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Debt sharing after Covid-19: How the direct involvement of EU institutions could impact the recovery path of a member state

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Abstract: *The likely substantial impact of Covid-19 related measures on the public finances of European countries has prompted an unprecedented call for new and significant policies at a European level to alleviate the pressures on individual member states. The administrative closures adopted across a number of economies has resulted in a complete cessation of certain types of economic activity, a significant increase in unemployment and profound fiscal challenges for the countries in question. In this paper we use a SOE-DSGE model to assess the role European institutions can play in mitigating the negative economic and fiscal effects of the crisis for a particular member state by participating directly in the sovereign debt management of that country. Our results indicate that the direct involvement of EU institutions via sovereign bonds purchases increases the efficiency of the extraordinary fiscal stimulus packages undertaken by member states. A fiscal stimulus at the national level backed by EU financing reduces the output losses in the first year which would otherwise occur. The reduction in the output loss ranges from 0.8 per cent to 1.4 per cent depending on the mix of fiscal policies chosen by the member state. The cumulative reduction in output loss over a five year horizon could sum to 2.5 per cent to 4.1 per cent depending on the fiscal policy mix chosen.*

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JEL codes: I18, E62, O43 and N24.

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Abstract

The likely substantial impact of Covid-19 related measures on the public finances of European countries has prompted an unprecedented call for new and significant policies at a European level to alleviate the pressures on individual member states. The administrative closures adopted across a number of economies has resulted in a complete cessation of certain types of economic activity, a significant increase in unemployment and profound fiscal challenges for the countries in question. In this paper we use a SOE-DSGE model to assess the role European institutions can play in mitigating the negative economic and fiscal effects of the crisis for a particular member state by participating directly in the sovereign debt management of that country. Our results indicate that the direct involvement of EU institutions via sovereign bonds purchases increases the efficiency of the extraordinary fiscal stimulus packages undertaken by member states. A fiscal stimulus at the national level backed by EU financing reduces the output losses in the first year which would otherwise occur. The reduction in the output loss ranges from 0.8 per cent to 1.4 per cent depending on the mix of fiscal policies chosen by the member state. The cumulative reduction in output loss over a five year horizon could sum to 2.5 per cent to 4.1 per cent depending on the fiscal policy mix chosen.

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1 Introduction

The emergence of Covid-19 in 2020 as a major public health concern has prompted Governments across the western world to adopt a number of extraordinary measures, unprecedented in peacetime. While absolutely necessary from a health perspective, the cumulated impact of these measures on national economies has resulted in unprecedented economic fallout with millions of workers across Europe being made unemployed in a very short period of time. To mitigate the negative impact of the pandemic, European Governments have initiated extraordinary fiscal responses at a national level. These significant expenditure measures coupled with the expected fall in taxation receipts due to the decline in economic activity will result in most countries facing substantial fiscal challenges with key metrics such as the general Government balance and debt to GDP ratios set to be adversely impacted. Given the likely scale of the challenge, a number of commentators have called for a coordinated response at a European level to address this impending fiscal crisis with Baldwin and Weder di Mauro (2020) providing a summary of recommendations from noted contributors. There have already been a number of significant policy developments in that regard. Most notably to date, in early May, the French and German Governments proposed a €750 bn EU Commission fund to tackle the economic impact of Covid-19. This proposal is innovative in that it allows the EU commission to borrow on its account and so create a new class of EU bonds.

In this paper we have two main aims; the first is to examine the impact on the Irish economy of the unfolding pandemic crisis and the second, given the increase in extraordinary expenditures at national level, is to assess the role European institutions can play in mitigating the negative demand and supply effects of the crisis for a particular member state by participating directly in the sovereign debt management of that country. In doing so, we use a medium scale small open economy dynamic stochastic general equilibrium (SOE-DSGE) model calibrated for Ireland that has been developed in Varthalitis (2019).[1]

To conduct this exercise, we extend the model in three ways. First, we introduce demand and supply shocks in the model so as to gauge the adverse impact of the pandemic in key macroeconomic aggregates of a small open economy member of Eurozone. By now, most commentators expect a significant economic fallout in Ireland see e.g. McQuinn et al. (2020).[2] Second, we develop the fiscal block of the model so as to incorporate a set of extraordinary fiscal instruments that are used by national fiscal authorities to mitigate the negative effect of the pandemic. Third, and, perhaps more importantly, we study the impact of European institutions directly intervening in the debt management of a member state economy. This is accomplished by enhancing a SOE model to add a union-wide policymaker that can directly intervene in the debt management of the domestic economy.

In particular, under our policy experiment, we assume that two policy authorities can intervene in the small open economy member of a currency union. The national fiscal authority (the treasury) and a supra-national foreign policymaker (EU institutions). The role of the national fiscal authority is to finance its government expenditure, conventional and extraordinary, by levying taxes and/or issuing sovereign bonds. The role of EU institutions, under our experiment, is to buy sovereign bonds from the member states and set the union-wide interest rate policy. Thus, each member state public debt can now be held by two types of institutional creditors, namely private markets and EU institutions. Therefore, EU policy can generate additional fiscal space for the national governments in the short to medium run. The timing of when these

[1] FIR-GEM is a small open economy DSGE model for Ireland. Since the structure of the model is thoroughly analysed in Varthalitis (2019) in this paper we mostly focus on the extensions and the policy implications.

[2] Figures in McQuinn et al. (2020) are in line with estimates in IFAC, Fiscal Assessment Report (May 2020), IMF World Economic Outlook for Ireland (see IMF WEO 2020) and European Commission (May 2020), Central Bank of Ireland (April 2020).

bonds will start impacting domestic public finances depends on the purchasing policy of the EU institution.[3]

In terms of the impact of the pandemic shock, we consider two possible outcomes. One outcome involves the impacts of the outbreak fading swiftly with economic activity, as a consequence, recovering quite quickly. We refer to as the "v-shaped" recovery. We also consider an outcome where the pandemic endures and, thus, the adverse effects on the economy are more prolonged. This is referred to as the "long-lasting" outcome.

Our results indicate that the direct financial assistance of the EU institutions via sovereign bonds purchases increases the efficiency of the extraordinary national fiscal stimulus packages. A fiscal stimulus at the national level backed by EU financing reduces the output losses in the first year which would otherwise occur. The reduction in the output loss ranges from 0.8 per cent to 1.4 per cent depending on the mix of fiscal policies chosen by the member state. The cumulative reduction in output loss over a five year horizon could sum to 2.5 per cent to 4.1 per cent depending on the fiscal policy mix chosen. In terms of national policy, we find that extraordinary expenditures such as spending related to enhance public health, labour income subsidies and/or cash transfers targeted to financially constrained households perform better in countering the negative impacts of the recession. Fiscal packages should target households with no other sources of income and, thus, with a higher propensity to consume. We also conduct sensitivity analysis. Our paper contributes to the growing literature that extends medium scale DSGE models used for policy analysis to study macroeconomic and policy implications of the pandemic, see e.g. Bayer et al. (2020) and Faria-e-Castro (2020) who focus on closed economy models and Hagedorn and Mitman (2020) who discuss the role of the ECB through the lens of a HANK model. We study these issues in a small open economy model where the country is a member of a currency union.[4] We think that our key findings provide a basis for the proposals summarized in section 2 below.

The rest of the paper is structured as follows; in section 2 we summarize the debate on the role that could be played by EU institutions. Section 3 and 4 develops the extensions and calibrates the model. Section 5 presents the main scenarios simulated. Section 6 explains our results and sections 7 conducts sensitivity analysis. Section 8 outlines some concluding comments. An online Appendix provides technical details.

2 Increased role for EU institutions in sharing the debt of member states?

The inevitable pressure that the emergence of Covid-19 will place on the public finances of countries across European has raised once again the issue of whether European institutions should provide more support to member states incurring significant fiscal difficulties. In the present context a number of different options have been advanced. Blanchard (2020), for example, has called for the ECB to act directly and buy Italian bonds. Whelan (2020) has endorsed the proposal by Gros and Mayer (2012) that the European Stability Mechanism (ESM) should be provided with a liquidity backstop by having it registered as a bank.

Alesina and Giavazzi (2020) have called for the ECB to lift, temporarily, the constraints on its asset purchase program and in particular the capital key. Furthermore, they suggest that the additional expenditure required by member states to address the Covid-19 issue should be part

[3] Arguably, the most likely manifestation of the policy experiment assessed is the direct purchase by the ECB of Government bonds. The ECB are already likely to purchase €15 to €20 billion of Irish debt in 2020 on the secondary market.

[4] Hagedorn and Mitman (2020) discuss the role of the ECB through the lens of the HANK model.

of an EU program. Bénassy-Quéré et al. (2020) and Gourinchas (2020) both support a massive debt-financed fiscal stimulus at the European level.

In our exercise, it is not our intention to recommend the most effective or preferable form of European intervention but to demonstrate the impact a particular form of intervention would have on the recovery path of the Irish economy.

3 The model

Our model is similar to the medium scale small open economy DSGE developed in Varthalitis (2019). We extend the model in the following ways: first, we allow for the negative demand and supply effect of the pandemic in the small open economy of a member state of the EU. Second, we develop the fiscal block of the model so as to incorporate a set of extraordinary fiscal instruments that are used by national fiscal authorities to mitigate the negative effect of the pandemic. Third, we allow for a greater policy role of EU institutions in providing financial assistance to an individual member state. We refer to Varthalitis (2019) for certain technical aspects of the model.

