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**Working Paper**

# Macroeconomic Policy Lessons for Greece from the Debt Crisis

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CESifo *Working Paper No. 8188*

# Macroeconomic Policy Lessons for Greece from the Debt Crisis


## Abstract

This paper first searches for the drivers of the Greek depression in the aftermath of the 2007-8 global crisis and in turn looks for engines of sustained growth. We use a micro-founded macroeconomic model calibrated to Greece. Our simulations show that the adopted adjustment program (namely, the fiscal austerity mix combined with the fiscal and monetary bailouts by the EU, ECB and IMF), jointly with the observed deterioration in institutional quality (specifically, in the degree of protection of property rights) can explain most (around 22% of GDP) of the cumulative loss in GDP in the data (around 24% of GDP) between 2009 and 2016. In particular, the adjustment program can explain a fall of around 12%, while the deterioration in property rights accounts for another 10%. Counterfactual simulations, on the other hand, show that the cumulative output loss could have been around 9% only, if the country had followed a different fiscal policy mix; if the degree of product marker liberalization was closer to that in the core euro zone countries; and, above all, if institutional quality in Greece had simply remained at its pre-crisis level. On the other hand, we show that, in the absence of the official fiscal bailouts, the depression would be much deeper, while the accommodative role played by the quantitative policies of the ECB has been vital to the Greek economy.


JEL-Codes: O400, H600, E020.

Keywords: growth, macroeconomic policy, institutions.

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# 1 Introduction

Among the euro zone (EZ) periphery countries hit by the global financial crisis of 2007-8, Greece experienced the worst decline and the biggest need for international support.[1] Between 2008 and 2016, Greece lost more than one fourth of its GDP. Also, since the eruption of the crisis, it had to rely on a number of official or unofficial programs of financial assistance provided in various forms by the EU, the ECB and the IMF; only the three official fiscal bailouts between 2010 and 2015 amounted to around 290 billion euros. Although GDP growth managed to rebound in 2017, the recovery has been fragile driven mainly by net exports and a rise in private consumption.[2] As this paper is written, private investment remains at around 11% of GDP only, public debt is around 175% of GDP, external liabilities are around 140% of GDP with the current account still in deficit, and unemployment is around 17%. Besides, as part of bailout programs, around 70% of Greek public debt is nowadays owned by public institutions of the EU and the ECB, while the country has agreed to achieve a number of ambitious fiscal surpluses in the years to come. At the saegme time, Greece scores poorly in institutional quality vis-à-vis other EU and OECD countries and, as is known, institutions are the backbone of economic activity and social stability.[3]

The aim of this paper is threefold. First, we search for the drivers of the Greek debt crisis. This includes driving forces and propagation mechanisms through which the driving forces shaped equilibrium outcomes and in particular the output loss since 2008. Second, we conduct a decomposion exercise to quantify the relative contribution of various driving forces, as they are in the data, to this output loss. Third, building upon the first two steps, we search for counter-factual scenaria that could have possibly given better outcomes since 2008. Putting all this together, our aim is to identify the barriers to, and the engines of, growth. This helps us to draw some

[1] For descriptions of the Greek crisis, see e.g. CESifo (2012 and 2014), Sinn (2014), Ioannides and Pissarides (2015), De Grauwe (2016, chapter 5), Alesina et al (2019, chapter 8), Brunnermeier and Reis (2019), Stournaras (2019) and Alogoskoufis (2019). For formal models, see e.g. House and Tesar (2015), Arellano and Bai (2016), Gourinchas et al (2017), Papageorgiou and Vourvachaki (2017), Economides et al (2017), Glomm et al (2018), Dellas et al (2018) and Chodorow-Reich et al (2019); see also the papers in the volume edited by Meghir et al (2017). See below for details and comparison to the literature.

[2] See e.g. European Commission (2019).

[3] See e.g. Acemoglu (2009, chapter 4). In Greece, weak institutions are captured by various indices reflecting the poor enforcement of the law, an inefficient public administration, a labyrinth of bureaucracy, a slow judicial system, laws and regulations that limit competition, tax evasion, a large shadow economy, poor education (PISA) scores, vandalism and violence, etc. For institutional quality in Greece relative to other countries, see e.g. Angelopoulos et al (2009), Masuch et al (2018), Micossi (2016), Papaioannou (2016), Afonso and Kazemi (2016) and Kollintzas et al. (2018). See also the data in "Global Competitiveness Report" published by World Economic Forum and the "Rule of Law Index" published by the World Justice Project. See below for details.

macroeconomic policy lessons that could be useful in the future.

To place our work in context, we need to recall the key events in Greece over the euro period. The magnitude of the Greek depression should not have come as a surprise. Greece was already in imbalance when the world financial crisis erupted in 2007-8. From the late 1990s to 2008, the country enjoyed an exceptional economic boom and declining unemployment. But this was driven by a big rise in private demand and pro-cyclical fiscal policies, both of which were financed by borrowing from optimistic banks in Greece and Northern Europe. The demand-driven boom led to accumulation of large private, public and external debts. It also led to rises in wages, prices and unit labor costs and hence to losses in competitiveness. In addition, and perhaps this went unnoticed, Greece displayed a big asymmetry in institutional quality relative to its EU partners. Then, in 2009, amid an unfavorable environment (the "sudden" recognition of the above imbalances, unpleasant news about the country's public finances, a deterioration in institutional quality (big riots in Athens in December 2008), political controversies and polarization, the release of reports by the European Commission (EC) and rating agencies expressing fears of sovereign insolvency, etc), confidence was undermined, expectations were reversed, GDP collapsed, debts-to-GDP exploded, and all this became a vicious cycle. Greece, along with Ireland and Portugal, was shut out from private capital markets and the Greek government had to resort to its first official fiscal bailout provided by the EU and the IMF in early 2010. Nevertheless, fear of default rose again, insolvency was admitted by all and, in 2012, the Greek government defaulted on its bonds held by private creditors. But again this was not enough. Greece had to receive two more official fiscal rescue loans provided by other EU states, EU institutions (EFSF, EFSM, ESM) and the IMF in 2012 and 2015. At the same time, and this has been since the very beginning of the crisis, the ECB has provided a supportive monetary policy easing package through a multitude of quantitative, or balance-sheet, policies often described as unconventional (e.g. direct or indirect intervention in the market for Greek government bonds, the support of private banks through various measures including a full allotment policy, the relaxation of collateral requirements or the provision of ELA, and the provision of cross-border liquidity that compensated for abrupt private capital inflows and known as *TARGET2* liabilities). All this complex financial (fiscal and monetary) assistance has been offered at much more favorable terms than markets would have imposed on Greece. On the other hand, it has been conditioned on a severe fiscal austerity plan monitored by the EC, the ECB and the IMF. Although the real motives behind the financial assistance, as well as the rationale of severe fiscal austerity, have been lively debated (see e.g. Alesina et al (2019, chapter 8)), this economic adjustment program has enabled Greece to remain in the euro area. However, fiscal austerity and economic depression, fuelled by political polarization and perhaps populism, have been associated

with a further worsening of institutional quality. As we shall below, the latter is reflected in indices measuring, for example, the rule of law, regulatory quality, and political instability and violence, which are the indices typically used to construct measures of the degree of protection of property rights. And, as is widely recognized, property rights shape individual incentives and hence are fundamental drivers of productivity and long-term growth.[4]

Our model will embed most of the above distinct features of the Greek economy. The vehicle of analysis is a medium-scale micro-founded macroeconomic model of a small open economy participating in a currency union. In addition to a number of real and nominal frictions commonly used by the quantitative macroeconomic literature, the model incorporates - in an attempt to mimic the Greek case - a rather detailed public sector including public employees as a separate income class, problems of institutional quality in the form of ill-defined property rights that trigger anti-social activities, and, since the beginning of the crisis in 2009, international financial assistance combined with fiscal austerity. To capture the menu of macroeconomic policy instruments available, we model separately the Treasury (fiscal authority) and the national central bank participating in the Eurosystem (monetary authority). In other words, the model incorporates the main ingredients of the economic adjustment program as described above, namely, fiscal austerity combined with international financial assistance, where the latter includes the official fiscal bailouts as well as balance-sheet, or quantitative, monetary policies by the Eurosystem. The revenue from the official fiscal bailouts make up for the loss of government revenue from being shut out from private capital markets and this happens at non-market interest rates. At the same time, financial frictions (see Curdia and Woodford (2011)), as well as the issuance of *TARGET2* liabilities as part of the monetary base of the national central bank (see Sinn (2014) and Whelan (2014, 2017)), provide the channels through which quantitative, or balance sheet, monetary policies, as allowed by the ECB, can have real effects and thus - like the official fiscal bailouts - "alleviate the fiscal burden" (see Reis (2017)). A more detailed description of our model can be found in subsection 2.1 below.

The model is first solved numerically using Greek data in the year 2008, which was the last year before the depression. This solution will in turn serve as a departure for various scenarios, actual and hypothetical. Our simulations show the following. The economic adjustment program (namely, the fiscal austerity mix combined with the official fiscal bailouts and the various types of monetary accommodation provided by the ES), jointly with developments in institutional quality (specifically, the deterioration of protection of property rights), can account for most of the cumulative loss in GDP since

[4]For the key importance of property rights among other measures of institutional quality, see e.g. Hall and Jones (1999), Grossman (2001), Rodrik (2003), Dixit (2004), Acemoglu (2009, chapter 4), Besley and Ghatak (2010), Acemoglu and Robinson (2012, 2019) and many others.

2009. In particular, when we feed our model with the adjustment program and an index of property rights, both as they are recorded in the data since 2009, the model, via its propagation mechanisms, produces around 22% fall in GDP between 2009 and 2016 as compared to 24% in the data. The adjustment program acounts for 12% and the deterioration in property rights adds another 10%.

Counterfactual scenarios, on the other hand, seem to imply the following. First, things could have been much worse. Despite the conflicting views about the content of the bail-out program, especially regarding its fiscal austerity preconditions, our numerical simulations seem to imply that financial assistance (provided by other EU counties and institutions, the ECB and the IMF) has helped the Greek economy to avoid the worst. For instance, if the fiscal needs were financed by, say, higher income taxes rather than by the three official fiscal bailouts, the loss in output would be tremendous, other things equal. Also, even if one is willing to make the unrealistic assumption that the Greek government had been able to keep selling its bonds to the private market, the high market interest rates it would have to pay would have led to a bigger output loss than that in the data. Besides, when we make the assumption that the ECB had not followed an accommodative policy towards Greece, the model ceases to exhibit a (stable) solution implying (to the extent that one trusts our model) that this scenario would be nonfeasible, other things equal. Second, things could also have been better. The output loss could have been significantly smaller if some things had been done slightly differently. In particular, the output loss could have been around 9% only (always relative to the year 2008), if the country had followed an alternative fiscal policy mix (for example, a cut in income taxes, or an increase in public investment, financed by a cut in tranfer payments), if reforms in the product market had been adopted and implemented in a faster and/or more effective way so as the degree of product market liberalization to get closer to that in the core EZ countries; and, above all, if institutional quality had not deteriorated since 2009 but had simply remained at its pre-crisis level. It has to be emphasized that improvements in these areas are not in the area of fantasy; we assume small changes vis-a-vis the values in the data. That is, small changes could make things much better.

Therefore, putting all this together, we can claim that the engines of growth for the Greek economy from now on will be a different fiscal policy mix, structural reforms especially in the product markets and the public sector, and last, but not least, a better institutional envrironment that protects property rights. Obviously, such changes, even at a small degree, presuppose political cohesion.

**Literature** As already mentioned, there has been a rich literature on the Greek crisis. Papers close to ours, which have also used micro-founded macroeconomic models to study the crisis, include Gourinchas et al (2017), Papageorgiou and Vourvachaki (2017), Economides et al (2017), Glomm et

al (2018), Dellas et al (2018) and Chodorow-Reich et al (2019).[5] A common finding of these papers, which is also a result shared by our work, is that roughly half of the loss in output is explained by the fiscal austeriry package adopted.

Our work enriches this literature along several dimensions. One key difference is the way we model economic policy. Here, we take a more balanced view by taking into account, not only the costs of fiscal austerity as the above papers have done, but also the role, and the potential benefits, of international financial assistance, where the latter has been both fiscal (fiscal bailouts) and monetary (ECB support) as well as both explicit (e.g. official rescue programs) and implicit (e.g. *TARGET2* liabilities). We do so because one cannot study fiscal austerity without taking into account the other side of the coin which is international financial assistance; as said, the former was the precondition for the latter in the adjustment program agreed between Greece and its creditors. We also study the role of the deterioration in institutional quality that occured at the same time and has been triggered by the fiscal austerity measures (and further fuelled by populism from several political sides). Another difference is that several of the above papers, especially Gourinchas et al (2017) and Chodorow-Reich et al (2019), employ a large menu of shocks to explain the crisis including shocks to productivity, to interest rates on public debt, to default rates, to banks' funding costs, etc. We feel however that such variables can hardly be considered as (extrinsic) shocks. Here, by contrast, most of these variables are endogenously determined. In our paper, there are two driving forces only (the time-paths of the economic adjustment program and institutional quality, both as recorded in the data), and then the propagation mechanisms of our model provide the channels through which these two driving forces shape macroeconomic and distributional outcomes. For example, to the extent that weak property rights distort private incentives leading to resource misallocation, this distortion shows up as an adverse productivity shock endogenizing the TFP.[6]

Putting all this together, despite a lively debate on the role of financial assistance and institutional quality in policy circles, there have not been theoretical general equilibrium models tailored to study these issues in a unified framework; our paper fills this gap by developing such a model and uses it to quantitatively evaluate their effects. Finally, in terms of findings,

[5] Additional quantitative papers with DSGE models for the Greek economy include Papageorgiou (2012), House and Tesar (2015) and Arellano and Bai (2016).

[6] The TFP measures the efficiency with which resources are used in production (see e.g. Prescott (2002) and Restuccia and Rogerson (2013)). As is widely acknowledged, differences in TFP are an important factor in accounting for differences in incomes across countries (see e.g. Prescott (2002)). But it is also acknowledged that TFP is endogenous at macro level being determined, for instance, by tax policies and institutions that shape the risks of expropriation. In our model, weak institutions lead to resource misallocation and this determines the effective TFP.

we add some new results to those of the literature. For example, we show what would have happened without international aid from the EU and ECB. We also show that the resource misallocation and output loss, caused by the further deterioration of property rights and the fear of predation since the end of 2008, are particularly large.

**Layout** The rest of the paper is organized as follows. The model is in section 2. Parameterization, data and the solution for the year 2008 are in section 3. Departing from this solution, section 4 presents positive results. Counterfactuals are in section 5. Section 6 closes the paper. Details are in an appendix.

# 2 A macroeconomic model for Greece

In this section, we present a micro-founded macroeconomic model for the Greek economy during the euro period. We will distinguish two sub-periods: the early years before the crisis, 2001-2008, and the crisis years after 2008, namely, 2009 to today. We will construct the model in such a way so as to be capable of accounting for both sub-periods with a simple re-parameterization.

We start with an informal description of the model.

## 2.1 Informal description of the model

Although we cannot include all details and capture the complexity of reality as described in the previous section and further analysed in subsection 3.2 below, we will at least try to construct a model that embeds the key features of the Greek economy. To do so, we add a number of frictions to a standard small open economy model. These frictions are of two categories. The first category includes real and nominal frictions commonly used by the quantitative macroeconomic literature. The second category includes Greek-specific features. The commonly used frictions include various types of adjustment costs, debt-elastic interest rates when the country borrows from abroad, imperfect competition, nominal rigidities, etc. The Greek-specific features include a relatively detailed public sector, problems of institutional quality and, since the beginning of the crisis in 2009, international financial assistance combined with fiscal austerity. In what follows, we briefly introduce the building blocks of the model.

**Households** There are three distinct types of households called entrepreneurs, workers and public employees.[7] Entrepreneurs receive profits from the ownweship of private firms and banks and can also participate in the international financial market. Private workers work in private firms.

[7] Some type of agent heterogeneity is necessary if we want to have savers and borrowers and hence different interest rates in equilbrium. See also Curdia and Woodford (2010, 2011), Benigno et al (2014), Woodford (2016), Philippopoulos et al (2017b) and many others.

Public employees work in state firms. Both workers and public employees can keep deposits at private banks acting as savers. All types of households consume a domestic and a foreign imported good, receive income from work, hold currency and are engaged in rent-seeking activities. Households are modeled in subsection 2.2.

**Private firms** The domestic 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 a la Dixit-Stiglitz and face nominal rigidities a la Rotemberg. Intermediate goods firms choose labor, capital and imported goods and also make use of productivity-enhancing public goods/services that enter the private production function as an externality. They finance their capital accumulation by retained earnings, by issuance of shares, which, as said, are bought by entrepreneurs, and by loans from private banks. There are also capital good firms that produce the capital demanded by intermediate goods firms. Any profits generated by firms are distributed to their owners, namely, the entrepreneurs. Firms are modeled in subsection 2.3.

**Private banks** On their assets side, private banks make loans to private firms and purchase government bonds. On the side of liabilities, they receive deposits from savers and loans from the national central bank. 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 framework introduced by Curdia and Woodford (2010, 2011) and in turn used by Corsetti et al. (2013) and many others. Specifically, the difference between deposit and lending interest rate emerges as a result of heterogeneity in patience between savers (workers and public employees) and borrowers (firms or, equivalently their owners, the entrepreneurs) as well as of costly financial intermediation. Any profits generated by banks are distributed to their owners, namely, the entrepreneurs. Banks are presented 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)** On the side of assets, the NCB makes loans to private banks and can also hold government bonds. On the liabilities side, the monetary base consists of banknotes in circulation and cross-border *TARGET2* liabilities (these are the two largest liability items in the Greek data). In other words, the NCB's spending is financed by printing new banknotes held by private agents and by issuing *TARGET2* liabilities to other NCB's according to the rules of the ES. Any portfolio profits generated

by the NCB are transferred to its government in the form of a dividend. This is in subsection 2.6.3.

**Treasury** On the revenue side, the Treasury, or the government, taxes income and consumption, receives a dividend from its NCB and/or from the ECB and issues sovereign bonds. The latter can be purchased by domestic investors (domestic private banks and the national central bank) and by foreign investors (where foreign investors can be both private and public like EU institutions and the ECB). 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. This is in subsection 2.6.2.

**Macroeconomic policy regime** Combining the Treasury and the NCB, we assume that during the crisis years monetary policy has been shaped by fiscal and lending requirements. Specifically, we assume that the ECB has followed an accommodative policy towards Greece, in the sense that quantitative monetary policies, and in particular *TARGET2* liabilities to the ES, have been adjusted to ensure that Greece's fiscal policy mix and lending to private banks are as in the data. This is analysed in subsection 2.6.5.

**Stationarity in a small open economy** As is known, we need an "imperfection" to get a stationary solution in a small-open economy model. Popular devices are a debt-elastic interest rate when agents borrow from abroad, or a transaction cost again when agents borrow from abroad, or an endogenous time preference rate (see e.g. Schmitt-Grohe and Uribe (2003) and Uribe and Schmitt-Grohe (2017, chapter 4)). Here, to bring the dynamics of the model closer to the data, we will assume both a debt-elastic country interest rate and transaction costs, although one is enough to guarantee stationarity. The country debt-elastic interest rate is in subsection 2.7, while transaction costs associated with borrowing from private foreign markets are in subsections 2.2.1 and 2.6.2.

