MEDSEA-NRG – MODELLING THE ENERGY SECTOR IN MALTA[1]

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This article documents the extension of MEDSEA, a small open economy DSGE model for Malta, with a detailed energy sector. The model contains relatively rich fiscal and energy blocks allowing the model to simulate the transitional costs related to the economy's decarbonisation, together with the effects of the possible recycling of carbon tax revenues. The article describes the main features of the model and offers a look into its simulation properties. Results show that taxing fossil-based energy leads to a drop in economic activity, together with a relatively short-lived increase in consumer price inflation. Energy taxes are found to have asymmetric effects on households, with poorer households being more heavily hit by higher energy prices.

Introduction

Under the Paris Agreement of the United Nations Framework Convention on Climate Change, all signatories have agreed to limit the increase in the global average temperature to well below 2°C above preindustrial levels, and to pursue efforts to limit the temperature increase to 1.5°C. In line with this target, EU member states have pledged to cut their Green House Gas (GHG) emissions by 55% by 2030, in a bid to turn the EU into a carbon neutral economy by 2050.

With almost 75% of all GHG emissions linked to energy production, most climate policies are targeted at transforming the global energy sector from a fossil-based production system to one which relies on renewable energy sources. Carbon taxing (i.e., taxing the carbon content of fuel used in energy production) has been touted as a key measure to reduce GHG emissions. Over the medium run, this is likely to add upward pressures on energy prices, which in turn will depend on the speed with which agents are willing to change the mix of fossil and renewable sources in energy production. These costs are also likely to asymmetrically affect poorer households which usually consume a consumption basket which is more heavily skewed towards energy consumption (see Darmanin, 2021). Taxing "brown" energy sources will on the other hand yield additional government revenue that can be recycled either across the board to all taxpayers, or targeted to compensate economic agents that are mostly affected by energy inflation. The transition of economies towards a lower carbon footprint constitutes a structural force that will be a significant contributor to the macroeconomic dynamics over the next decades (see Pisani-Ferri, 2021 and Lane, 2022).

Against this backdrop, it is important for policymakers to have tools that are detailed, yet flexible enough, to map how energy policies are likely to affect the macroeconomy. In this light, I extend a standard New Keynesian model with a detailed fiscal block (Rapa, 2017) with a multi-sectoral energy block. This version of the model uses a multisector setup for the production side in the spirit of Varga et al (2021) and Coenen et al (2023). I distinguish between the production of "green" and "brown" energy, with the former depending on the production of electricity through renewable sources. The production of green electricity explicitly requires investment in "green" capital which is allowed to crowd out investment in conventional capital which is required for the production of intermediate goods and services.

The model seeks to model the peculiarities of Malta's energy sector, in particular its fossil-fuel generation of electricity through a single Liquified Natural Gas (LNG)-fired complex, and its dependence on the Malta-Sicily interconnector, through which Malta imports a significant proportion of its electricity needs. Contrary to models in its class, I explicitly model the economy's dependency on fossil fuels, with electricity production relying explicitly on LNG, while other energy generation (most prominently used for transport) depending on other fossil fuels (such as petrol and gasoil). Finally, contrary to most models in its class, I also seek to explicitly model the asymmetric effects that

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energy price inflation is likely to have on poorer households. The latter is an important consideration, especially when considering the type of revenue recycling policies to adopt following carbon tax hikes.

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This article provides a general description of the new model, as well as a brief discussion of its simulation properties the article. In the conclusion, I also seek to highlight the potential uses of this new modelling tool.

