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ABSTRACT

The Greek economy experienced a boom until 2007, followed by a prolonged depression resulting in a 25 percent shortfall of GDP by 2016. Informed by a detailed analysis of macroeconomic patterns in Greece, we estimate a rich dynamic general equilibrium model to assess quantitatively the sources of the boom and bust. Lower external demand for traded goods and contractionary fiscal policies account for the largest fraction of the Greek depression. A decline in total factor productivity, due primarily to lower factor utilization, substantially amplifies the depression. Given the significant adjustment of prices and wages observed throughout the cycle, a nominal devaluation would only have short-lived stabilizing effects. By contrast, shifting the burden of adjustment away from taxes toward spending or away from capital taxes toward other taxes would generate longer-term production and consumption gains. Eliminating the rise in transfers to households during the boom would significantly reduce the burden of tax adjustment in the bust and the magnitude of the depression.

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1 Introduction

The Greek economy experienced a significant boom between 1999 and 2007, with real GDP per capita growing by 34 percent, followed by a sustained depression, with real GDP per capita contracting by 25 percent between 2007 and 2016. The magnitude and length of the depression and the ensuing fiscal adjustment have no precedent among modern developed economies. The severity is atypical even among economies experiencing sudden stops, sovereign defaults, or leverage cycles (Gourinchas, Philippon, and Vayanos, 2016).

In this paper we ask two set of questions. First, what are the driving forces of the Greek boom and bust and how important are frictions such as in the adjustment of nominal prices and wages or in financial markets for amplifying the effects of shocks? Second, to what extent would exchange rate devaluation or alternative fiscal policy have mitigated the depression?

Answering these questions is important for reasons that extend beyond the Greek case. The macroeconomics of great depressions (Kehoe and Prescott, 2002) has received less scholarly attention than analyses of typical business cycles possibly because contractions as large as in Greece rarely occur. The recent international business cycle literature attributes a role to price or wage rigidities (Schmitt-Grohé and Uribe, 2016) and financial frictions (Neumeyer and Perri, 2005; Mendoza, 2010) for understanding economic fluctuations when shocks are relatively small, but the role of rigidities and frictions may change with the magnitude and persistence of the recession. Likewise, the literature evaluating fiscal consolidations (Alesina and Ardagna, 2010) typically focuses on smaller contractions. Greece provides a unique case study of a developed economy undergoing large fiscal adjustments during a crisis of unprecedented magnitude.

We answer these questions quantitatively by developing and estimating a rich dynamic general equilibrium model of a small open economy operating within a currency union. We inform the model environment, the shocks influencing the economy, and the estimation of parameters with a detailed analysis of macroeconomic patterns in Greece during both the boom and the bust periods.

Several features of the Greek experience are important to our analysis. First, the boom period is characterized by an increase in labor and capital accumulation, whereas both declines in factors of production and total factor productivity (TFP) contribute to the bust of economic activity. We document that a significant fraction of the decline in TFP stems from the decline in the utilization of factors of production. The comovement of TFP and utilization informs our model economy in which endogenous TFP movements arise from firms' choice of how intensively to utilize factors.

Firm and household leverage increase significantly during the boom. Household leverage decreases throughout the bust, but firm leverage rebounds after a few years. These financial cycles occur in quantities rather than prices; while the secondary market interest rate for Greek sovereign debt rose to as high as 30 percent in 2012, the average rate paid by non-financial firms in that year barely exceeded 6 percent. The model, therefore, features quantity restrictions on borrowing. Financial conditions also motivate disaster risk in the model. Using option prices, we infer an elevated risk of an economic disaster coinciding with major events such as the debt restructuring in 2012 and the election and fiscal negotiations in 2015.

We model in detail fiscal policies motivated by the fact that the burden of the adjustment fell on both spending and taxes. Government purchases and transfers to households rise during the boom and fall precipitously during the bust even relative to GDP. Building on the methodology of Mendoza, Razin, and Tesar (1994), we construct effective tax rates on consumption, investment, labor, and capital. All tax rates rise sharply during the bust and remain elevated through 2016. For example, the capital tax rate in the non-traded sector, which includes property taxes, increases by roughly 20 percentage points in the last years of our sample.

While measures of production comove strongly between the traded and non-traded sectors, the dynamics of the terms of trade and real exchange rate lead us to consider a multi-sector environment as well as changes in the external demand for Greek traded goods. The considerable terms of trade appreciation during the boom motivates our modeling of Greek traded output as imperfectly substitutable with traded goods produced by the rest of the world. Using observed changes in exports and relative prices, we find a significant increase in external demand for Greek traded goods during the boom, a period coinciding with the entry of Greece to the euro and the hosting of the Olympic Games, and a significant decline during the bust, a period coinciding with a global slump in shipping that particularly impacted Greece.

We use the model to account for the drivers of the boom and bust. Our approach differs from estimated dynamic general equilibrium models in the tradition of Smets and Wouters (2007) in that we do not estimate the shocks that best fit macroeconomic data. Rather, we feed the time series of the exogenous processes as measured in the data without adding to them any measurement error and then estimate parameters with Bayesian Maximum Likelihood. This disciplines significantly our exercise as it restricts the freedom of shocks to account for the behavior of time series. Despite this discipline, the model performs well in accounting for the time series. The model accounts perfectly for the 11 percent increase in output in the boom (relative to 2 percent trend growth) and matches closely the contributions of labor, capital, and TFP. During the bust, the model generates an output decline of 30 percent (compared to 45 percent in the detrended data), a decline in labor of 16 percent (17 percent in the data), a decline in capital of 11 percent (19 percent in the data), and a decline in TFP of 17 percent (26 percent in the data).

What shocks drive the Greek boom and bust? In the absence of innovations to government spending, transfers, and tax rates, output in the estimated model would have been 15 percent higher in 2016.[1] Government spending cuts manifest mainly through declines in labor, whereas increases in tax rates manifest mainly through declines in capital and TFP. We find a significant role for external demand and, to a lesser extent, exogenous productivity during both the boom and bust. Financial conditions, such as firm and household leverage, interest rates, and disaster risk, partly account for the boom and the initial bust of macroeconomic variables. However, because these variables mostly revert back to their pre-crisis levels by the end of the sample, they collectively exert a limited role in accounting for the persistence of the Greek depression.

We provide an account of the structural elements of the model responsible for these conclusions. Without variable utilization, the model would generate 13 percentage points smaller declines in output and TFP by the end of the sample. By contrast, we find a limited role for price or wage rigidity in accounting for the magnitude of the boom and the persistence of the bust, reflecting the significant increase in nominal prices (11 percent relative to euro trend inflation) and wages (24 percent relative to trend) in the boom and decline in the bust (4 and 39 percent relative to trend). The observed shocks generate significant movements in labor without a high Frisch elasticity of labor supply (estimated at 0.48) or sensitivity of labor demand to firm borrowing constraints. Finally, we estimate a relatively high fraction of households who are constrained at their borrowing limit (0.43) and a strong complementarity between consumption and labor in preferences, both of which contribute to the consumption decline during the bust.

[1] We take the fiscal consolidation as given and quantify its macroeconomic effects. The fiscal consolidation itself was triggered by a combination of the 2008-2009 recession and the budget deficit revisions announced in October 2009 and became necessary due to the high pre-existing level of public debt. Martin and Philippon (2017) have adopted this interpretation of fiscal consolidations in periphery euro economies. Viewed through these lens, 15 percent should be interpreted as the gain in output if pre-existing conditions such as high debt level had not made the fiscal adjustment necessary or, alternatively, if Greece had received substantial additional debt relief. Ardagna and Caselli (2014) discuss further the political economy of the early stages of the Greek debt crisis and the negotiations with external creditors and institutions that influenced the fiscal adjustment.

The model generates modest government spending multipliers, with a unit increase in government spending raising output contemporaneously by 0.5 when financed by lump sum taxes and by 0.9 when financed with deficits. The most important parameter governing the multiplier in the presence of nominal rigidity is the persistence of government spending shocks because it determines the amount of crowding out of private consumption. Lowering the persistence in the autoregressive process from close to 1 in our baseline to 0.3 raises these impact multipliers to roughly 1.3. Conversely, the model generates larger tax multipliers over longer horizons and when tax rate changes are more persistent. The seven-year percent decline in output in response to a one percentage point increase in the labor tax rate is 0.35 and in the capital tax rate is close to 0.15. Variable utilization plays an important role for tax multipliers through its impact on TFP.

We consider three sets of counterfactual exercises to evaluate the benefits of alternative policies during the bust. The first is a nominal devaluation in 2010. This policy raises output on impact through an expenditure-switching channel. However, given the low estimated degree of nominal price and wage rigidity, a nominal devaluation boosts the economy only for one to two years. There is larger scope for mitigating the bust in output if Greece had followed different compositions of fiscal policy in order to achieve the observed reduction in deficits. A shift of the burden of fiscal consolidation in 2010 away from tax increases toward spending cuts raises output by close to 3 percent by 2016 and 2025. Alternatively, shifting away from labor and capital taxes toward consumption taxes generates output gains of almost 6 percent by 2025. Finally, we highlight the benefits of running less expansionary fiscal policies during the boom. Removing the debt-financed rise of household transfers during the boom and reallocating the freed-up resources to reduce capital taxes during the bust would generate output gains of 15 percent by 2016.[2]

The seminal paper of Gourinchas, Philippon, and Vayanos (2016) provides the first systematic analysis of macroeconomic aspects of the Greek depression. Confirming quantitatively a broad message of their analysis, we also attribute roughly half of the bust in output to fiscal consolidation. Whereas they use total revenues to infer the time series properties of a single income tax rate, our modeling and measurement of different tax rates leads to the more nuanced conclusion that

[2]Our analysis of the effects of capital income taxes is in line with the conclusions of Mendoza, Tesar, and Zhang (2014) that have first highlighted the importance of dynamic Laffer curve effects with respect to capital income tax rates in open economy models with variable utilization. Our results also corroborates the analysis of Martin and Philippon (2017) who demonstrate that if Greece had followed more conservative fiscal policies during the boom, the ensuing fiscal consolidation would have been smaller and employment would have dropped by substantially less between 2010 and 2012.

the tax side is at least as important as the spending side of the consolidation, especially in the later years of the depression. Another important departure from their work is that, in our model, endogenous movements in TFP from utilization emerge as a key propagation mechanism of the various shocks whereas they impose constant TFP.[3] Finally, Gourinchas, Philippon, and Vayanos (2016) externally set parameters implying a relatively high degree of price and wage rigidity and find that these rigidities help the model generate the boom and bust. We estimate the strength of these rigidities using observed quantities and prices and find a smaller role for nominal rigidities relative to other features of the model economy.[4]

The Greek experience contrasts with earlier narratives of the boom and bust in the broader euro area. For example, Schmitt-Grohé and Uribe (2016) emphasize the problem of downward nominal wage rigidity in preventing internal devaluation for several countries including Greece between 2008 and 2011, yet in Greece nominal wages (not detrended) fell by 18 percent from their peak in 2010 and nominal prices (not detrended) fell by 7 percent from their peak in 2012. This difference suggests that downward wage rigidity may depend on the persistence and severity of shocks. The misallocation literature in the euro area (Gopinath, Kalemli-Ozcan, Karabarbounis, and Villegas-Sanchez, 2017) emphasizes declines in TFP and the deterioration of resource allocation in Spain and Italy before the crisis, but for various Greek industries we do not observe significant declines in trend TFP during the boom. The strong comovement between the traded and non-traded sector and the fact that Greek traded output has not recovered despite a decline in wages challenge narratives of slow economic growth focused on non-traded sectors such as the government or housing.[5] To generate this comovement, our quantitative model attributes an important role to supply-side influences such as tax rates and supply-side amplification mechanisms such as utilization. Our emphasis on utilization to reconcile movements in output and factor inputs echoes

[3]Consistent with both our and the Gourinchas, Philippon, and Vayanos (2016) results, Economides, Philippopoulos, and Papageorgiou (2017) also attribute a substantial role to fiscal consolidation for the bust. Dellas, Malliaropulos, Papageorgiou, and Vourvachaki (2018) highlight the tax side of the fiscal consolidation and the amplification of the decline in measured economic activity by a sizable informal sector. Relative to these papers, we examine both the origins of the boom and the bust, study the propagation of fiscal shocks through endogenous changes in TFP, and allow external demand, price and wage rigidity, and financial forces to play a role. Fakos, Sakellaris, and Tavares (2018) present firm-level evidence that roughly half of the decline in manufacturing investment is accounted for by tighter credit constraints and the other half by lower productivity and demand.

[4]Additionally, Gourinchas, Philippon, and Vayanos (2016) infer a significant increase in the price markup shock that accounts for the lack of recovery in economic activity and a significant decrease in the wage markup shock that accounts for the decline in wages, whereas these shocks are absent from our analysis.

[5]Arkolakis, Doxiadis, and Galenianos (2017) document the difference between the experiences of Ireland, Portugal and Spain where most of the external adjustment is accounted for by increases in exports and the experience of Greece where all of the external adjustment is accounted for by a decline in imports.

the earlier work of Gertler, Gilchrist, and Natalucci (2007) on the East Asian financial crisis.

2 Model

We model Greece as a small open economy within a currency union. We quote domestic prices and values in domestic currency and use asterisks for variables denominated in foreign currency which is the euro. The small open economy takes as given the interest rate i_t^* on euro-denominated debt and the euro price $P_{F,t}^*$ of imported goods. Given that Greece uses the euro for most of our sample period, we let the exchange rate between domestic currency and the euro be $E_t = 1$. As a result, the interest rate on debt denominated in domestic currency equals $i_t = i_t^*$. The law of one price holds for traded goods, so the domestic price of foreign traded goods is given by $P_{F,t} = E_t P_{F,t}^* = P_{F,t}^*$. For our counterfactual analyses in which Greece exits the euro and devalues unexpectedly, the change in E_t introduces a wedge between $P_{F,t}$ and $P_{F,t}^*$.

2.1 Households

Household heterogeneity. There is a measure one of workers $i \in [0,1]$. Workers belong to two types of households $h = \{r, o\}$. A constant fraction ζ of households are relatively impatient and discount with factor β^r and a fraction $1-\zeta$ of households are more patient and discount with factor $\beta^o > \beta^r$. In steady state, impatient households choose to borrow as much as possible and do not hold firm shares, whereas patient households choose bonds and share holdings in an interior solution. Anticipating this result, we label households as rule-of-thumb r and optimizing o.[6]

Preferences. There is full insurance within each household and, thus, consumptions are equalized $c_t^h(i) = c_t^h$ for all members $i \in \mathcal{I}(h)$ belonging to household h. Members of the household supply differentiated labor services $\ell_t^h(i)$ to the market. Household h values flows of consumption and labor from its members according to:

$$V_t^h = \left[\left(c_t^h\right)^{1-\frac{1}{\rho}} \int_{i\in\mathcal{I}(h)} \left(1 + \left(\frac{1}{\rho} - 1\right) \frac{\chi\left(\ell_t^h(i)\right)^{1+\frac{1}{\epsilon}}}{1+\frac{1}{\epsilon}} \right)^{\frac{1}{\rho}} \mathrm{d}i + \beta^h \left(\mathbb{E}_t \left(V_{t+1}^h\right)^{1-\sigma}\right)^{\frac{1-\frac{1}{\rho}}{1-\sigma}} \right]^{\frac{1}{1-\frac{1}{\rho}}}. \tag{1}$$

This specification combines Epstein and Zin (1989) preferences, which allows us to disentangle risk aversion from intertemporal substitution in our analysis of disaster risk, with a constant Frisch

[6]We motivate the inclusion of rule-of-thumb households into the model by referring to the empirical evidence of Carroll, Slacalek, and Tokuoka (2014) who show that matching the distribution of liquid assets in the Greek population requires an average annual marginal propensity to consume of 0.34.

elasticity of labor supply. The latter is used, among others, by Shimer (2010) and Trabandt and Uhlig (2011) and is consistent with a balanced growth with constant hours. Parameter $\chi > 0$ governs the disutility of labor, $\sigma > 0$ governs risk aversion, and $\epsilon > 0$ is the Frisch elasticity of labor supply. Parameter $\rho > 0$ governs both the intertemporal elasticity of substitution in consumption and the complementarity between consumption and labor. When $\rho \to 1$ preferences are separable between consumption and labor and when $\rho < 1$ consumption and labor are complements.

Consumption is a CES aggregator of traded c_T and non-traded c_N goods, where traded goods are a CES aggregator of home-produced c_H and foreign-produced c_F goods:

$$c_t^h = \left(\omega^{\frac{1}{\phi}} \left(c_{T,t}^h\right)^{\frac{\phi-1}{\phi}} + (1-\omega)^{\frac{1}{\phi}} \left(c_{N,t}^h\right)^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}}, \; c_{T,t}^h = \left(\gamma^{\frac{1}{\eta}} \left(c_{H,t}^h\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}} \left(c_{F,t}^h\right)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}. \quad (2)$$

Parameters $\omega > 0$ and $\gamma > 0$ are preference weights for goods. The elasticity of substitution between traded and non-traded goods is $\phi > 0$ and the elasticity of substitution between traded goods is $\eta > 0$. Home traded and non-traded goods are CES bundles of a measure one of differentiated varieties indexed by j:

$$c_{H,t}^h = \left(\int_0^1 \left(c_{H,t}^h(j)\right)^{\frac{\varepsilon_p-1}{\varepsilon_p}} \mathrm{d}j \right)^{\frac{\varepsilon_p}{\varepsilon_p-1}}, \; c_{N,t}^h = \left(\int_0^1 \left(c_{N,t}^h(j)\right)^{\frac{\varepsilon_p-1}{\varepsilon_p}} \mathrm{d}j \right)^{\frac{\varepsilon_p}{\varepsilon_p-1}}. \quad (3)$$

In equation (3), $\varepsilon_p > 1$ is the elasticity of substitution across varieties. Varieties are monopolistically competitive, so ε_p governs the markup of price over marginal cost in both sectors.

Wage setting. To derive a demand for each differentiated variety of labor, we model a perfectly competitive employment agency aggregating labor inputs $\{\ell_t^r(i)\}$ and $\{\ell_t^o(i)\}$ from households and selling them to firms at price W_t. The profit maximization problem is:

$$W_t(\ell_t^r + \ell_t^o) - \int_{i \in \mathcal{I}(r)} W_t^r(i)\ell_t^r(i)\mathrm{d}i - \int_{i \in \mathcal{I}(o)} W_t^o(i)\ell_t^o(i)\mathrm{d}i, \quad (4)$$

where $\ell_t^h = \left(\int_{i \in \mathcal{I}(h)} \left(\ell_t^h(i)\right)^{\frac{\varepsilon_w-1}{\varepsilon_w}} \mathrm{d}i \right)^{\frac{\varepsilon_w-1}{\varepsilon_w}}$ is the bundle of labor for each type of household h with an elasticity of substitution across varieties $\varepsilon_w > 1$. In equation (4), $W_t^h(i)$ denotes the cost of hiring one unit of $\ell_t^h(i)$. The perfect substitutability between ℓ_t^r and ℓ_t^o implies a common wage W_t for both types of households. Workers in each household are symmetric and share consumption risks and, thus, in equilibrium we obtain $\ell_t^h = \ell_t^h(i)$ and $W_t = W_t^r(i) = W_t^o(i)$.

The first-order conditions from the optimization problem (4) yield a downward sloping demand function for labor varieties:

$$\ell_t^h(i) = \left(\frac{W_t^h(i)}{W_t} \right)^{-\varepsilon_w} \ell_t^h. \quad (5)$$

Households internalize these demand functions in setting wages $W_t^h(i)$ for their members. The parameter ε_w governs the markup of real wages over the marginal rate of substitution between leisure and consumption. To allow stickiness in nominal wages to potentially play a role in the Greek boom and bust, we introduce quadratic costs of changing after-tax wages $\mathrm{AC}_{w,t}^h(i) = \frac{\psi_w}{2}\left(\frac{(1-\tau_t^\ell)W_t^h(i)}{(1-\tau_{t-1}^\ell)W_{t-1}^h(i)} - 1\right)^2 (1-\tau_t^\ell)W_t^h \ell_t^h$, where $\psi_w \geq 0$ controls for the strength of these costs.[7]

Asset markets. Households trade internationally bonds B_t^h at an exogenous interest rate i_t.[8] They also hold shares ς_t^h at price Q_t^ς in a mutual fund paying out the dividends earned by domestic firms. The choices of bonds and shares are subject to the financial constraints:

$$B_{t+1}^h \leq \overline{B}_{t+1}^h, \quad \varsigma_{t+1}^h \geq 0. \tag{6}$$

The borrowing limit $\overline{B}_{t+1}^h > 0$ is exogenously set by the rest of the world. The assumption $\beta^o > \beta^r$ implies that, in steady state, rule-of-thumb households choose $B^r = \overline{B}^r$ and $\varsigma^r = 0$. We assume that this constraint also binds away from steady state, $B_t^r = \overline{B}_t^r$, which allows us to use perturbation methods to solve the model.

Budget constraint. Denoting by P_c the price of aggregate consumption, τ^c the consumption tax rate, τ^ℓ the labor income tax rate, T^h lump sum transfers, and Π firms' profits, households face a sequence of budget constraints:

$$(1+\tau_t^c)P_{c,t}c_t^h + (1+i_t)B_t^h + Q_t^\varsigma \varsigma_{t+1}^h + \int \mathrm{AC}_{w,t}^h(i)\mathrm{d}i$$
$$= (1-\tau_t^\ell)\int W_t^h(i)\ell_t^h(i)\mathrm{d}i + B_{t+1}^h + (Q_t^\varsigma + \Pi_t)\,\varsigma_t^h + T_t^h. \tag{7}$$

Household optimization. Taking as given fiscal policies τ_t^c, τ_t^ℓ, T_t^h, firm profits Π_t, consumption prices $P_{H,t}(j)$, $P_{F,t}$, $P_{N,t}(j)$, asset prices i_t, Q_t^ς, and the aggregate wage W_t, each household h chooses sequences of consumptions $c_{H,t}^h(j)$, $c_{F,t}^h$, $c_{N,t}^h(j)$, labor supplies $\ell_t^h(i)$, wages $W_t^h(i)$, bonds B_{t+1}^h, and shares ς_{t+1}^h in order to maximize its utility in equation (1) subject to the downward sloping demand for labor (5), the financial constraints (6), and the budget constraint (7).[9]

[7] Influential work in the open economy by Schmitt-Grohé and Uribe (2016) emphasizes downward nominal wage rigidity of the form $W_t \geq \gamma W_{t-1}$, where parameter γ disciplines the extent of rigidity. We adopt quadratic adjustment costs in part because this specification allows us to use standard perturbation methods to solve the model and then estimate its parameters. We acknowledge the qualitative difference between our specification and downward nominal wage rigidity, but wish to highlight that our inference of relatively flexible nominal wages is informed by their 18 percent decline (when not detrended) between 2010 and 2016. In Appendix B.4 we demonstrate that using sample windows after 2008-2011 leads to lower estimates of γ than in Schmitt-Grohé and Uribe (2016).

[8] If households expect the exchange rate to always be $E_t = 1$, domestic currency and foreign currency bonds are perfect substitutes. To ease the exposition, we focus on bonds denominated in domestic currency.

[9] The price indices generated by household optimization are given by $P_{c,t} = \left(\omega P_{T,t}^{1-\phi} + (1-\omega)P_{N,t}^{1-\phi}\right)^{\frac{1}{1-\phi}}$, $P_{T,t} =$

2.2 Firms

There are two types of firms. Production is done by intermediate goods firms who use labor and capital to supply traded y_H and non-traded y_N goods to retailers. Price setting is done by retailers, who transform these intermediate inputs into differentiated traded goods $y_H(j)$ sold to domestic households, production firms, and the rest of the world and differentiated non-traded goods $y_N(j)$ sold to domestic households and the government.

Production. Production of traded and non-traded intermediate goods is Cobb-Douglas:[10]

$$y_{H,t} = z_{H,t}u_{H,t}(s_t k_t)^{\alpha_H}(\ell_{H,t})^{1-\alpha_H}, \quad y_{N,t} = z_{N,t}u_{N,t}((1-s_t)k_t)^{\alpha_N}(\ell_{N,t})^{1-\alpha_N}, \tag{8}$$

where $\alpha_H, \alpha_N \in (0,1)$ govern the shares of capital income and z_H and z_N denote exogenous productivity in each sector.

Firms hire labor inputs $\ell_{H,t}$ and $\ell_{N,t}$ at a wage W_t. Production uses capital k_t, with fraction s_t allocated to the traded sector and fraction $1-s_t$ allocated to the non-traded sector.[11] Motivated by the observation that the significant drop in sectoral TFP (as measured by Solow residuals) in the bust coincides with declines in utilization, we allow firms to choose endogenously the utilization of factors u_H and u_N in production. The cost of utilizing factors more intensively is increased depreciation of capital:

$$\delta_{H,t} = \bar{\delta}_H + \frac{\bar{\xi}_H}{\xi_H}\left(u_{H,t}^{\xi_H} - 1\right), \quad \delta_{N,t} = \bar{\delta}_N + \frac{\bar{\xi}_N}{\xi_N}\left(u_{N,t}^{\xi_N} - 1\right), \tag{9}$$

where $\bar{\delta}_H, \bar{\delta}_N > 0$ are the depreciation rates when utilization is at its steady state value of one, $\bar{\xi}_H, \bar{\xi}_N > 0$ are constants normalized to target utilization of one in steady state, and $\xi_H, \xi_N > 1$ govern the responsiveness of depreciation to utilization. Capital accumulates according to:

$$k_{t+1} = (1 - (s_t\delta_{H,t} + (1-s_t)\delta_{N,t}))\,k_t + x_t, \tag{10}$$

where $x_t = \left(\gamma^{\frac{1}{\eta}}(x_{H,t})^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}}(x_{F,t})^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}$ is a bundle of traded investment goods and $x_{H,t}$ is a CES aggregator of varieties $x_{H,t}(j)$ similar to the consumption aggregator $c_{H,t}$ in equation (3).

$\left(\gamma P_{H,t}^{1-\eta} + (1-\gamma)P_{F,t}^{1-\eta}\right)^{\frac{1}{1-\eta}}$, $P_{H,t} = \left(\int_0^1 (P_{H,t}(j))^{1-\varepsilon_p}\,\mathrm{d}j\right)^{\frac{1}{1-\varepsilon_p}}$, and $P_{N,t} = \left(\int_0^1 (P_{N,t}(j))^{1-\varepsilon_p}\,\mathrm{d}j\right)^{\frac{1}{1-\varepsilon_p}}$.

[10] The representative firm setup is appropriate in our context given that declines in value added and employment in the bust occurred throughout the firm size distribution (Appendix Figure B.1). Additionally, for almost all industries, the decline in labor productivity is accounted for by declines in labor productivity within size class rather than by a reallocation of economic activity across firms of different sizes (Appendix Figure B.2).

[11] We model the allocation of capital s_t without adjustment costs because the time series generated by the model are not significantly affected by these adjustment costs and, thus, parameters of the adjustment cost technology are not well-identified.

Asset markets. Producers issue bonds B_t^f internationally at exogenous interest rate i_t. They finance a fraction $\kappa \in [0,1]$ of employee compensation with working capital. Following Jermann and Quadrini (2012), intraperiod loans for working capital $\kappa W_t(\ell_{H,t} + \ell_{N,t})$ and next period debt B_{t+1}^f equal an exogenous fraction θ_t of the value of firm capital $Q_t^k k_{t+1}$ used as collateral, where Q_t^k is the price of capital:[12]

$$B_{t+1}^f + \kappa W_t \left(\ell_{H,t} + \ell_{N,t}\right) = \theta_t Q_t^k k_{t+1}. \tag{11}$$

Intermediate goods optimization. The objective of firms is to maximize their value $\tilde{J}_t = \tilde{\Pi}_t + \mathbb{E}_t \Lambda_{t,t+1}^o \tilde{J}_{t+1}$ where, in anticipation of the result that rule-of-thumb households do not hold any shares, $\Lambda_{t,t+1}^o$ is the stochastic discount factor of optimizing households. Flow profits $\tilde{\Pi}_t$ are:

$$\begin{aligned}\tilde{\Pi}_t = &\left(1-\tau_{H,t}^k\right)\left(\tilde{P}_{H,t} y_{H,t} - W_t \ell_{H,t}\right) + \left(1-\tau_{N,t}^k\right)\left(\tilde{P}_{N,t} y_{N,t} - W_t \ell_{N,t}\right) - (1+\tau_t^x) P_{T,t} x_t - \mathrm{AC}_{k,t} \\ &+ B_{t+1}^f - (1+i_t) B_t^f + \tau_{H,t}^k s_t \left(\bar{\delta}_H Q_t^k k_t + i_t B_t^f\right) + \tau_{N,t}^k (1-s_t)\left(\bar{\delta}_N Q_t^k k_t + i_t B_t^f\right) - \mathrm{AC}_{\pi,t}, \end{aligned} \tag{12}$$

where $\tilde{P}_{H,t}$ and $\tilde{P}_{N,t}$ are the prices of intermediate traded and non-traded goods supplied to the retailers and τ^k and τ^x are capital income and investment spending taxes. Capital income taxes are sector specific, $\tau_{H,t}^k$ and $\tau_{N,t}^k$, motivated by the observation that property taxes increased significantly during the bust period and these taxes fall predominately on the non-traded sector. Depreciation and interest on debt are deducted from taxable income. Dividend adjustment costs, $\mathrm{AC}_{\pi,t} = \frac{\psi_\pi}{2}\left(\frac{\tilde{\Pi}_t}{P_{F,t}} - \frac{\tilde{\Pi}}{P_F}\right)^2 P_{F,t}$, constrain firms from issuing enough equity to overcome their financing constraint, where $\psi_\pi \geq 0$ controls for the strength of these costs and $\tilde{\Pi}/P_F$ denotes steady state profits relative to the foreign price. Capital adjustment costs, $\mathrm{AC}_{k,t} = \frac{\psi_k}{2}\left(\frac{k_{t+1}-k_t}{k_t}\right)^2 P_{F,t} k_t$, smooth the dynamics of capital, where $\psi_k \geq 0$ controls for the strength of these costs.