**Institutions** As said above, poor institutions, in most situations, show up in ill-defined property rights and the most common way of modeling the latter has been to assume that private and/or communal properties are "common pools".[8] Access to a common pool distorts individual incentives to work or save and this leads to resource misallocation and to poor macroeconomic performance that can hurt everybody in equilibrium. Here, we will assume that, because of weak property rights, producers can appropriate only a fraction of their output, while the rest can be taken away by rent seekers, where the latter are assumed to be all types of households who compete with each other for a fraction of the contestable prize in a Tullock-type redistributive contest. Our measure of the degree of property rights

[8] See e.g. Persson and Tabellini (2000, chapter 14), Drazen (2000, chapters 8 and 10), Hillman (2009, chapter 2), Besley and Ghatak (2010), Grossman (2001) and Acemoglu and Robinson (2019) for reviews of models with common-pool problems and thus weak property rights and extraction.

will be as in the data, while the rent-seeking technology is in subsection 2.2.1.

Modelling details will be provided as we present each building block of the model. Before we proceed, we should make two further remarks about the model. First, 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. We have 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. Second, we do not model explicitly the fear of being forced out of the eurozone (or what is known as the fear of Grexit). Nevertheless, most indices of institutional quality are based on both observable data and perceptions. The index of property rights used in our paper is not an exception. Although sometimes this implies weakness, it is useful in our case because our measure of institutional quality reflects both hard data and perceptions/sentiments and the latter also incorporate the fear of Grexit affecting agents' decisions.

## 2.2 Households

There are three distinct types of households, called entrepreneurs, workers and public employees. Entrepreneurs 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 ratios, we define $n^k = \frac{N^k}{N}$, $n^w = \frac{N^w}{N}$ and $n^b = \frac{N^b}{N}$. For simplicity, total population and its decomposition to the three income groups is exogenous and kept constant over time. We also assume away mobility from one group to another.

### 2.2.1 Households as entrepreneurs

There are $k = 1, 2, ..., N^k$ identical entrepreneurs. Entrepreneurs own the firms and banks and receive their profits. They also have the opportunity to borrow, or lend, in a risk-free internationally traded bond. Besides, like all other types of households, they receive income from work, hold currency and are engaged in rent-seeking activities. Note that, to save on notation, we do not allow entrepreneurs to borrow directly from private banks; this is not important, because they own the firms, receive their profits and these firms do have access to bank loans (see below).

**Entrepreneur's problem** Each $k$ maximizes discounted lifetime utility:

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

where $c_{k,t}$, $u_{k,t}$ and $h_{k,t}$ denote respectively $k$'s consumption, leisure time and end-of-period currency (in real terms),[9] $\overline{y}_t^g$ denotes the per capita quantity of public goods/services provided and produced by the government, and $0 < \beta_k < 1$ is capitalists' time discount factor.

For our numerical solutions, we will use a utility function of additive form:

$$u\left(c_{k,t}, u_{k,t}, h_{k,t}; \overline{y}_t^g\right) = \mu_1 \log c_{k,t} + \mu_2 \log u_{k,t} + \mu_3 \log h_{k,t} + \mu_4 \log \overline{y}_t^g$$

where $0 < \mu_1,\ \mu_2,\ \mu_3,\ \mu_4 < 1$ are preference parameters with $\mu_1 + \mu_2 + \mu_3 + \mu_4 = 1$.

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 good relative to the foreign good.

The time constraint of each $k$ in each time 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 anti-social or rent seeking activities.

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

$$\begin{aligned}
&(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{k,t}^h + \frac{p_t^f}{p_t}c_{k,t}^f\right) + (1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t} f_{k,t-1} + \\
&+ q_t R_{k,t} + \frac{p_t^h}{p_t}\psi^p(.) + h_{k,t} = \\
&\equiv (1-\tau_t^y) w_t^k l_{k,t} + (q_t + \pi_{k,t}^i) R_{k,t-1} + \pi_{k,t}^p \\
&+ \frac{e_t p_t^*}{p_t} f_{k,t} + \frac{p_{t-1}}{p_t} h_{k,t-1} + \overline{g}_t^{tr} + \\
&+ \left(\frac{\Gamma^k (s_{k,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right)(1 - PR_t) Y_t
\end{aligned} \tag{3b}$$

[9] To give currency a role, we use a money-in-the-utility-function model. Alternatively, we could use a cash-in-advance model.

where $f_{k,t}$ is the real value of one-period foreign debt denominated in foreign prices and acquired by each $k$ at $t$ on which $k$ pays the country-specific nominal interest rate $i^*_{t+1}$ at $t+1$ (if $k$ is a lender, $f_{k,t} < 0$ and $i^*_{t+1}$ denotes a return),[10] $R_{k,t}$ denotes the number of firms' shares purchased by each $k$ at time $t$ at a price $q_t$, $p^h_t$ is the price of the domestic good, $p^f_t$ 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 (an increase means a depreciation), $w^k_t$ is the real wage rate paid to entrepreneurs, $\pi^i_{k,t}$ stands for the share's dividend paid to each $k$ by private firms net of taxes, $\pi^p_{k,t}$ is the profit generated by private banks and paid to each $k$ net of taxes, $h_{k,t-1}$ is the real value of currency carried over from $t-1$ to $t$, $\psi^p(.)$ is a transaction cost function associated with the agent's participation in the foreign capital market (defined below), $\overline{g}^{tr}$ is a uniform transfer from the government and $0 \leq \tau^c_t$, $\tau^y_t < 1$ are the tax rates on final consumption goods and income.

The last term on the RHS of (3b) is the share extracted by each $k$ from the common pool. Given weak property rights, we assume that total real output, defined as $Y_t$,[11] becomes a common pool or a contestable prize, so that only a fraction of it, $PR_tY_t$, remains in the hands of its producers because the rest, $(1-PR_t)Y_t$, is taken away by rent seekers, where the rents extracted by each person depend on the anti-social activities employed by him/her relative to total anti-social activities.[12] That is, $0 < PR_t \leq 1$ is the degree of protection of property rights and 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, as in e.g. Dixit (2004, chapter 5) and Hillman (2009, chapter 2), the power coeffcient, $\gamma$, is between 0 and 1 and measures how quickly diminishing returns arise in anti-social activities, while the parameter $\Gamma^k$ measures the efficacy of $k$'s aggresion. Both are measures of the technology of fighting. If $\Gamma^k$ increases and/or $\gamma$ decreases, agent $k$ has a stronger incentive to devote effort time to rent seeking. Note that this specification, specifically, the different values of $\Gamma^k$, $\Gamma^w$ and $\Gamma^b$, allows us to

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

[11] As we shall see below, $Y_t \equiv N^i \frac{p^h_t}{p_t} y^h_{i,t}$, where $N^i$ is the number of private firms and $y^h_{i,t}$ is the product of each of those firms.

[12] Ill-defined property rights obviously hurt those who are productive and so reduce their incentives to produce and invest (see below the firm's problem), but there are social losses on the side of predators as well, since the pursuit of a share of a contestable prize, where contestability is made possible by weak property rights or ill-meant publicness, distorts their own incentives and talents (see e.g. Murphy et al (1991), Hillman (2009, chapter 2), Angelopoulos et al (2009), Besley and Ghatak (2010), Esteban and Ray (2011) and Acemoglu and Robinson (2019)). This is the case in our model with Tullock-type rent seeking competition.

have asymmetries in equilibrium; namely, different types of rent seekers can choose different allocations and at the same time receive different wages.

Regarding the per agent cost associated with participation in the foreign financial market, it is assumed to take the form:

$$\psi^p(.) \equiv \frac{1}{N_t^k}\frac{\psi^p}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(N_t^k f_{k,t} + F_t^g\right)}{\frac{p_t^h}{p_t}Y_t} - \overline{f}\right]^2 Y_t \tag{4}$$

where $\psi^p \geq 0$ is a transaction cost parameter associated with participation in foreign capital markets, $F_t^g$ denotes total public foreign debt (i.e. public debt issued by the domestic government and held by foreign private investors) denominated in foreign currency,[13] $N_t^k f_{k,t}$ denotes total private foreign debt denominated in foreign currency, $Y_t$ is total real output and the parameter $\overline{f}$ is a threshold value of the country's foreign debt as share of GDP above which such costs arise. In other words, the cost is increasing in the country's total real foreign debt to total real GDP.

**First-order conditions** Each $k$ acts competitively choosing $\{c_{k,t}^h,\ c_{k,t}^f,\ c_{k,t},\ l_{k,t},\ s_{k,t},\ R_{k,t},\ f_{k,t},\ h_{k,t}\}_{t=0}^{\infty}$. The first-order conditions include the definition in (2), the constraints in (3a-3b) and:

$$\frac{\mu_2}{(1 - l_{k,t} - s_{k,t})} = \frac{\mu_1(1-\tau_t^y)w_t^k}{(1+\tau_t^c)c_{k,t}} \tag{5a}$$

$$\frac{\mu_2}{(1 - l_{k,t} - s_{k,t})} = \left(\frac{\mu_1}{(1+\tau_t^c)c_{k,t}}\right)\left(\frac{\gamma\Gamma^k(s_{k,t})^{\gamma-1}(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^{\gamma} + n^w\Gamma^w(s_{w,t})^{\gamma} + n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{5b}$$

$$q_t\frac{(1+\tau_{t+1}^c)c_{k,t+1}}{(1+\tau_t^c)c_{k,t}} = \beta_k(q_{t+1} + \pi_{k,t}^i) \tag{5c}$$

$$\frac{(1+\tau_{t+1}^c)c_{k,t+1}}{(1+\tau_t^c)c_{k,t}}\frac{e_t p_t^*}{p_t} = \frac{(1+\tau_{t+1}^c)c_{k,t+1}}{(1+\tau_t^c)c_{k,t}}\frac{e_t p_t^*}{p_t}\times$$
$$\times\psi^p\left[\frac{\frac{e_t p_t^*}{p_t}\left(N_t^k f_{k,t} + F_t^g\right)}{\frac{p_t^h}{p_t}Y_t} - \overline{f}\right] + \beta_k\frac{e_{t+1}p_{t+1}^*}{p_{t+1}}(1+i_{t+1}^*)\frac{p_t^*}{p_{t+1}^*} \tag{5d}$$

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

$$\frac{\mu_3}{h_{k,t}} + \beta_k\frac{1}{(1+\tau_{t+1}^c)c_{k,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau_t^c)c_{k,t}} \tag{5f}$$

[13] For more details, see the government budget constraint below.

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

$$p_t = (p_t^h)^\nu (p_t^f)^{1-\nu} \tag{6}$$

### 2.2.2 Households as workers

There is a pool of $w = 1, 2, ..., N^w$ identical households-workers. They are employed by private firms (see below). Like all other households, workers consume, work, hold currency and participate in rent-seeking activities. Workers can also save in the form of bank deposits.[14]

**Worker's problem** Each worker $w$ maximizes:

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

where variables are defined as above in the entrepreneurs' problem if we replace the subscript $k$ with the subscript $w$ and $0 < \beta < 1$ is workers' time discount factor. We will assume $0 < \beta_k < \beta < 1$, which will induce savers (here, workers and public employees) to have bank deposits and borrowers (here, entrepreneurs) to take on debt in equilibrium.[15]

As above, we use the utility function:

$$u\left(c_{w,t}, u_{w,t}, h_{w,t}; \overline{y}_t^g\right) = \mu_1 \log c_{w,t} + \mu_2 \log u_{w,t} + \mu_3 \log h_{w,t} + \mu_4 \log \overline{y}_t^g$$

and the consumption index:

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

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

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

and the budget constraint:

[14] The assumption that workers and public employees do not participate in all financial markets is without loss of generality; we could assume that all agents face transaction costs that make costly their participation in financial markets but workers and public employees face higher costs.

[15] See also e.g. Benigno et al (2014), Korinek and Simsek (2016) for permanent differences in discount factors between savers and borrowers like in our paper. Curdia and Woodford (2011) also assume differences in the degree of impatience among savers and borrowers although this difference does not remain fixed over time (this is not important to our results). Also, in Gertler and Karadi (2011), bankers face a probability of exit which effectively reduces their discount factor.

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

$$\equiv(1-\tau_t^y)w_t^w l_{w,t}+(1+i_t^d)\frac{p_{t-1}}{p_t}j_{w,t-1}+\frac{p_{t-1}}{p_t}h_{w,t-1}+\overline{g}_t^{tr}+$$

$$+\left(\frac{\Gamma^w(s_{w,t})^\gamma}{N^k\Gamma^k(s_{k,t})^\gamma+N^w\Gamma^w(s_{w,t})^\gamma+N^b\Gamma^b(s_{b,t})^\gamma}\right)(1-PR_t)Y_t \tag{9b}$$

where $w_t^w$ is the real wage rate of workers and $j_{w,t}$ is the real value of each $w$'s bank deposits chosen at $t$ and paying a nominal interest rate $i_{t+1}^d$ at $t+1$. Notice that workers are assumed to have access to the same contestable prize as all other agents. They also receive the same transfer paid by the government to all other households.

**First-order conditions** Each $w$ acts competitively choosing $\{c_{w,t}^h,\, c_{w,t}^f,$ $c_{w,t},\, l_{w,t},\, s_{w,t},\, j_{w,t},\, h_{w,t}\}_{t=0}^\infty$. The first-order conditions include the definition in (8), the constraints in (9a-9b) and:

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})}=\frac{\mu_1(1-\tau_t^y)w_t^w}{(1+\tau_t^c)c_{w,t}} \tag{10a}$$

$$\frac{c_{w,t}^h}{c_{w,t}^f}=\frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{10b}$$

$$\frac{\mu_3}{h_{w,t}}+\beta\frac{1}{(1+\tau_{t+1}^c)c_{w,t+1}}\frac{p_t}{p_{t+1}}=\frac{1}{(1+\tau_t^c)c_{w,t}} \tag{10c}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})}=\left(\frac{\mu_1}{(1+\tau_t^c)c_{w,t}}\right)\left(\frac{\gamma\Gamma^w(s_{w,t})^{\gamma-1}(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma+n^w\Gamma^w(s_{w,t})^\gamma+n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{10d}$$

$$\frac{(1+\tau_{t+1}^c)c_{w,t+1}}{(1+\tau_t^c)c_{w,t}}=\beta(1+i_{t+1}^d)\frac{p_t}{p_{t+1}} \tag{10e}$$

### 2.2.3 Households as public employees

There are $b=1,2,...,N^b$ identical public employees. They are employed by state firms (see below). Like all other households, public employees consume, work, hold currency and are engaged in rent-seeking activities. Also, like workers, they can save in the form of bank deposits. Variables will be defined as above in the workers' problem if we replace the subscript $w$ with the subscript $b$.

**Public employee's problem** Each $b$ maximizes:

$$\sum_{t=0}^{\infty} \beta^t u\left(c_{b,t}, u_{b,t}, h_{b,t}; \overline{y}_t^g\right) \tag{11}$$

As above, we use the ulility function:

$$u\left(c_{b,t}, 1 - l_{b,t}, h_{b,t}; \overline{y}_t^g\right) = \mu_1 \log c_{b,t} + \mu_2 \log u_{b,t} + \mu_3 \log h_{b,t} + \mu_4 \log \overline{y}_t^g$$

and the consumption index:

$$c_{b,t} = \frac{(c_{b,t}^h)^\nu (c_{b,t}^f)^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{12}$$

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

$$l_{b,t} + s_{b,t} + u_{b,t} = 1 \tag{13a}$$

and the budget constraint:

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

$$= (1 - \tau_t^y) w_t^g l_{b,t} + (1 + i_t^d) \frac{p_{t-1}}{p_t} j_{b,t-1} + \frac{p_{t-1}}{p_t} h_{b,t-1} + \overline{g}_t^{tr} +$$

$$+ \left(\frac{\Gamma^b (s_{b,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right)(1 - PR_t) Y_t \tag{13b}$$

where $w_t^g$ is the real wage in the public sector and $j_{b,t}$ is the real value of each $b$'s bank deposits chosen at $t$ and paying a nominal interest rate $i_{t+1}^d$ at $t+1$. Public sector employees are assumed to have access to the same contestable prize as all other agents. They also receive the same transfer paid by the government to all other households.

**First-order conditions** Each $b$ acts competitively choosing $\{c_{b,t}^h, c_{b,t}^f, c_{b,t}, l_{b,t}, s_{b,t}, j_{b,t}, h_{b,t}\}_{t=0}^{\infty}$.[16] The first-order conditions include the definition in (12), the constraints in (13a-13b) and the optimality conditions:

$$\frac{\mu_2}{(1 - l_{b,t} - s_{b,t})} = \frac{\mu_1 (1 - \tau_t^y) w_t^g}{(1 + \tau_t^c) c_{b,t}} \tag{14a}$$

[16] 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.

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \left(\frac{\mu_1}{(1+\tau_t^c)c_{b,t}}\right)\left(\frac{\gamma\Gamma^b(s_{b,t})^{\gamma-1}(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{14b}$$

$$\frac{c_{b,t}^h}{c_{b,t}^f} = \frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{14c}$$

$$\frac{\mu_3}{h_{b,t}} + \beta\frac{1}{(1+\tau_{t+1}^c)c_{b,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau_t^c)c_{b,t}} \tag{14d}$$

$$\frac{(1+\tau_{t+1}^c)c_{b,t+1}}{(1+\tau_t^c)c_{b,t}} = \beta(1+i_{t+1}^d)\frac{p_t}{p_{t+1}} \tag{14e}$$

## 2.3 Private firms and production of private goods

Private firms are owned by entrepreneurs. Following most of the related literature, there are three types of goods and three 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 a 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.

### 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, namely the entrepreneurs. Each final good firm produces an amount $y_{h,t}^h$ by using intermediate goods according to the standard Dixit-Stiglitz technology:

$$y_{h,t}^h = \left[\sum_{i=1}^{N^i}\frac{1}{N^i}(y_{i,t}^h)^\theta\right]^{\frac{1}{\theta}} \tag{15}$$

where $y_{i,t}^h$ denotes the quantity of intermediate good of variety $i = 1, 2, ..., N_t^i$ used by each final goods firm $h$ and $0 \leq \theta \leq 1$ is a parameter measuring the degree of substitutability (when $\theta = 1$, intermediate goods are perfect substitutes in the production of the final good and the intermediate goods sector is perfectly competitive).

Each final-good producer chooses $y^h_{i,t}$ to maximize real profits:

$$y^h_{h,t} - \sum_{i=1}^{N^i} \frac{1}{N^i} \frac{p^h_{i,t}}{p^h_t} y^h_{i,t} \tag{16}$$

where $p^h_t$ is the price of the final good and $p^h_{i,t}$ is the price of intermediate good $i$.

Taking prices as given, the first-order condition for $y^h_{i,t}$ gives the demand function:

$$p^h_{i,t} = p^h_t \left( \frac{y^h_{i,t}}{y^h_{h,t}} \right)^{\theta-1} \tag{17a}$$

which in turn implies from the zero-profit condition:

$$p^h_t = \left[ \sum_{i=1}^{N^i} \frac{1}{N^i} (p^h_{i,t})^{\frac{\theta}{\theta-1}} \right]^{\frac{\theta-1}{\theta}} \tag{17b}$$

Note that, in a symmetric equilibrium, $y^h_{h,t} = y^h_{i,t}$ and $p^h_{h,t} = p^h_{i,t}$.