3.1 Households

There are two type of households. Ricardian households (or Savers) indexed by r and non Ricardians (or Non Savers) indexed by nr. Ricardian households solve a standard maximization problem, i.e. maximize lifetime utility, $V_0^r \equiv E_0 \sum_{t=0}^{\infty} \beta_t \left(U\left(c_t^r, g_t^h\right) + G\left(l_t^{H,r}, l_t^{NT,r}, l_t^{P,r}\right)\right)$, subject to the sequential budget constraint:

$$\begin{aligned} &P_t\left(1+\tau_t^c\right)c_t^r + \mu_t^c P_t c_t^r + P_t x_t^{H,r} + P_t x_t^{NT,r} + P_t b_t^r + S_t P_t^* f_t^{*r} + \Phi^*\left(f_t^{*r}, f^{*r}\right) \\ &= \left(1-\tau_t^n\right)P_t\left(w_t^H \phi_t^H l_t^{H,r} + w_t^{NT}\phi_t^{NT} l_t^{NT,r} + w_t^P \phi_t^P l_t^{P,r}\right) + \left(1-\tau_t^k\right)P_t\left(r_t^{NT,r}k_{t-1}^{NT,r} + \omega_t^{NT,r}\right) \\ &+ \left(1-\tau_t^k\right)P_t\left(r_t^{H,k}k_{t-1}^{H,r} + \omega_t^{H,r}\right) + R_{t-1}P_{t-1}b_{t-1}^r + Q_{t-1}S_t P_{t-1}^* f_{t-1}^r - P_t\tau_t^{l,r} \\ &+ \tau_t^{covid,r}P_t\left(w^H l^{H,r} + w^{NT} l^{NT,r} - \left(w_t^H\phi_t^H l_t^{H,r} + w_t^{NT}\phi_t^{NT} l_t^{NT,r}\right)\right) + P_t\tau_t^{cash,r} \end{aligned} \tag{1}$$

where, P_t is the nominal price of the final good, $l_t^{j,r}$, $x_t^{j,r}$, $k_t^{j,r}$, $r_t^{j,k}$, $w_t^{j,r}$ and $\omega_t^{j,r}$ are hours worked, gross investment, the beginning-of-period physical capital, the real return of capital, real wage rate and real profits in sector $j = H, NT$, w_t^p denotes public wages, b_t^r and f_t^{*r} are the real value of the end-of-period domestic government bonds and internationally traded assets respectively, S_t is the nominal exchange rate defined as the domestic currency price of one unit of foreign currency, $R_{t-1}, Q_{t-1} \geq 1$ denote the gross nominal return of domestic government bonds and international assets between $t-1$ and t respectively, $\tau_t^c, \tau_t^n, \tau_t^k$ are consumption, labour and capital tax rates respectively, $\tau_t^{l,r}$ is conventional public transfers targeted to Ricardian household r. Borrowing on the international market entails an adjustment cost $\Phi^*\left(f_t^{*r}, f^{*r}\right)$.

To model the impacts of the pandemic, we follow Eichenbaum et al. (2020) and introduce the term $\mu_t^c P_t c_t^r$ so as to proxy the negative effect on consumption from containment policies aimed at reducing social interactions. In normal times, $\mu_t^c = 0$, while during the pandemic, $\mu_t^c > 0$. Also, the parameters $\phi_t^H, \phi_t^{NT}, \phi_t^P$ measures productivity of labour in the different sectors of the economy (for tractability let us use $\phi_t = \phi_t^H = \phi_t^{NT} = \phi_t^P$). During normal times, $\phi_t = 1$, which means that the household supply their full capacity of hours worked across all sectors of the economy. In the case of a pandemic, $\phi_t < 1$, because some members of the households are infected and/or cannot work due to the restrictive measures.

In response to the pandemic, the Government launches a set of extraordinary spending instruments to alleviate the negative economic effects. We assume that these spending instruments are: first, spending related to public health, g_t^h. We assume that this type of spending is a strong complement to private consumption. The parameter, $\vartheta^g < 0$, measures the degree of complementarity between private consumption and this type of public spending. The economic logic of this assumption is that the extreme containment measures curtail a large part of consumption activities. Households will only be able to restore their levels of private consumption if the Government can guarantee a certain level of safety while goods are being consumed. Public good/services, g_t^h, captures the extraordinary public expenditures that can restore a certain level of private consumption in the short run. As such this expenditure can be thought of as a strong complement to private consumption.

Second, $\tau_t^{covid,r}$ is an income subsidy which is proportional to the loss of income experienced in the private sector. That is, the Government pays back a fraction, $\tau_t^{covid,r}$, of the income losses occured during the pandemic. Due to the nature of the pandemic shock and the extraordinary nature of these subsidies aimed at curtailing the income loss, we assume that households do not internalize $\tau_t^{covid,r}$ in their labour supply decisions. Third, $P_t \tau_t^{cash,r}$, denotes direct extraordinary cash transfers. We model the exogenous effect of the pandemic in Ricardians and non-Ricardians to be symmetric.Non-Ricardian households (non-Savers) receive income from working in the tradable, non-tradable and public sectors; but they have no access to capital or/and financial markets. Similarly with Ricardians households the extraordinary spending instruments can benefit non Ricardians. To account for targeted fiscal policies to different income classes, we allow income subsidies and cash transfers to differ between Ricardian and Non-Ricardian households. Details are available in the online Appendix.

3.2 Policy

We now extend Varthalitis (2019) by allowing national fiscal policy to use an extraordinary set of spending instruments in a discretionary manner (see section **3.2.4**) while we allow for an enhanced role of the EU institutions (see section **3.2.5**).

3.2.1 Institutional composition of public debt

Following Economides et al. (2020),[5] we assume that Ireland's public debt can be purchased by two types of creditors that differ in their institutional state: (i) private markets, i.e. domestic and foreign agents that participate in the domestic and international financial markets and (ii) EU institutions (e.g. ECB/ESM). Total public debt in period t expressed in nominal terms is:

$$P_t F_t^M + S_t P_t^* F_t^{*EU} \tag{2}$$

where $P_t F_t^M \equiv P_t B_t + S_t P_t^* F_t^{*g}$ denotes public debt in private markets and is further decomposed in public debt held by domestic private agents, $P_t B_t$, and foreign private agents, $S_t P_t^* F_t^{*g}$. In what follows, $P_t F_t^M$ will be referred to as market-held public debt. $S_t P_t^* F_t^{*EU}$ denotes public debt that is purchased by EU institutions and it will be referred as EU-held public debt. Below, we assume that each type of public debt incurs different borrowing costs as well as entails different implications for the domestic country's public finances.

[5] This modelling choice is motivated by Irish data on Irish public debt holders, e.g. Larkin et al. (2019) in Central Bank of Ireland Quarterly Bulletin (Q2, 2019) estimate that 29% of Irish public debt was held by EU institutions at the end of 2018.

3.2.2 Borrowing cost and type of institutional creditor

We assume that the borrowing cost faced by the small open economy depends on the institutional state of the creditor. In terms of public debt in private markets, we assume that the interest rate at which Ireland borrows from the private markets is debt-elastic (as in e.g. Philippopoulos et al. (2017)):

$$Q_t = Q_t^* + \psi^d \left(e^{\frac{P_t F_t^M}{P_t y_t^{gdp}} - \mathcal{F}^M} - 1 \right) \tag{3}$$

where Q_t^* denotes the union-wide interest rate, ψ^d is a parameter which measures the elasticity of the interest rate with respect to deviations of the market-held public debt to GDP ratio from its threshold value, $\mathcal{F}^M$.

In terms of public debt purchased by EU institutions, we assume that the EU can lend to a member state at an interest rate lower than the one the member would face in the private markets, i.e. $Q_t^* < Q_t$. Since it depends on the economic fundamentals and policies of the currency union (e.g. the interest rate policy of the ECB). As noted in Reis (2016) in the absence of any sovereign risk premium the two type of bonds are equivalent. However, the higher the sovereign risk due to higher debt held by private markets (or other reasons captured in ψ^d) the larger the importance of the institutional type of the creditor.

3.2.3 Government Budget Constraint

The sequential government budget constraint in nominal and aggregate terms is written as:

$$\begin{aligned} P_t F_t^M + S_t P_t^* F_t^{*EU} = R_{t-1} \lambda_{t-1}^g P_{t-1} F_{t-1}^M + Q_{t-1} \tfrac{S_t}{S_{t-1}} \left(1 - \lambda_t^g\right) P_{t-1} F_{t-1}^M \\ + Q_{t-1}^* \tfrac{S_t}{S_{t-1}} S_{t-1} P_{t-1}^* F_{t-1}^{*EU} + P_t G_t + P_t G_t^{covid} - P_t T_t \end{aligned} \tag{4}$$

where $P_t F_t^M$ is market-held public debt and $\lambda_t^g = \frac{P_t B_t}{P_t F_t^M}$ and $(1 - \lambda_t^g) \equiv \frac{S_t P_t^* F_t^{*g}}{P_t F_t^M}$ are shares of market-held public debt held by domestic and foreign (non-Irish residents) households respectively. $S_t P_t^* F_t^{*EU}$ is public debt held by EU institutions. We assume that the Government has two sets of spending instruments the conventional nominal government spending, $P_t G_t$, which includes non-utility enhancing government consumption, G_t^c, investment, G_t^i, the public wage bill, G_t^w, and total public transfers, $T_t^{l,r} \equiv T_t^{l,r} + T_t^{l,nr} < 0$:

$$P_t G_t \equiv P_t G_t^c + P_t G_t^i + P_t G_t^w - P_t T_t^l \tag{5}$$

and a set of extraordinary spending instruments, $P_t G_t^{covid}$. The latter includes labour income subsidies,$\tau^{covid,r}$ and $\tau^{covid,nr}$, direct cash transfers, $\tau_t^{cash,r}$ and $\tau_t^{cash,nr}$, targeted to Ricardians and Non-Ricardians respectively and public health related government spending, G_t^h:

$$\begin{aligned} P_t G_t^{covid} \equiv P_t \tau_t^{covid,r} N^r \left(w^H l^{H,r} + w^{NT} l^{NT,r} - \left(w_t^H \phi_t^H l_t^{H,r} + w_t^{NT} \phi_t^{NT} l_t^{NT,r} \right) \right) \\ + \tau_t^{covid,nr} N^{nr} \left(w^H l^{H,nr} + w^{NT} l^{NT,nr} - \left(w_t^H \phi_t^H l_t^{H,nr} + w_t^{NT} \phi_t^{NT} l_t^{NT,nr} \right) \right) \\ + P_t N^r \tau_t^{cash,r} + P_t N^{nr} \tau_t^{cash,nr} + P_t G_t^h \end{aligned} \tag{6}$$

Furthermore, $P_t T_t$ are total nominal tax revenues. The government generates tax revenues by levying consumption, labour and capital taxes:

$$\begin{aligned} P_t T_t \equiv P_t \tau_t^c \left(N^r c_t^r + N^{nr} c_t^{nr} \right) \\ P_t \tau_t^n N^r \left(w_t^H \phi_t^H l_t^{H,r} + w_t^{NT} \phi_t^{NT} l_t^{NT,r} + w_t^P \phi_t^P l_t^{P,r} \right) \\ + P_t \tau_t^n N^{nr} \left(w_t^H \phi_t^H l_t^{H,nr} + w_t^{NT} \phi_t^{NT} l_t^{NT,nr} + w_t^P \phi_t^P l_t^{P,nr} \right) \\ + \tau_t^k N^r P_t \left(r_t^{H,k} k_{t-1}^{H,r} + \widetilde{\omega}_t^{H,r} + r_t^{NT,k} k_{t-1}^{NT,r} + \widetilde{\omega}_t^{NT,r} \right) \end{aligned} \tag{7}$$

Thus, the national fiscal policymaker has seven conventional fiscal policy instruments and five extraordinary spending instruments at their disposal. In our experiments, we assume that market-held public debt, F_t^M, is adjusted residually to satisfy the government budget constraint in each period t; while the EU Institutions determine the supply of EU-purchased public debt, F_t^{*EU} as well as the interest rate paid on this debt Q_t^* (see section 3.2.5). Ireland is a member of a currency union; thus we solve for a monetary regime without monetary independence and a fixed exchange rate regime. For simplicity, we normalize the nominal depreciation rate, $\frac{S_t}{S_{t-1}}$, to unity.

