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The Macroeconomics of the Greek Depression†

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Greece experienced a boom until 2007, followed by a collapse of unprecedented magnitude and persistence. We assess the sources of the boom and the bust, using a rich estimated dynamic general equilibrium model. External demand and government consumption fueled the boom in production, whereas transfers fueled the boom in consumption. Different from the standard narrative, wages and prices declined substantially during the bust. Tax policy accounts for the largest fraction of the bust in production, whereas uninsurable risk accounts for the bust in consumption and wages. We assess how the composition of fiscal adjustment and bailouts affected the crisis. (*JEL* E21, E23, E24, E32, E62, F41, H20)

The Greek economy experienced a significant boom between 1998 and 2007, with real GDP per capita growing by more than 30 percent, followed by a sustained depression, with real GDP per capita contracting by roughly 20 percent between 2007 and 2017. Figure 1 documents that the magnitude and length of the Greek depression have no precedent among modern middle- and high-income economies. The severity of the depression is atypical even among economies experiencing sudden stops, sovereign defaults, or leverage cycles (Gourinchas, Philippon, and Vayanos 2016).[1]

A standard narrative (for example, Schmitt-Grohé and Uribe 2016) of a boom-bust cycle in a small open economy with a currency peg unfolds as follows. Output grows during the boom because of increased productivity or demand, and capital flows into the country. The boom ends with a reversal of the favorable economic conditions and capital outflows. Downward nominal wage rigidity and commitment to the currency peg prevent real wages from adjusting downward, which generates a large fall in income and employment. While the Greek experience shares some elements with this narrative, the key mechanism that amplifies the depression is at odds with the observation that nominal wages and prices fell sharply during the Greek bust. This

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[1] Online Appendix Figure B.1 analyzes the magnitude and persistence of output drops during the sudden stop episodes identified in Gourinchas, Philippon, and Vayanos (2016) based on the methodology of Calvo, Izquierdo, and Talvi (2006) and Korinek and Mendoza (2014).

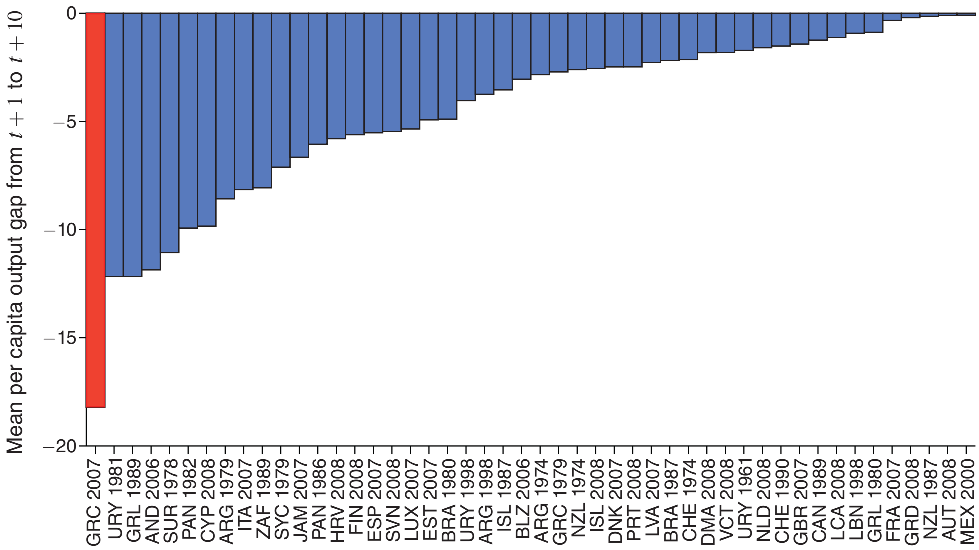

Figure 1. The Greek Depression Relative to Other Depressions

Notes: Figure 1 displays episodes in which mean real output per capita (World Development Indicators code NY.GDP.PCAP.KN) declined between a peak and ten years following the peak. We define a peak as when real GDP per capita exceeds the maximum of the preceding three and succeeding two years. Each bar shows mean real GDP per capita gap relative to the peak. For example, Greece, represented by the red bar, experienced an 18 percent gap between 2008 and 2017, relative to 2007. Our sample covers all upper-middle- and high-income countries, according to the World Bank definition, between 1960 and 2019, excluding oil producers and tax havens.

opens up the possibility that the mechanisms amplifying shocks into great depressions and the policies mitigating them differ profoundly from those during relatively smaller contractions.

We focus our analysis on three questions. First, what are the driving forces of the Greek boom and bust? Second, how important are frictions in product, labor, and financial markets for amplifying the macroeconomic effects of shocks? Third, by how much did fiscal and financial policies amplify or mitigate the depression? Answering these questions is important for reasons that extend beyond the Greek case. The macroeconomics of great depressions (Kehoe and Prescott 2002; Gorodnichenko, Mendoza, and Tesar 2012) have received less scholarly attention than analyses of typical international business cycles, which attribute 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. Likewise, the literatures evaluating fiscal consolidations (Alesina and Ardagna 2010) and external adjustments (Aguiar and Gopinath 2007; García-Cicco, Pancrazi, and Uribe 2010) typically focus on smaller contractions.

We answer these questions by developing and estimating a rich dynamic general equilibrium model of a small open economy operating within a currency union. The model features heterogeneous households, firms that produce tradable and nontradable products, and banking, government, and external sectors. We inform the model environment with a detailed analysis of macroeconomic patterns in Greece during both the boom and the bust periods.

On the production side, we observe that increases in labor and capital drive output in the boom, whereas declines in both factors of production and total factor productivity (TFP) contribute to the bust in economic activity. Using firm surveys, we document a decline in factor utilization coincident with the decline in TFP. This observation informs our model economy in which endogenous TFP movements arise from firms' choice of how intensively to utilize factors.

Financial conditions are favorable in the boom and deteriorate in the crisis. We build on the frameworks of Gertler and Kiyotaki (2011) and Bocola (2016) to analyze the passthrough of sovereign risk to the rest of the economy. Financial developments, such as bank losses from holdings of sovereign debt and equity injections to the banking sector, affect real outcomes through changes in the equilibrium borrowing cost because firms face a working capital constraint that requires them to borrow in order to finance input purchases.

Measures of risk increase substantially during the crisis, impacting precautionary saving and intertemporal substitution. We model heterogeneous workers facing time-varying uninsurable idiosyncratic income risk. We discipline the evolution of idiosyncratic risk with changes in the long-term unemployment rate, which increased from below 5 percent before the crisis to almost 20 percent during the crisis. We model changes in the probability of an aggregate disaster and discipline this time-varying probability using option prices from the Greek stock market. Aggregate risk spikes around major political events, such as the 2015 bailout referendum.

