using the time-invariant model as a benchmark for the time-varying one, it is possible to see how the economy's responses have actually become more or less accentuated (or even if they have assumed a completely different shape) in specific points in time. Notwithstanding the remarkable gain in terms of modelling equipment at the Central Bank of Malta, a word of warning has to be made when commenting on the results. Besides all the relevant differences arising between time-invariant and time-varying models, throughout this paragraph the responses on the left panels are obtained by employing the algorithm developed in [Arias et al. \(2018\)](#) while those on the right by means of the algorithm in [Rubio-Ramirez et al. \(2010\)](#) for purely computational reasons. For this reason, further caution is necessary when comparing the two responses as they are stemming out of two different methodologies.

68% credible regions, while the right ones only the median responses for ease of presentation.<sup>20</sup> For a better comparability the charts report responses to a one standard deviation shock.<sup>21</sup>

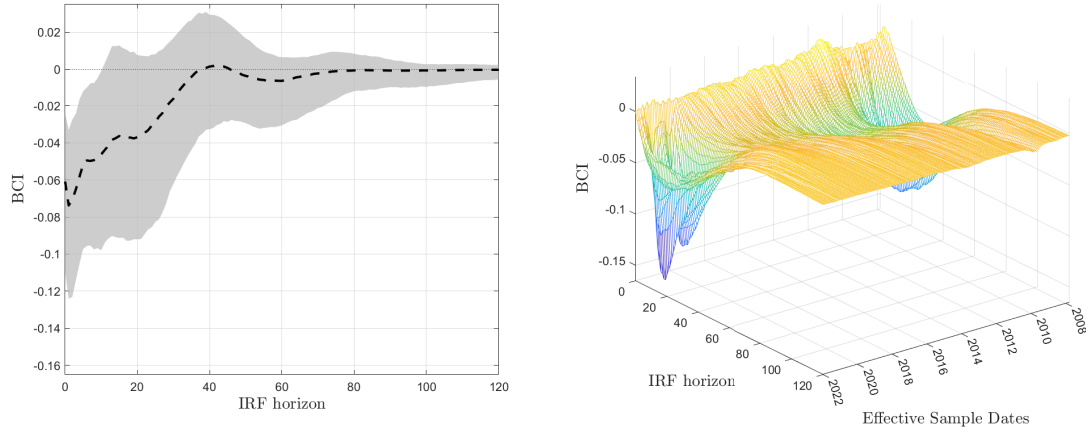


Figure 7: Time-invariant (left) and time-varying (right) response of Maltese business conditions index to an oil shock

Notes: The left panel of the figure shows the median response (black dashed line) and the 68% credible region (grey shaded area) to a 1-standard deviation oil shock in the time-invariant case. The right panel shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Figure 7 depicts the response of Maltese BCI. The two charts make a number of considerations arise. As in the time-invariant case, Maltese output experiences a downward pressure throughout the 2008-2022 period. However, the negative reaction presents two periods of elevated responsiveness: the years following the Great Recession and those following the COVID-19 outbreak. A remarkable difference between the two periods arises notwithstanding the relatively similar negative pressure of around -0.12. The experience of 2008-2010 is characterised by more persistent responses of the Maltese output when compared with the 2020-2022 period. More precisely, after the Great Recession the median response takes roughly twice as much the time as the pandemic period to go back to zero. A possible explanation for this phenomenon is the higher government's responsiveness in changing domestic energy prices in response to the identified oil shock during the Great Recession years. Conversely, more recently, the Maltese government has put in place a number of energy subsidies in order to keep energy prices fixed as of July 2020 thus dampening the negative consequence of surging global energy prices. The months between the two recessionary events are characterised by oil shocks depressing economic activity in a much more contained way with a declining peak value going from -0.04 to -0.02.

<sup>20</sup>The 68% credible regions for the time-varying responses are available upon request. In addition, a number of authors report the generalised impulse response functions calculated as in [Koop et al. \(1996\)](#) but then, for computational reasons, they report only a subset of the time-varying responses, e.g., [Benati and Mumtaz \(2007\)](#). This solution is here discarded because a high importance is given to the month-specific responses in the Maltese economy as it has been undergoing considerable structural changes over time.

<sup>21</sup>Appendix [D.1](#) provides the responses normalised to increase real oil price growth by 10%.

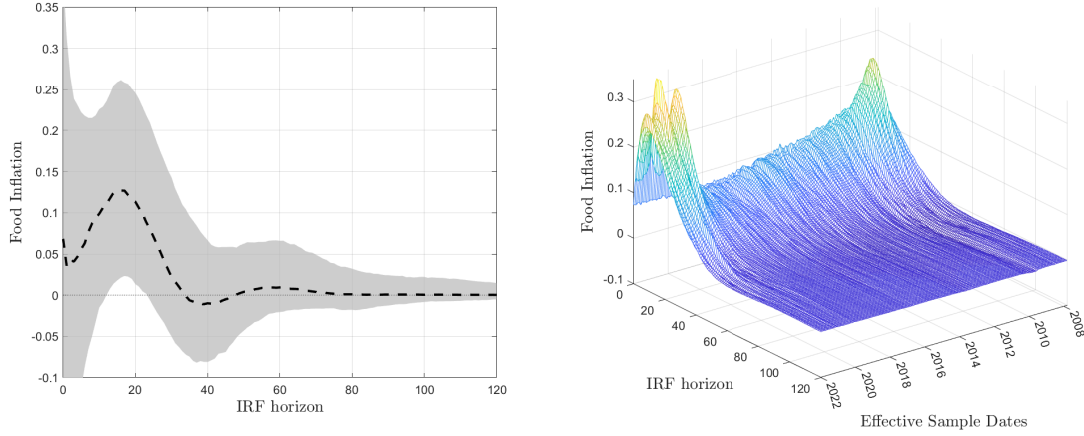


Figure 8: Time-invariant (left) and time-varying (right) response of Maltese food inflation to an oil shock

Notes: The left panel of the figure shows the median response (black dashed line) and the 68% credible region (grey shaded area) to a 1-standard deviation oil shock in the time-invariant case. The right panel shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Figure 8 depicts the food inflation response. The hump-shaped response characterising the time-invariant case is found only in conjunction with the two periods of heightened responsiveness detected previously in the time-varying case. The evident difference between the two is the more abrupt rise in responsiveness experienced in recent years when compared with the beginning of the effective sample despite the absence of spillovers from domestic energy prices, respectively with peaks of around 0.3% and 0.25%. A possible explanation for this could be due to the high import content of food from abroad and how the latter is experiencing elevated upward pressure as a result, also, of the economic recovery process after the pandemic. Another possible explanation might be the (domestic and foreign) food sellers' search of a higher mark-up following the period of subdued economic activity in 2020 and 2021. The relatively calm years between 2011 and 2019 are associated with more toned down and monotonic responses with peaks hovering 0.1%.

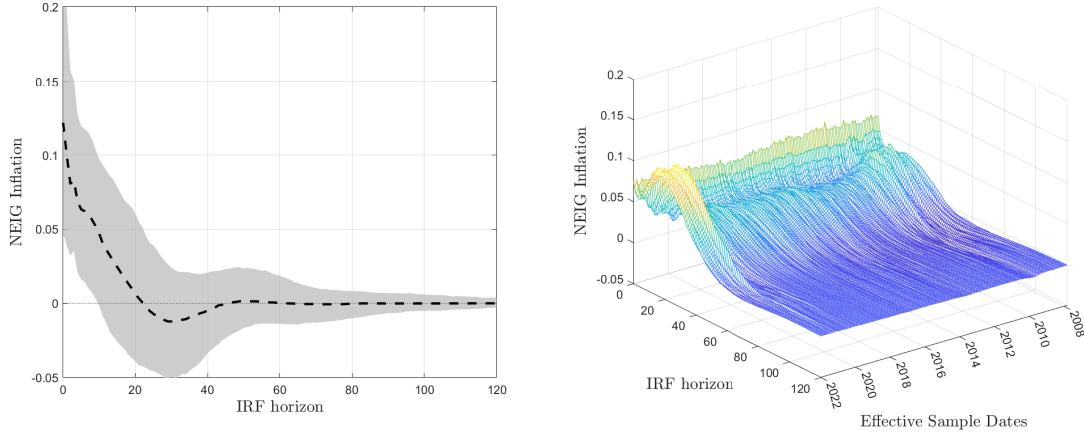


Figure 9: Time-invariant (left) and time-varying (right) response of Maltese non-energy industrial goods inflation to an oil shock

Notes: The left panel of the figure shows the median response (black dashed line) and the 68% credible region (grey shaded area) to a 1-standard deviation oil shock in the time-invariant case. The right panel shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Figure 9 evidences how the reaction of non-energy industrial goods has been historically characterised by a relatively similar shape in response to a one-standard deviation shock. Specifically, the impact response is similar throughout the period of analysis but at higher horizons a more persistent and hump-shaped response is found after the pandemic broke out. As in the time-invariant case, the prompt impact responsiveness could be explained by the fact that most of non-energy industrial goods in Malta are produced outside the national borders and, as such, they are likely to incorporate changes in global energy prices in a relatively quick way.<sup>22</sup>

<sup>22</sup>Should non-energy industrial goods be produced domestically, they would be likely to show a more hump-shaped reaction as they would need some time to incorporate the adjustment in domestic energy prices which has not historically taken place immediately.



