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The ECB's policy, the Recovery Fund and the importance of trust: The case of Greece[1]

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Abstract

This paper, using a microfounded macroeconomic model that embeds the key features of the Greek economy, studies the efficacy of the various policy measures taken, at national and EU level, to cushion the economic effects of the pandemic shock. The paper attempts to give quantitative answers to questions like: What are the effects of these policies and, especially, what are the implications of the fiscal transfers and grants from the Recovery Fund and the quantitative policies of the ECB, like the PEPP, for the Greek economy? Do they help the real economy and, if yes, by how much? What would have happened had these measures not taken? How costly will be the re-emergence of the fear of debt default and risk premia?

JEL classification: E5, E6, F3.

Keywords: Central banking, Fiscal policy, International lending, Pandemic.

1 Introduction

The covid-19 pandemic struck Greece in early 2020 when it was just starting to embark on a moderate growth path after many years of depression; Greece had already lost more than 25% of its GDP during its sovereign debt crisis in 2009-2016. Moreover, the pandemic crisis found the country with limited fiscal space; its public debt was already 180% of GDP in the end of 2019 and most of it (around 70%) was in the hands of European Union (EU) public institutions as a result of the three official fiscal bailouts in the 2010s.

In an effort to stem the pandemic, like most governments, the Greek government has been forced to take extended lockdown measures which have reversed the growth dynamics of the Greek economy and, at the same time, to take severe fiscal stimulus measures in order to counter the economic implications of the pandemic. At the same time, Greece can benefit from financial support from the European Commission (EC) and the European Central Bank (ECB). Regarding the EC, through the redistributive transfers of the Recovery Fund, it is anticipated that Greece will benefit up to a net amount of 32 billion euros in the form of loans and grants; this amount translates to around 17.5% of the Greek GDP in 2019 and can be used by the end of 2026 for investments and reforms. Regarding the ECB, the latter has decided not only to continue the various policy measures towards Greece since 2008 (support of private banks through a full allotment lending policy, the issuance of cross-border *TARGET2* liabilities to the Eurosystem (ES), etc), but also to include Greek government bonds in its new asset purchase program, the so-called Pandemic Emergency Purchase Programme (PEPP), so as to support their price and narrow bond spreads.

In this paper, we try to give quantitative answers to the following questions. What are the effects of these policies on the Greek macroeconomy? Do they help the real economy and, if yes, by how much? What would have happened had these measures not taken? What will happen if the fear of debt default and risk premia re-emerge?

Our vehicle of analysis is a medium-scale micro-founded DSGE model of a small open economy participating in a currency union like the ES. Particular attention is given to the nexus between fiscal policies and quantitative monetary policies in the context of the ES. Regarding fiscal policy, we feed the model with a spending-tax policy mix that mimics the national fiscal stimulus adopted by the Greek government since the beginning of 2020, as well as with the redistributive funds from the EU's Recovery Fund in the form of loans and grants. Regarding monetary policy, as implied by the financial statements of the National Central Bank (NCB) of Greece, we assume that the Greek NCB provides credit to private banks at a policy interest rate, issues banknotes held by the non-bank public and interest-bearing reserves held by private banks, participates in the secondary market for government bonds under the PEPP, receives a net redistributive dividend from the ES, and issues *TARGET2* liabilities to other NCBs in the ES as part of its monetary base. This complex policy mix is embedded into our DSGE model, which includes various real and nominal frictions typically used in the New Keynesian literature as well as some Greek-specific characteristics. In our model, interest rate policy can have real effects because of nominal rigidities, credit policy can have real effects because of private banks' borrowing constraints, and balance-sheet or quantitative monetary policies can have real effects because of transaction costs associated with financial intermediation as in e.g. Andrés et al (2004) and Cúrdia and Woodford (2011), while, the issuance of new *TARGET2* liabilities can work as an extra non-market mechanism through which the country borrows from other countries in the ES as argued by Sinn (2014).

Our main results are as follows. The fiscal stimulus of the Greek government and the financial assistance provided by the Recovery Fund and the pandemic-related ECB policies (e.g. PEPP) have helped the Greek economy to avoid the worse. In particular, our baseline simulations imply that, without any policy reaction, the fall in output in 2020 would be 12% relative to 2019 and would stay below its 2019 level for several years. By contrast, with the fiscal reaction and the EU assistance, the fall in 2010 is 8.5% (which is close to 9% in the data) and will rebound soon. Without financial assistance from the Recovery Fund and the ECB, that is, only with the national fiscal stimulus, the fall in output would be 10.5% in 2020 and again the rebound would come later.

Actually, the role of EU institutions is more important than the above numbers seem to imply. This is because one of the benefits that Greece receives from membership in these supra-national institutions is "the import of credibility" and, in particular, the anticipation of markets that these institutions will step in, in one way or another, if something goes wrong in the future. To provide a numerical example of the benefits of imported credibility, we allow for fear of default on public debt and hence for sovereign risk premia; in particular, we assume a 20% ex ante probability of default during 2022-2025 on Greek government bonds which is within the range experienced by Greece during its sovereign debt crisis. The simulated paths of output and public debt-to-GDP under this hypothetical scenario imply that the emergence of risk premia would make the recession much sharper and longer lasting and, at the same time, the debt-to-GDP ratio would skyrocket, even if domestic fiscal policy reacts to public debt imbalances and the fear of default does not materialize ex post. In other words, trust is important and any shock that triggers the loss of trust, and hence the re-emergence of risk premia and high interest rates, will bring the Greek economy in a position similar to that ten years ago. In particular, as is discussed below when we put our work in the context of the literature on international crises (see Lorenzoni (2014) for a review), such a crisis erupts when a country with weak fundamentals (like high public debt) is being hit by an adverse domestic or external adverse shock. The crisis of the previous decade has taught us that, in the case of Greece at least, these "shocks" can include a sudden political polarization that signals poor growth prospects, prolonged negotiations with EU institutions, reports of insolvency by big rating agencies, etc.

Our work differs from the literature mainly because we are aware of no other papers that embed the currently observed in practice nexus between fiscal and quantitative monetary policies in a DSGE model of a eurozone country that receives financial assistance from fiscal (see e.g. Recovery Fund) and monetary (see e.g. PEPP, TARGET2) EU instititutions.[1] Thus, we believe our work is more than a country study. The model used here builds on the models developed by Economides et al (2021a, 2021b). However, Economides et al (2021a), as well as Papageorgiou and Tsiaras (2021), have studied the Greek sovereign debt crisis of the previous decade, while, Economides et al (2021b) have studied the Greek pandemic crisis in a real model without monetary policy. Balfoussia et al (2020) have also examined the Greek economy in the pandemic but their focus is on the financial sector rather than on the fiscal-monetary policy nexus.

The rest of the paper is organized as follows. The model is presented in section 2. Parameterization, data and solution for the year 2019 are in section 3. Section 4 introduces pandemic scenaria. Sections 5, 6 and 7 present solutions. Section 8 closes the paper. An appendix contains algebraic and policy details as well as data.

2 Model

This section constructs a medium-scale micro-founded macroeconomic model for the Greek economy that accommodates the macroeconomic policies observed in practice. We start with an informal description of the model.

2.1 Informal description of the model

To capture the key features of the Greek economy, we add two types of frictions to a standard small open economy model. The first type includes real and nominal frictions commonly used by the quantitative macroeconomic literature (see e.g. Uribe and Schmitt-Grohé (2017)). The second type includes Greek-specific features. The commonly used frictions include various types of adjustment costs, imperfect competition, nominal rigidities, etc. The Greek-specific features include a relatively detailed public sector with public employees as a separate income group, state firms, problems of

[1] By contrast, there are several papers on this nexus in closed economy models for the US; see e.g. Sims and Wu (2020) and Chanda et al (2021).

institutional quality and financial assistance from EU institutions. In what follows, we briefly introduce the building blocks of the model.

Households There are three distinct types of households, called capital owners, workers and public employees. Capital owners own private firms and banks and so receive their profits. They can also keep deposits at domestic and foreign private banks. Private workers work in private firms. Public employees work in state firms. All types of households consume a domestic and a foreign good, provide labor services, hold currency and are engaged in rent-seeking activities (the latter are discussed below). The three types of households are modeled in subsection 2.2.

Private firms The domestic final good is produced by final good firms that act competitively using differentiated intermediate goods. The latter are produced by intermediate goods firms which act monopolistically à la Dixit-Stiglitz and face nominal rigidities à la Rotemberg. Intermediate goods firms choose labor, capital and imported goods and also make use of productivity-enhancing public goods/services. On their financial side, these firms can borrow from domestic and foreign private banks. There are also capital good firms that produce the capital demanded by intermediate goods firms. Any profits generated by private firms are distributed to capital owners. Firms are modeled in subsection 2.3.

Private banks On the asset side, private banks make loans to private firms at home and abroad, hold interest-bearing reserves at the NCB and buy domestic and foreign government bonds. On the side of liabilities, they receive deposits from savers, domestic and foreign, and loans from the NCB. To model the profit-maximizing behavior of private banks, and also account for the possibility that borrowing and lending takes place in equilibrium, we adopt the setup of Cúrdia and Woodford (2011).[2] Within this setup, the difference between the different interest rates (or the so-called asset pricing wedges) emerges as a result of costly financial intermediation. Any profits generated by private banks are distributed to capital owners. Banks are modeled in subsection 2.4.

State firms State firms use public employees, goods purchased from the private sector and public capital (the latter is augmented by public investment spending) to produce a public good that provides utility-enhancing services to households and productivity-enhancing services to firms, where the associated spending inputs as shares of GDP, as well as the fraction of public employees in population, will be set as in the data. State firms are in subsection 2.5.

National central bank (NCB) in the Eurosystem (ES) On the side of assets, the Greek NCB makes loans to private banks and purchases

[2] The model of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) is another popular model in this literature. We do not believe the particular model of the banking sector is important to our results. We use the Cúrdia-Woodford model for its relative simplicity. Walsh (2017, chapter 11) reviews this literature.

Greek government bonds in the secondary market where these bolds have been purchased by domestic and foreign private banks in the primary market. On the liabilities side, the monetary base consists of banknotes, reserves and cross-border TARGET2 liabilities. These are the largest asset and liability items in the data. In other words, the NCB's spending is financed by printing new banknotes held by private agents, by issuing reserves held by private banks and by issuing cross-border TARGET2 liabilities according to the rules of the ES. The NCB also receives a net transfer from the ES, which represents the difference between the monetary income paid by the Greek NCB to the common pool of the ES and the NCB's claim of that common pool. Any profits generated by the NCB are in turn transferred to its government. The NCB is modeled in subsection 2.6.3, while monetary policy details during the pandemic are discussed in subsection 4.2.

Treasury On the revenue side, the Treasury, or the government, taxes households' income and consumption as well as firms' profits, receives a transfer from its NCB and issues bonds. The latter can be purchased by domestic private investors/banks, foreign private investors/banks and EU public institutions (loans by, say, the ESM count as public debt and the same applies to funds from the Recovery Fund in the form of loans). On the expenditure side, the Treasury spends on wages of public employees, government investment, government purchases of goods from the private sector, as well as transfer payments to households. The Treasury is modeled in subsection 2.6.2, while fiscal policy details during the pandemic are discussed in subsection 4.2.

Institutions It is widely recognized that Greece is a country with relatively poor institutional quality.[3] An important aspect of the latter is rent seeking which is broadly defined as the engagement of interest groups with the public sector aiming for extra priviliges at the expense of social welfare. Here, we will assume that rent seeking takes the form of a social conflict over the distribution of a share of government transfers. In particular, we will assume that households devote time and energy to compete with each other for extra government transfers in a Tullock-type redistributive contest. Thus, here weak institutions are a problem of collective action. The rent-seeking technology is specified in subsection 2.2.

Modelling the economic impact of the lockdown Although the health crisis has damaged the real economy in many ways (see e.g. European Commission (2020)), here, similarly to e.g. Eichenbaum et al (2020) and Economides et al (2021b), we assume that the drop of economic activity is triggered by two effects/shocks: (i) an adverse labor supply shock and (ii) an increase in transaction costs associated with consumption. The first channel captures the adverse effect of the pandemic on work hours and employment

[3] See e.g. Angelopoulos et al (2009), Masuch et al (2018), Kollintzas et al (2018) and Christou et al (2021).

in general. The second channel aims at capturing the extra transaction costs that consumers face because of the same measures. In other words, the first channel operates through the supply side, whereas the second shock through the demand side of the economy. These shocks are modeled in subsections 2.2 and 4.1.

Modelling details will be provided as we present each building block of the above described model.[4]

2.2 Households

There are three distinct types of households, called capital owners, workers and public employees. Capital owners are indexed by the subscript $k = 1, 2, ..., N^k$, workers by the subscript $w = 1, 2, ...N^w$, and public employees by the subscript $b = 1, 2, ..., N^b$. That is, the total population is $N = N^k + N^w + N^b$. Equivalently, in terms of population shares, $n^k \equiv \frac{N^k}{N}$, $n^w \equiv \frac{N^w}{N}$ and $n^b \equiv \frac{N^b}{N} = 1 - n^k - n^w$. For simplicity, total population and its decomposition to the three groups is exogenous and kept constant over time; that is, we assume away occupational mobility from one group to another.

2.2.1 Households as capital owners

Capital owners own the firms and banks and so receive their profits. They can also save in the form of deposits at domestic and foreign banks. Besides, like all other types of households, they receive income from work, hold currency and are engaged in a rent-seeking competition for extra fiscal transfers.

Each capital owner, $k = 1, 2, ..., N^k$, maximizes discounted lifetime utility:

$$\sum_{t=0}^{\infty} \beta^t u \left(c_{k,t}, u_{k,t}; \overline{y}_t^g\right) \tag{1}$$

where $c_{k,t}$ and $u_{k,t}$ denote respectively k's consumption and leisure time, $\overline{y}_t^g$ denotes the per capita quantity of public goods/services provided and produced by the government, and $0 < \beta < 1$ is a time discount factor.

[4] Before we proceed, we make a remark about unemployment. By assuming market-clearing in the labor market(s), any fall in output is obviously reflected in a fall in hours of work rather than in unemployed people. This is for simplicity. In earlier versions of the paper, we experimented with an extended version of our model that allows for both less hours of work and less employed people whenever output happens to fall. In particular, we have implemented this by replacing the supply of labor function with a wage rigidity rule as in e.g. Blanchard and Gali (2007), and where any decrease in the demand for labor on the part of firms is divided between a decrease in work hours and a decrease in the number of working people as in Ball and Romer (1990). Since the main results are not affected by this extension, we present the version of the model without unemployed people.

For our numerical solutions, we will use the utility function (taking into account the calibration, our results do not depend on the functional form used) :

$$u\left(c_{k,t},u_{k,t};\overline{y}_t^g\right)=\mu_1\log c_{k,t}+\mu_2\log u_{k,t}+\mu_3\log\overline{y}_t^g$$

where $0<\mu_1,\ \mu_2,\ \mu_3<1$ are preference parameters with $\mu_1+\ \mu_2+\ \mu_3=1$.

Since there are two goods, home and foreign, we define the consumption index:

$$c_{k,t}=\frac{(c_{k,t}^h)^{\nu}(c_{k,t}^f)^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{2}$$

where $c_{k,t}^h$ and $c_{k,t}^f$ denote k's domestic and foreign consumption respectively and $0<\nu<1$ measures the weight given to the domestic relative to the foreign good.

The time constraint of each k in each period is:

$$l_{k,t}+s_{k,t}+u_{k,t}=1 \tag{3a}$$

where $l_{k,t}$ and $s_{k,t}$ are respectively k's effort time allocated to productive work and rent seeking activities.

The within-period budget constraint of each k written in real terms is:

$$(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{k,t}^h+\frac{p_t^f}{p_t}c_{k,t}^f\right)\Phi_t^c+j_{k,t}^h+\frac{e_tp_t^*}{p_t}j_{k,t}^f+\frac{p_t^f}{p_t}\frac{\upsilon}{2}\left(\frac{e_tp_t^*}{p_t}j_{k,t}^f-\overline{j^f}\right)^2+m_{k,t}=$$

$$=(1-\tau_t^y)w_t^k\Phi_t^l l_{k,t}+\pi_{k,t}^i+\pi_{k,t}^p+$$

$$+(1+i_t^d)\frac{p_{t-1}}{p_t}j_{k,t-1}^h+(1+i_t^{d*})\frac{p_{t-1}^*}{p_t^*}\frac{e_tp_t^*}{p_t}j_{k,t-1}^f+\frac{p_{t-1}}{p_t}m_{k,t-1}+$$

$$+\overline{g}_t^{tr}+\left(\frac{\Gamma^k(s_{k,t})^{\gamma}}{N^k\Gamma^k(s_{k,t})^{\gamma}+N^w\Gamma^w(s_{w,t})^{\gamma}+N^b\Gamma^b(s_{b,t})^{\gamma}}\right)(RS*G_t^{tr}) \tag{3b}$$

where p_t^h is the price of the domestic good, p_t^f is the price of the foreign good expressed in domestic currency, p_t is the country's CPI specified below, p_t^* is the CPI abroad, e_t is the nominal exchange rate where an increase means a depreciation, $j_{k,t}^h$ is the real value of k's end-of-period deposits held at domestic banks earning a nominal interest rate i_{t+1}^d in the next period, $j_{k,t}^f$ is the real value of k's end-of-period deposits held at foreign private banks expressed in foreign prices and earning a nominal interest rate i_{t+1}^{d*} in the next period, $\frac{\upsilon}{2}\left(\frac{e_tp_t^*}{p_t}j_{k,t}^f-\overline{j^f}\right)^2$ is a resource cost associated with banking abroad, $m_{k,t}$ is the real value of end-of-period currency carried over by k from t to $t+1$, w_t^k is the real wage rate earned by capital owners, $\pi_{k,t}^i$ is the dividend paid to each k by private firms net of taxes, $\pi_{k,t}^p$ is the dividend paid to each k by private banks net of taxes, and $0\leq\tau_t^c,\ \tau_t^y<1$ are the tax rates on consumption and income. Also, $0 < \Phi_t^l \leq 1$ measures the degree of restrictions imposed by containment measures on work hours and $\Phi_t^c \geq 1$ is a proxy for the extra transaction costs that consumers face because of the same measures (both are similar to those introduced by Eichenbaum et al (2020)); these exogenous stochastic variables are modeled in subsection 4.1 below.

The two terms in the last line of (3b) are government transfers. The first one, $\overline{g}_t^{tr}$, denotes a lump-sum transfer that is common across agents and independent of rent-seeking activities. The second one is an extra transfer extracted by each k from the common pool, where the latter is the total amount of public spending earmarked for transfers, G_t^{tr}. That is, only a fraction, $0 < (1 - RS) \leq 1$, of G_t^{tr} is available to be distributed equally to everybody, while, the rest, $(RS * G_t^{tr})$, is taken away by rent seekers, where the rent extracted by each individual depends on the effort time allocated by him/her to rent-seeking activities relative to total rent-seeking activities.[5] In other words, the term $\left(\frac{\Gamma^k(s_{k,t})^\gamma}{N^k\Gamma^k(s_{k,t})^\gamma + N^w\Gamma^w(s_{w,t})^\gamma + N^b\Gamma^b(s_{b,t})^\gamma}\right)$ is the fraction of the common pool extracted by each k in a Tullock (1980) type rent-seeking competition. Regarding the rent-seeking technology, the power coefficient, γ, is between 0 and 1 and measures how quickly diminishing returns arise in anti-social activities, while the parameter Γ^k measures the efficacy of k's aggression. If Γ^k increases and/or γ decreases, agent k has a stronger incentive to devote effort time to rent seeking.[6]

To give money a role, we use a cash-in-advance constraint like:

$$m_{k,t} \geq (1 + \tau_t^c)\Phi_t^c \left(\frac{p_t^h}{p_t} c_{k,t}^h + \frac{p_t^f}{p_t} c_{k,t}^f\right) \tag{3c}$$

Each k acts competitively choosing $\{c_{k,t}^h,\ c_{k,t}^f,\ c_{k,t},\ l_{k,t},\ s_{k,t},\ j_{k,t}^h, j_{k,t}^f$ $m_{k,t}\}_{t=0}^{\infty}$ subject to the above. The first-order conditions are in Appendix A.1.

2.2.2 Households as workers

Workers are employed by private firms. They consume, work, hold currency and participate in rent-seeking activities.

[5] That is, $G_t^{tr} = N\overline{g}_t^{tr} + (RS * G_t^{tr}) = (1 - RS)G_t^{tr} + (RS * G_t^{tr})$. This is as in e.g. Esteban and Ray (2011), who call RS the degree of "publicness" of the common pool, Angelopoulos et al (2009), Christou et al (2021), etc. In the calibration section below, we use an index of the degree of property rights to quantify RS.

[6] For similar rent seeking technologies, see e.g. Murphy et al (1991), Dixit (2004, chapter 5), Hillman (2009, chapter 2), Angelopoulos et al (2009), Esteban and Ray (2011), Economides et al (2021a, 2021b), Christou et al (2021), etc. Note that our specification, specifically, the different values of Γ^k, Γ^w and Γ^b, allows us to have asymmetries in equilibrium; namely, different types of rent seekers can choose different allocations and receive different wages even if they attack the same pie and share the same preferences.

Each worker, $w = 1, 2, ..., N^w$, maximizes:

$$\sum_{t=0}^{\infty} \beta^t u\left(c_{w,t}, u_{w,t}; \overline{y}_t^g\right) \tag{4}$$

where variables are defined as above in the capital owners' problem if we replace the subscript k with the subscript w.

As above, we use the utility function:

$$u\left(c_{w,t}, u_{w,t}; \overline{y}_t^g\right) = \mu_1 \log c_{w,t} + \mu_2 \log u_{w,t} + \mu_3 \log \overline{y}_t^g$$

and the consumption index:

$$c_{w,t} = \frac{(c_{w,t}^h)^\nu (c_{w,t}^f)^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{5}$$

Also, as above, the maximization is subject to the time constraint:

$$l_{w,t} + s_{w,t} + u_{w,t} = 1 \tag{6a}$$

the budget constraint:

$$\begin{gathered}(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{w,t}^h + \frac{p_t^f}{p_t}c_{w,t}^f\right)\Phi_t^c + m_{w,t} = \\ = (1-\tau_t^y)w_t^w \Phi_t^l l_{w,t} + \frac{p_{t-1}}{p_t}m_{w,t-1} + \\ +\overline{g}_t^{tr} + \left(\frac{\Gamma^w (s_{w,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right)(RS * G_t^{tr})\end{gathered} \tag{6b}$$

and the cash-in-advance constraint:

$$m_{w,t} \geq (1+\tau_t^c)\Phi_t^c \left(\frac{p_t^h}{p_t}c_{w,t}^h + \frac{p_t^f}{p_t}c_{w,t}^f\right) \tag{6c}$$

where w_t^w is the real wage rate of workers.

Each w acts competitively choosing $\{c_{w,t}^h,\ c_{w,t}^f,\ c_{w,t},\ l_{w,t},\ s_{w,t},\ m_{w,t}\}_{t=0}^{\infty}$ subject to the above. The first-order conditions are in Appendix A.2.

2.2.3 Households as public employees

Public employees are employed by state firms. Like workers, they consume, work, hold currency and are engaged in rent-seeking activities. Variables will be defined as above in the workers' problem if we replace the subscript w with the subscript b.

Each public employee, $b = 1, 2, ..., N^b$, maximizes:

$$\sum_{t=0}^{\infty} \beta^t u\left(c_{b,t}, u_{b,t}, ; \overline{y}_t^g\right) \tag{7}$$

As above, the utility function and the consumption index are:

$$u\left(c_{b,t}, u_{b,t}, ; \overline{y}_t^g\right) = \mu_1 \log c_{b,t} + \mu_2 \log u_{b,t} + \mu_3 \log \overline{y}_t^g$$

$$c_{b,t} = \frac{(c_{b,t}^h)^\nu (c_{b,t}^f)^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{8}$$

Also, as above, the maximization is subject to the time constraint:

$$l_{b,t} + s_{b,t} + u_{b,t} = 1 \tag{9a}$$

the budget constraint:

$$(1+\tau_t^c)\left(\frac{p_t^h}{p_t} c_{b,t}^h + \frac{p_t^f}{p_t} c_{b,t}^f\right) \Phi_t^c + m_{b,t} =$$

$$= (1-\tau_t^y) w_t^g \Phi_t^l l_{b,t} + \frac{p_{t-1}}{p_t} m_{b,t-1} +$$

$$+\overline{g}_t^{tr} + \left(\frac{\Gamma^b (s_{b,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right) (RS * G_t^{tr}) \tag{9b}$$

and the cash-in-advance constraint:

$$m_{b,t} \geq (1+\tau_t^c) \Phi_t^c \left(\frac{p_t^h}{p_t} c_{b,t}^h + \frac{p_t^f}{p_t} c_{b,t}^f\right) \tag{9c}$$

where w_t^g is the real wage in the public sector while the rest of the variables are defined as in the worker's problem.

Each b acts competitively choosing $\{c_{b,t}^h, c_{b,t}^f, c_{b,t}, l_{b,t}, s_{b,t}, m_{b,t}\}_{t=0}^{\infty}$ subject to the above.[7] The first-order conditions are in Appendix A.3.

2.3 Private firms and production of private goods

Private firms are owned by capital owners. Following most of the related New Keynesian literature, there are three types of goods produced by three associated types of firms. There is a single domestic final good produced by competitive final good firms. There are also differentiated intermediate goods used as inputs for the production of the final good. Each differentiated intermediate good is produced by an intermediate goods firm that acts as a monopolist in its own product market à la Dixit-Stiglitz facing Rotemberg-type nominal fixities. Finally, competitive capital good firms produce capital used as an input in the production of intermediate goods.

[7] The choice of $l_{b,t}$ can be thought as a choice of work effort. Allowing for a fixed shift, or hours of work, in the public sector would not change our results to the extent that public employees can still choose the effort they make while at work.