3.2.4 National Fiscal Policy

Conventional fiscal policy instruments Domestic fiscal policymakers set the seven conventional policy instruments according to the following simple fiscal rules:

$$f_t - f = \rho^f \left(f_{t-1} - f\right) + \gamma^f \left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{8}$$

where $f_t = \left\{s_t^{g,c}, s_t^{g,i}, s_t^w, s_t^l, \tau_t^c, \tau_t^n, \tau_t^k\right\}$ is the vector of the seven national fiscal policy instruments and f is the vector with the associated policy targets which are set equal to their steady state values. The conventional spending instruments are expressed as output ratios. $\rho^f \in [0,1)$ are autoregressive coefficients that capture fiscal persistence, γ^f are the feedback policy coefficients that measure the magnitude of the policy reaction to the market-held public debt to output ratio (more details in Appendix E).

We assume that the national fiscal authorities use one or more fiscal instruments to only react to public debt held by private markets. This assumption implies that, in the short run, the EU funded public debt does not impose an extra fiscal burden on the member state's public finances. This could be thought as a policy in which EU policymakers suspends the stringency of the fiscal targets amid the pandemic crisis. Thus, it creates additional fiscal space for national fiscal policymakers to adjust their public finances in an attempt to mitigate the negative economic effects of Covid-19.

On the other hand, it should be noticed that public debt held by EU institutions enters the government budget constraint (see equation 4), thus, eventually, it will result in a fiscal cost. That is, in the medium/long run, the EU funded debt should be financed either by the issuance of new public debt in the private markets or by future fiscal adjustment (i.e. tax increases and/or spending decreases). The timing of this depends on the EU policy which is specified in the next section.

Extraordinary fiscal instruments To deal with the unprecedented nature of the shock national fiscal policymakers use a set of extraordinary fiscal instruments. The fiscal authority sets these instruments in a discretionary manner for the specific time period in which the economy is especially affected by the pandemic.

3.2.5 EU Institutions

In our model, however, we assume that EU institutions can utilize two policy instruments to intervene in managing the debt levels of a member state's economy, namely the union-wide interest rate, Q_t^*, and sovereign bonds holdings, F_t^{*EU}.[6] In terms of sovereign bonds holdings,

[6] For thorough discussion and modelling of the alternative instruments available at the Eurosystem see Economides et al. (2020) and references therein.

following Sims and Wu (2020), we assume that EU institutions purchases of sovereign bonds are set according to a Taylor-type reaction function:

$$F_t^{*EU} - F^{*EU} = \rho^{F^{*EU}} \left(F_{t-1}^{*EU} - F^{*EU} \right) + \gamma^{F^{*EU}} \left(\frac{DEF_t}{P_t y_t^{GDP}} - def \right) + \varepsilon_t^{F^{*EU}} \tag{9}$$

where $\gamma^{F^{*EU}}$ is the share of the public deficit[7] to output deviation from a target, def, that EU insitutions finance via EU bond holdings, $\rho^{F^{*EU}}$, capture the speed with which these bonds could be reduced and $\varepsilon_t^{F^{*EU}}$ is an iid shock that captures discretionary sovereign bonds purchases by the EU institutions.

The policy parameter $\gamma^{F^{*EU}}$ governs the share of the domestic deficit to output ratio that EU institutions allow to be financed via EU bond holdings in period t. The policy parameter $\rho^{F^{*EU}}$ governs the duration of the EU purchasing programme. For example, a short-lived purchasing programme, captured by a lower value of $\rho^{F^{*EU}}$, means that the member state that borrows from EU institutions will need to generate additional resources in a quicker manner to meet its financing needs, either by borrowing purely via private markets or by tax/spending adjustments.

3.3 Modelling the pandemic shock in a SOE-DSGE

It is widely accepted that the COVID-19 pandemic impacted economies as a combined supply and demand shock (see e.g. Eichenbaum et al. (2020) and Fornaro and Wolf (2020)).

On the demand side, the parameter μ_t^c that governs the cost of consumption follows simple AR(1) processes:

$$\mu_t^c = \rho^{\mu^c} \mu_{t-1}^c + \varepsilon_t^{\mu^c} \tag{10}$$

The outbreak of the pandemic in period 1 means that $\varepsilon_1^{\mu^c} > 0$; while the parameter $\rho^{\mu^{c1}}$ measures the persistence. In addition, on the demand side we implement a negative shock to the demand from the rest of the world for Irish exports. Following Varthalitis (2019) we assume that the demand for exports, x_t, is given by:

$$x_t = \rho^x x_{t-1} + (1 - \rho^x) \left(\frac{tot_t}{tot} \right)^{-\gamma^x} x + \varepsilon_t^x \tag{11}$$

where, ρ^x, is a parameter that governs the persistence of exports, x are exports in the steady state; while the term $\left(\frac{tot_t}{tot}\right)^{-\gamma^x}$ reflects that exports are also function of deviations in the terms of trade[8] from its steady state value.[9] The effect of the pandemic on exports is modelled as negative shock in period 1, $\varepsilon_1^x < 0$. On the supply side, we assume that ϕ_t follows an AR(1) process:

$$\phi_t = \rho^\phi \phi_{t-1} + \left(1 - \rho^\phi\right) 1 + \varepsilon_t^\phi \tag{12}$$

The outbreak of the pandemic means that in period 1, $\varepsilon_1^\phi < 0$; while ρ^ϕ measure the persistence of the pandemic effects on labour supply.

[7] National public deficit in nominal terms is defined as, $DEF_t \equiv (R_{t-1} - 1) \lambda_{t-1}^g P_{t-1} F_{t-1}^M + (Q_{t-1} - 1) \frac{S_t}{S_{t-1}} \left(1 - \lambda_{t-1}^g\right) P_{t-1} F_{t-1}^M + P_t G_t + P_t G_t^{covid} - P_t T_t$, i.e. government spending minus tax revenues plus the interest payments on market-held public debt.

[8] The terms of trade are defined as the price of exports with respect to the price of imports.

[9] The latter term ensures dynamic stability and allows exports to have an endogenous feedback from changes in the relative price of Irish exports. Where, $\gamma^x > 0$, implies that an increase in the relative price of exports to imports results in a decrease in the world demand for the home produced tradable good.

4 Calibration

This section discusses the calibration of the model. For most of the structural parameters of the model we follow the calibration strategy developed in Varthalitis (2019). More details can be found in Table E.1 in the Appendix G. Here, we focus on the parameters that are important for our experiments. Tables 1 and 2 present the key structural parameters and policy parameters respectively.

Table 1: Key structural parameter values

Parameter	Implied Value	Description
ϑ^g	-1	complementarity between private consumption and public spending related to public health
ψ^d	0.015	sovereign risk premium coefficient on market-held private debt
ρ^{μ^c}	0.2 (0)	persistence of the ad hoc cost in private consumption
ρ^{ϕ}	0.2 (0)	persistence of the labour supply shock
ρ^{x}	0.2 (0)	persistence of the shock of the RoW demand for exports

Table 2:Policy parameter values

Parameter	Implied Value	Description
$\rho^{s^{g,c}}$	0	autoregressive coefficient on govt. consumption
$\gamma^{s^{g,c}}$	-0.07	govt. consumption reaction on market-held public debt output ratio
$\mathcal{F}^M$	0.6[10]	Debt target on national fiscal rules
ρ^{Q^*}	0	autoregressive coefficient of public debt held by EU
$\rho^{F^{*EU}}$	0	autoregressive coefficient of public debt held by EU
$\gamma^{F^{*EU}}$	0	reaction coefficient that determines the share of the national deficit to output ratio financed by EU institutions
def	-0.01	Deficit to output target in EU rules

Parameters that govern the impact of the pandemic The set of parameters that govern the persistence and the magnitude of the pandemic are set so as to generate a first year output recession of -10.5 per cent in the long-lasting scenario. The magnitude of the output fallout is within the ranges of the recession forecasted for Ireland by a number of policy institutions.

Sovereign risk premium The parameter that governs the sensitivity of the international market interest rate to deviations of the market-held public debt from a threshold is set equal

[10] The threshold value is the average value of the market held public debt to GDP ratio between 2001-2018 and also coincides with the limit imposed by the Maastricht Criteria for all EU countries.

to 0.015. This value is consistent with recent empirical work on the Irish sovereign premium (Cronin et al. (2018)).[11]

Policy Unless otherwise stated, we assume that the national fiscal policymaker uses the conventional government consumption, $s_t^{g,c}$, to react to market-held public debt deviations from its target. By setting, $\gamma^{s^{g,c}}$, equal to 0.07 which is the lowest value for which we get dynamic stability. Furthermore, in what follows when we assume that the EU institutions do not intervene in the member state economy, i.e. $\rho^{Q^*} = \rho^{F^{*EU}} = \gamma^{F^{*EU}} = 0$ in equation (9). On the other hand, when we allow EU institutions to intervent in the member state economy these feedback policy coefficients are set equal to $\rho^{F^{*EU}} = 0.99$ and $\gamma^{F^{*EU}} = 1$ (more details in section **??**).

5 Scenarios analysis

We assume two different recovery outcomes for the Irish economy. A v-shaped recovery, where the economy is expected to recover quite quickly and a long-lasting outcome, where the negative effects of the pandemic endure for a longer period

5.1 Policy responses

The Government is assumed to utilize the set of a extraordinary fiscal instruments specified in section 3.2.4 above in a discretionary manner to mitigate the negative impact of the pandemic. Initially, we examine the impact of one fiscal instrument at a time in order to quantify the effects on output of each fiscal instrument separately (normalized to 1% of steady state output). Two alternative public financing scenarios of these extraordinary fiscal packages are now considered. First, via private markets where the emerging public deficits are financed by an increase in market-held public debt at the market interest rate. Second, we allow EU institutions to provide financial assistance to member states in the form of purchases of government bonds.

6 Results

6.1 Pandemic impact on the Irish economy

Figure 1 presents the dynamic responses of the key endogenous macroeconomic variables under the two recovery outcomes based on the "v-shaped" and the "long-lasting" recovery.