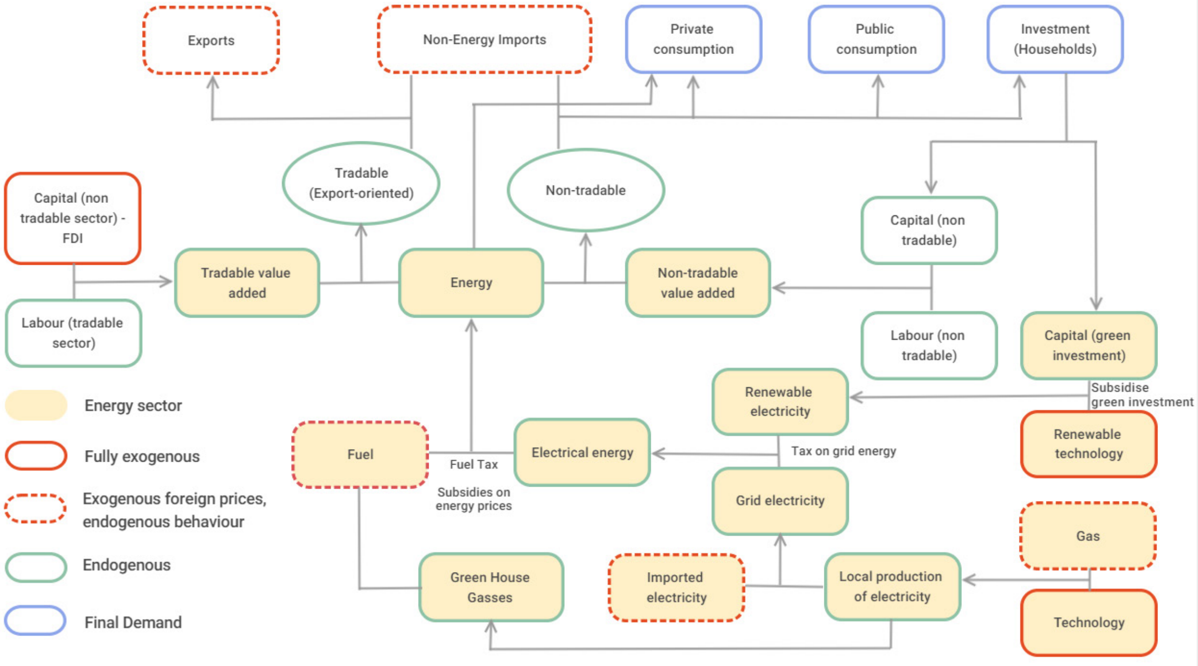
A description of MEDSEA-NRG

The new model builds on the fiscal version of MEDSEA (Rapa, 2017). The Maltese economy is modelled within a monetary union, thereby lacking an independent inflation targeting rule. There are two types of intermediate goods producers, one producing goods and services meant for local consumption and another producing output designed to be directly exported. The model also has a very detailed fiscal block making it a very appropriate baseline for an energy or environmental extension, especially when taking in consideration the predominant role that fiscal policy is expected to play in steering the economy towards a more carbon-neutral energy mix. Chart 1 provides a general overview of the setup of the model.

Energy Demand

The model assumes two types of energy demand; energy used in the production of goods and service in the economy by both domestic-oriented and export-oriented sectors, as well as energy consumed directly by households.

Chart 1
A BIRD’S-EYE VIEW OF MEDSEA-NRG



Source: Author’s calculations.

I assume that intermediate goods are produced in two stages, similar in essence to what is assumed in Coenen et al (2023). In the first step, the two types of intermediate good firms choose the optimal allocation of labour and capital to produce a “valued added” composite, which is then combined with an energy input in a second stage for using a Constant Elasticity of Substitution (CES) technology.