2.3.1 Final good firms

There are N^h final good firms indexed by subscript $h = 1, 2, ..., N^h$. For notational simplicity, we will set $N^h = N^k$, that is, the number of final good firms equals the number of their owners. Each final good firm produces an amount $y_{h,t}^h$ by using intermediate goods according to the standard Dixit-Stiglitz technology:

$$y_{h,t}^h = \left[\sum_{i=1}^{N^i} \frac{1}{N^i} (y_{i,t}^h)^\theta \right]^{\frac{1}{\theta}} \tag{10}$$

where $y_{i,t}^h$ denotes the quantity of intermediate good of variety $i = 1, 2, ..., N_t^i$ used by each final good firm h and $0 \leq \theta \leq 1$ is a parameter where $1/(1-\theta)$ measures the degree of substitutability between intermediate goods.

Each final-good producer h chooses inputs $y_{i,t}^h$ to maximize real profits:

$$\pi_{h,t} = y_{h,t}^h - \sum_{i=1}^{N^i} \frac{1}{N^i} \frac{p_{i,t}^h}{p_t^h} y_{i,t}^h \tag{11}$$

where p_t^h is the price of the final good and $p_{i,t}^h$ is the price of intermediate good i.

The firm maximizes its profit acting competitively subject to the above. The familiar in the Dixit-Stiglitz literature first-order condition for inputs is in Appendix A.4.

2.3.2 Intermediate goods firms

There are N^i intermediate goods firms indexed by the subscript $i = 1, 2, ..., N^i$. Since they are owned and managed by capital owners, we again set $N^i = N^k$ for notational simplicity. These firms make investment and other factor decisions facing capital adjustment costs and Rotemberg-type price adjustment costs. New investment is financed by retained earnings and loans from private banks.[8]

Each firm's net real dividend, $\pi_{i,t}$, distributed to its owners, is (see Appendix A.5):

$$\pi_{i,t} = (1 - \tau_t^\pi) \left[\frac{p_{i,t}^h}{p_t} y_{i,t}^h - w_t^w l_{i,t}^w - w_t^k l_{i,t}^k - \frac{p_t^f}{p_t} m_{i,t}^f \right] -$$

[8]For simplicity, we assume that firms do not issue shares but simply distribute net profits to their owners (the capital owners). Allowing for issuance of shares leaves our results unchanged to the extent that we impose that the number of shares is constant (say at one) before solving the firm's optimization problem (this is as in e.g. McGrattan and Prescott (2005), Miao (2014, chapter 14) and Uribe and Schmitt-Grohé (2017, chapter 4)). For richer problems of the firm with non-trivial corporate finance decisions and the Modigliani-Miller neutrality result, see e.g. Turnovsky (1995, chapters 10 and 11), Altug and Labadie (1994, chapter 4), Auerbach (2002) and Gourio and Miao (2010, 2011).

$$-\frac{p_t^h}{p_t}x_{i,t}-\frac{p_t^h}{p_t}\frac{\xi^k}{2}\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)^2 k_{i,t-1}-\frac{p_t^h}{p_t}\frac{\xi^p}{2}\left(\frac{p_{i,t}^h}{p_{i,t-1}^h}-1\right)^2\overline{y}_{i,t}^h+$$

$$+\left(L_{i,t}^h-(1+i_t^l)\frac{p_{t-1}}{p_t}L_{i,t-1}^h\right)+\frac{e_t p_t^*}{p_t}\left(L_{i,t}^f-(1+i_t^{l*})\frac{p_{t-1}^*}{p_t^*}L_{i,t-1}^f\right) \quad (12)$$

where $l_{i,t}^w$ is labor services provided by workers and used by firm i, $l_{i,t}^k$ is labor services provided by capital owners and used by i, $m_{i,t}^f$ is imported goods used by each i, $x_{i,t}$ is i's investment in capital goods and $k_{i,t}$ is i's stock of capital goods used in production in the next period (as we shall see below, the relative price of capital is 1), $L_{i,t-1}^h$ and $L_{i,t-1}^f$ are the real values of beginning-of-period loans received from domestic and foreign private banks respectively on which the firm pays a nominal interest rate, i_t^l, and i_t^{l*}, respectively in the current period, $0 \leq \tau_t^\pi < 1$ a profit tax rate, ξ^k is a parameter measuring standard capital adjustment costs and ξ^p is a parameter measuring Rotemberg-type price adjustment costs.[9]

The law of motion of the firm's capital stock is:

$$k_{i,t}=x_{i,t}+(1-\delta)\,k_{i,t-1} \quad (13)$$

where the parameter $0 \leq \delta \leq 1$ is the capital depreciation rate.

For the firm's production function, we adopt the form:

$$y_{i,t}^h=A^p\left(\frac{N^g y_{g,t}^g}{N^i}\right)^\sigma\left[\left(\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m_{i,t}^f)^{op}\right)^{\frac{\alpha}{op}}\left(A^w l_{i,t}^w+A^k l_{i,t}^k\right)^{1-\alpha}\right]^{1-\sigma} \quad (14)$$

where the parameter $0 \leq \chi^p \leq 1$ measures the intensity of capital, $k_{i,t-1}$, relative to goods imported from abroad, $m_{i,t}^f$, the parameter $op \geqslant 0$ is a measure of the degree of substitutability between capital and imported goods, the coefficient $1-a$ is the share of labor inputs, the parameters A^w and A^k measure the relative productivity of workers and capital owners respectively, $A^p > 0$ is TFP in the private sector and $0 \leq \sigma \leq 1$ is the contribution of public goods/services per firm to private production.

Firms are subject to a working capital constraint.[10] Following e.g. Walsh (2017, p. 208) and Uribe and Schmitt-Grohé (2017), we assume that firms have to finance a fraction of payments to labor with loans from domestic and foreign private banks:

$$L_{i,t}^h+\frac{e_t p_t^*}{p_t}L_{i,t}^f \geq \eta(w_t^w l_{i,t}^w+w_t^k l_{i,t}^k) \quad (15)$$

[9]Rotemberg-type costs associated with price changes are assumed to be proportional to average output, $\overline{y}_{i,t}^h$, which is taken as given by each i. This is not important but helps the smooth dynamics of the model.

[10]We could assume different types of constraints as in e.g. Gertler and Karadi (2011) and Sims and Wu (2020).

where the parameter $\eta \geq 0$ measures the tightness of borrowing conditions.

Each firm i maximizes the discounted sum of dividends distributed to its owners:

$$\sum_{t=0}^{\infty} \beta_{i,t} \pi_{i,t} \tag{16}$$

where, since firms are owned by capital owners, we will ex post postulate that the firm's discount factor, $\beta_{i,t}$, equals the capital owners' marginal rate of substitution between consumption at t and $t+1$.[11]

Each firm i chooses $\{l_{i,t}^{w},\ l_{i,t}^{k},\ m_{i,t}^{f},\ k_{i,t},\ L_{i,t}^{h},\ L_{i,t}^{f}\}_{t=0}^{\infty}$ to maximize its stream of dividends or net profits, as defined in (12) and (16), subject to the law of motion of capital (13), the production function in (14), the borrowing constraint in (15) and the inverse demand function for its product coming from the final good firm's problem. Details and the firm's first-order conditions are in Appendix A.5.

2.3.3 Capital good firms

There are N^c capital good firms indexed by the subscript $c = 1, 2, ..., N^c$. Since they are owned by capital owners, we again set $N^c = N^k$ for notational simplicity. We assume that capital good producers acquire the depreciated capital stock, choose investment activity and sell the latter to intermediate goods firms. Here, this problem is modeled in the simplest possible way by assuming away adjustment costs, so that, in each period, each firm c maximizes its profit given by:[12]

$$\pi_{c,t} = Q_t x_{c,t} - x_{c,t} \tag{17}$$

where $x_{c,t}$ is the amount of investment produced and Q_t is the relative price of capital also known as Tobin's q. Here, without capital adjustment costs, the first-order condition is simply $Q_t = 1$ as assumed above. Also, the profit is zero in equilibrium.

2.4 Private banks

There are N^p private banks indexed by the subscript $p = 1, 2, ..., N^p$. Since they are owned and managed by capital owners, we again set $N^p = N^k$ for notational simplicity. In addition to their standard role, which is the provision of intermediation between lenders and borrowers by converting bank deposits into loans to firms, we also allow private banks to hold interest-bearing reserves at the NCB and to purchase domestic and foreign government bonds. In other words, on the assets side, we have loans to private firms, reserves held at the NCB and domestic and foreign government

[11] See e.g. Uribe and Schmitt-Grohé (2017, pp. 110-111).

[12] See also Miao (2014, chapter 14), Güntner (2015), Uribe and Schmitt-Grohé (2017, chapter 4) and many others.

bonds, while on the liabilities side, we have deposits from domestic and foreign households and loans from the NCB. Any profits made by banks are distributed to capital owners.

As it is the case in reality, we assume that there is a secondary market for government bonds. In particular, we assume that, in the beginning of the current period t, the private bank can keep a fraction, $0 \leq \Lambda_t \leq 1$, of the domestic government bonds purchased at $t-1$, $b_{p,t-1}$, and sell the rest, $0 \leq 1-\Lambda_t \leq 1$, to its NCB at a price Φ_t. That is, when it does the latter, the private bank receives the amount $\Phi_t(1-\Lambda_t)\frac{p_{t-1}}{p_t}b_{p,t-1}$ from the NCB and this is credited in its reserves account held at the NCB. The general idea behind such transactions is that they reduce possible risks and costs associated with holding bonds issued by a highly indebted government and also provide extra liquidity to private banks (see also below).[13]

Each bank's net real dividend, $\pi_{p,t}$, distributed to its owners, is (see Appendix A.6):

$$\pi_{p,t} = (1-\tau_t^{\pi})\,[(1+i_t^l)\frac{p_{t-1}}{p_t}L_{p,t-1}+(1+i_t^{b*})\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{p,t-1}+(1+i_t^r)\frac{p_{t-1}}{p_t}m_{p,t-1}+$$

$$+(1+i_t^b)\frac{p_{t-1}}{p_t}\Lambda_t b_{p,t-1}+\Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)b_{p,t-1}-$$

$$-(1+i_t^d)\frac{p_{t-1}}{p_t}j_{p,t-1}-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}-\frac{p_t^h}{p_t}\Xi(\cdot)]-$$

$$-L_{p,t}-b_{p,t}-\frac{e_t p_t^*}{p_t}f_{p,t}-m_{p,t}+j_{p,t}+z_{p,t} \tag{18}$$

where $L_{p,t}$ are loans given to domestic and foreign firms (namely, $L_{p,t} = L_{i,t}^h + L_{i,t}^{f*}$, where $L_{i,t}^{f*}$ is loans demanded by foreign firms from domestic banks expressed in domestic prices) on which the bank receives a nominal interest rate i_{t+1}^l one period later, $f_{p,t}$ is the real value of one-period foreign government bonds denominated in foreign prices and acquired by each p at t on which the bank receives a nominal interest rate i_{t+1}^{b*} at $t+1$,[14] $m_{p,t}$ is the real value of interest-bearing reserves held at the NCB on which the bank earns a nominal interest rate i_{t+1}^r at $t+1$, $b_{p,t}$ is the real value of one-period domestic government bonds purchased by the bank at t and earning

[13]Strictly speaking, these costs and risks apply more to long-term bonds as studied Andrés et al (2004) and in more detail by Chen et al (2012). Long-term bonds also allow the real return to them to depend on the change in their market price, in the sense that the real return to inherited long-term bonds increases not only with the interest rate but also with the increase in their market price. However, to keep the model relatively simple, we work with one-period maturity bonds only.

[14]This is denominated in foreign currency. That is, if $F_{p,t}$ is the nominal value for each agent k, the real value is $f_{p,t} \equiv \frac{F_{p,t}}{p_t^*}$.

a nominal interest rate i^b_{t+1} at $t+1$ if the bank keeps them or Φ_t if the bank sells them to its NCB in the secondary market, $j_{p,t}$ is deposits obtained by domestic and foreign households (namely, $j_{p,t} = j^h_{k,t} + j^{f*}_{k,t}$, where $j^{f*}_{k,t}$ is deposits of foreign households at domestic banks expressed in domestic prices) on which the bank pays a nominal interest rate i^d_{t+1} one period later, $z_{p,t}$ is loans from the NCB to the private bank on which the latter pays a nominal policy interest rate i^z_{t+1} one period later and $\Xi(\cdot)$ captures real operational costs faced by banks. Also, τ^π_t is the profit tax rate as already defined above.

Real operational costs, $\Xi(\cdot)$, are assumed to be increasing in the volumes of government bonds, loans given to firms and loans taken from the NCB, while they are decreasing in the volume of reserves held at the NCB.[15] That is, $\Xi(\cdot) = \Xi(L_{p,t-1}, b_{p,t-1}, \frac{e_t p^*_t}{p_t} f_{p,t-1}, m_{p,t-1}, z_{p,t-1})$. In our numerical solutions, we will use the functional form:

$$\Xi(\cdot) = \frac{\xi^l}{2}(L_{p,t-1})^2 + \frac{\xi^b}{2}(\Lambda_t b_{p,t-1})^2 + \frac{\xi^f}{2}(\frac{e_t p^*_t}{p_t} f_{p,t-1})^2 +$$

$$+\frac{\xi^m}{2}(m_{p,t-1} + \Phi_t(1-\Lambda_t)b_{p,t-1})^{-2} + \frac{\xi^z}{2}(z_{p,t-1})^2$$

which produces well-defined demand and supply functions for different assets and liabilities. Notice above that the bank's costs are affected by credit operations in the secondary market, in the sense that, when the NCB purchases bonds in the secondary market, private banks' bonds are reduced and, at the same time, their reserves increase by the same amount. Also note, as is discussed in more detail below in subsection 2.6.1, that such transaction costs produce asset pricing wedges which in turn allow quantitative monetary policies to have real effects. This is on top of the real effects that monetary policy can have through nominal fixities like Rotemberg type in our model.

Each private bank p maximizes the discounted sum of dividends distributed to its owners:

$$\sum_{t=0}^{\infty} \beta_{p,t}\pi_{p,t} \tag{19}$$

where, since banks are owned by capital owners, we will ex post postulate that the firm's discount factor, $\beta_{p,t}$, equals the capital owners' marginal rate of substitution between consumption at t and $t+1$.

Each bank p chooses $\{L_{p,t}, b_{p,t}, f_{p,t}, m_{p,t}, z_{p,t}\}^{\infty}_{t=0}$ to maximize its stream of dividends, as defined in (18) and (19). The bank's problem is solved as in e.g. Cúrdia and Woodford (2011) and Corsetti et al (2013). Details and first-order conditions are in Appendix A.6.

[15] This is similar to e.g. Cúrdia and Woodford (2011), where banks intermediate between borrowers and lenders and the associated intermediation cost falls with bank reserves held at the central bank.

2.5 State firms and production of public goods/services

We now model the way in which state enterprises produce the publicly provided good/service. There are N^g state firms indexed by the subscript $g = 1, 2, ..., N^g$ producing a single public good/service. For notational simplicity, we will set $N^g = N^b$, that is, the number of state firms equals the number of public employees.

The cost of each state firm g for producing the public good is in real terms:

$$w_t^g l_{g,t} + \frac{p_t^h}{p_t}(g_{g,t}^g + g_{g,t}^i) + \frac{p_t^f}{p_t} m_{g,t}^g \tag{20}$$

where $l_{g,t}$ is labor services used by each state firm g, $g_{g,t}^g$ is goods purchased from the private sector by each g, $g_{g,t}^i$ is investment made by each g, and $m_{g,t}^g$ is imported goods used by each g.

The production function of each state firm g is assumed to be similar to that in the private sector:

$$y_{g,t}^g = A^g \left(\chi^g (k_{g,t-1}^g)^{og} + (1-\chi^g)(m_{g,t}^g)^{og}\right)^{\frac{\theta_1}{og}} (l_{g,t})^{\theta_2} \left(g_{g,t}^g\right)^{1-\theta_1-\theta_2} \tag{21}$$

where $0 \leq \chi^g \leq 1$ measures the intensity of public capital, $k_{g,t-1}^g$, relative to goods imported from abroad, $m_{g,t}^g$, the parameter $og \geqslant 0$ is a measure of the degree of substitutability between public capital and imported goods, the coefficients $0 < \theta_1$, θ_2, $1 - \theta_1 - \theta_2 < 1$ measure the shares of the associated factors in production and $A^g > 0$ is TFP in the public sector.

The stock of each state firm's capital evolves over time as:

$$k_{g,t}^g = (1 - \delta^g) k_{g,t-1}^g + g_{g,t}^i \tag{22}$$

where $0 < \delta^g < 1$ is the depreciation rate of public capital.

To specify the level of output produced by each state firm, $y_{g,t}^g$, and hence the total amount of public goods/services provided to the society, we obviously have to specify the amounts of inputs, $l_{g,t}$, $g_{g,t}^g$, $m_{g,t}^g$ and $k_{g,t}^g$ (or equivalently $g_{g,t}^i$). Except from work hours or effort which is determined by public employees (see their problem above), we will consider the case in which the values of these inputs are as implied by the data, meaning that the total number of public employees as a share of population, as well as the associated government expenditures (on public investment, public wages, goods purchased from the private sector and imported goods), as shares of GDP, are set as in the data. Specifically, we define $g_{g,t}^i = \frac{s_t^i n^k y_{i,t}^h}{n^b}$, $g_{g,t}^g = \frac{s_t^g n^k y_{i,t}^h}{n^b}$, $m_{g,t}^g = \frac{p_t^h}{p_t^f} \frac{s_t^m n^k y_{i,t}^h}{n^b}$ and $w_t^g = \frac{s_t^w \frac{p_t^h}{p_t} n^k y_{i,t}^h}{n^b l_{b,t}}$, where $n^b \equiv \frac{N^b}{N}$ is the fraction of public employees in population and s_t^i, s_t^g, s_t^m and s_t^w are respectively the GDP shares of government expenditures on investment, goods purchased from the private sector, imported goods and public wages; these values will be set according to the data (see section 3).

2.6 Fiscal and monetary policy

This section models separately the Treasury and the Greek National Central Bank participating in the Eurosystem (ES). This can help us to understand the menu of fiscal and monetary policy instruments available to policymakers and how these instruments interact with each other. Before we proceed formally, in the first subsection, we put our work in the context of the literature on the nexus between fiscal, public financing and quantitative monetary policies.

2.6.1 Quantitative monetary policies and what differs in the ES

As is well known, the massive expansion in central bank balance sheets since the onset of the 2007-8 global financial crisis has forced a re-examination of Wallace's (1981) neutrality property according to which the central bank's balance sheet, or quantitative, policies (which have to do with the total size of the central bank's balance sheet and the mix of assets and liabilities that the central bank holds) do not have any real effects. However, as a response to these massive quantitative policies, the literature has added various financial frictions to the benchmark framework that result in asset pricing wedges and thereby departures from Wallace's property. Examples of such frictions, through which quantitative monetary policies affect the real economy, include transaction costs associated the relative supplies of different assets, borrowing constraints, market segmentation, limited market participation, moral hazard, etc (see e.g. Andrés et al (2004), Gertler and Kiyotaki (2010), Gertler and Karadi (2011), Cúrdia and Woodford (2011), Benigno and Nisticò (2017), Bassetto and Sargent (2020), Sims and Wu (2000), while see e.g. Walsh (2017, chapter 11) for a rich review). Once we allow for such frictions, quantitative monetary policies can have fiscal and real implications. In our model, as said above, this role is played by the transaction cost function $\Xi(\cdot)$ in the private bank's problem.

On top of this, as e.g. Sinn and Wollmershauser (2012), Sinn (2014, 2020) and Reis (2017) have pointed out, in a currency union like the ES,[16] there can be extra, direct routes through which quantitative monetary policies can alleviate fiscal burdens and relax national constraints, even in the absence of financial frictions like the above. Specifically, Reis (2017, section 10) has argued that several of the ECB's policies (like the SMP, the provision of

[16] For the policy of the ECB, especially since the global financial crisis of 2008, see e.g. Whelan (2012), Wyplosz (2012), Sibert (2012), Merler et al (2012), Sinn (2014), de Grauwe (2016), Hartmann and Smets (2018), Brunnermeir and Reis (2019), Rostagno et al (2019, 2021), Coenen et al (2020), Havlik and Heinemann (2020), Fabiani et al (2021) and Lane (2021). For the effects of ECB's policies on asset prices and/or the macro economy in particular, see e.g. Gibson et al (2016, 2019), Gambetti and Musso (2017), Quint and Tristani (2017), Larkin et al (2017), Moessner (2018), Rostagno et al (2019, 2021), Coenen et al (2020) and many others.

ELA and the way ECB's dividends are re-allocated to member-countries of the EZ) can belong to this category allowing for redistribution of real resources among governments and nations within the ES. A parallel, and hotly debated, literature (starting with Sinn and Wollmershauser (2012)) has argued that the issuance of new *TARGET2* balances can also work in a redistributive way (*TARGET2* balances, which are particularly large in the case of the Greek NCB are discussed below). But one needs a formal criterion to judge whether a quantitative, or balance-sheet, monetary policy of the ES can play a direct allocative role: it can, if, once market-clearing conditions, etc, have been taken into account, this policy instrument remains as an item in the economy's resource constraint, namely, in its balance of payments. According to this criterion, one can show that policies, like redistributed dividends from the ES to the NCB beyond those contributed by the NCB to the ES, bond purchases by the ES beyond those purchased by the NCB and at a price above the market-price, or the issuance of new TARGET2 liabilities to the ES can, at least in principle, not only alleviate national fiscal burdens but also (since they appear in the country's balance of payments) increase national resources. This will be formalized below when we present the balance of payments.

2.6.2 The Treasury (fiscal authorities)

The Treasury, or the fiscal branch of government, uses revenues from various taxes, the issuance of new bonds and a direct receipt/dividend from the NCB to finance its various spending activities. This is standard; we will only differ in who can hold Greek public debt so as to allow for the official bail outs during the sovereign debt crisis and the loans from the EU's Recovery Fund during the pandemic crisis.

Holders of public debt Let us define the real and per capita public debt at the end of period t as d_t. We assume that it can be held by three different types of creditors: domestic private agents/banks, foreign private agents/banks, and EU public institutions. The latter refers to loans from the ESM and other euro states during the sovereign debt crisis and loans from the Recovery Fund during the pandemic. Notice that, in the end of 2019, namely, just before the eruption of the pandemic crisis, as a result of the three official bailouts in 2010, 2012 and 2015, around 70% of Greek public debt was owned by EU public institutions (see Appendix B.1 for the holders of Greek public debt over time). Also recall that central banks in the ES can buy government bonds in the secondary market only (see next subsection).

Therefore, d_t is decomposed to the three above holders:

$$d_t \equiv b_t^d + \frac{e_t p_t^*}{p_t} f_t^g + \frac{e_t p_t^*}{p_t} f_t^{eu} \tag{23a}$$

where, expressing them as fractions of total debt, we define:[17]

$$b_t^d \equiv \lambda_t^d d_t \tag{23b}$$

$$\frac{e_t p_t^*}{p_t} f_t^g \equiv \lambda_t^g d_t \tag{23c}$$

$$\frac{e_t p_t^*}{p_t} f_t^{eu} \equiv \lambda_t^{eu} d_t \tag{23d}$$

where $0 \leq \lambda_t^d,\ \lambda_t^g,\ \lambda_t^{eu} \leq 1$ are the fractions of Greek public debt held respectively by domestic private agents, foreign private agents and the EU, where $\lambda_t^d + \lambda_t^g + \lambda_t^{eu} = 1$. If the policy and rest-of-the-world variables, λ_t^g and λ_t^{eu}, are exogenously given (they will be set as in the data), then residually $\lambda_t^d = (1 - \lambda_t^g - \lambda_t^{eu})$.[18]

Budget constraint of the Treasury Using this notation, the flow budget constraint of the government written in per capita and real terms is:

$$g_t^{tr} + n^b \left[w_t^g l_{g,t}^g + \frac{p_t^h}{p_t} \left(g_{g,t}^g + g_{g,t}^i \right) + \frac{p_t^f}{p_t} m_{g,t}^g \right] +$$

$$+ (1 + i_t^b) \frac{p_{t-1}}{p_t} \lambda_{t-1}^d d_{t-1} + (1 + i_t^b) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^g d_{t-1} +$$

$$+ (1 + i^*) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^{eu} d_{t-1} \equiv d_t + \frac{T_t}{N} + rcb_t^g \tag{24}$$

where g_t^{tr} is transfers (both lump-sum and extracted via rent seeking as explained above), $n^b[w_t^g l_{g,t}^g + \frac{p_t^h}{p_t}(g_{g,t}^g + g_{g,t}^i) + \frac{p_t^f}{p_t} m_{g,t}^g]$ is the cost of the inputs used by state firms, $\frac{T_t}{N}$ is tax revenues (defined right below) and rcb_t^g is a direct transfer from the NCB to the Treasury. The rest of the terms capture interest payments on public debt where notice that the interest rates can vary depending on the identity of the creditor. For instance, we assume that when the government borrows from the (domestic and foreign) market, is pays the market interest rate, i_t^b, while, when the government borrows from the EU or the ES, it pays an exogenous and constant rate, i^*.