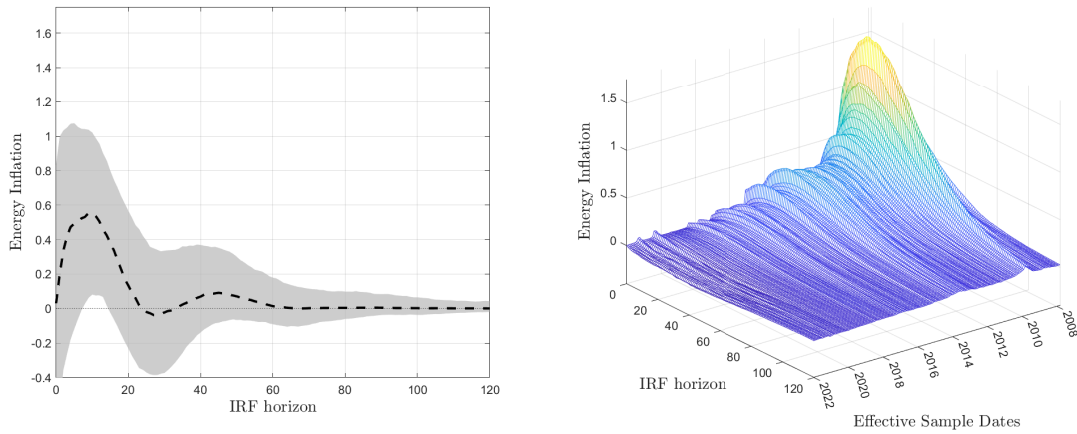


Figure 10: Time-invariant (left) and time-varying (right) response of Maltese energy inflation to an oil shock

Notes: The left panel of the figure shows the median response (black dashed line) and the 68% credible region (grey shaded area) to a 1-standard deviation oil shock in the time-invariant case. The right panel shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

The response of domestic energy inflation in figure 10 is the main result of interest and the model is able to clearly detect the well expected declining government's responsiveness over time. The time-invariant case on the left suggests a pure hump-shaped response. This indicates that the transmission from international to domestic energy prices typically tends to take a certain amount of time as new tariffs and prices need to be fixed. Conversely, on the right panel, in the time-varying case the response gets muter and muter as the time period approaches the end of the effective sample. If on the one hand, the time-invariant case would suggest a median peak response of about 0.55%, on the other hand the time-varying response changes from a purely hump-shaped one with a 1.5% peak in 2010 to a flat one in recent months.

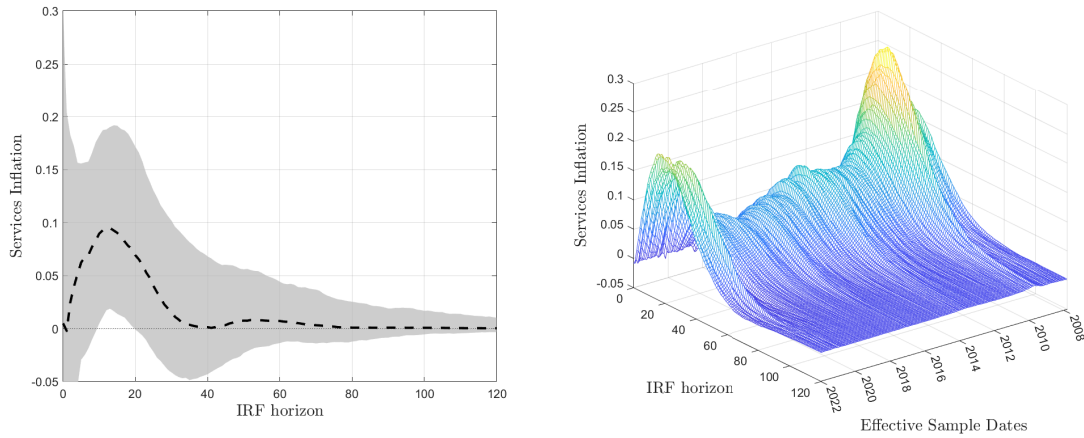


Figure 11: Time-invariant (left) and time-varying (right) response of Maltese services inflation to an oil shock

Notes: The left panel of the figure shows the median response (black dashed line) and the 68% credible region (grey shaded area) to a 1-standard deviation oil shock in the time-invariant case. The right panel shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Finally, figure 11 deals with services inflation response. On the right panel, independently of the month it refers to, the latter gradually increases reaching a medium-term peak and presents again two periods of heightened responsiveness: the Great Recession and the pandemic. The peak response of this index of inflation appears more pronounced in 2010 and probably this can be explained by the adjustment to faster-moving domestic energy prices back then. On the other hand, the relatively lower peak reaction during the last months in the sample might be due to the effective sample ending in March 2022. To be more specific, tourism-related services and recreational activities account for the biggest chunk of the services basket and they experience higher demand during the Summer season. For this reason, the full effect on services inflation is likely to take place in subsequent months which are outside the effective sample. As far as the peak responses are concerned, the peak invariant response of slightly below 0.1% compares with a time-invariant one ranging from around 0.05% and 0.17%.

### 4.3 Pass-through to domestic energy inflation

What can the time-varying response in figure 10 tell us about the pass-through of international energy prices into domestic ones? In order to provide an answer to this question, this subsection shows the responses of domestic energy prices to an oil shock normalised to increase real oil price growth by 10% on impact. In order to go deeper into the nature of domestic energy responses, the reaction on a number of selected months as well as a number of selected horizons is shown. The normalisation of the responses to a 10% increase in real oil price is done in a bid to better compare the effect over time from a policy perspective.<sup>23</sup>

<sup>23</sup>Some caution is needed when carrying out this exercise. The reason being that there is no guarantee that by scaling up or down the responses is a reasonable way to approximate what would have happened in a certain

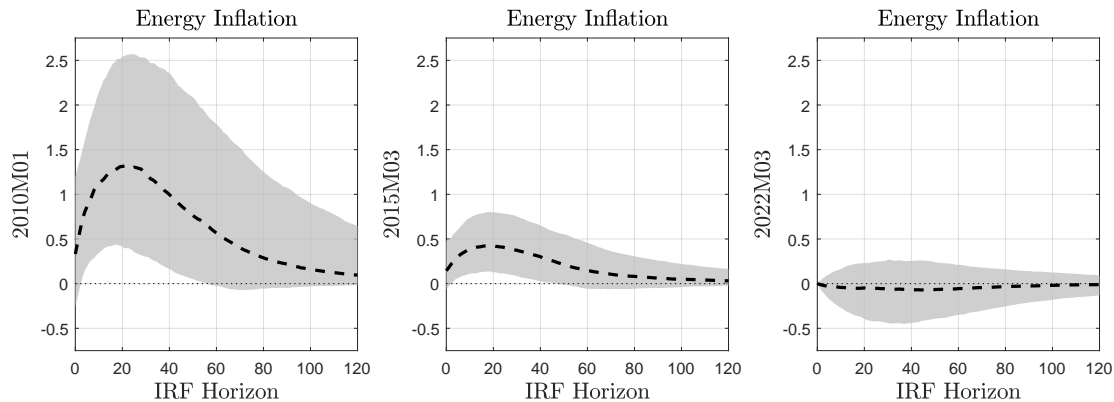


Figure 12: Response of Maltese energy inflation to an oil shock on selected months

Notes: The figure shows the median response (black dashed line) and the 68% credible region (grey shaded area) to an oil shock normalised to increase real oil price by 10% on a number of selected months.

Figure 12 selects three episodes that are arbitrarily chosen as considered to be indicative of the changing pass-through of global energy prices into domestic ones. January 2010, in the left panel, is the month associated with the highest government's responsiveness. A shock normalised to increase real oil by 10% on impact would increase energy inflation by 0.4% within the same month and would reach a peak response of about 1.4% after around 20 months. The chart in the middle aims at shedding light on how the pass-through has become less and less pronounced. Specifically, the period revolving around the installation of the Malta-Sicily interconnector and decommissioning of the Marsa power plant can be considered indicative of the softening responses of domestic energy inflation to global energy prices. The panel displays the response as of March 2015, i.e., when the interconnector became operative. Compared with the 2010 experience the dynamic response appears remarkably smaller in size with a 0.1% increase on impact and a peak of below 0.5% after 20 months. Finally, the right panel evidences the government's commitment in sheltering the domestic economy from swings in global oil markets, i.e., by keeping domestic energy prices fixed via the implementation of a number of energy subsidies. This resulted in a flat response as of March 2022 which marks the last observation in the estimation sample.

