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MEDSEA
A Small open economy DSGE model for Malta

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Abstract

This paper describes MEDSEA, a compact small open economy DSGE model of the Maltese economy. The model is similar in nature to other small open economy models, thus containing a number of nominal and real frictions allowing the model to replicate the sluggish reaction of economic variables documented in empirical research. Moreover, MEDSEA contains key modifications designed to account for Malta's specific characteristics. The model distinguishes between a tradable and non-tradable sector reflecting the different nature of exports when compared to other production meant for domestic use. Furthermore, the model features distribution costs in the export sector allowing for a wedge to exist between wholesale and retail export prices. In light of Malta's membership of the European Monetary Union, MEDSEA includes an exogenously set nominal interest rate and exchange rate. The model is calibrated in order to match the key ratios observed in Maltese data. This model, together with its future extensions is meant to be used as a complement to existing policy analysis tools available at the Central Bank of Malta.

JEL classification: E12, E30, E50
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Table of Contents

1. Introduction

The popularity of traditional large scale macroeconometric models among central banks as tools for policy analysis has been eroding rapidly especially in the light of the several critiques aimed at these types of models. Most notably, Lucas (1976) criticized the policy recommendations derived from traditional models on the basis that the latters' estimated coefficients are not policy-invariant, leading to potentially misleading policy conclusions. Moreover, traditional models have been repeatedly criticized as being unable to predict business cycles. As an answer to these criticisms, Kydland and Prescott (1982) proposed a new paradigm based on private optimizing agents that benefit from rational expectations whilst behaving in a general equilibrium environment. Despite their elegant structures, these Real Business Cycle (RBC) models were often accused of ignoring the short-run roles of aggregate demand and monetary policy as well as overestimating the contribution of technology shocks to the business cycle (Blanchard, 2008). Against this background, a new consensus modelling strategy has been reached in the birth of the New Keynesian paradigm.

Similar to the Neo-Classical thought that gave birth to RBC models, the New Keynesian School believed that macroeconomic analysis needs to be rigorously microfounded. However, contrary to the Neo-Classical economists, New Keynesians believed that the economy was not perfectly flexible but contained nominal rigidities and imperfections. Against this backdrop New Keynesians augmented RBC models with two imperfections; imperfect competition, thereby introducing price setters in the economy, and a staggered nominal pricing system, giving rise to the New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model[2]. These extensions also allowed the introduction of a broader set of disturbances that could be used to characterise the economic business cycle. DSGEs were subsequently enhanced with a range of rigidities such as quantity adjustment costs, habit formation as well as price and wage indexation allowing DSGEs to better explain output and inflation persistence.

Contrary to traditional macroeconometric models, New Keynesian DSGE models are especially suited to counterfactual simulations and policy evaluations that are immune to the Lucas' critique. Moreover, unlike traditional models, New Keynesian DSGEs include an explicit treatment of expectations allowing the study of the anticipatory or precautionary behaviour of agents in response to expected shocks. Moreover, being fully microfounded, DSGE models can

[2] Seminal contributions in this respect are Gali (2008), Smets and Wouters (2003) and Christiano et al (2005).

be used to rank policy alternatives through a welfare criterion as well as to identify potential synergies between different policies.

The combination of strong theoretical foundations together with an ever improving empirical fit have made DSGEs the model of choice of both academic and policy making institutions. Some notable examples include the European Central Bank's NAWM (Christoffel et al, 2008), PESSOA (Almeida et al, 2013) developed at the Banco de Portugal, BEMOD (Andres et al, 2006) of the Banco de Espana, the Bank of England's COMPASS (Burgess et al, 2011) and GIMF (Anderson et al, 2013) currently in use at the IMF. Other large-scale models especially designed to study spill-over effects are the EAGLE (Gomes et al, 2010) and the NMCM (Dieppe et al, 2011).

As part of its general modelling strategy, the Central Bank of Malta has embarked on a project aimed at constructing a DSGE model for the Maltese economy. The model described in this paper is intended to be a first step towards a set of more detailed DSGE models and will therefore serve as a basis for extensions allowing a more detailed treatment of the themes and questions of interest. MEDSEA belongs to the small open economy category, similar in nature to the models found in Gali and Monacelli (2005) but contains key modifications designed to account for Malta's specific characteristics. In particular, in line with Almeida (2009), the Maltese economy is modelled within a monetary union, thereby lacking an independent inflation targeting rule. Furthermore, the model features a modified export sector specifically designed to account for the characteristics of the Maltese export sector. First, unlike similar models in its class, the tradable production of the model is explicitly targeted to be exported and is therefore not complementary to other production meant for local household consumption, investment or government expenditure. This feature is meant to reflect the fact that the goods and services meant for Maltese consumption and investment are intrinsically different from those that are exported. Secondly, through its export production process the model is able to reflect the reliance of Maltese exports on imported content. Moreover, in line with Corsetti et al (2005) and Cristadoro et al (2008), the model features goods market separation through the presence of distribution costs in the tradable sector. The model allows for habit persistence price and wage indexation as well as investment adjustment costs in an effort to capture the persistence and dynamics usually found in the data. Also, similar to Monacelli (2003), the model allows for deviations in the law of one price introducing a sluggish pass-through of foreign to import prices.

This paper provides a comprehensive documentation of the model, its calibration as well as its simulation properties. The next section presents a complete description of the baseline model with a clear description of the optimality conditions that characterise the behaviour of economic agents. Section 3 presents the calibration of the parameters of the model while Section 4 provides an overview of the model's simulation properties. The last section summarises this discussion while presenting the way forward.

2. The Model Specification

MEDSEA contains five types of agents, households, intermediate good producers, final good firms, aggregators and the government. Households maximize a lifetime utility over an infinite life horizon. Labour is differentiated over a continuum of households introducing some monopoly power over wages, in turn allowing the introduction of sticky wages. Intermediate goods firms are of three types, firms producing tradable and non-tradable output, and those responsible for importing foreign production. All firms in the intermediate sector optimise prices subject to some nominal rigidities. The economy produces three final goods (consumption, investment and exports), produced by final good firms that combine a continuum of heterogeneous products, produced by the tradable and non-tradable intermediate firms, with imports. Producers of final export goods require distribution services produced by perfectly competitive producers that purchase a basket of non-tradables to deliver the final export goods to the rest of the world. The government pursues a balanced budget and finances public spending through a lump-sum tax.

2.1 The Household Sector

Households are indexed by $j \in (0,1)$. A representative household derives utility from consumption $C_t(j)$ relative to a consumption habit $H_t(j)$ defined as a proportion of the household's consumption in the previous period, $\chi C_{t-1}(j)$, and from leisure $1 - N_t(j)$, where $N_t(j)$ is the amount of labour supplied by household (j). Lifetime utility is thus characterised by the following function:

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t(j) = E_0 \sum_{t=0}^{\infty} \beta^t \left[\varepsilon_t^c (1-\chi) \ln[C_t(j) - H_t(j)] - \frac{1}{1+\eta} N_t(j)^{1+\eta} \right] \quad (1)$$

Where β is the discount factor, ε_t^C represents a general shock to preferences that affects the intertemporal elasticity of substitution of households and η is the inverse of the elasticity of work with respect to the real wage. Households hold wealth in terms of domestic and foreign bonds, $B_t(j)$ and $B_t^*(j)$, and capital, $K_t(j)$, which is rented to firms which decide how much capital to accumulate. Bonds are one period securities with price b_t and b_t^* and gross return R_t and $R_t^* \xi(\phi_t, \varepsilon_t^R)$.[3] As is common in small open economy literature[4], foreign bond returns are adjusted by a premium $\xi(\phi_t, \varepsilon_t^R)$, assumed to be an increasing function of a debt premium ϕ_t, and a risk premium shock ε_t^R. This mechanism works as a disincentive to buy or sell local bonds, acting as a stabiliser of the level of local indebtedness, with this being crucial to pin down a well-defined steady-state for the model, in the absence of an endogenously set interest rate.