Total tax revenues in real and per capita terms are:

$$\frac{T_t}{N} \equiv \tau_t^c [n^k \Phi_t^c (\frac{p_t^h}{p_t} c_{k,t}^h + \frac{p_t^f}{p_t} c_{k,t}^f) + n^w \Phi_t^c (\frac{p_t^h}{p_t} c_{w,t}^h + \frac{p_t^f}{p_t} c_{w,t}^f) +$$

[17] That is, if F_t^g denotes the nominal value of total public foreign debt expressed in foreign currency, $f_t^g \equiv \frac{F_t^g}{p_t^* N}$ is its per capita and real value

[18] We have also experimented with the case in which the bonds bought by the EU have more than one period maturity so as to capture the longer maturity of these loans in reality. We report that adding multi-period safe loans by the EU (and the associated interest rates) does not change our main results. Perhaps this is because optimizing private agents are rational and forward-looking.

$$+n^b\Phi_t^c(\frac{p_t^h}{p_t}c_{b,t}^h+\frac{p_t^f}{p_t}c_{b,t}^f)]+\tau_t^y[n^kw_t^k\Phi_t^l l_{k,t}+n^ww_t^w\Phi_t^l l_{w,t}+n^bw_t^g\Phi_t^l l_{b,t}]+$$

$$+\tau_t^\pi n^k[\frac{p_t^h}{p_t}y_{i,t}^h-w_t^w l_{i,t}^w-w_t^k l_{i,t}^w-\frac{p_t^f}{p_t}m_{i,t}^f]+$$

$$+\tau_t^\pi n^k[(1+i_t^l)\frac{p_{t-1}}{p_t}L_{p,t-1}+(1+i_t^{b*})\frac{p_{t-1}^*}{p_t^*}\frac{e_tp_t^*}{p_t}f_{p,t-1}+(1+i_t^r)\frac{p_{t-1}}{p_t}m_{p,t-1}+$$

$$+(1+i_t^b)\frac{p_{t-1}}{p_t}\Lambda_t b_{p,t-1}+\Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)b_{p,t-1}-$$

$$-(1+i_t^d)\frac{p_{t-1}}{p_t}j_{p,t-1}-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}-\frac{p_t^h}{p_t}\Xi(\cdot)] \qquad (25)$$

One of the policy variables must follow residually to close the Treasury's budget constraint in (24). In our solutions below, since they capture the period 2019 and after, this role will be played by the end-of-period total public debt, d_t, while the spending-tax policy instruments will be set as in the data.[19]

2.6.3 The Greek National Central Bank in the Eurosystem

On the side of assets of the Greek NCB, we include loans to private banks and government bonds purchased in the secondary market. In particular, we allow the Greek NCB to purchase Greek governments bonds in the secondary market where these bonds are in the hands of both domestic and foreign private investors/banks (this applies only to the period after 2019 and in particular to the PEPP because Greek government bonds have been excluded from the PSPP which has been the biggest part of the large-scale APP of the ES that started in 2015).[20] On the side of liabilities, we include banknotes, reserves and *TARGET2* liabilities to the ES.[21] These have been

[19]By contrast, between 2010 and 2018, there was no market for Greek government bonds. All borrowing was from EU public institutions.

[20]For simplicity, we assume away purchases of other securities (domestic and foreign) by the Greek NCB. Also we assume away purchases of Greek government bonds by other NCBs in the ES or the ECB itself in the secondary market. This is for simplicity but also because, according to the rules of the ES, the ECB cannot hold more than 10% of sovereign bonds of each member-country.

[21]As first pointed out by Sinn and Wollmershauser (2012) and Sinn (2014), and also studied by Whelan (2014, 2017), Perotti (2020) and many others, TARGET2 balances are net bilateral positions vis-a-vis the ES, which means that the NCB of a member country transferring money abroad records a *TARGET2* liability to the rest of the ES, while the NCB of a member country receiving money from abroad records a *TARGET2* asset. These *TARGET2* balances cancel each other out at aggregate ES level (this is by construction) and therefore do not appear in the consolidated balance sheet of the ES. However, they do appear in the balance sheets of individual NCBs and the ECB, in the sense that they

the largest (asset and liability) items in the financial statements of the Greek NCB at least since 2008 (see Appendix B.2).

Budget constraint of the NCB The budget constraint of the NCB linking changes in assets and liabilities is in real and per capita terms:

$$\Phi_t(1-\Lambda_t)\frac{p_{t-1}}{p_t}\lambda^d_{t-1}d_{t-1}+\Phi_t(1-\Lambda_t)\frac{p^*_{t-1}}{p^*_t}\frac{e_tp^*_t}{p_t}\frac{p_{t-1}}{e_{t-1}p^*_{t-1}}\lambda^g_{t-1}d_{t-1}+$$

$$+n^kz_{p,t}+n^k(1+i^r_t)\frac{p_{t-1}}{p_t}m_{p,t-1}+rcb^g_t\equiv$$

$$\equiv(1-\Lambda_t)(1+i^b_t)\frac{p_{t-1}}{p_t}\lambda^d_{t-1}d_{t-1}+(1-\Lambda_t)(1+i^b_t)\frac{p^*_{t-1}}{p^*_t}\frac{e_tp^*_t}{p_t}\frac{p_{t-1}}{e_{t-1}p^*_{t-1}}\lambda^g_{t-1}d_{t-1}+$$

$$+n^k(1+i^z_t)\frac{p_{t-1}}{p_t}z_{p,t-1}+n^km_{p,t}+\left(m_{n,t}-\frac{p_{t-1}}{p_t}m_{n,t-1}\right)+$$

$$+\left(TARG_t-\left(1+i^{MRO}_t\right)\frac{p_{t-1}}{p_t}TARG_{t-1}\right)+pmi_t \tag{26}$$

where $n^kz_{p,t}$ is the end-of period loans to private banks, $n^km_{p,t}$ is the end-of period interest-bearing reserves held by private banks at the NCB, $m_{n,t}$ denotes the end-of-period stock of banknotes in circulation held by the non-bank public,[22] $(1-\Lambda_t)\lambda^d_{t-1}d_{t-1}$ and $(1-\Lambda_t)\lambda^g_{t-1}d_{t-1}$ are sovereign bonds having been purchased by domestic and foreign private banks respectively in the primary market in the past and repurchased in the current period by the NCB in the secondary market at a price Φ_t on which the NCB earns the market interest rate i^b_t,[23] rcb^g_t is the direct transfer/dividend from the NCB to its own government (as said above, this is the NCB's balance-sheet earnings rebated to the Treasury), $TARG_t$ is the end-of-period stock of *TARGET2* liabilities to the ES on which the NCB pays the main refinancing operations' interest rate, i^{MRO}_{t+1}, in the next period, and pmi_t is the net

enter as an extra item of liabilities for a country with Intra-Eurosystem liabilities like Greece (see e.g. Whelan, 2014, Table 2) or as an extra item of assets for a country with Intra-Eurosystem claims like Germany (see e.g. Whelan, 2014, Table 3). Focusing on the Greek economy, since 2008, *TARGET2* liabilities have become a big part of the monetary base created by its NCB in accordance with the rules of the ES (see Appendix B.2 for data).

[22] That is, $m_{n,t}=n^km_{k,t}+n^wm_{w,t}+n^bm_{b,t}$ *at* each t.

[23] For simplicity but also for lack of data, we assume the same fraction, $1-\Lambda_t$, of government bonds purchased by the NCB from domestic and foreign private banks. See also below.

transfer from pooling monetary income (i.e. the dividend received by the ES minus the dividend paid to the ES).[24]

Notice that, in our model, $m_{n,t}+n^k m_{p,t}+TARG_t \equiv MB_t$ is the monetary base of the Greek NCB within the ES. To put the same thing differently, *TARGET2* liabilities to the ES are the difference between the monetary base and the amount of money held by the non-bank public and private banks. Quoting Sinn (2014, p. 180), *TARGET2* balances "reflect the amount of central bank credit that has been issued in excess of the liquidity needs for transcations within the NCB's national jurisdictions". The way in which these cross-country liabilities are used will become clear below when we present the country's balance of payments.

One of the policy variables must follow residually to close the NCB's budget constraint in (26). In our solutions below, this role will be played by the transfer to the Greek Treasury, rcb_t^g. Appendix A.7 presents the budget constraint of the consolidated public sector (Treasury and the NCB seen as a single policy entity).

2.7 Balance of payments

To make the direct allocative role of EU institutions more transparent, we present the country's balance of payments. If we add up the budget constraints of all agents above, we get the balance of payments (written in real and per capita terms):

$$\frac{p_t^f}{p_t}\left(n^k \Phi_t^c c_{k,t}^f + n^w \Phi_t^c c_{w,t}^f + n^b \Phi_t^c c_{b,t}^f + n^k m_{i,t}^f + n^b m_{g,t}^g\right) - \frac{p_t^h}{p_t} c_t^{f*} +$$

[24] In other words, trying to mimic the complexity of reality, the monetary policy instruments are: (i) loans to private banks or the associated nominal interest rate; (ii) reserves held by private banks at the NCB or the associated nominal interest rate; (iii) non-interest bearing currency held by the non-bank public for transaction purposes; (iv) the amount of bonds purchased in the secondary by the NCB or their price; (v) the transfer to the Treasury; (vi) the nominal exchange rate; (vii) TARGET2 balances and the associated nominal interest rate and (viii) the net transfer to the ES. In a small open economy participating in the ES, (vi)-(viii) are taken as given and will be set as in the data. Regarding (i)-(ii), we will assume that the central bank sets the interest rates (as in the data) and banks decide the quantities of loans and reserves. Regarding (iii), the central bank will accommodate the demand side. Regarding (iv), we simply asssume that the NCB sets the price of governmnet bonds purchased in the secondary market and we also set the respective amount as in the data. Note that, strictly speaking, as in any market, the NCB can set either the price or the quantity of bond repurchases. We could allow the private bank to choose the quantity of bonds sold to the NCB given prices (i.e. to have an extra Euler condition in the banks' problem), but, since the parameterization is such so as to pin down the amount as it is in the data, we prefer for simplicity to treat both the price and the amount as exogenously given to private banks. Also note that we do not consider other monetary policies like the relaxation of collateral requirements, the extension of loan maturity and forward guidance.

$$+n^k \frac{e_t p_t^*}{p_t} j_{k,t}^f + n^k \frac{p_t^f}{p_t} \frac{\upsilon}{2} \left(\frac{e_t p_t^*}{p_t} j_{k,t}^f - \overline{j^f} \right)^2 + n^k \frac{e_t p_t^*}{p_t} f_{p,t} + n^k L_{i,t}^{f*}$$

$$+n^k (1+i_t^d) \frac{p_{t-1}}{p_t} j_{k,t-1}^{f*} + n^k (1+i_t^{l*}) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} L_{i,t-1}^f +$$

$$+ \Big((1+i_t^b)\Lambda_t + \Phi_t (1-\Lambda_t) \Big) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^g d_{t-1}$$

$$+(1+i^*) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^{eu} d_{t-1} =$$

$$= n^k \left(1+i_t^{d*}\right) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} j_{k,t-1}^f + n^k (1+i_t^*) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} f_{p,t-1} +$$

$$+n^k \left(1+i_t^l\right) \frac{p_{t-1}}{p_t} L_{i,t-1}^{f*} + n^k j_{k,t}^{f*} + n^k \frac{e_t p_t^*}{p_t} L_{i,t}^f$$

$$+\lambda_t^g d_t + \lambda_t^{eu} d_t + \left(t\arg_t - \left(1+i_t^{MRO}\right) \frac{P_{t-1}}{P_t} t\arg_{t-1} \right) + pmi_t \qquad (27)$$

Inspection of the balance of payments confirms the redistributive role that the ES can play at least in principle. This can be done by dividends from the ES beyond those contributed by the Greek NCB to the ES (see the net term pmi_t which can be positive or negative) and the issuance of new TARGET2 liabilities (see the term $(t\arg_t - \left(1+i_t^{MRO}\right) \frac{P_{t-1}}{P_t} t\arg_{t-1}))$.[25] This is in addition to official bond purchases by the EC (see the term $\lambda_t^{eu} d_t$). All these items can be used, at least in principle, to finance trade deficits, to repay foreign debt or to finance investments abroad. In the case of Greece, as discussed in Appendix B.2, the latter has taken the form of capital flight to safety (during the country's sovereign debt crisis of the previous decade) or the purchase of government bonds held by investors abroad in the secondary market by the Greek NCB (this has been happening since the eruption of the pandemic under the ECB's PEPP).[26] Note that had we allowed for bond purchases by the ES beyond those purchased by the NCB and at a

[25] Had the economy been closed, or had we have a small open economy with a national currency, this term could not be present in the balance of payments. Here, it becomes possible thanks to participation in a currency union which means that the money market clears at currency union level, rather than at national level within each jurisdiction, and that the currency issued (euro) works like an "international" currency at least within the EZ. See Economides et al (2021a) for further details.

[26] See e.g. Fabiani et al (2021) for recent econometric evidence that TARGET2 balances act as as automatic stabilizer counteracting sudden stops in private capital inflows.

price above the market-price, these transactions would have also appeared in the balance of payments and hence could play a redistributive allocative role similar to that played by $\lambda_t^{eu} d_t$, pmi_t and the change in TARGET2 liabilities.

2.8 Macroeconomic system

Market-clearing conditions, the macroeconomic system and the list of endogenous and exogenous variables are presented in detail in Appendix A.8. The system consists of 58 equations in 58 endogenous variables. This is given the paths of the exogenously set variables whose values will be set as in the data.

Non-explosive public debt dynamics usually requires at least one of the exogenously set fiscal policy instruments to react to the gap between the public debt to GDP ratio and a target value. This is also the case in our model, especially since the eruption of the pandemic crisis. Without loss of generality, we start by assuming that this role is played by government transfers which are the least distorting fiscal instrument in this class of models. In particular, we propose that the GDP share of government transfers, s_t^{tr}, follows a Taylor-type reaction function:

$$s_t^{tr} = \rho s_{t-1}^{tr} + (1-\rho)\, s^{tr} - \gamma \left(\frac{d_{t-1}}{y_{t-1}} - \frac{d}{y} \right) \tag{28}$$

where s^{tr} and $\frac{d}{y}$ are target values for the GDP share of transfers and the public debt to GDP ratio respectively, $0 \leq \rho \leq 1$ is a persistence parameter and $\gamma \geqq 0$ is a feedback policy coefficient on public debt imbalances (all these values are specified below in subsection 3.1).

2.9 How we are going to work

In the next sections, we will parameterize the model, present the data used and solve it numerically. In particular, our quantitative analysis will consist of the following steps. First, after calibrating the model to data averages from the Greek economy, we will get a initial steady state solution using data of the year 2019 for the model's exogenous variables. As we shall see, this solution can match reasonably well the main features of the Greek macroeconomy just before the eruption of the pandemic crisis and can thus serve as a departure point in what follows. This will be in section 3. In turn, in section 4, we will specify the lockdown shocks and the policies adopted during the pandemic. In other words, departing from the initial steady state defined as the year 2019, transition dynamics will be driven by lockdown shocks and policy reactions to these shocks. Simulation results will be reported in sections 5, 6 and 7. In our solutions throughout the paper, we assume that all this is common knowledge so that we solve the model under perfect foresight by using a non-linear Newton-type method implemented in Dynare.[27]

3 Calibration, data and solution for the year 2019

Subsection 3.1 presents parameter values and the data used.[28] Then, subsection 3.2 will present a solution for the year 2019 which was the last year before the burst of the pandemic.

3.1 Calibration and data

Regarding structural parameters for technology and preferences, most of them are calibrated on the basis of Greek annual data, while, for the rest, we use commonly employed values and then check their robustness. Unless otherwise stated, the period over which we use Greek macroeconomic data to calibrate the model extends from 1995 to 2019. Parameter values, either calibrated or set, are listed in Table 1. We report at the outset that our main results are robust to changes in these baseline parameter values at least within reasonable ranges.

Starting with preference parameters, private agents' time discount factor, β, is calibrated from the steady state version of the Euler equation for domestic deposits (equation (S5) in Appendix A.8) by using the weighted average value of the real deposit rate of Greek private banks for households' deposits during the years 2002-2019 ($i^d = 1.33\%$; the data are from the Bank of Greece). The resulting value is $\beta = 0.9869$.

The weights given to private consumption and leisure, μ_1 and μ_2, in the households' utility function are calibrated, for given μ_3, from the steady state versions of equations (S2), (S3), (S12), (S13), (S20) and (S21) in Appendix A.8, using data for the share of private consumption to GDP (0.6747), the labour income share (0.583), the percentage of time devoted to leisure (0.59236) and own calculations for the effective income and consumption tax rates (0.30194 and 0.18537).[29] The obtained values of μ_1 and μ_2, by

[27] We have also solved the model assuming that exogenous variables follow, for example, a random walk process and that private agents' next period expected values are equal to their current values. We report that the main results are not affected.

[28] Our calibration section is based on Economides et al (2021b). The main difference is that now we also have private banks and monetary policy.

[29] These are average values. The data regarding the share of total labor compensation in GDP, the percentage of time devoted to leisure and the share of private consumption in GDP are from "The Conference Board Total Economy Database" of Eurostat and our own calculations. In what concerns rent seeking, we assume that this takes place during hours at work where the latter are as in the data, i.e. non-leisure time includes both productive and unproductive effort. Also, following usual practice, we have defined total hours available on a yearly basis as $52 \times 14 \times 7 = 5096$. Finally, the series of the effective tax rates are based on our own calculations using data from Eurostat (details on the standard formulas used can be found in e.g. Kollintzas et al (2018)).

assuming $\mu_3 = 0.05$, are 0.5436 and 0.4064 respectively. We report that our main results are robust to changes in μ_3, namely, the weight given to utility-enhancing public services, whose value is agnostic and is usually set between 0 and 0.1 (see e.g. Baxter and King (1993) and Baier and Glomm (2001)).

The degree of preference for home over foreign goods in consumption, ν, also known as home bias, is calibrated from the equilibrium expression $\frac{e_t p_t^*}{p_t} = (\frac{p_t^f}{p_t^h})^{2\nu-1}$ (see Appendix A.8), where $\frac{e_t p_t^*}{p_t}$ is the real exchange rate and $\frac{p_t^f}{p_t^h}$ is the ratio of the price level of the foreign imported good to the price level of the domestically produced good. Using annual data for the average real effective exchange rate (1.07450) and the average ratio of foreign to domestic prices (1.14243), the resulting value is $\nu = 0.77$.[30]

Continuing with technology parameters, in the production function of private goods, the exponent on labor, $1-\alpha$, is calibrated from the expression $(1-\alpha)(1-\sigma) = 0.583$, where 0.583 is the above mentioned average labour income share in the data and measures the contribution of productivity-enhancing public goods/services in private production. Following e.g. the early paper by Baxter and King (1993), the recent work of Ramey (2020) and many others, we set σ equal to 0.05. This value for σ implies that α, which is the exponent on the composite CES term including capital and imported goods, equals 0.387. The parameter measuring the intensity of capital vis-a-vis imported goods, χ^p, is calibrated using data for imported capital goods and gross fixed capital formation, both as shares of GDP. We consider the sum of these two components to give total investment in physical capital, domestic and foreign, in the economy. Using as a proxy for χ^p the share of fixed gross capital formation over total investment in physical capital, we end up with a value for χ^p equal to 0.504 (the same value of 0.504 will be used for χ^g in the state firm's production function discussed below).[31] Regarding the substitutability parameter in the private production function, op, is set at 0.5; which implies an elasticity of substitution between capital and imported goods in private production of 2 (the same value of 0.5 will be used in the state firm's production function below); note that this is a commonly used value for CES production functions (see e.g. Stokey (1996)). Finally, the work productivity parameters of capital owners and workers in the private production function, A^k and A^w, are set at 2 and 1 respectively; this difference produces a skill wage premium around 2 which is within usual

[30] The data on the real effective exhange rate have been obtained from the Federal Reserve Bank of ST. Louis, while, for the ratio of foreign to domestic prices, as a proxy, we use the ratio of foreign to domestic GDP deflator. Regarding the foreign GDP deflator, we have chosen to use the German one, whereas the data for both deflator, i.e. the Greek and the German one, are obtained from Eurostat.

[31] The data regarding fixed gross capital formation are obtained from AMECO, whereas, the data for imported capital goods are obtained from OECD.

ranges in the literature on income inequality (see e.g. Autor (2014)).

In the state firms' production function, the Cobb-Douglas exponents on public capital and public employment, θ_1 and θ_2, are set respectively at 0.309 and 0.398, which correspond to average payments for public investment and public wages, expressed as shares of total public payments to all inputs used in the production of public goods (the data are from Eurostat). In turn, the Cobb-Douglas exponent on goods purchased from the private sector, $1-\theta_1-\theta_2$, follows residually and is 0.293.

The capital depreciation rate, δ, is set at 0.04. This value results from calibrating the steady state version of equation (S33) in Appendix A.8 by using annual data for gross fixed capital formation and net capital stock from AMECO. The same value will be used for the depreciation rate of public capital. Both the TFP parameters (in the private and in the public sector production functions) are normalized at 1.

In the rent-seeking technology, $(1-RS)$ is set at the degree of property rights in the data. This is defined as the average of three sub-indices: "the rule of law", "regulatory quality" and "political stability and absence of violence/terrorism", which are three indicators commonly used for the construction of a measure of property rights protection (the data are from the World Governance Indicators) rescaled in the 0 to 1 range (the higher the value, the better the quality of institutions). This gives $RS=0.464$ for the degree of publicness. The power coefficient, γ, is assumed to be common for capital owners and private workers and is set at 0.5, while for public employees is set to 0.65. The effectiveness parameters of public employees, private workers and capital owners, Γ^b, Γ^w and Γ^k are set respectively at 3, 0.5 and 1.5 to reflect their relative political power in rent extraction. This parameterization contributes to getting hours at work within data averages and also makes public employees the main winners from rent extraction. As is widely recognized, in the Greek economy, the power of public sector employees is bigger relative to other social groups (see e.g. Kollintzas et al. (2018)), and this is captured by the choice of these specific values.

We calibrate the transaction cost parameter associated with capital changes in the firm's problem so as the investment loss in terms of output to be around 1%. This obtains for $\xi^k=0.45$. However, we report that our main results are robust to changes in the value of ξ^k. The transaction cost parameters associated with private participation in the foreign market for deposits, υ and $\overline{j^f}$, are set to 0.5 and 0.178 respectively, so as to get deposits at foreign private banks equal to 0.25 of their respective deposits at domestic private banks (i.e. $j^f=0.25*j^h$).

Following the econometric study by Dinopoulos et al. (2020) for the Greek economy, we set the exports elasticity, represented by parameter θ in equation (S53) in Appendix A.8, at 3.040; we report however that our main results are robust to changes in the value of θ.

Continuing with the banking sector, we set the parameters in the cost function of banks so as to match data for 2019. In particular, we set the cost parameters associated with private loans to firms, ξ^l, reserves, ξ^m, and loans provided by the NCB, ξ^z, at 0.11, 0.00003 and 0.135 so as to match the GDP shares of Greek private banks' loans to small and medium size enterprises (SMEs), reserves held at the NCB and loans by the NCB (the data are from the website of the Bank of Greece). We set the cost function parameter associated with domestic government bonds, ξ^b, at 0.022, to match the average value of the real interest rate in the data (where the latter is the difference of the nominal interest rate on the 10-year Greek government bond and the inflation rate measured by the percentage change of the Greek GDP deflator).[32]

The population fractions of public employees, n^b, and capitalists or self-employed, n^k, are set at 0.2 and 0.2 respectively, similarly to data from OECD so that the fraction of private workers, n^w, follows residually at 0.6. For our baseline simulations, we assume that the shares in total population of final good firms $\left(n^h\right)$, intermediate goods firms $\left(n^i\right)$, capital good firms (n^c) and private banks (n^p), are all equal to the share in total population of their owners, namely, the capitalists $\left(n^k\right)$, that is, $n^h = n^i = n^c = n^p = n^k = 0.2$. We also set $n^b = n^g = 0.2$, that is, the share in total population of state firms equals the share in total population of public sector employees.

To set the Dixit-Stiglitz parameter measuring imperfect competition in the product market, ϑ, we use information from Eggertson et al (2014), who report that the gross markup in traded goods (recall that we have traded goods only in our model) is around 1.17 in the periphery countries of the EZ (and 1.14 in the core countries). Thus, as in Eggertson et al (2014, section 3.7), we pin down by targeting a steady state gross markup of 1.17 and this gives $\vartheta = 0.85$ (note that this corresponds to 6.88 in the Eggertson et al functional specification). We also set the parameter in the Rotemberg-type price adjustment costs, ξ^p, to 3, which is a value within commonly used parameter ranges.

[32] The data are from Eurostat.