Taking as given the stochastic discount factor $\Lambda_{t,t+1}^o$, fiscal policies $\tau_{H,t}^k$, $\tau_{N,t}^k$, τ_t^x, intermediate good prices $\tilde{P}_{H,t}$, $\tilde{P}_{N,t}$, asset prices i_t, Q_t^k, the price of traded investment goods $P_{T,t}$, and the aggregate wage W_t, firms choose sequences of capital k_t, s_t, labor demand $\ell_{H,t}$, $\ell_{N,t}$, utilization $u_{H,t}$, $u_{N,t}$, and bonds B_{t+1}^f in order to maximize the presented discounted value of profits in

[12] The baseline specification of Jermann and Quadrini (2012) features intraperiod loans on output instead of the wage bill. However, they show that this difference is relatively immaterial for the quantitative effects of θ_t shocks on the model-generated time series of output and labor. Similarly to them, we write equation (11) with equality assuming that the financial constraint always binds. In the steady state of our model the borrowing constraint always binds because interest expenses are deducted from taxes and financing production with debt maximizes firm value. We assume that the constraint also binds in an approximation around the steady state, which allows us to infer θ_t directly from equation (11). The most important difference is that Jermann and Quadrini (2012) impose $\kappa = 1$, whereas we estimate $\kappa = 0.12$ because in the data the comovement between firm leverage θ_t and labor $\ell_t \equiv \ell_{H,t} + \ell_{N,t}$ is weak.

equation (12) subject to the production functions (8), depreciation rates (9), capital accumulation (10), and the financial constraint (11).

Price setting. Retailers in the traded sector produce differentiated varieties $y_{H,t}(j)$ using the intermediate traded good $y_{H,t}$. Retailers choose price $P_{H,t}(j)$ to maximize their value $J_{H,t}(j) = \Pi_{H,t}(j) + \mathbb{E}_t \Lambda^o_{t,t+1} J_{H,t+1}(j)$, where flow profits are $\Pi_{H,t}(j) = \left(P_{H,t}(j) - \tilde{P}_{H,t}\right) y_{H,t}(j) - \text{AC}_{H,t}(j)$. To allow stickiness in nominal prices to potentially play a role in the Greek boom and bust, we introduce quadratic costs of changing prices $\text{AC}_{H,t}(j) = \frac{\psi_p}{2}\left(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1\right)^2 P_{H,t} y_{H,t}$ as in Rotemberg (1982), where $\psi_p \geq 0$ controls for the strength of these costs.

When setting prices, retailers internalize the residual demand for their variety by households, intermediate goods firms, and the rest of the world:

$$y_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon^p} \left[\gamma \left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\eta} \left(\zeta c^r_{T,t} + (1-\zeta) c^o_{T,t} + x_t\right) \; + (1-\gamma)\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta} \bar{a}_{T,t}\right]. \qquad (13)$$

The first term in the bracket of equation (13) comes from the domestic demand for traded goods for household consumption $c^r_{H,t}(j)$ and $c^o_{H,t}(j)$ and firm investment $x_{H,t}(j)$. The second term comes from consumption and investment demand for Greek traded goods from the rest of the world $\bar{c}_{H,t}(j) + \bar{x}_{H,t}(j)$. Given a price $P_{H,t}$ for Greek traded goods that is determined endogenously from price setting decisions, the variable $\bar{a}_{T,t}$ represents shifts in the world demand for Greek traded goods occurring for reasons exogenous to the domestic economy.[13]

Retailers in the non-traded sector produce differentiated varieties $y_{N,t}(j)$ using the intermediate traded good $y_{N,t}$. They choose price $P_{N,t}(j)$ to maximize the value $J_{N,t}(j) = \Pi_{N,t}(j) + \mathbb{E}_t \Lambda^o_{t,t+1} J_{N,t+1}(j)$, where flow profits are $\Pi_{N,t}(j) = \left(P_{N,t}(j) - \tilde{P}_{N,t}\right) y_{N,t}(j) - \text{AC}_{N,t}(j)$ and adjustment costs of changing nominal prices are $\text{AC}_{N,t}(j) = \frac{\psi_p}{2}\left(\frac{P_{N,t}(j)}{P_{N,t-1}(j)} - 1\right)^2 P_{N,t} y_{N,t}$. The residual demand for their variety comes from household consumption $c^r_{N,t}(j)$ and $c^o_{N,t}(j)$ and government spending on non-traded goods $g_t(j)$:

$$y_{N,t}(j) = \left(\frac{P_{N,t}(j)}{P_{N,t}}\right)^{-\varepsilon^p} \left[\zeta c^r_{N,t} + (1-\zeta) c^o_{N,t} + g_t\right]. \qquad (14)$$

[13] Denoting with an upper bar rest of the world variables, under CES preferences the quantity of Greek traded goods demanded from the rest of the world is $\bar{c}_{H,t}(j) + \bar{x}_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon^p} (1-\bar{\gamma}_t)\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta} (\bar{c}_{T,t} + \bar{x}_t)$, where $P_{F,t} = \bar{P}_{T,t}$ because Greece is too small to affect the price of traded goods in the rest of the world. Therefore, external demand, $\bar{a}_{T,t} = \frac{1-\bar{\gamma}_t}{1-\gamma}(\bar{c}_{T,t} + \bar{x}_t)$, reflects a combination of preferences for Greek goods and overall traded-goods consumption and investment by the rest of the world.

2.3 Government

The government raises revenues from taxes on consumption τ_t^c, investment τ_t^x, labor income τ_t^ℓ, and capital income $\tau_{H,t}^k$,$\tau_{N,t}^k$, issues debt B_t^g at exogenous interest rate $r_t = r_t^*$, transfers T_t^r and T_t^o to households, and spends g_t on non-traded goods.[14] The government budget constraint is:

$$\begin{aligned}
&\tau_t^c P_{c,t}\left(\zeta c_t^r + (1-\zeta)c_t^o\right) + \tau_t^x P_{T,t}x_t + \tau_t^l\left(\zeta W_t\ell_t^r + (1-\zeta)W_t\ell_t^o\right)\\
&+\tau_{H,t}^k\left(\tilde{P}_{H,t}y_{H,t} - W_t\ell_{H,t} - s_t\left(\bar{\delta}_H Q_t^k k_t + i_t B_t^f\right)\right)\\
&+\tau_{N,t}^k\left(\tilde{P}_{N,t}y_{N,t} - W_t\ell_{N,t} - (1-s_t)\left(\bar{\delta}_N Q_t^k k_t + i_t B_t^f\right)\right)\\
&\qquad\qquad = P_{N,t}g_t + (1+r_t)B_t^g - B_{t+1}^g + \zeta T_t^r + (1-\zeta)T_t^o. \qquad (15)
\end{aligned}$$

2.4 Driving Forces

The first set of exogenous processes consists of sectoral productivities $\log z_{H,t}$ and $\log z_{N,t}$. The second set includes rest of the world demand for Greek goods $\bar{a}_{T,t}$ and the price of imports $P_{F,t}^*$. Financial processes include government debt $\log B_t^g$, the borrowing limit of rule-of-thumb households $\log \bar{B}_t^r$, the interest rate r_t^* on public debt, the interest rate i_t^* on private debt, and the fraction θ_t of the value of capital firms use as collateral to borrow. Finally, fiscal processes include government spending $\log g_t$, transfers to rule-of-thumb households $\log T_t^r$, and tax rates τ_t^c, τ_t^l, τ_t^x, $\tau_{H,t}^k$, and $\tau_{N,t}^k$.

To these forces we add a rare disaster following Gourio (2012). We motivate the possibility of rare disasters by the elevated uncertainty Greece experienced around 2012 and 2015 during the debt negotiations and the possibility of exit from the euro.[15] A disaster event moves the economy permanently to a state in which the levels of variables such as productivity and external demand scale down by a factor $\exp(-\varphi) < 1$ (see Appendix A.2 for details). Disasters occur with time-varying probability π_t. To discipline our quantitative exercise, we fix φ to a constant and assume a disaster does not actually occur in sample. Instead, we consider only the impact of changes in the probability of a disaster π_t as estimated from options data. An increase in π_t is equivalent to an increase in the effective discount factor of optimizing households, $\beta^o\left(1-\pi_t+\pi_t\exp((\sigma-1)\varphi)\right)^{\frac{\frac{1}{\rho}-1}{\sigma-1}}$,

[14]The government allocates spending $P_{N,t}g_t$ across varieties of non-traded goods which yields the demand functions $g_t(j) = \left(\frac{P_{N,t}(j)}{P_{N,t}}\right)^{-\varepsilon^p} g_t$ used in equation (14).

[15]Owing to the rich production side of the economy, our model abstracts from endogenous sovereign default. Arellano and Bai (2017) explore fiscal incentives and constraints that trigger default in the context of the Greek depression, but the depression is triggered by productivity shocks that are not matched to data.

because we estimate an elasticity of intertemporal substitution $\rho < 1$.

The exogenous processes are collected in vector $\mathbf{z}_t$ and follow an autoregressive process:

$$\mathbf{z}_{t+1} = \bar{\mathbf{z}} + \mathbb{R}\mathbf{z}_t + \Sigma\nu_{t+1}, \tag{16}$$

where $\bar{\mathbf{z}}$ is a constant that depends on steady state values and the size of the disaster φ, $\mathbb{R}$ is a diagonal matrix containing the persistence of each stochastic process, Σ is a diagonal matrix containing the standard deviations of the innovations, and the vector of innovations $\nu_{t+1} \sim \mathbb{N}(0, \mathbb{I})$.

2.5 Equilibrium

Given exogenous processes $\mathbf{z}_t$, an equilibrium is a sequence of quantities and prices such that households and firms maximize their values, the labor market clears $\ell_t \equiv \ell_{H,t} + \ell_{N,t} = \zeta \int \ell_t^r(i)\mathrm{d}i + (1-\zeta)\int \ell_t^o(i)\mathrm{d}i$, traded goods markets clear $y_{H,t}(j) = \zeta c_{H,t}^r(j) + (1-\zeta)c_{H,t}^o(j) + x_{H,t}(j) + \bar{c}_{H,t}(j) + \bar{x}_{H,t}(j)$, non-traded goods markets clear $y_{N,t}(j) = \zeta c_{N,t}^r(j) + (1-\zeta)c_{N,t}^o(j) + g_t(j)$, the equity market clears $\zeta\varsigma_t^r + (1-\zeta)\varsigma_t^o = 1$ where aggregate profits are $\Pi_t = \tilde{\Pi}_t + \int_0^1 \Pi_{H,t}(j)\mathrm{d}j + \int_0^1 \Pi_{N,t}(j)\mathrm{d}j$, and the government budget constraint (15) holds. We let transfers to optimizing households T_t^o adjust endogenously to satisfy the government budget constraint (15).

Appendix A.1 collects all conditions in the symmetric equilibrium of the model.[16] We solve the model using a first-order approximation of the equilibrium conditions around the steady state. We prefer a first-order approximation because it facilitates the estimation of parameters. Appendix Figure C.1 shows that, for given parameters, paths of model-generated variables do not differ significantly between the first-order, second-order, and third-order approximations of the equilibrium conditions.

3 Measurement

Our sample covers the period between 1998 and 2016. We use 1998 as a burn-in period to initiate the dynamics of the model from steady state and display time series beginning from 1999 when the euro area was formed. We divide all quantities by total population in Greece. To account for trend growth we deflate per capita quantities with 2 percent per year, which is the average growth rate

[16] The equilibrium is symmetric across types of labor services, so we obtain $\ell_t^r(i) = \ell_t^r$, $\ell_t^o(i) = \ell_t^o$, and $W_t^r(i) = W_t^o(i) = W_t$. The equilibrium is symmetric across varieties of traded and non-traded goods, so we also obtain $y_{H,t}(j) = y_{H,t}$, $y_{N,t}(j) = y_{N,t}$, $c_{H,t}^r(j) = c_{H,t}^r$, $c_{H,t}^o(j) = c_{H,t}^o$, $c_{N,t}^r(j) = c_{N,t}^r$, $c_{N,t}^o(j) = c_{N,t}^o$, $g_t(j) = g_t$, $\Pi_{H,t}(j) = \Pi_{H,t}$, $\Pi_{N,t}(j) = \Pi_{N,t}$, $P_{H,t}(j) = P_{H,t}$, and $P_{N,t}(j) = P_{N,t}$.

of constant-price GDP per capita in Greece between 1970 and 1998 from the Penn World Tables. To account for trend inflation we deflate prices and interest rates with 1 percent per year, which is the average euro inflation rate during our sample. Values and nominal wages are deflated with 3 percent per year. Finally, we deflate productivity measures with $((1+0.02)^{0.46}-1) \approx 0.9$ percent per year, where 0.46 is the mean labor share observed in our sample. While we prefer to detrend variables to account for trend growth and inflation, we also report results without detrending in sensitivity analyses below.

3.1 Outcomes

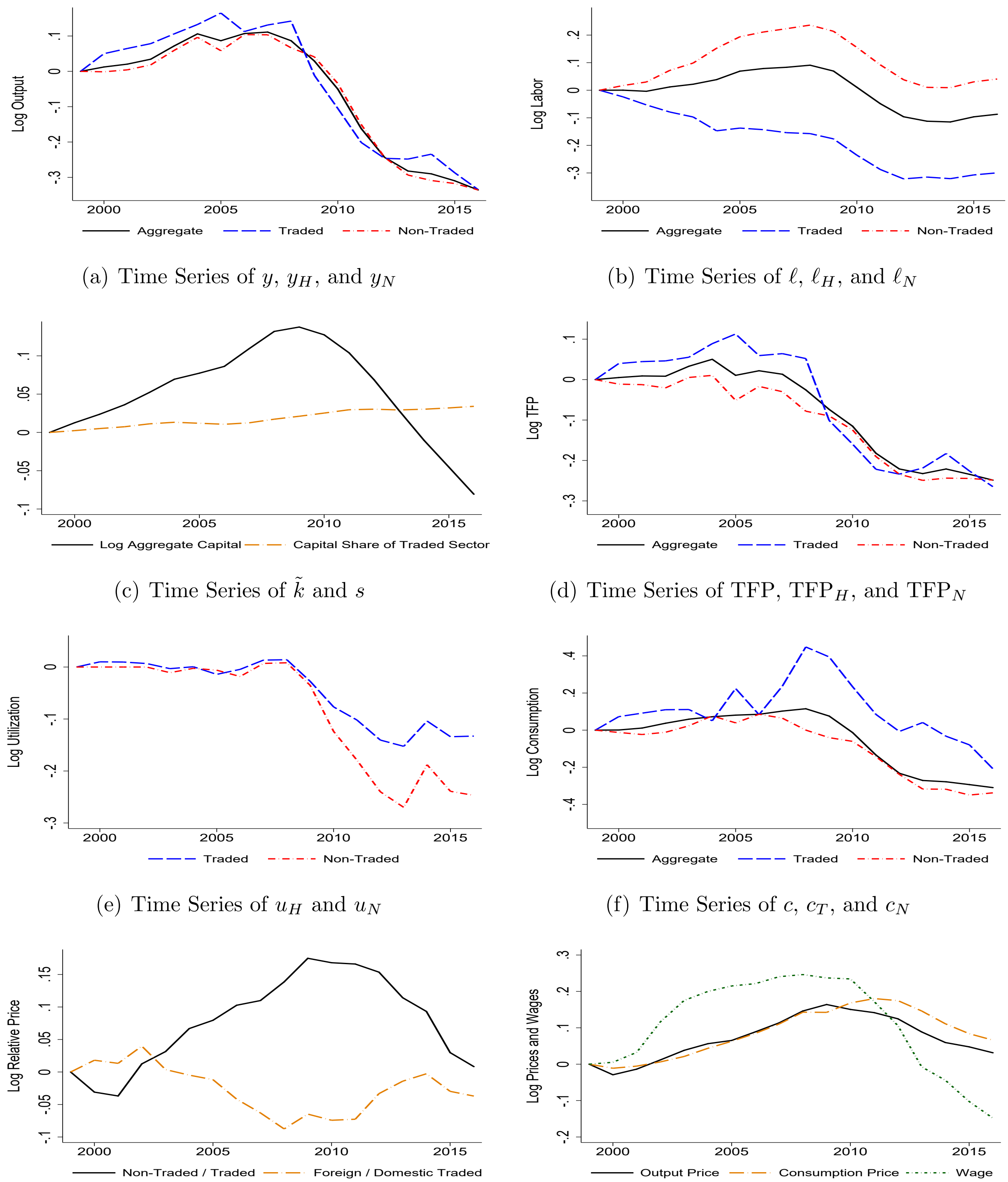
We begin by describing the measurement and evolution of outcome variables used to estimate and evaluate the model. Figure 1 presents their deviations from 1999 values. We use 11 outcome variables to estimate 11 parameters and collect the time series in a vector:

$$\mathbf{y} = \left(\log \ell_H, \log \ell_N, \log u_H, \log u_N, \log \tilde{k}, s, \log c, \log(P_N c_N), \log \frac{P_N}{P_T}, \log P_y, \log W\right). \tag{17}$$

We obtain constant-price total output y and its price P_y from the Eurostat National Accounts ESA 2010 database.[17] The traded sector consists of agriculture, mining, manufacturing, transportation, and accommodation and food services. The latter belong to the traded sector because a significant fraction of economic activity in accommodation and food services in Greece is related to tourism. Denoting the current-price value added of industry i by $P_i y_i$, we sum up value added for traded goods $P_H y_H = \sum_{i \in H} P_i y_i$, construct their price P_H as the Paasche price index of the underlying prices P_i, and obtain constant-price value added y_H as the ratio of the two. We follow a similar procedure to measure P_N and y_N. Figure 1(a) shows strong comovement between y_H and y_N over time. Both variables increase up to 2007, decline by roughly 30 percent between 2007 and 2012, and do not recover after 2012.

Labor inputs ℓ_H and ℓ_N are total hours worked per capita in each sector. These measures include both employee hours and hours of the self-employed. The underlying source data come from national surveys of households and establishments. As Figure 1(b) shows, both labor inputs fell by roughly 15 percent after 2008 despite their divergence over the first part of the sample. Labor inputs have recovered only weakly in the last years of the sample.

[17] In the model we define P_y as a Paasche price index of P_H and P_N and $y = \frac{P_H y_H + P_N y_N}{P_y}$.



(a) Time Series of y, y_H, and y_N

(b) Time Series of ℓ, ℓ_H, and ℓ_N

(c) Time Series of $\tilde{k}$ and s

(d) Time Series of TFP, TFP_H, and TFP_N

(e) Time Series of u_H and u_N

(f) Time Series of c, c_T, and c_N

(g) Time Series of P_N/P_T and P_F/P_H

(h) Time Series of P_y, P_c, and W

Figure 1: Outcomes

Figure 1 plots the evolution of macroeconomic variables relative to 1999. H denotes the traded sector for production measures and T for consumption measures. N denotes the non-traded sector. y is output, ℓ is labor, $\tilde{k}$ is the capital stock, s is the share of capital in the traded sector, TFP is total factor productivity, u is utilization, c is consumption, P_N/P_T is the price of non-traded goods relative to traded goods, P_F/P_H is price of foreign to domestic traded goods (terms of trade), P_y is price of output, P_c is price of consumption, and W is the wage. Quantities are detrended with 2 percent per year, prices with 1 percent, TFP with 0.9 percent, wages with 3 percent.

To construct the stock of capital, we use the perpetual inventory method with a fixed depreciation rate for each of four types of assets (structures, machinery and equipment, cultivated biological resources, and intellectual property assets) and the time series of constant-price investment x from the national accounts. We denote this variable by $\tilde{k}_t = (1-\bar{\delta})\tilde{k}_{t-1} + x_t$ to distinguish it from the variable k in the model which accounts for variable depreciation due to utilization. We measure the share of capital allocated to the traded sector s using Eurostat industry-level fixed asset accounts. Figure 1(c) shows a roughly 10 percent increase in capital during the boom period, followed by a roughly 20 percent decline after 2010. The significant decline in the capital stock reflects a more than 80 percent collapse of investment between 2008 and 2016. By contrast, the share of capital across sectors remains relatively stable over time.

We obtain total factor productivities using a growth accounting approach (see Appendix B.2 for details). Within each sector, we use a constant returns to scale production function with time-varying income shares that maps labor and capital services into value added. To construct capital services, we aggregate the four type of assets using user cost weights that depend on asset-specific depreciation rates and a common required net return. These measures capture both within-industry productivity and the reallocation of inputs across industries within sectors.[18] Figure 1(d) shows the evolution of sectoral and aggregate TFP. Relative to trend, TFP in the traded sector increases in the first years of the sample whereas TFP in the non-traded sector decreases slightly. Both TFP indices decrease substantially during the bust period and do not recover.

Measures of utilization u_H and u_N come from two Joint Harmonised European Commission Surveys. We average the quarterly responses to the Industry Survey question "*At what capacity is your company currently operating (as a percentage of full capacity)?*" to obtain utilization in the manufacturing sector. For services industries, we use the question added in 2011 to the Services Survey: "*If the demand expanded, could you increase your volume of activity with your present resources? If so, by how much?*". We use the fraction of respondents reporting "None" to the question "*What main factors are currently limiting your business?*" to extend this measure back in time.[19] We then aggregate within sectors to obtain u_H and u_N. Figure 1(e) shows that utilization

[18] Applying the Basu (1996) decomposition of total factor productivity into a within industry component and a between industry component, we find a relatively small role for reallocation across industries in accounting for the dynamics of total factor productivity at the sectoral or aggregate level.

[19] In Appendix B.2, we present an alternative series for utilization based on Basu (1996). This approach relates unobserved utilization to the growth of materials inputs. Our baseline survey measures and the implied utilization measures from this alternative approach yield consistent time series for utilization and, in particular, both measures show a sharp decline in utilization during the bust period.

declined substantially in both sectors between 2007 and 2012 and remained depressed thereafter.

We measure current-price consumption of non-traded goods as value added of non-traded output less government purchases of consumption and investment, $P_N c_N = P_N y_N - P_N g_t$. Consumption expenditure on traded goods is, therefore, $P_T c_T = P_c c - P_N c_N$, where $P_c c$ is current-price consumption of households and non-profits. We obtain c_N using the Paasche index P_N from the underlying industry prices that comprise the non-traded sector, c_T using the Paasche price index P_T from the price of domestic traded goods P_H and the price of foreign traded goods P_F, and c from the consumption price index P_c.[20] Figure 1(f) displays a consumption boom in until 2007 and then a significant decline and lack of recovery. Expenditure on non-traded goods comprises roughly 70 percent of total expenditure and, thus, total consumption comoves more closely with non-traded consumption than with traded consumption.

Figures 1(g) and 1(h) display the evolution of prices and wages. Until 2008, the relative price of non-traded goods was increasing and the Greek terms of trade was appreciating. These trends reverse after 2010. Relative to their corresponding trends, the Greek price indices of output and consumption increased by roughly 10 percent in the first part of the sample and declined by roughly the same amount in the second part. Finally, relative to their trend, wages increased by more than 20 percent by 2010 and then declined by more than 30 percent. We measure wages as total employee compensation divided by total employee hours. In Appendix B.3 we document that this measure correlates highly with other wage series available for Greece including the Eurostat Labor Cost Index and the quadrennial Structure of Earnings Survey, that both public and private sector employees experienced declines in nominal wages after 2010, and that significant nominal wage declines occur across all age groups, skill categories, and throughout the wage distribution.

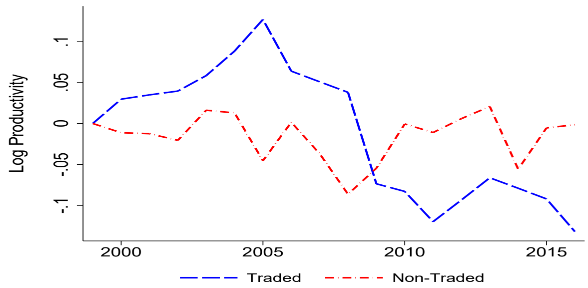
3.2 Driving Forces

We next describe the measurement of the exogenous processes that drive the model:

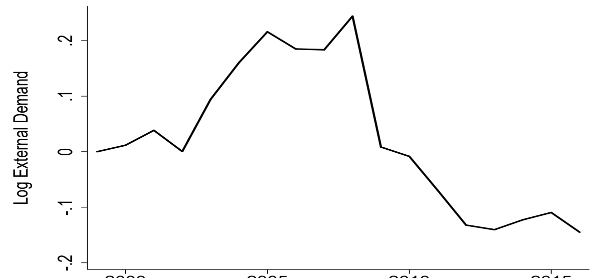
$$\mathbf{z} = \left(\log z_H, \log z_N, \log \bar{a}_T, \log P_F^*, \log B^g, \log \bar{B}^r, r^*, i^*, \theta, \pi, \log g, \log T^r, \tau^c, \tau^x, \tau^\ell, \tau_H^k, \tau_N^k\right). \qquad (18)$$

Productivity. We obtain (utilization-adjusted) traded and non-traded productivity, z_H and z_N, by subtracting the contribution of utilizations, u_H and u_N, from the TFP measures displayed

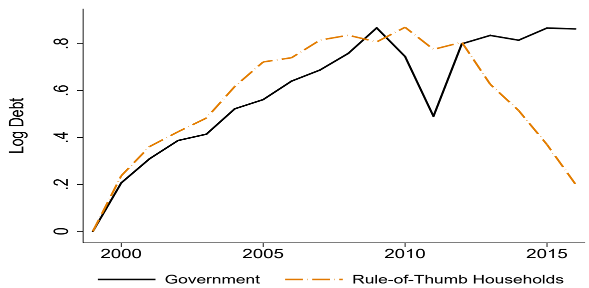
[20] As in the model, these price indices are basic meaning that they exclude indirect taxes. Expenditure series and price indices in national accounts are at market prices, meaning that they map into to $(1 + \tau^c) P_c$. We use our series on the consumption tax rate τ^c described below to obtain P_c from the national accounts price index.