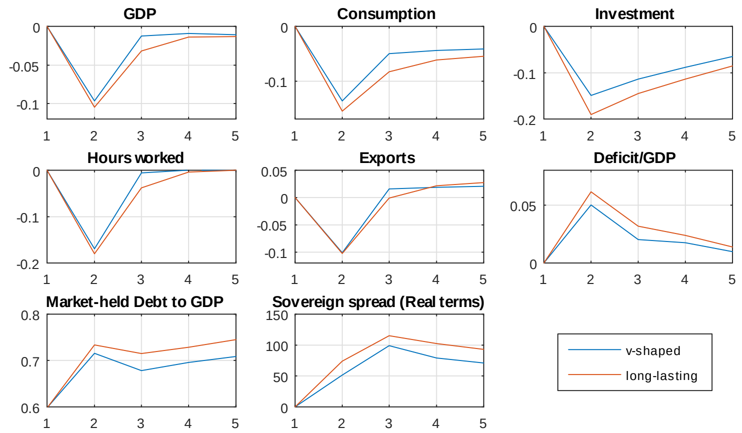
On the demand side, due to the administrative closedowns and the higher risk of becoming infected households reduce consumption sharply in the short-run. Similarly, the rest of the world reduces its demand for Irish goods and services resulting in a large reduction in domestic exports. On the supply side, the pandemic shock causes a substantial fall in hours worked. Subsequently, the large decrease in hours worked and consumption will also reduce investment. As a result, the combined negative impact of demand and supply causes a significant reduction in output.

As expected, the combined effects of these shocks have significant implications for key fiscal metrics. The large drop in demand and supply leads to a drop in wages and returns on capital across sectors. As a result, the tax bases of the economy which consists of consumption and income from labour and capital are expected to experience a significant fall. Accordingly, there is a sharp rise in the national deficit. In figure 1, we assume that the deficit is financed by an increase in borrowing via private markets. Thus, the public debt held by private markets

[11] In a recent analysis, McQuinn (2020) using several variants of the empirical model in Cronin et al. (2018) have estimated that this parameter varies from 0.005 to 0.025 using Irish data over the period 2000-2019.

increases and this puts upward pressure on the sovereign premia. The rise in real interest rates feeds back into the economy and further suppresses investment and consumption.

Figure 1: Duration of the pandemic shock and impact on the Irish economy



Notes: Unless otherwise stated, endogenous variables are in % from their steady state values; Market-held public debt, deficit to GDP and sovereign premia in real terms are ratios and rate respectively.

6.2 The role of policy

In Table 1 we quantify the implications of the extraordinary national fiscal policy measures on output levels in the first year by varying the fiscal policy instrument (2nd-4th rows) used to alleviate the negative effect as well as the method of public financing these extraordinary fiscal packages (3rd-4th columns).

In the first column of Table 1, we report which fiscal instrument is used to deal with the economic fallout. In particular, the fiscal instruments which are utilized are additional spending in "public health", cash transfers targeted at financially constrained households, labour income subsidies targeted at financially constrained households and a spending fiscal mix of these items. For comparison, the size of fiscal stimulus in each case is normalized to 1 per cent of steady state output while in the case of the spending mix sums to 3 per cent of steady state output.

The results under the two scenarios of public financing are presented in the third and fourth column. In particular, the results when the Government borrows from private markets are presented in the third column of Table 1. The results when EU institutions provide financial assistance in the form of purchases of sovereign bonds are presented in the fourth column. In the second column, the results for when there is no policy intervention at either national or supranational level are also presented.[12]

[12] For comparability, across all three scenarios, the Government uses conventional government consumption to react of market-held public debt so as to ensure fiscal sustainability.

Table 1: First year output recession under various policy scenarios

Policy instrument	No policy	Market-held debt	EU-held debt
g_t^h	-10.5%	-9.9%	-8.7%
$\tau_t^{cash,nr}$	-10.5%	-10.4%	-9.3%
$\tau_t^{covid,nr}$	-10.5%	-10.3%	-9.5%
Spending mix	-10.5%	-9.8%	-8.4%

In terms of mitigating the negative impact on output, the most effective instrument is spending associated with public health, followed by a targeted fiscal policy which supports the income of non Savers either via labour income subsidies or direct cash transfers. The least effective fiscal instruments are labour income subsidies and cash transfers targeted at Savers.[13] However, the mitigation effect is quantitatively small in most of the cases when these extraordinary fiscal measures are financed solely via newly issued public debt in the private markets (see the explanation below).

In contrast, when EU institutions actively engage in sovereign bonds purchases the effect of the extraordinary national fiscal measures increases significantly across all fiscal instruments (compare the third and fourth column). In particular, increasing spending related to public health by 1 per cent of GDP could reduce the output loss by 1.2 per cent more when EU institutions provide financial assistance, i.e. from 9.9 per cent to 8.7 per cent. Similarly, increases in direct cash transfers and labour income subsidies targeted to Non-Ricardians/Non-Savers backed by EU purchased bonds could reduce the output loss by 1.1 per cent and 0.8 per cent respectively. In terms of the spending mix, EU purchased sovereign bonds mitigate the recession by 1.4 per cent.

Finally, the EU institutions sovereign bonds purchasing programme could enable a quicker recovery of the economy. In particular, the cumulative reduction in output loss over a five year horizon sum to 2.49 per cent, 2.98 per cent, 2.77 per cent and 4.1 per cent for the direct cash transfers, labour income subsidies, spending related to public health and the spending mix respectively (see computations in Appendix I).

6.3 The underlying mechanism

Now, we examine the mechanism by which the intervention of EU institutions can help to mitigate the negative impact of the pandemic. We focus on the extraordinary spending mix presented in Table 1 above. Figure 2 compares the dynamic responses of the key macroeconomic variables under the two public financing scenarios. In particular, the scenarios in which the national deficits are financed via market-held public debt and where the national deficits are financed via EU institutions. These are labelled as "Market-bonds financed" and "EU-bonds financed" respectively. For comparability, we also present results from the scenario in which there is no policy response at the national and supra-national level; this is labelled as "No response".

In terms of the key macroeconomic variables, an EU bond purchasing programme can significantly mitigate the negative effect on consumption and investment in the short and medium run. This could suppress the initial reduction in output and ultimately allows for a quicker recovery

[13] We have also examine the case in which the Government increases cash transfers and labour income loss subisidies targeted to Savers. However, our results suggests that these extraordinary fiscal instruments are not efficient in terms of aggregate output. The economic logic is that Savers have other sources of income, such as access to domestic and international financial markets, thus it is expected that these fiscal measures will not affect their consumption plans in the short run. To save space we exclude these results from Table 1.

in the medium run. As expected, on the fiscal side, financing the emerging deficits via the less costly EU bond holdings allows extra fiscal space for the member state in the short and medium run. Thus, the rise in the deficit and public debt is far less prolonged in this case.

Figure 2: National fiscal package and public financing scenarios

Notes: see Figure 1.

Borrowing from EU institutions leads to a smaller rise in market held public debt in the short run while it also keeps public debt in the medium/longer run at low levels despite the increase in national deficits. EU held public debt absorbs the temporary fiscal imbalances and thus stabilizes domestic public finances in the medium/longer run.

Lower public debt issued in private markets subsequently leads to lower real interest rates. Since the latter affects households' economic decisions, it makes national extraordinary fiscal measures more effective by crowding out less investment and consumption. In turn, the milder reduction in consumption and investment leads to a faster recovery in hours worked. Thus, labour and capital incomes of households experience a smaller decline which creates a further positive feedback loop on output.

This results in a milder reduction in the associated tax bases, resulting in a lower rise in the national deficit across all time horizons. The combined effect of a lower rise in interest rates and a smaller decline in the tax revenues leads to a smaller rise in the national deficit. Overall, the EU bond holdings can play a role of foreign financial capital flows in the resource constraint of the small open economy (i.e. the balance of payments) which can help the member state economy to mitigate the negative effects of the pandemic.

7 Sensitivity analysis

In this section we conduct sensitivity analysis with respect to key structural and policy parameters of the model. To save space, we selectively report some key results only (a full set of results is available upon request). First, we experiment with the parameter that governs the sensitivity of the nominal interest at which Ireland borrows from the private markets, i.e. ψ^d, in equation (3). We experiment with values $0.005 < \psi^d < 0.025$, where the lower and upper bounds correspond to the estimated value that we find using Irish data over the period 2000-2008 and 2000-2019 respectively. This analysis indicates that the larger is the parameter, ψ^d, the greater the importance of EU institutions intervention in mitigating the pandemic effects. Second, we experiment with the parameters in EU institutions reaction function, equation (9), that governs the size and timing of sovereign purchasing programme, i.e. $\rho^{*F^{EU}}$, $\gamma^{F^{*EU}}$. As expected, the timing and the size of EU intervention matters, i.e. the longer the period and the larger the size of the EU government bonds purchasing programme the larger the effect on the member state output. We also study a relatively more conventional EU policy intervention. In particular, EU policy institutions cut the policy rate, Q_t^*, which leads to a reduction in the interest rate paid on sovereign bonds in private markets. The latter scenario mimics an ECB interest rate cut. We report that results and the mechanisms at work under this scenario are very similar to ones reported in section 3.2. However interest rate policy are always constrained by the effective zero lower bound. Finally, we simulate scenarios in which the emerging deficits are financed via mixed public financing schemes, i.e. borrowing from both private markets and EU institutions while the national fiscal authorities implement fiscal adjustments in the medium run. The latter implies switching on the feedback policy coefficients, γ^f, in the associated fiscal rules in equation (8). We experiment with fiscal adjustments involving tax raises and/or conventional spending decreases to bring public debt down. We report that our main qualitative and quantitative results do not change.

8 Conclusions

As with most western economies, both the impact of the Covid-19 virus itself and the measures taken by the public authorities to counter the spread of the virus will have a dramatic and negative impact on the Irish economy. Like a number of similar exercises, we model the impact of the virus with a standard SOE-DSGE model with both demand and supply-side shocks. Given the small open nature of the Irish economy, there is also a substantial impact through a trade channel. In simulating the impact of the shock, we assume two potential outcomes, (i) a v-shaped recovery where the containment measures succeed in containing the virus within a short period of time and (ii) a long-lasting recovery, where the supply and demand effects of the pandemic will endure for a relatively longer period.

Our modelling results indicate that an EU bond purchasing programme significantly mitigates the negative effect of the virus-related shock on consumption and investment in the short and medium run. As a result, the impact on economic output is also reduced with a quicker recovery being facilitated in the medium run. Under our policy experiment, the ability of a member state to finance part of the emerging deficit via less costly EU bond holdings, does result in extra fiscal space for the domestic authorities in the short and medium run. This reduces the subsequent increase in the deficit and public debt than would otherwise be the case.

In light of the policy measures announced to date, it is fair to say that EU institutions have committed to play a more expansive role in dealing with the present crisis then in previous cases. In order to maximise the efficiency of this support, it is important to be able to quantify the impact of this greater involvement on both member state's key fiscal variables and growth outlooks. We believe our paper makes a significant contribution in that regard.