With regards to the determination of energy demand by households, I utilise a similar two-step setup. The model assumes that the economy is populated by two types of households, Ricardian households indexed by i, who are assumed to have access to financial markets and can thus smoothen consumption, and Hand-to-mouth households, indexed by j, who cannot access financial markets to smoothen shocks and are therefore bound to consume their disposable income. The former type of households also owns all firms and capital in the economy and therefore receive remunerations on their capital as well as the dividends earned by firms (over and above labour income). Overall consumption of both types of households is a bundle of private consumption and public goods, in line with Forni et al. (2010). In MEDSEA-NRG, private consumption is a further bundle between non-energy and energy consumption modelled in a CES fashion:

$$C_t^P(k) = \left[\phi_E(k)^{\frac{1}{\nu_E(k)}} E_t^C(k)^{\frac{\nu_E(k)-1}{\nu_E(k)}} + \left(1-\phi_E(k)\right)^{\frac{1}{\nu_E(k)}} C_t^{P,NE\,\frac{\nu_E(k)-1}{\nu_E(k)}}\right]^{\frac{\nu_E(k)}{\nu_E(k)-1}} \quad for\ k \in (i,j).$$

Contrary to other models in this class, I allow for the composition of private consumption to vary between Ricardian and non-Ricardian households. $\phi_E(k)$ is a household-specific weight of energy in the consumption basket, and $\nu_E(k)$ is the household-specific elasticity of substitution between energy consumption, $E_t^C(k)$, and non-energy private consumption $C_t^{P,NE}(k)$. Thus, the private consumption bundle is different across households reflecting the fact that the weight of energy in the private consumption basket of liquidity-constrained households (which in this model also proxy households with lower income) is larger than that of richer households (which are proxied by Ricardian households). This asymmetry in private consumption composition is meant to better capture the asymmetric distributional effects of energy policies and energy-specific shocks.

Energy Supply

Contrary to most models in this class, the energy sector does not simply distinguish between “green” and “brown” energy. Instead, energy is produced using a layered multistage production process where energy firms optimally combine different energy types and fuels. In the first layer of energy production, I distinguish between electrical and “fuel” based energy, with the latter proxying the energy produced directly by economic agents when they burn fuels to produce either heat or kinetic energy. This distinction is important first because data shows that GHG emissions per MWh of electricity production is lower than that of energy produced by directly burning fuels. Second, one of Malta’s commitments with regards to the abatement of GHG emissions relates specifically to the reduction of GHGs emanating from sectors other then electricity production. Indeed, under the Effort Sharing legislation, Malta is required to cut GHG emissions of sectors not covered by the Emission Trading system (therefore excluding the electricity production sector) by 19%, when compared to 2015 levels, by 2030.[2] Transportation, and therefore the direct burning of fossil fuels, has by far the largest GHG emissions among non-ETS sectors, implying that directly modelling the demand for fossil fuels is extremely important to adequately design the policy required for Malta to reach its environmental commitments.

Fuels used directly by economic agents to produce power (mainly for transport and heat) is assumed to be imported by fuel importers operating in a monopolistic setup. “Wholesale” fuel prices are therefore a markup over foreign imported prices. The retail prices of fuels are then equal to the sum of wholesale prices and excise duties levied on the volume of fuels less any potential subsidies that can be adjusted endogenously in the model to smoothen out changes in wholesale fuel prices. Apart from helping to match data, the distinction between retail and wholesale prices is meant to capture the administrative nature of fuel prices in Malta by introducing a tax/subsidy wedge that is occasionally used by Government to stabilise fuel prices against the backdrop of changing foreign fuel prices.

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[2] See European Parliament Briefing on Climate Action in Malta.

Electrical energy is a further combination of “brown” electricity produced using conventional fuels, and electricity produced using renewable sources. The former is a combination of locally produced electricity and electricity imported from the Malta-Sicily interconnector. This distinction is quite important. All electricity produced by Malta’s sole electricity producer, is the output of an LNG-burning powerplant. On the contrary, electricity imported from the interconnector is produced using a mix of fuels, ranging from coal, LPG, nuclear and renewable fuels.[3] This distinction is important first because the GHG intensity of electricity produced locally through conventional powerplants is generally higher than imported electricity. Secondly, the price dynamics of LNG and LPG (the type of gas that powers most of continental Europe gas powerplants) can be quite different as the former is not dependent on pipeline infrastructure for transportation, making it less prone to supply shocks due to continental geopolitical issues. Electricity generated locally in conventional power plants is produced using some local (fixed) capital and LNG, such that its price is heavily dependent on the prices at which Malta’s electricity producer can source LNG. The price of imported electricity is on the other hand simply equal to the price of euro area electricity and is therefore fully exogenous.