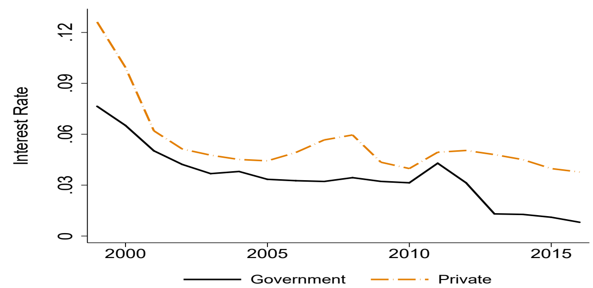
(a) Time Series of z_H and z_N



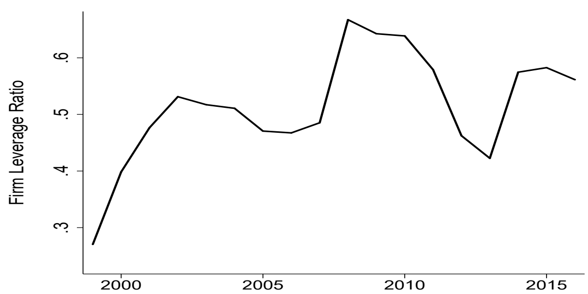
(b) Time Series of $\bar{a}_T$



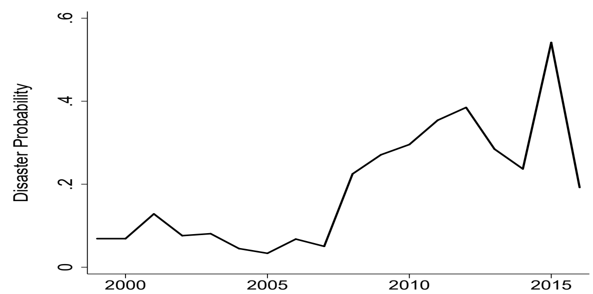
(c) Time Series of B^g and $\bar{B}^r$



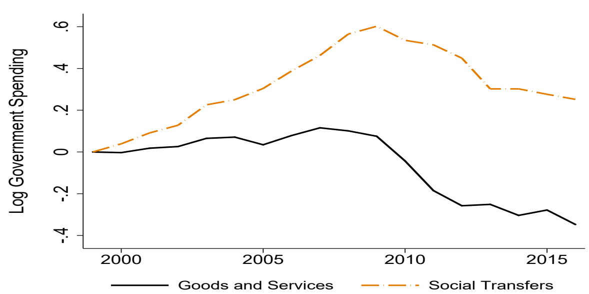
(d) Time Series of r^* and i^*



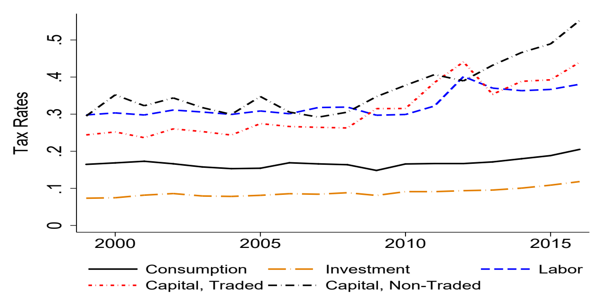
(e) Time Series of θ



(f) Time Series of π



(g) Time Series of g and T^r



(h) Time Series of $\tau^c, \tau^x, \tau^\ell, \tau^k_H, \tau^k_N$

Figure 2: Driving Forces

Figure 2 plots the evolution of exogenous driving processes. H and T denotes the traded sector and N denotes the non-traded sector. z is exogenous productivity, $\bar{a}$ is external demand, B^g is government debt, $\bar{B}^r$ is the borrowing limit of rule-of-thumb households, r^* is the government interest rate, i^* is the private interest rate, θ is firm leverage, π is the probability of a disaster, g is government consumption and investment, T^r is lump sum transfers to rule-of-thumb households, and $\tau^c, \tau^x, \tau^\ell, \tau^k_H, \tau^k_N$ are tax rates on consumption, investment, labor income, and capital income. Quantities are detrended with 2 percent per year, productivity with 0.9 percent, and values with 3 percent.

in Figure 1. Figure 2(a) shows that traded productivity z_H increases in the first years of the sample and then decreases significantly during the bust period. By contrast, non-traded productivity z_N does not display systematic fluctuations over the sample.

External demand. We measure external demand $\bar{a}_T$ for Greek goods using equation (13) in the symmetric equilibrium of the model:

$$P_{H,t}y_{H,t} = \gamma \left(\frac{P_{T,t}}{P_{H,t}}\right)^{\eta-1} P_{T,t}\left(c_{T,t}+x_t\right) + (1-\gamma)\left(\frac{P_{F,t}}{P_{H,t}}\right)^{\eta-1} P_{F,t}\bar{a}_{T,t}. \tag{19}$$

Given values $\gamma = 0.24$ and $\eta = 1.65$ that we estimate below, we populate this equation with traded value added $P_H y_H$, traded domestic demand $P_T(c_T + x)$, and prices of traded goods P_H and P_F to solve for external demand $\bar{a}_T$. Figure 2(b) displays a roughly 20 percent increase in $\bar{a}_T$ from the beginning of the sample until 2008, followed by a cumulative decline of roughly 30 percent until the end of the sample. To understand this behavior of $\bar{a}_T$, equation (19) decomposes the value of Greek production of traded goods into the value of the domestic absorption of Greek traded goods (the first term) and the value of exports (the second term). Given a trade elasticity $\eta > 1$, Greek exports increase when the terms of trade P_F/P_H depreciate. Figure 1(g) shows an appreciation of P_F/P_H in the first part of the sample and a depreciation after roughly 2010. In the absence of movements in external demand $\bar{a}_T$, the behavior of the terms of trade would generate a decrease in Greek exports initially and then an increase. As a result, the increase and then decline in $\bar{a}_T$ rationalizes the increase and then decline in exports, given the behavior of the terms of trade.[21]

The increase in $\bar{a}_T$ over the first part of the sample coincides with the entry of Greece into the euro area and the hosting of the Olympic Games. The bust of $\bar{a}_T$ coincides with a period of depressed global demand. In Appendix B.5, we further investigate the bust period and document that the lack of recovery in exports is concentrated in the Greek shipping industry (water transportation). Kalouptsidi (2014) documents substantial increases in freight rates globally and a surge in the new ship backlog between 2003 and 2008 driven by a growth of raw material imports particularly in China. Given substantial time to build constraints, she argues that the 2008 crisis

[21]Since $P_H y_H$ is value added in the Greek traded sector, the second term in equation (19) corresponds to value-added exports and not gross exports as reported in the national income accounts. Value-added exports differ from gross exports because of imports of intermediate goods used in the production of gross exports. For example, Greece imports crude petroleum and exports refined petroleum products. Accordingly, we could have obtained $\bar{a}_T$ using data on the value-added content of exports from input-output data and the procedure of Johnson and Noguera (2012). Appendix Figure B.5 shows that the value-added export series and the implied $\bar{a}_T$ obtained from equation (19) are comparable to alternative series for value-added exports and $\bar{a}_T$ using data from the World Input-Output Database. Our preferred measure understates the importance of $\bar{a}_T$ during the boom years. The two measures display similar declines during the bust period and neither measure recovers by the end of the sample.

led to a persistent decline in freight rates and the idling of the existing fleet. These developments are consistent with a persistent decline in $\bar{a}_T$ after 2008.

Financial conditions. Figure 2(c) plots the evolution of government debt B^g from flow of funds data reported by the Greek Central Bank. Government debt B^g is the market value of debt and loans at all maturities net of assets, currency held, and deposits. The visible decline in B^g in the figure reflects the mid-2011 announcement that private lenders would incur a roughly 20 percent decline in the net present value of their bond holdings. The increase in B^g after 2012 to pre-2011 levels reflects the long-term loans made to Greece by the European Union and the International Monetary Fund under the second bailout program in the beginning of 2012.

Figure 2(c) also plots the borrowing limit of rule-of-thumb households $\bar{B}^r$. We measure $\bar{B}^r$ with household short-term liabilities in loans and other payables from the flow of funds. Thus, we assume that constrained households use short-term liabilities to finance their consumption expenditures and unconstrained households incur only long-term liabilities, to which we add assets, currency, and deposits to arrive at B^o. Figure 2(c) shows the leveraging cycle for rule-of-thumb households who increased their borrowing by roughly 80 percent until 2010 and then decreased it by roughly 60 percent by the end of the sample.

Figure 2(d) plots the evolution of government r^* and private i^* interest rates. We measure r^* as an effective interest rate on government debt by dividing (net) interest payments by the government from the national accounts to the market value of debt B^g from the flow of funds. The interest rate i^* is the interest rate on loans with duration less than one year for non-financial corporations available from the European Central Bank. Consistent with the experience of other Southern economies of the euro area, both interest rates exhibit a downward trend over time with most of the decline concentrated in the first years of the sample.

We invert equation (11) to measure firm-level leverage $\theta = \frac{B_t^f + \kappa W_t \ell_t}{Q_t^k k_{t+1}}$ using flow of funds data for the non-financial corporate sector. The numerator equals debt, loans, and other payable liabilities less assets, currency held, and deposits. In the denominator, we measure the price of capital Q^k as the ratio of the market value of equity and debt to the replacement cost of all assets (physical and financial) and we impute capital k for the non-financial corporate sector using the capital of the business sector available in the national accounts. Figure 2(e) shows a significant increase in θ until 2007, a decline through 2013, and a recovery since then. The contrast between θ, which would decline if firms find borrowing prohibitively expensive, and the interest rate i^*, which does not necessarily increase when firms cannot borrow, demonstrates the importance of modeling changes in leverage in addition to changes in the interest rates.[22]

Disaster risk. We follow Barro and Liao (2016) to recover a time series of disaster probabilities π from prices of far-out-of-the-money put options. A far-out-of-the-money put option pays off only when stock prices fall by a large amount, so the price of such an option provides information about the probability a disaster occurs (in which case the option becomes in the money), the size of a disaster conditional on one occurring, and risk aversion. Appendix B.6 details our implementation of the Barro and Liao (2016) procedure. Our data contain the universe of put options traded on the Athens Stock Exchange between 2001 and 2017. The Barro and Liao (2016) model fits the data well, with an elasticity of the option price to moneyness similar to that found for other countries. We estimate monthly averages of daily disaster probabilities which we then annualize and average across months in a year to arrive at our series for π plotted in Figure 2(f). Figure B.6 reports the monthly series and shows that the peaks of the disaster probability coincide with major political and economic events during the crisis period.

Government spending. Government purchases of goods and services g_t include both own-account production and purchases of market goods for consumption and investment. We equate transfers to rule-of-thumb households T_t^r with social benefits to persons which include transfers such as pensions, health insurance, disability insurance, unemployment insurance, and in-kind benefits. Figure 2(g) shows that both g and T^r rise during the boom, but T^r by significantly more. Both series contract during the bust by roughly 40 percent.

Tax rates. Greece levies taxes on transactions, individuals, corporations, and property. We allocate all tax receipts and actual social contributions into taxes on consumption, investment, labor, and capital. Our methodology for measuring tax rates builds on Mendoza, Razin, and Tesar (1994) who calculate effective tax rates using national income and product accounts. There are two reasons to use effective rather than statutory tax rates. First, tax evasion in Greece is rampant.[23] Effective tax rates capture changes in tax compliance over time that would otherwise

[22] Bocola (2016) emphasizes that, at times of elevated sovereign default risk, banks may perceive firms as riskier and reduce lending or increase rates. While we think of θ as capturing lending constraints arising both from reduced bank liquidity and higher perceived risk and, additionally, we allow for elevated disaster risk π in our model, we acknowledge that θ and π could be affected by policies that reduce risk and by fiscal consolidation.

[23] Artavanis, Morse, and Tsoutsoura (2016) use bank-level data to document that in industries with significant fraction of self-employed, such as accounting, education, law, tourism, and medicine, household debt payments are close to or exceed reported income. Based on a statistical model of banks' adaptation to underreporting of income, they infer that almost half of self-employed income goes unreported.

not show up in statutory rates because the European System of National Accounts records taxes "only when evidenced by tax assessments, declarations ... and missing taxes are not imputed" (page 106-107 in Eurostat, 2013). Second, income taxes in Greece depend not only on income but also on so-called objective criteria such as the surface of a house or the type of car engines individuals own. This feature of the tax code makes it difficult to estimate tax rates accurately even in the most complete micro datasets. We summarize the most important aspects of our measurements here and refer the reader to Appendix B.7 for more details.

Taxes on production and imports less subsidies are allocated to consumption and investment, with the exception of property taxes paid by enterprises which are allocated to capital income. From taxes on production and imports net of property taxes, we allocate a part that unambiguously falls on consumption and the residual to consumption and investment in proportion to their expenditure shares. We then calculate the tax rates as $\tau^c = \frac{\text{consumption taxes}}{\text{consumption}-\text{consumption taxes}}$ and $\tau^x = \frac{\text{investment taxes}}{\text{investment}-\text{investment taxes}}$. The denominators subtract taxes from spending because in national accounts spending is at market prices and includes taxes. Figure 2(h) shows that τ^c and τ^x increase by roughly 4 and 3 percentage points after 2010. This is consistent with the increase in statutory VAT rates from 19 to 23 percent in 2011 (Eurostat, 2010).

We measure the labor income tax rate τ^ℓ as the sum of the tax rate on social security contributions $\tau^{\text{SS}} = \frac{\text{social security contributions}}{\text{labor income}}$ and the tax rate on labor income net of social security contributions $\tau^{\text{NL}} = \tau^y \left(1 - \frac{\text{social security contributions}}{\text{labor income}}\right)$. Labor income in the denominators equals compensation of employees, which includes social security contributions, adjusted for the income of the self-employed that we allocate proportionally between labor and capital. The tax rate τ^{NL} equals the fraction of labor income not subject to social security contributions taxed at the individual income tax rate τ^y, where:

$$\tau^y = \frac{2.08 \times (\text{taxes on individual income} - \text{taxes on dividends and interest})}{\text{GDP} - \text{production/import taxes, contributions, depreciation, dividends, interest}}. \tag{20}$$

The individual income tax base includes unambiguous labor income (such as income from salaried employment), unambiguous capital income (such as dividends, interest, and rentals), and ambiguous income (such as income from self-employment, agriculture, and liberal professions). Equation (20) excludes dividend and interest from the numerator and denominator because for those types of capital income we have independent information on tax payments and allocate them directly to capital taxes. The factor 2.08 in the numerator represents our estimate of the gap between the average marginal tax rate and the average average tax rate.[24] Figure 2(h) shows that τ^{ℓ} increases by roughly 10 percentage points between 2010 and 2012 and then remains at levels higher prior to 2010. In Appendix Figure B.7 we document that the timing of these increases coincides well with the observed increases in statutory income tax rates and that these increases affect especially lower income households.

We measure capital tax rates τ_H^k and τ_N^k as capital tax payments divided by taxable capital income generated in each sector. There are six types of capital tax payments. Property taxes paid by households are allocated to the non-traded sector. Property taxes paid by corporations are allocated to each sector in proportion to its share of non-residential structures used in production. The other four categories, taxes on dividends and interest, income and capital gains taxes paid by corporations, taxes on capital income paid by households, and other capital taxes, are allocated to each sector in proportion to its share of capital income net of depreciation. Finally, taxable capital income equals the capital share of GDP less net taxes on products and imports less depreciation. Figure 2(h) shows a significant increase in both capital taxes after 2012. The increase in τ_N^k exceeds the increase in τ_H^k, reflecting the significant increase in property taxes falling on the residential sector after 2011.[25]

4 Parameterization

Parameters set without solving the model. Beginning in the upper panel of Table 1, the coefficient of relative risk aversion is $\sigma = 3$, consistent with the Barro and Liao (2016) choice of σ and our implementation of their methodology for recovering the time-varying disaster probability π. Using their methodology, we estimate $\varphi = 0.24$ so that the economy scales down by $\exp(-\varphi) = 0.79$ conditional on a disaster. Goods and labor demand elasticities, ε_p and ε_w, are such that in the flexible price and wage equilibrium markups equal 10 percent, consistent with the range of estimates reported by Basu and Fernald (1997). We estimate depreciation rates when utilization takes its mean value, $\bar{\delta}_H = 0.08$ and $\bar{\delta}_N = 0.05$, using sectoral data on depreciation and capital

[24] To estimate this ratio, we use binned up data from the Statistics of Income (SOI) between 2006 and 2011. This ratio is relatively stable over time. The SOI data has not been publicly disclosed after 2011. Corporate income taxes are generally flat in Greece and, so, we focus on average capital tax rates. Using the SOI, we have confirmed that the ratio of marginal to average corporate income tax is close to one.

[25] As shown in Appendix Figure B.7, statutory tax rates on corporate income increased from 20 percent to 26 percent in 2013 and to 29 percent in 2016. Taxes for properties with objective values above 400,000 euros in 2011 and 200,000 in 2012 were introduced as part of the fiscal adjustment programs. In 2014, Greece introduced taxes on the unified property owned by individuals (ENFIA) without exemptions.

Table 1: Parameters Values – Without Solving the Model

A. Parameter		Value	Rationale
σ	risk aversion	3.00	Barro and Liao (2016)
φ	size of disaster	0.24	estimation of Barro and Liao (2016) model
ε_p	elasticity of product demand	11.00	10 percent price markup
ε_w	elasticity of labor demand	11.00	10 percent wage markup
$\bar{\delta}_H$	mean depreciation rate, traded	0.08	sample average 1998-2007
$\bar{\delta}_N$	mean depreciation rate, non-traded	0.05	sample average 1998-2007
η	trade elasticity	1.65	regression of $\Delta \ln \left(\frac{P_{H,t}a_{H,t}}{P_{F,t}a_{F,t}}\right)$ on $\Delta \ln \left(\frac{P_{H,t}}{P_{F,t}}\right)$
γ	weight on tradeables	0.24	absorption of home to all tradeables
B. Mean of exogenous process		**Value**	**Rationale**
z_H	productivity, traded	1.00	normalization
$\bar{a}_T$	external demand	1.00	normalization
P_F^*	price of foreign traded goods	1.00	normalization
B^g	government debt	1.18	sample average 1998-2007
r^*	government interest rate	0.05	sample average 1998-2007
i^*	private interest rate	0.07	sample average 1998-2007
θ	firm leverage ratio	0.45	sample average 1998-2007
π	probability of disaster	0.07	sample average 1998-2007
g	government spending	0.28	sample average 1998-2007
τ^c	tax rate on consumption	0.16	sample average 1998-2007
τ^x	tax rate on investment	0.08	sample average 1998-2007
τ^ℓ	tax rate on labor	0.30	sample average 1998-2007
τ_H^k	tax rate on capital, traded	0.30	sample average 1998-2007
τ_N^k	tax rate on capital, non-traded	0.30	sample average 1998-2007

from the national accounts.

We estimate a trade elasticity $\eta = 1.65$ (standard error 0.25) in the CES aggregator of traded goods (2), using the first-order conditions for traded goods which give rise to a regression of $\Delta \ln \left(\frac{P_{H,t}a_{H,t}}{P_{F,t}a_{F,t}}\right)$ on $\Delta \ln \left(\frac{P_{H,t}}{P_{F,t}}\right)$, where $a_{H,t}$ and $a_{F,t}$ denote Greek expenditure on domestic and foreign traded goods. Our estimate is comparable to the value of 1.5 found in Backus, Kehoe, and Kydland (1994) and used extensively in the literature. Finally, we recover the preference weight $\gamma = 0.24$ as the sample average ratio of domestic absorption of domestic traded goods to domestic

Table 2: Persistence and Volatility of Exogenous Processes

Exogenous process		Persistence	Standard Deviation
$\log z_H$	productivity, traded	0.94	0.04
$\log z_N$	productivity, non-traded	0.16	0.03
$\log \bar{a}_T$	external demand	0.87	0.07
$\log P_F^*$	price of foreign traded goods	0.48	0.01
$\log B^g$	government debt	0.84	0.06
r^*	government interest rate	0.84	0.01
i^*	private interest rate	0.64	0.01
$\log \bar{B}^r$	rule-of-thumb debt	0.83	0.10
θ	firm leverage ratio	0.64	0.07
π	probability of disaster	0.79	0.12
$\log g$	government spending	1.00	0.05
$\log T^r$	transfers to rule-of-thumb	0.85	0.06
τ^c	tax rate on consumption	0.84	0.01
τ^x	tax rate on investment	1.00	0.01
τ^ℓ	tax rate on labor	0.79	0.02
τ_H^k	tax rate on capital, traded	0.92	0.04
τ_N^k	tax rate on capital, non-traded	1.00	0.03

absorption of all traded goods.[26]

The lower panel of Table 1 displays means of exogenous processes that drive the model. We normalize the levels of traded productivity, external demand, and foreign price to one. The mean value of all other exogenous processes equals their sample average between 1998 and 2007. We choose this time frame for estimating the means because disaster risk, fiscal policies, and financial conditions in Greece before 2008 provide a closer approximation to their long-term values than the period after 2008 characterized by an unprecedented depression of economic activity. Mean values of debt and government spending are relative to the value of output, $P_y y$, as our choice of parameters implies that $P_y = y = 1$ in the steady state of the model.

Parameter estimates of exogenous processes. Table 2 displays estimates of the persis-

[26]For the estimation of the trade elasticity η, our identifying assumption is that preference for Greek relative to foreign goods γ is uncorrelated with relative prices. We identify the foreign country as the euro area and extend the procedure in Johnson and Noguera (2012) to recover Greek value-added exports and imports from the euro area. In Appendix B.8 we describe the details of this procedure and discuss other trading partners, potential differences between elasticities of exports and imports, and industry aggregation.

tence and standard deviation of the autoregressive processes that we estimate outside the model using ordinary least squares between 1998 and 2016. Several of the exogenous processes display high persistence, with some of the fiscal processes exhibiting nearly random walk dynamics.[27] Shocks to external demand $\bar{a}_T$, the borrowing limit of rule-of-thumb households $\bar{B}^r$, firm leverage θ, and the probability of disaster π display the largest volatilities.

Parameters calibrated to steady state targets. The upper panel of Table 3 presents values of parameters calibrated from steady state conditions involving endogenous model variables. The disutility of labor χ and the shifters in the utilization technologies, $\bar{\xi}_H$ and $\bar{\xi}_N$, are chosen to normalize output and utilizations to one in the steady state of the model. We choose the preference weight on traded goods ω such that the steady state expenditure share of traded goods equals the sample average between 1998 and 2007. We calibrate the capital elasticities, α_H and α_N, such that the capital-output ratios equal their sample averages over the same period. We choose the mean value of the debt limit per rule-of-thumb household $\bar{B}^r$ such that, in combination with our estimate of their fraction ζ in the population, steady state debt accumulated by rule-of-thumb households over output equals the 1998-2007 sample average value. We choose the mean value of lump sum transfers to rule-of-thumb households, T^r, to equalize consumption per capita in steady state between the two types of households, $c^r = c^o$, and the mean value of non-traded productivity z_N to normalize the steady state price of non-traded goods to one. Finally, we calibrate the discount factor of optimizing households to $\beta^o = 0.89$ such that the steady state interest rate equals 0.07, given our estimates of the elasticity of intertemporal substitution ρ, the mean disaster probability π, and the size of the disaster φ. For rule-of-thumb households we set $\beta^r = 0.87$, which follows from the result in Carroll, Slacalek, and Tokuoka (2014) that reproducing the observed distribution of liquid assets in Greece requires a 0.02 gap of discount factors between households.[28]

Estimated parameters. The lower panel of Table 3 presents means of parameters estimated with Bayesian Maximum Likelihood along with 90 percent confidence intervals (see Fernandez-Villaverde, Rubio-Ramirez, and Schorfheide (2016) for a primer on these methods).[29] We estimate

[27] Due to rounding these processes are displayed with a persistence of one in the table. We set to 0.999 the persistence of processes estimated to be above 0.999.

[28] Following Schmitt-Grohé and Uribe (2003), we induce stationarity of net foreign assets using an interest rate $i_t^* + \psi_b \left(\exp \left(\frac{B_{t+1}}{P_{y,t} y_t} - \bar{b} \right) - 1 \right)$, where $B_t = \zeta B_t^r + (1-\zeta) B_t^o + B_t^f + B_t^g$ is total Greek debt. We set $\psi_b = 0.001$ and choose $\bar{b}$ to target the in-sample average of debt to output.

[29] Appendix Table C.1 presents the priors used in the estimation and Table C.2 and Figure C.2 present some sensitivity analyses of the priors.

Table 3: Parameters Values – Solving the Model

A. Parameters calibrated from steady state		Value	Rationale
χ	disutility of labor	0.82	$y = 1$
$\bar{\xi}_H$	utilization constant, traded	0.37	$u_H = 1$
$\bar{\xi}_N$	utilization constant, non-traded	0.17	$u_N = 1$
ω	weight on traded goods	0.28	$(p_T c_T)/(P_c c) = 0.28$
α_H	capital elasticity, traded	0.32	$(Qk_H)/(P_H y_H) = 1.71$
α_N	capital elasticity, non-traded	0.58	$(Qk_N)/(P_N y_N) = 3.81$
$\bar{B}^r$	mean debt of rule-of-thumb	0.32	$(\zeta \bar{B}^r)/(P_y y) = 0.14$
T^r	mean transfers to rule-of-thumb	0.32	$c^r = c^o$
z_N	mean productivity, non-traded	0.64	$P_N = 1$
β^o	discount factor, optimizing	0.89	$i^* = 0.07$
β^r	discount factor, rule-of-thumb	0.87	Carroll, Slacalek, and Tokuoka (2014)
$\bar{b}$	steady state debt	1.00	$B/(P_y y) = 1$
B. Parameters estimated from time series		**Value**	**90 percent interval**
ρ	intertemporal elasticity of substitution	0.32	[0.18,0.45]
ϕ	traded-nontraded elasticity	0.79	[0.26,1.31]
ϵ	frisch elasticity	0.48	[0.23,0.70]
κ	working capital requirement	0.12	[0.00,0.26]
ζ	fraction rule-of-thumb	0.43	[0.33,0.54]
ξ_H	utilization elasticity, traded	4.98	[4.52,5.43]
ξ_N	utilization elasticity, non-traded	3.22	[2.75,3.65]
ψ_π	adjustment cost, profits	0.14	[0.04,0.24]
ψ_k	adjustment cost, capital	11.58	[8.16,15.14]
ψ_p	adjustment cost, prices	47.16	[21.07,70.73]
ψ_w	adjustment cost, wages	38.08	[6.25,66.89]

11 parameters and use both the vector of outcome variables $\mathbf{y}$ and the vector of exogenous processes $\mathbf{z}$ as observables for the estimation. Crucially, we feed the time series of $\mathbf{z}$ as measured in the data prior to the estimation of the parameters and we do not add to them measurement error. This disciplines our exercise as it restricts the freedom of shocks to account for the behavior of observed outcome variables. For the estimation, we instead allow for measurement error in each element of the vector of outcome variables $\mathbf{y}$. We subsequently remove the measurement error component

when evaluating the performance of the model and in the counterfactual analyses.

We estimate an intertemporal elasticity of substitution $\rho = 0.32$, starting from a prior mean of 1, with a tight confidence interval. This parameter also controls the strength of the complementarity between consumption and labor. Our estimate of $\rho < 1$ accords well with other estimates found in the literature, including Barsky, Juster, Kimball, and Shapiro (1997) who estimate $\rho = 0.18$ based on survey responses on intertemporal substitution, Hall (2009) who picks $\rho = 0.5$ based on a collection of studies focusing on the observed covariation between consumption growth and interest rates, and Chodorow-Reich and Karabarbounis (2016) who estimate $\rho = 0.66$ based on the observed decline in consumption upon unemployment. A value of $\rho < 1$ means that disaster risk effectively increases households' patience and makes consumption and labor complements in the utility function, both of which help the model to match consumption fluctuations.

We estimate an elasticity between traded and non-traded goods of $\phi = 0.79$, starting from a prior mean of 0.44 from the international business cycle model of Stockman and Tesar (1995). A value of ϕ closer to one reflects the relative stability of expenditure shares despite significant fluctuations in the relative price of non-traded goods. However, the confidence interval for this parameter is wide and we cannot exclude values as low as 0.3 and as high as 1.3.

We estimate a Frisch elasticity of labor supply of $\epsilon = 0.48$ with a confidence interval ranging from 0.2 to 0.7. Our observables contain information to identify ϵ, since the mean prior was set at 1.5 as a compromise between numerous labor supply studies discussing the role of the extensive margin and the gap between micro and macro estimates (see, for example, the discussion in Chetty, Guren, Manoli, and Weber, 2012). We also estimate a small fraction of the wage bill subject to working capital, $\kappa = 0.12$, with a confidence interval that includes the value of 0. As a comparison, the value of $\kappa = 1$ is found in Jermann and Quadrini (2012) in their study of financial sources in U.S. business cycles and Neumeyer and Perri (2005) in their study of interest rates shocks in emerging markets. The small κ in our case reflects the weak comovement between labor and firms' leverage ratio θ. Given the size of shocks hitting the Greek economy and the amplification of these shocks through variable utilization, the model generates significant fluctuations in labor without a high ϵ or κ.

We estimate a fraction of rule-of-thumb households equal to $\zeta = 0.43$, with a confidence interval ranging from 0.3 to 0.5. The significant fraction of rule-of-thumb households reflects the strong comovement of consumption and labor income over the entire sample. This estimate falls within the set of values that have been used elsewhere in the literature, ranging from 0.25 in Drautzburg and Uhlig (2015) to 0.5 in Mankiw (2000) and Gali, Lopez-Salido, and Valles (2007). Martin and Philippon (2017) use the value 0.65 for Greece, based on the fraction of households with liquid assets below two months of income.

Our estimated elasticities of utilization are $\xi_H = 5.0$ and $\xi_N = 3.2$ and are also tightly estimated. Lower values of ξ_H and ξ_N are associated with lower responsiveness of depreciation to utilization and, therefore, larger responsiveness of utilization to fluctuations in the marginal revenue product of capital. The low estimated ξ_H and ξ_N reflect the sharp decline in utilization in the bust period in Figure 1. Utilization in the non-traded sector collapses by more than in the traded sector, consistent with a lower estimated value of ξ_N than ξ_H.