The household budget constraint net of adjustment costs is therefore given by:

$$B_t(j) + B_t^*(j) = R_t B_{t-1}(j) + R_t^* \xi(\phi_t, \varepsilon_t^R) + Y_t(j) - P_t^C C_t(j) - P_t^I I_t(j) - \Omega_t(j) - Tax_t(j) \quad (2)$$

Where $Y_t(j)$ is household income, $I_t(j)$ is investment conducted by household (j), P_t^C and P_t^I are consumption and investment prices respectively and $Tax_t(j)$ is a lump-sum tax raised by the government. Ω_t are adjustment costs arising from deviations in export, import and domestic prices and are defined as follows:

$$\Omega_t(j) = P_t^X X_t S^X\left(\frac{\pi_t^X}{\pi_{t-1}^X}\right) + P_t^M X_t S^M\left(\frac{\pi_t^M}{\pi_{t-1}^M}\right) + P_t^M X_t S^M\left(\frac{\pi_t^M}{\pi_{t-1}^M}\right) \quad (3)$$

These costs are used to introduce New Keynesian features in the models, so as to replicate the sluggish adjustment of real variables to shocks shown in empirical research[5].

Household (j) is the sole supplier of labour type (j) and thus holds some monopoly power over the wages it charges. Each household is not able to set its wage optimally due to the presence of some adjustment costs modelled as in Rotemberg (1982). Furthermore, households are the sole owners of the firms in the economy and receive their profits as dividends $Div_t(j)$. Also, following Christiano et al (2005) we assume that each household participates in a market for

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[3] A no-arbitrage condition implies that $b_t B_t \leq B_{t-1}$, so $B_t = \frac{1}{b_t} B_{t-1}$. Therefore $\frac{1}{b_t} = (1 + i_t) = R_t$. Similarly for foreign bonds: $\frac{1}{b_t^*} = (1 + i_t^*) = R_t^* \xi(\phi_t, \varepsilon_t^R)$.

[4] See for instance Benigno (2003), Adolfson et al (2005) and Almeida et al (2009).

[5] See for instance Christiano, Eichenbaum and Evans (1998).

state-contingent assets with a net income of $A_t(j)$ so that all households are insured against household specific labour income variations. As a result each household's labour income equals aggregate labour income making the expenditure decisions perfectly symmetric across households. For simplicity we assume that the aggregate value of state-contingent assets equals zero, i.e. $\int_0^1 A_t(j)dj = 0$.

$$Y_t(j) = \left[W_t(j)N_t(j) - S^W\left(\frac{\pi_t^W}{\pi_{t-1}^W \pi^{bar}}\right) + A_t(j)\right] + [R_t^K K_{t-1}(j)] + Div_t(j) \tag{4}$$

Income of household (j) is therefore made up of labour income net of wage adjustment costs, $W_t(j)N_t(j) - S^W\left(\frac{\pi_t^W}{\pi_{t-1}^W \pi^{bar}}\right) + A_t(j)$, the return on capital stock owned, $R_t^K K_{t-1}(j)$, and the dividends derived from the imperfect competitive firms, $Div_t(j)$. Capital follows an accumulation function stating that capital available at the end of period t, $K_t(j)$, is equal to the capital stock available at the end of period $t-1$, $K_{t-1}(j)$, net of depreciation of period $t-1$, $\delta K_{t-1}(j)$, plus the amount of investment made during period t net of adjustment costs, $S^I\left(\frac{I_t}{I_{t-1}}\right)$. The latter are modelled in line with Christiano et al (2005) and are a positive function of the change in investment between period t and $t-1$.

$$K_t(j) = \delta K_{t-1}(j) + I_t(j)\left(1 - S^I\left(\frac{I_t}{I_{t-1}}\right)\right) \tag{5}$$

Households maximise the objective function equation (1) subject to the constraints imposed by equations (2), (3), (4) and (5).

This yields the following first order conditions with respect to $C_t(j), B_t(j), B_t^*(j), I_t(j)$ and $K_t(j)$.

$$[C_t(j) - \chi C_{t-1}(j)]\lambda_t(j) = \varepsilon_t^c(1-\chi) \tag{6}$$

$$\lambda_t(j) = \beta E_t\left[\frac{\lambda_{t+1}(j)R_{t+1}}{\pi_{t+1}^C}\right] \tag{7}$$

$$\lambda_t(j) = \beta E_t\left[\frac{\lambda_{t+1}(j)R_{t+1}^*\xi\left(\phi_t,\varepsilon_t^R\right)}{\pi_{t+1}^C}\right] \tag{8}$$

$$P_t^I(j) = Q_t(j)\left[1 - S^I\left(\frac{I_t(j)}{I_{t-1}(j)}\right) - S^{I'}\left(\frac{I_t(j)}{I_{t-1}(j)}\right)\left(\frac{I_t(j)}{I_{t-1}(j)}\right)\right] + \beta E_t\left[Q_{t+k}(j)\frac{\lambda_{t+1}(j)}{\lambda_t(j)}S^{I'}\left(\frac{I_{t+1}(j)}{I_t(j)}\right)\left(\frac{I_{t+1}(j)}{I_t(j)}\right)^2\right] \tag{9}$$

$$\tilde{P}_t^K(j) = \beta E_t\left(\frac{\pi_{t+1}^C}{R_{t+1}}\right)\left[(1-\delta)\tilde{P}_{t+1}^K(j) + \frac{R_{t+1}^K(j)}{P_{t+1}^C}\right] \tag{10}$$

Where $\lambda_t(j)$ is the Lagrange multiplier associated with the real household budget constraint, and equivalent to the marginal utility of an additional unit of resources available to consume, purchase bonds or invest. $Q_t(j)$ is interpreted as Tobin's Q and is equal to $\tilde{P}_t^K(j)$, the implicit price of capital, and to $\frac{\Theta_t(j)}{\lambda_t(j)}$, where $\Theta_t(j)$ is the Lagrange multiplier associated with the capital accumulation function.

Combining equations (6) and (7) yields the consumption Euler equation:

$$\frac{\varepsilon_t^C[C_{t+1}(j) - \chi C_t(j)]}{\varepsilon_{t+1}^C[C_t(j) - \chi C_{t-1}(j)]} = \frac{\pi_{t+1}^C}{\beta R_{t+1}} \tag{11}$$

While equations (7) and (8) result in the uncovered interest rate parity condition (UIPC):

$$R_t = R_t^* \xi\left(\phi_t, \varepsilon_t^R\right) \tag{12}$$

All optimising households face the same conditions, and due to the existence of a market for state-contingent assets behave symmetrically. Thus we can drop the (j) subscript from the above first order conditions resulting in the following identities: $C_t(j) = C_t$; $K_t(j) = K_t$; $I_t(j) = I_t$; $P_t^k(j) = Q_t(j) = P_t^k = Q_t$; $B_t(j) = B_t$; $N_t(j) = N_t$; $\lambda_t(j) = \lambda_t$.

Each household (j) exercises its monopoly power to set its wage by maximising equation (1) subject to equations (2), (3), (4), (5) and to a downward sloping demand curve derived from the intermediate labour unions (discussed in section 2.2.3) that aggregate labour of types (j) across $j \in (0,1)$.

The first order condition with respect to $W_t(j)$ is given by:

$$\frac{W_t}{P_t^C} = \left\{ \begin{array}{l} \lambda_t \left[\left(\frac{1}{\mathcal{M}_t^W - 1} \right) + \varphi_W \left(\frac{\pi_t^W}{\pi_{t-1}^{W^{\iota W}} \pi^{bar^{1-\iota W}}} \right) \left(\frac{\pi_t^W}{\pi_{t-1}^{W^{\iota W}} \pi^{bar^{1-\iota W}}} - 1 \right) \right] - \\ \beta E_t \left[\lambda_{t+1} \varphi_W \left(\frac{\pi_{t+1}^{W^2}}{\pi_t^{W^{\iota W}} \pi^{bar^{1-\iota W}}} \right) \left(\frac{\pi_{t+1}^W}{\pi_t^{W^{\iota W}} \pi^{bar^{1-\iota W}}} - 1 \right) \frac{N_{t+1}}{N_t} \right] \end{array} \right\}^{-1} \frac{\mathcal{M}_t^W}{\mathcal{M}_t^W - 1} N^\eta \tag{13}$$

Where π_t^W is wage inflation, $\varphi_W > 0$ is the parameter governing the degree of wage adjustment costs, and $1 - \iota_W$ corresponds to the fraction of households that index their wage demands with overall inflation in steady-state.