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A Technical Appendix

B Households

B.1 Ricardian households (Savers)

Each Ricardian household r maximizes its expected discounted lifetime utility, V_0^r, in any given period t :

$$V_0^r \equiv E_0 \sum_{t=0}^{\infty} \beta_t \left(U\left(c_t^r, g_t^h\right) + G\left(l_t^{H,r}, l_t^{NT,r}, l_t^{P,r}\right)\right) \tag{13}$$

The period utility functional form is:

$$\frac{\left(c_t + \vartheta^g \overline{g}_t^c\right)^{1-\sigma}}{1-\sigma} - \chi^H \frac{\left(l_t^{H,r}\right)^{1+\eta^H}}{1+\eta^H} - \chi^{NT} \frac{\left(l_t^{NT,r}\right)^{1+\eta^{NT}}}{1+\eta^{NT}} - \chi^P \frac{\left(l_t^{P,r}\right)^{1+\eta^P}}{1+\eta^P} \tag{14}$$

subject to the sequential budget constraint in period t and the laws of motion of capital:

$$\begin{aligned}
&P_t\left(1+\tau_t^c\right) c_t^r + \mu_t^c P_t c_t^r + P_t x_t^{H,r} + P_t x_t^{NT,r} + P_t b_t^r + S_t P_t^* f_t^{*r} + \Phi^*\left(f_t^{*r}, f^{*r}\right) \\
&= \left(1-\tau_t^n\right) P_t \left(w_t^H \phi_t^H l_t^{H,r} + w_t^{NT} \phi_t^{NT} l_t^{NT,r} + w_t^P \phi_t^P l_t^{P,r}\right) + \left(1-\tau_t^k\right) P_t \left(r_t^{NT,r} k_{t-1}^{NT,r} + \omega_t^{NT,r}\right) \\
&+ \left(1-\tau_t^k\right) P_t \left(r_t^{H,k} k_{t-1}^{H,r} + \omega_t^{H,r}\right) + R_{t-1} P_{t-1} b_{t-1}^r + Q_{t-1} S_t P_{t-1}^* f_{t-1}^r - P_t \tau_t^{l,r} \\
&+ \tau_t^{covid,r} P_t \left(w^H l^{H,r} + w^{NT} l^{NT,r} - \left(w_t^H \phi_t^H l_t^{H,r} + w_t^{NT} \phi_t^{NT} l_t^{NT,r}\right)\right) + P_t \tau_t^{cash,r}
\end{aligned} \tag{15}$$

$$k_t^{H,r} = \left(1-\delta^H\right) k_{t-1}^{H,r} + x_t^{H,r} - \frac{\psi^H}{2}\left(\frac{k_t^H}{k_{t-1}^H} - 1\right)^2 k_{t-1}^H \tag{16}$$

$$k_t^{NT,r} = \left(1-\delta^{NT}\right) k_{t-1}^{NT,r} + x_t^{NT,r} - \frac{\psi^{NT}}{2}\left(\frac{k_t^{NT}}{k_{t-1}^{NT}} - 1\right)^2 k_{t-1}^{NT} \tag{17}$$

Each household r maximizes its lifetime utility (13) in any given period t by choosing purchases of the final consumption good, c_t^r, hours of work in the tradable, $l_t^{H,r}$, non-tradable sector, $l_t^{NT,r}$, and public sector, $l_t^{P,r}$, the end-of-period physical capital stocks, $k_t^{H,r}$, and $k_t^{NT,r}$, the end-of-period holdings of domestic government bond, b_t^r, and international traded assets expressed in foreign currency, f_t^{*r}, subject to the constraint (15) (in which we incorporate constraints (16) and (17)).

The Lagrange multiplier associated with constraint (15) is Λ_t^r . The first-order conditions with respect to c_t^r, $l_t^{H,r}, l_t^{NT,r}, l_t^{P,r}, k_t^{H,r}, k_t^{NT,r}, b_t^r$ and f_t^{*r} are given by:

$$\left(c_t^r + \vartheta^g g_t^h\right)^{-\sigma} = \Lambda_t^r \left(1 + \tau_t^c + \mu_t^c\right) \tag{18}$$

$$\chi^H \left(l_t^{H,r}\right)^{\eta^H} = \Lambda_t^r \left(1-\tau_t^n\right) w_t^H \phi_t^H \tag{19}$$

$$\chi^{NT} \left(l_t^{NT,r}\right)^{\eta^{NT}} = \Lambda_t^r \left(1-\tau_t^n\right) w_t^{NT} \phi_t^{NT} \tag{20}$$

$$\chi^P \left(l_t^{P,r}\right)^{\eta^P} = \Lambda_t^r \left(1-\tau_t^n\right) w_t^P \phi_t^P \tag{21}$$

$$\Lambda_t^r \left(1+\psi^H \left(\frac{k_t^{H,r}}{k_{t-1}^{H,r}}-1\right)\right) = \\ E_0 \beta \Lambda_{t+1}^r \left(1-\delta^H + \left(1-\tau_{t+1}^k\right) r_{t+1}^{H,k} - \frac{\psi^H}{2}\left(\frac{k_{t+1}^{H,r}}{k_t^{H,r}}-1\right)^2 + \psi^H \left(\frac{k_{t+1}^{H,r}}{k_t^{H,r}}-1\right)\left(\frac{k_{t+1}^{H,r}}{k_t^{H,r}}\right)\right) \tag{22}$$

$$\Lambda_t^r \left(1+\psi^{NT} \left(\frac{k_t^{NT,r}}{k_{t-1}^{NT,r}}-1\right)\right) = \\ E_0 \beta \Lambda_{t+1}^r \left(1-\delta^{NT} + \left(1-\tau_{t+1}^k\right) r_{t+1}^{NT,k} - \frac{\psi^{NT}}{2}\left(\frac{k_{t+1}^{NT,r}}{k_t^{NT,r}}-1\right)^2 + \psi^{NT} \left(\frac{k_{t+1}^{NT,r}}{k_t^{NT,r}}-1\right)\left(\frac{k_{t+1}^{NT,r}}{k_t^{NT,r}}\right)\right) \tag{23}$$

$$\Lambda_t^r = E_0 \beta \Lambda_{t+1}^r \frac{1}{\Pi_{t+1}} \tag{24}$$

$$\Lambda_t^r \left(p_t^F + \psi^* \left(p_t^F f_t^{*r} - p^F f^{*r}\right)\right) = \\ E_0 \beta \Lambda_{t+1}^r Q_t p_{t+1}^F \frac{1}{\Pi_{t+1}^*} \tag{25}$$

B.2 Non-Ricardian Households (Non-savers)

Each non-Ricardian household nr has the same preferences as Ricardian households and chooses $c_t^{nr}, l_t^{T,nr}, l_t^{NT,nr}$ and $l_t^{P,nr}$ to maximize its expected discounted lifetime utility, V_0^{nr}:

$$V_0^{nr} \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left(U\left(c_t^{nr}, g_t^h\right) + G\left(l_t^{H,nr}, l_t^{NT,nr}, l_t^{P,nr}\right)\right) \tag{26}$$

subject to the sequential budget constraint in period t (in nominal terms):

$$(1+\tau_t^c) + \mu_t^c P_t c_t^{nr} = \\ (1-\tau_t^n) P_t \left(w_t^H \phi_t^H l_t^{H,nr} + w_t^{NT} \phi_t^{NT} l_t^{NT,nr} + w_t^P \phi_t^P l_t^{P,nr}\right) - P_t \tau_t^{l,nr} \\ + P_t \tau_t^{covid,nr} \left(w^H l^{H,nr} + w^{NT} l^{NT,nr} - \left(w_t^H \phi_t^H l_t^{H,nr} + w_t^{NT} \phi_t^{NT} l_t^{NT,nr}\right)\right) + P_t \tau_t^{cash,nr} \tag{27}$$

Each household nr maximizes its lifetime utility (26) in any given period t by choosing purchases of the final good, c_t^{nr}, hours of work in the tradable, $l_t^{H,nr}$, non-tradable sector, $l_t^{NT,nr}$, and public sector, $l_t^{P,nr}$ subject to the constraint (27). The Lagrange multiplier associated with constraint (27) is Λ_t^{nr} . The first-order conditions with respect to c_t^{nr}, $l_t^{H,nr}, l_t^{NT,nr}$, $l_t^{P,nr}$ are:

$$\left(c_t^{nr} + \vartheta^g g_t^h\right)^{-\sigma} = \Lambda_t^{nr}\left(1+\tau_t^c+\mu_t^c\right) \tag{28}$$

$$\chi^H \left(l_t^{H,nr}\right)^{\eta^H} = \Lambda_t^{nr}\left(1-\tau_t^n\right) w_t^H \phi_t^H \tag{29}$$

$$\chi^{NT} \left(l_t^{NT,nr}\right)^{\eta^{NT}} = \Lambda_t^{nr}\left(1-\tau_t^n\right) w_t^{NT} \phi_t^{NT} \tag{30}$$

$$\chi^P \left(l_t^{P,nr}\right)^{\eta^P} = \Lambda_t^{nr}\left(1-\tau_t^n\right) w_t^P \phi_t^P \tag{31}$$

C Firms

The production sector of the economy is identical to that in Varthalitis (2019). We briefly summarize the structure of the production sector in our model and, where necessary, we refer to the relevant sections in Varthalitis (2019).

There are two stages of private production. In the final stage, the final good that is used for private and public consumption and investment is produced. There are two firms namely a final good and a composite tradable good producer (the associated problems are solved in sections 3.3.1 and 3.3.2 in Varthalitis (2019)). The final good producer utilizes the composite tradable and the single intermediate non-tradable good to produce the final good. Similarly, the composite tradable good producer utilizes the home produced tradable good and the imported good to produce the composite tradable good.

In the intermediate stage, the intermediate non-tradable and tradable bundles are produced (the associated problems are solved in sections 3.3.3 and 3.3.4 in Varthalitis (2019)). Non-tradable firms hire labour and rent physical capital from households to produce differentiated varieties of non-tradable goods. A non-tradable distributor combines all varieties into an intermediate non-tradable bundle. Similarly, home tradable firms hire labour and rent physical capital from households to produce differentiated varieties of tradable goods. A tradable distributor combines all varieties into an intermediate home tradable bundle.

D Definition of GDP

For our quantitative analysis we need to define a measure of aggregate domestic output, y_t^{gdp}. In the present model we incorporate public employment which yields income from public wages, thus, in order to be consistent with national accounts definitions we include the public wage bill in the definition of aggregate domestic output following Forni et al. (2010) and Papageorgiou (2014). Nominal GDP, $P_t y_t^{gdp}$, at current prices and per capita terms is given by:

$$y_t^{gdp} = p_t^H y_t^H + p_t^{NT} y_t^{NT} + g_t^w \tag{32}$$

We use, $P_t y_t^{gdp}$, to express several theoretical variables as GDP shares.