We model fiscal policies in detail, motivated by the significant fluctuations in both spending and taxes in the data. The government spends on consumption and investment goods, provides transfers to workers, and issues debt. Government purchases and transfers to workers rise during the boom and fall precipitously during the bust. Capturing the misreporting of government statistics before the crisis, we model workers as perceiving changes in their wealth when the government lies about its current deficit and debt. On the revenue side, the government receives transfers from European Union structural funds and raises taxes from consumption, investment, labor, and capital. Following the methodology of Mendoza, Razin, and Tesar (1994), we demonstrate that all tax rates rise sharply during the bust and remain elevated through 2017. As part of its tax policy, the government also sets the fraction of taxes that firms have to prepay before their revenues are realized. This fraction increases from 50 percent to 100 percent during the crisis.

While measures of production comove strongly between the traded and nontraded sectors, the dynamics of terms of trade and the real exchange rate lead us to consider a multisector 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 infer a significant increase in external demand for Greek traded goods during the boom, a period coinciding with Greece's adoption of the euro and hosting of the Olympic Games, and a significant decline during the bust, a period coinciding with a slump in the global shipping industry, in which Greece plays a substantial role.

We estimate the parameters of the model using standard Bayesian techniques. Our approach differs from estimated models in the tradition of Smets and Wouters

(2007), which infer latent shocks that best fit macroeconomic outcomes. Instead, our observables include counterparts of all exogenous processes, and we force these structural shocks into the model without adding to them any measurement error. Despite this discipline on the shocks, the model generates a boom and bust in output, labor, TFP, consumption, and investment that are in line with the data.

What factors account for the boom and bust in economic activity? Two demand shifters, the increase in demand for traded goods by the rest of the world and for nontraded goods by the government, account for the largest fraction of the boom in production. The consumption boom, facilitated by increased external borrowing, is driven by realized and perceived transfers to workers and by transfers from structural funds to the government. Contractionary tax policy plays the most important role for the bust in production, contributing an 18 percentage points decline in output.[2] For the bust in consumption, prices, and wages, the model attributes the most important role to the increase in uninsurable idiosyncratic risk, which increases precautionary saving.

We provide an account of the structural elements of the model responsible for these conclusions. Without variable utilization, by the end of the sample, the model would generate declines in output and TFP that are more than 10 percentage points smaller. By contrast, we find a moderate role for price or wage rigidity in accounting for the persistence of the bust, reflecting the significant increase in nominal prices (14 percent relative to euro trend inflation) and wages (24 percent relative to trend) in the boom and their decline in the bust (7 percent and 34 percent relative to trend). The working capital constraint on firms amplifies the bust in production by 16 percentage points. Incomplete asset markets play an important role for the bust in consumption, prices, and wages because they generate a role for precautionary saving in response to idiosyncratic risk.

Why do these shocks and elements matter the most? The Greek experience is characterized by a persistent increase and then decline in production, prices, and wages. The boom and bust in prices and wages and the persistence of the output decline argue against the importance of nominal rigidities. Tax increases, variable utilization, and financial frictions play an important role because they amplify the output decline and generate persistence. The increase in the fraction of taxes that firms have to prepay tightens their working capital constraint and decreases their factor demand. However, these forces do not generate comovement between prices and quantities. To achieve such a comovement, the estimated model gives a prominent role to demand shifters such as changes in external demand from foreigners and changes in idiosyncratic risk.

We use the estimated model to evaluate alternative fiscal policies. The model generates tax multipliers that are larger than its spending multipliers. As a result, we find that the bust in output would have been 7 percentage points smaller by 2017 if the burden of fiscal consolidation had shifted toward further spending cuts instead of tax

[2] As in Martin and Philippon (2017), 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. It became necessary because of the high preexisting level of public debt. Considered through this lens, 18 percentage points should be interpreted as an upper bound of the gain in output if preexisting conditions such as the high debt level had not made the fiscal adjustment through taxes necessary or alternatively, if Greece had received substantial additional debt relief.

increases. We also 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 more than 15 percentage points by 2017.[3]

Finally, we assess the role of bailouts. The external bailout of Greece provided additional debt, implicit transfers because of the lower borrowing cost (Gourinchas, Martin, and Messer 2020), and resources to bail out domestic banks. Without this assistance, Greece would have either further reduced spending or further increased taxes, resulting in an additional shortfall of output of roughly 20 percentage points at the beginning of the crisis and 5 percentage points by the end. The model attributes an important role to the bank bailout component of the assistance, which increased output by roughly 4 percentage points in 2017, relative to a counterfactual in which Greece had used these resources to cut taxes.

The seminal paper by Gourinchas, Philippon, and Vayanos (2016) provides the first systematic analysis of macroeconomic aspects of the Greek depression. We quantitatively confirm a broad message of their analysis by attributing roughly one-half of the boom in output to increased government spending and of the bust 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 the tax side is more important than the spending side of the consolidation, especially in the later years of the depression.[4] Our model departs from their work in several other dimensions, the most quantitatively important of which are the role of external demand in the boom and bust, endogenous movements in TFP due to utilization and in precautionary saving due to idiosyncratic risk, the endogenous passthrough from bank net worth to the borrowing cost, and the treatment of nominal rigidities.[5]

The Greek experience contrasts with earlier narratives of the boom and bust in the euro area. For the boom, Gopinath et al. (2017) emphasize the decline in TFP due to a deterioration of resource allocation in Spain and Italy. However, Greek traded industries did not experience declines in trend TFP during the boom. For the bust, Schmitt-Grohé and Uribe (2016) emphasize the problem of downward nominal wage rigidity in preventing internal devaluation for several countries between 2008 and 2011, including Greece. While it is true that Greek nominal wages kept increasing until 2010, they then fell by 17 percent. This timing suggests that downward nominal rigidity may be more important for countries that face relatively small contractions or that they are more important in the early stage of a crisis and become less important as shocks become larger and the crisis persists (Schmitt-Grohé and

[3] Our analysis of the effects of capital income taxes confirms the conclusions of Mendoza, Tesar, and Zhang (2014) regarding dynamic Laffer curve effects with respect to capital income tax rates in open economy models with variable utilization.

[4] Economides, Philippopoulos, and Papageorgiou (2017) also attribute a substantial role to fiscal consolidation in the bust. Dellas et al. (2018) highlight the tax side of the consolidation and the role of the informal sector. Relative to these papers, ours examines the origins of both the boom and the bust and allows for a richer set of shocks and transmission channels. Fakos, Sakellaris, and Tavares (2022) present firm-level evidence that roughly one-half of the decline in manufacturing investment is accounted for by tighter credit constraints.

[5] 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 in quantities. They allow for markup shocks that help them match the boom and bust in prices and wages.