2.2 Firms

Focusing on the supply side, there are three broad categories of firms operating in the economy: intermediate good firms, final good firms and aggregators.

2.2.1 Intermediate Good Firms

There are three types of intermediate firms, those producing non-tradable goods, those producing a homogenous import good and firms producing tradable goods for the export market.

Non-tradable goods

There is a continuum of non-tradable good firms indexed by $n \in (0,1)$. A representative firm (n) produces non-tradable output intended solely for domestic purposes using the following Cobb Douglas production function:

$$Y_t^N(n) = A_t^N(n) K_{t-1}^N(n)^{1-\gamma_N} N_t^N(n)^{\gamma_N} \tag{14}$$

Where γ_N is the labour share in non-tradable output and A_t^N is an exogenous (stationary) technology term which follows an autoregressive process.

Each firm operates in perfect competition in their input markets renting capital from households at the rental rate R_t^K, and hiring labour from labour aggregators at wage rate W_t. Therefore the static problem of firms consists in choosing the optimal labour-capital mix by minimising their cost function subject to equation (14) for each time period t. The first order conditions with respect to N_t and K_{t-1} are:

$$W_t^N = \frac{\kappa_t Y_t^N(n)}{L_t^N(n)} \gamma_N \tag{15}$$

$$R_t^{KN} = \frac{\kappa_t Y_t^N(n)}{K_{t-1}^N(n)} (1 - \gamma_N) \tag{16}$$

Where κ_t is the Lagrange multiplier associated with the firm's cost minimisation problem which is interpreted as the marginal cost and which depends on factor costs and technology shocks and is therefore the same for all firms. Similarly, the capital-labour ratio depends on the input prices and shares and is therefore also equal across firms.

In their output market, firms operate in a monopolistically competitive environment exploiting their price setting power due to their differentiated product. They therefore need to decide what price to charge for their output by maximising a real profit function subject to the production function and subject to the demand for $Y_t^N(i)$ raised by the final good firm or aggregator (derived in section 2.2.3).

We assume that in doing so, firms face a quadratic cost of adjustment measured in terms of final non-tradable goods Y_t^N and modelled as in Rotemberg (1982):

$$\frac{\varphi_N}{2} \left(\frac{P_t^N(i)/P_{t-1}^N(i)}{{\pi_{t-1}^N}^{\iota_N} \pi bar^{1-\iota_N}} - 1 \right)^2 Y_t^N \tag{17}$$

Where $\varphi_N > 0$ is the degree of nominal price rigidity and where parameter ι_N governs the extent to which inflation is backward looking. Upon maximising the profit function and imposing symmetry (i.e. $Y_t^N(n) = Y_t^N$ and $P_t^N(n) = P_t^N$) we get the New Keynesian Phillip's curve for the non-tradable sector which takes the form:

$$P_t^N = \begin{Bmatrix} \left(\frac{1}{\mathcal{M}_t^N - 1} \right) + \varphi_N \left(\frac{\pi_t^N}{{\pi_{t-1}^N}^{\iota_N} \pi bar^{1-\iota_N}} - 1 \right) \left(\frac{\pi_t^N}{{\pi_{t-1}^N}^{\iota_N} \pi bar^{1-\iota_N}} \right) - \\ \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \varphi_N \left(\frac{\pi_{t+1}^N}{{\pi_t^N}^{\iota_W} \pi bar^{1-\iota_W}} - 1 \right) \left(\frac{\pi_{t+1}^N}{{\pi_t^N}^{\iota_W} \pi bar^{1-\iota_W}} \right) \frac{Y_{t+1}^N}{Y_t^N} \end{Bmatrix}^{-1} \frac{\mathcal{M}_t^N}{\mathcal{M}_t^N - 1} MC_t^N \tag{18}$$

Where $\mathcal{M}_t^N$ is the time-varying mark-up of non-tradable goods. One can note that at the steady-state (i.e. where $\pi_t^N = \pi_{t-1}^N$) or in the case that prices are perfectly flexible (i.e. $\varphi_N = 0$), the above Phillips Curve reduces to the standard relation that treats prices as being a mark-up over marginal costs.

Importers

There is a continuum $m \in (0,1)$ of importing firms that buy a homogenous good Y_t^{*M} at price P_t^{*M} and rebrand it using a brand naming technology. Under the small country assumption, home country demand for foreign goods does not affect their prices so that the marginal cost faced by the importing firms is equal to

$$MC_t^M = P_t^{*M} * S_t \tag{19}$$

Where S_t is the exchange rate, which is assumed as 1 in view of Malta's membership of the European Monetary Union. Each firm will maximise its profits subject to (19) and subject to the import demand function (derived in section 2.2.3) of the import good aggregator that uses heterogeneous import goods $Y_t^M(m)$ to produces a homogenous import good Y_t^M.

Moreover, in order to account for the incomplete pass-through of import prices to the rest of the economy, we follow Adolfson et al (2005) and assume that each importer faces quadratic adjustment costs similar to those faced by producers of non-tradable goods. The first order condition after imposing symmetry is:

$$P_t^M = \begin{Bmatrix} \left(\frac{1}{\mathcal{M}_t^M - 1}\right) + \varphi_M \left(\frac{\pi_t^M}{{\pi_{t-1}^M}^{\iota_M} \pi bar^{1-\iota_M}} - 1\right)\left(\frac{\pi_t^M}{{\pi_{t-1}^M}^{\iota_M} \pi bar^{1-\iota_M}}\right) - \\ \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \varphi_M \left(\frac{\pi_{t+1}^M}{{\pi_t^M}^{\iota_M} \pi bar^{1-\iota_M}} - 1\right)\left(\frac{\pi_{t+1}^M}{{\pi_t^N}^{\iota_M} \pi bar^{1-\iota_M}}\right) \frac{Y_{t+1}^M}{Y_t^M} \end{Bmatrix}^{-1} \frac{\mathcal{M}_t^M}{\mathcal{M}_t^M - 1} MC_t^M \tag{20}$$

Where parameters have a similar interpretation to those found in (18). Similar to the non-tradable case, the import prices Phillips Curve reduces to an equation linking import prices to marginal costs either at steady-state or when prices are perfectly flexible.

Tradable producers

Tradable producers operate in a perfectly competitive market both in the input and output sector. The problem faced by these producers can be characterised by a representative firm that produces a homogenous good aimed at the export market using the following Cobb Douglas function:

$$Y_t^{XD} = A_t^{XD} \bar{K}_{t-1}^{XD\,1-\gamma_{XD}} N_t^{XD\,\gamma_{XD}} \tag{21}$$

Where γ_{XD} is the labour share in tradable output and A_t^{XD} is an exogenous (stationary) technology term which follows an autoregressive model.