### 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 entrepreneurs, we again set $N^i = N^k$ for notational simplicity. These firms make investment and other factor decisions facing capital and Rotemberg-type price adjustment costs. New investment is financed by retained earnings, by issuing shares and by obtaining loans from private banks.[17]

**Firm's problem** The gross profit of each intermediate goods firm $i$, denoted as $\pi^{gross}_{i,t}$, is sales minus the wage bill minus the cost of imported goods minus adjustment costs associated with changes in capital and prices:

$$\pi^{gross}_{i,t} \equiv PR_t \frac{p^h_{i,t}}{p_t} y^h_{i,t} - w^w_t l^w_{i,t} - w^k_t l_{k,t} - \frac{p^f_t}{p_t} m^f_{i,t} -$$

$$- \frac{p^h_t}{p_t} \frac{\xi^k}{2} \left( \frac{k_{i,t}}{k_{i,t-1}} - 1 \right)^2 k_{k,t-1} - \frac{p^h_t}{p_t} \frac{\xi^p}{2} \left( \frac{p^h_{i,t}}{p^h_{i,t-1}} - 1 \right)^2 \overline{y}^h_{i,t} \tag{18a}$$

where $l^w_{i,t}$ is labor services provided by workers and used by each firm $i$, $l^k_{i,t}$ is labor services provided by entrepreneurs and used by each $i$, $m^f_{i,t}$ is imported goods used by each $i$, $k_{i,t}$ is capital goods purchased from capital

[17] See e.g. Miao (2014, chapter 14) and Uribe and Schmitt-Grohe (2017, chapter 4), while for a more detailed analysis of the corporate finance problem see e.g. Altug and Labadie (1994, chapter 4) and Turnovsky (1995, chapter 11).

good producers by each $i$ in the current period (the relative price of capital is 1 - see below), $\xi^k$ is a parameter measuring standard capital adjustment costs and $\xi^p$ is a parameter measuring Rotemberg-type price adjustment costs.[18]

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

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

$$+ \pi_{i,t} R_{i,t} + i_t^l \frac{p_{t-1}}{p_t} L_{i,t-1} \tag{18b}$$

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

$$\frac{p_t^h}{p_t} \left[ k_{i,t} - (1-\delta) k_{i,t-1} \right] \equiv RE_{i,t} + (R_{i,t} - R_{i,t-1}) q_t + (L_{i,t} - \frac{p_{t-1}}{p_t} L_{i,t-1}) \tag{18c}$$

Combining the above constraints, we get:

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

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

$$\equiv (\pi_{i,t} R_{i,t-1} - (R_{i,t} - R_{i,t-1}) q_t) - \left( L_{i,t} - (1 + i_t^l) \frac{p_{t-1}}{p_t} L_{i,t-1} \right) \tag{18d}$$

where the left-hand side is the net cash flow of the firm.

If the number of shares is exogenous, say $R_{i,t} \equiv 1$ at any $t$, the net profit, $\pi_{i,t}$, simplifies to:[19]

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

[18] Notice that 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 proportionality is not important but helps the smooth dynamics of the model.

[19] This is as in e.g. Miao (2014, chapter 14) and Uribe and Schmitt-Grohe (2017, chapter 4). Note that imposing this market-clearing condition ex ante makes the optimization problem of the firm relatively simple. See e.g. Brock and Turnovsky (1981), Altug and Labadie (1994, chapter 4) and Turnovsky (1995, chapter 11) for richer problems.

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

$$+\left(L_{i,t}-(1+i_t^l)\frac{p_{t-1}}{p_t}L_{i,t-1}\right) \tag{19}$$

For the production function, we adopt the form:

$$y_{i,t}^h = A^p\left(\frac{N^g y_{g,t}^g}{N^i}\right)^\sigma\left[\left(\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m_{i,t}^f)^{op}\right)^{\frac{\alpha}{op}}\left(A^w l_{i,t}^w + A^k l_{i,t}^k\right)^{1-\alpha}\right]^{1-\sigma} \tag{20}$$

where the parameter $0 \leq \chi^p \leq 1$ measures the intensity of the beginning-of-period capital, $k_{i,t-1}$, relative to goods imported from abroad, $m_{i,t}^f$, the parameter $op \geqslant 0$ measures the degree of substitutability between domestic capital and imported goods, the coefficient $1-a$ gives the share of labor inputs used by the firm, the parameters $A^w$ and $A^k$ measure the relative productivity of workers and entrepreneurs 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 assumed to be subject to a borrowing constraint.[20] Following most of the related literature (see e.g. Garin (2015), Guntner (2015), etc), we assume that firms can borrow up to a fraction of their capital:

$$L_{i,t} \leq \rho^l \frac{p_t^h}{p_t} k_{i,t-1} \tag{21}$$

where the parameter $\rho^l \geq 0$ measures the tightness of borrowing conditions.

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

$$\sum_{t=0}^{\infty}(\beta_{i,t})^t \pi_{i,t} \tag{22}$$

where, since firms are owned by entrepreneurs, we will ex post postulate that the firm's discount factor, $\beta_{i,t}$, equals the entrepreneur's marginal rate of substitution between consumption at $t$ and $t+1$, $\beta_{i,t} \equiv \frac{\beta_k(1+\tau_t^c)c_{k,t}}{(1+\tau_{t+1}^c)c_{k,t+1}}$.[21]

**First-order conditions** The maximization is subject to the profit definition in (19), the inverse demand function in (17a), the production function in (20) and the borrowing constraint in (21). The first-order conditions for $\{l_{i,t}^w,\, l_{i,t}^k,\, m_{i,t}^f,\, k_{i,t},\, L_{i,t}\}_{t=0}^{\infty}$ are respectively:

[20] We could assume that firms face a cash-in-advance constraint as in e.g. Uribe and Schmitt-Grohe (2017, chapter 4). This is not important to our results.

[21] See also e.g. Altug and Labadie (1994, pp. 165-6), Gertler and Karadi (2011) and Uribe and Schmitt-Grohe (2017, pp. 110-111).

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

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)\overline{y}_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^w y_{i,t}^h}{(A^k l_{i,t}^k + A^w l_{i,t}^w)} \tag{23a}$$

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

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)\overline{y}_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^k y_{i,t}^h}{(A^k l_{i,t}^k + A^w l_{i,t}^w)} \tag{23b}$$

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

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)\overline{y}_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)\alpha y_{i,t}^h(1-\chi^p)(m_{i,t}^f)^{op-1}}{\left[\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m_{i,t}^f)^{op}\right]} \tag{23c}$$

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

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

$$-\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}(\theta-1)r_{t+1}^k+$$

$$+\beta_{i,t+1}\frac{p_{t+2}^h}{p_{t+2}}\xi^p\left(\frac{p_{t+2}^h}{p_{t+1}^h}-1\right)\frac{p_{t+2}^h}{p_{t+1}^h}(\theta-1)r_{t+1}^k+\beta_{i,t}N_{i,t+1}\rho^l\frac{p_{t+1}^h}{p_{t+1}} \tag{23d}$$

$$1=\beta_{i,t}(1+i_{t+1}^l)\frac{p_t}{p_{t+1}}+N_{i,t} \tag{23e}$$

and we also have the complementary slackness condition on the borrowing constraint (21):

$$N_{i,t}\left(L_{i,t}-\rho^l\frac{p_t^h}{p_t}k_{i,t-1}\right)=0 \tag{23f}$$

where $N_{i,t}$ is the multiplier associated with (21) and we define $r_{t+1}^k \equiv \frac{\partial y_{i,t+1}^h}{\partial k_{k,t}} = \frac{(1-\sigma)\alpha y_{i,t+1}^h \chi^p (k_{k,t})^{op-1}}{\left[\chi^p(k_{i,t})^{op}+(1-\chi^p)(m_{i,t+1}^f)^{op}\right]}$.[22]

[22] Notice that the Euler equation for bank loans, jointly with the Euler equation for bank

### 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 and managed by entrepreneurs, we again set $N^c = N^k$ for notational simplicity. Working similarly to e.g. Guntner (2015), Uribe and Schmitt-Grohe (2017, pp. 79 and 110), and many others, we assume that capital good producers aquire 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 $c$ maximizes:

$$\pi_{c,t} \equiv Q_t x_{c,t} - x_{c,t} \tag{24}$$

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 $Q_t = 1$. 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 entrepreneurs, we again set $N^p = N^k$ for notational simplicity, that is, the number of private banks equals the number of their owners. 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 receive loans from the NCB and to purchase government bonds. Therefore, on the side of liabilities, private banks receive deposits from households and take loans from the NCB, while, on the assets side, they make loans to private firms and purchase government bonds. Note that we do not include reserves held by private banks at the NCB; this is simply because they are small in the data (for financial statements of the Bank of Greece, see subsection 3.2 below). Any profits made by banks are distributed to their owners, namely the entrepreneurs. With small modifications, private banks are modelled in a way similar to that in Curdia and Woodford (2010, 2011).

**Bank's problem** The budget constraint of each $p$ that connects changes in its assets and liabilities is (written in real and per capita terms):

$$L_{p,t} + b_{p,t} + \pi_{p,t} + (1+i_t^d)\frac{p_{t-1}}{p_t} j_{p,t-1} + \frac{p_t^h}{p_t}\Xi(L_{p,t}, z_{p,t}, b_{p,t}) + (1+i_t^z)\frac{p_{t-1}}{p_t} z_{p,t-1} \equiv$$
$$\equiv (1+i_t^l)\frac{p_{t-1}}{p_t} L_{p,t-1} + (1+i_t^*)\frac{p_{t-1}}{p_t} b_{p,t-1} + j_{p,t} + z_{p,t} \tag{25}$$

deposits in the savers' problem, reveals that $i_{t+1}^l$ can differ from $i_{t+1}^d$, which is helpful in the private banks' optimization problem that comes next.

where $L_{p,t}$ is loans given to firms on which banks receive the nominal interest rate $i^l_{t+1}$ one period later, $b_{p,t}$ is one-period government bonds purchased by banks at $t$ on which banks receive the country-specific nominal interest rate $i^*_{t+1}$ one period later, $\pi_{p,t}$ is profits distributed to bank owners in a lump-sum fashion, $j_{p,t}$ is bank deposits on which banks pay the nominal interest rate $i^d_{t+1}$ one period later, $z_{p,t}$ is loans from the NCB to the private bank on which private banks pay the nominal policy interest rate $i^z_{t+1}$ one period later and $\Xi(L_{p,t}, z_{p,t}, b_{p,t})$ is real operational costs faced by banks that are assumed to be increasing in the volume of loans given to firms, increasing in the volume of loans taken from the NCB and decreasing in holdings of government bonds (the latter captures the idea that government bonds are used as a collateral for taking loans from the NCB). In what folows, we will use the functional form $\Xi(L_{p,t}, b_{p,t}) = \frac{\xi^l}{2}(L_{p,t})^2 + \frac{\xi^z}{2}(z_{p,t})^2 + \frac{\xi^b}{2}(b_{p,t})^{-2}$ which can give well-defined demand and supply functions).[23]

Loans from the NCB to private banks are assumed to be subject to a borrowing constraint. Similarly to the firm's problem above, we assume that each private bank can borrow up to a fraction of its assets:

$$z_{p,t} \leq \rho^z (L_{p,t} + b_{p,t}) \tag{26}$$

where the parameter $\rho^z \geq 0$ measures teh tightness of borrowing conditions.

Working as in Curdia and Woodford (2010, 2011), we set in each time period:

$$(1+i^d_t)\frac{p_{t-1}}{p_t} j_{p,t-1} + (1+i^z_t)\frac{p_{t-1}}{p_t} z_{p,t-1} = (1+i^l_t)\frac{p_{t-1}}{p_t} L_{p,t-1} + (1+i^*_t)\frac{p_{t-1}}{p_t} b_{p,t-1} \tag{27a}$$

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

$$j_{p,t} = \frac{(1+i^l_{t+1})\frac{p_t}{p_{t+1}} L_{p,t} + (1+i^*_{t+1})\frac{p_t}{p_{t+1}} b_{p,t} - (1+i^z_{t+1})\frac{p_t}{p_{t+1}} z_{p,t}}{(1+i^d_{t+1})\frac{p_t}{p_{t+1}}} \tag{27b}$$

**First-order conditions** Using (27a) into (25), each private bank maximizes in each period:

$$\pi_{p,t} \equiv j_{p,t} + z_{p,t} - L_{p,t} - b_{p,t} - \frac{p^h_t}{p_t}\Xi(L_{p,t}, z_{p,t}, b_{p,t}) \tag{28}$$

subject to the borrowing constraint in (26).

The optimality conditions for $L_{p,t}$ and $z_{p,t}$ are respectively:

[23] In Curdia and Woodford (2010, 2011), the banks intermediate between borrowers and lenders and the associated intermediation cost falls with reserves held at the central bank.

$$\frac{p_t^h}{p_t}\xi^l L_{i,t} = \frac{(1+i_{t+1}^l)}{(1+i_{t+1}^d)} - 1 + N_{p,t}\rho_p \tag{29a}$$

$$\frac{p_t^h}{p_t}\xi^z z_{p,t} = 1 - \frac{(1+i_{t+1}^z)}{(1+i_{t+1}^d)} - N_{p,t} \tag{29b}$$

and we also have the complementary slackness condition on the borrowing constraint (26):

$$N_{p,t}\left(z_{p,t} - \rho^z(L_{p,t} + b_{p,t})\right) = 0 \tag{29c}$$

where $N_{p,t}$ is the multiplier associated with (26).

Notice that these are well-defined supply and demand functions. Also notice we can also derive the optimal demand for government bonds. However, instead of choosing $b_{p,t}$, we prefer to simply set it (namely, the fraction of Greek public debt purchased by private domestic banks) exogenously as in the data. This helps us to bring the model closer to the data and can be justified by the fact that, in Greece, there is a nexus of public-finance policy and private banks (see e.g. Brunnermeier and Reis (2019) for this nexus in EZ periphery countries).

### 2.5 State firms and production of public goods or services

We now model the way in which state enterprises produce the publicly provided good. 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 the state firms equals the number of public employees.

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

$$w_t^g l_t^g + \frac{p_t^h}{p_t}(g_{g,t}^g + g_{g,t}^i) + \frac{p_t^f}{p_t} m_{g,t}^g \tag{30}$$

where $l_t^g$ 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:

$$y_{g,t}^g = A^g \left(\chi^g (k_{g,t-1}^g)^{og} + (1-\chi^g)(m_{g,t}^g)^{og}\right)^{\frac{\theta_1}{og}} (l_{g,t}^g)^{\theta_2} \left(g_{g,t}^g\right)^{1-\theta_1-\theta_2} \tag{31}$$

where $0 \leq \chi^g \leq 1$ measures the intensity of the beginning-of-period public capital, $k_{g,t-1}^g$, relative to goods imported from abroad, $m_{g,t}^g$, the parameter $og \geqslant 0$ measures the degree of substitutability between public capital and imported goods, the coefficients $0 < \theta_1,\ \theta_2,\ 1-\theta_1-\theta_2 < 1$ 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:

$$k^g_{g,t} = (1 - \delta^g)k^g_{g,t-1} + g^i_{g,t} \tag{32}$$

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

To specify the level of output produced by each state firm, $y^g_{g,t}$, and hence the total amount of public goods/services provided to the society, we obviously have to specify the amounts of inputs, $l^g_{g,t}$, $g^g_{g,t}$, $m^g_{g,t}$ and $k^g_{g,t}$ (or equivalently $g^i_{g,t}$). Except from work hours or effort which is chosen by public employees (see above), we will consider the case in which the values of these inputs are as implied by the actual data, meaning that the total number of public employees as share of population, as well as government expenditures on public investment, public wages, goods purchased from the private sector and imported goods, all four as shares of GDP, are as in the data. Specifically, $g^i_{g,t} = \frac{s^i_t n^k y^h_{i,t}}{n^b}$, $g^g_{g,t} = \frac{s^g_t n^k y^h_{i,t}}{n^b}$, $m^g_{g,t} = \frac{p^h_t}{p^f_t}\frac{s^m_t n^k y^h_{i,t}}{n^b}$, while, for the wage rate, we have $w^g_t = \frac{s^w_t \frac{p^h_t}{p_t} n^k y^h_{i,t}}{n^b l_{b,t}}$, where $n^b$ is the fraction of public employees in population and $s^i_t$, $s^g_t$, $s^m_t$ and $s^w_t$ denote 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 subsection 3.2 below).

## 2.6 Fiscal and monetary policy

This section models the Treasury and the National Central Bank (NCB) participating in the Eurosystem (ES). Before we do so, it is necessary to put our work in the context of the recent literature on the nexus between fiscal, public finance and quantitative monetary policies.

### 2.6.1 On the nexus between fiscal, public finance and quantitative monetary policies (standardized and in the ES)

It is convenient to start with monetary policy. It used to be customary in macroeconomic models, especially before the global crisis of 2008, to focus on the so-called conventional monetary policy (the policy instruments of this category include typically a nominal policy interest rate, the nominal quantity of a monetary aggregate and the nominal exchange rate, which are dependent to each other) leaving aside balance sheet or quantitative policies which have to do with the size and the mix of central bank assets and liabilities. Related to this, it also used to be customary to lump the budget constraint of the Treasury and the budget constraint of the Central Bank into a single constraint, the so-called consolidated government budget

constraint. As explained, for example, by Reis (2013, 2017), Walsh (2017, chapter 11) and Benigno and Nistico (2017), the origin of this tradition dates back to the benchmark model in Wallace (1981) in which the size and mix of central bank's balance sheet can neither affect the economy's real allocation (see especially Walsh (2017, chapter 11)) nor help to alleviate fiscal burdens (see especially Reis (2017)). That is, in this benchmark framework, there is a strong neutrality property, which implies, among other things, that resources from the central bank to the fiscal authorities may not exist at all in equilibrium (as Reis (2017) puts it, one type of liability just replaces another) or, even if they exist, they are small in magnitude (see e.g. the real value of seigniorage revenue).

However, the massive expansion in central bank balance sheets since the onset of the 2007-8 global crisis has forced a re-examination of the nexus between monetary, fiscal and public finance policies. Leaving aside conventional monetary policy instruments (whose independent use is reduced, or fully lost, in a small open economy participating in a currency union), central bank balance sheet policies have been key elements of monetary policy around the world since 2007-8.[24] The ECB has not been an exception to this; the size of its balance sheet has increased by around 500% since 2008. As a response to the massive quantitative policies adopted by most central banks, the academic literature has recenly added several financial frictions to the benchmark framework that result in departures from Wallace's neutrality property. Examples of such financial frictions include transaction costs, household heterogeneity, market segmentation, borrowing constraints, limited market participation, moral hazard, preferred habitat, non-rational expectations, etc (see Walsh (2017, chapter 11) and Sims and Wu (2020) for reviews of this literature).[25] On top of this, Reis (2013, 2017) has pointed out an extra route through which quantitative monetary policies can alleviate fiscal burdens and relax national constraints even in the absence of financial frictions like the above: in a currency union, the currency union's central bank, like the ECB in the ES, can play a redistributive role by relaxing the fiscal and resource constraints of some regions and by tightening those of others. Specifically, Reis (2017) has argued that several of the ECB's policies (like the SMP, the provision of ELA and the way ECB's div-

[24] Historically, quantitative policies have always been key elements of standard monetary policy. It is only since the 1970s, that such policies have been regarded as unconventional. The 2007-8 crisis has simply forced a re-examination of this. See e.g. the papers presented in the workshop on "Threat of Fiscal Dominance?" organised by the Bank for International Settlements and the OECD in 2012 (BIS/OECD, 2012).

[25] As Walsh (2017, chapter 11) points out, this happens when financial frictions create pricing wedges, so that different asset and liabilities of the central bank become imperfect substitutes, that in turn affect real decisions and output. In this context, altering the relative quantities of central bank's assets and liablities can have real effects. Note that the Curdia and Woodford (2010, 2011) setup, also adopted here, is one out of several setups allowing for such a deviation from Wallace's benchmark case.

idends are distributed to each member-country) can belong to this category allowing for redistribution of real resources among governments and nations within the ES. A parallel literature (Sinn and Wollmershauser (2012) and Sinn (2014)) has argued that the issuance of *TARGET2* balances can work in the same way (*TARGET2* balances, which are particularly big in the case of Greece, are discussed and modeled below).