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month if a shock normalised to increase oil by 10% had occurred. If that happened in real life the economy might have reacted differently.

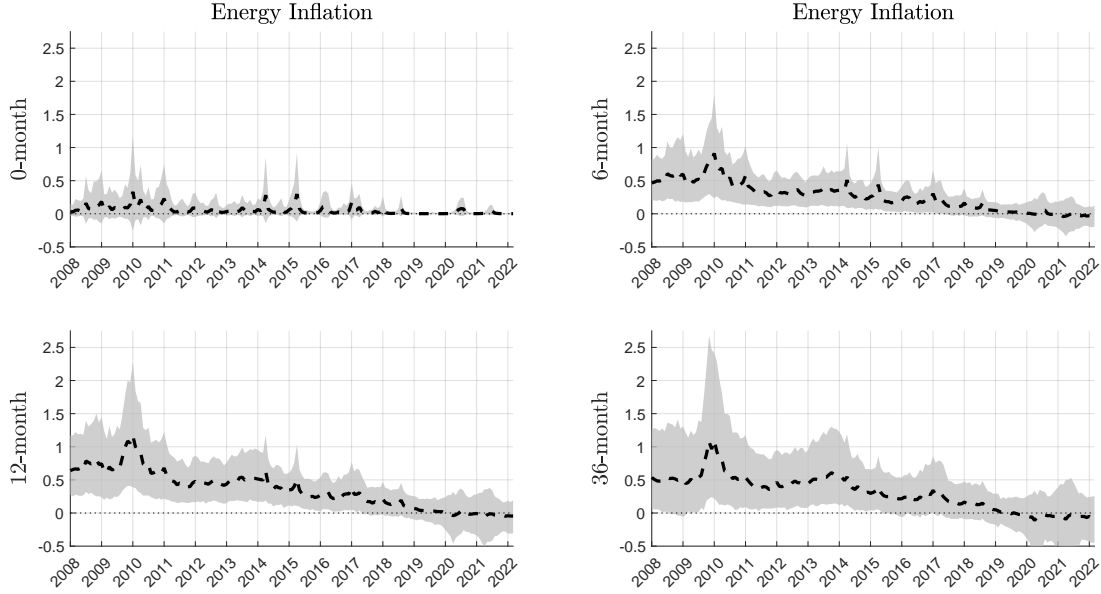


Figure 13: Time-varying response of Maltese energy inflation to an oil shock at selected horizons

Notes: The figure shows the time-varying median response (black dashed line) and the 68% credible region (grey shaded area) to an oil shock normalised to increase real oil price by 10% at a number of selected horizons.

To provide a wider understanding of the declining pass-through of global energy prices into domestic energy inflation, it is interesting to have a look at the responses from a more historical perspective. To this end, figure 13 depicts how domestic energy inflation would have reacted in each month going from January 2008 till March 2022 and for a selected number of horizons. Independently of the horizon considered, January 2010 is the month associated with the highest pass-through of oil prices to domestic energy inflation. Figure 13 further confirms the declining pass-through found previously in figures 10 and 12. To keep things simple, it is convenient to distinguish four periods: the Great Recession of 2008-2010, a period stretching from 2011 to 2014, the period following the installation of the interconnector in 2015 till 2019 and, finally, the COVID-19 pandemic. The first of the four sees a relatively high pass-through with a 10% oil increase reflecting into an increase of domestic energy inflation in the range of 0.5% and 1% at horizons until 36 months. The second period, instead, sees a pass-through stabilising at 0.5%, while after the interconnector is laid and the Marsa power plant was phased out, the pass-through becomes gradually smaller, i.e., from 0.5% to virtually 0%. Finally, from 2020 onwards the pass-through has become virtually null thus indicating the absence of energy prices changes in response to developments on global markets for energy.

#### 4.4 Pass-through to other inflation rates

The responses in figures 8, 9 and 11 help provide information regarding the pass-through to the other three inflation sub-indices should a shock normalised to increase real oil by 10% hit the world economy.

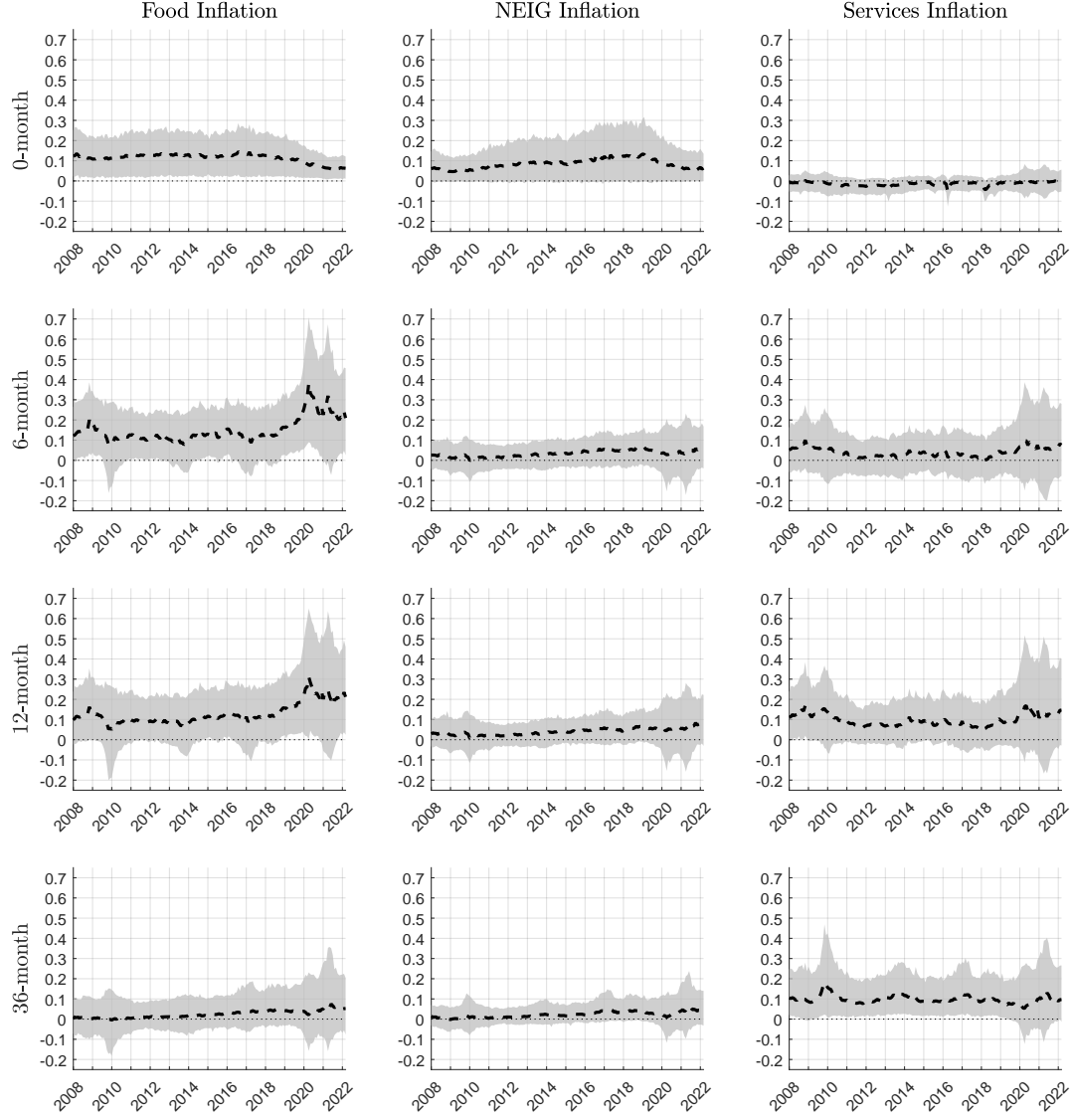


Figure 14: Time-varying response of Maltese food, non-energy industrial goods and services inflation to an oil shock at selected horizons

Notes: The figure shows the time-varying median response (black dashed line) and the 68% credible region (grey shaded area) to an oil shock normalised to increase real oil price by 10% at a number of selected horizons.

Figure 14 highlights a few interesting results. First, a 10% oil price increase would reflect into an immediate 0.1% upward pressure in food and non energy-industrial goods inflation. Second, the medium term pass-through to non-energy industrial goods declines relatively quickly as the horizon grows large, while for services it stabilises at around 0.1% after one or two years. Finally, the medium-term pass-through on food reaches its highest values after six to 12 months. Interestingly, over the 2020-2022 period the latter goes up from around 0.1% to values ranging from 0.2% to above 0.3%.