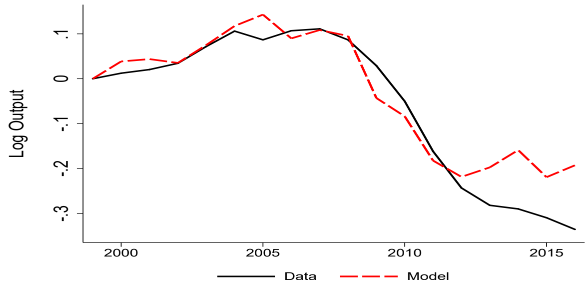
Finally, the estimated adjustment cost parameters are mainly tied to the observed movements in capital, prices, and wages. As we discuss further below, we characterize price and wage rigidities as having only short-lived effects because under $\psi_p = 0$ and $\psi_w = 0$ the evolution of quantities at horizons longer than one to two years is similar to the baseline with estimated values of $\psi_p = 47$ and $\psi_w = 38$ and because under the estimated values $\psi_p = 47$ and $\psi_w = 38$ an exchange rate devaluation leads to short-lived only changes in real variables. This characterization is consistent with the significant declines in Greek prices and wages observed during the bust period.

5 Quantitative Results

We begin by demonstrating the ability of the model to account for key macroeconomic time series. Next, we quantify the importance of each driving force in generating time series that resemble those observed in the data. Finally, we assess the importance of various model elements for the performance of the model and present model-generated fiscal multipliers.

5.1 Model Fit

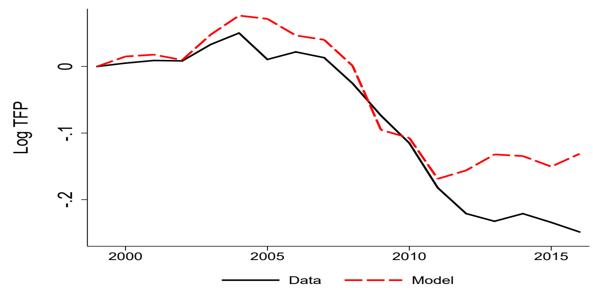
Figure 3 compares time series of production measures generated by the model to their analogs in the data. The model generates an increase in output y between 1999 and 2007 that mimics closely the increase observed in the data. Similar to the experience of Greece in the boom period, the growth of output is mostly accounted for by growing labor and capital inputs and not so much by changes in TFP. The model is also successful in generating comovement across sectors, with both traded output y_H and non-traded output y_N increasing by roughly as much as in the data.



(a) Time Series of y

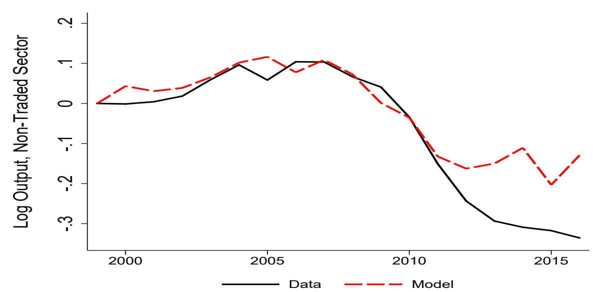
(b) Time Series of ℓ

(c) Time Series of $\tilde{k}$

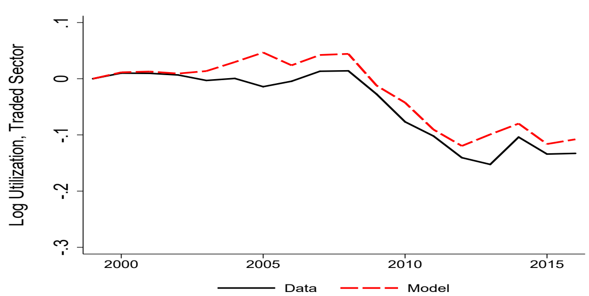


(d) Time Series of TFP

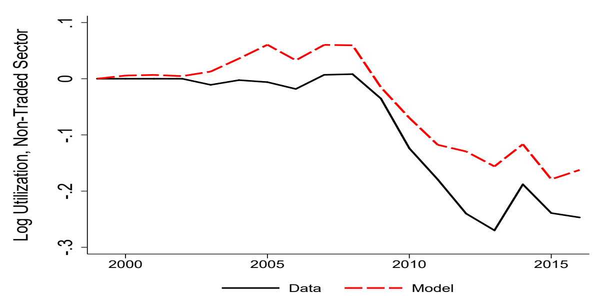
(e) Time Series of y_H



(f) Time Series of y_N



(g) Time Series of u_H



(h) Time Series of u_N

Figure 3: Model vs Data: Production

Figure 3 plots the evolution of macroeconomic variables relative to 1999 in the model and in the data. H denotes the traded sector and N denotes the non-traded sector. y is output, ℓ is labor, $\tilde{k}$ is the capital stock, TFP is total factor productivity, and u is utilization. Quantities are detrended with 2 percent per year and TFP with 0.9 percent.

Turning to the bust period after 2007, the model generates roughly two-thirds of the observed decline in output. As in the data, the decline in output is accounted for by both a decline in factors of production and in TFP. The model performs better in the early years of the bust, when output fell by more than 20 percent. After 2012, there is a divergence between output in the data which continues to fall (relative to trend) and output in the model which remains depressed at roughly 20 percent below its 1999 value. This discrepancy concerns mainly the non-traded sector, in which the model generates a smaller decline in utilization than observed in the data.[30]

Figure 4 compares expenditures and prices generated by the model to their analogs in the data. During the first part of the sample, the model generates increases in consumption c, investment x, exports, and imports that are broadly consistent with the increases in the data.[31] Additionally, the model generates increases in the price of traded goods P_H, non-traded goods P_N, the consumer price index P_c, and wages W that quantitatively match the increases observed in the data.

The model generates a decline in expenditures during the bust. However, the decline in consumption is significantly smaller than the decline observed in the data by 2016. Part of the discrepancy occurs because the consumption decline in the model begins three years prior to the decline in the data. The model performs better with respect to investment, generating roughly two-thirds of its decline until the end of the sample. The model generates a larger drop in exports than observed in the data, but accounts quite well for their lack of recovery after 2012. Additionally, the model generates exactly the drop in imports observed in the data. Regarding prices, the model generates a significant fraction of the observed devaluation in the price of non-traded goods and in wages, although the model and data trends diverge somewhat in the last few years.

5.2 The Sources of the Greek Boom and Bust

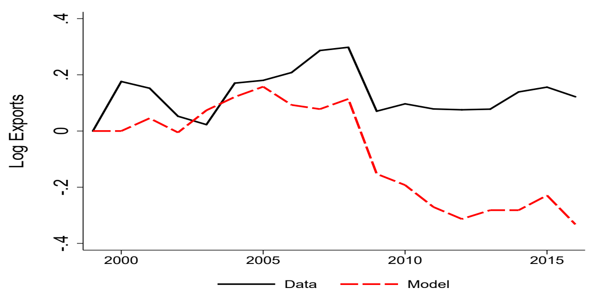
Table 4 documents the sources of the boom (1999-2007) and Table 5 the sources of the bust (2007-2016). The first two rows of each table report changes in selected variables in the data and the model. In each other row, we shut off the time evolution of particular exogenous processes and

[30]We have detrended quantities in the data with a constant rate of 2 percent per year. Detrending with a smaller rate would lower the success of the model during the boom and close the discrepancy during the bust. We highlight that our estimates of price and wage rigidities are very similar when we do not detrend the data. Appendix Figure C.3 presents model results against the raw data.

[31]Exports are $y_H - \gamma \left(\frac{P_H}{P_T}\right)^{-\eta} (\zeta c_T^r + (1-\zeta) c_T^o + x)$ and imports are $(1-\gamma) \left(\frac{P_F}{P_T}\right)^{-\eta} (\zeta c_T^r + (1-\zeta) c_T^o + x)$ in the model. To maximize the length of the sample in this figure, for the data series we use constant-price exports and imports from national accounts which are in gross terms and include intermediate imports.

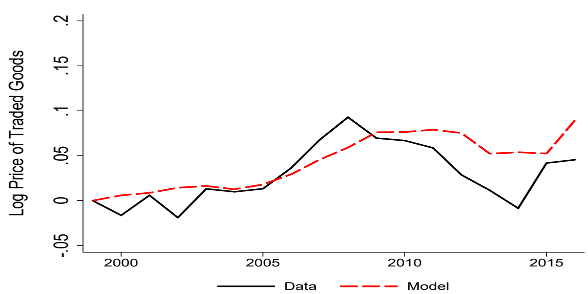
(a) Time Series of c

(b) Time Series of x

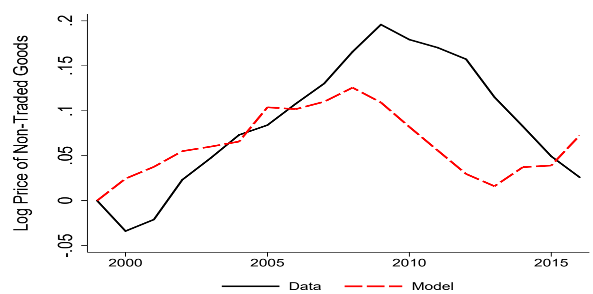


(c) Time Series of Exports

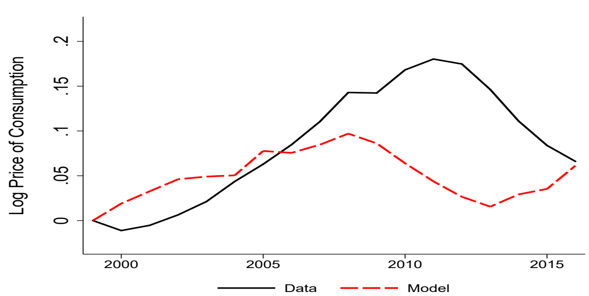
(d) Time Series of Imports



(e) Time Series of P_H



(f) Time Series of P_N



(g) Time Series of P_c

(h) Time Series of W

Figure 4: Model vs Data: Expenditures and Prices

Figure 4 plots the evolution of macroeconomic variables relative to 1999 in the model and in the data. H denotes the traded sector and N denotes the non-traded sector. c is consumption, x is investment, P_H is the price of Greek traded goods, P_N is the price of Greek non-traded goods, P_c is the price of consumption, and W is wages. Quantities are detrended with 2 percent per year, prices with 1 percent, and wages with 3 percent.

Table 4: Sources of Macroeconomic Dynamics: Boom Period 1999-2007

	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log \text{TFP}$	$\log c$	$\log P_c$	$\log P_N$	$\log W$
Data	0.11	0.08	0.11	0.01	0.10	0.11	0.13	0.24
Model	0.11	0.07	0.07	0.04	0.12	0.08	0.11	0.18
Productivity	0.04	0.03	0.01	0.02	0.03	0.01	0.02	0.03
$\log z_H$	0.03	0.00	0.01	0.03	0.02	0.00	0.01	0.02
$\log z_N$	0.00	0.03	0.00	-0.01	0.01	0.00	0.01	0.01
External	0.02	0.01	0.03	0.00	0.04	0.05	0.06	0.09
$\log \bar{a}_T$	0.02	0.00	0.03	0.00	0.03	0.04	0.05	0.09
$\log P_F^*$	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Financial	0.03	0.02	0.03	0.00	0.07	0.00	0.01	0.03
$\log B^g$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\log \bar{B}^r$	0.01	0.02	0.00	0.00	0.02	0.00	0.00	0.00
r^*	0.00	0.00	0.01	0.00	0.03	0.01	0.01	0.02
i^*	0.00	0.00	0.02	-0.01	-0.01	-0.01	-0.01	-0.01
θ	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00
π	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Fiscal Spending	0.03	0.02	0.01	0.01	-0.01	0.01	0.01	0.02
$\log g$	0.02	0.02	0.01	0.00	-0.04	0.00	0.00	0.00
$\log T^r$	0.01	0.00	0.00	0.01	0.03	0.01	0.01	0.02
Tax Rates	-0.01	-0.01	-0.01	0.00	-0.01	0.02	0.02	0.01
τ^c	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
τ^x	0.00	0.00	-0.01	0.00	0.00	0.00	0.01	0.00
τ^ℓ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
τ_H^k	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
τ_N^k	-0.01	-0.01	-0.01	0.00	-0.01	0.01	0.01	0.00

set them equal to a constant. A positive entry means that the time evolution of the exogenous process contributes to an increase of a variable. For each variable, summing up entries across exogenous processes totals the reported sum in the model row. We summarize the contributions of the driving forces in five categories (productivity, external, financial, fiscal spending, and taxes).

Beginning with the boom period in Table 4, we note the importance of traded productivity z_H for output and external demand $\bar{a}_T$ for output, consumption, and prices. Financial forces are significant contributors to the boom of many variables. Among financial driving forces, we note

Table 5: Sources of Macroeconomic Dynamics: Bust Period 2007-2016

	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log \text{TFP}$	$\log c$	$\log P_c$	$\log P_N$	$\log W$
Data	-0.45	-0.17	-0.19	-0.26	-0.41	-0.04	-0.10	-0.39
Model	-0.30	-0.16	-0.11	-0.17	-0.09	-0.02	-0.04	-0.19
Productivity	-0.09	-0.03	-0.01	-0.07	-0.06	-0.01	-0.03	-0.07
$\log z_H$	-0.08	0.00	-0.02	-0.07	-0.05	-0.01	-0.02	-0.05
$\log z_N$	-0.01	-0.03	0.00	0.01	-0.01	-0.01	-0.01	-0.01
External	-0.07	-0.05	-0.02	-0.03	-0.07	-0.07	-0.09	-0.17
$\log \bar{a}_T$	-0.07	-0.05	-0.03	-0.04	-0.07	-0.07	-0.09	-0.17
$\log P_F^*$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Financial	0.01	0.01	-0.01	0.01	0.00	-0.01	-0.02	-0.01
$\log B^g$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\log \bar{B}^r$	-0.02	-0.02	-0.01	-0.01	-0.05	0.00	0.00	-0.01
r^*	0.01	0.00	0.01	0.00	0.04	0.01	0.01	0.03
i^*	0.01	0.01	0.00	0.01	0.00	-0.01	-0.01	0.00
θ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
π	0.02	0.03	-0.02	0.02	0.01	-0.02	-0.02	-0.03
Fiscal Spending	-0.08	-0.08	-0.03	-0.03	0.09	-0.03	-0.04	-0.04
$\log g$	-0.07	-0.08	-0.02	-0.02	0.15	-0.01	-0.02	0.00
$\log T^r$	-0.02	0.00	0.00	-0.01	-0.06	-0.01	-0.02	-0.04
Tax Rates	-0.07	-0.01	-0.03	-0.05	-0.04	0.10	0.14	0.10
τ^c	-0.01	-0.01	0.00	0.00	-0.02	0.00	0.00	0.00
τ^x	-0.01	0.00	-0.01	0.00	0.00	0.01	0.01	0.01
τ^ℓ	-0.02	-0.03	0.00	0.00	-0.03	0.01	0.01	0.03
τ_H^k	-0.02	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00
τ_N^k	-0.03	0.02	-0.01	-0.03	0.00	0.09	0.12	0.07

the importance of declining interest rates i^* and r^* and relaxation of the borrowing constraint $\bar{B}^r$, especially in fuelling a consumption boom. Among fiscal driving forces, government spending g contributes to the production boom and transfers to rule-of-thumb households T^r contribute to the consumption boom. Taxes do not contribute significantly to any variable because they do not vary much during this period.

Table 5 presents the sources of the Greek bust. The decline in traded productivity z_H contributes significantly to the decline in output, but only directly and not through the observed declines in factors of production. Non-traded productivity z_N does not contribute significantly to any macroeconomic variable. The decline in external demand $\bar{a}_T$ is at least as important for output as the decline in productivity and contributes to the bust both through a decline in factors of production and through a decline in TFP. Changes in external demand also matter more than productivity quantitatively in generating declines in prices and wages during the bust.

We find a limited role for financial shocks during the bust period. The exception is the decline in the borrowing limit of rule-of-thumb households $\bar{B}^r$ which is quantitatively important for generating a decline in consumption. The leverage ratio of firms θ does not contribute significantly to the bust because, as seen in Figure 2(e), it rebounds quickly to pre-2007 levels. The probability of disaster π exerts a significant effect on consumption until 2012 and again in 2015, but these effects dissipate quickly by 2016 when π reverts back to lower levels.[32]

We find a significant role for fiscal shocks during the bust. Collectively, fiscal forces generate a 15 percent decline in output, reflecting declines in both factors of production and TFP. Disaggregating fiscal shocks into the various components, we note the importance of government spending g and labor income taxes τ^ℓ for labor and the importance of capital income taxes τ_H^k and τ_N^k for capital and TFP. While taxes and transfers T^r account for a significant fraction of the decline in consumption, reduced government spending more than offsets this decline. At the same time, declines in fiscal spending generate declines in prices and wages, but the increase in capital income taxes in the non-traded sector substantially mitigates the devaluation of the economy.[33]

5.3 The Importance of Structural Elements

In this section, we assess the quantitative importance of the model's mechanisms in accounting for the Greek boom (1999-2007) and bust (2007-2016). The first two rows in each panel of Table 6 report changes in selected variables in the data and in the baseline model for the boom period (upper panel) and the bust period (lower panel). Each other row reports changes in the same variables when we feed the same sequence of shocks but under different parameter values relative to the baseline model. This exercise also clarifies the identification of the estimated parameters.

[32] Appendix Table C.3 documents the contribution of exogenous processes in the first part of the bust period and shows that π accounts for a 12 percent consumption decline between 2007 and 2012.

[33] Farhi, Gopinath, and Itskhoki (2014) analyze the optimal mix of tax instruments that allow a small open economy to replicate the real effects of a nominal devaluation. We note two prominent deviations of the Greek tax adjustments relative to their prescriptions. First, the labor wedge induced by taxes, $\frac{1-\tau^\ell}{1+\tau^c}$, increases by roughly 15 percent during the bust period. Second, capital income taxes increased substantially more than labor income taxes, distorting the equilibrium mix of factors of production.

Table 6: Role of Structural Elements

A. Boom: 1999-2007	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log \text{TFP}$	$\log c$	$\log P_c$	$\log P_N$	$\log W$
Data	0.11	0.08	0.11	0.01	0.10	0.11	0.13	0.24
Baseline Model	0.11	0.07	0.07	0.04	0.12	0.08	0.11	0.18
$\xi_H = \xi_N = \infty$	0.08	0.13	0.04	0.00	0.14	0.14	0.18	0.23
$\xi_H = \xi_N = 2$	0.11	0.06	0.08	0.05	0.12	0.07	0.09	0.17
$\epsilon = 1$	0.12	0.09	0.07	0.04	0.13	0.08	0.10	0.16
$\rho = 1$	0.09	0.06	0.07	0.03	0.08	0.08	0.10	0.17
$\zeta = 0$	0.09	0.05	0.06	0.03	0.07	0.08	0.10	0.16
$\eta = 0.9$	0.11	0.07	0.08	0.04	0.13	0.10	0.13	0.21
$\eta = 2.4$	0.11	0.07	0.06	0.04	0.12	0.08	0.10	0.17
$\psi_p = 0$	0.08	0.04	0.06	0.03	0.09	0.12	0.15	0.17
$\psi_p = 1000$	0.15	0.11	0.09	0.05	0.17	0.03	0.04	0.22
$\psi_w = 0$	0.10	0.04	0.07	0.05	0.11	0.09	0.12	0.25
$\psi_w = 1000$	0.16	0.17	0.07	0.05	0.17	0.06	0.08	0.07
$\psi_\pi = 0$	0.10	0.06	0.07	0.04	0.12	0.09	0.11	0.18
$\psi_\pi = 0.5$	0.13	0.13	0.07	0.04	0.15	0.08	0.11	0.19
$\psi_k = 0$	0.25	0.21	0.23	0.03	0.19	0.01	0.01	0.13
$\psi_k = 100$	0.10	0.06	0.04	0.05	0.12	0.10	0.13	0.19
B. Bust: 2007-2016	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log \text{TFP}$	$\log c$	$\log P_c$	$\log P_N$	$\log W$
Data	-0.45	-0.17	-0.19	-0.26	-0.41	-0.04	-0.10	-0.39
Baseline Model	-0.30	-0.16	-0.11	-0.17	-0.09	-0.02	-0.04	-0.19
$\xi_H = \xi_N = \infty$	-0.17	-0.22	-0.05	-0.04	-0.05	-0.23	-0.30	-0.32
$\xi_H = \xi_N = 2$	-0.35	-0.14	-0.09	-0.24	-0.11	0.05	0.06	-0.14
$\epsilon = 1$	-0.34	-0.23	-0.11	-0.18	-0.13	0.00	-0.01	-0.12
$\rho = 1$	-0.30	-0.16	-0.08	-0.18	-0.03	0.00	-0.01	-0.14
$\zeta = 0$	-0.25	-0.11	-0.11	-0.14	0.06	-0.01	-0.02	-0.13
$\eta = 0.9$	-0.28	-0.16	-0.07	-0.17	-0.03	0.01	0.01	-0.12
$\eta = 2.4$	-0.31	-0.15	-0.12	-0.17	-0.11	-0.04	-0.05	-0.21
$\psi_p = 0$	-0.30	-0.16	-0.10	-0.17	-0.08	-0.04	-0.06	-0.18
$\psi_p = 1000$	-0.33	-0.18	-0.09	-0.19	-0.14	0.02	0.02	-0.21
$\psi_w = 0$	-0.29	-0.13	-0.12	-0.16	-0.07	-0.03	-0.05	-0.21
$\psi_w = 1000$	-0.40	-0.35	-0.10	-0.19	-0.18	0.04	0.04	0.02
$\psi_\pi = 0$	-0.30	-0.15	-0.11	-0.17	-0.09	-0.02	-0.04	-0.19
$\psi_\pi = 0.5$	-0.29	-0.14	-0.11	-0.17	-0.08	-0.03	-0.04	-0.18
$\psi_k = 0$	-0.28	-0.12	-0.20	-0.12	-0.09	-0.01	-0.03	-0.17
$\psi_k = 100$	-0.31	-0.16	-0.10	-0.18	-0.09	-0.02	-0.03	-0.18

Variable utilization of factors plays a central role in the model's ability to account for the Greek macroeconomic time series. In the absence of variable utilization ($\xi_H = \xi_N = \infty$), the model would generate larger increases in labor, consumption, and prices during the boom and smaller declines in output and TFP during the bust. Increasing the responsiveness of utilization relative to the baseline ($\xi_H = \xi_N = 2$) allows the model to generate a larger decline in output and TFP in the bust but at the cost of generating a counterfactual increase in prices and a smaller decline in wages than observed in the data. The tension between accounting for the behavior of quantities and the behavior of prices during the bust explains why our estimated elasticities of utilization ($\xi_H = 5.0$ and $\xi_N = 3.2$) lie between these more extreme values.

Turning to preference parameters and household heterogeneity, Table 6 shows that increasing the Frisch elasticity of labor supply ϵ to 1 relative to the baseline value of 0.48 allows the model to generate a larger decline in output during the bust period. However, such a higher value would counterfactually generate a larger decline in labor and a smaller decline in wages than observed in the data. Both complementarities between labor and consumption (reflected in a low value of ρ) and rule-of-thumb behavior (reflected in a significant value of ζ) are important in generating a decline in consumption during the bust. With the exceptions of consumption and wages during the bust, the performance of the model is not too sensitive to substantial variations of the trade elasticity η around our point estimate of 1.65.

The last rows in each panel illustrate the role of adjustment costs. Shutting off price or wage rigidity completely does not affect significantly the performance of the model in terms of accounting for the boom and bust relative to the baseline with $\psi_p = 47$ and $\psi_w = 38$. We explore why the model favors a low degree of nominal rigidity by increasing the price or wage rigidity to the extreme values of $\psi_p = 1000$ and $\psi_w = 1000$. Under these extreme values, the consumption decline during the bust comes closer to matching the data. However, higher degrees of nominal rigidity introduce significant deviations of the model from the data in terms of consumption in the boom and, most importantly, in terms of prices and wages in both the boom and bust. The magnitude of the boom and bust is not too sensitive to the value of the adjustment costs of profits ψ_π. By contrast, the magnitude of the boom in the model is sensitive to the value of the adjustment cost of capital ψ_k because, without the adjustment cost, the model would generate an excessive boom relative to the data.

5.4 Fiscal Multipliers

Table 7 presents fiscal multipliers generated by our estimated model for each instrument $f = \{g, \zeta T^r, \tau^c, \tau^x, \tau^\ell, \tau^k_H, \tau^k_N\}$. Entries denote the cumulative output multiplier at horizon h:

$$M^y_f(h) = \frac{\sum_{t=1}^{h}(1+i^*)^{1-t}\Delta y_t}{\sum_{t=1}^{h}(1+i^*)^{1-t}\Delta f_t}, \tag{21}$$

generated by an initial impulse ν^f_0 in fiscal instrument f and its autoregressive process in equation (16). Changes in output Δy_t are calculated as the difference between the path of output given the fiscal impulse and the path of output in the absence of the fiscal impulse. Because output in steady state equals one, the multipliers with respect to tax rates can be interpreted as the percent change in output resulting from a one percentage point change in a tax rate. In the table we report contemporaneous multipliers at horizon $h = 1$ year, cumulative multipliers at horizon $h = 7$ years to benchmark our results to the fiscal adjustment that began in 2010, and multipliers at infinite horizon $h = \infty$. We discount future changes at the steady state interest rate of $i^* = 0.07$.

The upper panel of Table 7 reports multipliers under various financing systems and horizons.[34] The model generates a government spending multiplier of around 0.5 when financed with lump sum transfers T^o. The multiplier with respect to transfers to rule-of-thumb households ranges from roughly 0.6 upon impact to 0.1 as we increase the horizon. Capital income and investment tax multipliers are increasing in the horizon, whereas labor income and consumption taxes are more stable with respect to the horizon. At infinite horizon, tax multipliers range from less than -0.3 to roughly -0.1. With respect to the financing system, we stress the importance of deficit financing B^g for the government spending multiplier upon impact which rises from 0.5 to 0.9.

To understand the importance of model elements for the multipliers, the second panel reports multipliers under different parameterizations of the model for the case with T^o financing and horizon of $h = 7$ years. In the presence of nominal rigidity, the most important parameter for the spending multiplier is the persistence ρ_f of the fiscal shocks because it determines the required increase in taxes and, therefore, the degree of crowding-out of private consumption. Lowering

[34] The baseline case considers lump sum transfers to optimizing households T^o adjusting to satisfy the government budget constraint in equation (15). As an alternative we allow lump sum transfers to both types of households, T^r and T^o, to adjust by introducing innovations to T^r such that the change in T^r equals the change in T^o in every period and the budget balances. Finally, we consider deficit finance in which we keep T^o fixed to its steady state value and introduce an innovation to B^g with size such that, upon impact, the government budget constraint holds. For subsequent periods, B^g follows its autoregressive process in equation (16) and we solve for innovations to T^r and T^o to satisfy the budget constraint.