Table 1 **Baseline parameterization**			
Parameter	Description	Value	
ν	home goods bias in consumption	0.77	calibr
μ_1	weight of consumption in utility	0.5436	calibr
μ_2	weight of leisure in utility	0.4064	calibr
μ_3	weigh of utility-enhancing public services	0.05	calibr
β	time discount factor	0.9869	calibr
δ and δ^g	depreciation rate of priv and pub capital	0.04	calibr
υ	transaction cost in foreign deposit market	0.5	calibr
$\overline{j^f}$	threshold in foreign deposit market	0.178	calibr
A^p	TFP in private sector's production function	1	set
A^g	TFP in public sector's production function	1	set
A^k	capital owners' labour productivity	2	calibr
A^w	workers' labour productivity	1	calibr
$1-\alpha$	share of labor in private production	0.613	calibr
σ	contribution of public output to private production	0.05	set
θ_1	share of capital and imported goods in public production	0.309	calibr
θ_2	share of labor in public production	0.398	calibr
χ^p	intensity of private capital relative to imported goods (private)	0.504	calibr
op	substitutability between capital and imported goods (private)	0.5	calibr
χ^g	intensity of public capital relative to imported goods (public)	0.504	calibr
og	substitutability between capital and imported goods (public)	0.5	calibr
ξ^p	coefficient in Rotemberg-type costs	3	set
ξ^k	capital adjustment cost parameter	0.45	calibr
ξ^l	transaction cost associated with bank loans to firms	0.11	calibr
ξ^z	transaction cost associated with NCB loans to banks	0.135	calibr
ξ^b	transaction cost associated with banks' gov bonds	0.022	calibr
ξ^m	transaction cost associated with banks' reserves	0.00003	calibr

Table 1 cont. Baseline parameterization			
Parameter	Description	Value	
Γ^k	efficiency of capital owners' anti-social activity	1.5	calibr
Γ^w	efficiency of workers' anti-social activity	0.5	calibr
Γ^b	efficiency of public employees' anti-social activity	3	calibr
RS	degree of publicness	0.464	data
γ^k	measure of diminishing returns in anti-social activities of capitalists	0.5	set
γ^w	measure of diminishing returns in anti-social activities of workers	0.5	set
γ^b	measure of diminishing returns in anti-social activities of public employees	0.6	set
θ	exponent in the function of exports	3.040	set
ϑ	substitutability between intermediate goods	0.85	calibr
n^k	share of cap owners in population	0.2	data
n^w	share of priv workers in population	0.6	data
n^b	share of pub employees in population	0.2	data
n^g	share of state firms in population	0.2	set
n^i	share of private firms in population	0.2	set
n^c	share of capital firms in population	0.2	set
n^p	share of private firms in population	0.2	set

In addition, to solve the model, we also need data for the exogenous variables, namely, policy instruments and rest-of-the-world variables for the year 2019. Regarding spending-tax policy instruments, using data from Eurostat and our own calculations, we set s_t^i, s_t^g, s_t^m, s_t^w, τ_t^c, τ_t^y and τ_t^π, which are respectively the GDP shares of government spending on investment, goods purchased from the private sector, imported goods/capital, public wages, as well as the effective tax rates on consumption, income and corporate profits, at $0.022, 0.077, 0.045, 0.117, 0.225, 0.354$ and 0.273 respectively. In what concerns the effective corporate tax rate τ_t^π, we use as a proxy the effective tax rate on capital income. In addition, we set s_t^{tr} at 0.2 (in the average data the respective value is 0.207) to target the steady state value of the public debt to GDP ratio as in the data in the year 2019 (around 180%). Regarding monetary policy instruments, using data from ECB, we set i_t^r, i_t^z and i_t^{MRO}, which are the interest rates on reserves, bank loans and main refinancing operations at -0.5%, 0.25% and 0% respectively. Also, we set the ratio of ES dividends to GDP, $\frac{pmi}{y}$, at 0.0002, which is the average value in the data over 2012-2019 (the data are from the website of the Bank of Greece). The fractions of Greek public debt in the hands of foreign private agents/banks and EU institutions, λ_t^g and λ_t^{eu}, as in subsection 2.6.2 above, are set at 0.1596 and 0.7087 respectively as indicated in the data for 2019 (see Appendix B.1 for details and the evolution of λ_t^g and λ_t^{eu} over time). The interest rate on EU loans, i^*, is set at 1%. Also, in the solution for 2019, we assume zero government bonds purchases in the secondary market by the central bank $(1 - \Lambda_t = 0)$; this is because Greek government bonds became part of the ES's asset purchase programmes after the eruption of the pandemic and in particular under the PEPP program. Finally, in the feedback policy rule equation (28), the values of s^{tr} and $\frac{d}{y}$ are those in the departure year 2019, while the persistence parameter, ρ, is set at 0.5, and the feedback coefficient parameter, γ, is set at 0.04 which is the lowest possible value needed to ensure dynamic stability at least in our baseline simulations.

For the exogenous rest-of-the-world variables, we set, for simplicity, domestic bank loans to foreign firms, $L_{i,t}^{f*}$, and deposits by foreign households at domestic banks, $j_{k,t}^{f*}$, at 0. The foreign lending rate, i_t^{l*}, is set at 5.39%, which is the interest rate on loans to Greek non-financial corporations, while the foreign deposit rate, i_t^{d*}, is set at 1.06%, which is the average annual rate of German private banks.[33] Finally, the interest rate on foreign government bonds is calculated from the steady state version of equation (S42) in Appendix A.8. For simplicity, we set the foreign government bond's rate equal to the domestic deposit rate, $i_t^{b*} = i_t^d$, which implies that the domestic private banks do not hold foreign government bonds.

Data averages of policy variables over the period 1995-2019, as well as policy parameters, are presented in Table 2, while data of foreign financial variables are presented in Table 3.

[33] Data averages are calculated over the period 2002-2019. Data are from Bundensbank and Bank of Greece.

Table 2 Policy variables (1995-2019) and parameters			
Parameter	Description	Value	
s^i	public investment to output (%)	0.022	data
s^g	gov purchases from the priv sector to output (%)	0.077	data
s^m	gov spending on imports to output (%)	0.045	data
s^w	public wage bill/output (%)	0.117	data
s^{tr}	gov transfers/output (%)	0.2	calibr
τ^c	eff consumption tax rate	0.225	data
τ^y	effective income tax rate	0.354	data
τ^π	eff tax rate on capital income	0.273	data
λ^{eu}	share of total public debt held by EU institutions	0.7087	data
λ^g	share of total public debt held by foreign banks	0.1596	data
i^r	interest rate on reserves	-0.5%	data
i^z	interest rate on CB's loans	0.25%	data
i^{MRO}	interest rate on main ref operations	0%	data
i^*	interest rate on EU loans	1%	set
$1-\Lambda$	CB's gov bonds' purchases	1	set
ρ	persistence parameter in the policy rule	0.5	set
γ	feedback coefficient in the policy rule	0.04	set

Table 3 Rest-of-the-world variables			
Variable	Descritpion	Value	
j_k^{f*}	deposits of foreign agents	0	set
$L_{i,t}^{f*}$	loans to foreign firms	0	set
i^{d*}	foreign deposit rate (%)	1.06	calibr
i^{l*}	foreign lending rate (%)	5.39	calibr
i^{b*}	foreign gov bonds rate (%)	1.33	set

3.2 Solution for the year 2019

Using the above parameter values and data of the year 2019, the steady state solution of the model is reported in Table 4. In this solution, variables do not change (so it can be thought as the "trend" of the Greek economy after its sovereign debt crisis and before the burst of the pandemic crisis) and all exogenous variables have been set as in the data of the year 2019.

As can be seen, this solution is in line with actual data in 2019 and can thus provide a reasonable departure for the policy scenaria studied in the next sections. In particular, the solution does a relatively good job at mimicking, for example, the position of the country in the international capital market, as well as the consumption-investment behavior of the private sector.

Table 4 Main variables in the solution for the year 2019		
Variable	Descritpion	Value
c/y	consumption/output	0.63
inv/y	investment/output	0.15
b/y	public debt/output	1.81
k/y	capital/output	3.11
l/y	private loans/output	0.19
d/y	deposits/output	0.45
m_p/y	reserves/output	0.05
z/y	CB loans/output	0.04
m/y	money/output	0.77
π^f/y	firms' profits/output	0.18
c_k	consumption of capital owner	0.57
c_w	consumption of private worker	0.19
c_b	consumption of public employee	0.30
l_k	work hours of capital owner	0.24
l_w	work hours of private worker	0.49
l_b	work hours of public employee	0.31
$1-u$	non-leisure time	0.45
w^k	wage of capital owner	1.11
w^w	wage of private worker	0.55
w^b	wage of public employee	0.85
p^f/p^h	ratio of foreign to domestic prices	0.47
s_k	capitalist's effort time allocated to anti-social activities	0.03
s_w	worker's effort time allocated to anti-social activities	0.01
s_b	public employee's effort time allocated to anti-social activities	0.18
i^l	interest rate on loans (%)	5.39
i^d	interest rate on deposits	1.33
i^b	interest rate on government bonds (%)	2.35

4 Lockdown shocks and policy scenaria studied

In this section, we first model the two lockdown shocks, Φ_t^c and Φ_t^l, needed to trigger the pandemic economic downturn, and then define the policy scenaria (factual and hypothetical) we will focus on. These shocks and policies will drive the transition dynamics departing from the initial 2019 solution.

4.1 Modelling the lockdown shocks

As in Economides et al (2021b), we assume that, in 2020, Φ_t^l and Φ_t^c changed by 15% relative to their value in the absence of lockdown effects (this value is 1)[34] and then evolve according to the $AR(1)$ processes:

$$\Phi_t^l = \left(\overline{\Phi}^l\right)^{1-\gamma^{\Phi^l}} \left(1 - \Phi_t^l\right)^{\gamma^{\Phi^l}} \tag{29a}$$

$$\Phi_t^c = \left(\overline{\Phi}^c\right)^{1-\gamma^{\Phi^c}} \left(1 - \Phi_t^c\right)^{\gamma^{\Phi^c}} \tag{29b}$$

where γ^{Φ^l} and γ^{Φ^c} are persistence parameters chosen so as the impact of the lockdown on economic activity to weaken gradually, without any government reaction, within four to five years, whereas as said above $\overline{\Phi}^l = \overline{\Phi}^c = 1$.

4.2 Policy reaction to the pandemic at national and EU level

We now discuss policy responses at national and EU level. These responses will then be added formally to our model.

4.2.1 Fiscal policy reaction at national level

We start with the main policy measures adopted by the Greek government during 2020 and 2021. In particular, we assume that the total size of the national fiscal stimulus (i.e. labour income compensation, tax discounts, increases in government spending, etc.) is as in the data, that is around 17.5% of GDP in 2020, and around 8% (estimated) in the current year of 2021. Since we do not have detailed data on the exact use of this fiscal stimulus, we make the assumption that it is equally used for tax discounts and spending rises. Specifically, we assume that the government makes a lump-sum transfer payment to all households so as to cover the reduction in their labor incomes caused by the pandemic shocks assumed above. In other words, we add extra transfers into the budget constraints of the three income groups, denoted as $g_{k,t}^{con}$, $g_{w,t}^{con}$ and $g_{b,t}^{con}$ respectively, that are provided in a lump-sum fashion and take the form:

$$g_{k,t}^{con} = (1 - \tau^y)\, w_t^k \left(1 - \Phi_t^l\right) l_{k,t} \tag{30a}$$

$$g_{w,t}^{con} = (1 - \tau^y)\, w_t^w \left(1 - \Phi_t^l\right) l_{w,t} \tag{30b}$$

$$g_{b,t}^{con} = (1 - \tau^y)\, w_t^g \left(1 - \Phi_t^l\right) l_{b,t} \tag{30c}$$

On top of the above, we assume that the Greek government provides subsidies to private firms in an attempt to maintain their demand for labor during 2020-21. Specifically, we assume that the government subsidizes the

[34] That is, $\Phi_t^l = 0.85$ and $\Phi_t^c = 1.15$ in 2020. The magnitude of these initial Covid shocks is chosen so as to match the size of the Greek recession in 2020.

labor cost by 11% in 2020 and by 3% in 2021 (these numbers are consistent with announcements made by the Greek government). We also assume that the government increases temporarily its spending on public investment and government purchases from the private sector as shares to GDP, by 1 percentage point in both 2020 and 2021. Finally, we assume that the government cuts temporarily the tax rates on income, consumption and corporate profits by 2 percentage points in 2020 and by 1 percentage point in 2021. Before proceeding, we should point out that all policy changes throughout the paper are financed by adjustments in the end-of-period public debt which, as said above, is the residual public financing instrument.

4.2.2 Financial assistance from the Recovery Fund

In addition to the above responses, the Greek economy can benefit from resources coming from the EU's newly established Recovery and Resilience Facility, whose aim, as said in the Introduction, is to raise funds from private markets and new taxes and then allocate them to member-countries depending on how much they have been hurt by the COVID-19 pandemic. Greece can benefit up to a net amount of around 32 billion euros in the form of grants and loans where the latter are provided at non-market interest rates. The amount of 32 billion euros translates into around 17.5% of the Greek GDP in 2019 and should be used by the end of 2026. As has been decided by the EU, 40.63% (or 13/32) of the total funds received will be in the form of loans received during 2021-2026 (and hence they will be added to the amount of Greek public debt held already by EU institutions as modeled in subsection 2.6.2 above) and the rest will be in the form of grants (these are cash transfers that are added as an extra item to the budget constraint of the Greek government and hence of the country's balance of payments again from 2021 to 2026). In our numerical simulations, we will assume a time-to-spend lag regarding the actual use of these amounts which means that they will be equally divided in each year between 2022 and 2027 (i.e. one sixth in each year). Hence, the total amount of Greek public debt held by EU institutions in each period since 2019 evolves as:

$$\lambda_t^{eu} d_t = \lambda_{2019}^{eu} d_{2019} + 40.63\% * \mathrm{Re}\, covery\_Fund_t \tag{31}$$

Regarding the way these funds are used, we assume that the Greek government uses half of them to finance an increase in public investment, $g_{g,t}^i$, government purchases from the private sector, $g_{g,t}^g$, and imported capital goods, $m_{g,t}^g$, which all of them are used for the production of public goods/services (see section 2.5 above), while, the other half goes to transfers. In particular, we assume that 25.29% of the 16 extra billion euros is used to finance public investment, $g_{g,t}^i$, 48.58% of the 16 extra billion euros is used to finance government purchases from the private sector, $g_{g,t}^g$, 26.13% of the extra 16 biilion euros is used to finance imported capital goods, $m_{g,t}^g$, while, the other 16 extra billion euros are added to the transfer payments, g_t^{tr}.

4.2.3 Financial assistance from the ECB in the pandemic

With respect to monetary policy, we assume that ES keeps the main policy interest rates at their 2019 levels, and, in addition, permits the issuance of new TARGET2 liablities by the Greek NCB and purchases Greek government bonds in the secondary market (both are as in the data).

Regarding TARGET2 liabilities, we assume that from 2020 onwards they react to debt imbalances by following the feedback policy rule:

$$dt\arg_t = \rho dt\arg_{t-1} + \gamma^{TARG}\left(\frac{d_{t-1}}{y_{t-1}} - \frac{\overline{d}}{y}\right) \tag{32}$$

where $dt\arg t = t\arg_t - \frac{P_{t-1}}{P_t} t\arg_{t-1}$ is the change in TARGET balances, ρ is a persistent parameter set at 0.5 and γ is a feedback policy coefficient set at a low value, 0.05 (this parameterization helps us to get a debt-to-GDP ratio around 205% in 2020 which is close to the data).

Regarding purchases of Greek government bonds by the Greek NCB from domestic and foreign private banks in the secondary market under PEPP, we assume, as in the data, that cumulative purchases (the average maturity of these bonds is 8 years) are around 18.9 billion euros at the end of Januray 2021, which translate to around 10% of the Greek GDP in 2019, while, following the announcements of the ECB, we assume that the NCB will purchase a similar amount of bonds in 2021 and continue these purchases up to March 2022.[35] In terms of modelling, this means that the Greek government bonds repurchased by the Greek NCB from private banks at home and abroad is:

$$\Phi_t(1-\Lambda_t)\frac{p_{t-1}}{p_t}\lambda_{t-1}^d d_{t-1} + \Phi_t(1-\Lambda_t)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^g d_{t-1} = By_t \tag{33}$$

where B is a parameter which is set at $B = 0.1$ in 2020 and 2021, and at 0.025 in 2022. Finally, we assume that the NCB buys government bonds in the secondary market at a fixed price, Φ, which is above the "shadow" market-price; in particular, we set $\Phi_t = 1.2 * (1 + i_{2019}^b)$, where i_{2019}^b is the nominal interest rate on government bonds in the 2019 solution.

4.2.4 Baseline scenaria

Given the above, we find it natural to start with two baseline scenaria. The first is the case with the lockdown shocks only, assuming away any policy

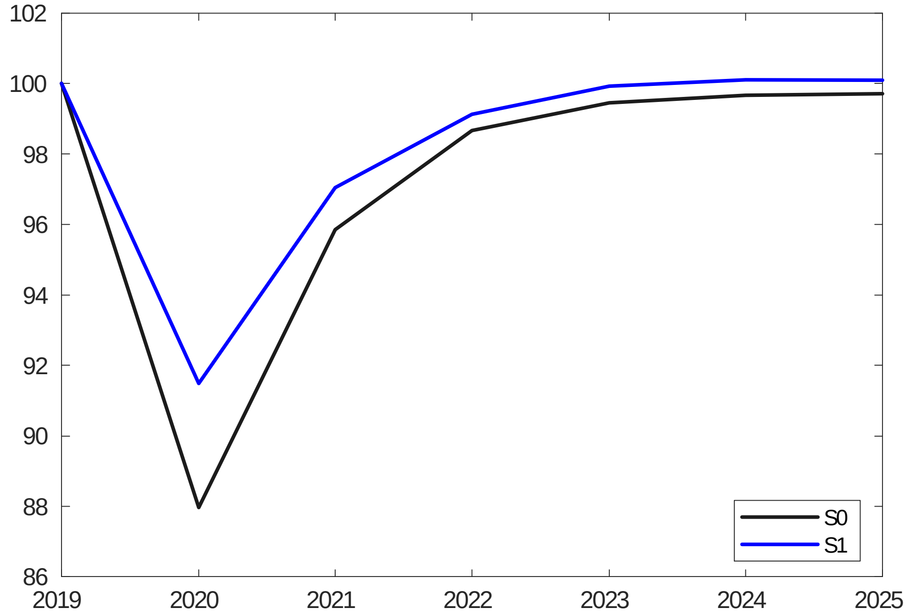
[35] According to the ECB website, the Governing Council will terminate net asset purchases under the PEPP once it judges that the COVID-19 crisis phase is over, but in any case not before the end of March 2022.

reaction. This can help us to understand the economic consequences of the pandemic had policy not reacted at all. We label this S0. Second, the "actual" case with the lockdown shocks and policy reaction at both national and EU level as described above. We label this S1. Results are reported next.

5 Results for the baseline scenaria

Graph 1 illustrates the simulated path of GDP as % deviation from its 2019 value under S0 and S1. In both cases, the pandemic-related shocks, Φ_t^l and Φ_t^c, take the value of 0.85 and 1.15 respectively in 2020 and then gradually return to their pre-COVID value (i.e. 1) according to (28a)-(28b). As said above, S0 describes what would have happened without any policy reaction to the economic consequences of the pandemic (i.e. we keep all fiscal and monetary policy variables constant at their values in the initial steady state solution of 2019 and we only allow, as said above, government trnasfers to react to debt-to-GDP ratio for dynamic stability reasons), while S1 mimics what has been happening in reality which means that there is policy reaction as that in the data and this is both at national and EU level (i.e. on top of S0, this incorporates the national fiscal stimulus, the funds from the Recovery Fund and accommodative monetary policy in the form of PEPP and TARGET2's reaction to debt imbalances). As can be seen, under S0 (the black line), the economy would have lost around 12% of its output in 2020 relatively to 2019; to make it worse, the economy could not have managed to rebound in the years after, in the sense that GDP would remain below its 2019 level for several years. By contrast, under S1 (the blue line), the simulated output loss in 2020 is limited to about 8.5%, which is close to the data; moreover, after 2023, the GDP can be close to its pre-crisis 2019 level.

Graph 1: Real GDP under S0 and S1
(% deviation of output from its 2019 value)



We also report welfare (i.e. discounted lifetime utility) results in terms of consumption equivalents as in the policy reform literature (see e.g. Lucas (1990)). Vis-a-vis the initial year, 2019, S0 and S1 need welfare subsidies 6% and 1.5% respectively. That is, one would need a 6% permanent increase in consumption in each period to compensate households from the economic consequences of the pandemic shock had no policy reaction taken place, while, this is reduced to 1.5% thanks to the comprehensive policy reaction that has taken place. Notice that these are non-negligible numbers.[36] Overall, these results show the big vulnerability of the Greek economy to shocks (both supply and demand). They also imply that policy intervention has been more than necessary.

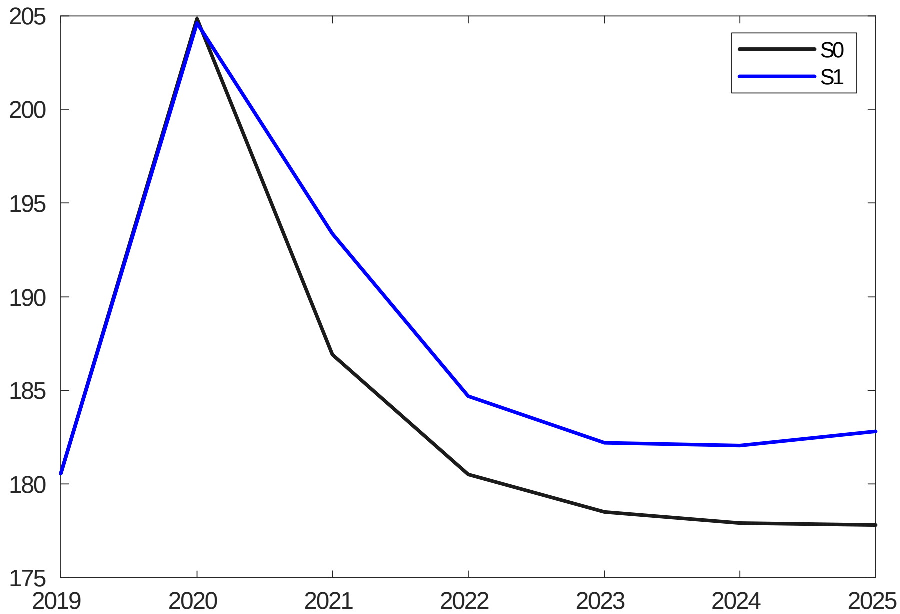
Graph 2 presents the simulated path of the public debt to GDP ratio under S0 and S1. Under both S0 and S1, this ratio jumps to around 205% in 2020, which is close to the data (206%), and then de-escalates after the impact year as the GDP rebounds.[37] On the other hand, the increased fiscal

[36] For comparison, Lucas (1990) concludes with a welfare gain between 0.75 and 1.25% of consumption even if the reform studied in his paper is radical (from the existing US tax structure to an optimal Ramsey structure with zero capital taxes over time).

[37] We report that a higher value of the feedback policy coefficient γ^{TARG}, in the policy rule helps the debt-to-GDP ratio to stabilize faster at its 2019 level.

cost of the national stimulus as well as the funds in the form of debt coming from the Recovery Fund imply a higher debt to GDP ratio under S1 than under the no-policy-reaction scenario S0, despite the smaller fall in GDP under the former. That is, as expected, the relative small output loss under S1 comes at the cost of higher debt.

Graph 2: Public debt to GDP under S0 and S1 (%)

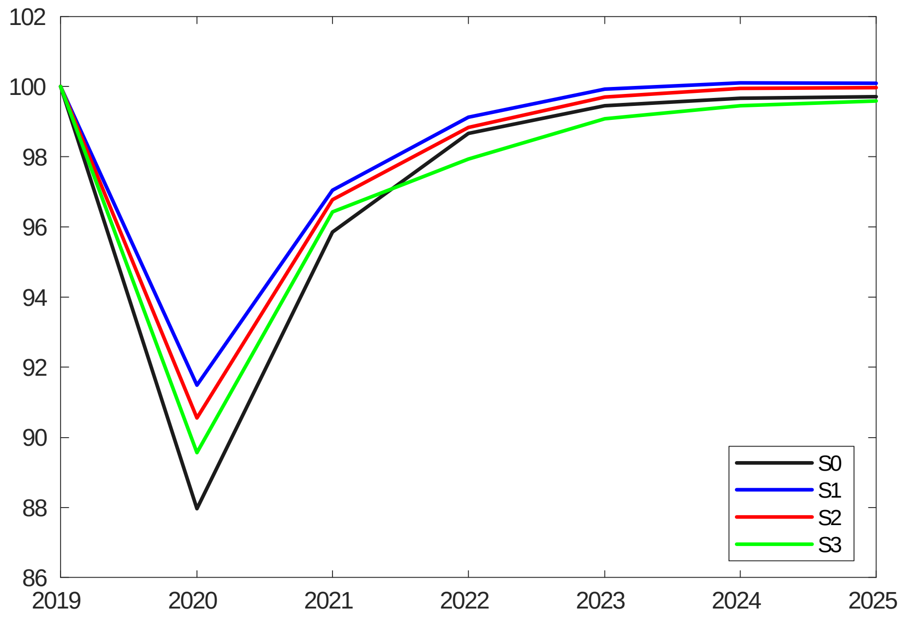


6 What would have happened without financial assistance from the EU

In this section we perform two counterfactual experiments. We examine what would have happened without financial assistance from EU institutions. To quantify the role of the ES, we first consider what would have happened without the new measures taken by the ES since 2019. In particular, relative to S1, we switch-off bond purchases under PEPP and the rise of TARGET2 liabilities resulting from their feedback reaction to rising public debt. This scenario is labelled S2. Second, on top of S2, we also switch off the resources coming from the Recovery Fund. In other words, under this scenario, labelled S3, the Greek economy can only benefit from the national fiscal stimulus adopted by the Greek government. Of course, in both S2 and S3, the economy continues to benefit from financial assistance as in the pre-covid years (see the 2019 solution).

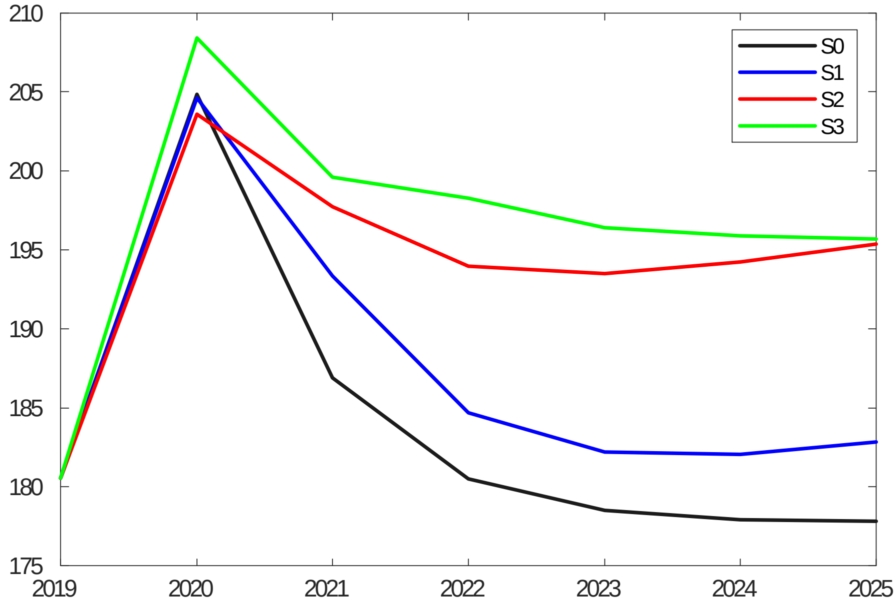
Graph 3 presents S2 (red line), S3 (green line) but also includes S1 (blue line) and S0 (black line) for expositional convenience. Comparison of S1 and S2 reveals the extra benefits of the new financial assistance provided by the ES. In particular, without the latter (i.e. under S2), the output loss in 2020 would be 9.5% relative to 2019. It is important to report here that these benefits would be even bigger if we increase the magnitude and/or the duration of the PEPP purchases, as well as their price. Higher benefits would also be delivered if we allow a stronger reaction of TARGET liabilities to debt imbalances. Next, if, on top of this, there were no fiscal assistance from the Recovery Fund either, then the output loss in 2020 would be even bigger, 10.5%. Recall that with the full package (S1), the loss is 8.5%. In addition, notice that the recession would last longer under both S2 and S3. Regarding the welfare losses, always vis-a-vis the year 2019, these are 2.3% under S2 and 3.6% under S3; again, non-negligible.