## 4.5 The response of headline HICP inflation

How can the sub-indices' responses in figures 8 to 11 help us understand the reaction of domestic headline inflation to the identified oil shocks? This subsection aims at shedding further light on the effect on Maltese headline inflation by combining the different time-varying responsiveness of the four main inflation sub-indices. As a matter of fact, each of them provides an indication of how each component of the consumption basket contributes to the overall inflation fluctuations.

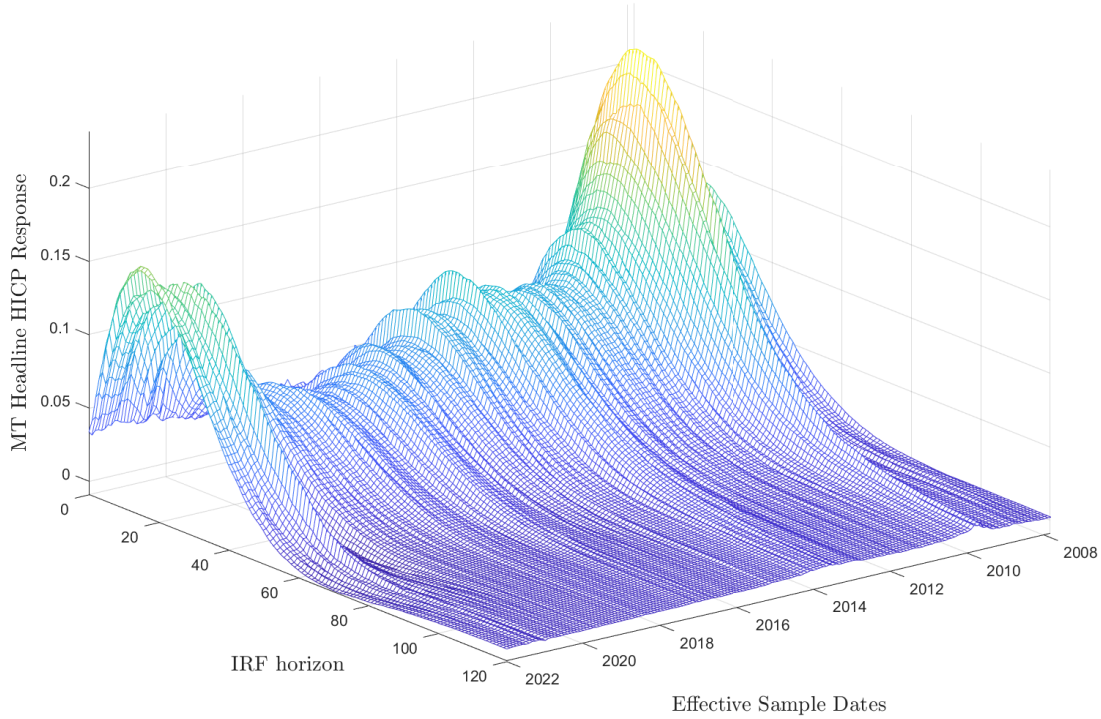


Figure 15: Time-varying response of Maltese headline inflation to an oil shock

Notes: The figure shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Figure 15 shows how the median headline inflation response to a one standard deviation shock has changed over time. The surface has been obtained by weighing each sub-index's response by its respective weight in the consumption basket for each year going from 2008 to 2022.<sup>24</sup> As expected, the highest responsiveness of headline inflation takes place in 2008-2010 and a number of reasons are behind this result. First, more than 40% of the consumption basket is made of services and, as such, the inflation response in figure 11 tends to dominate. Second, more importantly and as previously discussed, the 2008-2010 period saw a rapid and substantial pass-through of the identified shocks into domestic energy prices. Third, the smaller upward pressure experienced during the recent months is explained by fixed domestic energy prices. Finally, the month-specific shock had a declining inflationary effect during the years between the two recessionary events.

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<sup>24</sup>Please see figure A.2 in Appendix A to see the evolution of the sub-indices' weights.



## 4.6 Decomposing recent headline inflation fluctuations

How can the model help us understand the surging headline inflation experienced, especially, over the recent years? What lies beneath such a surge? A closer look at the identified structural shocks can provide us with valuable information to start tackling these questions.

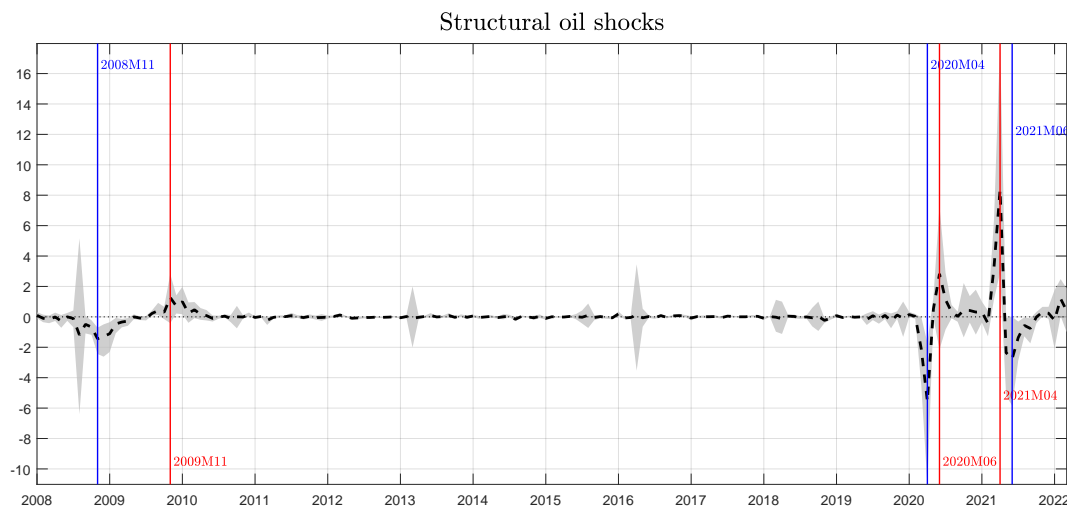


Figure 16: The estimated structural oil shocks

Notes: The figure shows the median (black dashed line) and the 68% credible region (grey shaded areas) of the estimated structural oil shock hitting the world economy.

Figure 16 shows the structural oil shocks obtained through the identification scheme outlined in table 1. Two main characteristics are evident. First, behind the two periods of higher inflation responsiveness discussed through figures 8 to 11 and figure 15 there are structural shocks of elevated magnitude. Those taking place after the pandemic broke out appear to be larger and more abrupt than those in conjunction with the Great Recession. Second, between the latter two periods, the model estimates a number of years featuring way smaller shocks.

The six vertical lines in the figure mark months in which sizeable shocks are estimated: negative disturbances in blue, while positive ones in red. The months are chosen arbitrarily as they are deemed to be representative of the most relevant inflationary moments: the trough and recovery from the Great Recession, the fall in activity and then timid recovery when the pandemic broke out and, finally, the stronger recovery process in Spring 2021 once the vaccination programs started being rolled out in most of the world.

How can this be reconciled with the recent high inflationary pressures? In order to gauge the overall effect on inflation it is necessary to look at the magnitude of the month-specific shocks and multiply them by the responses they generate.<sup>25</sup> To simplify the matter, this exercise is carried out only on the six months marked by vertical lines in figure 16. For simplicity, the three periods will be here referred to as the Great Recession, the COVID-19 outbreak and the COVID-19 recovery.

<sup>25</sup>This exercise is similar, in nature, to a historical decomposition of the fluctuations of the variables in the autoregression on the basis of the identified structural shock.

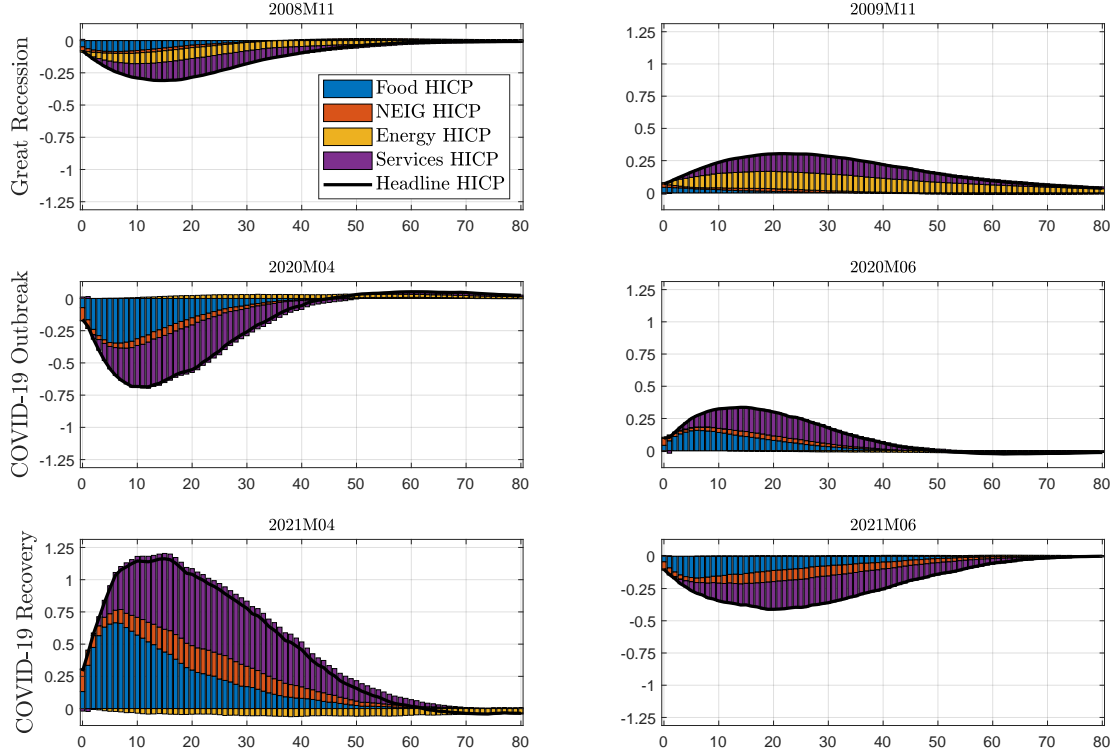


Figure 17: Headline inflation responses and their sub-indices' contributions on selected months