The wholesale price of “brown” electricity is a markup over its marginal cost (which is in turn a weighted average of the spot interconnector prices) and prices of locally produced electricity. The retail price of “brown” electricity is then equal to the wholesale price plus an ad-valorem tax less any subsidies that the government might use to stabilise electricity prices. Mirroring the discussion about retail fuel prices in Malta, the distinction between wholesale and retail “brown” electricity prices is also important as it helps to capture the administrative nature of electricity prices.

“Green” electricity produced with renewable sources is generated using green capital that is financed through local savings. “Green” electricity within the model captures the energy that is presently produced by households and firms using photovoltaic panels and other renewable sources, which is then either consumed directly or sold to the national grid. The wholesale price of “green” electricity (thus excluding any subsidies/taxes) is given as a markup over marginal cost which is heavily dependent on the rental rates or price of capital used to produce renewable energy and its efficiency. The retail price of renewable electricity is equal to the sum of wholesale green electricity prices and an ad-valorem subsidy. This emulates the favourable feed-in tariffs used by local authorities to incentivise the demand for green energy and investment.

Calibration

The model is calibrated on Maltese data. The parameters determining the steady-state of standard macroeconomic variables are calibrated on long-run averages spanning the period 2000-2019. Parameters governing the dynamics of the standard part of the model have remained largely unchanged when compared to Rapa (2017). All parameters governing the steady-state of the energy production sector are calibrated in line with 2019 data.[4]

The main data source for the calibration of energy ratios is the database of Energy Balance Flows published on Eurostat. This database is quite detailed and allows the user to trace the source of all energy products entering and exiting the national territory of a country. It also allows the user to trace the transformation of energy products to different energy types. This granularity is important as it allows the netting out of energy products that enter the Maltese territory for the sole purpose of being re-exported, allowing all energy ratios to be calibrated using data netted of marine bunkering operations. The database also shows a breakdown of energy in oil (and oil derivatives) and electricity, together with the main sector that absorbs each energy type, thus differentiating between energy used in the production process and energy directly consumed by households.

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[3] Electrical power purchased through the interconnector is not entirely “brown”. Interconnector energy is soured through the Italian grid which is in turn connected with the European one. Thus, power purchased through this source is generated using a variety of fuels including renewable ones. Still, the majority of imported electricity is generated using conventional methods with the data for 2023 for instance, showing that only around 10% of the electricity purchased by Malta through the interconnector is produced using renewable sources. In its current version, the model assumes that the fuel mix providing imported electricity is exogenously determined. This assumption will be relaxed when this model is merged with a euro-area-rest of the world model with environmental features (see Giovannini, 2023).

[4] The choice of 2019 as reference year of the calibration of energy-related ratios is warranted by the fact that between 2015 and 2016, the energy sector in Malta has undergone profound transformations with the setting up of a completely new powerplant and the installation of the interconnector linking the islands to the European grid. 2019 was judged to be a year that was stable enough to correctly reflect the energy reforms that have taken place.