Uribe 2017). Martin and Philippon (2017) provide a joint analysis of the boom and the bust in European countries between 2000 and 2012. Like us, they conclude that more conservative fiscal policies during the boom could have allowed a smaller fiscal consolidation in the bust. Our model differs from theirs in several important respects, including allowing for endogenous movements in TFP, capital accumulation, a banking sector, endogenous exports, time variation in taxes, and idiosyncratic risk. These elements result in better fit of the data and lead to substantively different conclusions about the main driving forces and propagation mechanisms.[6]

The strong comovement between the traded and nontraded sector and the fact that Greek traded output did not recover despite a decline in wages challenge narratives of slow economic growth focused solely on nontraded sectors such as the government or housing. To generate this comovement, our model attributes an important role to supply-side influences, such as higher tax rates and amplification mechanisms such as higher borrowing costs and lower utilization.[7] Similar to the study of Gorodnichenko, Mendoza, and Tesar (2012) on the Finnish depression in the early 1990s, we also attribute an important role to depressed external demand for the Greek bust. Our analysis differs from theirs in that, in our model, external shocks generate a decline in both employment and wages, and we do not impose significant wage rigidity.

The open economy literature has debated the importance of permanent productivity shocks for consumption drops and sudden stops during crises (Aguiar and Gopinath 2007; García-Cicco, Pancrazi, and Uribe 2010). For Greece, which experienced a significantly larger consumption drop and sudden stop than those faced by a typical small open economy, we attribute the most important role to the rise of uninsurable idiosyncratic risk. The rise of idiosyncratic risk differs from productivity shocks, in that it generates declines in both prices and consumption, as observed in Greece. Empirical studies such as Storesletten, Telmer, and Yaron (2004) and Guvenen, Ozkan, and Song (2014) have documented the cyclicality of idiosyncratic risk. Quantitative studies show how elevated idiosyncratic risk depresses aggregate demand in models with heterogeneous households and nominal rigidities (Bayer et al. 2019) and how monetary policy affects aggregate and household outcomes in the open economy (Guo, Ottonello, and Perez 2021). A contribution of our paper to this emerging literature is to extend insights from Constantinides and Duffie (1996) to estimate a rich model with uninsurable idiosyncratic risk.

[6] For example, Martin and Philippon (2017) report that their model accounts for 82 percent of the observed variation in output, 65 percent in labor, 10 percent in the terms of trade, and 45 percent in net exports. Our model accounts for 97 percent, 92 percent, 41 percent, and 87 percent of the variation of these observables, respectively. The driving forces in their model exclude taxes or idiosyncratic risk, which we find to be important contributors to the bust.

[7] Our emphasis on utilization to reconcile movements in output and factor inputs echoes earlier work on the Mexican tequila crisis (Meza and Quintin 2007) and on the East Asian financial crisis (Gertler, Gilchrist, and Natalucci 2007). Unlike these articles, our paper directly measures utilization from firm surveys, which motivates our attention to this explanation for the TFP decline rather than to other factors such as imperfect substitution of intermediate inputs (Mendoza and Yue 2012).

I. Model

We model Greece as a small open economy in a currency union. Trend productivity grows at constant rate $(1-\alpha)\mu > 1$, where $1-\alpha$ is labor's elasticity in production and μ is output's growth rate in the balanced growth path. To facilitate the presentation of the model, we remove trend growth from variables and write the model directly in terms of the transformed stationary variables.[8]

A. *Households*

Heterogeneity.—Workers $\iota \in [0,1]$ differ in two dimensions. First, a constant fraction ζ of workers discount with factor β^r, and a fraction $1-\zeta$ of workers discount with factor $\beta^o > \beta^r$. The more impatient workers choose to borrow as much as possible and do not hold firm shares, whereas the more patient workers choose bonds and share holdings in an interior solution. Anticipating this result, we say that the former workers belong to the rule-of-thumb household *r* and the latter workers belong to the optimizing household *o*. Second, workers in the optimizing household are heterogeneous in their income, whereas all workers in the rule-of-thumb household have the same income.

Preferences.—Worker ι in household $h = \{r,o\}$ values flows of consumption and labor with

$$V_{\iota t}^h = \left\{ \left(c_{\iota t}^h\right)^{1-\frac{1}{\rho}} \left[1 + \left(\frac{1}{\rho} - 1\right) \frac{\chi\left(\ell_{\iota t}^h\right)^{1+\frac{1}{\epsilon}}}{1+\frac{1}{\epsilon}}\right]^{1/\rho} + \beta^h e^{(1-1/\rho)\mu} \left[E_{\iota t}\left(V_{\iota t+1}^h\right)^{1-\sigma}\right]^{\frac{1-\frac{1}{\rho}}{1-\sigma}} \right\}^{\frac{1}{1-\frac{1}{\rho}}}, \tag{1}$$

where $c_{\iota t}^h$ is consumption and $\ell_{\iota t}^h$ is differentiated labor services. This specification combines Epstein and Zin (1989) preferences, which allow us to disentangle risk aversion from intertemporal substitution, with a constant Frisch elasticity of labor supply. The latter is used by Shimer (2010) and Trabandt and Uhlig (2011), among others, and is consistent with a balanced growth with constant labor. 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.

[8] The model features an aggregate disaster shock that permanently moves state variables to a lower level. For that reason, we treat state variables, x^*, differently than control variables, y^*, when detrending. If x_t^* is a state variable growing at rate μ along the balanced growth path, we define the detrended variable x_t by dividing with the trend factor at the end of the previous period, $x_t = x_t^*/e^{\mu(t-1)}$. If y_t^* is a control variable growing at rate μ, we define the detrended variable y_t by dividing with the trend factor at the beginning of the period, $y_t = y_t^*/e^{\mu t}$.

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

$$(2) \qquad c_t = \left[\omega_c^{1/\phi}\left(c_{T,t}\right)^{\frac{\phi-1}{\phi}} + \left(1-\omega_c\right)^{1/\phi}\left(c_{N,t}\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}},$$

$$c_{T,t} = \left[\gamma^{\frac{1}{\eta}}\left(c_{H,t}\right)^{\frac{\eta-1}{\eta}} + \left(1-\gamma\right)^{\frac{1}{\eta}}\left(c_{F,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}.$$

Parameters $\omega_c > 0$ and $\gamma > 0$ are preference weights for goods, and parameters $\phi > 0$ and $\eta > 0$ are elasticities of substitution between goods. Home traded and nontraded goods are CES bundles of differentiated varieties indexed by j:

$$(3) \qquad c_{H,t} = \left\{\int_0^1 \left[c_{H,t}(j)\right]^{\frac{\varepsilon_p-1}{\varepsilon_p}} dj\right\}^{\frac{\varepsilon_p}{\varepsilon_p-1}},$$

$$c_{N,t} = \left\{\int_0^1 \left[c_{N,t}(j)\right]^{\frac{\varepsilon_p-1}{\varepsilon_p}} dj\right\}^{\frac{\varepsilon_p}{\varepsilon_p-1}}.$$

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.