The static problem of these firms consists in choosing a desired labour input that minimises their cost function. Following Clancy and Merola (2014), we assume that capital input is decided exogenously, reflecting the fact that in small open economies, capital input decisions in the exporting sector are not necessarily made domestically. Shocks to this process can be interpreted as exogenous influxes of capital in the Maltese tradable sector, decided, for example, by the parent branch of multinational corporations operating within the Maltese economy. The first order condition of the cost minimisation problem with respect to labour is given by:

$$P_t^{XD} = MC_t^{XD} = \frac{W_t N_t^{XD}}{\gamma_{XD} Y_t^{XD}} \tag{22}$$

2.2.2 Final Good Firms

Final good firms operate as packers that produce a composite good made up of local non-tradable goods produced by intermediate firms and a homogenous imported good. There are three types of final good packers those producing a final homogenous consumption good Y_t^C, a final homogenous investment good Y_t^I and a final homogenous export good Y_t^X. The first two indexed by $f \in \{C, I\}$ operate in a perfectly competitive structure both in the input and output markets and use similar CES production technologies to produce their final good. These firms choose the final level of production by maximising profits subject to their production technology:

$$Y_t^f = \left[\alpha_f^{\frac{1}{\eta_f}} Y_t^{fM\,\frac{\eta_f - 1}{\eta_f}} + (1-\alpha_f)^{\frac{1}{\eta_f}} Y_t^{fN\,\frac{\eta_f - 1}{\eta_f}} \right]^{\frac{\eta_f}{\eta_f - 1}} \tag{23}$$

For $\forall\, f \in \{C, I\}$, where α_f is inversely related to the degree of home bias in preferences and serves as an index of openness. $\eta_f > 0$ measures the elasticity of substitution between domestic and foreign goods. The optimal allocation of expenditure on imported and local consumption and investment is therefore given by:

$$Y_t^{fM} = \alpha_f \left(\frac{P_t^M}{P_t^f}\right)^{-\eta_f} Y_t^f; \qquad Y_t^{fN} = \left(1-\alpha_f\right)\left(\frac{P_t^N}{P_t^f}\right)^{-\eta_f} Y_t^f \tag{24}$$

Using equations (24) and imposing a zero profit condition, we can derive aggregate price levels for consumption and investment:

$$P_t^f = \left[\alpha_f {P_t^M}^{1-\eta_f} + \left(1-\alpha_f\right){P_t^N}^{\eta_f}\right] \tag{25}$$

The problem faced by the final export good producers is similar in nature to the producers of local non-traded goods, except for the presence of distribution costs. The production of the final export good is done by a continuum of final export good producers indexed as $x \in (0,1)$ that buy the locally produced tradable output, Y_t^{XD}, and the homogenous import good, Y_t^M, in perfectly competitive markets and transform them into heterogeneous export goods, $Y_t^X(x)$, using a Leontief production function:

$$Y_t^X(x) = min\left\{\frac{Y_t^{XD}}{(1-\alpha_X)}, \frac{Y_t^M}{\alpha_X}\right\} \tag{26}$$

The choice of a Leontief production function implies that for any given level of export good demanded, the inputs for the final export good are combined in fixed proportions. This assumption is justified by the fact that in small open economies such as Malta, the imported component is often irreplaceable by domestic sources, and thus changes in relative prices should not influence the use of imported intermediate goods in the production of the final export good. Under these assumptions, the marginal cost faced by final export good producers is given as a weighted average of the costs of each input to the production mix:

$$MC_t^X(x) = (1-\alpha_X)MC_t^{XD} + \alpha_X P_t^M \tag{27}$$

The dynamic problem of exporters is similar to that of non-tradable producers. However, following Corsetti et al (2005) and Cristadoro et al (2008) we assume that export manufacturers require distribution services intensive in local non-tradables to deliver their final product to the final consumers. Distributors are assumed to operate in a perfectly competitive market. They purchase foreign tradable goods and distribute them using $\theta \geq 0$ units of non-tradables where θ is given by a constant elasticity of substitution basket of non-tradable brands:

$$\theta = \left[\int_0^1 \theta(n)^{\frac{1}{\mathcal{M}_t^N}} dn\right]^{\mathcal{M}_t^N} \quad (28)$$

Where $\mathcal{M}_t^N$ is the time dependent mark-up on nontradeables which depends on the elasticity of substitution between non-tradable brands, $\varepsilon_t^N > 1$, such that $\mathcal{M}_t^N = \frac{\varepsilon_t^N}{\varepsilon_t^N - 1}$. This creates a wedge between the wholesale and consumer prices for each export good (x), such that:

$$P_t^X = P_t^{XW} + \theta P_t^N \quad (29)$$

Implying that the consumer export price of the final export good faced by the foreign exporter, P_t^X, is the sum of the wholesale export price, P_t^{XW}, and the value of the basket of non-traded goods that are necessary to distribute the export goods to its consumers, θP_t^N.

Firms operating in the tradable sector set wholesale prices by exploiting their monopolistic powers over the production of the heterogeneous good $Y_t^X(x)$, facing quadratic costs associated with price changes:

$$\frac{\varphi_X}{2}\left(\frac{P_t^{XW}(x)/P_{t-1}^{XW}(x)}{\pi_{t-1}^{XW\,\iota_X}\pi^{bar^{1-\iota_X}}} - 1\right)^2 Y_t^X \quad (30)$$

Each good, $Y_t^X(x)$, is demanded by aggregators that use a rebranding technology to produce a single homogenous export good, Y_t^X. Firms will therefore choose a wholesale price in period t that maximises the real present value of all future profits subject to a sequence of demand constraints (derived in section 2.2.3) and costs of adjustment functions given by equation (30). After imposing symmetry, the first order condition associated with this problem takes the form of:

$$P_t^{XW} = \begin{Bmatrix} \left(\frac{1}{\mathcal{M}_t^X - 1}\right) + \varphi_X\left(\frac{\pi_t^X}{\pi_{t-1}^{X\ \iota_X}\pi^{bar^{1-\iota_X}}} - 1\right)\left(\frac{\pi_t^X}{\pi_{t-1}^{X\ \iota_X}\pi^{bar^{1-\iota_X}}}\right) - \\ \beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\varphi_X\left(\frac{\pi_{t+1}^X}{\pi_t^{X\iota_X}\pi^{bar^{1-\iota_X}}} - 1\right)\left(\frac{\pi_{t+1}^X}{\pi_t^{X\iota_X}\pi^{bar^{1-\iota_X}}}\right)\frac{Y_{t+1}^X}{Y_t^X} \end{Bmatrix}^{-1} \frac{\mathcal{M}_t^X}{\mathcal{M}_t^X - 1} MC_t^X \quad (31)$$

2.2.3 Aggregators

Aggregators solve the mismatch between the supply of differentiated products and the demand for homogenous goods. For each type of differentiated product being supplied, there is an aggregator that buys the different varieties and combines them to produce homogenous products using a CES technology. All aggregators operate in a perfectly competitive structure both in their input and output markets and take prices of both their outputs and inputs as given.

The labour aggregator buys different labour varieties, $N_t(j)$, and combines them into a homogenous labour input, N_t, which is demanded by tradable and non-tradable good intermediate firms. The homogenous labour input is given by:

$$N_t = \left(\int_0^1 N_t(j)^{\frac{1}{\mathcal{M}_t^M}} dj\right)^{\mathcal{M}_t^M} \tag{32}$$

Where $\mathcal{M}_t^W$ is the time-varying wage mark-up which relates to the elasticity of substitution between varieties of labour, $\varepsilon_t^W > 0$, such that $\mathcal{M}_t^W = \frac{\varepsilon_t^W}{\varepsilon_t^W - 1}$. Labour aggregators choose the combination of labour varieties that maximises profits subject to (32). The first order condition of this problem is given by:

$$N_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\frac{\mathcal{M}_t^W}{\mathcal{M}_t^W - 1}} N_t \tag{33}$$

Which corresponds to the demand curve used as constraint in the derivation of the wage Phillips Curve (13).