Here, we will use a formal criterion that helps us to judge whether a quantitative or balance-sheet monetary policy can play a direct allocative role: it can, if this policy remains *as an item* in the consolidated government budget constraint and in the economy's resource constraint meaning the balance of payments, once market-clearing conditions have been taken into account. According to this criterion, as we shall see below, purchases of government bonds by the ES beyond those purchased by the NCB, dividends given by the ES to the national government again beyond those transferred by its NCB, as well as the issuance of *TARGET2* liabililities by the NCB as part of its monetary base, can, at least in principle, play an allocative role and practically work like foreign public assistance that can replace private capital inflows from abroad.

The rest of this subsection will model the above narrative within the context of the Greek economy. The government will be separated into its two agencies, fiscal and monetary. That is, following e.g. Reis (2013, 2017), Bassetto and Messer (2013), Del Negro and Sims (2015), Woodford (2016), Benigno and Nistico (2017) and Sims and Wu (2020), we will present separately the budget constraint of the fiscal authorities (Treasury) and the budget constraint of the monetary authorities (the National Central Bank, NCB, as part of the ES). This will help us to understand the menu of fiscal and monetary policy options available to policymakers and how the various policy instruments interact with each other.

### 2.6.2 The Treasury

The Treasury, or the fiscal branch of government, uses revenues from taxes on labor income, capital income and consumption, the issuance of government bonds and a direct receipt/dividend from the central bank to finance its various spending activities. This is standard; we will only differ in who can hold Greek public debt so as to embed the official fiscal bail out.

**Public debt and its holders** 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 purchased by four different types of creditors: domestic private agents/banks, the national central bank, foreign private agents/banks and foreign public institutions, where the latter includes EU states and institutions as well as other national central banks or the ECB itself - which we will label as the

"EU".[26] [27] In the pre-crisis period (2001-2008), the public debt was mainly held by private (domestic and foreign) agents/banks, while during the crisis most of public debt has changed hands and is now being held by the "EU" as part of Greece's bailout program.

In particular, $d_t$ is decomposed to:

$$d_t = b_t^d + b_t^{ncb} + \frac{e_t p_t^*}{p_t} f_t^g + \frac{e_t p_t^*}{p_t} f_t^{eu} \tag{33a}$$

where, expressing them as fractions of total debt, we define:[28]

$$b_t^d \equiv \lambda_t^d d_t \tag{33b}$$

$$b_t^{ncb} \equiv \lambda_t^{ncb} d_t \tag{33c}$$

$$\frac{e_t p_t^*}{p_t} f_t^g \equiv \lambda_t^g d_t \tag{33d}$$

$$\frac{e_t p_t^*}{p_t} f_t^{eu} \equiv \lambda_t^{eu} d_t \tag{33e}$$

where $0 \leq \lambda_t^d$, $\lambda_t^{ncb}$, $\lambda_t^g$, $\lambda_t^{eu} \leq 1$ are the fractions of Greek public debt held respectively by domestic private agents/banks, the NCB, foreign private agents/banks and the EU, where $\lambda_t^d + \lambda_t^{ncb} + \lambda_t^g + \lambda_t^{eu} = 1$.[29] If the policy and rest-of-the-world variables, $\lambda_t^{ncb}$, $\lambda_t^g$ and $\lambda_t^{eu}$, are exogenously given (they will be set as in the data), then residually $\lambda_t^d = (1 - \lambda_t^{ncb} - \lambda_t^g - \lambda_t^{eu})$.[30]

[26] We allow for bond purchases by the NCB only for generality and comparison to the literature. In our numerical solutions, by contrast, we will set the fraction of public debt purchased by the NCB at zero, $\lambda_t^{ncb} = 0$. This is because the early asset purchase programs (SMP, CBPP, etc), according to which the ES bought the debt of countries in trouble, were conducted mainly in the secondary market, which means that any beneficial effects (e.g. reductions in sovereign spreads) on public finances were indirect (see e.g. Gibson et al. (2015)). In addition, Greece has not been included in the official APP of the ECB that started in 2015. We will therefore find it natural, in our numerical solutions, to set government bond purchases by the NCB at zero so that any forms of monetary accommodation of fiscal policy will be captured by the direct transfer from the NCB to the Treasury, $rcb_t^g$, only. Also note that the ECB and NCBs in the ES can purchase government bonds subject to the so-called capital key, which is based on the population and the size of the economy in each member country. Similar rules apply to direct dividends to national fiscal authorities (see e.g. Reis (2017)).

[27] We could also allow for a secondary market for government bonds, in the sense that the NCB or the ECB purchase part or all of the existing (beginning-of-period) stock of bonds held by private agents/banks. We do not do it to avoid further additions to an already detailed model.

[28] 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

[29] As said, in our solutions, we will set $\lambda_t^{ncb} = 0$.

[30] 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.

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

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

$$+(1+i_t^*)\frac{p_{t-1}}{p_t}\lambda_{t-1}^d d_{t-1} + (1+i^*)\frac{p_{t-1}}{p_t}\lambda_{t-1}^{ncb} d_{t-1} +$$

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

$$+\frac{p_t^h}{p_t}\psi^g(.) \equiv d_t + \frac{T_t}{N} + rcb_t^g \tag{34}$$

where $\overline{g}_t^{tr}$ is transfers to households, $n^b \left[ w_t^g l_{g,t}^g + \frac{p_t^h}{p_t} \left( g_{g,t}^g + g_{g,t}^i \right) + \frac{p_t^f}{p_t} m_{g,t}^g \right]$ is the cost of state firms, $\psi^g(.)$ is a transaction cost function associated with the government's participation in the foreign capital market (defined right below), $\frac{T_t}{N}$ denotes tax revenues (defined right below) and $rcb_t^g$ is a direct transfer/dividend from the central bank to the Treasury.[31] The rest of the terms capture interest payments on public debt where notice that the interest rates vary depending on the identity of the creditor. For instance, we assume that when the government borrows from the EU or the ES, it pays the constant world interest rate, $i^*$, only, while, when the government borrows from the market, is pays the country's interest rate, $i_t^*$, which inludes a premium (see subsection 2.8 below).

As in equation (4) above, we assume that the cost associated with participation in the foreign financial market takes the form:

$$\psi^g(.) \equiv \frac{\psi^g}{2} \left[ \frac{\frac{e_t p_t^*}{p_t} \left( n^k f_{k,t} + \lambda_t^g d_t \right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f} \right]^2 n^k y_{i,t}^h \tag{35}$$

where $\psi^g \geq 0$ is a transaction cost parameter associated with public borrowing from foreign markets.

Total tax revenues in real (but not per capita) terms are defined as:

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

[31] See also e.g. Walsh (2017, chapter 4), Reis (2013, 2017), Bassetto and Messer (2013), Woodford (2016) and Benigno and Nistico (2017), while see Reis (2017, section 10) for details on such transfers in the ES.

$$+N^b(\frac{p_t^h}{p_t}c_{b,t}^h + \frac{p_t^f}{p_t}c_{b,t}^f)] + \tau_t^y N^k[\frac{p_t^h}{p_t}r_t^k k_{k,t-1} + \pi_{k,t} + w_t^k l_{k,t}]$$
$$+\tau_t^y N^w w_t^w l_{w,t} + \tau_t^y N^b w_t^g l_{b,t} \quad (36)$$

One of the policy variables must follow residually to close the Treasury's budget constraint in (34); this is defined below after we present the budget constraint of the NCB.

### 2.6.3 The National Central Bank (NCB) in the Eurosystem

Before we introduce the Greek NCB, we need to clarify how the balance sheet of a NCB participating in the Eurosystem (ES) is related to the consolidated balance sheet of the ES.

**The ES and its NCBs** The financial statement and the budget constraint of the ECB is not different from that of a standardized central bank. In other words, as is typically the case with central banks (see e.g. Reis (2009, 2013) and Whelan (2014, section 2.1)), the assets side of the balance sheet of the ECB consists mainly of foreign currency, loans to euro area credit institutions related to monetary policy operations (e.g. main refinancing operations, MROs, longer-term refinancing operations, LTROs, marginal lending facilities, etc, and also emergency liquidity assistance, ELA) and securities (e.g. the covered bond purchase program (CBPP), the securities markets program (SMP), the APP program since 2015, etc). The liabilities side on the other hand consists mainly of banknotes in circulation (held by the non-bank public as currency), reserves which are also called current accounts (held by private banks at the central bank) and government deposits; these liabilities are the main items of the monetary base of the ES.[32]

However, the consolidated balance sheet of the ES shows assets and liabilities of the Eurosystem NCBs vis-à-vis third parties only. In other words, it does not include credits and debits between the Eurosystem's NCBs, known as Intra-Eurosystem claims and liabilities and recorded respectively as *TARGET2* assets and *TARGET2* liabilities in the financial statements of the individual NCBs participating in the ES. As first pointed out by Sinn and Wollmershauser (2012) and Sinn (2014) and further studied by e.g. Whelan (2014, 2017), these are net bilaterals 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 the money from abroad records a *TARGET2* asset. These *TARGET2* balances cancel each other out at aggregate ES

[32] For details on the ECB, see e.g. "User guide on the Eurosystem consolidated weekly financial statement" and "Annual consolidated balance sheet of the Eurosystem" published by the ECB. For the conduct of monetary policy in the Eurosystem, see e.g. "The monetary policy of the ECB" (ECB, 2011, chapter 4, pp. 111-5).

level (this is by construction) and therefore do not appear in the consolidated balance sheet of the ECB.[33] However, they do appear in the balance sheets of the individual NCBs in the sense that they 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). In other words, for a country like Greece, *TARGET2* liabilities have become a part of the monetary base created by its NCB in accordance with the rules of the ES.[34]

Looking at the data, as is well known, there has been an explosion of *TARGET2* balances after 2008.[35] For the ES as a whole, *TARGET2* balances were very small prior to the crisis but have increased substantially since then (they were 186 billion euros in May 2008, 416 billions in July 2011, 1.09 trillion in August 2012 and 1.24 trillion in September 2017; see Whelan (2017, Figure 1)). In the case of Greece, *TARGET2* liabilities were, for instance, 105 billion euros in 2011 which translates into 105/168=62% of total liabilities or 105/207=51% of GDP, and 94 billion euros in 2015, which translates into 94/163=58% of total liabilities or 94/177=53% of GDP.[36] Actually, as we shall see in the next section, in the case of Greece, *TARGET2* liabilities have been by far the largest item of liabilities, and hence of the monetary base of the Greek NCB, in every year between 2008 and 2017 (included).

Before we move on, it is worth recalling that, since the publication of the seminal paper by Sinn and Wollmershauser (2012), there has been a heated debate at both academic and policy circles over the role of these assets and liabilities. Opinions have ranged from *TARGET2* being an innocent protocol

[33] See e.g. Whelan (2014, 2017) for the mechanics of the *TARGET2* system and how assets and liabilities of both private banks and NCBs change in response to various changes like moving money from a bank account in country A to a bank account in country B. As Sinn (2014, p. 187) says, "the outflow of money from Greece goes hand-in-hand with ... the inflow of money into Germany, ... in turn, leads to additional liquidity that German banks do not need and which they therefore choose to lend to the Bundesbank with the effect that the money is removed from the economy".

[34] As Sinn (2014) has pointed out, a natural question to ask is whether NCBs in the ES can freely issue liabilities in euros, namely, print banknotes, issue reserves and create *TARGET2* liabilities. The answer is a qualified "yes" (see e.g. Sinn (2014) and Whelan (2014, 2017)) to the extent that they act according to the rules defined by the ECB council. As said already, the latter has loosened the requirements for private banks obtaining loans, has provided funding for longer periods, has allowed for ELA against collateral that was not included in ECB's list, etc.

[35] For detailed data across euro area countries, see e.g. Whelan (2014, 2017). See also ECB's publications like "User guide on the Eurosystem consolidated weekly financial statement", "Target balances of participating NCBs" and "The ECB's asset purchase programme and TARGET balances: monetary policy implementation and beyond".

[36] As the data show (e.g. Whelan (2014, 2017)), the same happened in other periphery countries of the EZ. For instance, in Ireland, *TARGET2* liabilities peaked at 91% of GDP in 2010. See also Lane (2014) for Ireland.

of the ES to being a hidden bailout of the periphery EZ countries in trouble (see Sinn (2014)). Today, to the best of our understanding, there is a kind of consensus, in the sense that the enormous magnitude of *TARGET2* balances during the crisis (a) is closely related to fears of default and a euro break up (b) is closely related to loans to private banks facilating a capital flight from the periphery to the core (c) is not clearly timed to current account deficits in the periphery. See e.g. the paper by Whelan (2014) and its discussants for a summary of facts and views.

**Balance sheet and budget constraint of the NCB** Given the above facts, on the side of assets of the Greek NCB, we will include loans to private banks and government securities, while, on the liabilities side, we include banknotes in circulation and *TARGET2* liabilities. These are the largest asset and liabilities items in the financial statemenst of the Greek NCB (see next section for detailed data).[37]

Then, the budget constraint of the NCB linking changes in assets and liabilities is (written in real and per capita terms):

$$n^k z_{p,t} + \lambda_t^{ncb} d_t + rcb_t^g \equiv$$

$$\equiv \left(h_t^n - \frac{p_{t-1}}{p_t} h_{t-1}^n\right) + \left(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}\right) +$$

$$+ n^k (1 + i_t^z) \frac{p_{t-1}}{p_t} z_{p,t-1} + (1 + i_t^*) \frac{p_{t-1}}{p_t} \lambda_{t-1}^{ncb} d_{t-1} \tag{37}$$

where $n^k z_{p,t}$ is the end-of period loans to private banks, $\lambda_t^{ncb} d_t \equiv b_t^{ncb}$ is the end-of-period government bonds purchased by the NCB (however, for the reasons explained in subsection 2.6.2 above, we will set $\lambda_t^{ncb} \equiv 0$ in our numerical solutions), $rcb_t^g$ is the direct transfer/dividend from the NCB to its government (as said above, this is the NCB's balance-sheet earnings rebated to the Treasury), $h_t^n$ denotes the end-of-period stock of banknotes in circulation and $TARG_t$ denotes the end-of-period stock of *TARGET2* liabilities (for notational simplicity, which is also close to the data, we assume that the refinancing rate on $TARGET2$ balances is zero). In other words, in our model, $h_t^n + TARG_t \equiv MB_t$ is the monetary base of the Greek NCB within the ES.

In equilibrium, banknotes in circulation are equal to the currency held by the public for liquidity-providing services, namely, $h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$ in each $t$. In this case, *TARGET2* liabilities are the difference between $MB_t$ and $n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$. In other words, to the extent that the monetary base of the NCB exceeds the amount of currency held by the

[37] See e.g. Reis (2009) and Sims and Wu (2020) for liabilities of the FED where reserves held by private banks play a big role.

public for liquidity services,[38] or, loosely speaking, to the extent that the funds made available by the NCB are not only used to hold a larger stock of money balances, the country has a *TARGET2* liability to the rest of the ES.[39]

We should make two points here regarding *TARGET2* liabilities. First, they are possible because, in a currency union (CU), the money market clears at a CU level rather than at local/national level. Second, the way in which these cross-country liabilities affect the real economy, and how they can be used, will become clear below when we present the consolidated government budget constraint and the balance of payments (as said in subsection 2.6.1 above, this is our formal criterion).

Summing up, in (37), the NCB's spending is financed by issuing banknotes and *TARGET2* liabilities to the rest of the NCB's in the ES under the rules of the ES (as said, these are the two biggest items of the monetary base in the Greek data), as well as by interest income earned on loans to banks and securities bought in the past.

One of the monetary variables must adjust residually to close the budget constraint in (37); this is defined below jointly with the fiscal policy variable that closes the Treasury's budget constraint in (34).

### 2.6.4 Consolidated government budget constraint

Adding up the budget constraints of the Treasury and the NCB, (34) and (37), and using the market-clearing condition $h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$, we get the consolidated government budget constraint (in real and per capita terms):

$$\overline{g}_t^{tr} + (1+i_t^*)\frac{p_{t-1}}{p_t}\lambda_{t-1}^d d_{t-1} +$$

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

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

$$+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h = (\lambda_t^d + \lambda_t^g + \lambda_t^{eu}) d_t + \frac{T_t}{N} +$$

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

[38] Or, equivalently, since assets are equal to liabilities by definition, to the extent that the claims of the NCB on its private sector exceed the amount of currency held for liquidity services.

[39] We are grateful to Hans-Werner Sinn for comments on this issue. Any errors are ours.

$$-n^k\left(z_{p,t}-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}\right)+\left(TARG_t-\frac{p_{t-1}}{p_t}TARG_{t-1}\right) \tag{38}$$

where all variables have been defined above.

Inspection of the above constraint confirms some standard properties but also reveals some distinct features of the ES. Regarding the standard properties, the NCB's purchase of government bonds, $\lambda_t^{ncb}d_t$, as well as the provision of transfers/dividends to its own government, $rcb_t^g$, do not appear in the consolidated government budget constraint. As said above, this is simply because when the NCB transfers resources to its own government, or vice versa, one type of liability replaces another (see Reis (2013, 2017) and also Bassetto and Messer (2013), Woodford (2016) and Benigno and Nistiko (2017)) so that the NCB can only generate revenue for its government through the real value of seigniorage, $\left(h_t^n-\frac{p_{t-1}}{p_t}h_{t-1}^n\right)$. This is standard. On the other hand, the same constraint reveals how, in a currency union, a single central bank like the ECB, that faces different fiscal authorities, can redistribute resources and thereby alleviate the fiscal burden of member-countries in need (see Reis (2017, section 10)). In particular, as the above constraint reveals, this can be done via purchases of government bonds beyond those purchased by the NCB (see the term $\lambda_t^{eu}d_t$ which, as said, can, in principle at least, include ECB's holdings) and by the permission to issue *TARGET2* liabilities to the extent that this issue is beyond the amount of currency held by the public for liquidity services. As we shall see, the very same terms will also appear in the balance of payments presented below. Finally, it is worth adding that had we allowed for direct transfers/dividends by the ECB beyond those provided by the NCB, these transfers/dividends would also remain in the consolidated government budget constraint (as wel as in the balance of payments below) and hence could play a redistributive allocative role similar to that played by $\lambda_t^{eu}d_t$ and *TARGET2* liabilities; since bond purchases by the EU as well as *TARGET2* liabilities can play this role anyway, we find no reason to add another type of redistributive policies by the ECB.

As in (34) and (37) above, one policy variable must adjust residually to close the consolidated budget constraint in (38); this is defined next.

### 2.6.5 Fiscal-monetary policy regime

By policy regime, we typically mean a choice of which policy variables are set by the policy authorities and which have to follow endogenously/residually to accommodate the policy decisions made (see e.g. Reis (2009)).

The constraints of the Treasury and the NCB, in (34) and (37) respectively, make clear the various options available to fiscal and monetary authorities or, equivalently, the possible policy regimes. In other words, once one allows for a more realistic menu of monetary policy instruments as we

have done here (in particular, assets and liabilities of the NCB and the associated policy interest rates), there is a wide range of policy regimes even in a small open economy within a currency union or fixed exchange rates.