Idiosyncratic Income Risk.—Worker ι receives a share $\theta_{\iota t}^h$ of labor income and transfers net of wage adjustment costs accruing to household h. For workers in the optimizing household, the log share is random walk:

$$(4) \qquad \log\theta_{\iota t+1}^o = \log\theta_{\iota t}^o + \nu_{\iota t+1}^\theta,$$

where ν_ι^θ is an innovation to worker ι's income. Innovations wash out at the household level: $\int\exp\left(\nu_{\iota t}^\theta\right)d\iota = 1$. Workers in the rule-of-thumb household have the same income share, $\theta_{\iota t}^r = 1$.

The random walk process in equation (4) implies that consumption of worker ι is proportional to household consumption: $c_{\iota t}^o = \theta_{\iota t}^o c_t^o$. As a result, relative consumption among workers depends only on relative idiosyncratic shocks, which are uninsurable.[9] This convenient result allows us to solve for endogenous variables of the model using perturbation methods on a system of equilibrium conditions that includes only household consumption c_t^o and not individual consumption $c_{\iota t}^o$. The difference from a model with identical workers is that an increase in idiosyncratic risk, modeled as a mean preserving increase in the dispersion of $\nu_{\iota t}^\theta$, strengthens precautionary motives and reduces desired consumption for all members of the optimizing household.

[9] Owing to the random walk process for income shares, all workers expect their consumption to grow at the same rate, and none of them choose to trade securities with workers in the same household. This logic traces back to Constantinides and Duffie (1996), who first derived a no-trade theorem in an endowment economy. In online Appendix B.1 we show how their result extends in our richer framework that features Epstein-Zin preferences, trade of assets with the rest of the world, endogenous labor supply, wage markups, and wage adjustment costs.

We motivate changes in idiosyncratic risk over time with the observation that long-term unemployment in Greece increased substantially during the crisis. To link changes in idiosyncratic income risk in the model to observed changes in unemployment risk, we assume that $\nu_{\iota t}^{\theta}$ takes two values. With probability π_t^{θ}, which we measure with the long-term unemployment rate, workers are in a disaster state and receive $\nu_{\iota t}^{\theta} = -\varphi^{\theta}$. With probability $1 - \pi_t^{\theta}$, workers are in a good state and receive $\nu_{\iota t}^{\theta} = \log\left(\frac{1 - \pi_t^{\theta}\exp(-\varphi^{\theta})}{1 - \pi_t^{\theta}}\right)$, a value chosen to make idiosyncratic shocks wash out at the household level ($\int \exp(\nu_{\iota t}^{\theta}) d\iota = 1$).

Wage Setting.—A perfectly competitive employment agency rents bundles of labor to firms at price W_t. The agency chooses differentiated labor varieties $\ell_{\iota t}^h$ to maximize profits:

$$W_t(\ell_t^r + \ell_t^o) - \int W_{\iota t}^r \ell_{\iota t}^r d\iota - \int W_{\iota t}^o \ell_{\iota t}^o d\iota, \tag{5}$$

where $\ell_t^h = \left[\int \left(\ell_{\iota t}^h\right)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} d\iota\right]^{\frac{\varepsilon_w - 1}{\varepsilon_w}}$ is the bundle of labor for each type of household h with an elasticity of substitution across varieties $\varepsilon_w > 1$. In equation (5), $W_{\iota t}^h$ denotes the cost of hiring one unit of $\ell_{\iota t}^h$. The perfect substitutability between ℓ_t^r and ℓ_t^o implies a common wage W_t for both types of households. Workers in the rule-of-thumb household are symmetric, and thus, in equilibrium we obtain $\ell_{\iota t}^r = \ell_t^r$ and $W_{\iota t}^r = W_t$. While workers in the optimizing household are heterogeneous, their consumption and labor income scale with the same factor $\theta_{\iota t}^o$, and thus, in equilibrium we also obtain $\ell_{\iota t}^o = \ell_t^o$ and $W_{\iota t}^o = W_t$.

The first-order conditions from the optimization problem (5) yield a downward-sloping demand function for labor varieties:

$$\ell_{\iota t}^h = \left(\frac{W_{\iota t}^h}{W_t}\right)^{-\varepsilon_w} \ell_t^h. \tag{6}$$

Workers internalize these labor demand functions in setting wages. Parameter ε_w governs the markup of real wages over the marginal rate of substitution between leisure and consumption. Workers face quadratic costs of changing after-tax wages, $AC_{w,\iota t}^h = \frac{\psi_w}{2}\left[\frac{(1 - \tau_t^{\ell})e^{-\mu}W_{\iota t}^h}{(1 - \tau_{t-1}^{\ell})W_{\iota t-1}^h} - 1\right]^2 (1 - \tau_t^{\ell})W_t^h \ell_t^h$, where $\psi_w \geq 0$ controls for the strength of these costs.[10]

Asset Markets.—Workers can hold firm shares $\varsigma_{\iota t}^h$ and borrow in bonds $B_{\iota t}^h$. Choices of shares and bonds are subject to the financial constraints

$$\varsigma_{\iota t+1}^h \geq 0, \quad B_{\iota t+1}^h \leq \bar{B}_{t+1}^h. \tag{7}$$

[10]We model adjustment costs on after-tax wages because negotiated and posted salaries in Greece are commonly quoted in after-tax terms. We have confirmed the robustness of our results to modeling adjustment costs on a pretax basis.

The borrowing limit $\bar{B}^h_{t+1} > 0$ is exogenously set by the rest of the world. The assumption $\beta^o > \beta^r$ implies that in a neighborhood around the steady state, workers in the rule-of-thumb household choose $B^r_t = \bar{B}^r_t$ and $\varsigma^r_t = 0$.

Budget Constraint.—Workers face a sequence of budget constraints:

$$(8) \quad (1+\tau^c_t)P_{c,t}c^h_{\iota t} + \left[1 + i\left(B^h_{\iota t}\right)\right]e^{-\mu}B^h_{\iota t} - B^h_{\iota t+1} + Q^\varsigma_t \varsigma^h_{\iota t+1}$$
$$= \theta^h_{\iota t}\left[\left(1-\tau^\ell_t\right)\int W^h_{\iota t}\ell^h_{\iota t}d\iota - \int AC^h_{w,\iota t}d\iota + T^h_t + \frac{I(h = o)\left(\Pi^b_t + T^l_t\right)}{1-\zeta}\right]$$
$$+ \left(Q^\varsigma_t + \Pi^f_t\right)\varsigma^h_{\iota t},$$

where $P_{c,t}$ is the price of consumption, τ^c_t and τ^ℓ_t are consumption and labor income tax rates, $i(\cdot)$ is the interest schedule on bonds, Q^ς_t is the price of firm shares, T^h_t and T^l_t are lump-sum transfers, and Π^b_t and Π^f_t are bank and firm profits.