Notes: The figure shows the headline inflation response, and the contribution of its four main sub-indices, to oil shocks on a number of selected months. The responses are normalised to the size of the structural shock on the selected months.

Figure 17 shows the overall inflation response during the three periods as a black solid line. The latter is given by the sum of the coloured bars which are obtained by multiplying the month and variable-specific responses by their respective weights in the consumption basket in that specific point in time. Positive and negative responses respectively represent upward and downward pressures. The aim of figure 17 is also to provide information on the composition of the overall inflationary pressures experienced.

A few results stand out. First, by looking at the Great Recession in the top two graphs, the negative shock detected in November 2008 and the positive one taking place one year after produce inflation fluctuations of a similar size. However, the model would suggest that, back then, the government was more responsive to rising oil prices in November 2009 than falling ones in 2008. The reason being the energy contribution, in absolute terms, appearing bigger during the economic recovery period. Second, at the onset of the COVID-19 pandemic (April 2020), the decline in inflation was more pronounced than the inflationary pressure estimated at the beginning of Summer 2020 when a timid recovery was taking place. Third, Spring 2021 marks the period of highest inflationary pressure in the sample. The bottom left panel evidences how headline inflation receives an upward pressure peaking at about 1.15% driven mostly by surging food and services prices. Not only the response is large in size, but also quite persistent

in its duration. Additionally, the model appears to capture reasonably well the downward effect on energy inflation produced by the policies implemented by the government. Finally, the bottom right panel suggests that the negative shock estimated at the beginning of Summer 2021 produced a small cooling down in prices peaking at about 0.04%.<sup>26</sup>

## 5 Conclusion

This paper documents the development of a 2-block vector autoregression featuring time-varying parameters and stochastic volatility. The model is estimated through Bayesian methods and hinges on a small-country assumption whereby the Maltese economy, given its size, cannot influence the world one. The model is proven to be reliable and, as such, can be confidently used for further policy analyses at the Central Bank of Malta.

The framework is applied to the same dataset and identification strategy outlined in [Ruisi \(2022\)](#) and, as such, might be subject to the same limitations and criticisms of the mentioned piece of research. Despite this, the scope is providing additional knowledge with respect to the latter work. Specifically, it aims at detecting the changing spillover of global oil shocks into the Maltese economy over the period that goes from January 2008 to March 2022.

With respect to the time-invariant case a few results stand out. First, a certain degree of time-variation is detected in the whole system, especially for domestic energy prices. Specifically, the latter become more and more disconnected from developments in the global economy. Second, Maltese energy inflation becomes less and less responsive over time and so does the pass-through from international to domestic energy prices. As far as the latter is concerned, a 10% rise in real oil price growth translates into an increase in energy inflation of 0.5% to 1% over the medium-term until 2017. Afterwards, the pass-through declines to virtually zero. Contrary to this, the responses of food and services inflation rates appear to be more pronounced in conjunction with two periods of higher volatility on global oil markets: the Great Recession and the COVID-19 pandemic. The other three inflation indices experience a diverse pass-through. A 10% increase in real oil price translates into a 0.1% increase in food and services inflation rates in the medium-term, while, for non-energy industrial goods this takes place mostly at very short-horizons. Interestingly, during the 2020-2022 period, the pass-through to food prices goes up to values in the range of 0.2% to 0.3%. Finally, global oil shocks lead to negative responses of Maltese output. However, the recessionary effect produced appears to be longer-lived during the 2008-2010 period than in the 2020-2022 one, the latter characterised by the robust implementation of energy subsidies.

While the implications of energy policies are clear when looking at prices and output, their fiscal consequences still need to be assessed. This is particularly relevant in light of the recent surge in international energy prices and a domestic energy market heavily subsidised. Such

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<sup>26</sup> An additional interesting exercise to carry out by means of this framework would be the estimation of a counterfactual headline inflation rate in absence of government intervention aiming at keeping domestic retail energy prices fixed. To this end, a possibility would be to impose that, from July 2020 onwards and in response to the identified oil shock, domestic energy prices responded as some specific month in the pre-July 2020 period in such a way to be considered representative of a reasonable government reaction. Despite the relevance of this exercise from a policy perspective, the latter is left for future research as it would go beyond the scope of this work.

an assessment might provide valuable information should the government consider to revise energy prices and, therefore, it needs to quantify the amount of support necessary for the implementation of such a policy in the future. Despite the potential benefits of conducting such a study, this work did not tackle this topic as it would have deviated from its main scope towards a wider one deserving particular attention. For this reason, quantifying the fiscal impact of the Maltese government's energy policies is left for further research.

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## Appendix A Data

This appendix describes data series and transformations used in this work. The data frequency is monthly. Figure A.1 shows the Maltese variables in the top row, while the world ones in the bottom row. The monthly Maltese Business Conditions Index for the 1997M01-1999M12 period was approximated with the quarterly year-on-year real gross domestic product growth rate.



Figure A.1: Data used in the estimation of the Time-Varying Parameters and Stochastic-Volatility 2-country VAR

Notes: The figure shows the variables used in the VAR. The entire sample covers the 1997M01-2022M03 period while the training one stretches from 1997M01 to 2007M12. As a consequence, the effective sample covers the 2008M01-2022M03 period.



## A.1 Maltese variables

**Business conditions index:** Business conditions index developed in [Ellul \(2016\)](#) and computed by the Central Bank of Malta (CBM).

**HICP food inflation:** year-on-year growth rate of the monthly measure of the Harmonised Index of Consumer Prices relative to the food category. Source: Eurostat.

**HICP non-energy industrial goods inflation:** year-on-year growth rate of the monthly measure of the Harmonised Index of Consumer Prices relative to the non-energy industrial goods category. Source: Eurostat.

**HICP energy inflation:** year-on-year growth rate of the monthly measure of the Harmonised Index of Consumer Prices relative to the energy category. Source: Eurostat.

**HICP services inflation:** year-on-year growth rate of the monthly measure of the Harmonised Index of Consumer Prices relative to the services category. Source: Eurostat.

## A.2 World variables

**OECD industrial production:** year-on-year growth rate of the monthly industrial production index relative to the 38 OECD countries. Source: Organization for Economic Cooperation and Development (OECD).

**OECD consumer price index:** year-on-year growth rate of the monthly consumer price index relative to the 38 OECD countries. Source: Organization for Economic Cooperation and Development (OECD).

**Real oil price:** year-on-year growth rate of the monthly real global Brent crude oil price (U.S Dollars per barrel). The latter was calculated as the difference between annual growth rates of the nominal global Brent crude oil price and the all items consumer price index for all urban consumers in US city average. Source: Federal Reserve Economic Data (FRED).

**Baltic dry index:** year-on-year growth rate of the average monthly Baltic dry index. Source: Baltic Exchange in London.