Table 7: Fiscal Multipliers

A. Financing and Horizon		g	ζT^r	τ^c	τ^x	τ^ℓ	τ^k_H	τ^k_N
T^o financed	$h=1$	0.50	0.60	-0.25	-0.02	-0.26	-0.04	0.02
T^o financed	$h=7$	0.45	0.28	-0.22	-0.21	-0.35	-0.11	-0.14
T^o financed	$h=\infty$	0.46	0.10	-0.19	-0.29	-0.34	-0.12	-0.17
T^r, T^o financed	$h=1$	0.54	0.44	-0.12	0.06	-0.05	-0.01	0.12
T^r, T^o financed	$h=7$	0.45	0.19	-0.16	-0.19	-0.27	-0.10	-0.12
T^r, T^o financed	$h=\infty$	0.46	0.07	-0.16	-0.29	-0.30	-0.12	-0.17
B^g, T^r, T^o financed	$h=1$	0.90	0.72	-0.30	0.02	-0.31	-0.03	0.00
B^g, T^r, T^o financed	$h=7$	0.49	0.23	-0.18	-0.19	-0.31	-0.11	-0.13
B^g, T^r, T^o financed	$h=\infty$	0.48	0.11	-0.19	-0.29	-0.34	-0.12	-0.17

B. Parameters (T^o financed, $h=7$)	g	ζT^r	τ^c	τ^x	τ^ℓ	τ^k_H	τ^k_N
Baseline Model	0.45	0.28	-0.22	-0.21	-0.35	-0.11	-0.14
$\rho_f = 0.30$	0.92	0.54	-0.25	-0.20	-0.32	-0.07	-0.08
$\rho_f = 0.75$	0.74	0.35	-0.23	-0.23	-0.34	-0.10	-0.13
$\xi_H = \xi_N = \infty$	0.31	0.13	-0.17	-0.10	-0.33	-0.04	-0.01
$\xi_H = \xi_N = 2$	0.50	0.33	-0.23	-0.24	-0.35	-0.08	-0.21
$\epsilon = 1$	0.63	0.26	-0.27	-0.22	-0.46	-0.11	-0.14
$\rho = 1$	0.41	0.23	-0.25	-0.20	-0.30	-0.11	-0.14
$\zeta = 0$	0.45	.	-0.17	-0.22	-0.31	-0.11	-0.15
$\eta = 0.9$	0.46	0.35	-0.20	-0.07	-0.28	-0.04	-0.08
$\eta = 2.4$	0.44	0.23	-0.22	-0.27	-0.39	-0.14	-0.17
$\psi_p = 0$	0.42	0.13	-0.21	-0.29	-0.49	-0.16	-0.21
$\psi_p = 1000$	0.51	0.58	-0.23	0.00	-0.18	-0.01	0.03
$\psi_w = 0$	0.45	0.23	-0.22	-0.22	-0.28	-0.11	-0.16
$\psi_w = 1000$	0.44	0.47	-0.21	-0.14	-0.62	-0.11	-0.06
$\psi_\pi = 0$	0.45	0.28	-0.22	-0.21	-0.35	-0.11	-0.14
$\psi_\pi = 0.5$	0.45	0.29	-0.22	-0.20	-0.34	-0.11	-0.13
$\psi_k = 0$	0.54	0.32	-0.23	-0.26	-0.38	-0.09	-0.05
$\psi_k = 100$	0.43	0.29	-0.22	-0.19	-0.34	-0.11	-0.15

the persistence from close to 1 in our baseline to 0.3 raises the multiplier to roughly 0.9.[35] The government spending multiplier is more stable with respect to other parameters. Higher nominal price rigidity, a higher labor supply elasticity, and lower capital adjustment costs are associated with somewhat higher government spending multipliers. The transfer multiplier also increases when the persistence of fiscal shocks is lower and nominal price or wage rigidities are stronger.

How do the spending multipliers compare to the existing literature? On the theoretical side, our model contains elements — nominal stickiness, liquidity-constrained agents, and consumption-labor complementarity — identified by earlier literature (Nakamura and Steinsson, 2014; Farhi and Werning, 2016; House, Proebsting, and Tesar, 2017) as contributing to larger government spending multipliers for countries such as Greece that belong to a currency union. Despite this, our model generates smaller multipliers than in these papers for two reasons. First, this literature considers more transient changes in spending than observed in Greece.[36] Second, some of the theoretical literature considers complete asset markets whereas we model Greece operating within incomplete international asset markets. In response to government spending shocks, complete asset markets trigger a transfer of wealth that offsets the negative wealth effect on consumption and the rise in local prices. With incomplete asset markets, the multiplier in Nakamura and Steinsson (2014) falls from 1.4 to 0.8 and in House, Proebsting, and Tesar (2017) from 2.0 to 1.5.

On the empirical side, the closest analogs are estimates of government spending multipliers in subnational regions belonging to a currency union (such as U.S. states) or in countries with fixed exchange rates. Chodorow-Reich (2019) reviews empirical estimates of subnational multipliers and emphasizes that, because subnational spending is financed by the central government, these estimates should be compared to model-generated multipliers for transitory spending shocks for which the associated increase in tax burden is small. The impact multiplier of 1.3 for more transitory spending shocks in our model falls in the middle of the range of estimates he reviews. Using the identification scheme pioneered by Blanchard and Perotti (2002), Ilzetzki, Mendoza, and Vegh (2013) report multipliers above 1 for countries with fixed exchange rates, but smaller or

[35] The contemporaneous multiplier ($h = 1$) rises to roughly 1.3. We report these results in Appendix Table C.4. Additionally, in Appendix Tables C.5 and C.6 we report results for deficit financed multipliers at various horizons.

[36] In their quantitative evaluation, Farhi and Werning (2016) consider spending which lasts 1.25 years. Nakamura and Steinsson (2014) and House, Proebsting, and Tesar (2017) both consider spending with annual persistence of 0.75. The European Central Bank (2015) reports multipliers for 15 models maintained by central banks in the European System. The closest experiment to our own is the short-run impact of a permanent reduction in government purchases with no contemporaneous change in taxes. These multipliers range from 0.25 to 0.97, with the Bank of Greece model at 0.87, close to the value of 0.90 shown in Table 7 for the impact effect of a deficit-financed, persistent change in spending.

even negative multipliers for countries with high debt burdens such as Greece.[37]

The tax multipliers in Table 7 tend to decline in magnitude as the degree of price rigidity increases because output becomes less sensitive to supply-side distortions and adjusts to satisfy demand. Higher nominal wage rigidity also tends to lower the tax multipliers, with the exception of labor income taxes. The labor tax multiplier increases in magnitude the more responsive labor supply is, which in terms of our parameters corresponds to a higher nominal wage rigidity, a higher Frisch labor supply elasticity, and a higher complementarity between consumption and labor. Capital income tax multipliers are sensitive to variable utilization. To understand this result, we note that the first-order conditions for utilization in each sector $i = \{H, N\}$ imply $u_i = \left(\frac{(1-\tau_i^k)\tilde{P}_i y_i}{\xi_i (1+\tau^x) P_T k_i}\right)^{\frac{1}{\xi_i}}$. Capital taxes lower utilization and exert a negative impact on output even before capital adjusts. Finally, the model generates larger effects of capital income tax rates on output when tax rates are more persistent because persistent changes in taxes affect capital accumulation more.

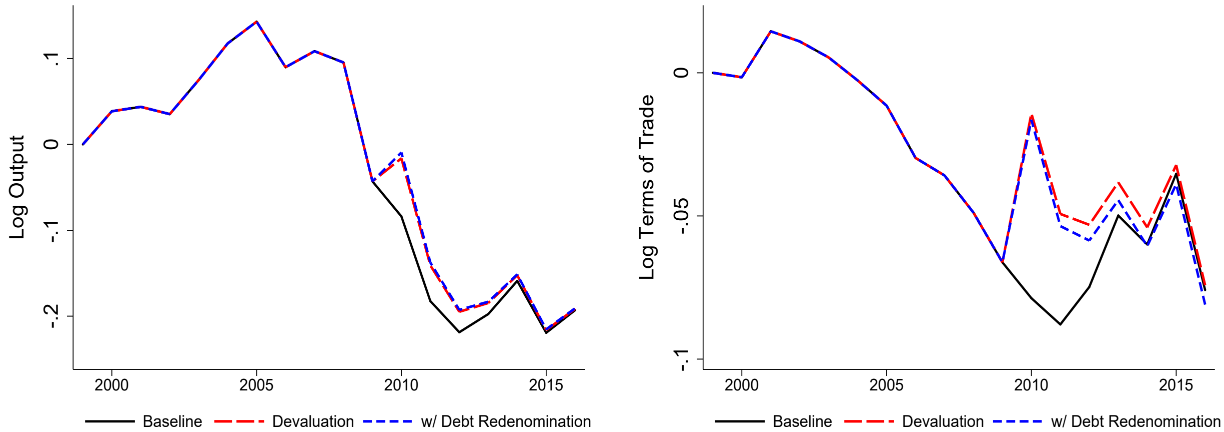
The closest related evidence for tax multipliers comes from the study of fiscal consolidations by Alesina, Favero, and Giavazzi (2019). Using a panel of countries which excludes Greece, they find that a change in tax rates resulting in a 1 percent increase in revenue to GDP over 4 years causes GDP to fall by 2 percent. They do not distinguish among different types of taxes. Comparing their estimated multiplier to ours requires converting the tax rate multipliers shown in Table 7 into revenue multipliers, which we report later in Table 9. This yields revenue multipliers of roughly -0.5 for consumption, -1 for labor, and -2 for investment and capital taxes at a 7-year horizon.[38]

6 Policy Experiments

Nominal devaluation. The first policy experiment is an exchange rate devaluation that would have accompanied a hypothetical Greek exit from the euro. Specifically, we set the exchange rate

[37]House, Proebsting, and Tesar (2017) arrive at somewhat larger multipliers in Europe for the post-2010 period by comparing forecast errors of government spending and output. However, this approach does not by itself isolate a government spending multiplier, since other variables could affect the forecast errors of both spending and output. Blanchard and Leigh (2013) find that forecasters underestimated fiscal multipliers during this period but do not distinguish between government spending and tax multipliers.

[38]Other evidence comes from the Mertens and Ravn (2013) implementation of the Romer and Romer (2010) discretionary tax changes for the United States. The short-run semi-elasticities of output to personal income taxes (roughly -1.5) and corporate income taxes (roughly -0.5) in Mertens and Ravn (2013) are significantly higher than ours (roughly -0.4 and 0 respectively). The revenue-based multipliers they report for personal income taxes (roughly -2.5) are higher than our labor income tax multiplier (roughly -1). Their revenue-based multipliers for capital taxes are similar to ours because in Table 9 we find no significant revenue effects from changing capital income taxes.



(a) Time Series of y

(b) Time Series of P_F/P_H

Figure 5: Macroeconomic Effects of Hypothetical Devaluation in 2010

Figure 5 plots the time series of selected variables in our baseline model and under a counterfactual where the nominal exchange rate depreciates by 10 percent in 2010. The red dashed line plots a counterfactual where debt is denominated in euro, and the blue dashed line a counterfactual where debt is denominated in local currency.

E_t to 1 for all years until 2009 and in 2010 introduce an unexpected and permanent increase in E_t to 1.1. The depreciation raises the domestic price of foreign traded goods $P_F = EP_F^*$ by 10 percent.[39] Figure 5 presents the evolution of output y and the terms of trade P_F/P_H in the baseline economy and in the counterfactual economy in which a devaluation happens in 2010. In the dashed-dotted red line, debt is denominated in euros and, as a result, the devaluation increases the local currency price of debt liabilities for households, firms, and the government. In the dashed blue line, debt is denominated in local currency and, as a result, the devaluation results in a transfer of resources from foreigners to Greece. In all cases, the devaluation stimulates output in the first couple of periods through a switch of expenditures toward cheaper domestically produced goods. However, given the low estimated degree of price and wage rigidity, a nominal devaluation would have only short-lived effects and would not have helped the Greek economy escape the depression after 2012.

Fiscal adjustment mix. The effects of fiscal innovations on macroeconomic outcomes in Table 5 maintain the assumption that lump sum transfers to optimizing households T^o adjust to satisfy the government budget constraint. The fiscal multipliers in Table 7 additionally consider adjustments in government debt B^g. Because changes in debt or direct transfers may not be

[39]We consider only the devaluation component of an exit and not any costs associated with transitioning to a new currency. Because the depreciation is unexpected and permanent, the uncovered interest parity implies an equalization of the domestic interest rate i to the foreign interest rate i^* in all periods.

Table 8: Effects of Different Fiscal Policies on Macroeconomic Outcomes

		Counterfactual change in 2016							
No innovations	Adjust	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log \mathrm{TFP}$	$\log c$	$\log P_c$	$\log P_N$	$\log W$
all τ's	g, T^r	0.025	-0.019	0.002	0.033	0.097	-0.098	-0.129	-0.107
all τ's	g	0.020	-0.029	0.000	0.034	0.144	-0.096	-0.126	-0.094
T^r	g	-0.005	-0.010	-0.001	0.000	0.036	0.003	0.004	0.013
τ^k_H, τ^k_N	τ^ℓ	0.012	-0.065	0.009	0.037	-0.032	-0.065	-0.087	0.002
all other τ's	τ^c	0.032	-0.021	0.010	0.036	-0.033	-0.090	-0.118	-0.089
		Counterfactual change in 2025							
No innovations	Adjust	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log \mathrm{TFP}$	$\log c$	$\log P_c$	$\log P_N$	$\log W$
all τ's	g, T^r	0.028	-0.017	0.042	0.013	0.116	-0.111	-0.149	-0.043
all τ's	g	0.015	-0.027	0.030	0.012	0.132	-0.115	-0.154	-0.048
T^r	g	-0.010	-0.008	-0.010	-0.001	0.013	-0.003	-0.004	-0.004
τ^k_H, τ^k_N	τ^ℓ	0.045	0.009	0.054	0.012	0.025	-0.091	-0.122	-0.040
all other τ's	τ^c	0.057	0.007	0.075	0.013	0.039	-0.101	-0.135	-0.034

politically feasible, we now assess the macroeconomic effects of more policy relevant scenarios under which alternative compositions of policy instruments $\{g, \zeta T^r, \tau^c, \tau^x, \tau^\ell, \tau^k_H, \tau^k_N\}$ are used to achieve fiscal consolidation.

Table 8 presents results from alternative fiscal consolidation policies. The first column of the table reports a set of fiscal instruments for which we set all innovations to zero beginning in 2010. The second column of the table reports which fiscal instruments adjust to balance the government budget constraint. For example, in the first row we set all tax innovations to zero starting in 2010 and introduce innovations to government spending g and transfers to rule-of-thumb households T^r such that the government budget constraint is satisfied. In these experiments, households and firms perceive the law of motion of fiscal instruments to still be governed by the autoregressive process in equation (16). As a result, all changes we introduce to fiscal instruments are unexpected, which we view as a desirable property of our exercise since the Greek fiscal consolidation process went through various unexpected changes during the three adjustment programs.

We find significant macroeconomic effects of tilting the Greek fiscal adjustment process away from tax increases toward spending cuts. In the first rows of each panel of Table 8, this alternative fiscal mix would increase output y by 2.5 percent in 2016 relative to the observed fiscal adjustment and by 2.8 percent in 2025 relative to the evolution of the economy predicted by our model but without changes in the composition of the adjustment.[40] The medium-term gains in output are mostly accounted for by an increase in TFP, whereas the longer-term gains accrue from capital accumulation. We also find significant gains in real wages W/P_c and private consumption c. The second row of the table shows that the production gains are smaller and the consumption gains are larger if the removal of tax increases is offset by only government spending g cuts. Similarly, the third row demonstrates that removing the decline in T^r and introducing even larger declines in g results in modest losses in production and gains in private consumption.[41]

The other rows of Table 8 present experiments that change the fiscal consolidation process on the tax side only. Removing the increases in capital taxes and substituting them with even larger increases in labor income taxes results in a modest increase in output by 2016, reflecting offsetting effects from an increase in TFP and a decline in labor. However, by 2025 such a policy leads to significant capital accumulation and is associated with output gains of 4.5 percent and consumption gains of 2.5 percent. The final row shows significant gains by tilting the consolidation away from all taxes other than consumption. By 2025 such a policy would generate output gains of 5.7 percent, accounted for by capital accumulation and an increase in TFP.[42]

To understand the relative effectiveness of the various options, Table 9 presents the output and revenue effects of each fiscal instrument. The output effects at 1-year, 7-year, and infinite horizon are given by the multipliers $M_f^y(h)$ in equation (21), under the assumption that lump-sum transfers T^o adjust to balance the budget. The revenue effects correspond to the change in lump-sum transfers required to balance the government budget constraint after a response ν_0^f in instrument $f = \{g, \zeta T^r, \tau^c, \tau^x, \tau^\ell, \tau_H^k, \tau_N^k\}$ following the autoregressive process in equation (16):

$$M_f^r(h) = \frac{\sum_{t=1}^h (1+i^*)^{1-t} \Delta(1-\zeta)T_t^o}{\sum_{t=1}^h (1+i^*)^{1-t} \Delta f_t}. \tag{22}$$

Dividing $M_f^y(h)$ by $M_f^r(h)$ yields the revenue-based multiplier for instrument f at horizon h. For example, at a 7-year horizon a cumulative one percentage point decrease in τ^ℓ would necessitate

[40] For periods after 2016, we set innovations to all exogenous processes in vector $\mathbf{z}_t$ to zero. The endogenous variables (including T^o) evolve according to their policy functions given the state vector and $\mathbf{z}_t$ evolves according to its autoregressive process in equation (16).

[41] We acknowledge that private consumption c is an imperfect proxy of welfare if government spending g is valued by households. For the policy experiments below in which we change only the tax side of the adjustment, g remains constant and changes in c are more relevant for welfare.

[42] Papageorgiou (2012) uses data up to 2008 and highlights that increasing consumption and lowering labor income taxes stimulates the economy. Our emphasis on capital income taxes is justified by their significant increase during the bust period.

Table 9: Output and Revenue Effects of Fiscal Instruments

	horizon $h = 1$		horizon $h = 7$		horizon $h = \infty$	
	Output	Revenues	Output	Revenues	Output	Revenues
g	0.50	-0.89	0.45	-0.94	0.46	-0.96
ζT^r	0.60	-0.63	0.28	-0.77	0.10	-0.88
τ^c	-0.25	0.41	-0.22	0.43	-0.19	0.46
τ^x	-0.02	0.21	-0.21	0.10	-0.29	0.06
τ^ℓ	-0.26	0.51	-0.35	0.40	-0.34	0.40
τ^k_H	-0.04	0.06	-0.11	0.03	-0.12	0.02
τ^k_N	0.02	0.25	-0.14	0.12	-0.17	0.07

additional lump-sum taxes of 0.4 units. A unit increase of revenues induced by higher τ^ℓ would then lower output by $-0.35/0.4 \approx -0.9$ units.

Table 9 highlights significant differences across fiscal instruments in their ability to raise revenues. A one percentage point increase in consumption or labor income taxes increases revenues by significantly more than a one percentage point increase in capital income taxes, with the difference magnified at longer horizons. In fact, the economy is close to the peak of the Laffer curve with respect to capital tax rates at longer horizons. This result explains why shifting the burden of adjustment away from capital taxes toward either consumption or labor taxes produces significant output and consumption gains by 2025 — the required increase in other taxes is relatively small.[43]

The production and consumption gains from adjusting through consumption taxes also reflect the equivalence between an anticipated declining path of consumption taxes and a decrease in capital income taxes. In the counterfactual, innovations in consumption tax rates between 2010 and 2016 are unexpected, while the post-2016 decline follows the autoregressive process (16) and is fully anticipated by households. Thus, this policy mimics an initial capital levy followed by declining capital income taxes.

Reducing spending in the boom and taxes in the bust. Martin and Philippon (2017)

[43] These results illustrate again the importance of variable utilization. The 7-year horizon output responses for τ^k_H and τ^k_N would decline in absolute values from -0.11 and -0.14 with variable utilization to -0.04 and -0.01 without variable utilization. The 7-year horizon revenue responses would increase from 0.03 and 0.12 with variable utilization to 0.04 and 0.16 without variable utilization. Our results corroborate the analysis of Trabandt and Uhlig (2011) who demonstrate that the Greek revenue maximizing capital tax rate is roughly 40 percent, implying small revenue losses from cutting capital taxes.

Table 10: Reducing Excessive Spending in the Boom and Taxes in the Bust

1999-2016	2010-2016	Counterfactual change in log output	
No innovations	Adjust	2007	2016
T^r, g	τ^k	-0.028	0.150
T^r	τ^k	-0.009	0.115
g	τ^k	-0.018	0.035
T^r, g	τ^ℓ	-0.028	0.036
T^r	τ^ℓ	-0.009	0.026
g	τ^ℓ	-0.018	0.010

argue that reducing fiscal spending in the boom would have allowed both Greece and other periphery euro countries to adjust by less in the bust. Table 10 repeats the spirit of their exercise within our model economy. Each row represents an experiment in which we shut off innovations in transfers to rule-of-thumb households T^r or government spending g in the entire sample. Between 1999 and 2009, government debt B^g adjusts to make the flow government budget constraint hold. Starting in 2010, we solve for the path of capital taxes τ^k or labor taxes τ^ℓ such that the flow government budget constraint holds and government debt B^g grows linearly back to its observed level in 2016. Effectively, our exercise calculates the macroeconomic outcomes that Greece could have accomplished if in 2010 it had entered with a lower stock of debt and used the freed-up resources to reduce distortionary taxes during the depression.

As Table 10 documents, removing the spending during the boom years would lower output in 2007 by roughly 3 percent, with roughly two-thirds of this decline accounted for by the decline in government spending. If the freed-up resources from a lower debt level in 2010 were used to finance a reduction in capital taxes, output would have been 15 percent higher by 2016. We note a significant difference between shutting off the growth of transfers T^r, which account for roughly three-quarters of the 15 percent increase, and government spending g. This difference occurs partly because T^r grows by more than g in euros during the boom and partly because the transfer multiplier is lower than the government spending multiplier. As the table reveals, using the freed-up resources to lower labor income taxes would have produced significantly smaller output gains. The difference between labor and capital taxes is consistent with our findings in Table 9 showing that the economy is closer to the peak of the Laffer curve with respect to capital income taxes.

7 Conclusion

We develop and estimate a rich macroeconomic model of the Greek economy with the goal of understanding the boom and bust experienced over the past two decades. Our exercise is disciplined by detailed analysis of macroeconomic patterns and by feeding in directly time series of shocks as measured in the data. Lower external demand for traded goods and contractionary fiscal policies account for the largest fraction of the Greek depression. Financial forces account for some of the boom but have a limited part in accounting for the persistence of the depression. In terms of mechanisms, we attribute an important role to lower utilization of factors in amplifying the depression. On the other hand, the observed adjustment of prices and wages throughout the cycle suggest a limited role for nominal rigidities in terms of accounting for the significant boom and the sustained depression of the Greek economy. While these conclusions challenge some prevailing narratives of the Greek and broader southern euro experience, they follow from equilibrium analysis of simple patterns in the macroeconomic data.

We use the model to evaluate alternative policies that Greece might have pursued. A nominal devaluation raises output on impact, but, given the low estimated degree of nominal price and wage rigidity, would have only short-lived stabilizing effects. In contrast, shifting the burden of adjustment away from taxes toward spending or from capital income taxes toward other taxes would generate significant and persistent production and consumption gains. Finally, we quantify substantial benefits if Greece had avoided the debt-financed rise of household transfers during the boom and used the additional fiscal space to reduce capital taxes during the bust.

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The Macroeconomics of the Greek Depression

Online Appendix

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A Model Appendix

In Appendix A.1 we list the equilibrium conditions of the model and in Appendix A.2 we describe how we incorporate rare disasters into the model.

A.1 Equilibrium Conditions

We present the equilibrium conditions for the baseline model in which the exchange rate is $E_t = 1$ and households and firms expect E_t to always be constant. For the exchange rate devaluation experiment we assume that E_t rises unexpectedly and permanently. Because the depreciation is unexpected and permanent, the uncovered interest parity implies an equalization of the domestic interest rate i to the foreign interest rate i^* in all periods.

A.1.1 Households (24 equations)

The first-order conditions for household $h \in \{o, r\}$ are:

$$\frac{c^h_{T,t}}{c^h_{N,t}} = \frac{\omega}{1-\omega}\left(\frac{P_{N,t}}{P_{T,t}}\right)^{\phi},$$

$$\frac{c^h_{H,t}}{c^h_{F,t}} = \frac{\gamma}{1-\gamma}\left(\frac{P_{H,t}}{E_t P^*_{F,t}}\right)^{-\eta},$$

$$\frac{\varepsilon^w}{\varepsilon^w - 1}\frac{\chi c^h_t (\ell^h_t)^{\frac{1}{\epsilon}}}{\rho + (1-\rho)\frac{\chi\left(\ell^h_t\right)^{1+\frac{1}{\epsilon}}}{1+\frac{1}{\epsilon}}} = \frac{1-\tau^\ell_t}{1+\tau^c_t}\frac{W_t}{P_{c,t}}\times$$

$$\left[1 + \frac{\psi_w}{\varepsilon^w - 1}\left(\left(\frac{(1-\tau^\ell_t)W_t}{(1-\tau^\ell_{t-1})W_{t-1}} - 1\right)\frac{(1-\tau^\ell_t)W_t}{(1-\tau^\ell_{t-1})W_{t-1}}\right.\right.$$
$$\left.\left. - \mathbb{E}_t\Lambda^h_{t,t+1}\left(\frac{(1-\tau^\ell_{t+1})W_{t+1}\ell^h_{t+1}}{(1-\tau^\ell_t)W_t\ell^h_t}\right)\left(\frac{(1-\tau^\ell_{t+1})W_{t+1}}{(1-\tau^\ell_t)W_t} - 1\right)\frac{(1-\tau^\ell_{t+1})W_{t+1}}{(1-\tau^\ell_t)W_t}\right)\right],$$

$$(1+\tau^c_t)\,P_{c,t}c^h_t + (1+i^*_t)B^h_t + Q^\varsigma_t\varsigma^h_{t+1} + \mathrm{AC}^h_{w,t} = \left(1-\tau^\ell_t\right)W_t\ell^h_t + B^h_{t+1} + (Q^\varsigma_t + \Pi_t)\varsigma^h_t + T^h_t,$$

$$\text{AC}^h_{w,t} = \frac{\psi_w}{2}\left(\frac{(1-\tau^\ell_t)W^h_t}{(1-\tau^\ell_{t-1})W^h_{t-1}} - 1\right)^2 (1-\tau^\ell_t)W^h_t\ell^h_t,$$

$$c^h_t = \left(\omega^{\frac{1}{\phi}}\left(c^h_{T,t}\right)^{\frac{\phi-1}{\phi}} + (1-\omega)^{\frac{1}{\phi}}\left(c^h_{N,t}\right)^{\frac{\phi-1}{\phi}}\right)^{\frac{\phi}{\phi-1}},$$

$$c^h_{T,t} = \left(\gamma^{\frac{1}{\eta}}(c^h_{H,t})^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}}(c^h_{F,t})^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}},$$

$$\Lambda^h_{t,t+1} = \beta^h\left(1-\pi_t+\pi_t e^{-\varphi(1-\sigma)}\right)^{\frac{1-\frac{1}{\rho}}{1-\sigma}}(\text{ce}^h_t)^{\sigma-\frac{1}{\rho}}(v^h_{t+1})^{\frac{1}{\rho}-\sigma}\times$$

$$\frac{(c^h_{t+1})^{-\frac{1}{\rho}}\left(1+\left(\frac{1}{\rho}-1\right)\frac{\chi\left(\ell^h_{t+1}\right)^{1+\frac{1}{\epsilon}}}{1+\frac{1}{\epsilon}}\right)^{\frac{1}{\rho}}}{(c^h_t)^{-\frac{1}{\rho}}\left(1+\left(\frac{1}{\rho}-1\right)\frac{\chi\left(\ell^h_t\right)^{1+\frac{1}{\epsilon}}}{1+\frac{1}{\epsilon}}\right)^{\frac{1}{\rho}}}\frac{(1+\tau^c_t)P_{c,t}}{(1+\tau^c_{t+1})P_{c,t+1}},$$

where

$$(v^h_t)^{1-\frac{1}{\rho}} = \left(c^h_t\right)^{1-\frac{1}{\rho}}\left(1+\left(\frac{1}{\rho}-1\right)\frac{\chi\left(\ell^h_{t+1}\right)^{1+\frac{1}{\epsilon}}}{1+\frac{1}{\epsilon}}\right)^{\frac{1}{\rho}} + \beta^h\left(1-\pi_t+\pi_t e^{-\varphi(1-\sigma)}\right)^{\frac{1-\frac{1}{\rho}}{1-\sigma}}(\text{ce}^h_t)^{1-\frac{1}{\rho}},$$

$$\text{ce}^h_t = \left(\mathbb{E}_t(v^h_{t+1})^{1-\sigma}\right)^{\frac{1}{1-\sigma}},$$

and for household o:

$$1 = \mathbb{E}_t\Lambda^o_{t,t+1}(1+i^*_{t+1}),$$

$$Q^\varsigma_t = \mathbb{E}_t\Lambda^o_{t,t+1}\left(\Pi_{t+1}+Q^\varsigma_{t+1}\right),$$

and for household r:

$$B^r_{t+1} = \bar{B}^r_t,$$

$$\varsigma^r_{t+1} = 0.$$

A.1.2 Firms (24 equations)

Production. Let μ_t be the multiplier on the borrowing constraint (11) and λ_t be the multiplier on the firm's flow of funds constraint (12).