Producers of non-tradable products, final export goods and importers, follow analogous problems. Each one of these types of firms takes varieties of non-tradable, import and export goods, indexed by $g \in [N, M, X]$, and aggregate them into homogenous products using the following CES technologies:

$$Y_t^g = \left(\int_0^1 Y_t^g(k)^{\frac{1}{\mathcal{M}_t^g}} dk\right)^{\mathcal{M}_t^g} \quad \forall\, g \in [N, M, X] \tag{34}$$

Where $\mathcal{M}_t^g$ is the time-varying mark-up, dependent on the elasticity of substitution between varieties of non-tradable, export and import goods, $\varepsilon_t^g > 1$, such that $\mathcal{M}_t^g = \frac{\varepsilon_t^g}{\varepsilon_t^g - 1}$. The first order conditions of these optimisation problems correspond to the demand functions faced by the producers of non-tradables, heterogeneous imports and exports used above to derive the New-Keynesian Phillips' curves described in (18), (20) and (31). These demand functions take the following functional form:

$$Y_t^g(i) = \left(\frac{P_t^g(i)}{P_t^g}\right)^{-\frac{\mathcal{M}_t^g}{\mathcal{M}_t^g - 1}} Y_t^g \quad \forall\, g \in [N, M, X] \tag{35}$$

2.3 Rest of the World

The domestic economy's homogenous export good is demanded by foreign agents who combine it with other imported goods and their own domestic homogenous good to produce Y_t^*. The foreign economy's demand for the local export good, X_t, is given as the optimal allocation of foreign expenditure on local export goods and takes the following form:

$$X_t = \left(\frac{P_t^X}{P_t^*}\right)^{-\eta_x} Y_t^* \tag{36}$$

Where η_x represents the elasticity of substitution between local exports X_t and foreign substitutes. P_t^* and Y_t^* are foreign export prices and foreign demand respectively, both derived as AR(1) processes.

2.4 Government

In line with Clancy and Merola (2015), the fiscal authority is stylised and is primarily included to obtain a more accurate calibration of key steady-state ratios. Government output is specified as a time-varying fraction of steady-state output $\bar{Y}$:

$$Y_t^G = \varsigma_t \bar{Y} \tag{37}$$

Where ς_t follows an AR(1) process. Moreover, government consumption is assumed to consist entirely of domestic non-tradable production and to be financed by a lump-sum tax τ_t, ensuring a balanced budget in every period.

$$P_t^N Y_t^G = \tau_t \tag{38}$$

2.5 Monetary authority and net foreign asset position

In view of Malta's membership of the European Monetary Union and due to the small open economy assumption (which implies that the domestic economy is too small to affect macroeconomic aggregates in the Euro area), monetary policy is assumed to be exogenously set by the European Central Bank. Instead of a Taylor rule, stationarity around a well-defined steady-state is induced by assuming a debt-contingent premium within the UIPC in equation (12), in line with Schmitt-Grohe and Uribe (2003). We assume that $\xi\,(\phi_t, \mu_t)$ takes the following functional form:

$$\xi\,(\phi_t, \varepsilon_t^R) = e^{(\phi_t + \varepsilon_t^R)} \tag{39}$$

where ε_t^R is a time-varying shock to the risk premium and ϕ_t is a positive function of the debt to GDP ratio defined as:

$$\phi_t = \rho_\phi \left(\log\left(\frac{B_t}{Y_t}\right) - \log\left(\frac{\bar{B}}{\bar{Y}}\right)\right) \tag{40}$$

where $0 < \rho_\phi < 1$, corresponds to the sensitivity of ϕ_t to changes in the overall debt level of the domestic economy.

The aggregate level of domestic debt evolves in line with accumulated current account balances:

$$B_t = B_{t-1} R_t - (P_t^X Y_t^X - P_t^M Y_t^M) \tag{41}$$

2.6 Market Clearing Conditions

In the composite good market, the supply of non-tradable local goods must equate the amount necessary to satisfy the demand for all types of locally produced goods. Thus:

$$Y_t^{CN} = C_t^D \tag{42}$$

$$Y_t^{IN} = I_t^D \tag{43}$$

$$Y_t^G = G_t \tag{44}$$

And therefore:

$$Y_t^N = C_t^D + I_t^D + G_t \tag{45}$$

Similarly the demand for locally produced export goods must equate its supply. Thus:

$$Y_t^{XD} = X_t^D \tag{46}$$

At the aggregate level, overall domestic output must equate total demand for local production. This implies that:

$$Y_t = C_t^D + I_t^D + G_t + X_t^D = Y_t^N + Y_t^{XD} \tag{47}$$

Lastly, the demand for all types of foreign goods must equate their respective supply. Thus:

$$Y_t^{CM} = C_t^M \tag{48}$$

$$Y_t^{IM} = I_t^M \tag{49}$$

And therefore:

$$C_t^M + I_t^M = Y_t^M = M_t \tag{50}$$

In the final goods market the following clearing identities must also hold:

$$C_t = Y_t^C \tag{51}$$

$$I_t = Y_t^I \tag{52}$$

$$X_t = Y_t^X \tag{53}$$

Besides the market clearing conditions, it is useful to consider a measure of nominal GDP which follows the National Accounts definition and corresponds to the sum of all demand expenditure.

$$GDP_t = P_t^C C_t + P_t^I I_t + P_t^G G_t + P_t^X X_t - P_t^M M_t \tag{54}$$

The following aggregations are also useful to solve the model:

$$N_t = N_t^N + N_t^{XD} \tag{55}$$

$$K_t = K_t^N + \bar{K}_{t-1}^{XD} \tag{56}$$

3. Calibration

The model is calibrated so as to allow for the specific nature of the Maltese economy[6]. The calibration strategy employed can be subdivided in two parts. First, the parameters meant to pin down values for the steady-state ratios were calibrated so as to match the observed great ratios in Malta. Given the significant structural shocks that have hit the economy in the last decades, the choice of appropriate steady-state values is rather difficult. Most of the parameters linked to the steady-state of the model were calibrated so as to replicate the long run average (2000-2015) observed from the national accounts statistics. Secondly, given the lack of micro data studies for Malta, most of the parameters which govern the dynamics of the model were calibrated consistently with existing DSGE literature on the Euro area[7] and in line with the Maltese economy calibration of EAGLE (Micallef, 2013).

All variables at the steady-state are stationary implying that the risk free rate of interest (which at steady-state is equal to the inverse of the discount factor β) must be equal to the rate of time preference[8]. In line with existing DSGE modelling literature, β was set so as to be consistent with an annualised interest rate of 3%. The nominal output shares of public expenditure and

[6] A complete description of the parameter values and steady-state ratios of the model can be found in the Appendix.
[7] See for instance Forni et al (2009), Clancy and Merola (2014), Adolfson et al (2005) and Almeida (2009).
[8] MEDSEA contains neither a real nor a nominal trend. Thus at steady-state, inflation is normalised to zero. This has two implications. First, at steady-state nominal and real rates are equal. Secondly, the inflation dynamics given by the model should be interpreted as deviations from the non-modelled ECB inflation target.

investment have been set to 19% and 20% respectively[9]. Given the model's structure, the steady-state trade balance is pinned down by the steady-state private debt to GDP ratio. The latter is therefore calibrated to replicate a trade balance surplus of around 0.4% of GDP, which is broadly equivalent to the actual trade balance recorded through the sample under consideration. The nominal consumption to GDP ratio is set as the residual of the sum of the other output shares and is equal to 61%, equivalent to the actual average consumption ratio recorded over the last 15 years.

In recent years, Malta has undergone a number of structural changes that has led to a shift of its export base from traditional industries towards higher value added activities in the services sector. These developments have changed significantly Malta's trading patterns implying that National Accounts data averaged over a long period might not be useful in capturing Malta's present international trade relations and export structure. The quasi-shares of intermediate imports in consumption and investment (α_C and α_I) were calibrated such that the model's steady-state matches real-world shares as estimated using the recently published Input Output tables for Malta[10,11]. This implies that α_C is set to 0.59 and α_I to 0.72[12]. The quasi-share of intermediate imports in exports (α_X) was calibrated to match the import to output ratio implied by Malta's Input Output tables adjusted for the presence of Special Purpose Entities. Thus α_X was set equal to 0.50, resulting in a real import share in exports that is broadly equivalent to the actual import intensity of exports as estimated from the same Input Output tables.