**Oil-BDI ratio:** ratio between the growth rates of real oil price and Baltic dry index. Source: author's calculations.

### A.3 Maltese HICP weights

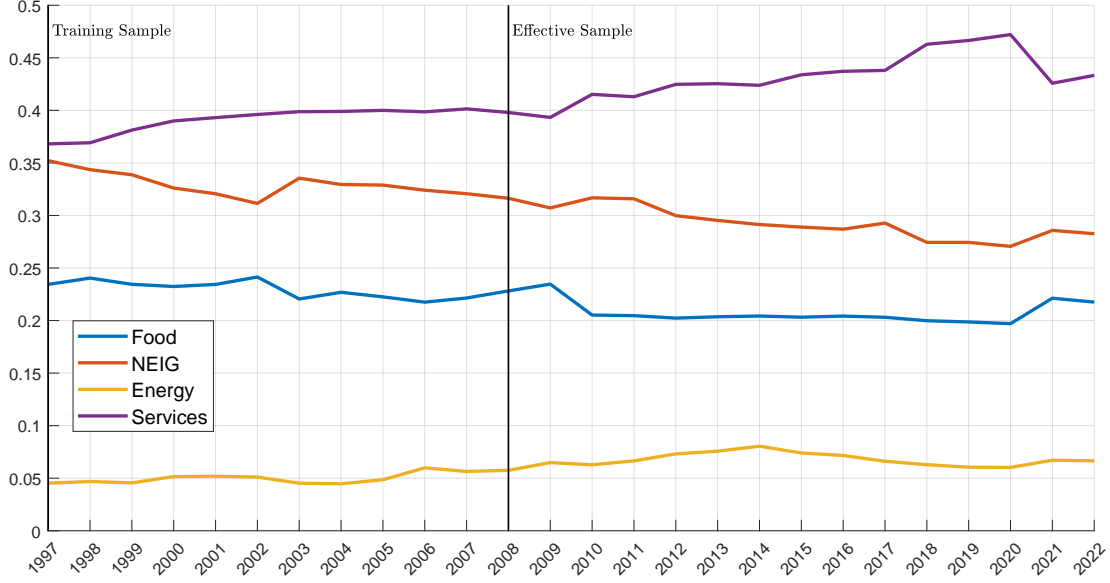


Figure A.2: Annual Maltese headline HICP weights relative to food, non-energy industrial goods, energy and services sub-indices. The period goes from 1997 to 2022. Source: Eurostat.

## Appendix B Technical details

### B.1 Stochastic volatility details

The stochastic volatility  $\Sigma_t$  in the model in equation 1 is modelled in a standard way. For each  $t = 1, \dots, T$ , it is assumed that  $\Sigma_t$  can be decomposed into the product of a lower unit triangular matrix, a diagonal matrix and the transpose of the lower unit triangular matrix.

$$\text{Var}(U_t) = \text{Var}\left(\begin{bmatrix} U_t^{MT} \\ U_t^W \end{bmatrix}\right) = \Sigma_t$$

$$\Sigma_t = A_t^{-1} H_t A_t^{-1'}$$

$$A_t = \begin{bmatrix} 1 & 0 & 0 & \dots & 0 \\ a_{2,1,t} & 1 & 0 & \dots & 0 \\ a_{3,1,t} & a_{3,2,t} & 1 & \ddots & 0 \\ \vdots & \vdots & \ddots & \ddots & 0 \\ a_{N,1,t} & a_{N,2,t} & \dots & a_{N,N-1,t} & 1 \end{bmatrix}$$

$$H_t = \begin{bmatrix} h_{1,t} & 0 & 0 & \dots & 0 \\ 0 & h_{2,t} & 0 & \dots & 0 \\ 0 & 0 & h_{2,t} & \ddots & 0 \\ \vdots & \vdots & \ddots & \ddots & 0 \\ 0 & 0 & \dots & 0 & h_{N,t} \end{bmatrix}$$

## 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 and reported in figure B.1.

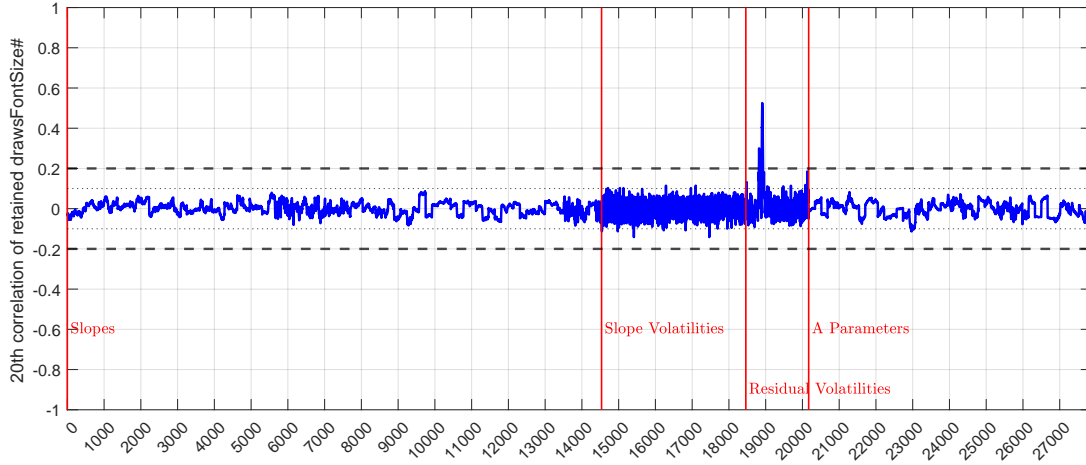


Figure B.1: 20<sup>th</sup> order autocorrelation of the retained draws

The red vertical lines separate the 27,865 autocorrelations into those relative to the time-varying intercept and slope coefficients in equation 1, i.e.,  $C_t$  and  $B_t$ , the volatilities of their laws of motion, i.e.,  $Q^{MT}$  and  $Q^W$ , the stochastic volatilities in  $H_t$  and the lower-diagonal entries in  $A_t$ . Apart from two cases, all the autocorrelations of the retained draws lie within the  $[-0.2, 0.2]$  interval and most of them within the  $[-0.1, 0.1]$  one. Despite the high dimensionality of the model, the algorithm performs in a satisfactory way and reaches convergence as the draws are nearly independent. As such, the latter can be used to conduct meaningful inference.

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

In order to trace the propagation of the shocks identified in Table 1 the following procedure is implemented. Recall the link between reduced form errors and structural shocks  $U_t = A_{0,t}V_t$  and the restrictions in table 1. This means that the relation in 4 can be further expanded as:

$$\begin{bmatrix} \underbrace{\begin{bmatrix} u_1^{MT} \\ \vdots \\ u_{N^{MT}}^{MT} \end{bmatrix}}_{U^{MT}} \\ \underbrace{\begin{bmatrix} u_1^W \\ \vdots \\ u_{N^W}^W \end{bmatrix}}_{U^W} \end{bmatrix} = \begin{bmatrix} \underbrace{\begin{bmatrix} a_{0,t}^{1,1} & \dots & a_{0,t}^{1,N^{MT}} \\ \dots & \ddots & \dots \\ a_{0,t}^{N^{MT},1} & \dots & a_{0,t}^{N^{MT},N^{MT}} \end{bmatrix}}_{A_{0,t}^{MT}} & \underbrace{\begin{bmatrix} ? & \dots & ? \\ \dots & \ddots & \dots \\ ? & \dots & ? \end{bmatrix}}_{A_{0,t}^{W \rightarrow MT}} \\ [0] & \underbrace{\begin{bmatrix} a_{0,t}^{N^{MT}+1,1} & \dots & a_{0,t}^{N^{MT}+1,N^W} \\ \dots & \ddots & \dots \\ a_{0,t}^{N^W,1} & \dots & a_{0,t}^{N^W,N^W} \end{bmatrix}}_{A_{0,t}^W} \end{bmatrix} \begin{bmatrix} \underbrace{\begin{bmatrix} v_1^{MT} \\ \vdots \\ v_{N^{MT}}^{MT} \end{bmatrix}}_{V^{MT}} \\ \underbrace{\begin{bmatrix} v_1^W \\ \vdots \\ v_{N^W}^W \end{bmatrix}}_{V^W} \end{bmatrix}$$

In order to obtain a factorisation satisfying the equation above, once past the burn-in stage, the following algorithm is implemented for each  $t = 1, \dots, T$ :<sup>27</sup>

1. Draw  $\Sigma_t$  as shown in B.1 and compute its Cholesky decomposition such that  $P_t P_t' = \Sigma_t$ .
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  $R_{MT}$  normalised to be positive. The matrix  $Q_{MT}$  has the uniform Haar measure.
3. Draw  $X_W \sim N(0, I_{N^W})$  and get  $Q_W$  such that  $Q_W R_W = X_W$ , i.e., an orthogonal matrix  $Q_W$  that satisfies the QR decomposition of  $X_W$  with the diagonal of  $R_W$  normalised to be positive. The matrix  $Q_W$  has the uniform Haar measure.
4. Build the  $N \times N$  matrix:

$$Q_{(N \times N)} = \begin{bmatrix} Q_{MT} & [0]_{(N^{MT} \times N^W)} \\ [0]_{(N^W \times N^{MT})} & Q_W \end{bmatrix}$$

5. Obtain the candidate draw  $A_{0,t} = Q P_t$ . If  $A_{0,t}$  satisfies the restrictions in table 1 then keep it otherwise discard it and return to step 1.

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<sup>27</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).