E National fiscal rules

The main spending-tax policy instruments react to the debt-to-GDP ratio while fiscal persistence is captured by including an autoregressive term. For our quantitative analysis we express all spending instruments as shares of steady state GDP, y^{gdp} , namely, the ratio of government consumption to GDP, $s_t^{g,c} \equiv \frac{g_t^c}{y^{gdp}}$, the ratio of public investment to GDP, $s_t^{g,i} \equiv \frac{g_t^i}{y^{gdp}}$, the ratio of public wages to GDP, $s_t^w \equiv \frac{g_t^w}{y^{gdp}}$, the ratio of total public transfers to GDP, $s_t^l \equiv \frac{g_t^l}{y^{gdp}}$. Then the associated fiscal rules are given by:

$$s_t^{g,c} - s^{g,c} = \rho^{g,c}\left(s_{t-1}^{g,c} - s^{g,c}\right) - \gamma^{g,c}\left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{33}$$

$$s_t^{g,i} - s^{g,i} = \rho^{g,i}\left(s_{t-1}^{g,i} - s^{g,i}\right) - \gamma^{g,i}\left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{34}$$

$$s_t^w - s^w = \rho^w \left(s_{t-1}^w - s^w\right) - \gamma^w \left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{35}$$

$$s_t^l - s^l = \rho^l \left(s_{t-1}^l - s^l\right) - \gamma^l \left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{36}$$

$$\tau_t^c - \tau^c = \rho^c \left(\tau_{t-1}^c - \tau^c\right) + \gamma^{\tau^c} \left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{37}$$

$$\tau_t^k - \tau^k = \rho^k \left(\tau_{t-1}^k - \tau^k\right) + \gamma^{\tau^k} \left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{38}$$

$$\tau_t^n - \tau^n = \rho^n \left(\tau_{t-1}^n - \tau^n\right) + \gamma^{\tau^n} \left(\frac{P_{t-1}F_{t-1}^M}{P_{t-1}y_{t-1}^{gdp}} - \mathcal{F}^M\right) \tag{39}$$

where $\rho^{g,c}$, $\rho^{g,i}$, ρ^w, ρ^l, ρ^c, ρ^k, $\rho^n \in [0,1)$ are autoregressive coefficients, $\gamma^{g,c}$, $\gamma^{g,i}$, γ^w, γ^l,γ^{τ^c}, γ^{τ^k}, $\gamma^{\tau^n} \geq 0$ are feedback policy coefficients on public debt held in private markets to GDP ratio while variables without time subscript denote policy target values which are set equal to their steady state values.

F Market clearing conditions

In this section we solve for a symmetric equilibrium in per capita terms. Without loss of generality we set $N^i = N^j = N$ and $\nu^r \equiv \frac{N^r}{N}$, $\nu^{nr} \equiv \frac{N^{nr}}{N}$ are Savers and Non-Savers population shares. Below, we present the market clearing conditions by market, i.e. the final good, tradable and non-tradable goods markets, labour markets, capital and bonds markets. In the final good market the market clearing condition yields:

$$y_t = \nu^r c_t^r + \nu^r x_t^{H,r} + \nu^r x_t^{NT,r} + \nu^{nr} c_t^{nr} + g_t^c + g_t^i + g_t^h \tag{40}$$

The market clearing condition in the tradable good market yields:

$$y_t^H = y_t^{H,d} + x_t \tag{41}$$

where $y_t^{H,d} \equiv \frac{Y_t^{H,d}}{N}$ and $x_t \equiv \frac{X_t}{N}$ denote domestic absorption the home tradable produced good and exports per capita. For the non-tradable good the market clearing condition is $y_t^{NT} = \frac{1}{N^i}\sum_{i=1}^{N^i} y_t^{NT,i}$. In capital markets:

$$\frac{1}{N}\sum_{j=1}^{N^j} k_t^{H,j} = k_t^{H,j} = \frac{1}{N}\sum_{r=1}^{N^r} k_t^{H,r} = \nu^r k_t^{H,r}$$

$$\frac{1}{N}\sum_{i=1}^{N^i} k_t^{NT,i} = k_t^{NT,i} = \frac{1}{N}\sum_{r=1}^{N^r} k_t^{NT,r} = \nu^r k_t^{NT,r}$$

In the labour market of the home tradable good the market clearing condition yields:

$$l_t^H = \upsilon^r \phi_t^H l_t^{H,r} + \upsilon^{nr} \phi_t^H l_t^{H,r} \tag{42}$$

In the labour market of the non-tradable good the market clearing condition yields:

$$l_t^{NT} = v^r \phi_t^{NT} l_t^{NT,r} + v^{nr} \phi_t^{NT} l_t^{NT,nr} \tag{43}$$

The market clearing condition in the labour market of the public good is:

$$l_t^g = v^r \phi_t^P l_t^{P,r} + v^{nr} \phi_t^P l_t^{P,nr} \tag{44}$$

The market clearing condition nn domestic government bonds market is:

$$\sum_{r=0}^{N^r} b_t^r = N_t^r b_t \tag{45}$$

Notice that aggregating total profits in the two sectors across firms and households yields $\sum_{r=1}^{N^r} \omega_t^{H,r} = N^r \omega_t^{H,r} = \sum_{i=1}^{N^i} \omega_t^{H,i} = N^i \omega_t^{H,i}$ and $\sum_{r=1}^{N^r} \omega_t^{NT,r} = N^r \omega_t^{NT,r} = \sum_{j=1}^{N^j} \omega_t^{NT,j} = N^j \omega_t^{NT,j}$.

F.1 The balance of payments

Combining the aggregate Ricardian household budget constraint with the government budget constraint and substituting the definitions for profits in the tradable and non-tradable sector, the market clearing conditions for final good, tradable and non-tradable goods, labour and capital markets and the aggregate budget constraint of non-Ricardian households yields a dynamic equation that governs the evolution of net foreign debt (assets). The evolution of net foreign debt in nominal aggregate terms is given by:

$$\begin{gathered}
(1-\lambda_t^g) P_t F_t^M + S_t P_t^* F_t^{*EU} - S_t P_t^* N^r f_t^{*r} = \\
Q_{t-1} \tfrac{S_t}{S_{t-1}} P_{t-1} F_{t-1}^M + Q_{t-1} \tfrac{S_t}{S_{t-1}} S_{t-1} P_{t-1}^* F_{t-1}^{*g} - Q_{t-1} S_t P_{t-1}^* N^r f_{t-1}^{*r} + P_t^F Y_t^F - P_t^H X_t \\
+ N \tfrac{\theta^{NT}}{2} \left(\tfrac{P_t^{NT}}{P_{t-1}^{NT}} - 1 \right)^2 P_t^{NT} y_t^{NT} + N \tfrac{\theta^H}{2} \left(\tfrac{P_t^H}{P_{t-1}^H} - 1 \right)^2 P_t^H y_t^H + N^r \Phi^* (f_t^*, f^*) \\
+ \mu_t P_t (N^r c_t^r + N^{nr} c_t^{nr})
\end{gathered}$$

The evolution of net foreign debt in real and per capita terms is given by:

$$\begin{gathered}
(1-\lambda_t^g) f_t^M + p_t^F f_t^{*EU} - p_t^F \nu^r f_t^{*r} = \\
Q_{t-1} \tfrac{S_t}{S_{t-1}} \tfrac{P_{t-1}}{P_t} f_{t-1}^M + Q_{t-1} \tfrac{S_t}{S_{t-1}} \tfrac{P_{t-1}}{P_t} \tfrac{S_{t-1} P_{t-1}^*}{P_{t-1}} f_{t-1}^{*EU} - Q_{t-1} \tfrac{S_t}{S_{t-1}} \tfrac{P_{t-1}}{P_t} \tfrac{S_{t-1} P_{t-1}^*}{P_{t-1}} \nu^r f_{t-1}^{*r} + p_t^F y_t^F - p_t^H x_t \\
+ \tfrac{\theta^{NT}}{2} \left(\tfrac{p_t^{NT}}{p_{t-1}^{NT}} \Pi_t - 1 \right)^2 p_t^{NT} y_t^{NT} + \tfrac{\theta^H}{2} \left(\tfrac{p_t^H}{p_{t-1}^H} \Pi_t - 1 \right)^2 p_t^H y_t^H + \nu^r \Phi^* (f_t^*, f^*) \\
+ \mu_t (\nu^r c_t^r + \nu^{nr} c_t^{nr})
\end{gathered} \tag{46}$$

where small case letters denote real and per capita quantities.

G Calibration

Table E.1: Parameter values

Parameter	Implied Value	Description
β	0.9588	time discount factor
σ	2	inverse of elasticity of substitution in consumption
ϑ^g	0	substitutability/complementarity between public and private consumption
η^H	2	inverse of Frisch labour elasticity in the tradable sector
η^{NT}	2	inverse of Frisch labour elasticity in the non-tradable sector
η^P	2	inverse of Frisch labour elasticity in public sector
$\chi^H, \chi^{NT}, \chi^g$	4	preference parameter related to work effort (all sectors)
δ^H	0.071	capital depreciation rate in the tradable sector
δ^{NT}	0.051	capital depreciation rate in the non-tradable sector
δ^g	0.0741	capital depreciation rate in the public sector
a^H	0.571	share of physical capital in the tradable sector
a^{NT}	0.244	share of physical capital in the non-tradable sector
a_1^g	0.183	share of public capital in the public sector
a_2^g	0.542	share of public labour in the public sector
κ^H	0.035	public capital elasticity in the production function (tradable)
κ^{NT}	0.035	public capital elasticity in the production function (non-tradable)
ε^H	11	price elasticity of demand in the tradable sector
ε^{NT}	3.5	price elasticity of demand in the non-tradable sector
ν	0.5817	share of tradable in the production of the final good
ν^H	0.03	share of domestic tradable in the production of the composite tradable good
ζ	0.5	elasticity of substitution between the composite tradable and the non-tradable good
ζ^H	1	elasticity of substitution between domestic tradable and imported good
ν^r	0.7	total population share of "Savers"
ν^{nr}	0.3	total population share of "non-Savers"
λ^g	0.5	share of public debt held by foreign investors
A^H, A^{NT}, A^g	1	productivity/scale parameter(s) (all sectors)
$\mathcal{F}^M$	0.6	market-held debt to GDP threshold value