There are three differences between workers in the rule-of-thumb household and workers in the optimizing household. First, workers in the optimizing household save in a neighborhood around the steady state, $B^o_{\iota t} \leq 0$, and receive an interest rate $i(B \leq 0) = \bar{i}_t$ taken as given from the rest of the world. Workers in the rule-of-thumb household borrow from domestic banks, $B^r_{\iota t} > 0$, and face an interest rate $i(B > 0) = i_t$, which is determined in equilibrium. Second, workers in the optimizing household own the banks and receive their profits Π^b_t. Finally, the transfer T^l_t (superscript l for "lie") appears only in the budget constraint of workers in the optimizing household. This variable captures perceptions of changes in wealth when the government lies about its current debt position and future tax revenue obligations. Misreporting of statistics does not generate an actual transfer of resources, and thus, we model the realized T^l_t as always equal to zero. To model the perception of changes in wealth, we assume that workers receive news of future transfers embedded in $E_t T^l_{t+1}$ that never realize during the sample path.

Household Optimization.—Worker ι in household h chooses sequences of consumption $c^h_{H,\iota t}(j)$, $c^h_{F,\iota t}$, $c^h_{N,\iota t}(j)$; labor supply $\ell^h_{\iota t}$; wages $W^h_{\iota t}$; bonds $B^h_{\iota t+1}$; and shares $\varsigma^h_{\iota t+1}$ in order to maximize their value in equation (1), subject to the law of motion of their income (4), the downward-sloping demand for labor (6), the financial constraints (7), and the budget constraint (8).

B. *Firms*

Intermediate goods firms use labor and capital to produce traded and nontraded goods, y_H and y_N. Retailers transform these into differentiated goods, $y_H(j)$ and $y_N(j)$, and set prices.

Production.—Production is Cobb-Douglas:

$$(9) \quad y_{H,t} = z_{H,t}u_{H,t}\left(e^{-\mu}k_{H,t}\right)^\alpha\left(\ell_{H,t}\right)^{1-\alpha}, \quad y_{N,t} = z_{N,t}u_{N,t}\left(e^{-\mu}k_{N,t}\right)^\alpha\left(\ell_{N,t}\right)^{1-\alpha},$$

where $z_{H,t}$ and $z_{N,t}$ denote exogenous productivity in each sector and parameter $\alpha > 0$ governs the capital share of income.[11] Firms hire labor inputs, $\ell_{H,t}$ and $\ell_{N,t}$, at a wage W_t. Share s_t of aggregate capital k_t is allocated to the traded sector, so $k_{H,t} = s_t k_t$ and $k_{N,t} = (1 - s_t)k_t$.

Firms choose endogenously the utilization of factors $u_{H,t}$ and $u_{N,t}$, motivated by the observation that the significant drop in sectoral TFP in the bust coincides with declines in utilization as measured in firm surveys. The cost of utilizing factors more intensively is increased depreciation rates of capital:

$$(10) \qquad \delta_{H,t} = \bar{\delta}_H + \frac{\bar{\xi}_H}{\xi_H}\left(u_{H,t}^{\xi_H} - 1\right), \quad \delta_{N,t} = \bar{\delta}_N + \frac{\bar{\xi}_N}{\xi_N}\left(u_{N,t}^{\xi_N} - 1\right),$$

where $\bar{\delta}_H, \bar{\delta}_N \geq 0$ are the depreciation rates when utilization equals the steady-state value of one, $\bar{\xi}_H, \bar{\xi}_N > 0$ are constants normalized to target steady-state utilization, and $\xi_H, \xi_N > 1$ govern the responsiveness of depreciation rates to utilization.

Capital accumulates according to

$$(11) \qquad k_{t+1} = \left\{1 - \left[s_t \delta_{H,t} + (1 - s_t)\delta_{N,t}\right]\right\} e^{-\mu} k_t + x_t + g_t^x,$$

where private investment $x_t = \left[\omega_x^{1/\phi}(x_{T,t})^{(\phi-1)/\phi} + (1 - \omega_x)^{1/\phi}(x_{N,t})^{(\phi-1)/\phi}\right]^{\phi/(\phi-1)}$ is a bundle of traded and nontraded goods with share parameter $\omega_x > 0$ and elasticity of substitution $\phi > 0$. In this bundle, $x_{T,t}$ is a CES aggregator between home $x_{H,t}$ and foreign $x_{F,t}$ traded goods similar to the $c_{T,t}$ aggregator in equation (2), and $x_{H,t}$ and $x_{N,t}$ are CES aggregators of varieties similar to the $c_{H,t}$ and $c_{N,t}$ aggregators in equation (3). We add to capital accumulation the government's spending on investment goods g_t^x, which is also a CES aggregator of traded and nontraded goods.

Asset Markets.—Firms require working capital to finance their operations because of a mismatch between the timing of revenues and expenses. Working capital generates a demand for bank loans and transmits changes in the borrowing cost i_t to intratemporal and intertemporal production decisions. Fractions $\kappa_x \in [0,1]$ of investment, $\kappa_\ell \in [0,1]$ of employee compensation, and $\kappa_{\tau,t} \in [0,1]$ of income taxes require financing at the beginning of the period, before all revenues realize. Firms have access to a fraction κ_y of income at the beginning of the period and finance the rest of their expenses by borrowing B_{t+1}^f from banks. Debt is repaid at the beginning of next period at the interest rate i_t. The working capital constraint is

$$(12) \qquad B_{t+1}^f + \kappa_y(P_{H,t}y_{H,t} + P_{N,t}y_{N,t}) = \kappa_x(1 + \tau_t^x)P_{x,t}x_t + \kappa_\ell W_t \ell_t + \kappa_{\tau,t} T_t^f + (1 + i_t)e^{-\mu} B_t^f,$$

[11] We use the same α for both sectors because the sample average labor share is nearly identical for both sectors. We justify the representative firm setup by noting that declines in value added and employment occurred throughout the firm size distribution in the bust (online Appendix Figure B.3). 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 (online Appendix Figure B.3).

where $P_{H,t}$ and $P_{N,t}$ are the prices of traded and nontraded goods, $(1+\tau_t^x)P_{x,t}$ is the after-tax price of investment goods, and T_t^f is income tax payments. Motivated by tax reforms during the crisis that raised tax prepayments of firms, we allow $\kappa_{\tau,t}$ to vary over time.