In line with Clancy and Merola (2014) we assume that the tradable sector is less labour intensive than the non-tradable sector. Moreover, over the last 15 years, Malta's share of compensation per employee to Gross Value Added has been consistently lower than the euro area average. In this light, the paper follows Micallef (2013) and sets the labour share in the tradable and non-tradable production functions, γ_{XD} and γ_N, to 0.6 and 0.65 respectively, lower than the values

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9 Similar to Clancy and Merola (2014), in order to calibrate the steady-state investment to GDP ratio, the depreciation parameter δ, had to be set to 0.04, higher than the more standard 0.025. Given that the sample period used for calibrating the model has been subject to a number of structural changes that have transformed the nature of the Maltese economy, it is reasonable to assume that the depreciation rate in Malta is higher than that registered in more developed economies.

10 Following the introduction of ESA 2010 methodology, National Accounts figures for exports and imports are inclusive of Special Purpose Entities (SPEs) that despite having no actual connection to the real economy, inflate substantially the overall imports and exports to GDP ratios. To account for this, the import intensity of exports was estimated by excluding trade carried out by subcomponents that are likely to include SPEs and which would therefore inflate the overall import intensity of overall exports.

11 The import intensities used in this model are broadly similar to the ones estimated from the OECD's Input Output tables and to the ones used in the Central Bank of Malta's STREAM (Grech and Rapa, 2016).

12 Note that these figures do not correspond directly to the import intensities since the real import shares are endogenously calculated within the model.

usually used for euro area economies[13]. This sets the share of labour in GDP to around 53%. Following Adolfson et al (2005) and Clancy and Merola (2014), the inverse elasticity of work effort to the marginal disutility of labour, η, is set to 1. Moreover, the steady-state level of foreign owned capital is set to approximately match the share of the stock of foreign direct investment in Maltese output[14]. The elasticity of substitution between locally produced and imported consumption and investment goods, η_C and η_I, is set at 1.1, lower than the values used in Gomes et al (2010) for the euro area. This reflects the fact that being a small open economy, the degree of substitutability between imported and domestically produced good is rather small.

Empirical micro-studies on mark-ups in the Maltese economy are quite limited. Borg (2009) estimates mark-ups in a number of markets and compares them with 22 European economies. This study finds that while exhibiting a large degree of heterogeneity, mark-ups in the Maltese economy are on average relatively high, especially in the wholesale and retail trade sector. On the other hand, the mark-up observed on other sectors which are more prone to export their production abroad (such as the Hotels and Restaurants and Manufacturing sectors) are closer to those found in other European economies. In this respect, the steady-state mark-up in the domestic non-tradable sector was set to be equal to 50%, consistent with an elasticity of substitution between varieties of non-tradables, ϵ_N, equal to 3. To reflect a stronger degree of competition in the tradable sector, the elasticity of substitution of export and import markets, ϵ_{XD} and ϵ_M, were set to 6, consistent with a steady-state mark-up of 20%. Given the unavailability of empirical estimates for labour market mark-ups for Malta, we set the elasticity of substitution between different varieties at 4.33, in line with Gomes et al (2010) and Micallef (2013), implying a steady-state mark-up of 30%.

According to the findings of the Wage Dynamics Network there is a vast degree of heterogeneity in the frequency of price re-optimisation across different sectors of the Maltese economy[15]. In the light of this heterogeneity the price and wage adjustment costs were set to be consistent with an annual re-optimisation frequency, in line with Micallef (2013). The Rotemberg price and wage adjustment costs were calibrated according to a study by Keen and Wang (2007)[16] which

[13] See for instance Gomes et al (2010).
[14] Between 2010 and 2013, the share of the total stock of foreign direct investment to output was roughly 150%. This value includes positions pertaining to financial firms which practically have no relations to the Maltese real economy. In this view, these positions were excluded from the calibration of this model, reducing the share of productive foreign owned capital to output to around 32%.
[15] See Central Bank of Malta Annual Report (2014).
[16] While micro studies provide valuable information in terms of frequency of price adjustments, they provide little statistics on the magnitude of price-adjustment costs. The study by Keen and Wang (2007) provides values of the

provides values for the Rotemberg adjustment costs consistent with a range of price re-optimisation frequencies. The parameter governing investment adjustment costs, ψ_I, is set to 6, in line with Gomes et al (2010).

In the absence of data, the habit formation parameter, χ is set equal to 0.6, in line with Adolfoson et al (2005). Moreover, following Gomes et al (2010) and Forni et al (2010) price and wage indexation were set at 0.5 and 0.8 respectively. Finally, there are no empirical studies that provide an estimate for the share of Maltese exports prices at the retail level that are accounted for by local non-tradables. Moreover, the composition of overall Maltese exports is very different from that of other developed economies with services making up a significant share. In this light, the value of the parameter θ is calibrated so as to set the share of the retail price of exports accounted for by the local non-tradables to approximately 25%, lower than the value of 50% set by Corsetti et al (2005) for the US and Cristadoro et al (2008) for Italy.

4. Simulations

This section presents a number of simulations intended to illustrate the transmission channels operating in MEDSEA. These refer to (i) a technology shock common to both tradable and non-tradable sectors, (ii) a shock to the non-tradable mark-up implying a temporary increase in the competitiveness of the sector, (iii) a wage mark-up shock implying a temporary improvement in labour market competitiveness.

4.1 Technology Shock

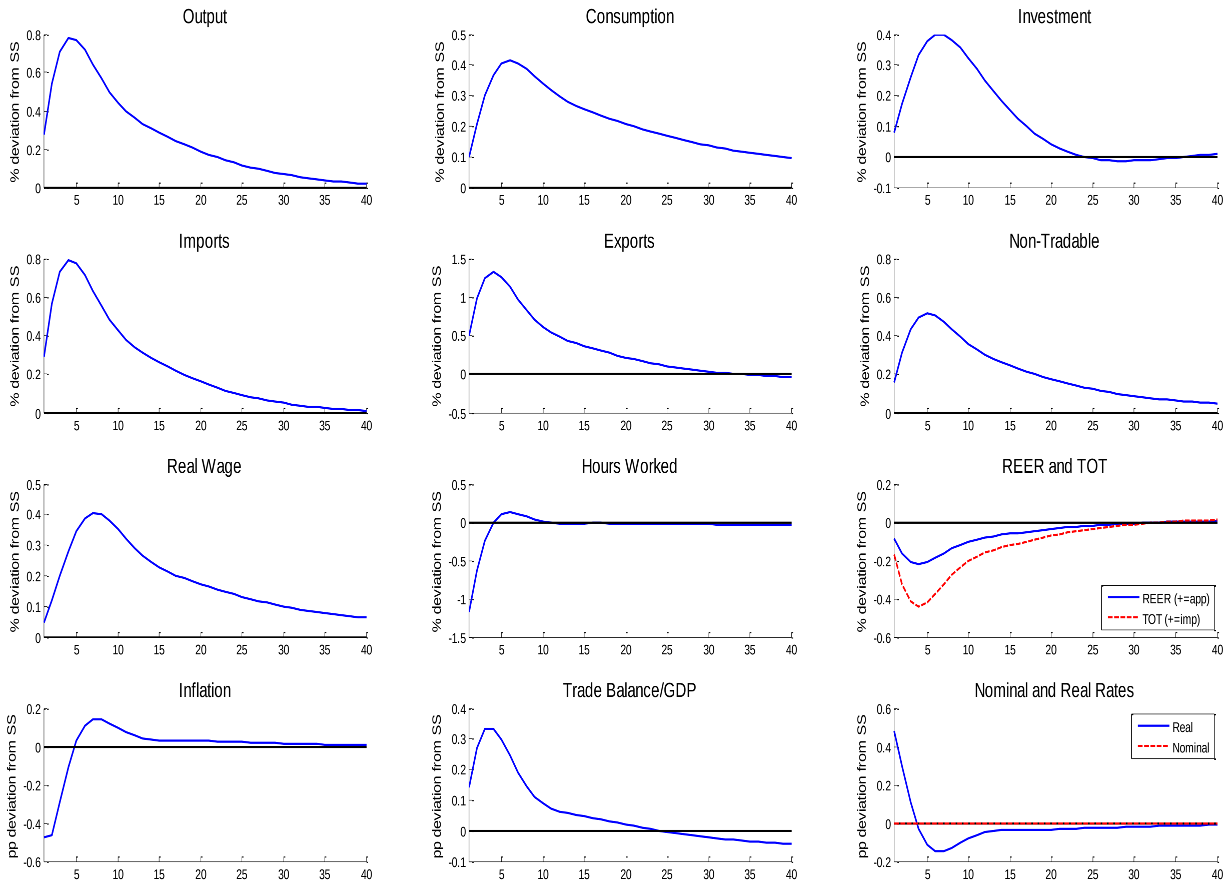
Figure 1 shows the reaction of a number of key variables to a standard positive technology shock which raises the productivity in both tradable and non-tradable sectors by 1%. This shock is temporary but very persistent, taking around 10 years to die out.