In normal times, a popular policy regime has been to assume that the end-of-period public debt, $d_t$, adjusts to satisfy the Treasury's budget constraint in (34) and, among other balance sheet variables, the transfer/dividend from the central bank to the government, $rcb_t^g$, adjusts to satisfy the NCB's budget constraint in (37), while, at the same time, the central bank is free to set all but one conventional monetary policy instruments.[40]

Here, to capture the fiscal austerity mix adopted by the Greek governments, the shutting out from private capital markets, as well as the official fiscal bailouts and the various accommodative policies followed by the ECB towards Greece during the crisis years, we will set all tax rates, all types of government spending as shares of GDP, the public debt-to-GDP ratio jointly with its decomposition to various holders (including the EU institutions and the IMF), all as they are in the data over the crisis years, and then assume that the direct receipt/dividend from the NCB, $rcb_t^g$, adjusts to close the government budget constraint in (34) and, at the same time, the change in the monetary base adjusts to close the NCB's budget constraint in (37). Actually, to the extent that the monetary base consists of banknotes in circulation and *TARGET2* liabilities, $MB_t \equiv h_t^n + TARG_t$, where the banknotes in circulation are determined by the currency demanded by the public for liquidity-providing services, $h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$, endogeneity of the change in the monetary base practically means endogeneity of the cross-border liquidity term, $TARG_t - \frac{P_{t-1}}{P_t} TARG_{t-1}$. Equivalently, if we merge the budget constraints of the government and the NCB into a single one, the consolidated government budget constraint in (38), $TARG_t - \frac{P_{t-1}}{P_t} TARG_{t-1}$ will be the residually determined policy item.

In other words, we assume that the ECB has been following an accommodative policy towards Greece, in the sense that it has increased its monetary base and specifically the issuance of *TARGET2* liabilities so as to accommodate the rest of policies as well as the macroeconomic developments occurring at the same time. At least at regional/national level, this is a regime of fiscal dominance meaning active fiscal policy and passive monetary policy (see e.g. Walsh (2017, chapter 4)).[41] The list of endogenous variables and the exogenously set policy instruments is presented in detail

[40] See e.g. Benigno and Nistiko (2017) for a detailed classification of a rich menu of policy instruments into exogenous and endogenous, although in a closed economy model in which the conventional monetary instruments are a nominal interest rate and the nominal quantity of a monetary aggregate.

[41] As Reis (2019) points out, fiscal dominance at Eurozone level has been avoided. On the other hand, redistribution (via e.g. purchase of national government bonds, sharing of dividends, ELA, etc) has worked like fiscal dominance in the member-countries hit by the crisis.

in Appendix A.

### 2.7 Balance of payments

If we add up the budget constraints of all agents, we get the country's resource constraint, namely, its balance of payments (written in real and per capita terms):

$$\frac{p_t^f}{p_t}\left(n^k c_{k,t}^f + n^w c_{w,t}^f + n^b c_{b,t}^f + n^k m_{i,t}^f + n^b m_{g,t}^g\right) - \frac{p_t^h}{p_t} c_t^{f*} + (1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t} n^k f_{k,t-1} +$$

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

$$+\frac{p_t^h}{p_t}\frac{\psi^p}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h +$$

$$+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h =$$

$$= \frac{e_t p_t^*}{p_t} n^k f_{k,t} + \lambda_t^g d_t + \lambda_t^{eu} d_t + \left(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}\right) \tag{39}$$

Inspection of the balance of payments reveals, as the consolidated government budget constrainst also did in (38), the redistributive role that the ECB can play at least in principle. This can be done by purchases of government bonds beyond those purchased by the NCB (see the term $\lambda_t^{eu} d_t$ which, as said above, can include ECB's holdings) and by allowing the NCB to issue excess liquidity in the form of $TARGET2$ liabilities to the rest of the ES (see the term $TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}$, which, also as said above, becomes possible when the monetary base of the NCB exceeds the amount of currency held by the public for liquidity services).[42] These items, capturing the quantitative or balance-sheet policy of the ECB, can be used to finance imported goods, to repay foreign debt or to finance investment abroad (see the various terms in (39)).

A final clarification of the role of *TARGET2*: As pointed out by Sinn (2014, p. 180), our term $\left(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}\right)$ is the increase in "the amount of central bank credit that has been issued in excess of liquidity

[42] The same can happen, as said above, via direct transfers/dividends by the ECB beyond those provided by the NCB.

needs for transactions within the NCB's national jurisdiction". 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; there could not be any use of extra self-created money in those cases. 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 within the EZ.[43]

### 2.8 Country's interest rate

Following most of the literature on small open economies (e.g. Schmitt-Grohé and Uribe (2003) and Uribe and Schmitt-Grohé (2017)), we assume that the interest rate at which the country (meaning both private and public agents) borrows from abroad, $i_t^*$, is public debt-elastic (except in the case in which it borrows from non-market institutions like the EU). In particular, we use the functional form:

$$i_t^* = i^* + \psi^* \left( \exp(\frac{d_t}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{d}) - 1 \right) \tag{40}$$

where $\psi^*$ is an interest-rate premium parameter and the parameter $\overline{d} \geq 0$ is a threshold value for the public debt-to-GDP ratio above which country premia emerge (see also Philippopoulos et al. (2017a) and the references therein).

### 2.9 How we will work in the rest of the paper

Collecting all the above equations, the equilibrium system is presented in detail in Appendix A. It consists of 51 equations in 51 endogenous variables. This is given the paths of the exogenously set policy variables and the degree of property rights, whose values will be set as in the data. In the next sections, we will first parameterize the model, present the data and in turn solve the system numerically. Our quantitative analysis will consist of three

[43] To make the point clearer, consider a miniature version of our model without financial intermediaries, a government or foreign assets. The budget constraints of the private sector and the NCB are respectively $c_t + \Delta h_t = y_t + \Delta z_t$ and $\Delta z_t = \Delta MB_t = \Delta h_t + \Delta TARG_t$, where $h_t$ is currency held by the private agent, $z_t$ is a loan from the NCB (assume a zero interest rate), $MB_t$ denotes the monetary base, $\Delta x_t \equiv x_t - x_{t-1}$ and the rest are obvious and are as in the paper above. Then, adding them up, the economy's resource constraint or its balance of payments is $c_t = y_t + \Delta TARG_t$. We are grateful to Hans-Werner Sinn for this model specification. If the currency is national, so that the money market clears at national level, $h_t = z_t$ and hence $TARG_t = 0$.

steps. First, after presenting parameter values and Greek data, we will get a stationary solution using data in the year 2008. As we shall see, this solution can match the main features of the data before the eruption of the crisis reasonably well and can thus serve as a departure point in what follows. Second, departing from this solution, we will feed the model with the time-series of our exogenous forces (changes in policy variables, institutional quality, etc) as they are in the time-series in the data. This will allow us to provide a quantitative assessment of the main drivers of the Greek depression since 2009. In these solutions, along the transition of the economy to its new stationary equilibrium, we will assume that after 2017 (this is the last year that data for all exogenous variables are available) the model's exogenous variables remain as in 2017. Finally, we will experiment with various counter-factual scenarios since 2009 that could have possibly made the economic downturn milder or worse. We will assume that all this is common knowledge so that we solve under perfect foresight. In our solutions, we use a Newton-type non-linear method implemented in DYNARE.

# 3 Parameterization, data and solution for 2008

To make quantitative predictions, we need to solve the model numerically. In subsection 3.1, we will present structural parameters related to technology and preferences. In subsection 3.2, using data from Greece, we will specify the driving forces of the model, namely, the time paths of the exogenously set policy variables and the degree of property rights. Based on this, subsection 3.3 will then present the stationary solution of the model when we use data for the year 2008 which was the last year before the crisis in Greece.

## 3.1 Parameter values

Regarding structural parameters for technology and preferences, for most of them, we will use commonly employed values, while the rest will be calibrated so as the model to mimic some key Greek statistics. Parameter values 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, the time discount factors of savers and borrowers, $\beta$ and $\beta^k$, are set at 0.99 and 0.98 repectively so as to give a lending interest rate above the saving interest rate. The weights given to private consumption, leisure and real money holdings, $\mu_1$, $\mu_2$ and $\mu_3$ in households' utility function, are respectively 0.40, 0.55 and 0.03, while the remaining, 0.02, goes to utility-enhancing public goods/services; these values produce work hours, etc, within usual ranges. The degree of preference of home goods over foreign goods, $\nu$, is set at the neutral value of 0.5; this

also contributes to delivering reasonable ratios of home to foreign goods in households' consumption spending.

Continuing with technology parameters, in the production function of private goods, the exponent of labor, $1 - \alpha$, is set at 0.6, while, the rest, $a = 0.4$, is the exponent of the CES term that includes capital and imported goods. In the same production function, the contribution of productivity-enhancing public goods/services to private production, $\sigma$, is set at 0.1. The work productivity parameters of entrepreneurs and workers in the private good production function, $A^k$ and $A^w$, are set at 3 and 2 respectively; this difference produces a skilled wage premium within usual ranges. In the private firm's production function, the parameter measuring the intensity of capital vis-a-vis imported goods, $\chi^p$, as well as the parameter measuring the substitutability between capital and imported goods, $op$, are both set at 0.5; the same value of 0.5 is used for $\chi^g$ and $og$ in the state firm's production function. Also in the state firms' production function, the Cobb-Douglas exponents of public capital and public employment, $\theta_1$ and $\theta_2$, are set respectively at 0.3045 and 0.6, which correspond to payments for public investment and public wages, expressed as shares of total public payments to all inputs used in the production of public goods, as they are in the data (for similar practice, see e.g. Linnemann (2009) and Economides et al. (2014 and 2017)); in turn, the Cobb-Douglas exponent of goods purchased from the private sector, $1 - \theta_1 - \theta_2$, follows residually. Both private and public capital depreciation rates, $\delta$ and $\delta^g$, are set at 0.05. Similarly, both TFP parameters (in the private and public production functions) are normalized at 1 (note that public sector efficiency, and why it may differ from private sector efficiency, is crucial but is not an issue in this paper). In the baseline simulations, the Dixit-Stiglitz parameter capturing imperfect competition in product markets, $\theta$, is set at 0.75; this is close to the literature (see e.g. Eggertsson et al., 2014) and produces a profit ratio around 10%. In the rent-seeking technology, the power coefficient is set at 0.5 which is common for all types of agents, while the effectiveness parameters of public employees, entrepreneurs and workers, $\Gamma^b$, $\Gamma^k$ and $\Gamma^w$, are set at 1.3, 1 and 0.7 respectively to reflect their political power in rent extraction.

The transaction cost parameters associated with capital changes, bank loans to firms and NCB loans to private banks, $\xi^k$, $\xi^l$ and $\xi^z$, are all set at 0.3. The Rotemberg-type parameter associated with price changes, $\xi^p$, is set at 3. The two transaction cost parameters associated with participation in the foreign capital market, $\psi^p$ and $\psi^g$, are set at 0.5. The risk premium parameter in the debt-elastic interest rate rule, $\psi^*$, is set at 0.05; this belongs to usual ranges and also produces a foreign debt to GDP ratio as in the data when the crisis erupted. The fixed world interest rate, $i^*$, is set at 1%. The two parameters in the function of exports, $\Theta$ and $\vartheta$, are set at 0.5 and 2 respectively; these values contribute to producing a trade deficit close to the data. The threshold values of public debt and foreign debt as shares of

GDP, above which problems start, are set at 1.1 and 0.8 respectively which are values close to those in Reinhart and Rogoff (2009). The parameters in the two inequality borrowing constraints, $\rho^l$ and $\rho^z$, are set at 0.5.

Finally, the population fractions of public employees, $n^b$, and self-employed or entrepreneurs, $n^k$, are set at 0.2 and 0.2 respectively as in the data, so that the fraction of workers, $n^w$, follows residually at 0.6.

**Table 1: Baseline parameterization**

## 3.2 Data and a brief recollection of facts

In this subsection, we present the data used for the modelling of the exogenous variables. As has already been discussed in the Introductory section above, there have been at least three notable developments in the Greek economy since 2008. First, Greece has resorted to international financial assistance provided by other EU countries, European institutions (EFSF, EFSM, ESM and the ECB) and the IMF. Second, as a condition for the assistance received, Greece has been forced to take severe fiscal austerity measures and to promise the implementation of structural reforms in product and labor markets. Third, the fiscal austerity measures taken and the severe economic downturn that followed have been accompanied by a sharp deterioration in institutional quality. These three distinct developments are the main driving forces in our model; the rest is structural refoms captured by simple changes in parameter values like the Dixit-Stiglitz product substitutability parameter (see below). In what follows, we briefly comment on the main driving forces and present the related data.

### 3.2.1 International financial assistance (fiscal and monetary)

In the case of Greece, fiscal rescue operations have been expressed by three official bailouts. The first took place in 2010-11 through the Greek Loan Facility, the second in 2012-2015 through the EFSF and the third in 2015-2018 through the ESM (see ESM, 2018, for details). These programs were completed in August 2018 so the country is no longer reliant on ongoing official rescue loans for the first time since 2010. The total amount received by Greece since 2010 is around 290 billion euros. This is the largest financial assistance package in history. Most of this has been used for public debt servicing payments; this means the repayment of maturing government debt, the service of interest payments on existing government debt and various forms of bond exchanges that helped private banks and creditors to offload their holdings of Greek government bonds.[44] As a result, today, close to

[44] See e.g. Bortz (2015), Rocholl and Stahmer (2016) and ESM (2017, 2018) for a detailed decomposition, that is, how the loans were used by Greece in the three official bailout programs. Most of the rest of the bailout money has been used to finance the

70% of Greek public debt is owned by public institutions (member states of the euro area, EFSF, ESM, ECB and IMF).

Data for public debt, as well as the fractions of it held by EU public institutions and foreign private investors/banks over time, are reported in Table 2, while the rest is in the hands of domestic private investors/banks. In our model, the fiscal bailout is captured by setting the time-paths of total public debt as well as its decomposition between the four holders (see subesction 2.6.2 above) as in the time-series in the data.

**Table 2: Greek public debt and its main holders**

Regarding monetary policy by the ECB,[45] conventional responses include a sharp reduction of policy interest rates, while non-conventional responses, focusing on those related to Greece and other EZ periphery countries in trouble, include a fixed rate full allotment policy subject to collateral standards, the lowering of collateral standards, the extension of maturity of liquidity provision, the issuance of ELA credit under the guarantee of the NCB to help private banks overcome liquidity crises and probably insolvency problems, and the purchase of collateral themselves on the secondary market (e.g. the Securities Market Program, SMP, in 2011) to support their market price and keep the interest rates relatively low.[46] Furthermore, when uncertainty got worse in the summer of 2012, the ECB announced that it would buy an unlimited amount of government bonds in the secondary market if that would become necessary (this is the Outright Monetary Transactions, OMT, program), under the condition that the ECB is actively involved in the monitoring of countries in need budgetary policies as part of the Troika (see De Grauwe (2016, pp. 174-175, 210). Eventually, in early 2015, the

cost of the haircut in March 2012 (this is the so-called private sector involvement, PSI, according to which privately held governments bonds took a 53.5% cut of their face value - this corresponds to 107 billion euros reduction - but with an exchange of EFSF bonds so that the overall debt burden decreased by 52 billion euros only) and the cost of bank recapitalization. Little has been used to finance current government budget deficits.

[45] For the ECB's response to the crisis in the euro area, see e.g. Sinn (2010, 2014), ECB (2011) and De Grauwe (2016). For the FED's response to the crisis in the US, see e.g. Reis (2009).

[46] In addition to its active support to the banking system, the ECB, during 2011-2012, bought a limited amount of government securities of southern euro zone countries including Greece under its Securities Market Program (SMP); see e.g. Sinn (2014, pp. 147, 259) and De Grauwe (2016, pp. 210-2). In the case of Greece, since the collaterals, used for this credit, mainly consisted of Greek government bonds (i.e. the commercial banks were the largest holders of government bonds), these measures effectively constituted an indirect government financing through the ECB; see e.g. Sinn (2014, pp. 151, 158) and De Grauwe (2016, pp. 173-175, 210-2). Besides, as has been noted by several authors (see e.g. Sinn, 2014), there is no real difference between the controversial SMP and massive lending to private banks from the ECB, since private banks can use the extra liquidity to invest in bonds of distressed governments which can in turn be used as collaterals in new credit from the ECB.

ECB decided to start officially its QE asset-purchasing program although this has not applied to Greece. In addition, since the very early days of the crisis, there has been a big rise in *TARGET2* liabilities as studied in subsections 2.6 and 2.7 above.

Tables 3a and 3b present the main items in the balance sheets of the Bank of Greece. As can be seen, *TARGET2* balances have the lion's share of liabilities, while loans to private banks are the biggest item on the asset side. In our model, the accommodative and complex role of the ES during the Greek crisis is captured by treating the change in *TARGET2* as an endogenously determined variable.

**Tables 3a and 3b: Assets and liabilities of the Bank of Greece**

### 3.2.2 The stick: fiscal austerity and structural reforms

The above described international financial aid has been provided under the condition that Greece undertakes a severe fiscal austerity plan (a description of the Greek austerity plan is in e.g. Alesina et al (2019, chapter 8) and Alogoskoufis (2019)). Irrespectively of the arguments for and against it, the fact is that Greece has adopted a comprehensive fiscal consolidation plan including an increasing tax burden and cuts in various items of public spending. Data for total government revenue and total expenditure are reported in Table 4a, while data for effective tax rates ($\tau^y$ and $\tau^c$) and the main categories of public spending as shares of GDP ($s^i$, $s^g$, $s^{tr}$ and $s^w$) are reported in Table 4b (the GDP share of public spending on imported goods, $s^m$, is arbitrarily set at 0.03). These time-series will be used for the exogenously set fiscal and public finance instruments in our numerical solutions.

**Tables 4a and 4b: Fiscal data in Greece**

It should be also added here that, in addition to fiscal austerity measures already taken, Greece has adopted the commitment to maintain a primary surplus of 3.5% of GDP until 2022 and around 2% in the following years. It has has also promised to start structural (non-fiscal) reforms in labor and product markets, as well as in the functioning of its public sector (see e.g. ESM, 2018). Such much-needed reforms however still lag behind (see e.g. Rocholl and Stahmer (2016) and Masuch et al. (2018)), despite the optimism expressed by the European Commission (2019) in its enhanced surveillance report on Greece. In any case, as said above, structural reforms in the product market will be captured by changes in the Dixit-Stiglitz parameter, $\theta$.

### 3.2.3 Institutional quality

Figure 1a presents an index of property rights in Greece.

**Figure 1a: Property rights in Greece**

This index has been constructed as the average of three sub-indices: "the rule of law", "regulatory quality" and "political stability and absence of violence/terrorism", which are three variables commonly used for the construction of a measure of property rights protection. These data have been rescaled from 0 to 1. These three sub-indices in various EZ countries, including Greece, are shown in Figures 1b, 1c and 1d (these Figures have been borrowed from Christou et al (2019)).

**Figure 1b: Rule of law, comparison to other countries**
**Figure 1c: Regulatory quality, comparison to other countries**
**Figure 1d: Political stability and absence of violence/terrorism, comparison to other countries**

As can be seen, Greece, not only has always been a country with poor institutional quality, but, to make it worse, has been experiencing a sharp deterioration since 2008 as also pointed out by e.g. Micossi (2016), Papaioannou (2016) and Masuch et al (2018).

The property rights index as in Figure 1a will be used for the time-series of the exogenous $PR_t$ in our numerical solutions.

### 3.3 Solution for the year 2008

Using the parameter values listed in Table 1 and data of the year 2008, the stationary solution of the model is reported in Tables 5a and 5b (we report some key variables only). In this solution, variables do not change (so it can be thought as the "trend" of the Greek economy before the global crisis) and all exogenous variables have been set as in the data of the year 2008. The solution is in line with data averages over 2000-2008 and can thus provide a reasonable departure point for the changes that have been taking place since 2009 and are studied in the next sections. In particular, the solution does a relatively good job at mimicking the position of the country in the international capital market, as well as the consumption-investment behavior of the private sector over the pre-crisis years.