Intermediate Goods Optimization.—The objective of firms is to maximize their value $J_t^f = \Pi_t^f + E_t \Lambda_{t,t+1}^o J_{t+1}^f$, where $\Lambda_{t,t+1}^o$ is the common stochastic discount factor of workers in the optimizing household. Firms choose sequences of labor demand $\ell_{H,t}$, $\ell_{N,t}$; capital k_t, s_t; utilization $u_{H,t}$, $u_{N,t}$; and bonds B_{t+1}^f in order to maximize their value subject to the production functions (9), depreciation rates (10), capital accumulation (11), and the working capital constraint (12). Flow profit Π_t^f is

$$\begin{aligned}(13)\qquad \Pi_t^f = {} & \left(1-\tau_{H,t}^k\right)\left(P_{H,t}^f y_{H,t} - W_t \ell_{H,t} + \Pi_{H,t}\right) \\ & + \left(1-\tau_{N,t}^k\right)\left(P_{N,t}^f y_{N,t} - W_t \ell_{N,t} + \Pi_{N,t}\right) - AC_t^f + B_{t+1}^f \\ & - \left(1+\tau_t^x\right)P_{x,t}x_t - e^{-\mu}\Big[(1+i_t)B_t^f - s_t \tau_{H,t}^k\left(\bar{\delta}_H Q_t^k k_t + i_t B_t^f\right) \\ & \qquad - (1-s_t)\tau_{N,t}^k\left(\bar{\delta}_N Q_t^k k_t + i_t B_t^f\right)\Big],\end{aligned}$$

where $P_{H,t}^f$ and $P_{N,t}^f$ are the prices of intermediate goods supplied to retailers, τ_t^k and τ_t^x are capital income and investment taxes, and Q_t^k is the price of capital. 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 and fall disproportionally on the nontraded sector. To ensure that all nonlabor income is taxed, we make it so that taxable income includes the monopoly profits of retailers, $\Pi_{H,t}$ and $\Pi_{N,t}$. With depreciation and interest expenses deducted, income tax payments are $T_t^f = \sum_{i=H,N} \tau_{i,t}^k \left[P_{i,t}^f y_{i,t} - W_t \ell_{i,t} + \Pi_{i,t} - e^{-\mu} s_{i,t}\left(\bar{\delta}_i Q_t^k k_t + i_t B_t^f\right)\right]$. Finally, costs of adjusting dividends, investment, and labor are included in AC_t^f and are all quadratic.[12]

Price Setting.—Retailers in the traded sector produce differentiated varieties $y_{H,t}(j)$ using the intermediate traded good $y_{H,t}$. They choose price $P_{H,t}(j)$ to maximize their value $J_{H,t}(j) = \Pi_{H,t}(j) + E_t \Lambda_{t,t+1}^o J_{H,t+1}(j)$. Flow profits are $\Pi_{H,t}(j) = \left[P_{H,t}(j) - P_{H,t}^f\right] y_{H,t}(j) - AC_{H,t}(j)$, where $AC_{H,t}(j) = \frac{\psi_{H,p}}{2}\left[\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1\right]^2 P_{H,t} y_{H,t}$ are quadratic costs of changing nominal prices, as in Rotemberg (1982), and $\psi_{H,p} \geq 0$ controls for the strength of these costs.

[12] The adjustment cost terms equals $AC_t^f = AC_{\pi,t}^f + AC_{x,t}^f + AC_{\ell,t}^f - q_\ell W_t(\ell_t - \ell) + T_t^q$. Dividend adjustment costs are $AC_{\pi,t}^f = \frac{\psi_\pi}{2}\left(\frac{\Pi_t^f}{P_{F,t}} - \frac{\Pi^f}{P_F}\right)^2 P_{F,t}$, where $\psi_\pi \geq 0$ controls for the strength of these costs and Π^f/P_F denotes steady-state profits relative to the foreign price. Investment adjustment costs are $AC_{x,t}^f = \frac{e^\mu \psi_x}{2}\left(\frac{x_t}{x_{t-1}} - 1\right)^2 P_{F,t} x_{t-1}$, where $\psi_x \geq 0$ controls for the strength of these costs. Labor adjustment costs are $AC_{\ell,t}^f = \frac{\psi_\ell}{2}\left(\frac{\ell_t}{\ell_{t-1}} - 1\right)^2 W_t \ell_{t-1}$, where $\psi_\ell \geq 0$ controls for the strength of these costs. We add to adjustment costs a constant labor subsidy q_ℓ when labor exceeds its steady-state level ℓ, which we conveniently calibrate to target the labor share of income in steady state. Finally, $T_t^q = q_\ell W_t(\ell_t - \ell)$ is a lump-sum tax that offsets the subsidy.

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

$$y_{H,t}(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}}\right]^{-\varepsilon_p}\left[\gamma\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\eta}(c_{T,t} + x_{T,t} + g^c_{T,t} + g^x_{T,t}) + (1-\gamma)\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta}\bar{a}_{T,t}\right]. \tag{14}$$

The first term in the bracket of equation (14) is domestic demand for household consumption $c_{H,t}(j)$, firm investment $x_{H,t}(j)$, government consumption $g^c_{H,t}(j)$, and government investment $g^x_{H,t}(j)$. The second term is demand for Greek traded goods from the rest of the world, where the exogenous shifter $\bar{a}_{T,t}$ is a convolution of preferences for Greek goods and overall traded-goods demand by the rest of the world.[13]

Retailers in the nontraded sector produce differentiated varieties $y_{N,t}(j)$ using the intermediate nontraded good $y_{N,t}$. They choose price $P_{N,t}(j)$ to maximize their value $J_{N,t}(j) = \Pi_{N,t}(j) + E_t\Lambda^o_{t,t+1}J_{N,t+1}(j)$, where flow profits are $\Pi_{N,t}(j) = \left[P_{N,t}(j) - P^f_{N,t}\right]y_{N,t}(j) - AC_{N,t}(j)$ and adjustment costs of changing nominal prices are $AC_{N,t}(j) = \frac{\psi_{N,p}}{2}\left[\frac{P_{N,t}(j)}{P_{N,t-1}(j)} - 1\right]^2 P_{N,t}y_{N,t}$. The residual demand for their variety j is

$$y_{N,t}(j) = \left[\frac{P_{N,t}(j)}{P_{N,t}}\right]^{-\varepsilon_p}(c_{N,t} + x_{N,t} + g^c_{N,t} + g^x_{N,t}). \tag{15}$$

C. *Banks*

We model financial intermediation following Gertler and Kiyotaki (2011) and Bocola (2016). In this framework, financial developments such as sovereign default affect domestic production, investment, and consumption through changes in the borrowing cost, i_t, which is determined endogenously from decisions of banks and the private sector. Collectively, the banking sector and the financial constraints (7) on workers and (12) on firms make up the financial mechanisms in our framework.