Graph 3: Real GDP under S0, S1, S2 and S3
(% deviation of output from its 2019 value)



Graph 4 presents the simulated path of public debt to GDP ratio under scenaria S0, S1, S2 and S3. As can be seen, without assistance from the EU and especially from the Recovery Fund, the public debt to GDP ratio would be higher and longer lasting relative to the actual scenario S1.

Graph 4: Public debt to GDP under S0, S1, S2 and S3 (%)



Summing up, the above results show how necessary the policy reaction has been but also confirm the importance of financial assistance from EU institutions in crisis years.[38] Actually, the role of EU institutions (European Commission and ECB) is more important than what Graphs 1-4 seem to imply at first sight. This is because one of the main benefits that Greece receives from membership in these supra-national institutions is "the import of credibility" and, in particular, the anticipation of markets that these institutions will step in, in one way or another, if something goes wrong in the future. This is studied next.

7 The importance of trust

So far we have assumed away the fear of default on public debt and hence sovereign risk spreads. Actually, this is as in the data. It is remarkable that, since 2019, despite the fall in economic activity and the big rise in public debt-to-GDP ratios, even countries with heavy public debt burdens, like Greece, have been enjoying very small bond spreads (excess yields) over the German Bund - at least so far. For example, at the days of writing this

[38] See Economides et al (2021a) for a similar conclusion during the Greek sovereign debt crisis of the previous decade.

paper, the Greek government issues bonds with a 0.9% interest rate while its public debt is higher than 200% of GDP. We believe this happens for several reasons. One reason, as already said above, is the financial assistance from the ECB (see e.g. PEPP) and the EC (see e.g. the Recovery Fund) and, perhaps more importantly, the signals of support sent by these EU institutions if something goes wrong. Another complementary reason is the relative political stability in the heavily indebted countries combined with coordination and trust between EU leaders and national governments in the current situation. All this has increased markets' trust in the ability, or at least the wilingness, of these countries to repay their debts, at least so far.

But, as the experience of the European debt crisis in the previous decade has shown, a mix of weak economic fundamentals, negative shocks/news, and uncertainty over policy reaction, can very easily change the situation for the worse (see also the review paper of Lorenzoni (2014)). International crises are typically preceded by weak economic fundamentals, like persistent budget deficits and a large stock of public debt, persistent current account deficits and a large stock of foreign debt, an overvalued real exchange rate, poor quality of core institutions, etc.[39] These imbalances set the stage for a crisis. Then, if a negative shock hits a country with such weak fundamentals, sentiments can change, trust can be lost, investors will start selling domestic assets, risk premia will emerge to compensate for the fear of default, debt burdens will rise as interest rates rise, a recession will start and all this can become a vicious cycle and an international financial crisis. Various shocks can work as triggers of the crisis, including unrealistic promises that ignore the government's inter-temporal budget constraint; an institutional deterioration, fuelled by political polarization, that signals bad growth prospects; the loss of trust between national policymakers and EU institutions; a report by an international rating agency or organization expressing doubts about debt sustainability; etc.[40] Moreover, the crisis can have different implications depending on the ability of the political system to take the necessary steps, the relationship between creditors and debtors or, in the case of Greece, the trust between EU institutions (the ECB and EC) and the Greek governments (current and future), etc.

In other words, in a crisis episode, there can be many underlying causes, many triggers/shocks and many possible policy responses, and all of them shape the probability of default or the ex ante default rate and hence the size of risk spreads. Hence, a formal model of the latter cannot be but selective and incomplete. Which fundamentals, triggers/shocks and policy reactions

[39] The literature has explored the role of such fundamental variables in forecasting crises and debt defaults; see Lorenzoni (2014, section 6).

[40] Or, in the case of the US in 2007-8, the trigger was a decline in housing prices in 2006 that affected the shadow banking sector before being transmitted to the whole economy.

to include as arguments in the probability function?[41] Given all this, to provide a simple numerical example of the consequences of risk premia, here we just set it exogenously.[42] In particular, we assume that private agents fear that the government and domestic private banks will partially default on their obligations[43] and we set this ex ante default rate at 20% during 2022-2025 which is within the range observed in Greece during its sovereign debt crisis.[44] We add this fear of default scenario (labeled S4) to our baseline scenario S1 other things equal.

Graph 5 and 6 plot the simulated paths of output and debt-to-GDP ratio respectively under S4. We also include S1 for comparison. As can be seen, the emergence of risk premia makes the recession sharper and longer (see Graph 5) and, at the same time, the debt-to-GDP ratio skyrockets as long as interest rate risk premia exist (see Graph 6) as a result of a higher cost of borrowing and subsequently higher interest rate repayments. Note that, even if default does not actually materialize (i.e. the ex post default rate in the budget constraints is set at zero), the mere anticipation of default increases the relevant interest rates and this is enough to do the macroeconomic damage. Trust is important.

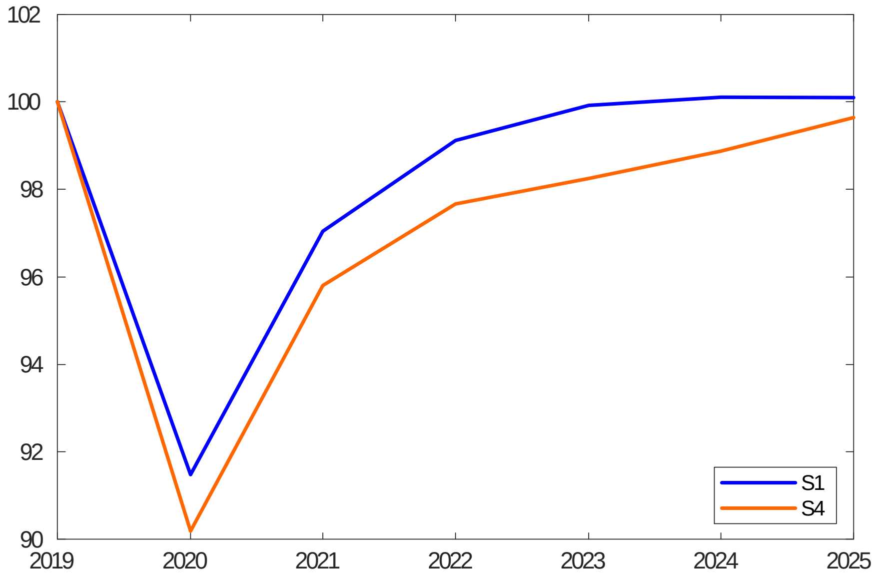
[41] It is usual to assume that this probability depends only on the stock of public or external debt relative to a threshold value, and perhaps on a shock with an assumed distribution function (see e.g. Corsetti et al (2013)). But, as Lorenzoni (2014) points out, fiscal conditions are not always the main culprit in these episodes. Corsetti et al (2013) also provide a brief review of the literature on debt default.

[42] See Kriwoluzky et al (2019) who also set the default rate exogenously. Actually, these authors assume a richer probabilistic structure (that includes several outcomes in addition to default) but, on the other hand, work with a simpler model.

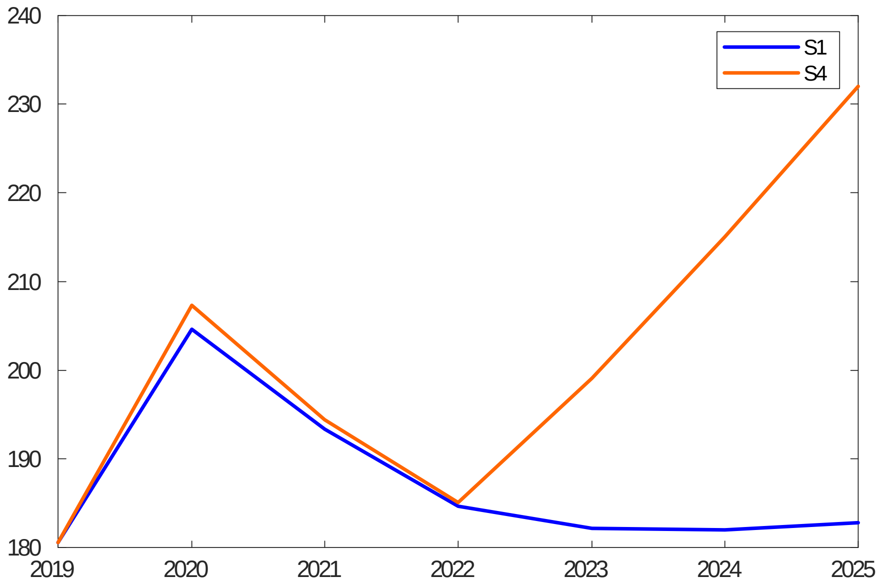
[43] The ex ante default rate adds new wedges to the Euler equations of deposits and government bonds. The new macroeconomic system with the ex ante default rate is presented in detail is Appendix A.9.

[44] We report that we have also experimented with various endogenous specifications according to which the ex ante default rate is a function of the gap between the public debt to GDP ratio and a threshold value, and/or the degree of deterioration of a core institutional fundamental like the protection of property rights. To the extent that we calibrate the underlying parameters in the probability function so as to account for the same rate as that set exogenously, the results remain basically the same. We thus model the fear of default in the simplest possible way.

Graph 5: Real GDP under S1 and S4
(% deviation of output from its 2019 value)



Graph 6: Public debt to GDP under S1 and S4
(%)



8 Closing the paper

Greece had just started to recover from its sovereign debt crisis when, like most countries, was hit by the pandemic shock in early 2020. The policy measures taken by the Greek government, the European Commission (e.g. Recovery Fund) and the ECB (e.g. PEPP) have helped the country to avoid the worse and reduce the economic downturn but this has come at the cost of public finances. These days, with a public debt above 200% of GDP (the implications of which have been masked so far mainly by the financial assistance and the imported credibility provided by these EU institutions), the country is vulnerable to economic and political shocks. As we showed, if something happens and the fear of debt default and risk premia re-emerge, the macroeconomic effects will be detrimental. One cannot rely on the assumption of low risk premia. Although exogenous factors cannot be controlled for, the country should at least not repeat the same mistakes as during the sovereign debt crisis of the previous decade (especially, political polarization and reform inertia both of which created uncertainty, raised risk premia and all this led to a vicious cycle of recession and debt).

Since the main results have already be written in the Introduction, we close with a possible extension. Here we studied a Eurozone periphery country receiving assistance within a small open economy model. It would be interesting to develop a two-counry model, with a periphery and a core country, and model the implications of the Recovery Fund and the ECB's policies, as they are in the data, for both countries.

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Appendix A: Solutions

A.1 Solution of capital owners' problem

Each k acts competitively choosing $\{c^h_{k,t}, c^f_{k,t}, c_{k,t}, l_{k,t}, s_{k,t}, j^h_{k,t}, j^f_{k,t}, m_{k,t}\}^{\infty}_{t=0}$. The first-order conditions include the definition in (2) and the constraints in (3a-3c) in the main text as well as:

$$\frac{\mu_1}{c_{k,t}} = (\lambda_{k,t} + \psi_{k,t})(1+\tau^c_t)\Phi^c_t \tag{A1a}$$

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \lambda_{k,t}(1-\tau^y_t)w^k_t\Phi^l_t \tag{A1b}$$

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \lambda_{k,t}\left(\frac{\gamma\Gamma^k(s_{k,t})^{\gamma-1}(RS*G^{tr}_t)}{n^k\Gamma^k(s_{k,t})^{\gamma}+n^w\Gamma^w(s_{w,t})^{\gamma}+n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{A1c}$$

$$\lambda_{k,t} = \beta\lambda_{k,t+1}(1+i^d_{t+1})\frac{p_t}{p_{t+1}} \tag{A1d}$$

$$\lambda_{k,t}\frac{e_tp^*_t}{p_t}\left(1+\frac{p^f_t}{p_t}\upsilon\left(\frac{e_tp^*_t}{p_t}j^f_{k.t}-\overline{j^f}\right)\right) = \beta\lambda_{k,t+1}\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}(1+i^{d*}_{t+1})\frac{p^*_t}{p^*_{t+1}} \tag{A1e}$$

$$\frac{c^h_{k,t}}{c^f_{k,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{A1f}$$

$$\lambda_{k,t} - \psi_{k,t} = \beta\lambda_{k,t+1}\frac{p_t}{p_{t+1}} \tag{A1g}$$

$$\psi_{k,t}\left((1+\tau^c_t)\Phi^c_t\left(\frac{p^h_t}{p_t}c^h_{k,t}+\frac{p^f_t}{p_t}c^f_{k,t}\right)-m_{k,t}\right) = 0 \tag{A1h}$$

where $\lambda_{k,t}$ and $\psi_{k,t}$ are the Lagrange multipliers associated with the budget and the cash-in-advance constraint respectively.

It also follows from the above equations that the CPI is:

$$p_t = (p^h_t)^{\nu}(p^f_t)^{1-\nu}$$

A.2 Solution of workers' problem

Each w acts competitively choosing $\{c^h_{w,t},\ c^f_{w,t},\ c_{w,t},\ l_{w,t},\ s_{w,t},\ m_{w,t}\}_{t=0}^{\infty}$. The first-order conditions include the definition in (5) and the constraints in (6a-6c) in the main text as well as:

$$\frac{\mu_1}{c_{w,t}} = (\lambda_{w,t} + \psi_{w,t})\,(1+\tau^c_t)\Phi^c_t \tag{A2a}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \lambda_{w,t}(1-\tau^y_t)w^w_t\Phi^l_t \tag{A2b}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \lambda_{w,t}\left(\frac{\gamma\Gamma^w(s_{w,t})^{\gamma-1}(RS*G^{tr}_t)}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{A2c}$$

$$\frac{c^h_{w,t}}{c^f_{w,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{A2d}$$

$$\lambda_{w,t} - \psi_{w,t} = \beta\lambda_{w,t+1}\frac{p_t}{p_{t+1}} \tag{A2e}$$

$$\psi_{w,t}\left((1+\tau^c_t)\Phi^c_t\left(\frac{p^h_t}{p_t}c^h_{w,t} + \frac{p^f_t}{p_t}c^f_{w,t}\right) - m_{w,t}\right) = 0 \tag{A2f}$$

where $\lambda_{w,t}$ and $\psi_{w,t}$ are the Lagrange multipliers associated with the budget and the cash-in-advance constraint respectively.

A.3 Solution of public employees' problem

Each b acts competitively choosing $\{c^h_{b,t},\ c^f_{b,t},\ c_{b,t},\ l_{b,t},\ s_{b,t},\ m_{b,t}\}_{t=0}^{\infty}$. The first-order conditions include the definition in (8) and the constraints in (9a-9c) in the main text as well as:

$$\frac{\mu_1}{c_{b,t}} = (\lambda_{b,t} + \psi_{b,t})\,(1+\tau^c_t)\Phi^c_t \tag{A3a}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \lambda_{b,t}(1-\tau^y_t)w^g_t\Phi^l_t \tag{A3b}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \lambda_{b,t}\left(\frac{\gamma\Gamma^b(s_{b,t})^{\gamma-1}(RS*G^{tr}_t)}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{A3c}$$

$$\frac{c^h_{b,t}}{c^f_{b,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{A3d}$$

$$\lambda_{b,t} - \psi_{b,t} = \beta\lambda_{b,t+1}\frac{p_t}{p_{t+1}} \tag{A3e}$$

$$\psi_{b,t}\left((1+\tau_t^c)\Phi_t^c\left(\frac{p_t^h}{p_t}c_{b,t}^h+\frac{p_t^f}{p_t}c_{b,t}^f\right)-m_{b,t}\right)=0 \tag{A3f}$$

where $\lambda_{b,t}$ and $\psi_{b,t}$ are the Lagrange multipliers associated with the budget and the cash-in-advance constraint respectively.

A.4 Solution of final good firms' problem

Each final good firm acts competitively. The first-order condition for $y_{i,t}^h$ gives the demand function:

$$p_{i,t}^h = p_t^h\left(\frac{y_{i,t}^h}{y_{h,t}^h}\right)^{\theta-1} \tag{A4a}$$

which in turn implies from the zero-profit condition:

$$p_t^h=\left[\sum_{i=1}^{N^i}\frac{1}{N^i}(p_{i,t}^h)^{\frac{\theta}{\theta-1}}\right]^{\frac{\theta-1}{\theta}} \tag{A4b}$$

That is, in a symmetric equilibrium, we will have $y_{h,t}^h=y_{i,t}^h$, $p_t^h=p_{i,t}^h$ and $\pi_{h,t}=0$.

A.5 Solution of intermediate goods firms' problem

The gross profit of firm i, denoted as $\pi_{i,t}^{gross}$, is defined as sales minus the wage bill minus the cost of imported goods minus adjustment costs associated with changes in capital and prices:

$$\pi_{i,t}^{gross}\equiv\frac{p_{i,t}^h}{p_t}y_{i,t}^h-w_t^w l_{i,t}^w-w_t^k l_{i,t}^k-\frac{p_t^f}{p_t}m_{i,t}^f-$$

$$-\frac{p_t^h}{p_t}\frac{\xi^k}{2}\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)^2k_{i,t-1}-\frac{p_t^h}{p_t}\frac{\xi^p}{2}\left(\frac{p_{i,t}^h}{p_{i,t-1}^h}-1\right)^2\overline{y}_{i,t}^h \tag{A5a}$$

This gross profit is used for retained earnings, the payment of corporate taxes to the government, dividends to shareholders and interest payments for loans received from private banks. Thus,

$$\pi_{i,t}^{gross}\equiv RE_{i,t}+\tau_t^\pi\left(\frac{p_{i,t}^h}{p_t}y_{i,t}^h-w_t^w l_{i,t}^w-w_t^k l_{i,t}^k-\frac{p_t^f}{p_t}m_{i,t}^f\right)+$$

$$+\pi_{i,t}+i_t^l\frac{p_{t-1}}{p_t}L_{i,t-1}^h+i_t^{l*}\frac{p_{t-1}^*}{p_t^*}\frac{e_tp_t^*}{p_t}L_{i,t-1}^f \tag{A5b}$$

Purchases of new capital, i.e. investment, are financed by retained earnings and new loans from private banks:

$$\frac{p_t^h}{p_t}\left[k_{i,t}-(1-\delta)k_{i,t-1}\right] \equiv RE_{i,t}+(L_{i,t}-\frac{p_{t-1}}{p_t}L_{i,t-1})+\frac{e_t p_t^*}{p_t}\left(L_{i,t}^f-\frac{p_{t-1}^*}{p_t^*}L_{i,t-1}^f\right) \tag{A5c}$$

Combining the above, we have as in the main text:

$$\begin{aligned}\pi_{i,t} \equiv (1-\tau_t^{\pi})\left[\frac{p_{i,t}^h}{p_t}y_{i,t}^h - w_t^w l_{i,t}^w - w_t^k l_{i,t}^k - \frac{p_t^f}{p_t}m_{i,t}^f\right] - \\ -\frac{p_t^h}{p_t}\left[k_{i,t}-(1-\delta)k_{i,t-1}\right] - \frac{p_t^h}{p_t}\frac{\xi^k}{2}\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)^2 k_{i,t-1} - \\ -\frac{p_t^h}{p_t}\frac{\xi^p}{2}\left(\frac{p_{i,t}^h}{p_{i,t-1}^h}-1\right)^2 \overline{y}_{i,t}^h + \\ +\left(L_{i,t}^h-(1+i_t^l)\frac{p_{t-1}}{p_t}L_{i,t-1}^h\right)+\frac{e_t p_t^*}{p_t}\left(L_{i,t}^f-(1+i_t^{l*})\frac{p_{t-1}^*}{p_t^*}L_{i,t-1}^f\right)\end{aligned} \tag{A5d}$$

Therefore, each firm i maximizes the discounted sum of dividends distributed to its owners:

$$\sum_{t=0}^{\infty}\beta_{i,t}\pi_{i,t} \tag{A5e}$$

where, since firms are owned by capital owners, we will ex post postulate that the firm's discount factor, $\beta_{i,t}$, equals the capital owners' marginal rate of substitution between consumption at t and $t+1$, that is $\beta_{i,t} \equiv \beta^t \frac{\lambda_{k,t}}{\lambda_{k,0}}$.

The first-order conditions for $\{l_{i,t}^w,\, l_{i,t}^k,\, m_{i,t}^f,\, k_{i,t},\, L_{i,t}^h,\, L_{i,t}^f\}_{t=0}^{\infty}$ are respectively:

$$\begin{aligned}(1-\tau_t^{\pi})w_t^w + N_{i,t}\eta w_t^w = [(1-\tau_t^{\pi})\theta_t\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}\frac{(\theta_t-1)\overline{y}_{i,t}^h}{y_{i,t}^h} + \\ +\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta_{t+1}-1)\overline{y}_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^w y_{i,t}^h}{(A^k l_{i,t}^k + A^w l_{i,t}^w)}\end{aligned} \tag{A5f}$$

$$\begin{aligned}(1-\tau_t^{\pi})w_t^k + N_{i,t}\eta w_t^k = [(1-\tau_t^{\pi})\theta_t\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}\frac{(\theta_t-1)\overline{y}_{i,t}^h}{y_{i,t}^h} + \\ +\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta_{t+1}-1)\overline{y}_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^k y_{i,t}^h}{(A^k l_{i,t}^k + A^w l_{i,t}^w)}\end{aligned} \tag{A5g}$$

$$(1-\tau_t^{\pi})\frac{p_t^f}{p_t} = [(1-\tau_t^{\pi})\theta_t\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}\frac{(\theta_t-1)\overline{y}_{i,t}^h}{y_{i,t}^h} +$$

$$+\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta_{t+1}-1)\overline{y}^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)\alpha y^h_{i,t}(1-\chi^p)(m^f_{i,t})^{op-1}}{\left[\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m^f_{i,t})^{op}\right]} \tag{A5h}$$

$$\frac{p^h_t}{p_t}\left[\frac{1}{\psi_t}+\xi^k\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)\right]=\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}[1-\delta+(1-\tau^\pi_{t+1})\theta_{t+1}r^k_{t+1}-$$

$$-\frac{\xi^k}{2}\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)^2+\xi^k\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)\frac{k_{i,t+1}}{k_{i,t}}]-$$

$$-\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}(\theta_{t+1}-1)r^k_{t+1}+$$

$$+\beta^2\frac{\lambda_{k,t+2}}{\lambda_{k,t}}\frac{p^h_{t+2}}{p_{t+2}}\xi^p\left(\frac{p^h_{t+2}}{p^h_{t+1}}-1\right)\frac{p^h_{t+2}}{p^h_{t+1}}(\theta_{t+2}-1)r^k_{t+1} \tag{A5i}$$

$$1+N_{i,t}=\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}(1+i^l_{t+1})\frac{p_t}{p_{t+1}} \tag{A5j}$$

$$\frac{e_tp^*_t}{p_t}+N_{i,t}\frac{e_tp^*_t}{p_t}=\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}(1+i^{l*}_{t+1})\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}\frac{p^*_t}{p^*_{t+1}} \tag{A5k}$$

and we also have the complementary slackness condition on the borrowing constraint:

$$N_{i,t}\left(\left(L^h_{i,t}+\frac{e_tp^*_t}{p_t}L^f_{i,t}\right)-\eta(w^w_t\frac{n^{w,e}_tn^w}{n^k}l_{w,t}+w^k_tl_{k,t})\right)=0 \tag{A5l}$$

where $N_{i,t}$ is i's multiplier associated with the borrowing constraint and $r^k_{t+1}\equiv\frac{\partial y^h_{i,t+1}}{\partial k_{i,t}}=\frac{(1-\sigma)\alpha y^h_{i,t+1}\chi^p(k_{i,t})^{op-1}}{\left[\chi^p(k_{i,t})^{op}+(1-\chi^p)(m^f_{i,t+1})^{op}\right]}$.

Notice that (A5j) and (A5k) jointly with the Euler equation for bank deposits in the savers' problem, reveals that i^l_{t+1} can differ from i^d_{t+1}, which is helpful in the private banks' optimization problem that follows below.