The impulse responses show that one year after the productivity shock, GDP increases by almost 0.8%, driven by both domestic and foreign sectors. Following the shock, the increased level of efficiency with which factors of production are used leads to an immediate fall in the

Rotemberg parameter which are consistent with the average time firms wait to re-optimise their prices ensuring a correct calibration of this parameter. The authors show that the specific size of the adjustment cost is related both to the frequency of price re-optimisation as well as to the average mark-up over marginal cost.

marginal cost of both tradable and non-tradable sectors leading to lower price pressures. Moreover, efficiency gains in the non-tradable sector have an indirect effect on export price inflation via the distribution channel, thereby amplifying the depreciation of the real exchange rate. This improves the competitiveness of the Maltese economy leading to an increase in exports. In line with the empirical findings of Gali (1999), higher efficiency results in a downward shift of the labour demand curve, implying a fall in the hours worked. Despite lower labour demand, real wages increase driven by lower levels of domestic inflation. The small country assumption implies that euro area inflation, and therefore, nominal interest rates in the euro area are unaffected by the fall in Malta's inflation. Still, following lower domestic inflation, the Maltese real interest rate increases. Despite a negative inter-temporal substitution effect, higher real labour income pushes up domestic consumption. In view of the lower domestic inflation, domestic non-tradable goods are perceived as cheaper than imported alternatives, thereby discouraging imports and increasing the production of non-tradables. This, together with a stronger export performance leads to an improved trade balance on impact. Strong economic performance leads to some inflationary pressures to start building up between the second and third years after the initial shock. This starts to gradually erode the country's competitiveness leading to a progressive return to the initial steady-state.

Figure 1: Common technology Shock

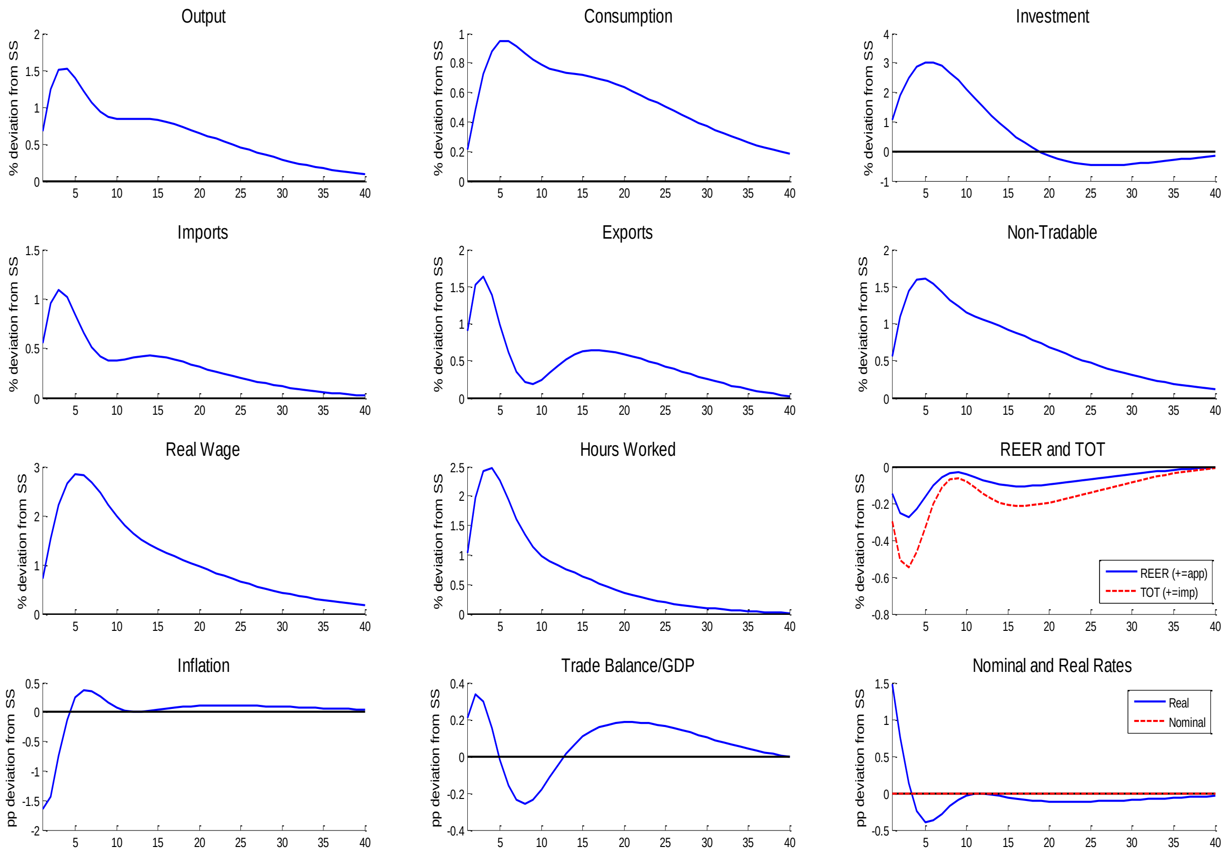


4.2 Non-tradable mark-up shock

Figure 2 shows the implications of a temporary mark-up shock in the non-tradable sector. This shock is normalised to be consistent with a fall in non-tradable mark-ups of 10pp. Similar to the previous simulation, despite being temporary, the shock is modelled as a persistent AR process with an AR coefficient of 0.9.

Following the reduction in mark-ups, non-tradable sector firms expand their output. The excess supply in non-tradables brings about a fall in non-tradable inflation and consequently, in overall consumer price inflation. Higher production leads firms to increase demand for inputs, thereby increasing both hours worked and investment. The increase in labour demand and the fall in domestic inflation bring about an increase in both nominal and real wages and therefore in labour income, pushing up household consumption in spite of a temporary increase in the real interest rate. Lower non-tradable inflation is transmitted into lower export inflation via the distribution sector, thereby leading to a depreciation of the real exchange rate. This increases exports within the first year after the initial shock. Improvements in exports are reversed by the second year after the shock, as increased demand for non-tradable goods starts exerting upward pressures on non-tradable price inflation leading to some positive effects on export good inflation, thereby appreciating the real exchange rate. The slowdown registered in imports is less pronounced, mainly due to a still high demand for consumption and investment goods, thereby shifting the response of the trade balance into negative territory between the second and third years.