$$\tilde{\Pi}_t = \frac{E_tP^*_{F,t}}{EP_F}\tilde{\Pi} + \left(\frac{E_tP^*_{F,t}}{\psi_\pi}\right)\left(\frac{1-\lambda_t}{\lambda_t}\right),$$

$$\frac{(1-\alpha_H)\tilde{P}_{H,t}y_{H,t}}{\ell_{H,t}} = W_t\left(1+\frac{\kappa\mu_t}{(1-\tau^k_{H,t})}\lambda_t\right),$$

$$\frac{(1-\alpha_N)\tilde{P}_{N,t}y_{N,t}}{\ell_{N,t}} = W_t\left(1+\frac{\kappa\mu_t}{(1-\tau^k_{N,t})}\lambda_t\right),$$

$$u_{H,t} = \left(\frac{(1-\tau^k_{H,t})\tilde{P}_{H,t}y_{H,t}}{\bar{\xi}_H(1+\tau^x_t)P_{T,t}s_tk_t}\right)^{\frac{1}{\xi_H}},$$

$$u_{N,t} = \left(\frac{(1-\tau^k_{N,t})\tilde{P}_{N,t}y_{N,t}}{\bar{\xi}_N(1+\tau^x_t)P_{T,t}(1-s_t)k_t}\right)^{\frac{1}{\xi_N}},$$

$$\left(\frac{(1-\tau^k_{H,t})\alpha_H\tilde{P}_{H,t}y_{H,t}}{s_tk_t} - \frac{(1-\tau^k_{N,t})\alpha_N\tilde{P}_{N,t}y_{N,t}}{(1-s_t)k_t}\right)$$

$$= \left[(1+\tau^x_t)P_{T,t}\left(\delta_{H,t}-\delta_{N,t}\right) - Q^k_t(\tau^k_{H,t}\bar{\delta}_H - \tau^k_{N,t}\bar{\delta}_N)\right],$$

$$Q^k_t = (1+\tau^x_t)P_{T,t} + E_tP^*_{F,t}\psi_k\left(\frac{x_t}{k_t}-\delta_t\right),$$

$$Q^k_t\left(1-\frac{\mu_t}{\lambda_t}\theta_t\right) =$$

$$+\mathbb{E}_t\Lambda^o_{t,t+1}\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\left(\frac{(1-\tau^k_{H,t+1})\alpha_H\tilde{P}_{H,t+1}y_{H,t+1}+(1-\tau^k_{N,t+1})\alpha_N\tilde{P}_{N,t+1}y_{N,t+1}}{k_{t+1}}\right)\right.$$

$$+(\tau^k_{H,t+1}s_{t+1}\bar{\delta}_H + \tau^k_{N,t+1}(1-s_{t+1})\bar{\delta}_N)Q_{t+1}$$

$$\left.+E_{t+1}P^*_{F,t+1}\frac{\psi_k}{2}\left(\left(\frac{x_{t+1}}{k_{t+1}}\right)^2 - {\delta_{t+1}}^2\right) + Q_{t+1}\left(1-\delta_{t+1}\right)\right],$$

$$\lambda_t - \mu_t = \mathbb{E}_t\Lambda^o_{t,t+1}\lambda_{t+1}\left(1+(1-(s_{t+1}\tau^k_{H,t+1}+(1-s_{t+1})\tau^k_{N,t+1}))i^*_{t+1}\right),$$

$$y_{H,t} = z_{H,t}u_{H,t}\left(s_tk_t\right)^{\alpha_H}\left(\ell_{H,t}\right)^{1-\alpha_H},$$

$$y_{N,t} = z_{N,t}u_{N,t}\left(\left(1-s_t\right)k_t\right)^{\alpha_N}\left(\ell_{N,t}\right)^{1-\alpha_N},$$

$$\delta_{H,t} = \bar{\delta}_H + \frac{\bar{\xi}_H}{\xi_H}(u^{\xi_H}_{H,t}-1),$$

$$\delta_{N,t} = \bar{\delta}_N + \frac{\bar{\xi}_N}{\xi_N}(u^{\xi_N}_{N,t}-1),$$

$$\delta_t = s_t\delta_{H,t} + (1-s_t)\delta_{N,t},$$

$$\tilde{\Pi}_t = \left(1-\tau^k_{H,t}\right)\left(\tilde{P}_{H,t}y_{H,t}-W_t\ell_{H,t}\right) + \left(1-\tau^k_{N,t}\right)\left(\tilde{P}_{N,t}y_{N,t}-W_t\ell_{N,t}\right) - (1+\tau^x_t)P_{T,t}x_t - \mathrm{AC}_{k,t}$$

$$+B^f_{t+1} - (1+i^*_t)B^f_t + \tau^k_{H,t}s_t\left(\bar{\delta}_HQ^k_tk_t + i^*_tB^f_t\right) + \tau^k_{N,t}(1-s_t)\left(\bar{\delta}_NQ^k_tk_t + +i^*_tB^f_t\right) - \mathrm{AC}_{\pi,t},$$

$$\mathrm{AC}_{\pi,t} = \frac{\psi_\pi}{2}\left(\frac{\tilde{\Pi}_t}{E_tP^*_{F,t}} - \frac{\tilde{\Pi}}{EP^*_F}\right)^2 E_tP^*_{F,t},$$

$$\mathrm{AC}_{k,t} = \frac{\psi_k}{2}\left(\frac{k_{t+1}-k_t}{k_t}\right)^2 E_tP^*_{F,t}k_t,$$

$$B^f_{t+1} + \kappa W_t\left(\ell_{H,t}+\ell_{N,t}\right) = \theta_tQ^k_tk_{t+1}.$$

Price setting. For price setting firm in sector $i \in \{H, N\}$:

$$P_{i,t} - \left(\frac{\varepsilon^p}{\varepsilon^p - 1}\right) \tilde{P}_{i,t}$$

$$+ \frac{\psi_p}{\varepsilon^p - 1} P_{i,t} \left(\left(\frac{P_{i,t}}{P_{i,t-1}} - 1\right) \frac{P_{i,t}}{P_{i,t-1}} - \mathbb{E}_t \Lambda^o_{t,t+1} \frac{P_{i,t+1} y_{i,t+1}}{P_{i,t} y_{i,t}} \left(\frac{P_{i,t+1}}{P_{i,t}} - 1\right) \frac{P_{i,t+1}}{P_{i,t}} \right) = 0,$$

$$\Pi_{i,t} = (P_{i,t} - \tilde{P}_{i,t}) y_{i,t} - \mathrm{AC}_{i,t},$$

$$\mathrm{AC}_{i,t} = \frac{\psi_p}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} - 1\right)^2 P_{i,t} y_{i,t}.$$

A.1.3 Government (1 equation)

$$\tau^c_t P_{c,t} \left(\zeta c^r_t + (1-\zeta) c^o_t\right) + \tau^x_t P_{T,t} x_t + \tau^l_t \left(\zeta W_t \ell^r_t + (1-\zeta) W_t \ell^o_t\right)$$

$$+ \tau^k_{H,t} \left(\tilde{P}_{H,t} y_{H,t} - W_t \ell_{H,t} - s_t \left(\bar{\delta}_H Q^k_t k_t + i^*_t B^f_t\right)\right)$$

$$+ \tau^k_{N,t} \left(\tilde{P}_{N,t} y_{N,t} - W_t \ell_{N,t} - (1 - s_t) \left(\bar{\delta}_N Q^k_t k_t + i^*_t B^f_t\right)\right)$$

$$= P_{N,t} g_t + (1 + r^*_t) B^g_t - B^g_{t+1} + \zeta T^r_t + (1-\zeta) T^o_t.$$

A.1.4 Market Clearing (6 equations)

$$\Pi_t = \tilde{\Pi}_t + \Pi_{H,t} + \Pi_{N,t},$$

$$\zeta \varsigma^r_{t+1} + (1-\zeta) \varsigma^o_{t+1} = 1,$$

$$k_{t+1} = (1 - \delta_t) k_t + x_t,$$

$$\ell_{H,t} + \ell_{N,t} = \zeta \ell^r_t + (1-\zeta) \ell^o_t,$$

$$y_{N,t} = \zeta c^r_{N,t} + (1-\zeta) c^o_{N,t} + g_t,$$

$$y_{H,t} = \gamma \left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\eta} \left(\zeta c^r_{T,t} + (1-\zeta) c^o_{T,t} + x_t\right) + (1-\gamma) \left(\frac{P_{H,t}}{E_t P^*_{F,t}}\right)^{-\eta} \bar{a}_{T,t}.$$

A.1.5 Auxiliary (22 equations)

Aggregate consumption and its associated price index are:

$$c_t = \zeta c^r_t + (1-\zeta) c^o_t,$$

$$P_{c,t} = \left(\omega {P_{T,t}}^{1-\phi} + (1-\omega) P^{1-\phi}_{N,t}\right)^{\frac{1}{1-\phi}}.$$

Aggregate traded consumption and its associated price index are:

$$c_{T,t} = \zeta c^r_{T,t} + (1-\zeta) c^o_{T,t},$$

$$P_{T,t} = \left(\gamma(P_{H,t})^{1-\eta} + (1-\gamma)(E_t P^*_{F,t})^{1-\eta}\right)^{\frac{1}{1-\eta}}.$$

Aggregate output and its associated Paasche index are:

$$y_t = \frac{P_{H,t}y_{H,t} + P_{N,t}y_{N,t}}{P_{y,t}},$$

$$\frac{P_{y,t}}{P_{y,t-1}} = \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{\frac{P_{H,t}y_{H,t}}{P_{H,t}y_{H,t}+P_{N,t}y_{N,t}}} \left(\frac{P_{N,t}}{P_{N,t-1}}\right)^{\frac{P_{N,t}y_{N,t}}{P_{H,t}y_{H,t}+P_{N,t}y_{N,t}}}.$$

Nominal GDP, net exports, the Paasche price index of GDP, and real GDP are defined as:

$$\mathrm{GDP}_t = (1+\tau^c_t)P_{c,t}c_t + (1+\tau^x_t)P_{T,t}x_t + P_{N,t}g_t + \mathrm{NX}_t,$$

$$\mathrm{NX}_t = P_{H,t}y_{H,t} - P_{T,t}c_{T,t} - P_{T,t}x_t - \zeta \mathrm{AC}^r_{w,t} - (1-\zeta)\mathrm{AC}^o_{w,t} - \mathrm{AC}_{H,t} - \mathrm{AC}_{N,t} - \mathrm{AC}_{\pi,t} - \mathrm{AC}_{k,t},$$

$$\frac{P_{\mathrm{gdp},t}}{P_{\mathrm{gdp},t-1}} = \left(\frac{(1+\tau^c_t)P_{c,t}}{(1+\tau^c_{t-1})P_{c,t-1}}\right)^{\frac{(1+\tau^c_t)P_{c,t}c_t}{\mathrm{GDP}_t}} \left(\frac{(1+\tau^x_t)P_{T,t}}{(1+\tau^x_{t-1})P_{T,t-1}}\right)^{\frac{(1+\tau^x_t)P_{T,t}x_t}{\mathrm{GDP}_t}} \left(\frac{P_{N,t}}{P_{N,t-1}}\right)^{\frac{P_{N,t}g_t}{\mathrm{GDP}_t}} \times$$
$$\left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{\frac{P_{H,t}y_{H,t}}{\mathrm{GDP}_t}} \left(\frac{P_{T,t}}{P_{T,t-1}}\right)^{-\frac{P_{T,t}c_{T,t}}{\mathrm{GDP}_t}} \left(\frac{P_{T,t}}{P_{T,t-1}}\right)^{-\frac{P_{T,t}x_{T,t}}{\mathrm{GDP}_t}},$$

$$\mathrm{gdp}_t = \frac{\mathrm{GDP}_t}{P_{\mathrm{gdp},t}}.$$

Aggregate labor is:

$$\ell_t = \ell_{H,t} + \ell_{N,t}.$$

Sectoral and aggregate capital as measured in the national accounts is:

$$\tilde{k}_{H,t+1} = (1-\bar{\delta}_H)\tilde{k}_{H,t} + s_t x_t,$$

$$\tilde{k}_{N,t+1} = (1-\bar{\delta}_N)\tilde{k}_{N,t} + (1-s_t)x_t,$$

$$\tilde{k}_t = \tilde{k}_{H,t} + \tilde{k}_{N,t}.$$

Aggregate TFP (inclusive of utilization) is defined as:

$$\frac{\mathrm{TFP}_t}{\mathrm{TFP}_{t-1}} = \frac{y_t}{y_{t-1}} \left(\frac{\ell_t}{\ell_{t-1}}\right)^{\frac{1}{2}\mathrm{lsh}_t + \frac{1}{2}\mathrm{lsh}_{t-1}} \left(\frac{\tilde{k}_t}{\tilde{k}_{t-1}}\right)^{1-\left(\frac{1}{2}\mathrm{lsh}_t + \frac{1}{2}\mathrm{lsh}_{t-1}\right)},$$

$$\mathrm{lsh}_t = \frac{W_t \ell_t}{P_{H,t}y_{H,t} + P_{N,t}y_{N,t}}.$$

TFP in each sector $i \in \{H, N\}$ is:

$$\frac{\mathrm{TFP}_{i,t}}{\mathrm{TFP}_{i,t-1}} = \frac{y_{i,t}}{y_{i,t-1}} \left(\frac{\ell_{i,t}}{\ell_{i,t-1}}\right)^{\frac{1}{2}\mathrm{lsh}_{i,t} + \frac{1}{2}\mathrm{lsh}_{i,t-1}} \left(\frac{\tilde{k}_{i,t}}{\tilde{k}_{i,t-1}}\right)^{1-\left(\frac{1}{2}\mathrm{lsh}_{i,t} + \frac{1}{2}\mathrm{lsh}_{i,t-1}\right)},$$

$$\text{lsh}_{i,t} = \frac{W_t \ell_{i,t}}{P_{i,t} y_{i,t}}.$$

Quantities of imports and exports are defined as:

$$\text{im}_t = (1-\gamma)\left(\frac{E_t P^*_{F,t}}{P_{T,t}}\right)^{-\eta}\left(\zeta c^r_{T,t} + (1-\zeta)c^o_{T,t} + x_t\right),$$

$$\text{ex}_t = y_{H,t} - \gamma\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\eta}\left(\zeta c^r_{T,t} + (1-\zeta)c^o_{T,t} + x_t\right).$$

A.1.6 Summary

We have 77 equations in 77 unknowns:

$c^o_t, c^o_{T,t}, c^o_{N,t}, c^o_{H,t}, c^o_{F,t}, \ell^o_t, B^o_{t+1}, \varsigma^o_{t+1}, \text{AC}^o_{w,t}, \Lambda^o_{t,t+1}, v^o_t, \text{ce}^o_t,$

$c^r_t, c^r_{T,t}, c^r_{N,t}, c^r_{H,t}, c^r_{F,t}, \ell^r_t, B^r_{t+1}, \varsigma^r_{t+1}, \text{AC}^r_{w,t}, \Lambda^r_{t,t+1}, v^r_t, \text{ce}^r_t,$

$\tilde{P}_{H,t}, y_{H,t}, \ell_{H,t}, u_{H,t}, \delta_{H,t}, \tilde{P}_{N,t}, y_{N,t}, \ell_{N,t}, u_{N,t}, \delta_{N,t}, \delta_t, \tilde{\Pi}_t, s_t, x_t, k_{t+1}, B^f_{t+1}, \text{AC}_{\pi,t}, \text{AC}_{k,t}, \lambda_t, \mu_t,$

$P_{H,t}, P_{N,t}, \Pi_{H,t}, \Pi_{N,t}, \text{AC}_{H,t}, \text{AC}_{N,t}, T^o_t, W_t, Q^k_t, Q^\varsigma_t, \Pi_t,$

$c_t, P_{c,t}, c_{T,t}, P_{T,t}, y_t, P_{y,t}, \text{GDP}_t, \text{gdp}_t, P_{\text{gdp},t}, \text{NX}_t, \ell_t, \tilde{k}_{H,t+1}, \tilde{k}_{N,t+1}, \tilde{k}_{t+1},$

$\text{TFP}_t, \text{lsh}_t, \text{TFP}_{H,t}, \text{lsh}_{H,t}, \text{TFP}_{N,t}, \text{lsh}_{N,t}, \text{im}_t, \text{ex}_t.$

A.2 Rare Disasters

In this appendix we discuss how we incorporate rare disasters into the model. As described in the main text, a time-varying probability of a rare disaster π_t enters multiplicatively with the discount factor in the intertemporal optimality conditions of the model. This simplifies significantly the solution and estimation of the model with time-varying disasters because it allows us to use standard perturbation techniques. This result, adapted from Gourio (2012), is a consequence of the assumptions that all endogenous and exogenous state variables scale with the cumulative realization of disasters over time. Owing to this assumption, we can reformulate the economy with disaster risk into a transformed economy in which the probability of disaster only enters into the intertemporal optimality conditions.

We denote by $\hat{n}$ some variable in the primitive formulation of the economy and by n the same variable in the transformed economy. The disaster process is:

$$\hat{\varphi}_{t+1} = \begin{cases} 0 \text{ with probability } 1-\pi_t, \\ \varphi \text{ with probability } \pi_t, \end{cases}$$

and the cumulative effect of disasters is:

$$\log \hat{\Phi}_t = \log \hat{\Phi}_{t-1} - \hat{\varphi}_t.$$

The exogenous state variables affected by disasters are given by:

$$\begin{aligned}
\log \hat{z}_{H,t} &= \log z_{H,t} + (1-\alpha_H)\log \hat{\Phi}_t, \\
\log \hat{z}_{N,t} &= \log z_{N,t} + (1-\alpha_N)\log \hat{\Phi}_t, \\
\log \hat{g}_t &= \log g_t + \log \hat{\Phi}_t, \\
\log \hat{T}^r_t &= \log T^r_t + \log \hat{\Phi}_t, \\
\log \hat{B}^g_{t+1} &= \log B^g_t + \log \hat{\Phi}_t, \\
\log \hat{\bar{B}}^r_{t+1} &= \log \bar{B}^r_t + \log \hat{\Phi}_t, \\
\log \hat{\bar{a}}_{T,t} &= \log \bar{a}_{T,t} + \log \hat{\Phi}_t.
\end{aligned}$$

The endogenous state variables affected by a disaster are given by:

$$\begin{aligned}
\hat{k}_{t+1} &\equiv \hat{k}'_{t+1} e^{-\hat{\varphi}_{t+1}} = ((1-\delta)\hat{k}_t + \hat{x}_t)e^{-\hat{\varphi}_{t+1}}, \\
\hat{B}^o_{t+1} &\equiv (\hat{B}^{o\prime}_{t+1})e^{-\hat{\varphi}_{t+1}}, \\
\hat{B}^f_{t+1} &\equiv (\hat{B}^{f\prime}_{t+1})e^{-\hat{\varphi}_{t+1}}, \\
\hat{W}_t &\equiv (\hat{W}'_t)e^{-\hat{\varphi}_{t+1}}.
\end{aligned}$$

In the last set of equations, primes denote choice variables at the end of the period which — due to a disaster — may differ from the endogenous state variables the next period.

For any endogenous variable n_t in a period we then define:

$$n_t \equiv \frac{\hat{n}_t}{\hat{\Phi}_t}, \tag{A.1}$$

except for the certainty equivalent for which we define:[1]

$$\text{ce}_t \equiv \left(\mathbb{E}_t v_{t+1}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}. \tag{A.2}$$

[1]In particular, equations (A.1) and (A.2) imply that:

$$\begin{aligned}
\frac{1}{\hat{\Phi}_t}\hat{\text{ce}}_t = \frac{1}{\hat{\Phi}_t}\left(\mathbb{E}_t(\hat{v}_{t+1})^{1-\sigma}\right)^{\frac{1}{1-\sigma}} &= \left(\mathbb{E}_t\left(v_{t+1}\left(\frac{\hat{\Phi}_{t+1}}{\hat{\Phi}_t}\right)\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} = \left(\mathbb{E}_t\left(v_{t+1}e^{-\varphi_{t+1}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \\
&= \left(1-\pi_t+\pi_t e^{-\varphi(1-\sigma)}\right)^{\frac{1}{1-\sigma}}\left(\mathbb{E}_t v_{t+1}^{1-\sigma}\right)^{\frac{1}{1-\sigma}} = \left(1-\pi_t+\pi_t e^{-\varphi(1-\sigma)}\right)^{\frac{1}{1-\sigma}}\text{ce}_t.
\end{aligned}$$

Solving for the equilibrium conditions of the original economy and then making use of equations (A.1) and (A.2) repeatedly, we obtain the equilibrium conditions of the transformed economy.

B Data Appendix

Appendix B.1 presents evidence on the decline in value added and employment by firm size and decomposes the decline in aggregate labor productivity. Appendix B.2 details the growth accounting methodology and the measurement of utilization. Appendix B.3 presents alternative measures of wages. Appendix B.5 presents alternative measures of value-added exports and external demand and decomposes the change in exports during the bust by industry. Appendix B.6 provides additional details on the estimation of disaster probabilities using options data. Appendix B.7 provides additional details on the measurement of effective tax rates. Appendix B.8 describes the estimation of the trade elasticity.

B.1 Value Added, Employment, and Productivity by Size Class

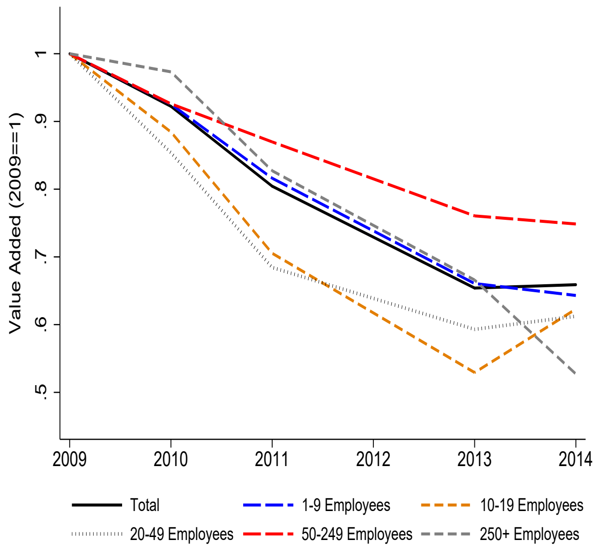
In this appendix we use data between 2009 and 2014 from the Structural Business Statistics to analyze the declines in value added, employment, and labor productivity for firms of different size classes. The Structural Business Statistics provide value added and employment aggregates for firms belonging to different employment sizes, ranging from firms with 1-9 employees to firms with more than 250 employees. The data are available at the industry level for up to four digits of disaggregation.

Figure B.1 presents value added and employment trends by firm size class. The decline in value added and employment is observed throughout the size distribution.

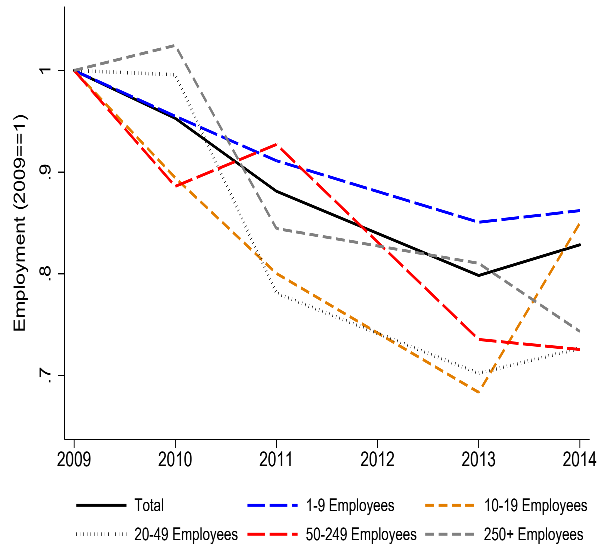
Figure B.2 decomposes the decline in labor productivity into a within-firm size component and a between-firm size component. Each industry is represented by a dot in the figure. For almost all industries, the decline in labor productivity is accounted for by declines in labor productivity within firms belonging to a particular size class rather than by a reallocation of economic activity across firms with different size classes and different levels of productivity.

B.2 Growth Accounting

This appendix details the construction of total factor productivity (TFP) and utilization.



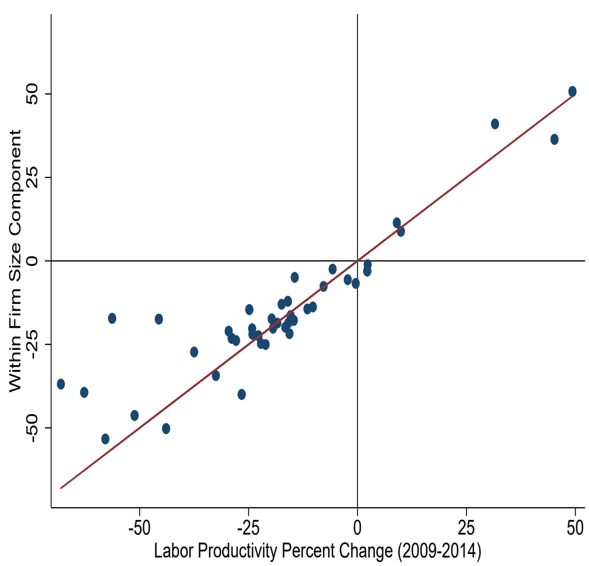
(a) Value Added



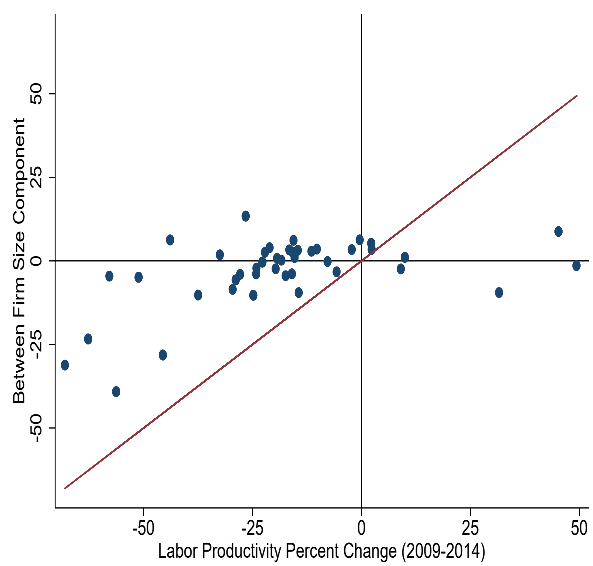
(b) Employment

Figure B.1: Value Added and Employment Trends by Size Class

Figure B.1 plots value-added and employment by firm size class based on data from the Structural Business Statistics.



(a) Within Component



(b) Between Component

Figure B.2: Labor Productivity Decomposition

Figure B.2 plots the within-firm size and between-firm size components of labor productivity growth based on data from the Structural Business Statistics.

B.2.1 Total Factor Productivity

We measure TFP as the Solow residual. Data on value-added and total hours worked come directly from Eurostat. We construct capital services by aggregating four types of capital (structures, machinery and equipment, cultivated biological resources, and intellectual property assets) using user cost weights based on actual depreciation and a required 5 percent net return.[2] Capital type-by-industry data come from the Eurostat non-financial asset accounts. Under the assumptions of competitive output markets and constant-returns-to-scale production, we calculate the hours elasticity by multiplying total labor compensation by the ratio of total to employee hours in each industry and obtain the capital elasticity as a residual.[3]

B.2.2 Utilization Measurement

Our main measures of utilization come from the Joint Harmonised European Union Industry Survey and the Joint Harmonised European Union Services Survey. Both surveys are administered quarterly by the European Commission and are representative of firms in their respective sectors. Since 1985, The Industry Survey has asked the question (INDU13QPS):

> *At what capacity is your company currently operating (as a percentage of full capacity)?*

We average the quarterly responses to obtain annual utilization for the manufacturing sector. In 2011 the Services Survey added the question (SERV8QPS):

> *If the demand expanded, could you increase your volume of activity with your present resources? If so, by how much?"*

For 2011 forward, we use the annual average of responses to this question to obtain utilization for the services sector. We extend the measure of utilization in the services sector further back in time using the fraction of respondents reporting "None" to the question (SERV7F1S):

> *What main factors are currently limiting your business?*

[2]We have experimented with thresholds for the required return up to 20 percent and an internal return based on capital income payments with little change in the results.

[3]As is well known, with non-competitive output markets the output elasticities equate to factor cost shares rather than factor revenue shares. It follows immediately that a time-invariant markup scales TFP growth by the markup. Time-varying markups pose additional difficulties which we do not pursue since we lack independent evidence on this margin.