A.6 Solution of private banks' problem

The gross profit of each bank p, denoted as $\pi^{gross}_{p,t}$, is defined as net interest income minus adjustment costs associated with changes in assets and liabilities:

$$\pi^{gross}_{p,t}\equiv(1+i^l_t)\frac{p_{t-1}}{p_t}L_{p,t-1}+(1+i^{b*}_t)\frac{p^*_{t-1}}{p^*_t}\frac{e_tp^*_t}{p_t}f_{p,t-1}+(1+i^r_t)\frac{p_{t-1}}{p_t}m_{p,t-1}+$$

$$+(1+i^b_t)\frac{p_{t-1}}{p_t}\Lambda_tb_{p,t-1}+\Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)b_{p,t-1}-$$

$$-(1+i_t^d)\frac{p_{t-1}}{p_t}j_{p,t-1}-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}-\frac{p_t^h}{p_t}\Xi(\cdot) \tag{A6a}$$

The gross profit is used to pay taxes, dividends to shareholders, $\pi_{p,t}$, and what is left is net worth, $n_{p,t}$:

$$\pi_{p,t}^{gross} \equiv \tau_t^{\pi}\pi_{p,t}^{gross}+\pi_{p,t}+n_{p,t} \tag{A6b}$$

where net worth is defined as assets minus liabilities:

$$n_{p,t} \equiv L_{p,t}+b_{p,t}+\frac{e_t p_t^*}{p_t}f_{p,t}+m_{p,t}-j_{p,t}-z_{p,t} \tag{A6c}$$

Combining the above, we have as in the main text:

$$\pi_{p,t}=(1-\tau_t^{\pi})\left[(1+i_t^l)\frac{p_{t-1}}{p_t}L_{p,t-1}+(1+i_t^{b*})\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{p,t-1}+(1+i_t^r)\frac{p_{t-1}}{p_t}m_{p,t-1}+\right.$$

$$+(1+i_t^b)\frac{p_{t-1}}{p_t}\Lambda_t b_{p,t-1}+\Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)b_{p,t-1}-$$

$$\left.-(1+i_t^d)\frac{p_{t-1}}{p_t}j_{p,t-1}-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}-\frac{p_t^h}{p_t}\Xi(\cdot)\right]-$$

$$-L_{p,t}-b_{p,t}-\frac{e_t p_t^*}{p_t}f_{p,t}-m_{p,t}+j_{p,t}+z_{p,t} \tag{A6d}$$

We solve the problem as in Curdia and Woodford (2011). Thus, we set in each time period:

$$(1+i_t^d)\frac{p_{t-1}}{p_t}j_{p,t-1}+(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}=(1+i_t^l)\frac{p_{t-1}}{p_t}L_{p,t-1}+$$

$$+(1+i_t^b)\Lambda_t\frac{p_{t-1}}{p_t}b_{p,t-1}+\Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)b_{p,t-1}+ \tag{A6e}$$

$$+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{p,t-1}+(1+i_t^r)\frac{p_{t-1}}{p_t}m_{p,t-1}$$

so that by leading it one period forward we have for the issuance of deposits at time t:

$$j_{p,t}=\frac{(1+i_{t+1}^l)\frac{p_t}{p_{t+1}}L_{p,t}+(1+i_{t+1}^b)\frac{p_t}{p_{t+1}}\Lambda_{t+1}b_{p,t}+\Phi_{t+1}\frac{p_t}{p_{t+1}}(1-\Lambda_{t+1})b_{p,t}}{(1+i_{t+1}^d)\frac{p_t}{p_{t+1}}}+$$

$$\frac{+(1+i^*_{t+1})\frac{p^*_t}{p^*_{t+1}}\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}f_{p,t}+(1+i^r_{t+1})\frac{p_t}{p_{t+1}}m_{p,t}-(1+i^z_{t+1})\frac{p_t}{p_{t+1}}z_{p,t}}{(1+i^d_{t+1})\frac{p_t}{p_{t+1}}} \quad \text{(A6f)}$$

Combining the above, we have:

$$\pi_{p,t}=j_{p,t}+z_{p,t}-L_{p,t}-b_{p,t}-\frac{e_t p^*_t}{p_t}f_{p,t}-(1-\tau^\pi_t)\frac{p^h_t}{p_t}\Xi(\cdot) \quad \text{(A6g)}$$

where we use:

$$\Xi(\cdot)=\frac{\xi^l}{2}(L_{p,t-1})^2+\frac{\xi^b}{2}(\Lambda_t b_{p,t-1})^2+\frac{\xi^f}{2}(\frac{e_t p^*_t}{p_t}f_{p,t-1})^2+$$
$$+\frac{\xi^m}{2}(m_{p,t-1}+\Phi_t(1-\Lambda_t)b_{p,t-1})^{-2}+\frac{\xi^z}{2}(z_{p,t-1})^2$$

which can give well-defined demand and supply functions.

Since private banks are owned by capital owners, we will ex post postulate that the banks's discount factor, $\beta_{p,t}$, equals the capital owners' marginal rate of substitution between consumption at t and $t+1$, $\beta_{p,t}\equiv\beta^t\frac{\lambda_{k,t}}{\lambda_{k,0}}$.

The first-order conditions for $L_{p,t}$, $b_{p,t}$, $f_{p,t}$, $m_{p,t}$ and $z_{p,t}$ are:

$$\frac{p^h_{t+1}}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}(1-\tau^\pi_{t+1})\xi^l(L_{p,t})=\frac{(1+i^l_{t+1})}{(1+i^d_{t+1})}-1 \quad \text{(A6h)}$$

$$\frac{p^h_{t+1}}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}(1-\tau^\pi_{t+1})\xi^b(\Lambda_{t+1}b_{p,t})\Lambda_{t+1}=\frac{(1+i^b_{t+1})\Lambda_{t+1}+\Phi_{t+1}(1-\Lambda_{t+1})}{(1+i^d_{t+1})}-1+ \quad \text{(A6i)}$$

$$+\frac{p^h_{t+1}}{p_{t+1}}\beta(1-\tau^\pi_{t+1})\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\xi^m\left(m_{p,t}+\Phi_{t+1}(1-\Lambda_{t+1})b_{p,t}\right)^{-3}\Phi_{t+1}(1-\Lambda_{t+1})$$

$$\frac{p^h_{t+1}}{p_{t+1}}\beta(1-\tau^\pi_{t+1})\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\xi^f\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}(\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}f_{p,t})=\frac{(1+i^*_{t+1})\frac{p^*_t}{p^*_{t+1}}\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}}{(1+i^d_{t+1})\frac{p_t}{p_{t+1}}}-\frac{e_t p^*_t}{p_t} \quad \text{(A6j)}$$

$$\frac{p^h_{t+1}}{p_{t+1}}\beta(1-\tau^\pi_{t+1})\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\xi^m\left(m_{p,t}+\Phi_{t+1}\frac{p_t}{p_{t+1}}(1-\Lambda_{t+1})b_{p,t}\right)^{-3}=1-\frac{(1+i^r_{t+1})}{(1+i^d_{t+1})} \quad \text{(A6k)}$$

$$\frac{p^h_{t+1}}{p_{t+1}}\beta(1-\tau^\pi_{t+1})\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\xi^z(z_{p,t})=1-\frac{(1+i^z_{t+1})}{(1+i^d_{t+1})} \quad \text{(A6l)}$$

A.7 Budget constraint of the consolidated public sector

To the extent that the transfer/dividend from the NCB to its government, rcb_t^g, is treated as an endogenous variable, we can merge the budget constraint of the Treasury and the budget constraint of the NCB into a single constraint, the budget identity of the consolidated public sector (see e.g. Reis (2017) and Benigno and Nisticò (2017) for details). That is, by also using the market-clearing condition for currency $m_{n,t} = n^k m_{k,t} + n^w m_{w,t} + n^b m_{b,t}$, we get (written in real and per capita terms):

$$
\begin{aligned}
& g_t^{tr} + n^b \left[w_t^g l_{g,t}^g + \frac{p_t^h}{p_t} \left(g_{g,t}^g + g_{g,t}^i \right) + \frac{p_t^f}{p_t} m_{g,t}^g \right] + \\
& + \left[\Lambda_t (1 + i_t^b) + (1 - \Lambda_t) \Phi_t \right] \frac{p_{t-1}}{p_t} \lambda_{t-1}^d d_{t-1} + \\
& + \left[\Lambda_t (1 + i_t^b) + (1 - \Lambda_t) \Phi_t \right] \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^g d_{t-1} + \\
& + (1 + i^*) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^{eu} d_{t-1} \equiv \\
& \equiv d_t + \frac{T_t}{N} + \\
& + \left(m_{n,t} - \frac{p_{t-1}}{p_t} m_{n,t-1} \right) + \\
& + n^k \left(m_{p,t} - (1 + i_t^r) \frac{p_{t-1}}{p_t} m_{p,t-1} \right) - n^k \left(z_{p,t} - (1 + i_t^z) \frac{p_{t-1}}{p_t} z_{p,t-1} \right) + \\
& + \left(TARG_t - (1 + i_t^{MRO}) \frac{p_{t-1}}{p_t} TARG_{t-1} \right) + pmi_t \qquad \text{(A7)}
\end{aligned}
$$

where all variables have been defined above.

A.8 Market-clearing conditions and the macroeconomic system

A.8.1 Market-clearing conditions

Recall first the definitions of populations and their fractions. That is, $N^k + N^w + N^b = N$, $n^k = \frac{N^k}{N}$, $n^b = \frac{N^b}{N}$, $n^w = \frac{N^b}{N} = 1 - n^k - n^b$. Recall also that we have assumed for notational simplicity $N^k = N^h = N^i = N^p$ and $N^b = N^g$.

Then, we have the following market-clearing conditions:

In the markets for dividends (firms and banks):

$$N^k \pi^i_{k,t} = N^i \pi_{i,t} = N^k \pi_{i,t} \tag{A8a}$$

$$N^k \pi^p_{k,t} = N^p \pi_{p,t} = N^k \pi_{p,t} \tag{A8b}$$

In the labor market for managerial services:

$$N^k \Phi^l_t l_{k,t} = N^i l^k_{i,t} = N^k l^k_{i,t} \tag{A8c}$$

In the labor market for public employees:

$$N^b \Phi^l_t l_{b,t} = N^g l_{g,t} = N^b l_{g,t} \tag{A8d}$$

In the labor market for private workers:

$$N^w \Phi^l_t l_{w,t} = N^i l^w_{i,t} = N^k l^w_{i,t} \tag{A8e}$$

In the bank deposit market:

$$N^p j_{p,t} = N^k j_{p,t} = N^k j^h_{k,t} + N^{k*} j^{f*}_{k,t} \tag{A8f}$$

where $j^{f*}_{k,t}$ denotes the deposits of foreign households in domestic banks expressed in domestic prices and N^{k*} is their respective number.

In the market for domestic bank loans:

$$N^p L_{p,t} = N^k L_{p,t} = N^k L^h_{i,t} + N^{k*} L^{f*}_{i,t} \tag{A8g}$$

where $L^{f*}_{i,t}$ is loans demanded by foreign firms from domestic banks expressed in domestic prices N^{k*} is their respective number. For simplicity we set $N^{k*} = N^k$.

Regarding sovereign bonds purchased by domestic private agents:

$$n^k b_{p,t} \equiv b^d_t = \lambda^d_t d_t \tag{A8h}$$

In the money market (currency):

$$m_{n,t} = n^k m_{k,t} + n^w m_{w,t} + n^b m_{b,t} \tag{A8i}$$

In the market for the domestically produced good:

$$n^k y_{i,t}^h = n^k c_{k,t}^h + n^w c_{w,t}^h + n^b c_{b,t}^h + n^k x_{k,t} + n^b (g_{g,t}^g + g_{g,t}^i) + c_t^{f*} + \tag{A8j}$$

$$+n^k \frac{\xi^k}{2} \left(\frac{k_{k,t}}{k_{k,t-1}} - 1 \right)^2 k_{k,t-1} + n^k \frac{\xi^p}{2} \left(\frac{p_t^h}{p_{t-1}^h} - 1 \right)^2 y_{i,t}^h +$$

$$+n^k (\frac{\xi^l}{2} (L_{p,t-1})^2 + \frac{\xi^b}{2} (\Lambda_t b_{p,t-1})^2 + \frac{\xi^f}{2} (\frac{e_t p_t^*}{p_t} f_{p,t-1})^2 +$$

$$+\frac{\xi^m}{2} (m_{p,t-1} + \Phi_t (1 - \Lambda_t) b_{p,t-1})^{-2} + \frac{\xi^z}{2} (z_{p,t-1})^2) \tag{A8k}$$

where c_t^{f*} denotes per capita exports to the rest of the world. Since in a small open economy this is an exogenous variable, we assume, following e.g. Lorenzoni (2014, p. 698), that $c_t^{f*} = \Omega \left(\frac{p_t^h}{p_t^f} \right)^{-\vartheta}$, where $\Omega, \vartheta > 0$ are parameters.

A.8.2 Macroeconomic system

Collecting all equations, the macroeconomic system that we solve numerically consists of the following equations:

Capital owners

$$c_{k,t} = \frac{(c_{k,t}^h)^\nu (c_{k,t}^f)^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{S1}$$

$$\frac{\mu_1}{c_{k,t}} = (\lambda_{k,t} + \psi_{k,t}) (1 + \tau_t^c) \Phi_t^c \tag{S2}$$

$$\frac{\mu_2}{(1 - l_{k,t} - s_{k,t})} = \lambda_{k,t} (1 - \tau_t^y) w_t^k \Phi_t^l \tag{S3}$$

$$\frac{\mu_2}{(1 - l_{k,t} - s_{k,t})} = \lambda_{k,t} \left(\frac{\gamma \Gamma^k (s_{k,t})^{\gamma-1} (RS * \overline{g}_t^{tr})}{n^k \Gamma^k (s_{k,t})^\gamma + n^w \Gamma^w (s_{w,t})^\gamma + n^b \Gamma^b (s_{b,t})^\gamma} \right) \tag{S4}$$

$$\lambda_{k,t} = \beta \lambda_{k,t+1} (1 + i_{t+1}^d) \frac{p_t}{p_{t+1}} \tag{S5}$$

$$\lambda_{k,t}\frac{e_t p_t^*}{p_t}\left(1+\frac{p_t^f}{p_t}\upsilon\left(\frac{e_t p_t^*}{p_t}j_{k.t}^f-\overline{j^f}\right)\right)=\beta\lambda_{k,t+1}\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}(1+i_{t+1}^{d*})\frac{p_t^*}{p_{t+1}^*} \quad \text{(S6)}$$

$$\frac{c_{k,t}^h}{c_{k,t}^f}=\frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \quad \text{(S7)}$$

$$\lambda_{k,t}-\psi_{k,t}=\beta\lambda_{k,t+1}\frac{p_t}{p_{t+1}} \quad \text{(S8)}$$

$$\psi_{k,t}\left((1+\tau_t^c)\Phi_t^c\left(\frac{p_t^h}{p_t}c_{k,t}^h+\frac{p_t^f}{p_t}c_{k,t}^f\right)-m_{k,t}\right)=0 \quad \text{(S9)}$$

Workers

$$c_{w,t}=\frac{(c_{w,t}^h)^\nu(c_{w,t}^f)^{1-\nu}}{\nu^\nu(1-\nu)^{1-\nu}} \quad \text{(S10)}$$

$$(1+\tau_t^c)\left(\frac{p_t^h}{p_t}\Phi_t^c c_{w,t}^h+\frac{p_t^f}{p_t}\Phi_t^c c_{w,t}^f\right)+m_{w,t}\equiv$$

$$\equiv(1-\tau_t^y)w_t^w\Phi_t^l l_{w,t}+\frac{p_{t-1}}{p_t}m_{w,t-1}+(1-RS)\overline{g}_t^{tr}+$$

$$+\frac{\Gamma^w(s_{w,t})^\gamma(RS*\overline{g}_t^{tr})}{n^k\Gamma^k(s_{k,t})^\gamma+n^w\Gamma^w(s_{w,t})^\gamma+n^b\Gamma^b(s_{b,t})^\gamma} \quad \text{(S11)}$$

$$\frac{\mu_1}{c_{w,t}}=(\lambda_{w,t}+\psi_{w,t})(1+\tau_t^c)\Phi_t^c \quad \text{(S12)}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})}=\lambda_{w,t}(1-\tau_t^y)w_t^w\Phi_t^l \quad \text{(S13)}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})}=\lambda_{w,t}\left(\frac{\gamma\Gamma^w(s_{w,t})^{\gamma-1}(RS*\overline{g}_t^{tr})}{n^k\Gamma^k(s_{k,t})^\gamma+n^w\Gamma^w(s_{w,t})^\gamma+n^b\Gamma^b(s_{b,t})^\gamma}\right) \quad \text{(S14)}$$

$$\frac{c_{w,t}^h}{c_{w,t}^f}=\frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \quad \text{(S15)}$$

$$\lambda_{w,t}-\psi_{w,t}=\beta\lambda_{w,t+1}\frac{p_t}{p_{t+1}} \quad \text{(S16)}$$

$$\psi_{w,t}\left((1+\tau_t^c)\Phi_t^c\left(\frac{p_t^h}{p_t}c_{w,t}^h+\frac{p_t^f}{p_t}c_{w,t}^f\right)-m_{w,t}\right)=0 \quad \text{(S17)}$$

Public employees

$$c_{b,t} = \frac{(c_{b,t}^h)^\nu (c_{b,t}^f)^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{S18}$$

$$(1+\tau_t^c)\left(\frac{p_t^h}{p_t}\Phi_t^c c_{b,t}^h + \frac{p_t^f}{p_t}\Phi_t^c c_{b,t}^f\right) + m_{b,t} =$$

$$= (1-\tau_t^y) w_t^g \Phi_t^l l_{b,t} + \frac{p_{t-1}}{p_t} m_{b,t-1} + (1-RS) * \overline{g}_t^{tr} +$$

$$+ \frac{\Gamma^b (s_{b,t})^\gamma (RS * \overline{g}_t^{tr})}{n^k \Gamma^k (s_{k,t})^\gamma + n^w \Gamma^w (s_{w,t})^\gamma + n^b \Gamma^b (s_{b,t})^\gamma} \tag{S19}$$

$$\frac{\mu_1}{c_{b,t}} = (\lambda_{b,t} + \psi_{b,t})(1+\tau_t^c)\Phi_t^c \tag{S20}$$

$$\frac{\mu_2}{(1 - l_{b,t} - s_{b,t})} = \lambda_{b,t}(1-\tau_t^y) w_t^g \Phi_t^l \tag{S21}$$

$$\frac{\mu_2}{(1 - l_{b,t} - s_{b,t})} = \lambda_{b,t}\left(\frac{\gamma \Gamma^b (s_{b,t})^{\gamma-1} (RS * \overline{g}_t^{tr})}{n^k \Gamma^k (s_{k,t})^\gamma + n^w \Gamma^w (s_{w,t})^\gamma + n^b \Gamma^b (s_{b,t})^\gamma}\right) \tag{S22}$$

$$\frac{c_{b,t}^h}{c_{b,t}^f} = \frac{\nu}{(1-\nu)} \frac{p_t^f}{p_t^h} \tag{S23}$$

$$\lambda_{b,t} - \psi_{b,t} = \beta \lambda_{b,t+1} \frac{p_t}{p_{t+1}} \tag{S24}$$

$$\psi_{w,t}\left((1+\tau_t^c)\Phi_t^c \left(\frac{p_t^h}{p_t} c_{b,t}^h + \frac{p_t^f}{p_t} c_{b,t}^f\right) - m_{b,t}\right) = 0 \tag{S25}$$

Price indexes

$$p_t = (p_t^h)^\nu (p_t^f)^{1-\nu} \tag{S26}$$

$$p_t^f = e_t p_t^{h*} \tag{S27}$$

Private (intermediate goods) firms

$$y_{i,t}^h = A^p \left(\frac{n^g y_{g,t}^g}{n^k}\right)^\sigma \left[\left(\chi^p (k_{i,t-1})^{op} + (1-\chi^p)(m_{i,t}^f)^{op}\right)^{\frac{\alpha}{op}} \left(A^k \Phi_t^l l_{k,t} + A^w \frac{n_t^{w,e} n^w \Phi_t^l l_{w,t}}{n^k}\right)^{1-\alpha}\right]^{1-\sigma} \tag{S28}$$

$$(1-\tau_t^\pi) w_t^w + N_{i,t} \eta w_t^w = [(1-\tau_t^\pi)\theta_t \frac{p_t^h}{p_t} - \frac{p_t^h}{p_t} \xi^p \left(\frac{p_t^h}{p_{t-1}^h} - 1\right) \frac{p_t^h}{p_{t-1}^h}(\theta_t - 1) +$$

$$+\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta_{t+1}-1)y^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)(1-\alpha)A^w y^h_{i,t}}{(A^k\Phi^l_t l_{k,t}+A^w\frac{n^{w,e}_t n^w\Phi^l_t l_{w,t}}{n^k})} \tag{S29}$$

$$(1-\tau^\pi_t)w^k_t+N_{i,t}\eta w^k_t=[(1-\tau^\pi_t)\theta_t\frac{p^h_t}{p_t}-\frac{p^h_t}{p_t}\xi^p\left(\frac{p^h_t}{p^h_{t-1}}-1\right)\frac{p^h_t}{p^h_{t-1}}(\theta_t-1)+$$

$$+\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta_{t+1}-1)y^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)(1-\alpha)A^k y^h_{i,t}}{(A^k\Phi^l_t l_{k,t}+A^w\frac{n^{w,e}_t n^w\Phi^l_t l_{w,t}}{n^k})} \tag{S30}$$

$$\frac{p^h_t}{p_t}\left[1+\xi^k\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)\right]=\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}[1-\delta+(1-\tau^\pi_{t+1})\theta_{t+1}r^k_{t+1}-$$
$$-\frac{\xi^k}{2}\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)^2+\xi^k\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)\frac{k_{i,t+1}}{k_{i,t}}]-$$
$$-\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}(\theta_{t+1}-1)r^k_{t+1}+$$
$$+\beta^2\frac{\lambda_{k,t+2}}{\lambda_{k,t}}\frac{p^h_{t+2}}{p_{t+2}}\xi^p\left(\frac{p^h_{t+2}}{p^h_{t+1}}-1\right)\frac{p^h_{t+2}}{p^h_{t+1}}(\theta_{t+2}-1)r^k_{t+1} \tag{S31}$$

$$(1-\tau^\pi_t)\frac{p^f_t}{p_t}=[(1-\tau^\pi_t)\theta\frac{p^h_t}{p_t}-\frac{p^h_t}{p_t}\xi^p\left(\frac{p^h_t}{p^h_{t-1}}-1\right)\frac{p^h_t}{p^h_{t-1}}(\theta_t-1)+$$

$$+\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta_{t+1}-1)y^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)\alpha y^h_{i,t}(1-\chi^p)(m^f_{i,t})^{op-1}}{\left[\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m^f_{i,t})^{op}\right]} \tag{S32}$$

$$k_{i,t}=x_{i,t}+(1-\delta)\,k_{i,t-1} \tag{S33}$$

$$\pi_{i,t}\equiv(1-\tau^\pi_t)\left[\frac{p^h_t}{p_t}y^h_{i,t}-w^w_t\frac{n^w}{n^k}\Phi^l_t l_{w,t}-w^k_t\Phi^l_t l_{k,t}-\frac{p^f_t}{p_t}m^f_{i,t}\right]-$$
$$-\frac{p^h_t}{p_t}\left[k_{k,t}-(1-\delta)k_{k,t-1}\right]-\frac{p^h_t}{p_t}\frac{\xi^k}{2}\left(\frac{k_{k,t}}{k_{k,t-1}}-1\right)^2k_{k,t-1}-$$

$$-\frac{p^h_t}{p_t}\frac{\xi^p}{2}\left(\frac{p^h_t}{p^h_{t-1}}-1\right)^2y^h_{i,t}+\left(L^h_{i,t}-(1+i^l_t)\frac{p_{t-1}}{p_t}L^h_{i,t-1}\right)+\frac{e_t p^*_t}{p_t}\left(L^f_{i,t}-(1+i^{l*}_t)\frac{p^*_{t-1}}{p^*_t}L^f_{i,t-1}\right) \tag{S34}$$

$$1 + N_{i,t} = \beta \frac{\lambda_{k,t+1}}{\lambda_{k,t}} (1 + i^l_{t+1}) \frac{p_t}{p_{t+1}} \tag{S35}$$

$$\frac{e_t p^*_t}{p_t} + N_{i,t} \frac{e_t p^*_t}{p_t} = \beta \frac{\lambda_{k,t+1}}{\lambda_{k,t}} (1 + i^{l*}_{t+1}) \frac{e_{t+1} p^*_{t+1}}{p_{t+1}} \frac{p^*_t}{p^*_{t+1}} \tag{S36}$$

$$N_{i,t} \left(\left(L^h_{i,t} + \frac{e_t p^*_t}{p_t} L^f_{i,t} \right) - \eta (w^w_t \frac{n^{w,e}_t n^w}{n^k} \Phi^l_t l_{w,t} + w^k_t \Phi^l_t l_{k,t}) \right) = 0 \tag{S37}$$

where $r^k_{t+1} \equiv \frac{\partial y^h_{i,t+1}}{\partial k_{k,t}} = \frac{(1-\sigma)\alpha y^h_{i,t+1} \chi^p (k_{k,t})^{op-1}}{\left[\chi^p (k_{i,t})^{op} + (1-\chi^p)(m^f_{i,t+1})^{op}\right]}$.