Figure 2: Non-tradable sector mark-up shock

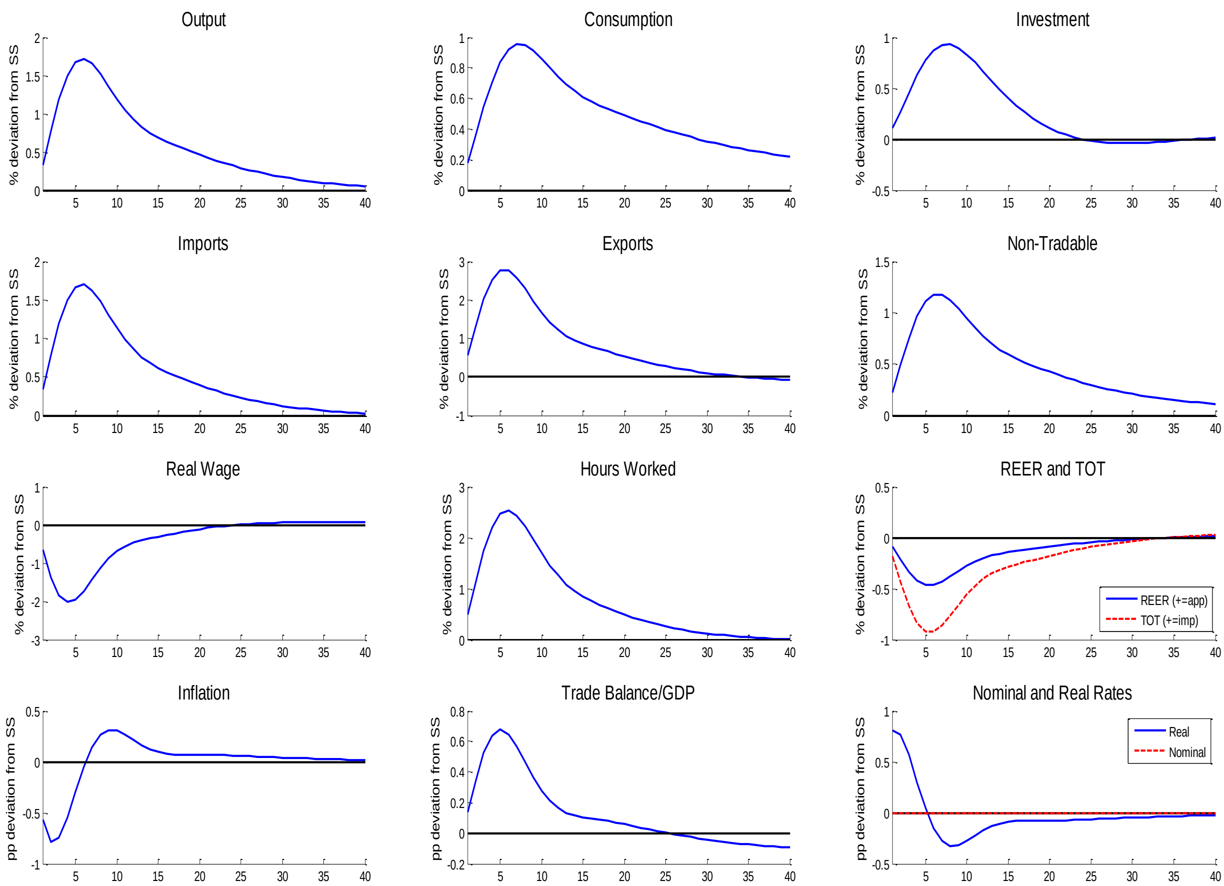


4.3 Wage Mark-up Shock

Figure 3 shows the results pertaining to a temporary improvement in the competitiveness of the Maltese labour market modelled through a transitory 10pp reduction in wage mark-ups. Similar to the previous cases, although temporary the shock is very persistent, with an AR coefficient on the autoregressive process modelling the shock of 0.9.

Following the shock, both domestic and foreign sectors benefit from lower costs of production pushing down domestic inflation, positively affecting the economy's cost competitiveness and reducing its terms of trade. The depreciation of the real exchange rate brings about an increase in exports. The increase in the demand for goods pushes up hours worked which boosts labour income and therefore household consumption, although the latter is partially offset by lower real wages and higher real rates. As firms increase their labour demand, they also start adjusting their

Figure 3: Wage mark-up shock



capital stock inducing an increase in investment. The increase in consumption, investment and exports bring about a rise in the imports necessary to produce final goods. However, the net result on the trade balance is still positive, at least for the first six years after the shock. Overall, driven by both domestic and foreign sector developments, real Maltese output increases by slightly less than 2% in the second year after the shock, before gradually returning to its steady-state level as the shock dies out.

5. Conclusions and way forward

This paper presents a newly-developed core DSGE model for the Maltese economy. The model is similar to other small open economy models commonly found in other Central Banks but features particular modifications allowing it to replicate more faithfully characteristics specific to the Maltese economy. Given Malta's membership of a monetary union, MEDSEA lacks an independent inflation targeting rule. Moreover, the export sector is modified in order to account for its different nature when compared to other production meant for domestic use as well as to reflect its reliance on imported components. Moreover, the model features distribution costs in the tradable sector allowing for a wedge to exist between wholesale and retail prices in the export sector. The paper also presents a set of temporary stochastic shocks showing the model's simulation properties as well as the transmission channels operating in it. Results documented in this paper are generally in line with those of other models in its class, for instance those found in Adolfson et al (2005) and Clancy and Merola (2014).

MEDSEA includes a number of nominal and real frictions such as sticky wages and prices, habit formation and capital adjustment costs, that have been shown to help produce more realistic short-term adjustments to shocks. Moreover, the model includes a number of shocks, such as wage and goods mark-up shocks that are very relevant from a policy analysis view-point, thereby allowing a theoretically coherent quantitative analysis of policy reforms. While being already useful for policy analysis purposes, the model presented in this paper should be interpreted as a first step towards a set of more detailed DSGE models that are better suited to explain the transmission mechanisms of certain shocks. Indeed, the model's compact and relatively simplistic nature allows it to be extended in a number of dimensions depending on the changing needs of the policy maker. For example the model completely abstracts from search and matching frictions and is thus unable to explain the existence of involuntary unemployment. Moreover, the treatment of fiscal policy in this model is very stylised. A further step would be the estimation of the model which would enable a historical decomposition of the shocks that drive the Maltese business cycle.

The model presented in this paper together with is future extensions is meant to be used as a complement to the existing policy analysis tools available at the Central Bank of Malta. While the Bank's traditional econometric model, STREAM (Grech and Rapa 2016) is envisaged to remain the main tool that assists in the production of forecasts and in other routine applications at the Bank, the new model together with its future extensions is expected to aid in answering research questions that require a more theoretically consistent framework that is immune to the Lucas critique.

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Appendix

Table 1: Steady-State Values

Domestic Demand (% of GDP)	
Household Consumption	61
Public Expenditure	19
Private Investment	20
Exports	106.4
Imports	106
Trade Balance	0.4
Import Content (% of each category)	
Household Consumption	50
Private Investment	64
Exports	56

Table 2: Parameters Affecting Steady-State Values

Quasi-Share of imports in consumption (α_C)	0.52
Quasi-Share of imports in investment (α_M)	0.66
Quasi-Share of imports in exports (α_X)	0.50
Labour share in non-tradables (γ_N)	0.65
Labour share in domestically produced tradables (γ_{XD})	0.60
Depreciation rate of capital (δ)	0.04
Discount factor (β)	0.99

Table 3: Parameters Affecting Dynamics, Prices and Wages

Households	
Habit formation parameter (χ)	0.6
Inverse elasticity of labour supply (η)	1
Production	
Elasticity of substitution between domestic and imported consumption (η_C)	1.1
Elasticity of substitution between domestic and imported investment (η_I)	1.1
Elasticity of substitution between exports and foreign output (η_X)	6
Mark-ups (Implied Elasticities of Substitution)	
Tradable mark-up $(\mathcal{M}^X)$	1.2 (6)
Non-Tradable mark-up $(\mathcal{M}^N)$	1.5 (3)
Import mark-up $(\mathcal{M}^M)$	1.2 (6)
Wages $(\mathcal{M}^W)$	1.3 (4.3)
Price Adjustment Parameters	
Export prices adjustment costs (φ_X)	58.3
Non-tradable prices adjustment costs (φ_N)	20.4
Import prices adjustment costs (φ_M)	58.3
Wages adjustment costs (φ_W)	38.8
Indexation of export prices (ι_X)	0.5
Indexation of non-tradable prices (ι_N)	0.5
Indexation of import prices (ι_M)	0.5
Wage indexation (ι_W)	0.8
Ratio of non-tradables per unit of tradables used by distributors (θ)	0.45