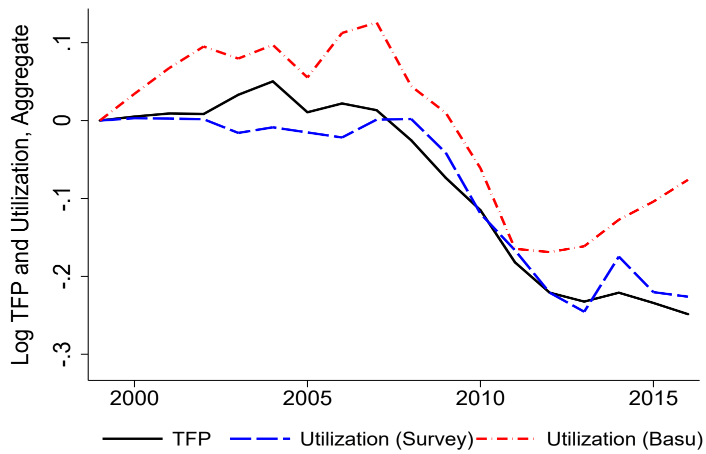


Figure B.3: Aggregate TFP and Alternative Measures of Utilization

Specifically, a regression of the four quarter change to question SERV8QPS, Δ_4SERV8QPS, on the four quarter change in this fraction, Δ_4SERV7F1S, yields:

$$\Delta_4\text{SERV8QPS} = -1.4 + 0.47\Delta_4\text{SERV7F1}, \ \ N = 19.$$

The Newey-West standard error with bandwidth of 4 on the coefficient for Δ_4SERV7F1 is 0.09 and the R^2 of the regression is 0.62, making the question a plausible proxy for the utilization question asked starting in 2011. We use the fitted values from this regression to impute SERV8QPS for quarters prior to 2011 and then take annual averages and cap the resulting measure at 100. Finally, as no survey measures exist covering agriculture or mining and quarrying, we assume no utilization margin exists in these industries.

We construct an alternative measure of utilization by building on the framework of Basu (1996). Suppressing superscripts for simplicity, this approach starts by specializing the production function for gross output to a CES aggregate of value-added $V(.)$ and materials m:

$$z\left[\xi_v^{\frac{1}{\sigma}}V\left(u_k k, u_\ell \ell\right)^{\frac{\sigma-1}{\sigma}} + \xi_m^{\frac{1}{\sigma}} m^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

where u_k and u_ℓ denote utilization of capital k and labor ℓ, ξ_v and ξ_m are distribution parameters, and σ is the elasticity of substitution between value added and materials. Letting R_v and R_m be the shadow costs of a unit of value-added and materials, cost minimization implies:

$$\mathrm{d}\log u \equiv \alpha_\ell \mathrm{d}\log u_\ell + \alpha_k \mathrm{d}\log u_k = \mathrm{d}\log m - (\alpha_\ell \mathrm{d}\log \ell + \alpha_k \mathrm{d}\log k) - \sigma\left(\mathrm{d}\log R_v - \mathrm{d}\log R_m\right). \quad \text{(B.1)}$$

Equation (B.1) says that when the growth of materials exceeds the weighted average growth of labor and capital, either the cost of materials must have risen by less than the cost of value-

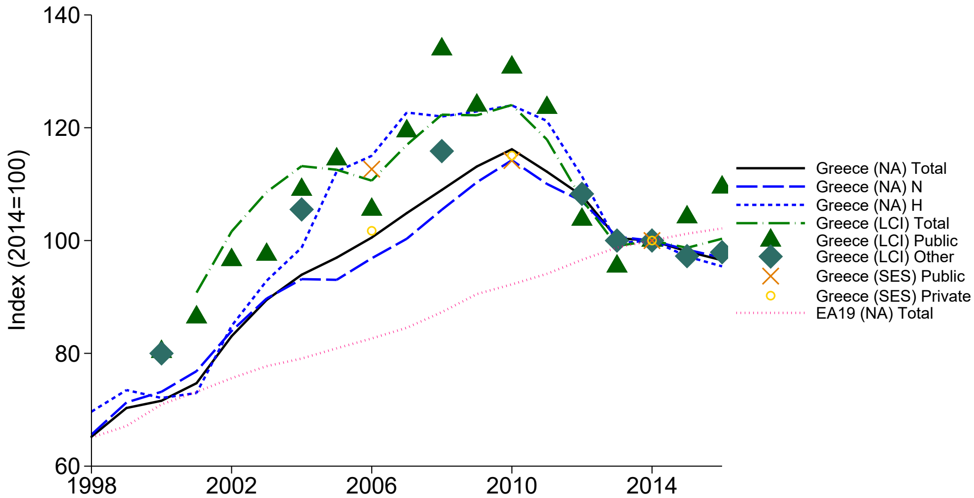


Figure B.4: Alternative Wage Series

Notes: The solid black line reports the ratio of total national accounts employee compensation to total employee hours worked. The dashed blue lines show the same wage concept separately for non-traded and traded industries. The dashed green line shows the labor cost index series for the total economy. The green triangles and diamonds show the labor cost indexes separately for public sector and private sector employees, respectively. The orange X and yellow o report public and private sector wages from the quadrennial Structure of Earnings Survey. The dotted pink line shows the national accounts wage measure for the total euro area.

added or unobserved utilization of capital and labor must have risen. When production is Leontief between value-added and materials ($\sigma = 0$), any excess growth of materials over labor and capital must reflect unobserved utilization. We implement equation (B.1) in the Leontief case. Figure B.3 plots aggregate TFP along with the two measures of utilization. As the figure shows, the survey measure of utilization displays a similar drop between 2007 and 2011 with the drop observed in the Basu (1996) measure of utilization.

B.3 Alternative Measures of Wages

Appendix B.3 reports alternative wage series. The wage data in this figure have not been detrended. The solid black line reports the measure used in the main analysis, equal to the ratio of total employee compensation to total employee hours worked. The dashed blue lines show the same wage concept separately for non-traded and traded industries. The dashed green line shows the labor cost index series for the total economy. The green triangles and diamonds show the labor cost indexes separately for public sector and private sector employees, respectively. The orange X and yellow o report public and private sector wages from the quadrennial Structure of Earnings

Survey. Finally, for comparison the dotted pink line shows the national accounts wage measure for the total euro area.

We next examine changes in hourly wages (not detrended) during the bust for different types of workers. These changes come from the Structure of Earnings Survey, a large sample enterprise-level survey conducted every four years by Eurostat. The sampling frame includes all establishments with at least 10 employees, excluding public administration. Table B.1 reports hourly wage changes between 2010 and 2014, by worker age, skill, and position in the within age-skill wage distribution. Strikingly, nominal wage declines occur across age groups, skill categories, and in all parts of the wage distribution. These patterns militate against interpretations of the aggregate data focused only on compositional effects or changes specific to certain parts of the wage distribution that arise, for example, from changes in the statutory minimum wage.

B.4 Downward Wage Rigidity Measures

In this appendix we repeat the analysis of Schmitt-Grohé and Uribe (2016) for the inference of downward nominal wage rigidity in our data. Before proceeding we make two comments. First, Schmitt-Grohé and Uribe (2016) infer the extent of downward wage rigidity using data between 2008 and 2011 and stopped their analysis in 2011 because later data were not available at the time they were conducting their analysis. Second, our inference of wage rigidity does not come from a particular time period as we estimate the model with Bayesian Maximum Likelihood using the time series of nominal wages between 1999 and 2016. Despite these differences, we document in this appendix that the inference of downward nominal wage rigidity can be sensitive to the timing of wage declines.

Schmitt-Grohé and Uribe (2016) impose a constraint of the form $W_t \geq \gamma W_{t-1}$ on the evolution of wages. Using quarterly data between 2008(1) and 2011(2), for Greece they estimate $\gamma^{\text{quarterly}}_{2011(2)/2008(1)} = 0.998$. To compare their to our estimates that come at annual frequency, we define the following two estimates of the extent of downward nominal wage rigidity:

$$\gamma^{\text{annual}}_t = \left(\frac{W_t}{W_{t-3}}\right)^{1/3}, \quad \gamma^{\text{quarterly}}_t = \left(\frac{W_t}{W_{t-3}}\right)^{1/12}. \tag{B.2}$$

In Table B.2 we calculate values of γ for different three year periods. We begin by noticing that, similarly to the experience of many other countries, the employment decline in Greece lagged the GDP decline by roughly one year. Our quarterly estimate of γ using data between 2008 and 2011

Table B.1: Hourly Earnings Changes by Group

Category	2010 emp. share	2010 mean wage	Percent change by mean/quantile, 2010-2014:			
			Mean	Decile 1	Median	Decile 9
All ages						
Non manual workers	74.4	11.61	−12.6	−15.4	−7.1	−8.4
Skilled manual workers	15.4	10.3	−14.8	−17.9	−11.6	−14.4
Elementary occupations	10.3	7.37	−18.9	−22.8	−27.2	−7.6
Total	100.0	10.97	−13.6	−31.0	−11.6	−10.1
Age less than 30						
Non manual workers	78.7	7.37	−22.5	−40.7	−24.2	−18.0
Skilled manual workers	12.6	7.39	−18.4	−41.3	−28.2	−14.3
Elementary occupations	8.7	6.25	−21.8	−36.8	−16.0	−15.2
Total	100.0	7.28	−22.8	−40.4	−24.1	−24.2
Age 30-39						
Non manual workers	77.6	10.06	−16.6	−16.7	−8.8	−15.4
Skilled manual workers	13.9	9.05	−14.0	−32.7	−17.5	−16.3
Elementary occupations	8.5	6.93	−18.0	−22.5	−24.5	−9.1
Total	100.0	9.66	−16.7	−31.7	−17.1	−18.5
Age 40-49						
Non manual workers	73.6	12.83	−14.1	−25.4	−14.5	−11.9
Skilled manual workers	15.9	11.05	−17.0	−25.9	−16.1	−14.0
Elementary occupations	10.5	7.53	−17.0	−23.4	−14.5	−10.4
Total	100.0	11.99	−14.7	−21.6	−13.8	−14.0
Age 50-59						
Non manual workers	66.2	15.79	−12.7	−17.8	−13.2	−15.7
Skilled manual workers	19.6	12.52	−17.0	−28.5	−14.6	−20.2
Elementary occupations	14.2	8.2	−19.6	−27.1	−18.9	−13.6
Total	100.0	14.07	−13.0	−24.5	−10.8	−18.1
Age greater than 59						
Non manual workers	72.3	19.91	−16.5	−10.3	−13.7	−21.9
Skilled manual workers	14.6	9.49	−6.1	−39.0	−15.6	7.7
Elementary occupations	13.1	7.79	−19.9	−29.0	−15.0	−19.6
Total	100.0	16.79	−15.8	−25.1	−8.7	−23.9

Table B.2: Downward Wage Rigidity Estimates

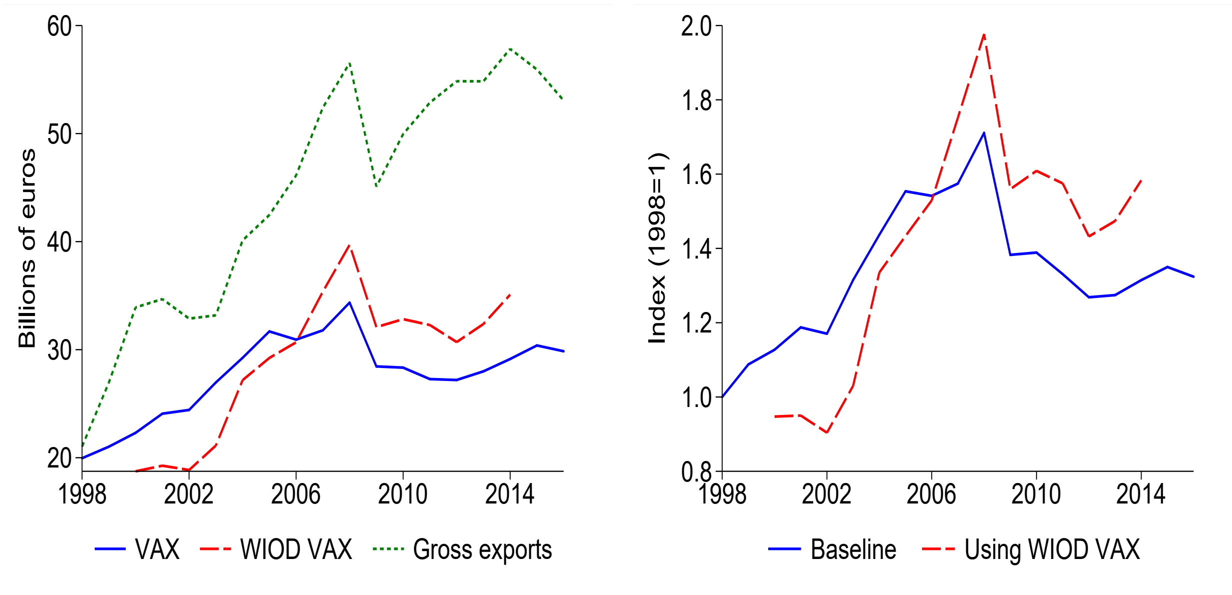
	Variables (detrended)			Implied γ	
(percent)	Real GDP	Employment	Wages	Annual	Quarterly
2010-2007	-15.6	-2.9	-0.5	0.998	1.000
2011-2008	-22.7	-10.2	-7.0	0.976	0.994
2012-2009	-24.6	-14.3	-12.2	0.957	0.989
2013-2010	-22.1	-13.3	-21.4	0.923	0.980

is 0.994. Part of the difference between our estimate of 0.994 and the estimate 0.998 in Schmitt-Grohé and Uribe (2016) comes from the different detrending. Schmitt-Grohé and Uribe (2016) detrend wages with 2.4 percent, appealing to the fact that growth in Southern European countries between 1990 and 2011 averaged 1.2 percent per year and inflation in Germany during 2008 and 2011 averaged 1.2 percent per year. We detrend wages with 3 percent, appealing to the fact that growth in Greece between 1970 and 1998 averaged roughly 2 percent and euro inflation between 1999 and 2016 averaged roughly 1 percent. The remaining difference in our estimates come from the fact that we use annual data (which averages across quarters) whereas Schmitt-Grohé and Uribe (2016) use data between 2008(1) and 2011(2).

Moving across rows in Table B.2 illustrates the sensitivity of the estimated γ to the three year window used in the estimation. During the particular Greek experience, the estimated γ falls when latter data is used during the recession. For example, if one used 2009 to 2012, which represents the window with the maximal GDP and employment decline, the quarterly γ is 0.989 and the annual γ is 0.957.

B.5 Alternative Measures of Exports and External Demand

This appendix reports alternative measures of value-added exports and external demand $\bar{a}_{T,t}$. Appendix Figure B.5 summarizes the results. The solid blue line in the left panel reports value-added exports (VAX) as implied by equation (19) of the main text. The dashed red line reports value-added exports using the procedure of Johnson and Noguera (2012) applied to the World Input-Output Database (WIOD), as described in detail in Appendix B.8. The dotted green line shows gross exports as reported in the national accounts. The right panel compares our preferred



(a) Exports

(b) External Demand $\bar{a}_T$

Figure B.5: Alternative Export and External Demand $\bar{a}_T$ Series

VAX stands for value-added exports and WIOD for the World Input-Output Database. The left panel compares VAX using the procedure described in equation (19) of the main text to the VAX obtained from applying the Johnson and Noguera (2012) procedure to the WIOD and to gross exports as reported in the national accounts. The right panel compares our preferred measure of external demand $\bar{a}_T$ to an alternative measure constructed using the WIOD VAX.

series for $\bar{a}_{T,t}$ (the solid blue line) to an alternative series constructed using the WIOD VAX (the dashed red line).

To gain further insight into the decline in $\bar{a}_T$ during the bust, Table B.3 reports the 2007 to 2014 change in gross exports and value-added exports by industry using the WIOD data, expressed as a percent of 2007 GDP. Four features merit mention. First, total gross exports barely grow despite the real exchange rate depreciation. Second, value-added exports actually fall, highlighting the importance of separating gross from value-added exports. Third, the difference between gross and value-added exports mostly comes from the refined petroleum industry, reflecting Greece's status as an importer of crude and exporter of refined petroleum. Fourth, the fall in shipping (formally, water transport) more than accounts for the decline in value-added exports.

B.6 Estimation of the Disaster Probability

We follow Barro and Liao (2016) to recover the time series of disaster probabilities π_t from prices of far-out-of-the-money put options. Important assumptions in the Barro and Liao (2016) model

Table B.3: Change in Exports, 2007 to 2014, WIOD

Industry	Gross exports	Value-added exports
	(Percent of 2007 GDP)	
Agriculture, forestry, fishing	0.14	0.08
Mining and quarrying	−0.04	0.04
Manufacture of coke and refined petroleum products	4.82	0.76
Other manufacturing	−0.62	−0.26
Land transport and transport via pipelines	−0.08	−0.15
Water transport	−3.08	−2.27
Air transport	0.01	0.03
All industries	0.30	−1.61

Notes: The table reports the change from 2007 to 2014 in nominal gross exports and value-added exports as measured in the World Input-Output Database, expressed as a percent of 2007 GDP. The last row includes industries not shown individually in the table.

are: (i) a representative agent with Epstein-Zin preferences; (ii) a downward jump component in the process for output; and (iii) a power law distribution of output loss conditional on a downward jump occurring.

Let $\Omega_{i,t}$ denote the price, expressed as a ratio to the date t stock price, of put option i at date t with strike S_i and remaining maturity $T_{i,t}$ in days. Let "moneyness" $M_{i,t}$ denote the ratio of S_i to the date t stock price. Equation (25) of Barro and Liao (2016) prices a put option with short enough maturity $T_{i,t}$ and low enough moneyness $M_{i,t}$ such that drift and diffusion components of the process for output growth have negligible effect on the option's price:

$$\Omega_{i,t} = \left[\frac{\alpha L_0^\alpha}{(\alpha - \sigma)(1 + \alpha - \sigma)}\right] T_{i,t} M_{i,t}^{1+\alpha-\sigma} \pi_t, \tag{B.3}$$

where α is the Pareto coefficient for loss conditional on a disaster occurring, L_0 is the minimum disaster size, σ is the coefficient of relative risk aversion, and π_t is the daily disaster probability. Thus, the model predicts a unit elasticity of the option price with respect to time-to-maturity and an elasticity with respect to moneyness which is a function of the Pareto coefficient and risk aversion.

Our data contain the universe of put options traded on the Athens Stock Exchange between 2001 and 2017.[4] Starting from the universe of transactions (53,121 observations), we keep only

[4]These data are available for purchase from the exchange: `http://www.helex.gr/en/web/guest/markets-derivatives` (last accessed November 29, 2018).

options on the FTSE/Athex Large Cap Index (renamed from FTSE/ATHEX 20 on December 3, 2012, 49,154 observations) and further follow Barro and Liao (2016) in restricting the estimation sample to options with maturity remaining of less than six months and moneyness less than 0.9 (4,025 observations). The estimation is robust to restricting maturity remaining to less than 60 or 30 days and to restricting to options at least 15 percent out of the money.

We take logs of equation (B.3) and estimate using OLS the log-linear equation:

$$\ln \Omega_{i,t} = b_T \ln T_{i,t} + b_M \ln M_{i,t} + d_{t_m} + \text{error}_{i,t}, \tag{B.4}$$

where b_T and b_M are coefficients to be estimated and d_{t_m} is a month fixed effect.[5] The model fits the data well. We estimate $\hat{b}_T = 1.16$, $\hat{b}_M = 5.82$, and obtain an $R^2 = 0.83$ and a "within" R^2 of 0.71. The estimate of $\hat{b}_T$ is close to the theory-predicted value of one and our recovered time series of π_t changes little if we impose $b_T = 1$ in the estimation. The estimate of $\hat{b}_M = 5.82$ is nearly identical to the estimate reported in Barro and Liao (2016) of 5.83 pooling across the nine countries in their data (none of which is Greece).

The exponentiated fixed effect $\exp(d_{t_m})$ pins down changes over time but not the level of the disaster probability. To obtain the level requires parameterizing the term in brackets in equation (B.3). We follow Barro and Liao (2016) and assume a minimum size of disaster L_0 of 10 percent and a coefficient of risk aversion $\sigma = 3$. Matching coefficients in equation (B.3) and equation (B.4), we obtain $\alpha = \hat{b}_M + \sigma - 1 = 7.82$. Given this estimate of α, we then recover the bracketed term in equation (B.3) and back out monthly averages of daily disaster probability as $\pi_t = \exp(d_{t_m}) / \left[\frac{\alpha L_0^\alpha}{(\alpha-\sigma)(1+\alpha-\sigma)}\right]$. We annualize these daily disaster probabilities and average across months in a year to arrive at the disaster probability series used in our analyses. Figure B.6 reports the monthly probabilities along with markers of important political and economic events. Finally, given the minimum size of disaster L_0 and our estimate of α, we recover a mean decline in output conditional on a disaster occurring equal 21 percent.

B.7 Measurement of Tax Rates

Greece levies taxes on transactions, individuals, corporations, and property. We allocate all tax receipts and actual social contributions into taxes on consumption, investment, labor, and capital. The two largest revenue categories are taxes on production and imports (code D.2) that account

[5] With more data, we could estimate a date fixed effect d_t rather than a month fixed effect d_{t_m}. The month fixed effect constrains the date fixed effects to be the same for every day in a month.

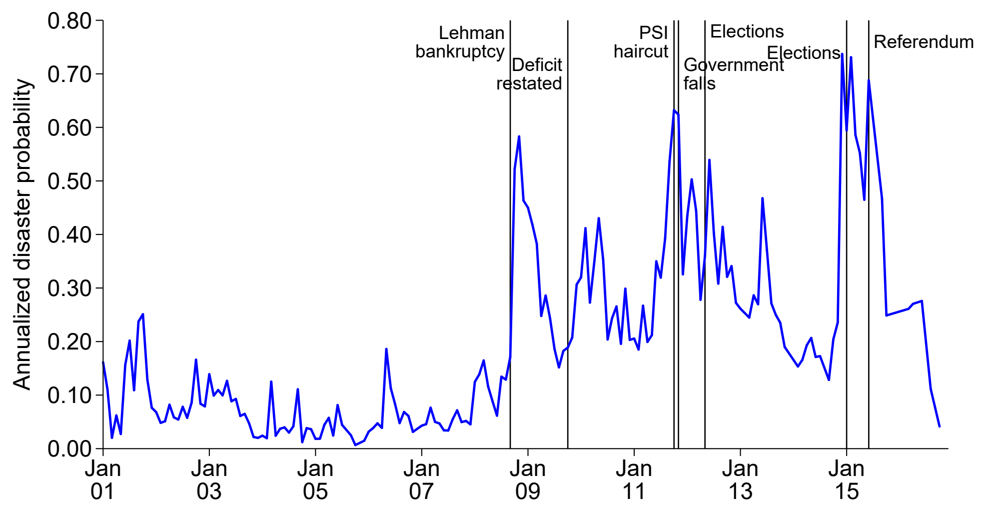


Figure B.6: Monthly Probability of Disaster

for roughly 60 percent of tax receipts and current taxes on income and wealth (D.5) that account for roughly 40 percent of tax receipts. Taxes on production and imports less subsidies are allocated to consumption and investment, with the exception of property taxes paid by enterprises (D.29) which are allocated to capital income. From taxes on production and imports net of property taxes, we allocate to consumption the taxes that unambiguously fall into consumption such as excise duties, taxes on entertainment, lotteries, and gambling, taxes on insurance premiums, and other taxes on specific services. We then allocate the residual to consumption taxes and investment taxes in proportion to their expenditure shares and calculate the tax rates as:

$$\tau^c = \frac{\text{consumption taxes}}{\text{consumption} - \text{consumption taxes}}, \quad \tau^x = \frac{\text{investment taxes}}{\text{investment} - \text{investment taxes}}. \tag{B.5}$$

The denominators subtract taxes from spending because in national accounts spending is at market prices and includes taxes.

Current taxes on individual's income fall on both labor and capital and current taxes on the income of corporations fall on capital. We measure the labor income tax rate τ^ℓ as the sum of the tax rate on social security contributions τ^{SS} and the tax rate on labor income net of social security contributions τ^{NL}, where:

$$\tau^{\text{SS}} = \frac{\text{social security contributions}}{\text{labor income}}, \quad \tau^{\text{NL}} = \tau^y \left(1 - \frac{\text{social security contributions}}{\text{labor income}}\right). \tag{B.6}$$

Labor income in the denominators equals compensation of employees, which includes social security contributions, adjusted for the income of the self-employed that we allocate proportionally between labor and capital. For τ^{SS}, we use an average tax rate because contribution rates are generally flat within each occupation up to a cap that, according to the Statistics of Income (SOI), affects less than two percent of tax payers.

The tax rate τ^{NL} equals the fraction of labor income not subject to social security contributions taxed at the individual income tax rate τ^{y}, where:

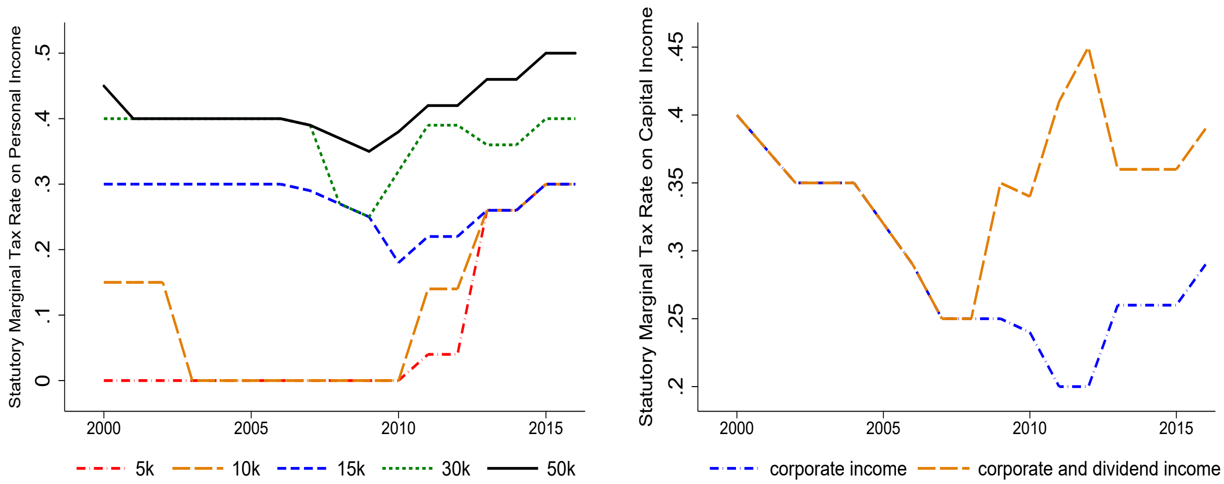
$$\tau^{y} = \frac{2.08 \times (\text{taxes on individual income} - \text{taxes on dividends and interest})}{\text{GDP} - \text{production, imports taxes, contributions, depreciation, dividends, interest}}. \quad \text{(B.7)}$$

In Greece taxes are levied on individual income which consists of unambiguous labor income (such as income from salaried workers), unambiguous capital income (such as dividends, interest, and rentals), and ambiguous income (such as income from self-employment, agriculture, and liberal professions). The denominator of equation (B.7) denotes taxable income which, in addition to taxes on production and imports, contributions, and depreciation, excludes dividends and interest because for those types of capital income we have independent information on their taxes and allocate them directly to capital taxes. The factor 2.08 represents our estimate of the gap between the average marginal tax rate and the average average tax rate.[6]

We measure capital tax rates τ_H^k and τ_N^k as capital tax payments divided by taxable capital income generated in each sector. There are six types of capital tax payments. Property taxes paid by households are allocated to the non-traded sector. Property taxes paid by corporations are allocated to each sector in proportion to its share of non-residential structures used in production. The other four categories, taxes on dividends and interest, income and capital gains taxes paid by corporations, taxes on capital income paid by households, and other capital taxes, are allocated to each sector in proportion to its share of capital income net of depreciation. Dividend and interest taxes are calculated as the product of their respective time-varying statutory tax rates with the size of dividends and interests from the national accounts. Income and capital gains taxes paid by corporations come directly from national accounts (in code D.51). Capital income taxes paid by individuals equals the product of the individual income tax rate τ^{y} in equation (B.7) with the share of net income accruing to capital. Other capital taxes (code D.91) include inheritance taxes, death duties, taxes on gifts, and capital levies. Finally, taxable capital income equals the capital share of GDP less net taxes on products and imports less depreciation.

In Figure B.7 we document the time series of statutory measures of taxes.

[6] To estimate this ratio, we use binned up data from the SOI in Greece between 2006 and 2011. This ratio is relatively stable over time. The SOI data has not been publicly disclosed after 2011.