Private banks

$$\pi_{p,t} \equiv j_{p,t} + z_{p,t} - L_{p,t} - \lambda^d_t d_t - \frac{e_t p^*_t}{p_t} f_{p,t} - m_{p,t} -$$

$$-\left(1 - \tau^\pi_t\right) \frac{p^h_t}{p_t} \Xi(L_{p,t-1}, \lambda^d_{t-1} d_{t-1}, m_{p,t-1}, \frac{e_t p^*_t}{p_t} f_{p,t-1}, z_{p,t-1}) \tag{S38}$$

$$j_{p,t} = \frac{(1 + i^l_{t+1}) \frac{p_t}{p_{t+1}} L_{p,t} + (1 + i^b_{t+1}) \frac{p_t}{p_{t+1}} \Lambda_{t+1} \lambda^d_t d_t + \Phi_{t+1} \frac{p_t}{p_{t+1}} (1 - \Lambda_{t+1}) \lambda^d_t d_t}{(1 + i^d_{t+1}) \frac{p_t}{p_{t+1}}} +$$

$$\frac{+(1 + i^*_{t+1}) \frac{p^*_t}{p^*_{t+1}} \frac{e_{t+1} p^*_{t+1}}{p_{t+1}} f_{p,t} + (1 + i^r_{t+1}) \frac{p_t}{p_{t+1}} m_{p,t} - (1 + i^z_{t+1}) \frac{p_t}{p_{t+1}} z_{p,t}}{(1 + i^d_{t+1}) \frac{p_t}{p_{t+1}}} \tag{S39}$$

$$\frac{p^h_{t+1}}{p_{t+1}} \beta \frac{\lambda_{k,t+1}}{\lambda_{k,t}} \left(1 - \tau^\pi_{t+1}\right) \xi^l (L_{p,t}) = \frac{(1 + i^l_{t+1})}{(1 + i^d_{t+1})} - 1 \tag{S40}$$

$$\frac{p^h_{t+1}}{p_{t+1}} \beta \frac{\lambda_{k,t+1}}{\lambda_{k,t}} \left(1 - \tau^\pi_{t+1}\right) \xi^b (\Lambda_{t+1} \lambda^d_t d_t) \Lambda_{t+1} = \frac{(1 + i^b_{t+1}) \Lambda_t + \Phi_{t+1} \left(1 - \Lambda_{t+1}\right)}{(1 + i^d_{t+1})} - 1 + \tag{S41}$$

$$+ \frac{p^h_{t+1}}{p_{t+1}} \beta \frac{\lambda_{k,t+1}}{\lambda_{k,t}} \left(1 - \tau^\pi_{t+1}\right) \xi^m \left(m_{p,t} + \Phi_{t+1} (1 - \Lambda_{t+1}) \lambda^d_t d_t\right)^{-3} \Phi_{t+1} (1 - \Lambda_{t+1})$$

$$\frac{p^h_{t+1}}{p_{t+1}} \beta \frac{\lambda_{k,t+1}}{\lambda_{k,t}} \left(1 - \tau^\pi_{t+1}\right) \xi^f \frac{e_{t+1} p^*_{t+1}}{p_{t+1}} (\frac{e_{t+1} p^*_{t+1}}{p_{t+1}} f_{p,t}) = \frac{(1 + i^*_{t+1}) \frac{p^*_t}{p^*_{t+1}} \frac{e_{t+1} p^*_{t+1}}{p_{t+1}}}{(1 + i^d_{t+1}) \frac{p_t}{p_{t+1}}} - \frac{e_t p^*_t}{p_t} \tag{S42}$$

$$\frac{p^h_{t+1}}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\left(1-\tau^{\pi}_{t+1}\right)\xi^m\left(m_{p,t}+\Phi_{t+1}\frac{p_t}{p_{t+1}}(1-\Lambda_{t+1})\lambda^d_t d_t\right)^{-3}=1-\frac{(1+i^r_{t+1})}{(1+i^d_{t+1})} \tag{S43}$$

$$\frac{p^h_{t+1}}{p_{t+1}}\beta\left(1-\tau^{\pi}_{t+1}\right)\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\xi^z(z_{p,t})=1-\frac{(1+i^z_{t+1})}{(1+i^d_{t+1})} \tag{S44}$$

where

$$n^k j_{p,t}=n^k j^h_{k,t}+n^k j^{f*}_{k,t} \tag{S45}$$

$$n^p L_{p,t}=n^k L_{p,t}=n^k L^h_{i,t}+n^k L^{f*}_{i,t} \tag{S46}$$

and where we use:

$$\Xi(L_{p,t-1},\lambda^d_{t-1}d_{t-1},m_{p,t-1},\frac{e_t p^*_t}{p_t}f_{p,t-1},z_{p,t-1})=\frac{\xi^l}{2}(L_{p,t-1})^2+\frac{\xi^b}{2}(\Lambda_t\lambda^d_{t-1}d_{t-1})^2+\frac{\xi^f}{2}(\frac{e_t p^*_t}{p_t}f_{p,t-1})^2+$$

$$+\frac{\xi^m}{2}(m_{p,t-1}+\Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)b_{p,t-1})^{-2}+\frac{\xi^z}{2}(z_{p,t-1})^2$$

State firms

$$y^g_{g,t}=A^g\left(\chi^g(k^g_{g,t-1})^{og}+(1-\chi^g)(m^g_{g,t})^{og}\right)^{\frac{\theta_1}{og}}(\Phi^l_t l_{b,t})^{\theta_2}\left(g^g_{g,t}\right)^{1-\theta_1-\theta_2} \tag{S47}$$

$$k^g_{g,t}=(1-\delta^g)k^g_{g,t-1}+g^i_{g,t} \tag{S48}$$

Consolidated government budget constraint

$$\overline{g}^{tr}_t+n^b\left[w^g_t\Phi^l_t l_{b,t}+\frac{p^h_t}{p_t}\left(g^g_{g,t}+g^i_{g,t}\right)+\frac{p^f_t}{p_t}m^g_{g,t}\right]+$$

$$+\Big((1+i^b_t)\Lambda_t+\Phi_t(1-\Lambda_t)\Big)\frac{p_{t-1}}{p_t}(1-\lambda^g_{t-1}-\lambda^{eu}_{t-1})d_{t-1}+$$

$$+\Big((1+i^b_t)\Lambda_t+\Phi_t(1-\Lambda_t)\Big)\frac{p^*_{t-1}}{p^*_t}\frac{e_t p^*_t}{p_t}\frac{p_{t-1}}{e_{t-1}p^*_{t-1}}\lambda^g_{t-1}d_{t-1}+$$

$$+(1+i^*)\frac{p^*_{t-1}}{p^*_t}\frac{e_t p^*_t}{p_t}\frac{p_{t-1}}{e_{t-1}p^*_{t-1}}\lambda^{eu}_{t-1}d_{t-1}=$$

$$=d_t+\frac{T_t}{N}+$$

$$+\left(n^k m_{k,t}+n^w m_{w,t}+n^b m_{b,t}-\frac{p_{t-1}}{p_t}(n^k m_{k,t-1}+n^w m_{w,t-1}+n^b m_{b,t-1})\right)+$$

$$+n^k\left(m_{p,t}-(1+i_t^r)\frac{p_{t-1}}{p_t}m_{p,t-1}\right)-n^k\left(z_{p,t}-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}\right)+$$

$$+\left(t\arg_t-\left(1+i_t^{MRO}\right)\frac{P_{t-1}}{P_t}t\arg_{t-1}\right)+pmi_t \tag{S49}$$

Gross Domestic Product (GDP) identity

$$n^k y_{i,t}^h=n^k\Phi_t^c c_{k,t}^h+n^w\Phi_t^c c_{w,t}^h+n^b\Phi_t^c c_{b,t}^h+n^k x_{k,t}+n^b(g_{g,t}^g+g_{g,t}^i)+c_t^{f*}+$$

$$+n^k\frac{\xi^k}{2}\left(\frac{k_{k,t}}{k_{k,t-1}}-1\right)^2 k_{k,t-1}+n^k\frac{\xi^p}{2}\left(\frac{p_t^h}{p_{t-1}^h}-1\right)^2 y_{i,t}^h+$$

$$+n^k\Xi(L_{p,t-1},\lambda_{t-1}^d d_{t-1},m_{p,t-1},\frac{e_t p_t^*}{p_t}f_{p,t-1},z_{p,t-1}) \tag{S50}$$

where c_t^{f*} is exports to the rest of the world (defined below).

Balance of payments (economy's resource constraint)

$$\frac{p_t^f}{p_t}\left(n^k\Phi_t^c c_{k,t}^f+n^w\Phi_t^c c_{w,t}^f+n^b\Phi_t^c c_{b,t}^f+n^k m_{i,t}^f+n^b m_{g,t}^g\right)-\frac{p_t^h}{p_t}c_t^{f*}+$$

$$+n^k\frac{e_t p_t^*}{p_t}j_{k,t}^f+n^k\frac{p_t^f}{p_t}\frac{\upsilon}{2}\left(\frac{e_t p_t^*}{p_t}j_{k,t}^f-\overline{j^f}\right)^2+n^k\frac{e_t p_t^*}{p_t}f_{p,t}+n^k L_{i,t}^{f*}$$

$$+n^k(1+i_t^d)\frac{p_{t-1}}{p_t}j_{k,t-1}^{f*}+n^k(1+i_t^{l*})\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}L_{i,t-1}^f$$

$$+\left((1+i_t^b)\Lambda_t+\Phi_t(1-\Lambda_t)\right)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^g d_{t-1}+$$

$$+(1+i^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{eu}d_{t-1}=$$

$$=n^k\left(1+i_t^{d*}\right)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}j_{k,t-1}^f+n^k\left(1+i_t^*\right)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{p,t-1}+n^k\left(1+i_t^l\right)\frac{p_{t-1}}{p_t}L_{i,t-1}^{f*}+$$

$$+n^k j_{k,t}^{f*}+n^k\frac{e_t p_t^*}{p_t}L_{i,t}^f$$

$$+\lambda_t^g d_t+\lambda_t^{eu}d_t+\left(t\arg_t-\left(1+i_t^{MRO}\right)\frac{P_{t-1}}{P_t}t\arg_{t-1}\right)+pmi_t \tag{S51}$$

Tax revenues

$$\frac{T_t}{N} \equiv \tau_t^c[n^k\Phi_t^c(\frac{p_t^h}{p_t}c_{k,t}^h + \frac{p_t^f}{p_t}c_{k,t}^f) + n^w\Phi_t^c(\frac{p_t^h}{p_t}c_{w,t}^h + \frac{p_t^f}{p_t}c_{w,t}^f) +$$

$$+n^b\Phi_t^c(\frac{p_t^h}{p_t}c_{b,t}^h + \frac{p_t^f}{p_t}c_{b,t}^f)] + \tau_t^y[n^k w_t^k\Phi_t^l l_{k,t} + n^w w_t^w \Phi_t^l l_{w,t} + n^b w_t^g \Phi_t^l l_{b,t}] +$$

$$+\tau_t^\pi n^k\left[\frac{p_t^h}{p_t}y_{i,t}^h - w_t^w\frac{n^w}{n^k}\Phi_t^l l_{w,t} - w_t^k\Phi_t^l l_{k,t} - \frac{p_t^f}{p_t}m_{i,t}^f\right] + \tag{S52}$$

$$+\tau_t^\pi n^k[(1+i_t^l)\frac{p_{t-1}}{p_t}L_{p,t-1} + (1+i_t^{b*})\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{p,t-1} + (1+i_t^r)\frac{p_{t-1}}{p_t}m_{p,t-1} +$$

$$+(1+i_t^b)\frac{p_{t-1}}{p_t}\Lambda_t\lambda_{t-1}^d d_{t-1} + \Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)\lambda_{t-1}^d d_{t-1} - (1+i_t^d)\frac{p_{t-1}}{p_t}j_{p,t-1}$$

$$-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1} - \frac{p_t^h}{p_t}\Xi(L_{p,t-1}, \lambda_{t-1}^d d_{t-1}, m_{p,t-1}, \frac{e_t p_t^*}{p_t}f_{p,t-1}, z_{p,t-1})]$$

Exports

$$c_t^{f*} = \Omega\left(\frac{p_t^h}{p_t^f}\right)^{-\vartheta} \tag{S53}$$

Public spending ratios

$$w_t^g = \frac{s_t^w\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^b l_{b,t}} \tag{S54}$$

$$g_{g,t}^g = \frac{s_t^g n^k y_{i,t}^h}{n^b} \tag{S55}$$

$$g_{g,t}^i = \frac{s_t^i n^k y_{i,t}^h}{n^b} \tag{S56}$$

$$\overline{g}_t^{tr} = s_t^{tr}\frac{p_t^h}{p_t}n^k y_{i,t}^h \tag{S57}$$

$$m_{g,t}^g = \frac{p_t^h}{p_t^f}\frac{s_t^m n^k y_{i,t}^h}{n^b} \tag{S58}$$

Endogenous and exogenous variables We therefore have a dynamic system of 58 equations, (S1)-(S58), in 58 endogenous variables which are $\{c_{k,t},\, c^h_{k,t},\, c^f_{k,t}\}^\infty_{t=0}$, $\{c_{w,t},\, c^h_{w,t},\, c^f_{w,t}\}^\infty_{t=0}$, $\{c_{b,t},\, c^h_{b,t},\, c^f_{b,t}\}^\infty_{t=0}$, $\{l_{k,t},\, l_{w,t},\, l_{b,t}\}^\infty_{t=0}$, $\{m_{k,t},\, m_{w,t},\, m_{bt}\}^\infty_{t=0}$, $\{s_{k,t},\, s_{w,t},\, s_{bt}\}^\infty_{t=0}$,$\{\lambda_{k,t},\, \lambda_{w,t},\, \lambda_{bt}\}^\infty_{t=0}$, $\{\psi_{k,t},\, \psi_{w,t},\, \psi_{bt}\}^\infty_{t=0}$, $\left\{\, j^h_{k,t},\, j^f_{k,t}\right\}^\infty_{t=0}$, $\{y^h_{i,t},\, k_{k,t},\, x_{k,t},\, m^f_{i,t},\, \pi_{i,t},\, w^k_t,\, w^w_t,\, L^h_{i,t},\, L^f_{i,t},\, N_{i,t}\}^\infty_{t=0}$, $\{\pi_{p,t}$, $j_{p,t}, z_{p,t}, m_{p,t}, L_{p,t}, f_{p,t}\}^\infty_{t=0}$, $\left\{y^g_{g,t},\, k^g_{g,t}\right\}^\infty_{t=0}$, $\{p_t,\, p^h_t,\, p^f_t,\, i^b_t,\, i^d_t,\, i^l_t\}^\infty_{t=0}$, $\left\{w^g_t,\, g^g_{g,t},\, g^i_{g,t},\, \overline{g}^{tr}_t,\, m^g_{g,t}\right\}^\infty_{t=0}$, $\{\frac{T_t}{N}\}^\infty_{t=0}$, $\{d_t\}^\infty_{t=0}$, $\{c^{f*}_t\}^\infty_{t=0}$. This is given the time-paths of fiscal policy instruments, $\{\tau^c_t,\, \tau^y_t,\, \tau^\pi_t,\, s^w_t,\, s^g_t,\, s^i_t,\, s^{tr}_t,\, s^m_t\}^\infty_{t=0}$, the fractions of public debt held by private agents abroad and by EU institutions, $\{\lambda^g_t,\, \lambda^{eu}_t\}^\infty_{t=0}$, the population shares, $\{n^k,\, n^w,\, n^b,\, n^g\}^\infty_{t=0}$, the policy nominal interest rates, $\{i^z_t$, $i^r_t,\, i^{MRO}_t\}^\infty_{t=0}$, foreign prices $\{p^{h*}_t,\, p^{f*}_t,\, p^*_t,\, i^{b*}_t,\, i^{d*}_t,\, i^{l*}_t\}^\infty_{t=0}$, foreign quantities, $\{j^{f*}_{k,t},\, L^{f*}_{i,t}\}^\infty_{t=0}$, the nominal exchange rate, $\{e_t\}^\infty_{t=0}$, which can be set at 1 in a currency union, TARGET2 balances, $\{t\arg_t\}^\infty_{t=0}$, net dividends from/to the ECB, $\{pmi_t\}^\infty_{t=0}$, and the pandemic shocks, $\{\Phi^l_t,\, \Phi^c_t\}^\infty_{t=0}$.

Transformed variables For convenience, we re-express some variables. We define $\frac{p^f_t}{p^h_t} \equiv TT_t$ to be the terms of trade (an increase means an improvement in competitiveness vis-à-vis the rest of the world). Then, we have $\frac{p^h_t}{p_t} = (TT_t)^{\nu-1}$, $\frac{p^f_t}{p_t} = (TT_t)^\nu$, $\frac{e_t p^*_t}{p_t} = (TT_t)^{2\nu-1}$, $\Pi_t \equiv \frac{p_t}{p_{t-1}} = \Pi^h_t \left(\frac{TT_t}{TT_{t-1}}\right)^{1-\nu}$ and $\frac{TT_t}{TT_{t-1}} = \frac{e_t}{e_{t-1}} \frac{\Pi^{h*}_t}{\Pi^h_t}$, where $\Pi^h_t \equiv \frac{p^h_t}{p^h_{t-1}}$. Also, $\frac{e_t}{e_{t-1}}$ is the gross exchange rate depreciation which is set at one all the time. Hence, in the final system, we have $\Pi_t = \Pi^h_t \left(\frac{TT_t}{TT_{t-1}}\right)^{1-\nu}$ and $\frac{TT_t}{TT_{t-1}} = \frac{e_t}{e_{t-1}} \frac{\Pi^{h*}_t}{\Pi^h_t}$ and, in all other equations, we use the transformations $\frac{p^h_t}{p_t} = (TT_t)^{\nu-1}$, $\frac{p^f_t}{p_t} = (TT_t)^\nu$, $\frac{e_t p^*_t}{p_t} = (TT_t)^{2\nu-1}$. In other words, regarding prices, instead of $\{p_t,\, p^h_t,\, p^f_t\}^\infty_{t=0}$, now the endogenous variables are $\left\{TT_t,\, \Pi^h_t,\, \Pi_t\right\}^\infty_{t=0}$. Recall that, in a small open economy, $\Pi^{h*}_t \equiv \frac{p^{h*}_t}{p^{h*}_{t-1}}$ is exogenous (we set it at 1 all the time), while $\Pi^*_t \equiv \frac{p^*_t}{p^*_{t-1}}$ can also be treated for simplicity as exogenous (we set it at 1 all the time) or, more generally, if we use $p^*_t = (p^{h*}_t)^\nu (p^{f*}_t)^{1-\nu}$, it can be written as $\Pi^*_t \equiv \frac{p^*_t}{p^*_{t-1}} = (\Pi^{h*}_t)^\nu \left(\Pi^h_t\right)^{1-\nu}$, (where we have set $\frac{e_t}{e_{t-1}} = 1$); in our solutions, we simply set $\Pi^*_t \equiv \frac{p^*_t}{p^*_{t-1}} = 1$ all the time.

A.9 The macroeconomic system with ex ante default

In this Appendix we present the macroeconomic system of Appendix A.8 when we also allow for ex ante default. In particular, as discussed in the main text, we assume that private agents fear that the government and domestic private banks will partially default on their obligations. In terms of modelling, we denote by $0 \leq \Theta_t < 1$ the actual default rate on sovereign public debt and the size of haircut/"bail-in" implemented by private banks on their respective deposits in case of government default, so that Θ_{t+1}^{e} denotes the ex ante default rate. When we solve the model, we set the ex post default rate at zero, $\Theta_t = 0$, and the ex ante one at 0.2, $\Theta_{t+1}^{e} = 0.2$.

Then, the new macroeconomic system is:

Capital owners

$$c_{k,t} = \frac{(c_{k,t}^{h})^{\nu}(c_{k,t}^{f})^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{A9.1}$$

$$\frac{\mu_1}{c_{k,t}} = (\lambda_{k,t} + \psi_{k,t})(1+\tau_t^c)\Phi_t^c \tag{A9.2}$$

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \lambda_{k,t}(1-\tau_t^y)w_t^k\Phi_t^l \tag{A9.3}$$

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \lambda_{k,t}\left(\frac{\gamma\Gamma^k(s_{k,t})^{\gamma-1}(RS * \overline{g}_t^{tr})}{n^k\Gamma^k(s_{k,t})^{\gamma} + n^w\Gamma^w(s_{w,t})^{\gamma} + n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{A9.4}$$

$$\lambda_{k,t} = \beta\lambda_{k,t+1}(1+i_{t+1}^{d})\left(1-\Theta_{t+1}^{e}\right)\frac{p_t}{p_{t+1}} \tag{A9.5}$$

$$\lambda_{k,t}\frac{e_t p_t^*}{p_t}\left(1+\frac{p_t^f}{p_t}\upsilon\left(\frac{e_t p_t^*}{p_t}j_{k.t}^{f} - \overline{j^f}\right)\right) = \beta\lambda_{k,t+1}\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}(1+i_{t+1}^{d*})\frac{p_t^*}{p_{t+1}^*} \tag{A9.6}$$

$$\frac{c_{k,t}^{h}}{c_{k,t}^{f}} = \frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{A9.7}$$

$$\lambda_{k,t} - \psi_{k,t} = \beta\lambda_{k,t+1}\frac{p_t}{p_{t+1}} \tag{A9.8}$$

$$\psi_{k,t}\left((1+\tau_t^c)\Phi_t^c\left(\frac{p_t^h}{p_t}c_{k,t}^{h} + \frac{p_t^f}{p_t}c_{k,t}^{f}\right) - m_{k,t}\right) = 0 \tag{A9.9}$$

Workers

$$c_{w,t} = \frac{(c^h_{w,t})^{\nu}(c^f_{w,t})^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{A9.10}$$

$$(1+\tau^c_t)\left(\frac{p^h_t}{p_t}\Phi^c_t c^h_{w,t} + \frac{p^f_t}{p_t}\Phi^c_t c^f_{w,t}\right) + m_{w,t} \equiv$$

$$\equiv (1-\tau^y_t)w^w_t\Phi^l_t l_{w,t} + \frac{p_{t-1}}{p_t}m_{w,t-1} + (1-RS)\overline{g}^{tr}_t +$$

$$+\frac{\Gamma^w(s_{w,t})^{\gamma}(RS*\overline{g}^{tr}_t)}{n^k\Gamma^k(s_{k,t})^{\gamma} + n^w\Gamma^w(s_{w,t})^{\gamma} + n^b\Gamma^b(s_{b,t})^{\gamma}} \tag{A9.11}$$

$$\frac{\mu_1}{c_{w,t}} = (\lambda_{w,t} + \psi_{w,t})(1+\tau^c_t)\Phi^c_t \tag{A9.12}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \lambda_{w,t}(1-\tau^y_t)w^w_t\Phi^l_t \tag{A9.13}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \lambda_{w,t}\left(\frac{\gamma\Gamma^w(s_{w,t})^{\gamma-1}(RS*\overline{g}^{tr}_t)}{n^k\Gamma^k(s_{k,t})^{\gamma} + n^w\Gamma^w(s_{w,t})^{\gamma} + n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{A9.14}$$

$$\frac{c^h_{w,t}}{c^f_{w,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{A9.15}$$

$$\lambda_{w,t} - \psi_{w,t} = \beta\lambda_{w,t+1}\frac{p_t}{p_{t+1}} \tag{A9.16}$$

$$\psi_{w,t}\left((1+\tau^c_t)\Phi^c_t\left(\frac{p^h_t}{p_t}c^h_{w,t} + \frac{p^f_t}{p_t}c^f_{w,t}\right) - m_{w,t}\right) = 0 \tag{A9.17}$$

Public employees

$$c_{b,t} = \frac{(c^h_{b,t})^{\nu}(c^f_{b,t})^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{A9.18}$$

$$(1+\tau^c_t)\left(\frac{p^h_t}{p_t}\Phi^c_t c^h_{b,t} + \frac{p^f_t}{p_t}\Phi^c_t c^f_{b,t}\right) + m_{b,t} =$$

$$= (1-\tau^y_t)w^g_t\Phi^l_t l_{b,t} + \frac{p_{t-1}}{p_t}m_{b,t-1} + (1-RS)\overline{g}^{tr}_t +$$

$$+\frac{\Gamma^b(s_{b,t})^{\gamma}(RS*\overline{g}^{tr}_t)}{n^k\Gamma^k(s_{k,t})^{\gamma} + n^w\Gamma^w(s_{w,t})^{\gamma} + n^b\Gamma^b(s_{b,t})^{\gamma}} \tag{A9.19}$$

$$\frac{\mu_1}{c_{b,t}} = (\lambda_{b,t} + \psi_{b,t})(1+\tau^c_t)\Phi^c_t \tag{A9.20}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \lambda_{b,t}(1-\tau_t^y)w_t^g\Phi_t^l \tag{A9.21}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \lambda_{b,t}\left(\frac{\gamma\Gamma^b(s_{b,t})^{\gamma-1}(RS*\overline{g}_t^{tr})}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{A9.22}$$

$$\frac{c_{b,t}^h}{c_{b,t}^f} = \frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{A9.23}$$

$$\lambda_{b,t} - \psi_{b,t} = \beta\lambda_{b,t+1}\frac{p_t}{p_{t+1}} \tag{A9.24}$$

$$\psi_{w,t}\left((1+\tau_t^c)\Phi_t^c\left(\frac{p_t^h}{p_t}c_{b,t}^h + \frac{p_t^f}{p_t}c_{b,t}^f\right) - m_{b,t}\right) = 0 \tag{A9.25}$$