**Table 5: Solution for the year 2008**

## 4 What has happened since 2009

In this section, departing from the 2008 solution, we feed the model with the time paths of policy variables and the index of property rights as they are in the data. In doing so, we assume that after 2017 the values of these variables remain unchanged as in 2017 which is the last value available in

the data. Our baseline simulation for GDP, as well as its actual path in the data, are illustrated in Graph 1, where the numbers indicate the percentage change in output relative to the 2008 solution. As can be seen, our model solution can mimic quite well the actual behaviour of GDP over the crisis years. For example, in 2017, the output loss generated by the model is 22% (namely, 100-78=22), while it is 24.4% (namely, 100-75.6=24.4) in the data, both relative to the year 2008.

**Graph 1: Output loss and data**

In Graph 2, we decompose the simulated output loss into its main drivers. As the graph reveals, about 12% of the loss is due to the economic ajustment package adopted (where the latter includes fiscal austerity, structural reforms and the various forms of bailout). Another 10% (specifically, 87.8-78.0) is due to the deterioration of institutional quality since 2008.

**Graph 2: Output loss and its main drivers**

# 5 Counterfactuals

In this section, we conduct two types of experiments. First, we consider what would have happened since 2009 without international financial aid. Second, we study what would have happened since 2009 if, given aid, some things had been done a bit better.

## 5.1 Counterfactuals: It could have been much worse

We first switch off fiscal aid. This is to examine what would have happened if EU states and institutions had not stepped in to repay debt obligations and purchase the Greek sovereign debt when the country was shut out of the bond market. Say, for example, that the Greek government would have to increase income taxes, $\tau^y$, to make up for the loss in public revenue due to setting $\lambda^{eu} = 0$. This experiment is shown in Graph 3. As can be seen, in this case, the depression would be much deeper and, most probably, would have triggered a social unrest.

**Graph 3: Counterfactual: No fiscal bailout**

We have also attempted to switch off *TARGET2* balances. This is to examine what would have happened if the ES, through the Greek NCB, had not followed an accommodative monetary policy towards Greece. In this case, we report that our model solution cannot exhibit dynamic stability.[47]

[47] When we set the change in *TARGET2* liabilities exogenously (in this particular counterfactual, equal to zero) another fiscal, or balance-sheet monetary, policy variable has to take its place in the category of endogenous variables. We have experimented with various possibilities. None of them delivers a stable solution.

This - according to our view - confirms the important role played by the ECB in the Greek bailout.

### 5.2 Counterfactuals: It could have been much better

In this subsection, we restore financial aid as in the baseline simulations and examine what would have happened if some things had been done slightly better. Graphs 4 and 5 illustrate respectively the simulated paths of the GDP when we assume lower income tax rates and higher public spending other things equal. That is, in these graphs, there is a milder fiscal austerity. In particular, in Graph 4, we have set the income tax rates 2 percentage points (pp) lower than in the data in each year, while in Graph 5 we have assumed that each item of public spending as share of GDP is 2 pp higher than in the data in each year. We thus change one thing at a time. As can be seen, the output loss would be milder although the gains are relatively small. Also note that in these cases, the cut in taxes, or the rise in spending, are like free lunches because any fiscal expansion has been assumed to be accommodated by a rise in TARGET2 liabilities which adjust residually. By contrast, in Graph 6, we assume a "budget neutral" fiscal policy mix in the sense that income tax rates are cut by 2 pp (or public investment as share of GDP rises by 2pp) and, at the same time, transfers as share of GDP are cut by 2pp. In this more realistic scenario, again the output loss would be milder but not by much. In Graph 7, we assume a stronger liberalization in product markets. In particular, we assume that the Dixit-Stiglitz parameter of product substitutability gets close to its value in the core countries of the EZ (from 0.75 to 0.80) as in Eggertsson et al (2014). Again, there is a milder depression but we cannot see spectacular improvements. Finally, in Graph 8, we combine the scenaria of Graphs 6 and 7, and, in addition, we set the index of property rigths as it it was in the Greek data before the crisis (specifically, we keep $PR_t$ constant at its 2008 value for ever). In this case, the output loss would be only 8.5% (namely, 100-91.5=8.5) which is close to that experienced by other EZ periphery countries hit by the global crisis. This confirms the key role played by institutional deterioration in the Greek depression.

**Graph 4: Counterfactual: Less fiscal austerity - lower taxes**
**Graph 5: Counterfactual: Less fiscal austerity - higher spending**
**Graph 6: Counterfactual: Alternative fiscal mixes**
**Graph 7: Counterfactual: Stronger product market liberalization**
**Graph 8: Putting counterfactuals together**

## 6 Closing remarks and possible extensions

In this paper, we have provided a more detailed anatomy of the Greek depression by using a medium-scale micro-founded macroeconomic model that incorporated the key features of the Greek economy. The focus was, not only on the role of fiscal austerity, but also on the roles of international aid and institutional deterioration both of which have been closely associated with fiscal austerity. This has made the anatomy more balanced. Since the main results have already been listed in the Introduction, here we close with discussion of possible extensions. First, it would be interesting to study more counterfactuals; for example, conditional aid and, in particular, how EU aid conditioned on improvements in institutional quality can help the economy over time. Second, we could look more carefully at public sector efficiency and in turn reforms to improve it. Third, it would be interesting to add a core creditor country like Germany, so as to have a closed general equibrium system of the EZ; this would enable us to examine how developments in one country affect the other country and, in particular, how the fiscal and monetary bailouts provided to Greece by the EU and the ECB have affected the core of the EZ. We leave these extensions for future work.

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# Appendices

## Appendix A: Algebraic details

### Aggregation and market-clearing conditions

We first define populations and their fractions: $N^k + N^w + N^b = N$, $n^k = \frac{N^k}{N}$, $n^b = \frac{N^b}{N}$, $n^w = \frac{N^b}{N} = 1 - n^k - n^b$, $n^{w,e} = \frac{N^{w,e}}{N^w}$ . Recall that we have also assumed for notational simplicity that $N^k = N^h = N^i = N^p$ and $N^b = N^g$. Then, we have the following conditions:

#### Dividend market

In the dividend markets for firms and banks:

$$N^k \pi^i_{k,t} = N^k \pi_{i,t} \tag{A1a}$$

$$N^k \pi^p_{k,t} = N^k \pi_{p,t} \tag{A1b}$$

#### Capital market

In the capital market:

$$N^k \pi^i_{k,t} = N^c \pi_{c,t} \tag{A2}$$

#### Labor market for managerial services

In the labor market for managerial services:

$$N^k l_{k,t} = N^i l^k_{i,t} = N^k l^k_{i,t} \tag{A3}$$

#### Labor market for public employees

In the labor market for public employees:

$$N^b l_{b,t} = N^g l^g_{g,t} \tag{A4}$$

#### Labor market for workers

In the labor market for private workers:

$$N^i l^w_{i,t} = N^k l^w_{i,t} = N^{w,e}_t l_{w,t} \tag{A5}$$

#### Bank deposit market

In the bank deposit market:

$$N^p j_{p,t} = N^w j_{w,t} + N^b j_{b,t} \tag{A6}$$

**Bank loan market**

In the market for bank loans:

$$N^p L_{p,t} = N^k L_{i,t} \tag{A7}$$

**Domestic market for sovereign bonds**

Regarding sovereign bonds purchased by domestic private agents/banks:

$$n^k b_{p,t} = b_t^d = \lambda_t^d d_t \tag{A8}$$

**Money market**

In the money market:

$$h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t} \tag{A9}$$

**Market for the domestically produced good**

In the market for the domestically produced good:

$$\begin{aligned} n^k y_{i,t}^h = n^k c_{k,t}^h + n^w c_{w,t}^h + n^b c_{b,t}^h + n^k x_{k,t} + n^b (g_{g,t}^g + g_{g,t}^i) + c_t^{f*} + \\ + n^k \frac{\xi^k}{2} \left( \frac{k_{k,t}}{k_{k,t-1}} - 1 \right)^2 k_{k,t-1} + n^k \frac{\xi^p}{2} \left( \frac{p_t^h}{p_{t-1}^h} - 1 \right)^2 y_{i,t}^h + \\ + n^k \left( \frac{\xi^l}{2} (L_{i,t})^2 + \frac{\xi^z}{2} (z_{p,t})^2 + \frac{\xi^b}{2} (b_{k,t})^{-2} \right) \end{aligned} \tag{A10}$$

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 $c_t^{f*} = \Theta \left( \frac{p_t^h}{p_t^f} \right)^{-\vartheta}$, where $\Theta, \vartheta > 0$ are parameters.

## Macroeconomic system

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

**Entrepreneur**

$$c_{k,t} = \frac{(c^h_{k,t})^\nu (c^f_{k,t})^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{S1}$$

$$\frac{\mu_2}{(1 - l_{k,t} - s_{k,t})} = \frac{\mu_1 (1-\tau^y_t) w^k_t}{(1+\tau^c_t) c_{k,t}} \tag{S2}$$

$$\frac{\mu_2}{(1 - l_{k,t} - s_{k,t})} = \left(\frac{\mu_1}{(1+\tau^c_t) c_{k,t}}\right) \left(\frac{\gamma \Gamma^k (s_{k,t})^{\gamma-1} (1 - PR_t) \frac{p^h_t}{p_t} n^k y^h_{i,t}}{n^k \Gamma^k (s_{k,t})^\gamma + n^w \Gamma^w (s_{w,t})^\gamma + n^b \Gamma^b (s_{b,t})^\gamma}\right) \tag{S3}$$

$$q_t \frac{(1+\tau^c_{t+1}) c_{k,t+1}}{(1+\tau^c_t) c_{k,t}} = \beta_k (q_{t+1} + \pi_{i,t}) \tag{S4}$$

$$\frac{(1+\tau^c_{t+1}) c_{k,t+1}}{(1+\tau^c_t) c_{k,t}} \frac{e_t p^*_t}{p_t} = \frac{(1+\tau^c_{t+1}) c_{k,t+1}}{(1+\tau^c_t) c_{k,t}} \frac{e_t p^*_t}{p_t} \times$$

$$\times \psi^p \left[ \frac{\frac{e_t p^*_t}{p_t} \left(n^k_t f^t_k + \lambda^g_t d_t\right)}{\frac{p^h_t}{p_t} n^k y^h_{i,t}} - \overline{f} \right] + \beta_k \frac{e_{t+1} p^*_{t+1}}{p_{t+1}} (1 + i^*_{t+1}) \frac{p^*_t}{p^*_{t+1}} \tag{S5}$$

$$\frac{c^h_{k,t}}{c^f_{k,t}} = \frac{\nu}{(1-\nu)} \frac{p^f_t}{p^h_t} \tag{S6}$$

$$\frac{\mu_3}{h_{k,t}} + \beta_k \frac{1}{(1+\tau^c_{t+1}) c_{k,t+1}} \frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau^c_t) c_{k,t}} \tag{S7}$$

**Worker**

$$c_{w,t} = \frac{(c^h_{w,t})^\nu (c^f_{w,t})^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{S8}$$

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

$$\equiv (1-\tau^y_t) w^w_t l_{w,t} + (1+i^d_t) \frac{p_{t-1}}{p_t} j_{w,t-1} + \frac{p_{t-1}}{p_t} h_{w,t-1} + \overline{g}^{tr}_t +$$

$$+ \frac{\Gamma^w (s_{w,t})^\gamma (1 - PR_t) \frac{p^h_t}{p_t} n^k y^h_{i,t}}{n^k \Gamma^k (s_{k,t})^\gamma + n^w \Gamma^w (s_{w,t})^\gamma + n^b \Gamma^b (s_{b,t})^\gamma} \tag{S9}$$

$$\frac{\mu_2}{(1 - l_{w,t} - s_{w,t})} = \frac{\mu_1 (1-\tau^y_t) w^w_t}{(1+\tau^c_t) c_{w,t}} \tag{S10}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \left(\frac{\mu_1}{(1+\tau_t^c)c_{w,t}}\right)\left(\frac{\gamma\Gamma^w(s_{w,t})^{\gamma-1}(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{S11}$$

$$\frac{c_{w,t}^h}{c_{w,t}^f} = \frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{S12}$$

$$\frac{\mu_3}{h_{w,t}} + \beta\frac{1}{(1+\tau_{t+1}^c)c_{w,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau_t^c)c_{w,t}} \tag{S13}$$

$$\frac{(1+\tau_{t+1}^c)c_{w,t+1}}{(1+\tau_t^c)c_{w,t}} = \beta(1+i_{t+1}^d)\frac{p_t}{p_{t+1}} \tag{S14}$$

**Public employee**

$$c_{b,t} = \frac{(c_{b,t}^h)^\nu (c_{b,t}^f)^{1-\nu}}{\nu^\nu(1-\nu)^{1-\nu}} \tag{S15}$$

$$\begin{aligned}(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{b,t}^h + \frac{p_t^f}{p_t}c_{b,t}^f\right) + j_{b,t} + h_{b,t} = \\ = (1-\tau_t^y)w_t^g l_{b,t} + (1+i_t^d)\frac{p_{t-1}}{p_t}j_{b,t-1} + \frac{p_{t-1}}{p_t}h_{b,t-1} + \overline{g}_t^{tr} + \\ + \frac{\Gamma^b(s_{b,t})^\gamma(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\end{aligned} \tag{S16}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \frac{\mu_1(1-\tau_t^y)w_t^g}{(1+\tau_t^c)c_{b,t}} \tag{S17}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \left(\frac{\mu_1}{(1+\tau_t^c)c_{b,t}}\right)\left(\frac{\gamma\Gamma^b(s_{b,t})^{\gamma-1}(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{S18}$$

$$\frac{c_{b,t}^h}{c_{b,t}^f} = \frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{S19}$$

$$\frac{\mu_3}{h_{b,t}} + \beta\frac{1}{(1+\tau_{t+1}^c)c_{b,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau_t^c)c_{b,t}} \tag{S20}$$

and (instead of having a second Euler equation for bank deposits that would create indeterminacy problems in steady state) we set:

$$j_{b,t} \equiv n^k j_{p,t} \tag{S21}$$

**Price indexes**

$$p_t = (p_t^h)^{\nu}(p_t^f)^{1-\nu} \tag{S22}$$

$$p_t^f = e_t p_t^{h*} \tag{S23}$$

**Private firms**

$$y_{i,t}^h = A^p \left(\frac{n^g y_{g,t}^g}{n^k}\right)^{\sigma} \left[\left(\chi^p (k_{i,t-1})^{op} + (1-\chi^p)(m_{i,t}^f)^{op}\right)^{\frac{\alpha}{op}} \left(A^k l_{k,t} + A^w \frac{n_t^{w,e} n^w l_{w,t}}{n^k}\right)^{1-\alpha}\right]^{1-\sigma} \tag{S24}$$

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

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^w y_{i,t}^h}{(A^k l_{k,t} + A^w \frac{n_t^{w,e} n^w l_{w,t}}{n^k})} \tag{S25}$$

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

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^k y_{i,t}^h}{(A^k l_{k,t} + A^w \frac{n_t^{w,e} n^w l_{w,t}}{n^k})} \tag{S26}$$

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

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

$$-\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}(\theta-1)r_{t+1}^k +$$

$$+\beta_{i,t+1}\frac{p_{t+2}^h}{p_{t+2}}\xi^p\left(\frac{p_{t+2}^h}{p_{t+1}^h}-1\right)\frac{p_{t+2}^h}{p_{t+1}^h}(\theta-1)r_{t+1}^k + N_{i,t}\rho^l\frac{p_t^h}{p_t} \tag{S27}$$

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

$$+\beta_{i,t}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta-1)y^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)\alpha y^h_{i,t}(1-\chi^p)(m^f_{i,t})^{op-1}}{\left[\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m^f_{i,t})^{op}\right]} \tag{S28}$$

$$k_{k,t}=(1-\delta)k_{k,t-1}+x_{k,t} \tag{S29}$$

$$\pi_{i,t}\equiv(1-\tau^\pi_t)\left[PR_t\frac{p^h_t}{p_t}y^h_{i,t}-w^w_t\frac{n^{w,e}_t n^w}{n^k}l_{w,t}-w^k_t l_{k,t}-\frac{p^f_t}{p_t}m^f_{i,t}\right]-$$

$$-\frac{p^h_t}{p_t}\left[k_{k,t}-(1-\delta)k_{k,t-1}\right]-\frac{p^h_t}{p_t}\frac{\xi^k}{2}\left(\frac{k_{k,t}}{k_{k,t-1}}-1\right)^2k_{k,t-1}-\frac{p^h_t}{p_t}\frac{\xi^p}{2}\left(\frac{p^h_t}{p^h_{t-1}}-1\right)^2y^h_{i,t}+$$

$$+\left(L_{i,t}-(1+i^l_t)\frac{p_{t-1}}{p_t}L_{i,t-1}\right) \tag{S30}$$

$$1=\beta_{i,t}(1+i^l_{t+1})\frac{p_t}{p_{t+1}}+N_{i,t} \tag{S31}$$

$$N_{i,t}\left(L_{i,t}-\rho^l\frac{p^h_t}{p_t}k_{i,t}\right)=0 \tag{S32}$$

where we use $r^k_{t+1}\equiv\frac{\partial y^h_{i,t+1}}{\partial k_{k,t}}=\frac{(1-\sigma)\alpha y^h_{i,t+1}\chi^p(k_{k,t})^{op-1}}{\left[\chi^p(k_{i,t})^{op}+(1-\chi^p)(m^f_{i,t+1})^{op}\right]}$, $\beta_{i,t}\equiv\frac{\beta_k(1+\tau^c_t)c_{k,t}}{(1+\tau^c_{t+1})c_{k,t+1}}$ and $\beta_{i,t+1}\equiv\frac{(\beta_k)^2(1+\tau^c_{t+1})c_{k,t+1}}{(1+\tau^c_{t+2})c_{k,t+2}}$.