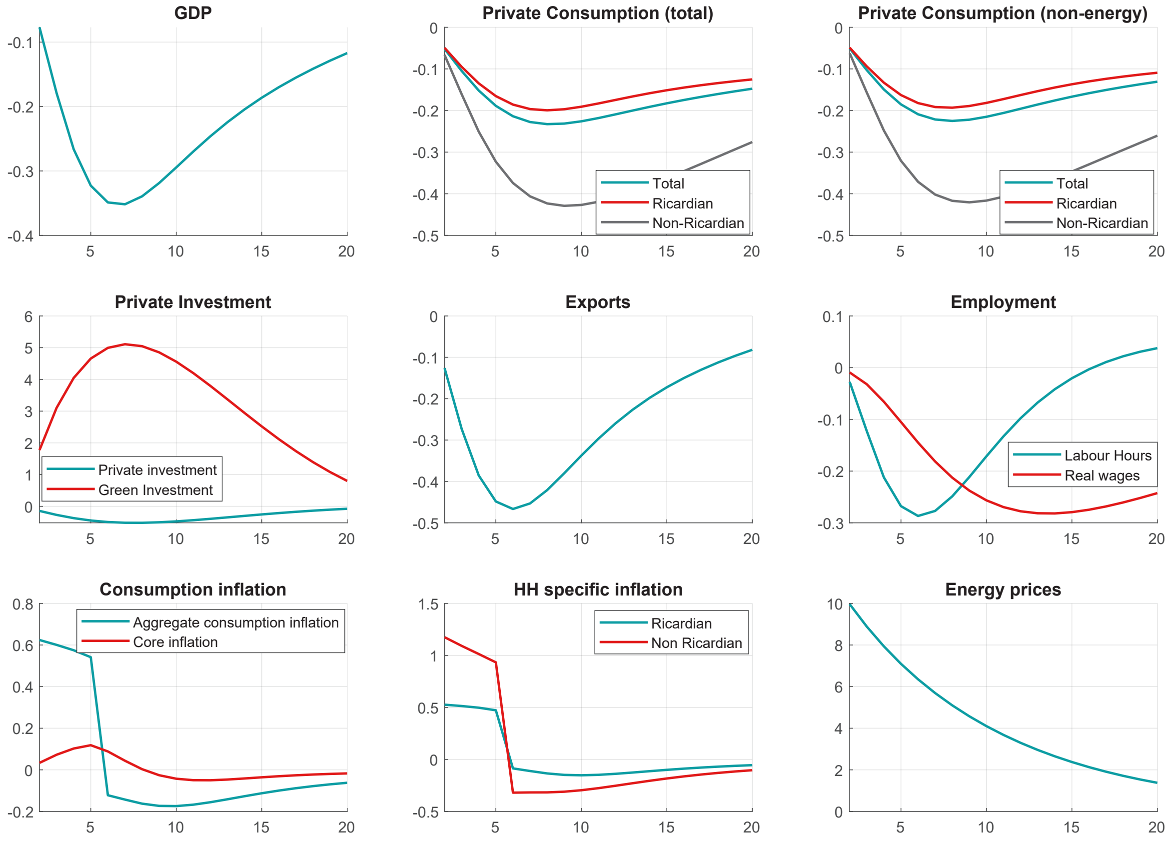
The size of the energy sector is calibrated as the expenditure on energy (electricity and other fuels) expressed as a share of nominal output, that is roughly 7%. The quasi-share of energy in the consumption basket of non-Ricardian households, $\phi_E(NR)$, is calibrated so as to pin down the share of nominal energy expenditure in the average consumption of households found in the lowest income quartile to 11%, in line with the results published in Darmanin (2021). I set the intensity of energy in the consumption basket of Ricardian households, $\phi_E(R)$, such that the average nominal share of energy in per-capita consumption is 5.9%, which is in line with the weight of energy in Malta's overall HICP.

Simulation properties

To understand the properties as well as potential uses of the new model, I show the response of the main macroeconomic as well as sector-specific variables to a hypothetical temporary shock to "brown" energy taxes. I therefore calibrate a temporary shock in the taxes levied by the Government on fuel and "brown" grid electricity (both locally produced and imported). The shock is calibrated such as to increase both prices of fuel and brown electricity by 10% on impact. The shock is then allowed to decay through an AR process. In this simulation I assume a passive fiscal policy, implying that following the shock, all other fiscal instruments are held constant, such as all results are only reflecting the change in the shocked instrument.