Price indexes

$$p_t = (p_t^h)^\nu(p_t^f)^{1-\nu} \tag{A9.26}$$

$$p_t^f = e_t p_t^{h*} \tag{A9.27}$$

Private (intermediate goods) firms

$$y_{i,t}^h = A^p\left(\frac{n^g y_{g,t}^g}{n^k}\right)^\sigma\left[\left(\chi^p(k_{i,t-1})^{op} + (1-\chi^p)(m_{i,t}^f)^{op}\right)^{\frac{\alpha}{op}}\left(A^k\Phi_t^l l_{k,t} + A^w\frac{n_t^{w,e}n^w\Phi_t^l l_{w,t}}{n^k}\right)^{1-\alpha}\right]^{1-\sigma} \tag{A9.28}$$

$$(1-\tau_t^\pi)w_t^w + N_{i,t}\eta w_t^w = [(1-\tau_t^\pi)\theta_t\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}(\theta_t-1)+$$

$$+\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta_{t+1}-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^w y_{i,t}^h}{(A^k\Phi_t^l l_{k,t} + A^w\frac{n_t^{w,e}n^w\Phi_t^l l_{w,t}}{n^k})} \tag{A9.29}$$

$$(1-\tau_t^\pi)w_t^k + N_{i,t}\eta w_t^k = [(1-\tau_t^\pi)\theta_t\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}(\theta_t-1)+$$

$$+\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta_{t+1}-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^k y_{i,t}^h}{(A^k\Phi_t^l l_{k,t} + A^w\frac{n_t^{w,e}n^w\Phi_t^l l_{w,t}}{n^k})} \tag{A9.30}$$

$$\frac{p_t^h}{p_t}\left[1+\xi^k\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)\right]=\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p_{t+1}^h}{p_{t+1}}[1-\delta+(1-\tau_{t+1}^{\pi})\theta_{t+1}r_{t+1}^k-$$

$$-\frac{\xi^k}{2}\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)^2+\xi^k\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)\frac{k_{i,t+1}}{k_{i,t}}]-$$

$$-\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}(\theta_{t+1}-1)r_{t+1}^k+$$

$$+\beta^2\frac{\lambda_{k,t+2}}{\lambda_{k,t}}\frac{p_{t+2}^h}{p_{t+2}}\xi^p\left(\frac{p_{t+2}^h}{p_{t+1}^h}-1\right)\frac{p_{t+2}^h}{p_{t+1}^h}(\theta_{t+2}-1)r_{t+1}^k \quad \text{(A9.31)}$$

$$(1-\tau_t^{\pi})\frac{p_t^f}{p_t}=[(1-\tau_t^{\pi})\theta\frac{p_t^h}{p_t}-\frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}(\theta_t-1)+$$

$$+\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta_{t+1}-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)\alpha y_{i,t}^h(1-\chi^p)(m_{i,t}^f)^{op-1}}{\left[\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m_{i,t}^f)^{op}\right]} \quad \text{(A9.32)}$$

$$k_{k,t}=\psi_t\left(x_{i,t}+(1-\delta)\,k_{i,t-1}\right) \quad \text{(A9.33)}$$

$$\pi_{i,t}\equiv(1-\tau_t^{\pi})\left[\frac{p_t^h}{p_t}y_{i,t}^h-w_t^w\frac{n^w}{n^k}\Phi_t^l l_{w,t}-w_t^k\Phi_t^l l_{k,t}-\frac{p_t^f}{p_t}m_{i,t}^f\right]-$$

$$-\frac{p_t^h}{p_t}\left[k_{k,t}-(1-\delta)k_{k,t-1}\right]-\frac{p_t^h}{p_t}\frac{\xi^k}{2}\left(\frac{k_{k,t}}{k_{k,t-1}}-1\right)^2 k_{k,t-1}-$$

$$-\frac{p_t^h}{p_t}\frac{\xi^p}{2}\left(\frac{p_t^h}{p_{t-1}^h}-1\right)^2 y_{i,t}^h+\left(L_{i,t}^h-(1+i_t^l)\frac{p_{t-1}}{p_t}L_{i,t-1}^h\right)+\frac{e_t p_t^*}{p_t}\left(L_{i,t}^f-(1+i_t^{l*})\frac{p_{t-1}^*}{p_t^*}L_{i,t-1}^f\right) \quad \text{(A9.34)}$$

$$1+N_{i,t}=\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}(1+i_{t+1}^l)\frac{p_t}{p_{t+1}} \quad \text{(A9.35)}$$

$$\frac{e_t p_t^*}{p_t}+N_{i,t}\frac{e_t p_t^*}{p_t}=\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}(1+i_{t+1}^{l*})\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}\frac{p_t^*}{p_{t+1}^*} \quad \text{(A9.36)}$$

$$N_{i,t}\left(\left(L_{i,t}^h+\frac{e_t p_t^*}{p_t}L_{i,t}^f\right)-\eta(w_t^w\frac{n_t^{w,e}n^w}{n^k}\Phi_t^l l_{w,t}+w_t^k\Phi_t^l l_{k,t})\right)=0 \quad \text{(A9.37)}$$

where $r_{t+1}^k\equiv\frac{\partial y_{i,t+1}^h}{\partial k_{k,t}}=\frac{(1-\sigma)\alpha y_{i,t+1}^h\chi^p(k_{k,t})^{op-1}}{\left[\chi^p(k_{i,t})^{op}+(1-\chi^p)(m_{i,t+1}^f)^{op}\right]}$.

Private banks

$$\pi_{p,t} \equiv j_{p,t} + z_{p,t} - L_{p,t} - \lambda_t^d d_t - \frac{e_t p_t^*}{p_t} f_{p,t} - m_{p,t} -$$

$$-\left(1-\tau_t^\pi\right)\frac{p_t^h}{p_t}\Xi(L_{p,t-1}, \lambda_{t-1}^d d_{t-1}, m_{p,t-1}, \frac{e_t p_t^*}{p_t} f_{p,t-1}, z_{p,t-1}) \tag{A9.38}$$

$$j_{p,t} = \frac{(1+i_{t+1}^l)\frac{p_t}{p_{t+1}}L_{p,t} + (1+i_{t+1}^b)\left(1-\Theta_{t+1}^e\right)\frac{p_t}{p_{t+1}}\Lambda_{t+1}\lambda_t^d d_t + \Phi_{t+1}\frac{p_t}{p_{t+1}}(1-\Lambda_{t+1})\lambda_t^d d_t}{(1+i_{t+1}^d)\left(1-\Theta_{t+1}^e\right)\frac{p_t}{p_{t+1}}} + \tag{A9.39}$$

$$+\frac{+(1+i_{t+1}^*)\frac{p_t^*}{p_{t+1}^*}\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}f_{p,t} + (1+i_{t+1}^r)\frac{p_t}{p_{t+1}}m_{p,t} - (1+i_{t+1}^z)\frac{p_t}{p_{t+1}}z_{p,t}}{(1+i_{t+1}^d)\left(1-\Theta_{t+1}^e\right)\frac{p_t}{p_{t+1}}}$$

$$\frac{p_{t+1}^h}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\left(1-\tau_{t+1}^\pi\right)\xi^l(L_{p,t}) = \frac{(1+i_{t+1}^l)}{(1+i_{t+1}^d)\left(1-\Theta_{t+1}^e\right)} - 1 \tag{A9.40}$$

$$\frac{p_{t+1}^h}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\left(1-\tau_{t+1}^\pi\right)\xi^b(\Lambda_{t+1}\lambda_t^d d_t)\Lambda_{t+1} = \frac{(1+i_{t+1}^b)\left(1-\Theta_{t+1}^e\right)\Lambda_t + \Phi_{t+1}\left(1-\Lambda_{t+1}\right)}{(1+i_{t+1}^d)\left(1-\Theta_{t+1}^e\right)} - 1 + \tag{A9.41}$$

$$+\frac{p_{t+1}^h}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\left(1-\tau_{t+1}^\pi\right)\xi^m\left(m_{p,t} + \Phi_{t+1}(1-\Lambda_{t+1})\lambda_t^d d_t\right)^{-3}\Phi_{t+1}(1-\Lambda_{t+1})$$

$$\frac{p_{t+1}^h}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\left(1-\tau_{t+1}^\pi\right)\xi^f\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}\left(\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}f_{p,t}\right) = \frac{(1+i_{t+1}^*)\frac{p_t^*}{p_{t+1}^*}\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}}{(1+i_{t+1}^d)\left(1-\Theta_{t+1}^e\right)\frac{p_t}{p_{t+1}}} - \frac{e_t p_t^*}{p_t} \tag{A9.42}$$

$$\frac{p_{t+1}^h}{p_{t+1}}\beta\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\left(1-\tau_{t+1}^\pi\right)\xi^m\left(m_{p,t} + \Phi_{t+1}\frac{p_t}{p_{t+1}}(1-\Lambda_{t+1})\lambda_t^d d_t\right)^{-3} = 1 - \frac{(1+i_{t+1}^r)}{(1+i_{t+1}^d)\left(1-\Theta_{t+1}^e\right)} \tag{A9.43}$$

$$\frac{p_{t+1}^h}{p_{t+1}}\beta\left(1-\tau_{t+1}^\pi\right)\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\xi^z(z_{p,t}) = 1 - \frac{(1+i_{t+1}^z)}{(1+i_{t+1}^d)\left(1-\Theta_{t+1}^e\right)} \tag{A9.44}$$

where

$$n^k j_{p,t} = n^k j^h_{k,t} + n^k j^{f*}_{k,t} \tag{A9.45}$$

$$n^p L_{p,t} = n^k L_{p,t} = n^k L^h_{i,t} + n^k L^{f*}_{i,t} \tag{A9.46}$$

and

$$\Xi(L_{p,t-1}, \lambda^d_{t-1} d_{t-1}, m_{p,t-1}, \frac{e_t p^*_t}{p_t} f_{p,t-1}, z_{p,t-1}) = \frac{\xi^l}{2}(L_{p,t-1})^2 + \frac{\xi^b}{2}(\Lambda_t \lambda^d_{t-1} d_{t-1})^2 + \frac{\xi^f}{2}(\frac{e_t p^*_t}{p_t} f_{p,t-1})^2 +$$

$$+ \frac{\xi^m}{2}(m_{p,t-1} + \Phi_t \frac{p_{t-1}}{p_t}(1-\Lambda_t) b_{p,t-1})^{-2} + \frac{\xi^z}{2}(z_{p,t-1})^2$$

State firms

$$y^g_{g,t} = A^g \left(\chi^g (k^g_{g,t-1})^{og} + (1-\chi^g)(m^g_{g,t})^{og}\right)^{\frac{\theta_1}{og}} (\Phi^l_t l_{b,t})^{\theta_2} \left(g^g_{g,t}\right)^{1-\theta_1-\theta_2} \tag{A9.47}$$

$$k^g_{g,t} = (1-\delta^g) k^g_{g,t-1} + g^i_{g,t} \tag{A9.48}$$

Consolidated government budget constraint

$$\overline{g}^{tr}_t + n^b \left[w^g_t \Phi^l_t l_{b,t} + \frac{p^h_t}{p_t}\left(g^g_{g,t} + g^i_{g,t}\right) + \frac{p^f_t}{p_t} m^g_{g,t} \right] +$$

$$+ \Big((1-\Theta_t)(1+i^b_t)\Lambda_t + \Phi_t(1-\Lambda_t) \Big) \frac{p_{t-1}}{p_t}(1 - \lambda^g_{t-1} - \lambda^{eu}_{t-1}) d_{t-1} +$$

$$+ \Big((1-\Theta_t)(1+i^b_t)\Lambda_t + \Phi_t(1-\Lambda_t) \Big) \frac{p^*_{t-1}}{p^*_t} \frac{e_t p^*_t}{p_t} \frac{p_{t-1}}{e_{t-1} p^*_{t-1}} \lambda^g_{t-1} d_{t-1} +$$

$$+ (1+i^*) \frac{p^*_{t-1}}{p^*_t} \frac{e_t p^*_t}{p_t} \frac{p_{t-1}}{e_{t-1} p^*_{t-1}} \lambda^{eu}_{t-1} d_{t-1} =$$

$$= d_t + \frac{T_t}{N} +$$

$$+ \left(n^k m_{k,t} + n^w m_{w,t} + n^b m_{b,t} - \frac{p_{t-1}}{p_t}(n^k m_{k,t-1} + n^w m_{w,t-1} + n^b m_{b,t-1}) \right) +$$

$$+ n^k \left(m_{p,t} - (1+i^r_t) \frac{p_{t-1}}{p_t} m_{p,t-1} \right) - n^k \left(z_{p,t} - (1+i^z_t) \frac{p_{t-1}}{p_t} z_{p,t-1} \right) +$$

$$+ \left(t\arg_t - \left(1 + i^{MRO}_t\right) \frac{P_{t-1}}{P_t} t\arg_{t-1} \right) + pmi_t \tag{A9.49}$$

Gross Domestic Product (GDP) identity

$$n^k y_{i,t}^h = n^k \Phi_t^c c_{k,t}^h + n^w \Phi_t^c c_{w,t}^h + n^b \Phi_t^c c_{b,t}^h + n^k x_{k,t} + n^b (g_{g,t}^g + g_{g,t}^i) + c_t^{f*} +$$

$$+ n^k \frac{\xi^k}{2} \left(\frac{k_{k,t}}{k_{k,t-1}} - 1 \right)^2 k_{k,t-1} + n^k \frac{\xi^p}{2} \left(\frac{p_t^h}{p_{t-1}^h} - 1 \right)^2 y_{i,t}^h +$$

$$+ n^k \Xi (L_{p,t-1}, \lambda_{t-1}^d d_{t-1}, m_{p,t-1}, \frac{e_t p_t^*}{p_t} f_{p,t-1}, z_{p,t-1}) \quad \text{(A9.50)}$$

where c_t^{f*} is exports to the rest of the world (defined below).

Balance of payments (economy's resource constraint)

$$\frac{p_t^f}{p_t} \left(n^k \Phi_t^c c_{k,t}^f + n^w \Phi_t^c c_{w,t}^f + n^b \Phi_t^c c_{b,t}^f + n^k m_{i,t}^f + n^b m_{g,t}^g \right) - \frac{p_t^h}{p_t} c_t^{f*} +$$

$$+ n^k \frac{e_t p_t^*}{p_t} j_{k,t}^f + n^k \frac{p_t^f}{p_t} \frac{\upsilon}{2} \left(\frac{e_t p_t^*}{p_t} j_{k,t}^f - \overline{j^f} \right)^2 + n^k \frac{e_t p_t^*}{p_t} f_{p,t} + n^k L_{i,t}^{f*}$$

$$+ n^k (1 - \Theta_t)(1 + i_t^d) \frac{p_{t-1}}{p_t} j_{k,t-1}^{f*} + n^k (1 + i_t^{l*}) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} L_{i,t-1}^f$$

$$+ \left((1 - \Theta_t)(1 + i_t^b) \Lambda_t + \Phi_t (1 - \Lambda_t) \right) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^g d_{t-1} +$$

$$+ (1 + i^*) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^{eu} d_{t-1} =$$

$$= n^k \left(1 + i_t^{d*} \right) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} j_{k,t-1}^f + n^k \left(1 + i_t^* \right) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} f_{p,t-1} + n^k \left(1 + i_t^l \right) \frac{p_{t-1}}{p_t} L_{i,t-1}^{f*} +$$

$$+ n^k j_{k,t}^{f*} + n^k \frac{e_t p_t^*}{p_t} L_{i,t}^f$$

$$+ \lambda_t^g d_t + \lambda_t^{eu} d_t + \left(t\arg_t - \left(1 + i_t^{MRO} \right) \frac{P_{t-1}}{P_t} t\arg_{t-1} \right) + pmi_t \quad \text{(A9.51)}$$

Tax revenues

$$\frac{T_t}{N} \equiv \tau_t^c[n^k\Phi_t^c(\frac{p_t^h}{p_t}c_{k,t}^h + \frac{p_t^f}{p_t}c_{k,t}^f) + n^w\Phi_t^c(\frac{p_t^h}{p_t}c_{w,t}^h + \frac{p_t^f}{p_t}c_{w,t}^f) +$$

$$+n^b\Phi_t^c(\frac{p_t^h}{p_t}c_{b,t}^h + \frac{p_t^f}{p_t}c_{b,t}^f)] + \tau_t^y[n^k w_t^k\Phi_t^l l_{k,t} + n^w w_t^w\Phi_t^l l_{w,t} + n^b w_t^g\Phi_t^l l_{b,t}] +$$

$$+\tau_t^\pi n^k\left[\frac{p_t^h}{p_t}y_{i,t}^h - w_t^w\frac{n^w}{n^k}\Phi_t^l l_{w,t} - w_t^k\Phi_t^l l_{k,t} - \frac{p_t^f}{p_t}m_{i,t}^f\right] + \tag{A9.52}$$

$$+\tau_t^\pi n^k[(1+i_t^l)\frac{p_{t-1}}{p_t}L_{p,t-1} + (1+i_t^{b*})\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{p,t-1} + (1+i_t^r)\frac{p_{t-1}}{p_t}m_{p,t-1} +$$

$$+(1+i_t^b)(1-\Theta_t)\frac{p_{t-1}}{p_t}\Lambda_t\lambda_{t-1}^d d_{t-1} + \Phi_t\frac{p_{t-1}}{p_t}(1-\Lambda_t)\lambda_{t-1}^d d_{t-1} - (1+i_t^d)(1-\Theta_t)\frac{p_{t-1}}{p_t}j_{p,t-1}$$

$$-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1} - \frac{p_t^h}{p_t}\Xi(L_{p,t-1}, \lambda_{t-1}^d d_{t-1}, m_{p,t-1}, \frac{e_t p_t^*}{p_t}f_{p,t-1}, z_{p,t-1})]$$

Exports

$$c_t^{f*} = \Omega\left(\frac{p_t^h}{p_t^f}\right)^{-\vartheta} \tag{A9.53}$$

Public spending ratios

$$w_t^g = \frac{s_t^w\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^b l_{b,t}} \tag{A9.54}$$

$$g_{g,t}^g = \frac{s_t^g n^k y_{i,t}^h}{n^b} \tag{A9.55}$$

$$g_{g,t}^i = \frac{s_t^i n^k y_{i,t}^h}{n^b} \tag{A9.56}$$

$$\overline{g}_t^{tr} = s_t^{tr}\frac{p_t^h}{p_t}n^k y_{i,t}^h \tag{A9.57}$$

$$m_{g,t}^g = \frac{p_t^h}{p_t^f}\frac{s_t^m n^k y_{i,t}^h}{n^b} \tag{A9.58}$$

We again have a system of 58 equations in the same 58 variables as above.

Appendix B: Policy details and data

B.1 Greek public debt and its holders

In the case of Greece, over the years of the sovereign debt crisis, official fiscal rescue operations have been expressed by three bailouts. The first took place in 2010-11, the second in 2012-2015 and the third in 2015-2018. These were loans provided by other EZ countries (via the EFSF, ESM, etc) and the IMF so they counted as public debt. To get these loans, obtained at below-market conditions, Greece signed a memorandum of understanding to implement an economic adjustment program that was officially terminated in August 2018. The total amount of loans received from these three official rescue operations was around 290 billion euros which is one of the largest financial assistance package in history. Most of this money was used for public debt servicing payments (i.e. the payment of the principal of government bonds at maturity and interest payment obligations) and the financing of primary budget deficits (there was no primary market for Greek bonds between 2010 and 2018). Most of the rest of the bailout money was used to finance the cost of the haircut in March 2012 and the cost of private banks recapitalization. See e.g. Economides et al (2021a) for references and details.

As a result of these loans, in 2019, close to 70% of Greek public debt was owned by EU public institutions (member states of the euro area, EFSF, ESM, etc). Data for Greek public debt as share of GDP, as well as the fractions of it held by EU public institutions (λ^{eu}) and foreign private investors/banks (λ^{g}) over time are reported in Table B.1, while the rest is in the hands of domestic private investors/banks.[45]

[45] See Economides et al (2021a) and Dimakopoulou et al (2021) for more details. As said, the Greek NCB or the ECB purchase government bonds in the secondary market only. Thus, the numbers in Table B1 can be thought of as purchases in the primary market.

Table B.1
Greek public debt to GDP and its main holders

Year	Total public debt (% of GDP)	λ^{eu} (% of total public debt)	λ^{g} (% of total public debt)
2008	109.4	0	75
2009	126.7	0	75
2010	146.2	9.3	46.3
2011	172.1	19.9	24.7
2012	159.6	59.9	20.3
2013	177.4	66.3	18.2
2014	178.9	67.2	16.9
2015	175.9	68.6	16.1
2016	178.5	69.8	16.0
2017	176.2	70.9	16.0
2018	181.2	70.9	16.0
2019	180.5	70.9	16.0

Source: Public Debt Management Agency and Greek Ministry of Finance.

Note that in the main paper we explain how λ^{eu} (namely, the fraction of public debt held by EU institutions) has been evolving since 2020 as a result of the loans received from the EU's Recovery Fund.

B.2 The Greek NCB in the ES

Here we clarify how the balance sheet of a NCB participating in the ES is related to the consolidated balance sheet of the ES and then discuss the Greek case.

The ES and its NCBs The consolidated balance sheet and the budget constraint of the ES are not different from those of a standardized central bank.[46] In other words, the asset side of the balance sheet of the consolidated ES consists mainly of foreign currency, loans to credit institutions[47] and securities/bonds.[48] The liability side consists mainly of banknotes in circulation (held by the non-bank public), reserves which are also called current accounts (held by private banks at the central bank) and government deposits.

However, the consolidated balance sheet of the ES shows assets and liabilities of the ES's NCBs and the ECB itself vis-à-vis third parties only. It

[46] See e.g. "Annual consolidated balance sheet of the ES" and "User guide on the ES consolidated weekly financial statement" (available at the website of the ECB).

[47] This includes the main refinancing operations (MROs), longer-term refinancing operations (LTROs), marginal lending facilities, etc. It also inludes emergency liquidity assistance (ELA) to private banks with severe liquidity problems.

[48] This includes the covered bond purchase program (CBPP), the securities markets program (SMP), the asset purchase program (APP) since 2015, the PEPP since 2020, etc.

does not include credits and debits among NCBs and the ECB, known as Intra-Eurosystem claims and liabilities and recorded respectively as *TARGET2* assets and *TARGET2* liabilities in the financial statements of the individual NCBs and the ECB. As explained in the main text, these *TARGET2* balances cancel each other out at aggregate ES level and therefore do not appear in the consolidated balance sheet of the ES; however, they do appear in the balance sheets of individual NCBs and the ECB.

TARGET2 data In the case of the ES as a whole, TARGET2 balances were very small prior to the global financial crisis in 2008 but have increased substantially since then; for instance, they were 186 billion euros in May 2008, 1.24 trillion in September 2017 and 1.63 trillion at at the end of 2020 (see website of the ECB).

In the case of Greece, TARGET2 liabilities to the ES were by far the largest item of liabilities of the Greek NCB, and hence of its monetary base, in every year between 2008 and 2017, with sharp rises during the politically turbulent years of 2010, 2011, 2012 and 2015. For instance, TARGET2 liabilities were 105 billion euros in 2011 which translated to 51% of GDP, and 94 billion euros in 2015, which translated to 53% of GDP. During that period and until the imposition of capital controls in the summer of 2015, this increase in TARGET2 liabilities mainly financed a flight of deposits from Greece towards core countries (see Whelan (2017, section 2.3.1) for a detailed example). After the sovereign debt crisis, namely after 2016, and before the eruption of the new pandemic crisis in early 2020, the size of the balance sheet of the Greek NCB decreased and the same happened to both bank loans and TARGET2 liabilities. However, since the beginning of 2020, there has been a new big rise in TARGET2 liabilities; these liabilities were 26 billion euros in 2019 (or 14% of GDP) and jumped to 80 billion euros in 2020 (or 47% of GDP) becoming again the largest item of liabilities in the balance sheet of the Greek NCB. Now this means that the Greek NCB issues money to finance the purchase of securities (like Greek government bonds as part of the PEPP that started in March 2020) from holders with accounts in another euro country (see Whelan (2017) for a detailed example (section 2.3.2 in his paper) and evidence from other NCBs in the ES since 2015 (section 3 in his paper)). Note that Greek sovereign bonds were not part of the PSPP that started in 2015 but are part of the PEPP that started in 2020. See Dimakopoulou et al (2021) for further details.

Balance sheet of the Greek NCB To confirm the above narrative, Tables B.2a and B.2b display the evolution of the total balance sheet as well as the biggest assets and liabilities of the Greek NCB.

Table B.2a
Bank of Greece's assets
(billions of euros, end of year)

Year	Lending to banks	Securities	Claims in foreign currency	Total assets
2007	9	10	1	42
2008	38	14	3	71
2009	50	21	1	86
2010	98	24	1	13
2011	128	21	2	168
2012	121	21	1	160
2013	73	21	1	109
2014	56	31	2	103
2015	107	40	3	163
2016	67	57	3	142
2017	34	74	3	125
2018	11	76	3	109
2019	8	75	3	109
2020	41	110	4	183

Source: Bank of Greece.

Table B.2b
Bank of Greece's liabilities
(billions of euros, end of year)

Year	Banknotes	TARGET2	Reserves	Total liabilities
2007	18	10	7	42
2008	20	35	8	71
2009	22	49	8	86
2010	29	87	10	138
2011	38	105	5	168
2012	41	98	2	160
2013	35	51	2	109
2014	32	49	3	103
2015	48	94	1	163
2016	43	72	1	142
2017	31	59	2	125
2018	29	29	7	109
2019	21	26	9	109
2020	21	80	27	183

Source: Bank of Greece.

Finally, in Table B.2c, we present profits and losses of the NCB of Greece (numbers are now in millions). Focusing on the role of the ES, the interesting column is the third one ("net result of pooling monetary income"), which reports the net income received by the ES.[49] If positive, it means that the Greek NCB is a net recipient (and vice versa if negative) from the ES. The numbers are positive in most periods, meaning that the NCB of Greece has been a recipient member of the ECB's dividend policy, although quantitatively very small. That is, redistribution, if any, in terms of dividends, was very small. The last column reports the final profit of the Greek NCB which is disbursed to the Greek government.

Table B.2c
Bank of Greece's profit and loss accounts
(milliions of euros, end of year)

Year	Net interest income	Income from equity shares and participating interests	Net result of pooling monetary income	Profit of the year
2007	542	3	6.7	825
2008	711	38	−135	225
2009	768	67	53	228
2010	826	12	2	190
2011	1.469	24	−44	97
2012	3.826	20	149	318
2013	2.341	54	52	831
2014	958	29	6	655
2015	1.762	32	15	1.163
2016	1.492	39	83	1.092
2017	1.157	39	140	942
2018	960	56	50	657
2019	836	135	15	842
2020	516	49	114	662

Source: Bank of Greece.

[49] This works as follows: the ECB collects all profits (the so-called monetary income) made out of NCBs in the ES and then redistributes them back to each NCB so as each NCB ends up with a share of the total monetary income that is proportional to its "capital key" (see e.g. Whelan (2014)). However, from 2015 onwards, the ECB, in an attempt to prevent redistribution through net income, instituted as a rule for its government bonds purchase program that 92% of net profits would stay at the national central banks (see Reis (2017)).

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