**Private banks**

$$\pi_{p,t}\equiv j_{p,t}+z_{p,t}-L_{i,t}-b_{k,t}-\frac{p^h_t}{p_t}\left(\frac{\xi^l}{2}(L_{i,t})^2+\frac{\xi^z}{2}(z_{p,t})^2+\frac{\xi^b}{2}(b_{k,t})^{-2}\right) \tag{S33}$$

where we use $n^kb_{k,t}=n^pb_{p,t}=b^d_t=\lambda^d_td_t=(1-\lambda^{ncb}_t-\lambda^g_t-\lambda^{eu}_t)d_t$ at each $t$.

$$j_{p,t}=\frac{(1+i^l_{t+1})\frac{p_t}{p_{t+1}}L_{i,t}+(1+i^*_{t+1})\frac{p_t}{p_{t+1}}b_{k,t}-(1+i^z_{t+1})\frac{p_t}{p_{t+1}}z_{p,t}}{(1+i^d_{t+1})\frac{p_t}{p_{t+1}}} \tag{S34}$$

$$\frac{p^h_t}{p_t}\xi^lL_{i,t}=\frac{(1+i^l_{t+1})}{(1+i^d_{t+1})}-1+N_{p,t}\rho_p \tag{S35}$$

$$\frac{p^h_t}{p_t}\xi^zz_{p,t}=1-\frac{(1+i^z_{t+1})}{(1+i^d_{t+1})}-N_{p,t} \tag{S36}$$

$$N_{p,t}\left(\mathbf{z}_{p,t}-\rho^z(\mathbf{L}_{p,t}+\mathbf{b}_{p,t})\right)=0 \tag{S37}$$

$$n^kj_{p,t}=n^wj_{w,t}+n^bj_{b,t} \tag{S38}$$

**State firms**

$$y^g_{g,t} = A^g \left(\chi^g (k^g_{g,t-1})^{og} + (1-\chi^g)(m^g_{g,t})^{og}\right)^{\frac{\theta_1}{og}} (l_{b,t})^{\theta_2} \left(g^g_{g,t}\right)^{1-\theta_1-\theta_2} \tag{S39}$$

$$k^g_{g,t} = (1-\delta^g)k^g_{g,t-1} + g^i_{g,t} \tag{S40}$$

**Consolidated government budget constraint**

$$\begin{aligned}
&\overline{g}^{tr}_t + (1+i^*_t)\frac{p_{t-1}}{p_t}(1-\lambda^{ncb}_{t-1}-\lambda^g_{t-1}-\lambda^{eu}_{t-1})d_{t-1}+ \\
&+(1+i^*_t)\frac{p^*_{t-1}}{p^*_t}\frac{e_t p^*_t}{p_t}\frac{p_{t-1}}{e_{t-1}p^*_{t-1}}\lambda^g_{t-1}d_{t-1} + (1+i^*)\frac{p^*_{t-1}}{p^*_t}\frac{e_t p^*_t}{p_t}\frac{p_{t-1}}{e_{t-1}p^*_{t-1}}\lambda^{eu}_{t-1}d_{t-1}+ \\
&+n^b\left[w^g_t l^g_{g,t} + \frac{p^h_t}{p_t}\left(g^g_{g,t}+g^i_{g,t}\right) + \frac{p^f_t}{p_t}m^g_{g,t}\right]+ \\
&+\frac{p^h_t}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p^*_t}{p_t}\left(n^k f_{k,t}+\lambda^g_t d_t\right)}{\frac{p^h_t}{p_t}n^k y^h_{i,t}} - \overline{f}\right]^2 n^k y^h_{i,t} = (1-\lambda^{ncb}_t)d_t + \frac{T_t}{N}+ \\
&+n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t} - \frac{p_{t-1}}{p_t}(n^k h_{k,t-1} + n^w h_{w,t-1} + n^b h_{b,t-1})- \\
&-n^k\left(z_{p,t} - \frac{P_{t-1}}{P_t}z_{p,t-1}\right) + \left(t\arg_t - \frac{P_{t-1}}{P_t}t\arg_{t-1}\right)
\end{aligned} \tag{S41}$$

where in equilibrium $n^k b_{k,t} = b^d_t = \lambda^d_t d_t = (1-\lambda^{ncb}_t - \lambda^g_t - \lambda^{eu}_t)d_t$ at any $t$.

**Gross Domestic Product (GDP) identity**

$$\begin{aligned}
&n^k y^h_{i,t} = n^k c^h_{k,t} + n^w c^h_{w,t} + n^b c^h_{b,t} + n^k x_{k,t} + n^b(g^g_{g,t}+g^i_{g,t}) + c^{f*}_t + \\
&+n^k\frac{\xi^k}{2}\left(\frac{k_{k,t}}{k_{k,t-1}}-1\right)^2 k_{k,t-1} + n^k\frac{\xi^p}{2}\left(\frac{p^h_t}{p^h_{t-1}}-1\right)^2 y^h_{i,t}+ \\
&+n^k\left(\frac{\xi^l}{2}(L_{i,t})^2 + \frac{\xi^z}{2}(z_{p,t})^2 + \frac{\xi^b}{2}(b_{k,t})^{-2}\right)
\end{aligned} \tag{S42}$$

where $c^{f*}_t$ is exports to the rest of the world.

**Balance of payments**

$$\frac{p_t^f}{p_t}\left(n^k c_{k,t}^f + n^w c_{w,t}^f + n^b c_{b,t}^f + n^k m_{i,t}^f + n^b m_{g,t}^g\right) - \frac{p_t^h}{p_t} c_t^{f*} + (1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t} n^k f_{k,t-1} +$$

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

$$+\frac{p_t^h}{p_t}\frac{\psi^p}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h +$$

$$+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h =$$

$$= \frac{e_t p_t^*}{p_t} n^k f_{k,t} + \lambda_t^g d_t + \lambda_t^{eu} d_t + \left(t\arg_t - \frac{P_{t-1}}{P_t} t\arg_{t-1}\right) \tag{S43}$$

**Definitions** *Tax revenues*

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

$$+ n^b (\frac{p_t^h}{p_t} c_{b,t}^h + \frac{p_t^f}{p_t} c_{b,t}^f)] + \tau_t^y n^k w_t^k l_{k,t} + \tau_t^y n_t^{w,e} n^w w_t^w l_{w,t} +$$

$$+\tau_t^y n^b w_t^g l_{b,t} + \tau_t^\pi n^k \left[PR_t \frac{p_t^h}{p_t} y_{i,t}^h - w_t^w \frac{n_t^{w,e} n^w}{n^k} l_{w,t} - w_t^k l_{k,t} - \frac{p_t^f}{p_t} m_{i,t}^f\right] \tag{S44}$$

*Exports*

$$c_t^{f*} = \Theta \left(\frac{p_t^h}{p_t^f}\right)^{-\vartheta} \tag{S45}$$

**Public spending ratios**

$$w_t^g = \frac{s_t^w \frac{p_t^h}{p_t} n^k y_{i,t}^h}{n^b l_{b,t}} \tag{S46}$$

$$g_{g,t}^g = \frac{s_t^g n^k y_{i,t}^h}{n^b} \tag{S47}$$

$$g_{g,t}^i = \frac{s_t^i n^k y_{i,t}^h}{n^b} \tag{S48}$$

$$\overline{g}_t^{tr} = s_t^{tr} \frac{p_t^h}{p_t} n^k y_{i,t}^h \tag{S49}$$

$$m_{g,t}^g = \frac{p_t^h}{p_t^f} \frac{s_t^m n^k y_{i,t}^h}{n^b} \tag{S50}$$

**Country's interest rate**

$$i_t^* = i^* + \psi^i \left( \exp(\frac{d_t}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{d}) - 1 \right) \tag{S51}$$

We therefore have a dynamic system of 51 equations in 51 variables. The latter are the paths of $\{c_{k,t},\, c_{k,t}^h,\, c_{k,t}^f\}_{t=0}^{\infty}$, $\{c_{w,t},\, c_{w,t}^h,\, c_{w,t}^f\}_{t=0}^{\infty}$, $\{c_{b,t},\, c_{b,t}^h,\, c_{b,t}^f\}_{t=0}^{\infty}$, $\{l_{k,t},\, l_{w,t},\, l_{b,t}\}_{t=0}^{\infty}$, $\{h_{k,t},\, h_{w,t},\, h_{bt}\}_{t=0}^{\infty}$, $\{s_{k,t},\, s_{w,t},\, s_{bt}\}_{t=0}^{\infty}$, $\{f_{k,t},\, j_{w,t},\, j_{bt}\}_{t=0}^{\infty}$, $\{y_{i,t}^h,\, k_{k,t},\, x_{k,t},\, m_{i,t}^f,\, \pi_{i,t},\, w_t^k,\, w_t^w,\, L_{i,t},\, N_{i,t}\}_{t=0}^{\infty}$, $\{\pi_{p,t},\, j_{p,t},\, z_{p,t},\, N_{p,t}\}_{t=0}^{\infty}$, $\{y_{g,t}^g,\, k_{g,t}^g\}_{t=0}^{\infty}$, $\{p_t,\, p_t^h,\, p_t^f,\, i_t^d,\, i_t^l,\, i_t^*,\, q_t\}_{t=0}^{\infty}$, $\{w_t^g,\, g_{g,t}^g,\, g_{g,t}^i,\, \overline{g}_t^{tr},\, m_{g,t}^g\}_{t=0}^{\infty}$, $\{t\arg_t\}_{t=0}^{\infty}$, $\{\frac{T_t}{N}\}_{t=0}^{\infty}$, $\{c_t^{f*}\}_{t=0}^{\infty}$. This is given the paths of the exogenously set policy variables, $\{\tau_t^c,\, \tau_t^y,\, \tau_t^\pi,\, s_t^w,\, s_t^g,\, s_t^i,\, s_t^{tr},\, s_t^m\}_{t=0}^{\infty}$, $\{\lambda_t^g,\, \lambda_t^{eu},\, \lambda_t^{ncb},\, \frac{d_t}{\frac{p_t^h}{p_t} n^k y_{i,t}^h},\, i_t^z\}_{t=0}^{\infty}$, the path of the degree of property rights, $\{PR_t\}_{t=0}^{\infty}$, and world prices $\{p_t^{h*},\, p_t^{f*},\, p_t^*\}_{t=0}^{\infty}$. The data are described in subsection 3.2.

**Transformed variables**

For convenience, we re-express some variables. We define $\frac{p_t^f}{p_t^h} \equiv TT_t$ to be the terms of trade (an increase means an improvement in competitiveness vis-à-vis the rest of the world). Then, we have $\frac{p_t^h}{p_t} = (TT_t)^{\nu-1}$, $\frac{p_t^f}{p_t} = (TT_t)^{\nu}$, $\frac{e_t p_t^*}{p_t} = (TT_t)^{2\nu-1}$, $\Pi_t \equiv \frac{p_t}{p_{t-1}} = \Pi_t^h \left(\frac{TT_t}{TT_{t-1}}\right)^{1-\nu}$ and $\frac{TT_t}{TT_{t-1}} = \frac{e_t}{e_{t-1}} \frac{\Pi_t^{h*}}{\Pi_t^h}$, where $\Pi_t^h \equiv \frac{p_t^h}{p_{t-1}^h}$. 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 $\Pi_t = \Pi_t^h \left(\frac{TT_t}{TT_{t-1}}\right)^{1-\nu}$

and $\frac{TT_t}{TT_{t-1}} = \frac{e_t}{e_{t-1}} \frac{\Pi_t^{h*}}{\Pi_t^h}$ and, in all other equations, we use the transformations $\frac{p_t^h}{p_t} = (TT_t)^{\nu-1}$, $\frac{p_t^f}{p_t} = (TT_t)^{\nu}$, $\frac{e_t p_t^*}{p_t} = (TT_t)^{2\nu-1}$. In other words, regarding prices, instead of $\{p_t,\, p_t^h,\, p_t^f\}_{t=0}^{\infty}$, now the endogenous variables are $\left\{TT_t,\, \Pi_t^h,\, \Pi_t\right\}_{t=0}^{\infty}$. Recall that, in a small open economy, $\Pi_t^{h*} \equiv \frac{p_t^{h*}}{p_{t-1}^{h*}}$ 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, if we use $p_t^* = (p_t^{h*})^{\nu}(p_t^{f*})^{1-\nu}$, it can be written as $\Pi_t^* \equiv \frac{p_t^*}{p_{t-1}^*} = (\Pi_t^{h*})^{\nu} \left(\Pi_t^h\right)^{1-\nu}$(where we have set $\frac{e_t}{e_{t-1}} = 1$); here, we simply set $\Pi_t^* \equiv \frac{p_t^*}{p_{t-1}^*} = 1$ all the time.

# Appendix B: Tables, figures and graphs

**Table 1**
**Baseline parameterization**

| Parameter | Description | Value |
|---|---|---|
| $\nu$ | home goods bias in consumption | 0.5 |
| $\mu_1$ | weight of consumption in utility | 0.4 |
| $\mu_2$ | weight of leisure in utility | 0.55 |
| $\mu_3$ | weight of money balances in utility | 0.03 |
| $\beta$ | savers' time discount factor | 0.99 |
| $\beta_k$ | borrowers' time discount factor | 0.98 |
| $\delta$ | depreciation rate of private capital | 0.05 |
| $\delta^g$ | depreciation rate of public capital | 0.05 |
| $\psi^p$ | transaction cost parameter in foreign capital market (private) | 0.5 |
| $\psi^g$ | transaction cost parameter in foreign capital market (public) | 0.5 |
| $A^p$ | TFP in private sector's production function | 1 |
| $A^g$ | TFP in public sector's production function | 1 |
| $A^k$ | entrepreneurs' labour productivity | 3 |
| $A^w$ | workers' labour productivity | 2 |
| $1-\alpha$ | share of labor in private production | 0.6 |
| $\sigma$ | contribution of public output to private production | 0.1 |
| $\theta_1$ | share of capital and imported goods in public production | 0.3045 |
| $\theta_2$ | share of labor in public production | 0.6 |
| $\chi^p$ | intensity of private capital relative to imported goods (private sector) | 0.5 |
| $op$ | substitutability between capital and imported goods (private sector) | 0.5 |
| $\chi^g$ | intensity of public capital relative to imported goods (public sector) | 0.5 |
| $og$ | substitutability between capital and imported goods (public sector) | 0.5 |
| $\xi^k$ | capital adjustment cost parameter | 0.3 |
| $\xi^l$ | transaction cost parameter associated with bank loans to firms | 0.3 |
| $\xi^z$ | transaction cost parameter associated to bank loans from the NCB | 0.3 |
| $\gamma$ | measure of diminishing returns in anti-social activities | 0.5 |
| $\psi^*$ | country's interest-rate premium parameter | 0.05 |
| $\overline{d}$ | threshold value of public debt to ouput | 1.1 |

**Table 1 continued**
**Baseline parameterization**

| Parameter | Description | Value |
|---|---|---|
| $\Gamma^k$ | efficiency of entrepreneurs' anti-social activity | 1 |
| $\Gamma^w$ | efficiency of workers' anti-social activity | 0.7 |
| $\Gamma^b$ | efficiency of public employees' anti-social activity | 1.3 |
| $\Theta$ | constant in the function of exports | 0.5 |
| $\vartheta$ | Cobb-Douglas exponent in the function of exports | 2 |
| $\overline{f}$ | threshold value of external debt to output | 0.8 |
| $i^*$ | constant term of world interest rate | 0.01 |
| $\theta$ | substitutability between intermediate goods | 0.75 |
| $\xi^p$ | price adjustment cost parameter (Rotemberg) | 3 |
| $\rho^l$ | fraction in firms' borrowing constraint | 0.5 |
| $\rho^z$ | fraction in banks' borrowing constraint | 0.5 |
| $n^k$ | share of capitalists in population | 0.2 |
| $n^w$ | share of workers in population | 0.6 |
| $n^b$ | share of public employees in population (data) | 0.2 |

**Table 2**
**Greek public debt to GDP and its main holders**

| Year | Total Public Debt (% of GDP) | $\lambda^{eu}$ (% of total public debt) | $\lambda^g$ (% 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** | 176.8 | 68.6 | 16.1 |
| **2016** | 180.8 | 69.8 | 16.0 |

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

**Table 3a**
**Bank of Greece's assets**
(billions of euros, end of year)

| Year | Lending to Banks | Securities | Government long-term debt | Total Assets |
|---|---|---|---|---|
| **2007** | 9 | 10 | 8 | 42 |
| **2008** | 38 | 14 | 8 | 71 |
| **2009** | 50 | 21 | 7 | 86 |
| **2010** | 98 | 24 | 7 | 13 |
| **2011** | 128 | 21 | 7 | 168 |
| **2012** | 121 | 21 | 6 | 160 |
| **2013** | 73 | 21 | 6 | 109 |
| **2014** | 56 | 31 | 5 | 103 |
| **2015** | 107 | 40 | 5 | 163 |
| **2016** | 67 | 57 | 6 | 142 |
| **2017** | 34 | 74 | 6 | 125 |
| **2018** | 11 | 76 | 5 | 109 |

**Source:** Bank of Greece.

**Table 3b**
**Bank of Greece's liabilities**
(billions of euros, end of year)

| Year | Banknotes | TARGET2 | Reserves | Government deposits | Total liabilities |
|---|---|---|---|---|---|
| **2007** | 16 | 10 | 7 | 1 | 42 |
| **2008** | 18 | 35 | 8 | 1 | 71 |
| **2009** | 21 | 49 | 8 | 1 | 86 |
| **2010** | 22 | 87 | 10 | 2 | 138 |
| **2011** | 23 | 105 | 5 | 5 | 168 |
| **2012** | 23 | 98 | 2 | 7 | 160 |
| **2013** | 25 | 51 | 2 | 8 | 109 |
| **2014** | 27 | 49 | 3 | 5 | 103 |
| **2015** | 29 | 94 | 1 | 5 | 163 |
| **2016** | 30 | 72 | 1 | 9 | 142 |
| **2017** | 31 | 59 | 2 | 12 | 125 |
| **2018** | 33 | 29 | 7 | 25 | 109 |

**Source:** Bank of Greece.

**Table 4a**
**Government revenue and expenditure**

| **Variable** (% of GDP) | **2008** | **2010** | **2011** | **2014** | **2016** | **2018** |
|---|---|---|---|---|---|---|
| Revenue | 40 | 41 | 44 | 47 | 49 | 48 |
| Expenditure | 50 | 53 | 54 | 51 | 49 | 48 |

Source: European Commission (Report on Public Finances in EMU).