> *"Firms producing intermediate goods face a rise in the costs of their energy bundles, increasing marginal costs and leading to a reduction in aggregate supply"*

Chart 2
ENERGY TAX SHOCK – MACROECONOMIC VARIABLES

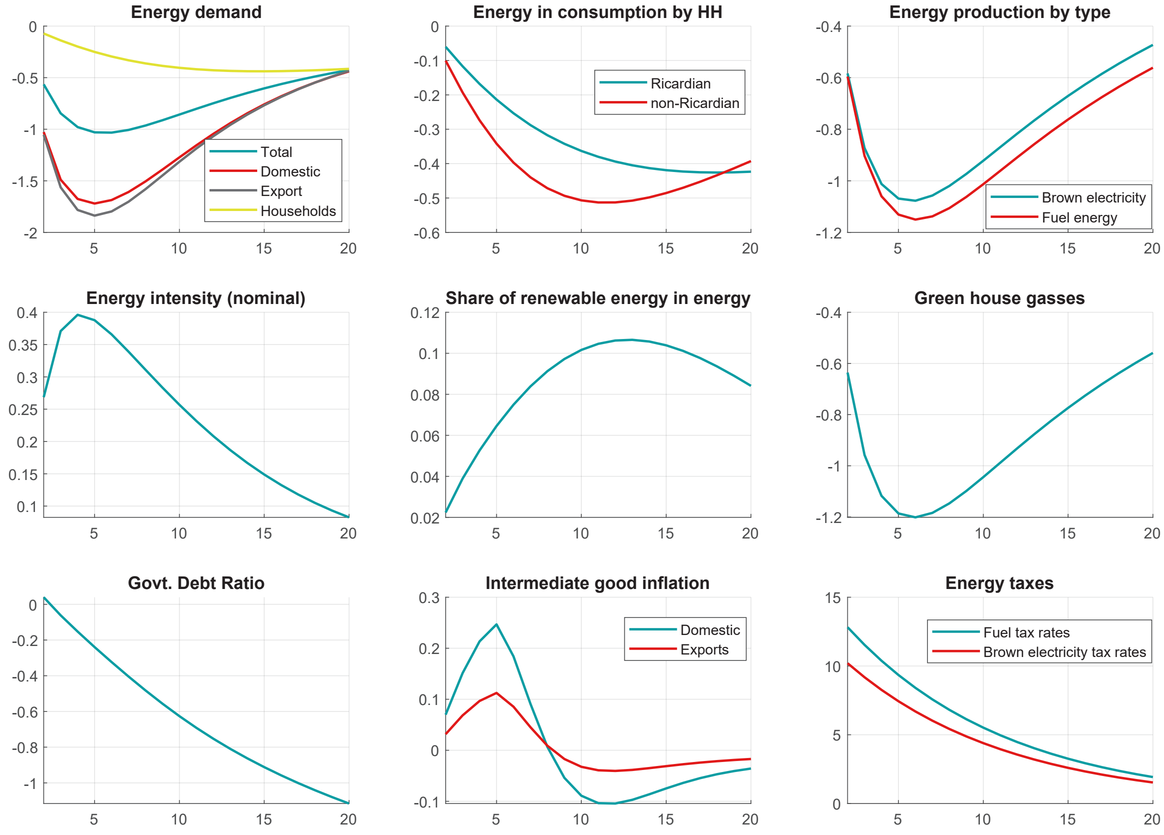


Source: Author's calculations.

Chart 2 shows that an increase in energy taxes translates into a rise in the retail price of fuel and electrical energy types. Firms aggregating the final energy product face an increase in the price of electrical and fuel energy leading them to utilise a higher proportion of green energy. However, this substitution is largely imperfect. First, green and brown electricity are imperfect substitutes. Second, the production of “green” electricity is heavily dependent on the installation of new green capital. Green capital accumulates slowly thus giving rise to a delayed response in the production capacity of “green” electricity. This implies that firms producing intermediate goods face a rise in the costs of their energy bundles, increasing marginal costs and leading to a reduction in aggregate supply. This increase in production costs leads to a rise in intermediate prices, both domestic and export oriented, with the former then reflected into an increase in core inflation. Core inflation peaks in the second year after the shock with an increase of around 0.12 percentage point in annualised terms, while overall consumer inflation peaks on impact with an increase of 0.63 percentage point.[5]