Bankers are members of the optimizing household. Each period, an incumbent banker exits with probability δ_b and is replaced by a new banker to keep the total measure of bankers constant. New bankers are endowed by the optimizing household with a fraction ω_b of aggregate output, $N^e_{t+1} = \omega_b(P_{H,t}y_{H,t} + P_{N,t}y_{N,t})$. Incumbent bankers hold a portfolio of firm debt B^f_{t+1} and rule-of-thumb

[13] Denoting rest of the world variables with an upper bar, 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 is $\bar{a}_{T,t} = \frac{1-\bar{\gamma}_t}{1-\gamma}(\bar{c}_{T,t} + \bar{x}_t)$.

debt ζB^r_{t+1}. They finance their portfolio with deposits B^b_{t+1} raised from the optimizing household and the rest of the world and with their net worth:

$$(16) \qquad N_t = e^{\mu}\left(B^f_{t+1} + \zeta B^r_{t+1} - B^b_{t+1}\right).$$

The net worth of bankers who continue to the next period, N^c_{t+1}, equals the return on private sector loans, $(1 + i_{t+1})\left(B^f_{t+1} + \zeta B^r_{t+1}\right)$, minus the cost of financing, $\left(1 + \bar{i}_{t+1}\right)B^b_{t+1}$. Applying the definition of incumbent bankers' net worth to equation (16), we obtain

$$(17) \qquad N^c_{t+1} = \left(1 + \bar{i}_{t+1}\right)e^{-\mu}N_t + \left(i_{t+1} - \bar{i}_{t+1}\right)\left(B^f_{t+1} + \zeta B^r_{t+1}\right).$$

Continuing bankers' net worth is augmented by the cost of funds $\bar{i}_{t+1}$ earned on previous period net worth and by the spread $i_{t+1} - \bar{i}_{t+1}$ earned on private sector loans. Profits distributed to the optimizing household equal the net worth of exiting bankers minus the funds required to finance new entrants: $\Pi^b_t = e^{-\mu}\left(\delta_b N^c_t - N^e_t\right)$.

The spread $i_{t+1} - \bar{i}_{t+1}$ arises from the limited enforcement of contracts. Bankers can divert a fraction κ_b of their assets to the optimizing household before repaying their debt. The return on loans i_{t+1} has to rise sufficiently above the cost of funds $\bar{i}_{t+1}$ so that bankers satisfy the incentive compatibility constraint that induces them to repay in equilibrium:

$$(18) \qquad \kappa_b\left(B^f_{t+1} + \zeta B^r_{t+1}\right) \leq J^b_t.$$

Bankers do not default in equilibrium when their value J^b_t exceeds the value of divertible assets.

Incumbent bankers choose sequences of investments B^f_{t+1} and B^r_{t+1}, financing B^b_{t+1}, and net worth N^c_{t+1} to maximize their value $J^b_t = E\Lambda^o_{t,t+1}\left[\delta_b N^c_{t+1} + (1 - \delta_b)J^b_{t+1}\right]$, subject to their net worth (16), the net worth evolution for continuing bankers (17), and the incentive compatibility constraint (18). As in Gertler and Kiyotaki (2011), the problem becomes tractable by conjecturing and then verifying that the value function J^b_t is proportional to net worth N_t for a factor of proportionality that we solve for in equilibrium.

Finally, the total net worth of the banking sector is

$$(19) \qquad N_{t+1} = (1 - \delta_b)N^c_{t+1} + N^e_{t+1} + T^b_{W,t} + e^{\mu}T^b_{G,t}.$$

Motivated by the global financial crisis and the Greek sovereign debt crisis, we introduce two exogenous processes in the evolution of bank net worth. The variable $T^b_{W,t}$ is net flows from the rest of the world to domestic banks and, in our quantitative results, equals changes in valuations of foreign assets held by domestic banks. The variable $T^b_{G,t}$ is net flows from the government to domestic banks and, in our quantitative results, equals changes in the value of sovereign debt held by domestic banks and equity injections from the government to domestic banks.[14]

[14] Banks in our model do not choose how to allocate their portfolio between private and government securities, owing to financial repression. However, through the variable $T^b_{G,t}$, changes in the value of these assets and government equity injections affect bank net worth.

D. *Government*

The government receives capital transfers from European Union structural funds T_t^g and raises revenues from taxes on consumption τ_t^c, investment τ_t^x, labor income τ_t^ℓ, and capital income $\tau_{H,t}^k, \tau_{N,t}^k$. Sovereign debt held by the rest of the world is $\bar{B}_t^g$ and pays an interest rate of $\bar{r}_t$. Debt held by domestic banks is subject to valuation effects that we quantify in the term $T_{G,t}^b$ in the banks' problem. The government spends its resources on consumption, $g_{T,t}^c$ and $g_{N,t}^c$, investment, $g_{T,t}^x$ and $g_{N,t}^x$, and transfers to households, T_t^r and T_t^o. The government budget constraint is

$$(20)\quad \bar{B}_{t+1}^g + T_t^g + \tau_t^c P_{c,t}\big[\zeta c_t^r + (1-\zeta)c_t^o\big] + \tau_t^x P_{x,t} x_t + \tau_t^\ell W_t\big[\zeta \ell_t^r + (1-\zeta)\ell_t^o\big]$$
$$+ \sum_{i=H,N} \tau_{i,t}^k\Big[P_{i,t}^f y_{i,t} - W_t \ell_{i,t} + \Pi_{i,t} - e^{-\mu} s_{i,t}\big(\bar{\delta}_i Q_t^k k_t + i_t B_t^f\big)\Big]$$
$$= (1+\bar{r}_t)e^{-\mu}\bar{B}_t^g + T_{G,t}^b + P_{T,t}\big(g_{T,t}^c + g_{T,t}^x\big) + P_{N,t}\big(g_{N,t}^c + g_{N,t}^x\big)$$
$$+ \zeta T_t^r + (1-\zeta)T_t^o.$$

E. *Driving Forces*

We organize the exogenous processes driving the model in six categories:

(i) *Productivity.*—Includes traded productivity $\log z_{H,t}$ and nontraded productivity $\log z_{N,t}$.

(ii) *External.*—Includes demand from the rest of the world for Greek products $\bar{a}_{T,t}$, the price of imports $P_{F,t}$, capital transfers from structural funds T_t^g, and anticipation of transfers T_t^l.

(iii) *Financial.*—Includes government debt held by the rest of the world $\log \bar{B}_t^g$, the borrowing limit of rule-of-thumb workers $\log \bar{B}_t^r$, the interest rate on government debt $\bar{r}_t$, the cost of funds $\bar{i}_t$, and the changes in banks' net worth related to foreign assets $T_{W,t}^b$ and holdings of sovereign debt $T_{G,t}^b = T_{Gd,t}^b + T_{Ge,t}^b$. We further split $T_{G,t}^b$ into two processes, valuation effects on banks' balance sheets from sovereign debt $T_{Gd,t}^b$ and equity injections from the government $T_{Ge,t}^b$.