H Decentralized Equilibrium

The Decentralized Equilibrium expressed in real and per capita terms is a set of 62 processes c_t^r, Λ_t^r, $l_t^{H,r}$, $l_t^{NT,r}$, $l_t^{P,r}$, $k_{t-1}^{H,r}$, $k_{t-1}^{NT,r}$, f_t^{*r}, c_t^{nr}, Λ_t^{nr}, $l_t^{H,nr}$, $l_t^{NT,nr}$, $l_t^{P,nr}$, $l_t^{H,i}$, $l_t^{NT,j}$, l_t^g y_t^H, mc_t^H, ω_t^H, $r_t^{H,k}$, w_t^H, y_t^{NT}, mc_t^{NT}, ω_t^{NT}, $r_t^{NT,k}$, w_t^{NT}, k_t^g, y_t^g, w_t^P, f_t^M, τ_t, y_t, y_t^T, $y_t^{H,d}$, y_t^F, y_t^{gdp}, Q_t, R_t, P_t^H, P_t^{NT}, P_t^T, P_t, P_t^F, x_t^H, x_t^{NT}, x_t, tot_t, g_t^c, g_t^i, g_t^w, τ_t^l, $s_t^{g,c}$, $s_t^{g,i}$, s_t^w, s_t^l, τ_t^c, τ_t^k, τ_t^n, g_t^{covid}, f_t^{*EU}, def_t, Q_t^* satisfying the following 62 equations, given the discretionary extraordinary set of fiscal instruments, g_t^h, $\tau_t^{covid,r}$, $\tau_t^{cash,r}$, $\tau_t^{covid,nr}$, $\tau_t^{cash,nr}$ the exogenous variables Π_t^*, $\phi_t^H, \phi_t^{NT}, \phi_t^P, \mu_t^c$ and $\frac{S_t}{S_{t-1}}$ and initial conditions for the state variables:

$$\left(c_t^r + \vartheta^g g_t^h\right)^{-\sigma} = \Lambda_t^r \left(1 + \tau_t^c + \mu_t^c\right) \tag{47}$$

$$\chi^H \left(l_t^{H,r}\right)^{\eta^H} = \Lambda_t^r \left(1 - \tau_t^n\right) w_t^H \phi_t^H \tag{48}$$

$$\chi^{NT} \left(l_t^{NT,r}\right)^{\eta^{NT}} = \Lambda_t^r \left(1 - \tau_t^n\right) w_t^{NT} \phi_t^{NT} \tag{49}$$

$$\chi^P \left(l_t^{P,r}\right)^{\eta^P} = \Lambda_t^r \left(1 - \tau_t^n\right) w_t^P \phi_t^P \tag{50}$$

$$\begin{gathered}\Lambda_t^r \left(1 + \psi^H \left(\frac{k_t^{H,r}}{k_{t-1}^{H,r}} - 1\right)\right) = \\ E_0 \beta \Lambda_{t+1}^r \left(1 - \delta^H + \left(1 - \tau_{t+1}^k\right) r_{t+1}^{H,k} - \frac{\psi^H}{2} \left(\frac{k_{t+1}^{H,r}}{k_t^{H,r}} - 1\right)^2 + \psi^H \left(\frac{k_{t+1}^{H,r}}{k_t^{H,r}} - 1\right) \left(\frac{k_{t+1}^{H,r}}{k_t^{H,r}}\right)\right)\end{gathered} \tag{51}$$

$$\Lambda_t^r\left(1+\psi^{NT}\left(\frac{k_t^{NT,r}}{k_{t-1}^{NT,r}}-1\right)\right)=$$
$$E_0\beta\Lambda_{t+1}^r\left(1-\delta^{NT}+\left(1-\tau_{t+1}^k\right)r_{t+1}^{NT,k}-\frac{\psi^{NT}}{2}\left(\frac{k_{t+1}^{NT,r}}{k_t^{NT,r}}-1\right)^2+\psi^{NT}\left(\frac{k_{t+1}^{NT,r}}{k_t^{NT,r}}-1\right)\left(\frac{k_{t+1}^{NT,r}}{k_t^{NT,r}}\right)\right) \tag{52}$$

$$\Lambda_t^r=E_0\beta\Lambda_{t+1}^r\frac{1}{\Pi_{t+1}} \tag{53}$$

$$\begin{gathered}\Lambda_t^r\left(p_t^F+\psi^*\left(p_t^F f_t^{*r}-p^F f^{*r}\right)\right)=\\ E_0\beta\Lambda_{t+1}^r Q_t p_{t+1}^F\frac{1}{\Pi_{t+1}^*}\end{gathered} \tag{54}$$

$$\left(c_t^{nr}+\vartheta^g g_t^h\right)^{-\sigma}=\Lambda_t^{nr}\left(1+\tau_t^c+\mu_t^c\right) \tag{55}$$

$$\chi^H\left(l_t^{H,nr}\right)^{\eta^H}=\Lambda_t^{nr}\left(1-\tau_t^n\right)w_t^H\phi_t^H \tag{56}$$

$$\chi^{NT}\left(l_t^{NT,nr}\right)^{\eta^{NT}}=\Lambda_t^{nr}\left(1-\tau_t^n\right)w_t^{NT}\phi_t^{NT} \tag{57}$$

$$\chi^P\left(l_t^{P,nr}\right)^{\eta^P}=\Lambda_t^{nr}\left(1-\tau_t^n\right)w_t^P\phi_t^P \tag{58}$$

$$\begin{gathered}\left(1+\tau_t^c\right)c_t^{nr}+\mu_t^c c_t^{nr}=\left(1-\tau_t^n\right)\left(w_t^H\phi_t^H l_t^{H,nr}+w_t^{NT}\phi_t^{NT}l_t^{NT,nr}+w_t^P\phi_t^P l_t^{P,nr}\right)-\tau_t^{l,nr}\\ +\tau_t^{covid,nr}\left(w^H l^{H,nr}+w^{NT}l^{NT,nr}-\left(w_t^H\phi_t^H l_t^{H,nr}+w_t^{NT}\phi_t^{NT}l_t^{NT,nr}\right)\right)+\tau_t^{cash,nr}\end{gathered} \tag{59}$$

$$y_t=\left[(v)^{\frac{1}{\zeta}}\left(y_t^T\right)^{\frac{\zeta-1}{\zeta}}+(1-v)^{\frac{1}{\zeta}}\left(y_t^{NT}\right)^{\frac{\zeta-1}{\zeta}}\right]^{\frac{\zeta}{\zeta-1}} \tag{60}$$

$$y_t^T=\frac{v}{1-v}\left(\frac{p_t^T}{p_t^{NT}}\right)^{-\zeta}y_t^{NT} \tag{61}$$

$$1=\left[v\left(p_t^T\right)^{1-\zeta}+(1-v)\left(p_t^{NT}\right)^{1-\zeta}\right]^{\frac{1}{1-\zeta}} \tag{62}$$

$$y_t^T=\left[\left(v^H\right)^{\frac{1}{\zeta^H}}\left(y_t^{H,d}\right)^{\frac{\zeta^H-1}{\zeta^H}}+\left(1-v^H\right)^{\frac{1}{\zeta^H}}\left(y_t^F\right)^{\frac{\zeta^H-1}{\zeta^H}}\right]^{\frac{\zeta^H}{\zeta^H-1}} \tag{63}$$

$$y_t^{H,d}=\frac{v^H}{1-v^H}\left(\frac{p_t^H}{p_t^F}\right)^{-\zeta^H}y_t^F \tag{64}$$

$$p_t^T=\left[v^H\left(p_t^H\right)^{1-\zeta^H}+\left(1-v^H\right)\left(p_t^F\right)^{1-\zeta^H}\right]^{\frac{1}{1-\zeta^H}} \tag{65}$$

$$\frac{p_t^F}{p_{t-1}^F}=\frac{\frac{S_t}{S_{t-1}}\Pi_t^*}{\Pi_t} \tag{66}$$

$$y_t^{NT}=A_t^{NT}\left\{y_t^g\right\}^{\varkappa_1^{NT}}\left\{\left(\nu^r k_{t-1}^{NT}\right)^{a^{NT}}\left(l_t^{NT,i}\right)^{1-a^{NT}}\right\}^{\varkappa_2^{NT}} \tag{67}$$

$$r_t^k = mc_t^{NT} a^{NT} \varkappa_2^{NT} \frac{y_t^{NT}}{\nu^r k_{t-1}^{NT,r}} \tag{68}$$

$$w_t^{NT} = mc_t^{NT} \left(1 - a^{NT}\right) \varkappa_2^{NT} \frac{y_t^{NT}}{l_t^{NT,i}} \tag{69}$$

$$\nu^r \omega_t^{NT,r} = p_t^{NT} y_t^{NT} - r_t^k \nu^r k_{t-1}^{NT,r} - w_t^{NT} l_t^{NT,i} \tag{70}$$

$$\begin{gathered} \left\{\left(1 - \varepsilon^{NT}\right) p_t^{NT} y_t^{NT} + \varepsilon^{NT} mc_t^{NT} y_t^{NT}\right\} \\ -\theta^{NT} \left(\tfrac{p_t^{NT}}{p_{t-1}^{NT}} \Pi_t - 1\right) p_t^{NT} y_t^{NT} \tfrac{p_t^{NT}}{p_{t-1}^{NT}} \Pi_t + \beta \tfrac{\Lambda_{t+1}^r}{\Lambda_{t+1}^r} \tfrac{1}{\Pi_{t+1}} \left\{\theta^{NT} \left(\tfrac{P_{t+1}^{NT}}{P_t^{NT}} \Pi_{t+1} - 1\right) P_{t+1}^{NT} y_{t+1}^{NT} \tfrac{P_{t+1}^{NT}}{P_t^{NT}} \Pi_{t+1}\right\} = 0 \end{gathered} \tag{71}$$

$$y_t^H = A_t^H \left\{y_t^g\right\}^{\varkappa_1^H} \left\{\left(\nu^r k_{t-1}^{H,r}\right)^{a^H} \left(l_t^{H,j}\right)^{1-a^H}\right\}^{\varkappa_2^H} \tag{72}$$

$$r_t^{H,k} = mc_t^H a^H \varkappa_2^H \frac{y_t^H}{\nu^r k_{t-1}^{H,r}} \tag{73}$$

$$w_t^H = mc_t^H \left(1 - a^H\right) \varkappa_2^H \frac{y_t^H}{l_t^{H,j}} \tag{74}$$

$$\nu^r \omega_t^{H,r} = p_t^H y_t^H - r_t^{H,k} \nu^r k_{t-1}^{H,r} - w_t^H l_t^{H,j} \tag{75}$$

$$\begin{gathered} \left\{\left(1 - \varepsilon^H\right) p_t^H y_t^H + \varepsilon^H mc_t^H y_t^H\right\} \\ -\theta^H \left(\tfrac{p_t^H}{p_{t-1}^H} \Pi_t - 1\right) p_t^H y_t^H \tfrac{p_t^H}{p_{t-1}^H} \Pi_t + \beta \tfrac{\Lambda_{t+1}^r}{\Lambda_{t+1}^r} \tfrac{1}{\Pi_{t+1}} \left\{\theta^H \left(\tfrac{P_{t+1}^H}{P_t^H} \Pi_{t+1} - 1\right) P_{t+1}^H y_{t+1}^H \tfrac{P_{t+1}^H}{P_t^H} \Pi_{t+1}\right\} = 0 \end{gathered} \tag{76}$$