(a) Personal Income Tax Rates by Income Level

(b) Capital Tax Rates

Figure B.7: Statutory Labor and Capital Tax Rates

B.8 Estimation of the Trade Elasticity of Substitution

Aggregating equation (13) across retailers and using the corresponding expression for the demand for the foreign traded good, we obtain an expression relating relative expenditure on domestic and foreign traded goods and the relative prices of these bundles:

$$\ln(P_{H,t}a_{H,t}/P_{F,t}a_{F,t}) = \ln\left(\gamma/\left(1-\gamma\right)\right) + \left(1-\eta\right)\ln(P_{H,t}/P_{F,t}), \tag{B.8}$$

where $a_{H,t}$ and $a_{F,t}$ denote Greek expenditure on the domestic and foreign traded goods, respectively. First differencing equation (B.8) and allowing for a normalizing constant and measurement error in relative absorption yields the estimating equation:

$$\Delta\ln(P_{H,t}a_{H,t}/P_{F,t}a_{F,t}) = b_0 + b_1\Delta\ln(P_{H,t}/P_{F,t}) + e_t, \tag{B.9}$$

where $\eta = 1 - b_1$. The identifying assumption is that preferences for Greek versus foreign goods, γ in our notation, are stable over time and hence do not appear in the linearized equation (B.9).

We estimate equation (B.9) using Eurostat data and identifying F with the euro area. Since our model abstracts from intermediate inputs in production, the price indexes and quantities in equation (B.9) correspond to a value-added concept. Value-added price indexes for the Greek (H) and euro area (F) traded goods sector come directly from the national accounts. However, national accounts do not report either value-added exports or imports. We extend the procedure in Johnson and Noguera (2012) and apply it to the World Input-Output Database (WIOD) described to recover Greek value-added exports to and imports from the euro area.[7] Estimating equation (B.9) over the period 2000-14, the maximum sample for which we have data from the WIOD, yields $\eta = 1.65$ with standard error equal to 0.25.

We now describe the Johnson and Noguera (2012) procedure for obtaining value-added exports to and imports from the euro area. The key equation is the (nominal) market-clearing condition:

$$\mathbf{Q} = \sum_j (\mathbf{I} - \mathbf{M})^{-1} \mathbf{c_j}, \tag{B.10}$$

where $\mathbf{Q}$ is an $NS \times 1$ vector of nominal gross output in each industry $s \in S$ and country $j \in N$, $\mathbf{c_j}$ is an $NS \times 1$ vector of final demand in country j of output from each country-sector, $\mathbf{M}$ is a global input-output matrix with generic entry given by the share of intermediate goods produced in sector s in country j used in sector s' of country i as a share of output of sector s' in country i, and we have dropped time subscripts for simplicity since the relationship in equation (B.10) holds statically. Under the assumption that the value-added content of an industry does not depend on whether the output is used domestically or exported, one can pre-multiply both sides by a diagonal matrix $\mathbf{R}$ of value-added shares of gross output in each country-sector to obtain:

$$\mathbf{Py} = \mathbf{R} \sum_j (\mathbf{I} - \mathbf{M})^{-1} \mathbf{c_j}, \tag{B.11}$$

where $\mathbf{Py}$ is the vector of nominal value-added. Total value-added exports from Greece are then:

$$P_H a_H^* = \iota'_{Greece} \mathbf{R} \sum_{j \neq Greece} (\mathbf{I} - \mathbf{M})^{-1} \mathbf{c_j}, \tag{B.12}$$

where ι_j is an $NS \times 1$ selection vector with a value of one in the rows corresponding to the traded sectors in country j and zeros elsewhere.[8] Greek value-added absorption of Greek traded goods is:

$$P_H a_H = P_H y_H - P_H a_H^*. \tag{B.13}$$

Similarly, we obtain Greek value-added imports from the euro area as:

$$P_F a_F = \sum_{j \in euro\ area} \iota'_j \mathbf{R} (\mathbf{I} - \mathbf{M})^{-1} \mathbf{c}_{Greece}. \tag{B.14}$$

[7] For a description of the WIOD, see Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), "An Illustrated User Guide to the World InputOutput Database: the Case of Global Automotive Production", Review of International Economics 23: 575605.

[8] In practice, we sum over the sectors which we include in the traded sector aggregate, even though other sectors may have small but positive value-added exports.

We make five remarks on the estimation of η. First, most Greek trade occurs with partners outside of the euro area. This fact does not invalidate the above procedure, because equation (B.8) follows directly from a first order condition for the relative expenditure between any two bundles of goods available to Greeks. Second, our model assumes the same elasticity governs both imports and exports. In that case, one can also estimate η using relative absorption of Greek and euro area products by euro area residents. Using the WIOD data, we obtain an almost identical coefficient of 1.64 for this specification (standard error 0.80). Third, two recent papers have raised criticisms of regressions designed to uncover the Armington elasticity. Imbs and Mejean (2015) argue that elasticity estimates based on aggregate data may understate the true elasticity because most aggregate variation comes from sectors with volatile prices which may also have low elasticities.[9] In our data, however, the aggregate elasticity exceeds the weighted mean sectoral elasticity, which is almost exactly unity. Feenstra, Luck, Obstfeld, and Russ (2018) argue the relevant elasticity in most models is that between domestic goods and imports but many papers instead estimate an elasticity across exports from different countries.[10] Equation (B.9) directly estimates the appropriate elasticity as advocated by Feenstra, Luck, Obstfeld, and Russ (2018). Fourth, we prefer the first-differenced specification (B.9) because any changes to preferences likely accumulate over time, making the levels specification (B.8) more vulnerable to mis-specification. Nonetheless, estimating the equation in levels implies a slightly lower estimate of η of 1.25 (standard error 0.15). Fifth, the WIOD does not measure local purchases by non-residents and hence the WIOD VAX measure excludes tourism exports. Effectively, we impute the same elasticity to the tourism sector as we obtain for other traded sectors.

We obtain γ as the sample average ratio of domestic absorption of domestic traded to domestic absorption of all traded, where we first normalize each variable by domestic output:

$$\gamma = \left[\left(\overline{\frac{P_{H,t} y_{H,t}}{P_t y_t}} \right) - \left(\overline{\frac{a_{H,t^*}}{P_t y_t}} \right) \right] \Big/ \left(\overline{\frac{P_{H,t} a_{H,t}}{P_t y_t}} \right).$$

Here, since γ depends on properly measuring the level of Greek absorption of Greek traded value-added, we add to the WIOD VAX Greek tourism exports reported in the Balance of Payments scaled by the ratio of value-added to gross output in accommodation and food services to arrive at a measure of value-added exports.

[9] Imbs, J., and I. Mejean (2015): "Elasticity Optimism," American Economic Journal: Macroeconomics, 7(3), 43-83.

[10] Feenstra, R. C., P. Luck, M. Obstfeld, and K. N. Russ (2018): "In Search of the Armington Elasticity," The Review of Economics and Statistics, 100(1), 135-150.

C Additional Model Results

In this appendix we present additional results from the model.

- Figure C.1 presents the path of variables in the model under a first-order (baseline), second-order, and third-order approximation of the policy functions. Second and third-order approximations are pruned. We start the higher-order approximations at the same initial point as the first-order approximation, which is the deterministic steady state in 1998. The plotted paths in the higher-order approximation difference out effects arising from differential transitional dynamics by taking the difference between the path with all innovations and the path with no innovations.

- Table C.1 presents the priors used in the estimation and various other statistics of the estimated parameters.

- Table C.2 presents estimated parameters under a higher prior mean for the adjustment costs of prices and wages. Figure C.2 shows that the model-generated paths of variables under the parameters estimated with these higher mean priors are similar to the paths under the baseline estimation.

- Figure C.3 compares model-generated variables to variables in the data without detrending. For this figure, we reestimate all model parameters. The estimated values for the price and wage rigidity are $\psi_p = 61$ (confidence interval 30 to 91) and $\psi_w = 42$ (confidence interval 9 to 76) as opposed to $\psi_p = 47$ (confidence interval 21 to 70) and $\psi_w = 38$ (confidence interval 6 to 67) in the baseline when we detrend the data.

- Table C.3 presents the sources of macroeconomic dynamics during the first part of the bust (2007-2012).

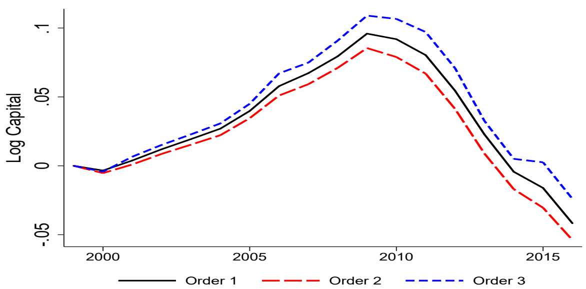
- Table C.4 present fiscal multipliers financed with lump sum transfers T^o at horizon $h = 1$ for various alternative parameter values.

- Table C.5 present fiscal multipliers financed initially with deficit B^g and then with lump sum transfers T^r and T^o at horizon $h = 1$ for various alternative parameter values.

- Table C.6 present fiscal multipliers financed initially with deficit B^g and then with lump sum transfers T^r and T^o at horizon $h = 7$ for various alternative parameter values.

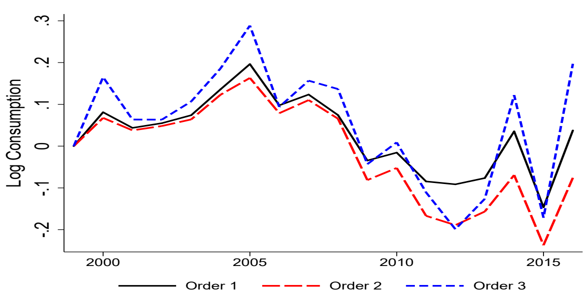
(a) Time Series of y

(b) Time Series of ℓ



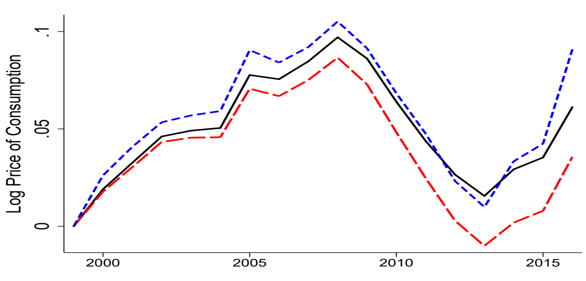
(c) Time Series of $\tilde{k}$

(d) Time Series of TFP

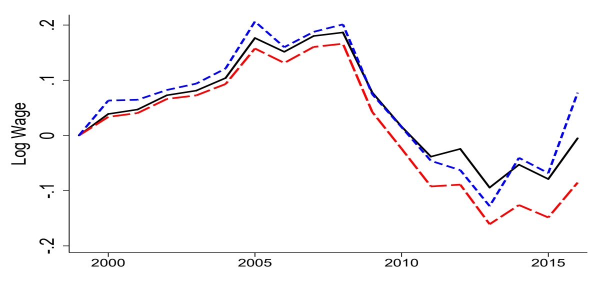


(e) Time Series of c

(f) Time Series of x



(g) Time Series of P_c



(h) Time Series of W

Figure C.1: Path of Variables with Higher-Order Approximations

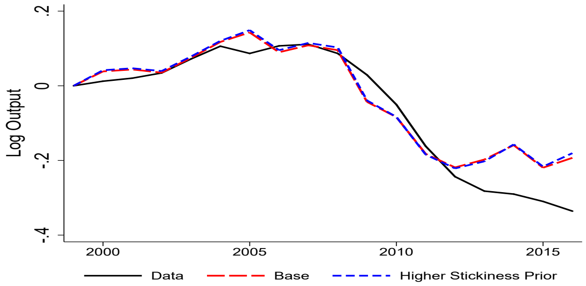
Figure C.1 plots model-generated variables under the baseline parameterization and different degrees of approximation of the equilibrium conditions. y is output, ℓ is labor, $\tilde{k}$ is the capital stock, TFP is total factor productivity, c is consumption, x is investment, P_c is the price of consumption, and W is wages. Quantities are detrended with 2 percent per year, TFP with 0.9 percent, prices with 1 percent, and wages with 3 percent.

Table C.1: Estimated Parameters

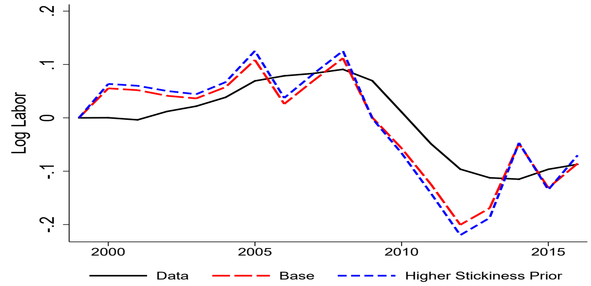
	Priors				Posteriors		
Parameter	Distribution	Support	Mean	St. Deviation	Mean	Median	90 Percent Interval
ρ	Beta	$[0, 2]$	1.00	0.25	0.32	0.31	[0.18,0.45]
ϕ	Gamma	$(0, \infty)$	0.44	0.20	0.79	0.74	[0.26,1.31]
ϵ	Gamma	$(0, \infty)$	1.50	0.75	0.48	0.46	[0.26,0.65]
κ	Beta	$[0, 1]$	0.25	0.15	0.12	0.09	[0.00,0.26]
ζ	Beta	$[0, 1]$	0.23	0.13	0.43	0.43	[0.33,0.54]
ξ_H	Gamma	$(0, \infty)$	4.00	1.00	4.98	4.96	[4.52,5.43]
ξ_N	Gamma	$(0, \infty)$	4.00	1.00	3.22	3.19	[2.75,3.65]
ψ_π	Gamma	$(0, \infty)$	0.50	0.25	0.14	0.13	[0.04,0.24]
ψ_k	Gamma	$(0, \infty)$	7.00	2.00	11.58	11.38	[8.16,15.14]
ψ_p	Gamma	$(0, \infty)$	40.00	25.00	47.16	45.08	[21.07,70.73]
ψ_w	Gamma	$(0, \infty)$	40.00	25.00	38.08	33.56	[6.25,66.89]

Table C.2: Estimated Parameters with Higher Priors Means for Price and Wage Adjustment Costs

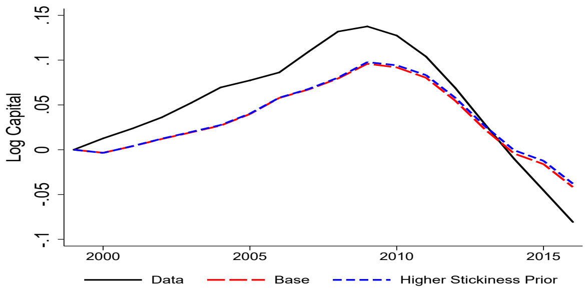
	Priors				Posteriors		
Parameter	Distribution	Support	Mean	St. Deviation	Mean	Median	90 Percent Interval
ρ	Beta	$[0, 2]$	1.00	0.25	0.32	0.31	[0.19,0.45]
ϕ	Gamma	$(0, \infty)$	0.44	0.20	0.77	0.72	[0.25,1.26]
ϵ	Gamma	$(0, \infty)$	1.50	0.75	0.33	0.29	[0.11,0.55]
κ	Beta	$[0, 1]$	0.25	0.15	0.12	0.10	[0.00,0.26]
ζ	Beta	$[0, 1]$	0.23	0.13	0.42	0.42	[0.32,0.54]
ξ_H	Gamma	$(0, \infty)$	4.00	1.00	5.13	5.10	[4.60,5.65]
ξ_N	Gamma	$(0, \infty)$	4.00	1.00	3.40	3.36	[2.88,3.93]
ψ_π	Gamma	$(0, \infty)$	0.50	0.25	0.15	0.14	[0.04,0.26]
ψ_k	Gamma	$(0, \infty)$	7.00	2.00	11.57	11.36	[7.97,15.14]
ψ_p	Gamma	$(0, \infty)$	120.00	75.00	66.21	63.68	[30.05,98.46]
ψ_w	Gamma	$(0, \infty)$	120.00	75.00	87.10	76.19	[10.95,159.89]



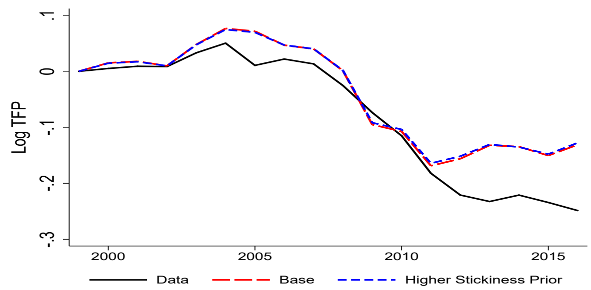
(a) Time Series of y



(b) Time Series of ℓ



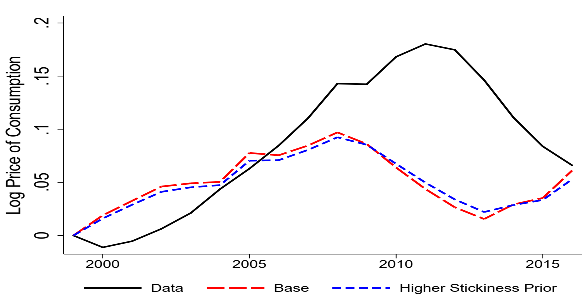
(c) Time Series of $\tilde{k}$



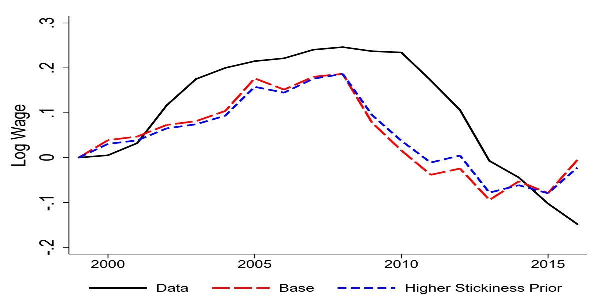
(d) Time Series of TFP

(e) Time Series of c

(f) Time Series of x



(g) Time Series of P_c



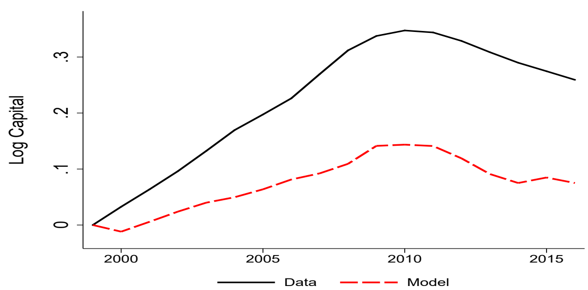
(h) Time Series of W

Figure C.2: Path of Variables with Higher Priors Means for Price and Wage Adjustment Costs

Figure C.2 plots variables in the data, model-generated variables under the baseline estimation, and model-generated variables under the estimation with higher prior means for price and wage stickiness. y is output, ℓ is labor, $\tilde{k}$ is the capital stock, TFP is total factor productivity, c is consumption, x is investment, P_c is the price of consumption, and W is wages. Quantities are detrended with 2 percent per year, TFP with 0.9 percent, prices with 1 percent, and wages with 3 percent.

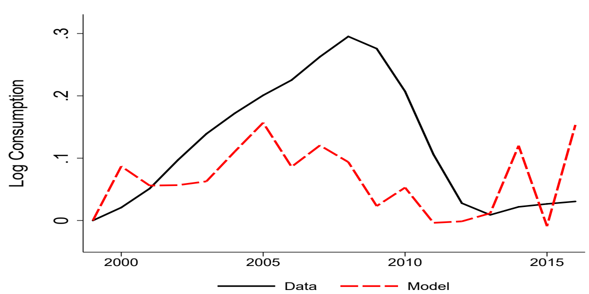
(a) Time Series of y

(b) Time Series of ℓ



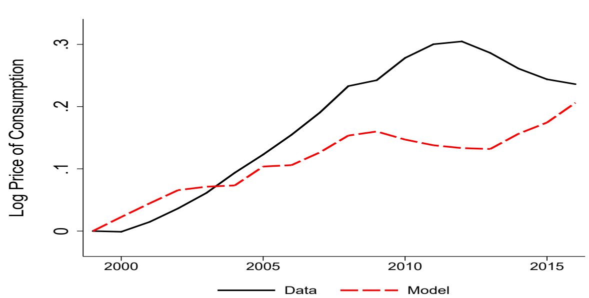
(c) Time Series of $\tilde{k}$

(d) Time Series of TFP



(e) Time Series of c

(f) Time Series of x



(g) Time Series of P_c

(h) Time Series of W

Figure C.3: Model vs Data Without Detrending

Figure C.3 compares data to model-generated variables when we do not detrend the data and reestimate all model parameters. y is output, ℓ is labor, $\tilde{k}$ is the capital stock, TFP is total factor productivity, c is consumption, x is investment, P_c is the price of consumption, and W is wages.

Table C.3: Sources of Macroeconomic Dynamics: Bust Period 2007-2012

Process	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log \text{TFP}$	$\log c$	$\log P_c$	$\log P_N$	$\log W$
Data	-0.35	-0.18	-0.04	-0.23	-0.33	0.06	0.03	-0.13
Model	-0.33	-0.27	-0.01	-0.20	-0.21	-0.06	-0.08	-0.20
Productivity	-0.08	-0.05	0.00	-0.06	-0.06	-0.01	-0.02	-0.06
$\log z_H$	-0.08	-0.01	0.00	-0.07	-0.05	0.00	-0.01	-0.04
$\log z_N$	-0.01	-0.04	0.01	0.01	-0.02	0.00	-0.01	-0.02
External	-0.10	-0.09	0.00	-0.05	-0.08	-0.06	-0.07	-0.16
$\log \bar{a}_T$	-0.09	-0.08	0.00	-0.05	-0.08	-0.05	-0.06	-0.15
$\log P_F^*$	0.00	-0.01	0.00	0.00	0.00	-0.01	-0.01	-0.01
Financial	-0.03	-0.01	-0.01	-0.02	-0.12	-0.03	-0.04	-0.09
$\log B^g$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
$\log \bar{B}^r$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
r^*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
i^*	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
θ	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
π	-0.03	-0.01	-0.01	-0.02	-0.12	-0.03	-0.03	-0.08
Fiscal Spending	-0.07	-0.08	0.00	-0.04	0.09	-0.01	-0.01	-0.01
$\log g$	-0.06	-0.06	0.00	-0.03	0.12	-0.01	-0.01	0.00
$\log T^r$	-0.01	-0.01	0.00	-0.01	-0.03	0.00	0.00	-0.01
Tax Rates	-0.04	-0.04	-0.01	-0.02	-0.03	0.05	0.06	0.11
τ^c	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
τ^x	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
τ^ℓ	-0.02	-0.05	0.00	0.00	-0.03	0.01	0.01	0.08
τ_H^k	-0.01	0.01	0.00	-0.01	0.00	0.00	0.00	0.00
τ_N^k	-0.01	0.01	0.00	-0.01	0.00	0.03	0.04	0.03

Table C.4: Fiscal Multipliers: T^o financed, horizon $h = 1$

Parameters	g	ζT^r	τ^c	τ^x	τ^ℓ	τ^k_H	τ^k_N
Baseline Model	0.50	0.60	-0.25	-0.02	-0.26	-0.04	0.02
$\rho_f = 0.30$	1.25	0.89	-0.31	-0.10	-0.23	-0.02	0.01
$\rho_f = 0.75$	1.09	0.71	-0.27	-0.10	-0.26	-0.03	-0.01
$\xi_H = \xi_N = \infty$	0.48	0.57	-0.24	-0.01	-0.26	-0.03	0.02
$\xi_H = \xi_N = 2$	0.50	0.61	-0.26	-0.02	-0.26	-0.03	0.04
$\epsilon = 1$	0.62	0.57	-0.27	-0.03	-0.31	-0.04	0.02
$\rho = 1$	0.47	0.49	-0.35	0.00	-0.21	-0.05	0.04
$\zeta = 0$	0.49	.	-0.16	-0.06	-0.22	-0.05	-0.02
$\eta = 0.9$	0.51	0.65	-0.24	0.15	-0.19	0.02	0.10
$\eta = 2.4$	0.50	0.57	-0.26	-0.09	-0.31	-0.07	-0.01
$\psi_p = 0$	0.41	0.33	-0.21	-0.23	-0.72	-0.17	-0.16
$\psi_p = 1000$	0.55	0.77	-0.27	0.09	-0.12	0.03	0.12
$\psi_w = 0$	0.50	0.56	-0.25	-0.03	-0.22	-0.04	0.01
$\psi_w = 1000$	0.50	0.70	-0.25	0.02	-0.37	-0.04	0.08
$\psi_\pi = 0$	0.50	0.60	-0.25	-0.03	-0.26	-0.04	0.02
$\psi_\pi = 0.5$	0.53	0.61	-0.26	0.03	-0.26	-0.03	0.05
$\psi_k = 0$	0.78	0.95	-0.32	0.30	-0.27	0.09	0.34
$\psi_k = 100$	0.50	0.59	-0.25	-0.03	-0.26	-0.04	0.02

Table C.5: Fiscal Multipliers: B^g, T^r, T^o financed, horizon $h = 1$

Parameters	g	ζT^r	τ^c	τ^x	τ^ℓ	τ_H^k	τ_N^k
Baseline Model	0.90	0.72	-0.30	0.02	-0.31	-0.03	0.00
$\rho_f = 0.30$	1.28	0.91	-0.30	-0.07	-0.25	-0.01	0.00
$\rho_f = 0.75$	1.18	0.78	-0.29	-0.05	-0.30	-0.03	-0.02
$\xi_H = \xi_N = \infty$	0.88	0.69	-0.30	0.02	-0.33	-0.03	-0.03
$\xi_H = \xi_N = 2$	0.89	0.73	-0.30	0.03	-0.31	-0.03	0.05
$\epsilon = 1$	0.97	0.68	-0.31	0.01	-0.35	-0.03	0.00
$\rho = 1$	0.80	0.59	-0.38	0.03	-0.25	-0.04	0.01
$\zeta = 0$	0.50	.	-0.16	-0.06	-0.22	-0.05	-0.02
$\eta = 0.9$	0.91	0.75	-0.28	0.16	-0.25	0.02	0.06
$\eta = 2.4$	0.88	0.69	-0.30	-0.05	-0.36	-0.06	-0.03
$\psi_p = 0$	0.65	0.41	-0.24	-0.22	-0.75	-0.17	-0.16
$\psi_p = 1000$	0.96	0.84	-0.30	0.10	-0.16	0.03	0.05
$\psi_w = 0$	0.90	0.68	-0.31	0.00	-0.28	-0.04	-0.03
$\psi_w = 1000$	0.90	0.79	-0.28	0.07	-0.40	-0.03	0.05
$\psi_\pi = 0$	0.89	0.71	-0.30	0.01	-0.31	-0.03	-0.01
$\psi_\pi = 0.5$	0.93	0.72	-0.30	0.07	-0.31	-0.03	0.02
$\psi_k = 0$	1.14	0.92	-0.28	0.34	-0.25	0.10	0.35
$\psi_k = 100$	0.90	0.71	-0.30	0.01	-0.31	-0.04	-0.01

Table C.6: Fiscal Multipliers: B^g, T^r, T^o financed, horizon $h = 7$

Parameters	g	ζT^r	τ^c	τ^x	τ^ℓ	τ_H^k	τ_N^k
Baseline Model	0.49	0.23	-0.18	-0.19	-0.31	-0.11	-0.13
$\rho_f = 0.30$	0.87	0.49	-0.21	-0.17	-0.29	-0.06	-0.06
$\rho_f = 0.75$	0.69	0.29	-0.19	-0.21	-0.31	-0.09	-0.11
$\xi_H = \xi_N = \infty$	0.35	0.13	-0.17	-0.09	-0.32	-0.04	-0.02
$\xi_H = \xi_N = 2$	0.54	0.27	-0.19	-0.23	-0.31	-0.08	-0.19
$\epsilon = 1$	0.66	0.22	-0.24	-0.21	-0.43	-0.11	-0.13
$\rho = 1$	0.45	0.19	-0.23	-0.19	-0.28	-0.11	-0.13
$\zeta = 0$	0.45	.	-0.18	-0.22	-0.31	-0.11	-0.15
$\eta = 0.9$	0.50	0.28	-0.16	-0.05	-0.22	-0.04	-0.07
$\eta = 2.4$	0.48	0.20	-0.20	-0.25	-0.36	-0.14	-0.16
$\psi_p = 0$	0.44	0.11	-0.19	-0.29	-0.48	-0.16	-0.21
$\psi_p = 1000$	0.57	0.49	-0.12	0.06	-0.03	0.02	0.09
$\psi_w = 0$	0.48	0.19	-0.19	-0.21	-0.26	-0.11	-0.15
$\psi_w = 1000$	0.48	0.36	-0.13	-0.12	-0.55	-0.11	-0.04
$\psi_\pi = 0$	0.49	0.23	-0.18	-0.20	-0.31	-0.11	-0.13
$\psi_\pi = 0.5$	0.49	0.24	-0.18	-0.18	-0.31	-0.10	-0.13
$\psi_k = 0$	0.57	0.24	-0.19	-0.26	-0.34	-0.09	-0.04
$\psi_k = 100$	0.48	0.24	-0.18	-0.18	-0.31	-0.11	-0.14