**Table 4b**
**Fiscal (spending-tax) policy variables**

| **Variable** (% of GDP) | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** |
|---|---|---|---|---|---|---|---|---|---|
| $s^g$ | 9.1 | 10.2 | 9.8 | 9.2 | 9.0 | 8.2 | 8.0 | 8.1 | 7.9 |
| $s^w$ | 11.6 | 13.0 | 12.4 | 12.6 | 12.8 | 12.2 | 12.2 | 12.2 | 12.3 |
| $s^i$ | 5.8 | 5.7 | 3.6 | 2.4 | 2.5 | 3.4 | 3.6 | 3.9 | 3.5 |
| $s^{tr}$ | 18.9 | 20.5 | 20.9 | 22.9 | 23.1 | 21.4 | 21.7 | 22.1 | 22.2 |
| $\tau^y$ | 27.3 | 26.6 | 26.9 | 29.1 | 32.5 | 31.3 | 32.4 | 33.6 | 35.5 |
| $\tau^c$ | 16.8 | 15.2 | 17.7 | 19.0 | 18.5 | 18.7 | 19.1 | 19.5 | 21.8 |
| $b/y$ | 109.4 | 126.7 | 146.2 | 172.1 | 159.6 | 177.4 | 178.9 | 176.8 | 180.8 |

**Source:** Eurostat.

**Table 5a**
**Main variables in the solution for the year 2008**

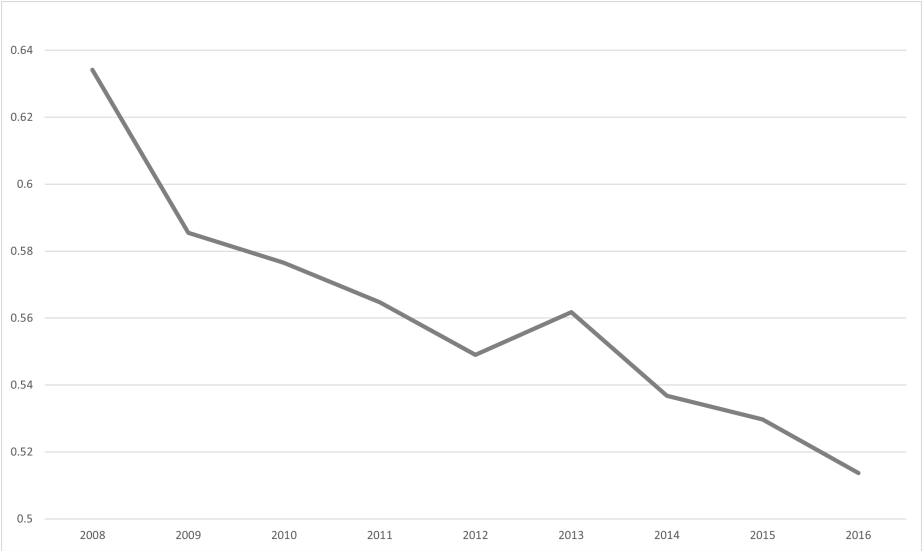
| **Variable** | **Description** | **Model solution** | **Data** |
|---|---|---|---|
| $c/y$ | Consumption to ouput | 85.6% | 67.4% |
| $inv/y$ | Investment to output | 19% | 23.8% |
| $f/y$ | Foreign debt to output | 82.1% | 76% |

**Source:** Eurostat.

**Table 5b**
**Other variables in the solution for the year 2008**

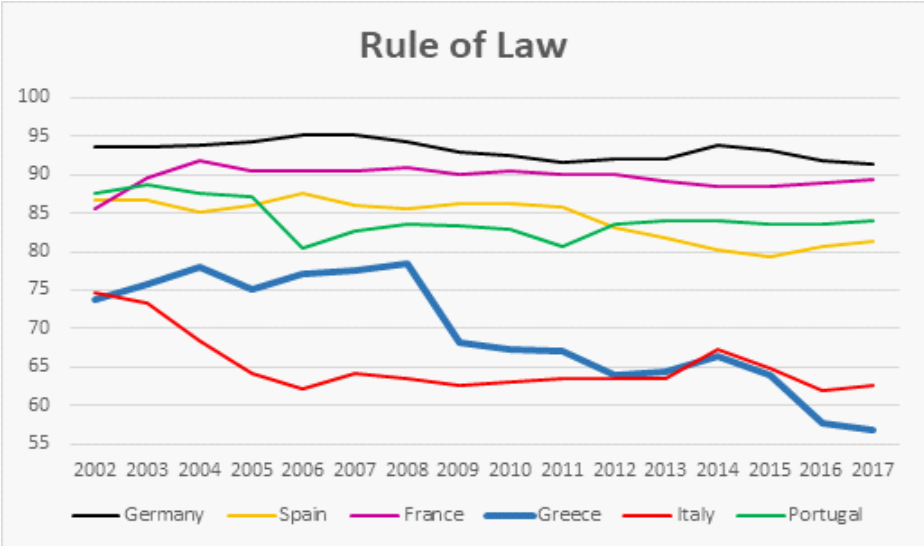
| **Variable** | **Descritpion** | **Value** |
|---|---|---|
| $c_k$ | consumption of capitalist | 0.306 |
| $c_w$ | consumption of private Worker | 0.16 |
| $c_b$ | consumption of public employee | 0.253 |
| $l_k$ | work hours of capitalist | 0.02 |
| $l_w$ | work hours of private Worker | 0.20 |
| $l_b$ | work hours of public employee | 0.175 |
| $TT$ | terms of trade | 0.31 |
| $y$ | per capita real output | 0.243 |
| $s_k$ | capitalist's effort time allocated to anti-social activities | 0.085 |
| $s_w$ | worker's effort time allocated to anti-social activities | 0.093 |
| $s_b$ | public employee's effort time allocated to anti-social activities | 0.126 |

**Figure 1a**
**Property rights in Greece**



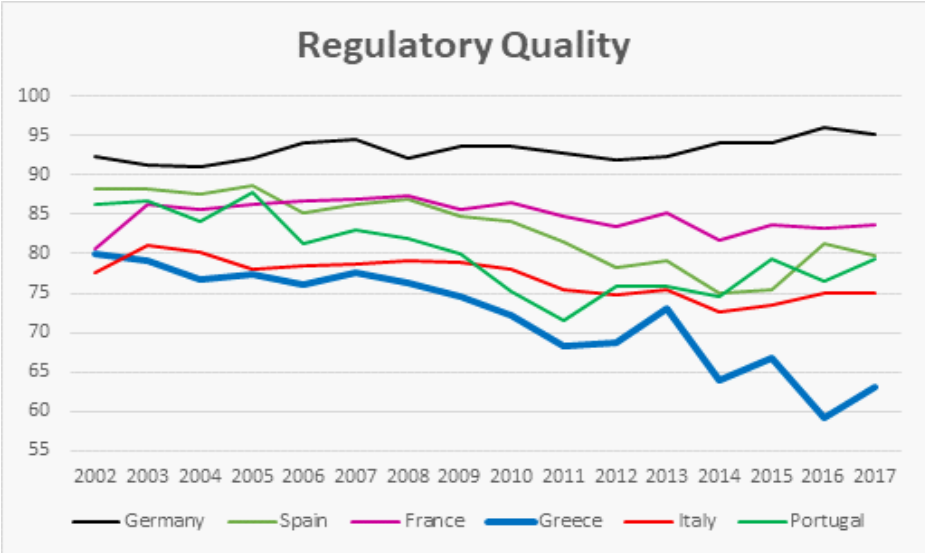

**Source:** World Governance Indicators.

**Figure 1b**
**Rule of law, comparison to other countries**



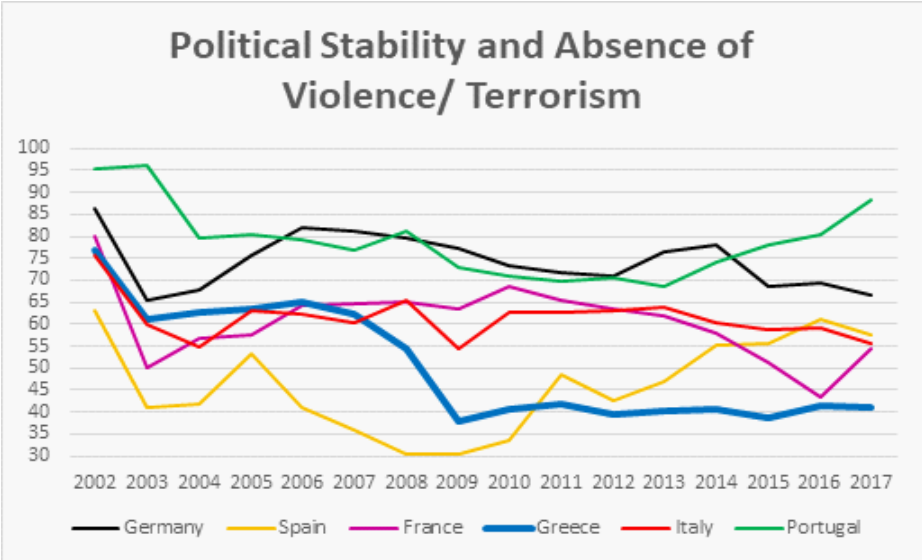

**Source:** World Governance Indicators.

**Figure 1c**
**Regulatory quality, comparison to other countries**



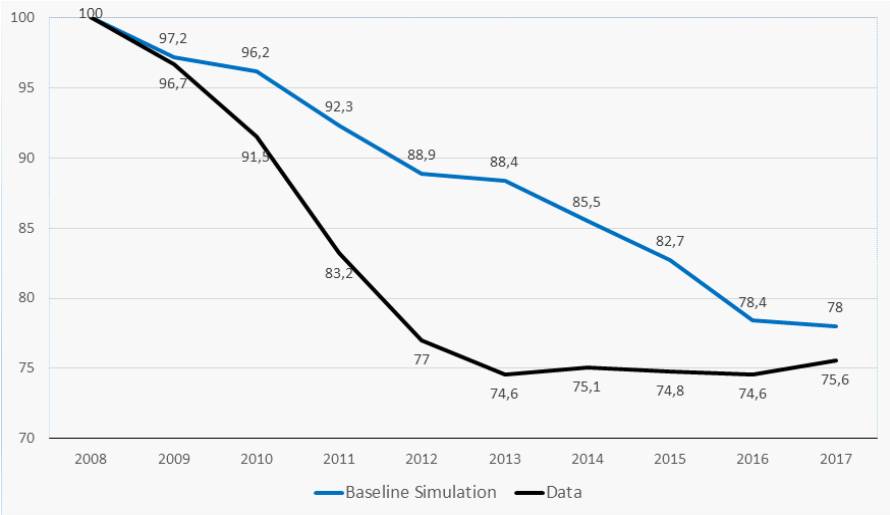

**Source:** World Governance Indicators.

**Figure 1d**
**Political stability and absence of violence/terrorism, comparison to other countries**



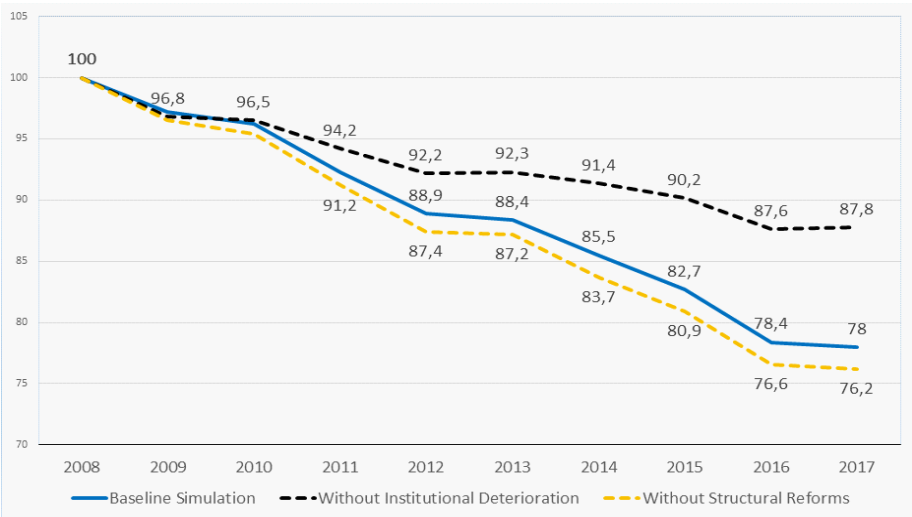

**Source:** World Governance Indicators.

**Graph 1**
**Output loss and data**

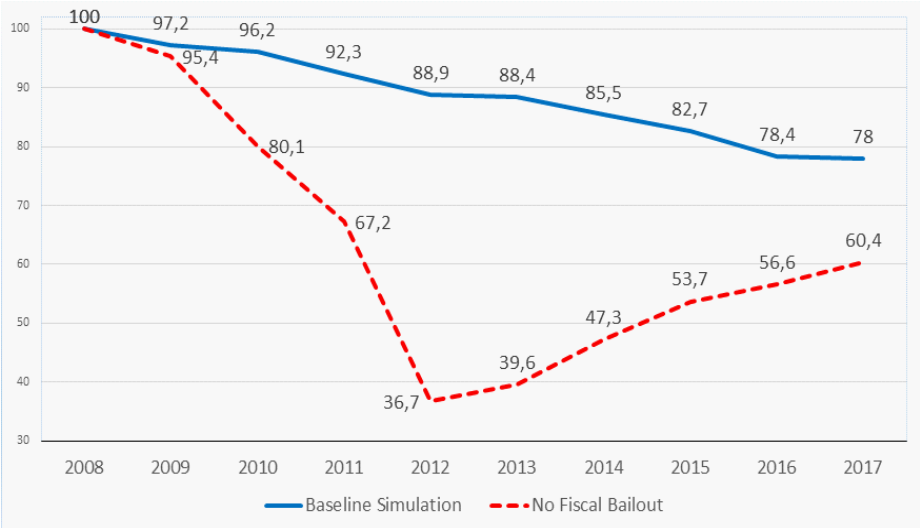



**Source:** Eurostat.

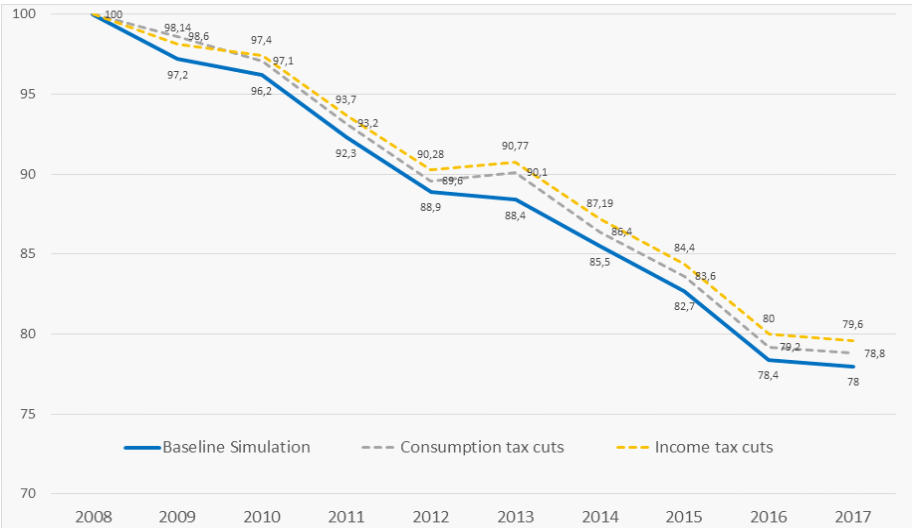
**Graph 2**
**Output loss and its main drivers**



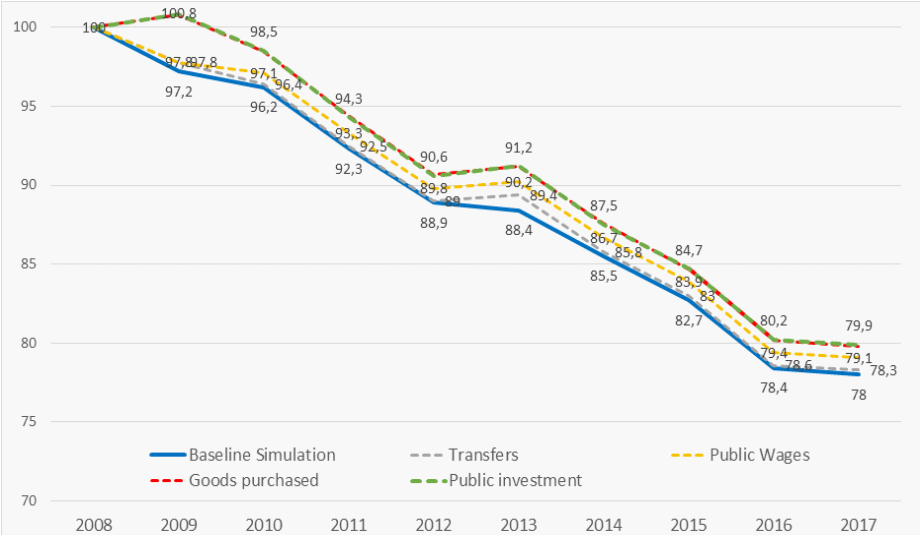
**Graph 3**
**No fiscal bailout**



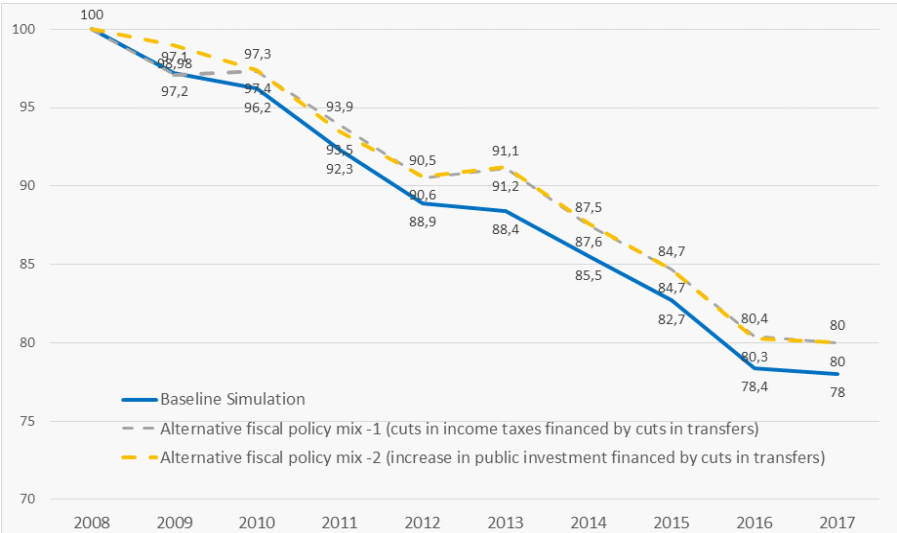

**Graph 4**
**Less fiscal austerity - lower taxes**



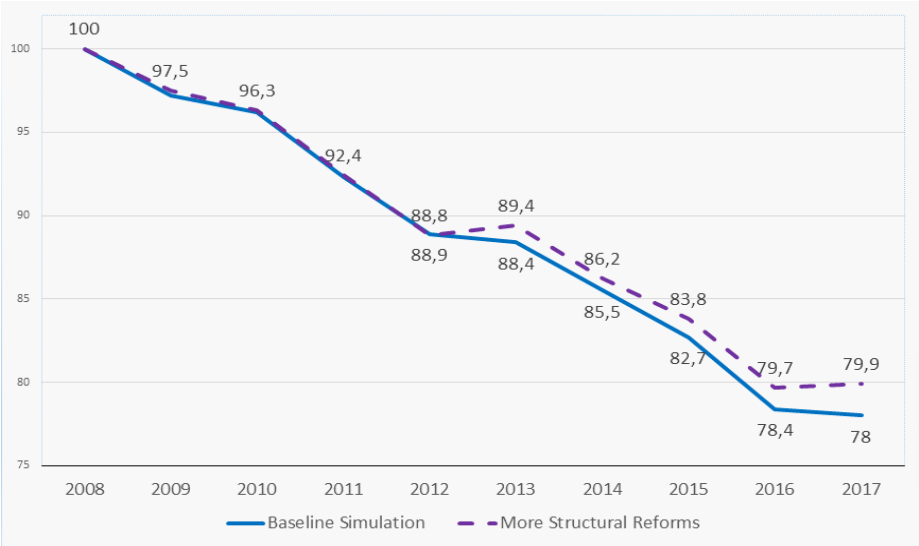
**Graph 5**
**Less fiscal austerity - higher spending**

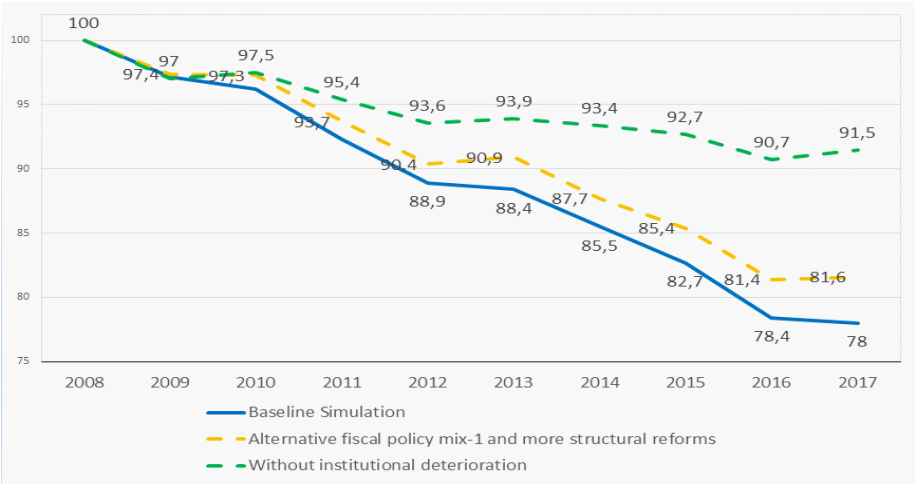



**Graph 6**
**Alternative fiscal mixes**



**Graph 7**
**Stronger product market liberalization**




**Graph 8**
**Putting counterfactuals together**