The rise in intermediate prices, leads to a worsening of Malta’s international competitiveness, leading to a fall in exports. Higher marginal costs lead to a reduction in the demand for factors of production, including energy. Lower demand for capital goods and labour inputs leads to a reduction in conventional (brown) investment and labour hours. The latter leads to a gradual fall in real wages (due to both nominal and real stickiness in wage formation). Higher inflation, as well as the effects of lower labour and capital income, lead to a negative income effect for both Ricardian and rule of thumb households who cut back on private consumption. This leads to a peak fall in real GDP of almost 0.35% by the second year after the shock.

Chart 3
ENERGY TAX SHOCK – SECTORAL VARIABLES



Source: Author’s calculations.

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[5] The increase in overall inflation is very much in line with the increase in inflation estimated using the Bank’s data-driven disaggregated inflation model after a similar shock.

“Non-Ricardian households experience a greater cut in their purchasing power, due to the greater share of energy in their consumption basket, leading to a greater fall in non-energy consumption”

Focusing on sectoral and distributional effects in Chart 3, non-Ricardian households experience a greater cut in their purchasing power, due to the greater share of energy in their consumption basket, leading to a greater fall in non-energy consumption when compared to Ricardian households. Indeed, overall consumer inflation for non-Ricardians peak at around 1pp, almost double the inflation increase experienced by Ricardian households. Energy for production purposes falls by a larger extent when compared to energy for consumption purposes. The increase in energy prices pushes up the share of energy expenditure in overall GDP. However, energy demand in real terms falls by more than real GDP implying that the economy becomes more energy efficient. Also, the steady increase in green investment (peaking at around 5% by the second year after the shock) leads to an increase in the proportion of green electricity in the overall energy mix of around 0.1 percentage point. These responses lead to a fall in overall GHG emissions of around 1.2% by the second year.

Conclusion

This article documents a new extension to the Central Bank of Malta’s DSGE model. The model combines a detailed fiscal block as in Rapa (2017) with a new multi-sectoral energy block. Energy is demanded both by intermediate good producers as well as by households for direct consumption. The model distinguishes between the production of “green” and “brown” energy with the former depending on the production of electricity through renewable sources. The production of green electricity explicitly requires investment in “green” capital. The model seeks to model the peculiarities of Malta’s energy sector, in particular the fact that all of its electricity generation is fossil-fuel based, and its dependence on the Malta-Sicily interconnector. Moreover, the model is able to account for the fact the energy-specific shocks might have important distributional effects by allowing for a household-specific bias in the demand for energy used directly for consumption.

Simulations show that a temporary increase in fossil-based energy taxes entails a hump-shaped fall in economic output driven by lower domestic demand and exports. Firms and households are unbale to perfectly substitute “brown” energy with electricity produced from renewable sources leading to an increase in production costs. As households can adjust energy consumption only gradually, the rise in energy prices leads households to experience negative income effects that are more pronounced for hand-to-mouth individuals. Demand for green energy increases, with the latter’s share in total energy climbing in the medium run. The drop in economic activity and the shift towards greener energy sources leads to a drop of GHG emissions.

This new model is very flexible and can be used to study several interesting policy scenarios. The rich fiscal block together with the detailed sectoral treatment of energy production allows for a detailed analysis of the macroeconomic and distributional costs surrounding the transition towards a greener energy sector. This version of the model can also be used to analyse the effects of public revenue recycling policies and how these can be used to reduce the adverse macroeconomic and distributional impacts of energy transition policies. Finally, the model can also be useful to study the general equilibrium effects of government tools that are used from time to time in an effort to reduce the impact of severe disruptions in foreign energy markets.

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