$$\begin{aligned} f_t^M + p_t^F f_t^{*EU} &= R_{t-1} \tfrac{1}{\Pi_t} \lambda_t^g f_{t-1}^M + Q_{t-1} \tfrac{S_t}{S_{t-1}} \tfrac{1}{\Pi_t} \left(1 - \lambda_{t-1}^g\right) f_{t-1}^M \\ &+ Q_{t-1}^* \tfrac{S_t}{S_{t-1}} p_{t-1}^F f_{t-1}^{*EU} + g_t^c + g_t^i + g_t^w + g_t^{covid} - \tau_t^l - \tau_t \end{aligned} \tag{77}$$

$$\begin{aligned} g_t^{covid} &= \tau^{covid,r} \nu^r \left(w^H \phi^H l^{H,r} + w^{NT} \phi^{NT} l^{NT,r} - \left(w_t^H \phi_t^H l_t^{H,r} + w_t^{NT} \phi_t^{NT} l_t^{NT,r}\right)\right) \\ &+ \tau^{covid,nr} \nu^r \left(w^H l^{H,nr} + w^{NT} l^{NT,nr} - \left(w_t^H \phi_t^H l_t^{H,nr} + w_t^{NT} \phi_t^{NT} l_t^{NT,nr}\right)\right) \\ &+ \nu^r \tau_t^{cash,r} + \nu^{nr} \tau_t^{cash,nr} + g_t^h \end{aligned} \tag{78}$$

$$\begin{gathered} \tau_t \equiv \tau_t^c \left(\nu^r c_t^r + \nu^{nr} c_t^{nr} +\right) + \tau_t^n \nu^r \left(w_t^H \phi_t^H l_t^{H,r} + w_t^{NT} \phi_t^{NT} l_t^{NT,r} + w_t^P \phi_t^P l_t^{P,r}\right) \\ + \tau_t^n \nu^{nr} \left(w_t^H \phi_t^H l_t^{H,nr} + w_t^{NT} \phi_t^{NT} l_t^{NT,nr} + + w_t^P \phi_t^P l_t^{P,nr}\right) + \tau_t^k \nu^r \left(r_t^{H,k} k_{t-1}^{H,r} + \omega_t^{H,r} + r_t^{NT,k} k_{t-1}^{NT,r} + \omega_t^{NT,r}\right) \end{gathered} \tag{79}$$

$$k_t^g = \left(1 - \delta^g\right) k_{t-1}^g + g_t^i \tag{80}$$

$$y_t^g = A_t^g \left(k_{t-1}^g\right)^{a_1^g} \left(l_t^g\right)^{a_2^g} \left(g_t^c\right)^{1-a_1^g-a_2^g} \tag{81}$$

$$y_t = \nu^r \left(c_t^r + x_t^{H,r} + x_t^{NT,r}\right) + \nu^{nr} c_t^{nr} + g_t^c + g_t^i + g_t^h \tag{82}$$

$$y_t^H = y_t^{H,d} + x_t \tag{83}$$

$$l_t^H = v^r \phi_t^H l_t^{H,r} + v^{nr} \phi_t^H l_t^{H,r} \tag{84}$$

$$l_t^{NT} = v^r \phi_t^{NT} l_t^{NT,r} + v^{nr} \phi_t^{NT} l_t^{NT,nr} \tag{85}$$

$$l_t^g = v^r \phi_t^P l_t^{P,r} + v^{nr} \phi_t^P l_t^{P,nr} \tag{86}$$

$$
\begin{aligned}
(1-\lambda^g)\, f_t^M + p_t^F f_t^{*EU} - p_t^F \tfrac{N^r}{N} f_t^{*r} = Q_{t-1} \tfrac{S_t}{S_{t-1}} \tfrac{1}{\Pi_t} (1-\lambda^g)\, f_{t-1}^M \\
+Q_{t-1}^* \tfrac{S_t}{S_{t-1}} \tfrac{1}{\Pi_t} p_{t-1}^F f_{t-1}^{*EU} - Q_{t-1} \tfrac{S_t}{S_{t-1}} p_{t-1}^F \tfrac{1}{\Pi_t} \nu^r f_{t-1}^{*r} \\
+\tfrac{P_t^F}{P_t} y_t^F - \tfrac{P_t^H}{P_t} x_t + \tfrac{\phi^{NT}}{2} \left(\tfrac{P_t^{NT}}{P_{t-1}^{NT}} - 1 \right)^2 P_t^{NT} y_t^{NT} \\
+\tfrac{\phi^H}{2} \left(\tfrac{P_t^H}{P_{t-1}^H} - 1 \right)^2 P_t^H y_t^H + \nu^r \tfrac{\phi^*}{2} \left(p_t^F f_t^{*r} - p^F f^{*r} \right)^2 + \mu_t^c \left(\nu^r c_t^r + \nu^{nr} c_t^{nr} \right)
\end{aligned}
\tag{87}
$$

$$
k_t^{H,r} = \left(1-\delta^H\right) k_{t-1}^{H,r} + x_t^{H,r} - \frac{\psi^H}{2} \left(\frac{k_t^{H,r}}{k_{t-1}^{H,r}} - 1 \right)^2 k_{t-1}^{H,r} \tag{88}
$$

$$
k_t^{NT,r} = \left(1-\delta^{NT}\right) k_{t-1}^{NT,r} + x_t^{NT,r} - \frac{\psi^{NT}}{2} \left(\frac{k_t^{NT,r}}{k_{t-1}^{NT,r}} - 1 \right)^2 k_{t-1}^{NT,r} \tag{89}
$$

$$
y_t^{gdp} = p_t^H y_t^H + p_t^{NT} y_t^{NT} + g_t^w \tag{90}
$$

$$
Q_t = Q_t^* + \psi^d \left(e^{\frac{f_t^M}{y_t^{gdp}} - \mathcal{F}^M} - 1 \right) \tag{91}
$$

$$
tot_t = \frac{p_t^H}{p_t^F} \tag{92}
$$

$$
x_t = \rho^x x_{t-1} + (1-\rho^x) \left(\frac{tot_t}{tot} \right)^{-\gamma^x} + \tag{93}
$$

$$
g_t^w = w_t^P \left(\nu^r l_t^{P,r} + \nu^{nr} l_t^{P,nr} \right) \tag{94}
$$

$$
s_t^{g,c} = \frac{g_t^{g,c}}{y_t^{gdp}} \tag{95}
$$

$$
s_t^{g,i} = \frac{g_t^{g,i}}{y_t^{gdp}} \tag{96}
$$

$$
s_t^w = \frac{g_t^w}{y_t^{gdp}} \tag{97}
$$

$$
s_t^l = \frac{\tau_t^l}{y_t^{gdp}} \tag{98}
$$

$$
s_t^{g,c} - s^{g,c} = \rho^{g,c} \left(s_{t-1}^{g,c} - s^{g,c} \right) - \gamma^{g,c} \left(\frac{f_{t-1}^M}{y_{t-1}^{gdp}} - f^M \right) \tag{99}
$$

$$
s_t^{g,i} - s^{g,i} = \rho^{g,i} \left(s_{t-1}^{g,i} - s^{g,i} \right) - \gamma^{g,i} \left(\frac{f_{t-1}^M}{y_{t-1}^{gdp}} - f^M \right) \tag{100}
$$

$$
s_t^w - s^w = \rho^w \left(s_{t-1}^w - s^w \right) - \gamma^w \left(\frac{f_{t-1}^M}{y_{t-1}^{gdp}} - f^M \right) \tag{101}
$$

$$
s_t^l - s^l = \rho^l \left(s_{t-1}^l - s^l \right) - \gamma^l \left(\frac{f_{t-1}^M}{y_{t-1}^{gdp}} - f^M \right) \tag{102}
$$

$$\tau_t^c - \tau^c = \rho^c \left(\tau_{t-1}^c - \tau^c\right) + \gamma^c \left(\frac{f_{t-1}^M}{y_{t-1}^{gdp}} - f^M\right) \tag{103}$$

$$\tau_t^k - \tau^k = \rho^k \left(\tau_{t-1}^k - \tau^k\right) + \gamma^k \left(\frac{f_{t-1}^M}{y_{t-1}^{gdp}} - f^M\right) \tag{104}$$

$$\tau_t^n - \tau^n = \rho^n \left(\tau_{t-1}^n - \tau^n\right) + \gamma^n \left(\frac{f_{t-1}^M}{y_{t-1}^{gdp}} - f^M\right) + \varepsilon_t^n \tag{105}$$

$$def_t \equiv \left(R_{t-1} - 1\right) \lambda_{t-1}^g \frac{1}{\Pi_t} f_{t-1}^M + \left(Q_{t-1} - 1\right) \frac{S_t}{S_{t-1}} \left(1 - \lambda_{t-1}^g\right) \frac{1}{\Pi_t} f_{t-1}^M + g_t + g_t^{covid} - \tau_t \tag{106}$$

$$f_t^{*EU} - f^{*EU} = \rho^{F^{*EU}} \left(f_{t-1}^{*EU} - f^{*EU}\right) + \gamma^* \left(\frac{def_t}{y_t^{gdp}} - def\right) + \varepsilon_t^{F^{*EU}} \tag{107}$$

$$Q_t^* = \rho^{Q^*} Q_{t-1}^* + \rho^{Q^*} Q^* + \varepsilon_t^{Q^*} \tag{108}$$

I The cumulative output loss

In this Appendix we compute the present value of the cumulative output loss under the two public financing scenarios discussed in section 5.1. The present value cumulative reduction in the $k-th$ period in output loss is given by:

$$\mathcal{PV}_k\left(\Delta y\right) = \sum_{j=0}^{k} \left\{ \left(\prod_{i=0}^{k} \left(\frac{\Pi_{t+i+1}^{EU}}{R_{t+i}^{EU}} \right) \right) y_{t+j}^{gdp,EU} - \left(\prod_{i=0}^{k} \left(\frac{\Pi_{t+i+1}}{R_{t+i}} \right) \right) y_{t+j}^{gdp} \right\} \tag{109}$$

where $y_t^{gdp,EU}$ and y_t^{gdp} are real output under EU-held and market-held financed scenarios respectively whereas $\frac{\Pi_{t+i+1}^{EU}}{R_{t+I}^{EU}}$ and $\frac{\Pi_{t+i+1}}{R_{t+i}}$ are the associated dynamic discount factors respectively.

Table G.1.: Present value of cumulative output recession over five years horizon

Policy instrument	Market-held debt	EU-held debt	$\mathcal{PV}_k\left(\Delta y\right)$
g_t^h	-15.56%	-12.58%	+2.98%
$\tau_t^{cash,nr}$	-16.41%	-13.92%	+2.49%
$\tau_t^{covid,nr}$	-16.64%	-13.87%	+2.77%
Spending mix	-16.4%	-12.3%	+4.1%