## Appendix C Response of the world economy to oil shocks

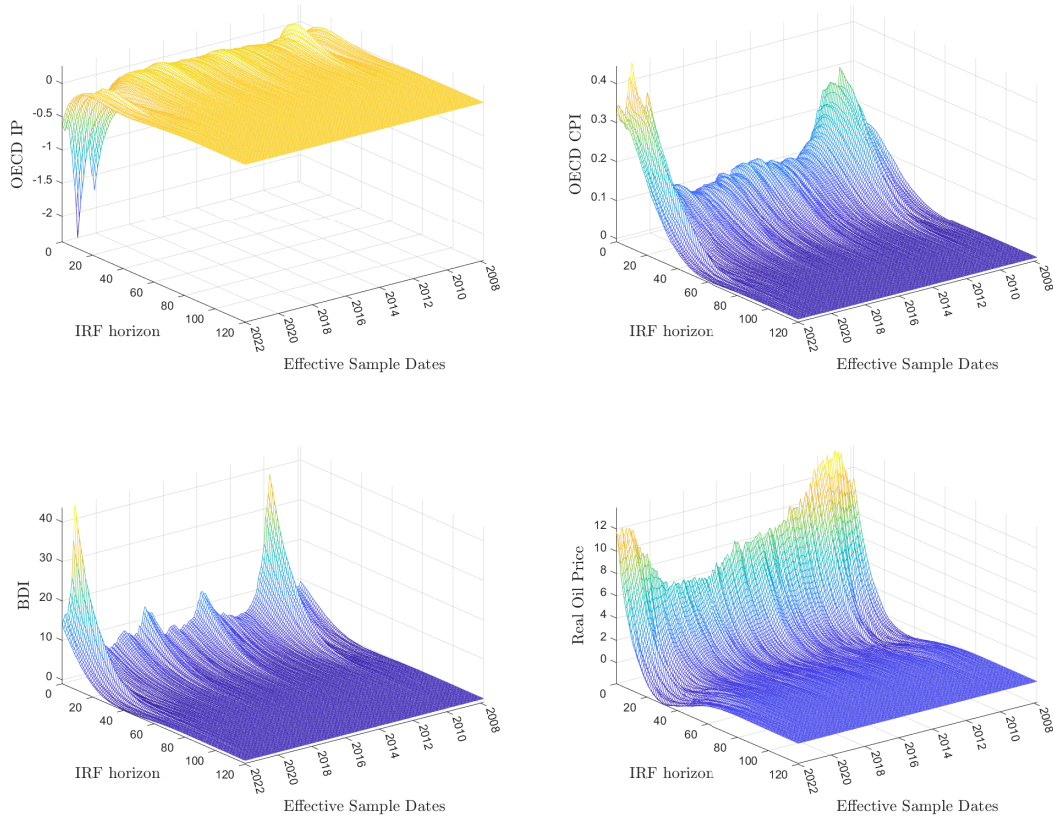


Figure C.1: Time-varying response of world variables to an oil shock

Notes: The figure shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Figure C.1 reports the responses of global economic activity and prices, Baltic dry index and real oil price. The main results are the following. First, until the pandemic broke out in early 2020, the identified oil shock produced a declining upward pressure on oil prices. Second, global activity and prices as well as shipping costs experience a more prompt response around the two recessionary events in the effective sample.

## Appendix D Additional results

### D.1 Response to a 10% oil shock

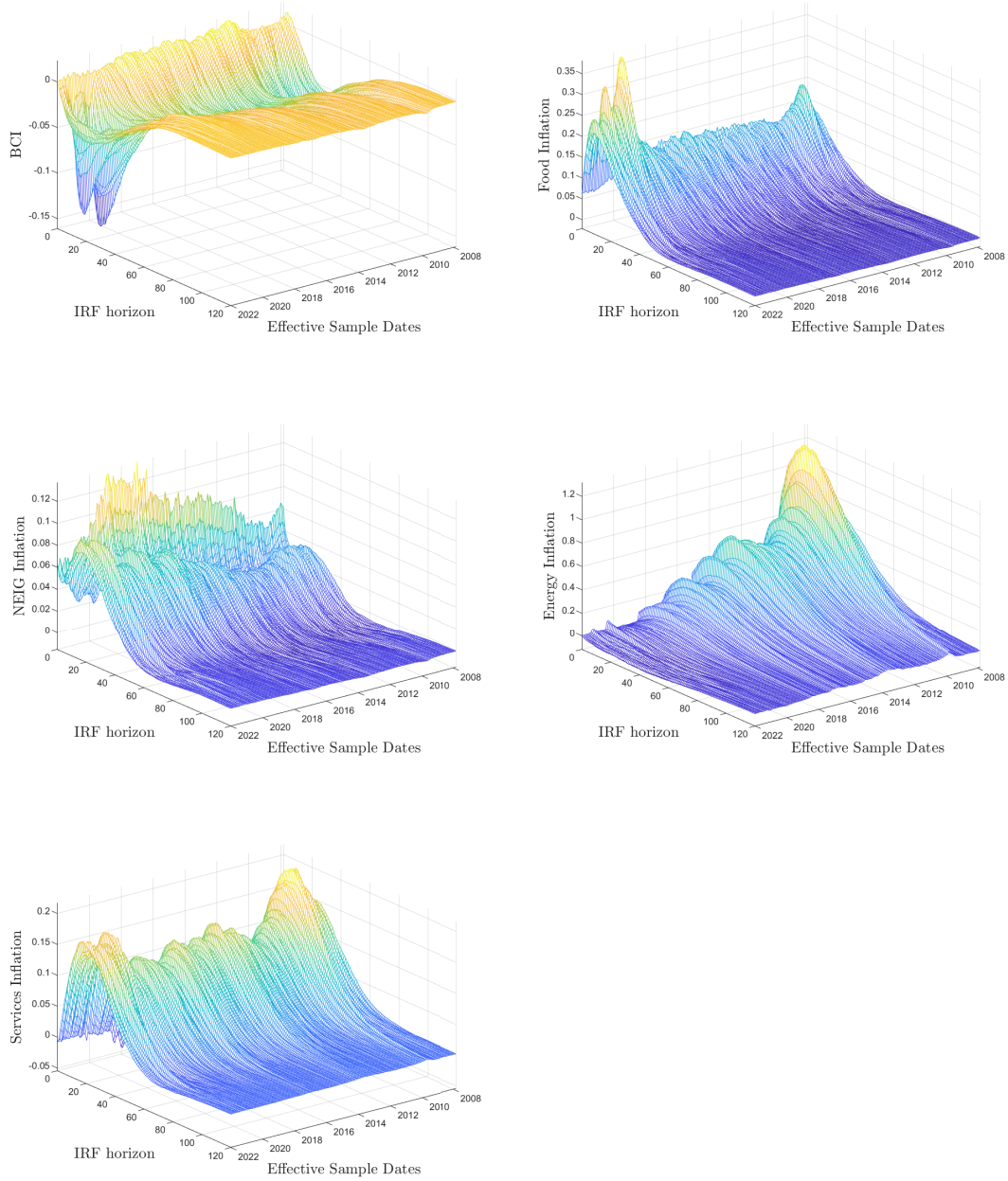


Figure D.2: Time-varying response of Maltese variables to an oil shock

Notes: The figure shows the median response to an oil shock normalised to increase real oil by 10% in the time-varying case. The credible region is not shown but is available upon request.

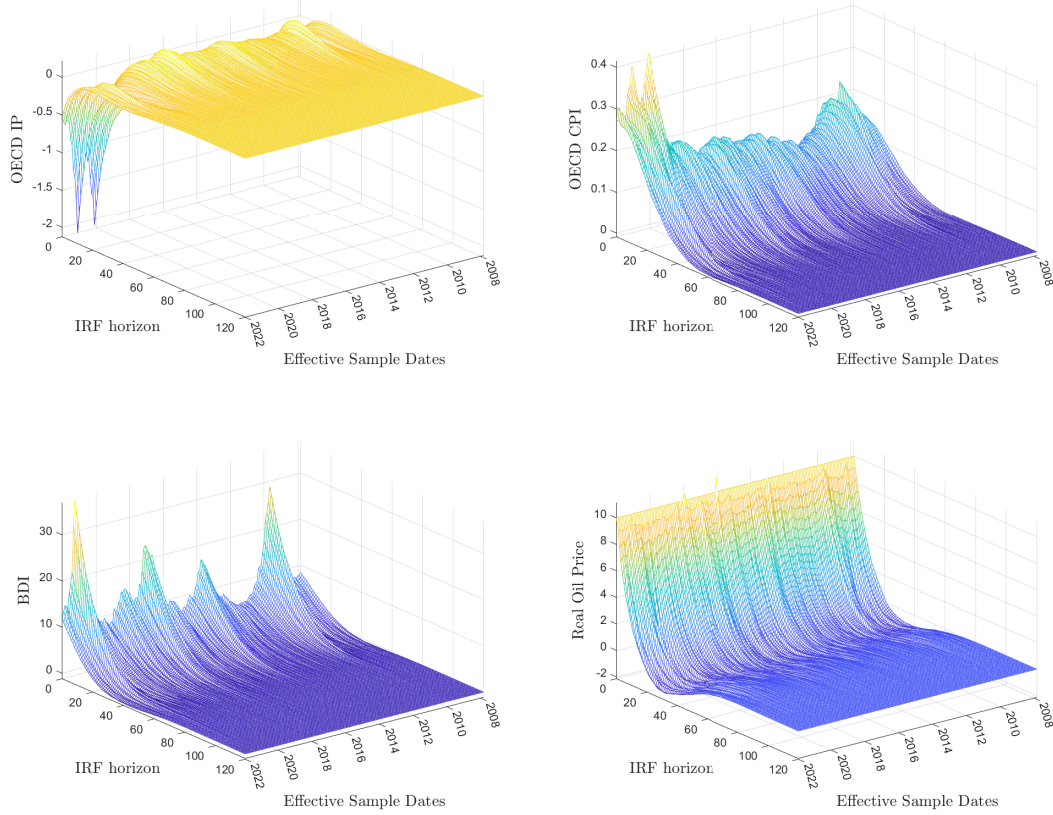


Figure D.3: Time-varying response of world variables to an oil shock

Notes: The figure shows the median response to an oil shock normalised to increase real oil by 10% in the time-varying case. The credible region is not shown but is available upon request.

Figures D.2 and D.3 respectively display the responses of Maltese and global economies to an oil shock normalised to increase oil price growth by 10%. By doing so, the results may be more easily communicated from a more policy perspective as they can better relate to real life experience.

## D.2 Shipping disruption shocks

### Shock Identification

	OECD IP	OECD CPI	BDI	Real Oil	Real Oil/BDI
Shipping	—	+	+	?	—

Notes: 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.

Table 2: Identifying sign restrictions on the World Economy - Impact responses



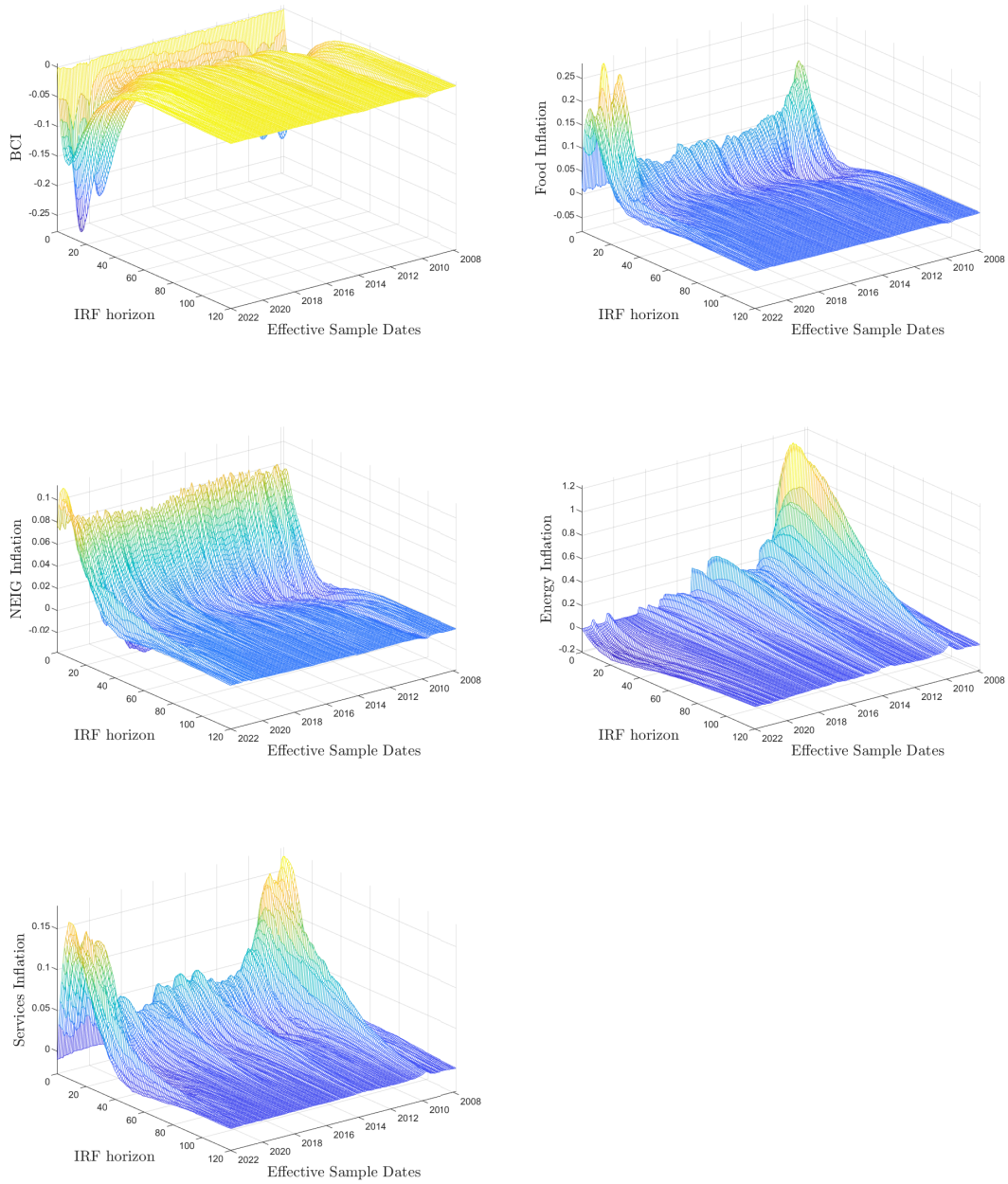


Figure D.4: Time-varying response of Maltese variables to a shipping disruption shock

Notes: The figure shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.



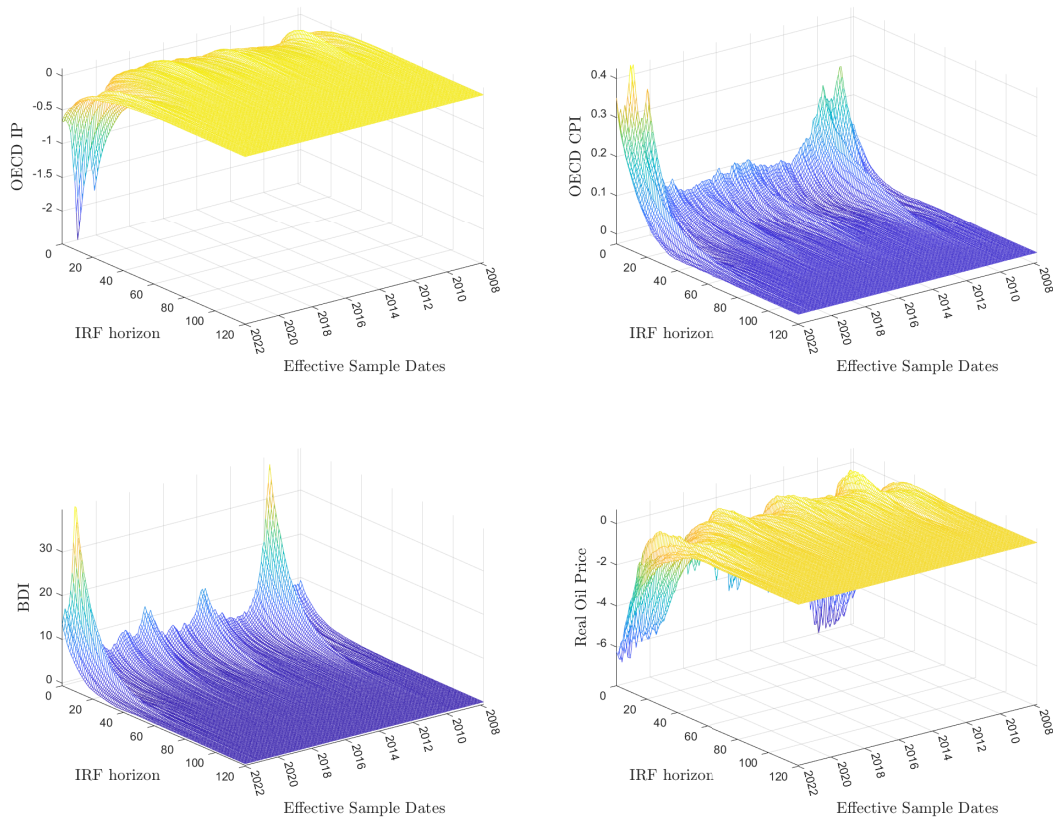


Figure D.5: Time-varying response of world variables to a shipping disruption shock

Notes: The figure shows the median response to a 1-standard deviation oil shock in the time-varying case. The credible region is not shown but is available upon request.

Figures D.4 and D.5 respectively display the responses of Maltese and world economies to a one standard deviation shipping disruption shock.