(iv) *Government Spending.*—Includes spending on consumption of traded goods $\log g_{T,t}^c$, consumption of nontraded goods $\log g_{N,t}^c$, investment of traded goods $\log g_{T,t}^x$, investment of nontraded goods $\log g_{N,t}^c$, and transfers to the rule-of-thumb household $\log T_t^r$.

(v) *Tax Policy.*—Includes taxes on consumption τ_t^c, investment τ_t^x, labor income τ_t^ℓ, capital income in the traded sector $\tau_{H,t}^k$, capital income in the nontraded sector $\tau_{N,t}^k$, and the fraction of taxes firms prepay $\kappa_{\tau,t}$.

(vi) *Disaster Risk.*—Includes the idiosyncratic disaster probability π_t^θ and the aggregate disaster probability π_t^a.

We add to the driving processes an aggregate disaster risk. We motivate aggregate disaster risk by the elevated aggregate uncertainty Greece experienced around 2012 and 2015, during the debt negotiations and the possibility of exit from the euro. The modeling of aggregate disaster risk follows Gourio (2012). A disaster event moves the economy permanently to a state in which variables such as productivity and external demand scale down by a factor $\exp(-\varphi^a) < 1$ (see online Appendix B.3 for details). Disasters occur with time-varying probability π_t^a. To discipline our quantitative exercise, we fix φ^a to a constant, assume a disaster does not occur in sample, and consider only the impact of changes in the probability of a disaster π_t^a.

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

$$\mathbf{z}_{t+1} = \mathbf{z} + \mathbb{R}\,\mathbf{z}_t + \Sigma\,\nu_{t+1}, \tag{21}$$

where $\mathbf{z}$ is a constant that depends on steady-state values and the size of the aggregate disaster φ^a, $\mathbb{R}$ is a diagonal matrix containing the persistence of each stochastic process, Σ is a diagonal matrix containing the standard deviations of the innovations, and $\nu_{t+1} \sim \mathbb{N}(0,\mathbb{I})$.[15]

F. *Equilibrium*

Given exogenous processes $\mathbf{z}_t$ and initial conditions on the state variables, an equilibrium is a sequence of quantities and prices such that workers, firms, and banks maximize their values; the labor market clears, $\ell_t \equiv \ell_{H,t} + \ell_{N,t} = \zeta\ell_t^r + (1-\zeta)\ell_t^o$; traded goods markets clear, $y_{H,t}(j) = c_{H,t}(j) + x_{H,t}(j) + g_{H,t}^c(j) + g_{H,t}^x(j) + \bar{c}_{H,t}(j) + \bar{x}_{H,t}(j)$; nontraded goods markets clear, $y_{N,t}(j) = c_{N,t}(j) + x_{N,t}(j) + g_{N,t}^c(j) + g_{N,t}^x(j)$; the equity market clears, $\zeta\varsigma_t^r + (1-\zeta)\varsigma_t^o = 1$; bond markets clear, meaning that banks hold assets B_{t+1}^r from the rule-of-thumb household and B_{t+1}^f from firms; and the government budget constraint (20) holds. As a baseline, we let transfers to the optimizing household T_t^o adjust endogenously to balance the government budget constraint and present several alternative ways of balancing the budget below. The equilibrium is symmetric across varieties, so henceforth, we omit the index j. Online Appendix B.2 collects all conditions in the symmetric equilibrium of the model. We solve the model using a first-order approximation of the equilibrium conditions around the steady state to facilitate the estimation of parameters.

II. Measurement

Our sample covers the period between 1998 and 2017. We summarize the definitions of variables and sources of data in online Appendix Tables B.4, B.3, and B.2. We divide quantities by population. To account for trend growth, we deflate per capita

[15] The correlation between shocks would matter for the properties of endogenous variables if one simulated the model by drawing shocks ν_{t+1}. Our approach, however, is to feed the path of ν_{t+1} that we obtain after estimating $\mathbb{R}$. Thus, in a first-order approximation of the model, off-diagonal elements of Σ do not enter the policy functions and do not affect the model-generated paths of endogenous variables.

quantities by 1.6 percent per year, which is the average growth of constant-price GDP per capita from the Penn World Tables in the 30 years before 1998. To account for trend inflation, we deflate prices and interest rates by 1 percent per year, which is the average euro inflation rate in our sample. Values and nominal wages are deflated by 2.6 percent, and productivity measures are deflated by $\left[(1+0.016)^{0.44}-1\right] \approx 0.7$ percent, where 0.44 is our estimated capital elasticity.

A. *Outcome Variables*

Figure 2 presents the outcome variables we use to estimate and evaluate the model, in deviations from their 1998 values. We obtain constant-price output y and its price P_y from Eurostat's European System of Accounts (ESA) database.[16] The traded sector consists of agriculture, mining, manufacturing, transportation, accommodation and food services, and travel agency and tour operators. The latter two categories belong to the traded sector because tourism composes a significant fraction of economic activity in these industries. 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 P_H as the Paasche price index of the underlying prices P_i, and obtain constant-price value added $y_H = \sum_{i \in H} P_i y_i / P_H$. We follow a similar procedure to measure P_N and y_N. Figure 2 (panel A) shows a strong comovement between y_H and y_N over time. Output in both sectors increases until 2007, declines by roughly 30 log points between 2007 and 2012, and does not recover after 2012.

Labor inputs ℓ_H and ℓ_N are hours worked per capita in each sector from national surveys of households and establishments. These measures include both employee hours and hours worked by self-employed workers. Figure 2 (panel B) shows that both labor inputs fell by roughly 15 log points after 2008, despite their divergence in the boom.

We use the perpetual inventory method with a fixed depreciation rate and private and public investment for four types of assets (structures, machinery and equipment, cultivated biological resources, and intellectual property assets) to measure capital. We denote this variable by $\tilde{k}$ and distinguish it from the variable k in the model, which accounts for variable depreciation. Figure 2 (panel C) shows a roughly 15 log points increase in capital until 2010, followed by a 20 log points decline. We measure the share of capital allocated to the traded sector, $\tilde{s}$, using Eurostat industry-level fixed asset accounts. This share remains relatively stable over time.

We obtain sectoral TFP by using growth accounting (see online Appendix C.3 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 types of assets, using user cost weights that depend on asset-specific depreciation rates and a common required net return. Our TFP measures capture both within-industry TFP and the reallocation of inputs across industries within sectors.[17] Figure 2 (panel D) shows

[16] In the model, P_y is a Paasche price index of P_H and P_N and $y = \frac{P_H y_H + P_N y_N}{P_y}$.

[17] Applying the Basu (1996) decomposition of TFP to a within-industry and a between-industry component, we find a small role for reallocation across industries in accounting for the dynamics of TFP at the sectoral or aggregate level.

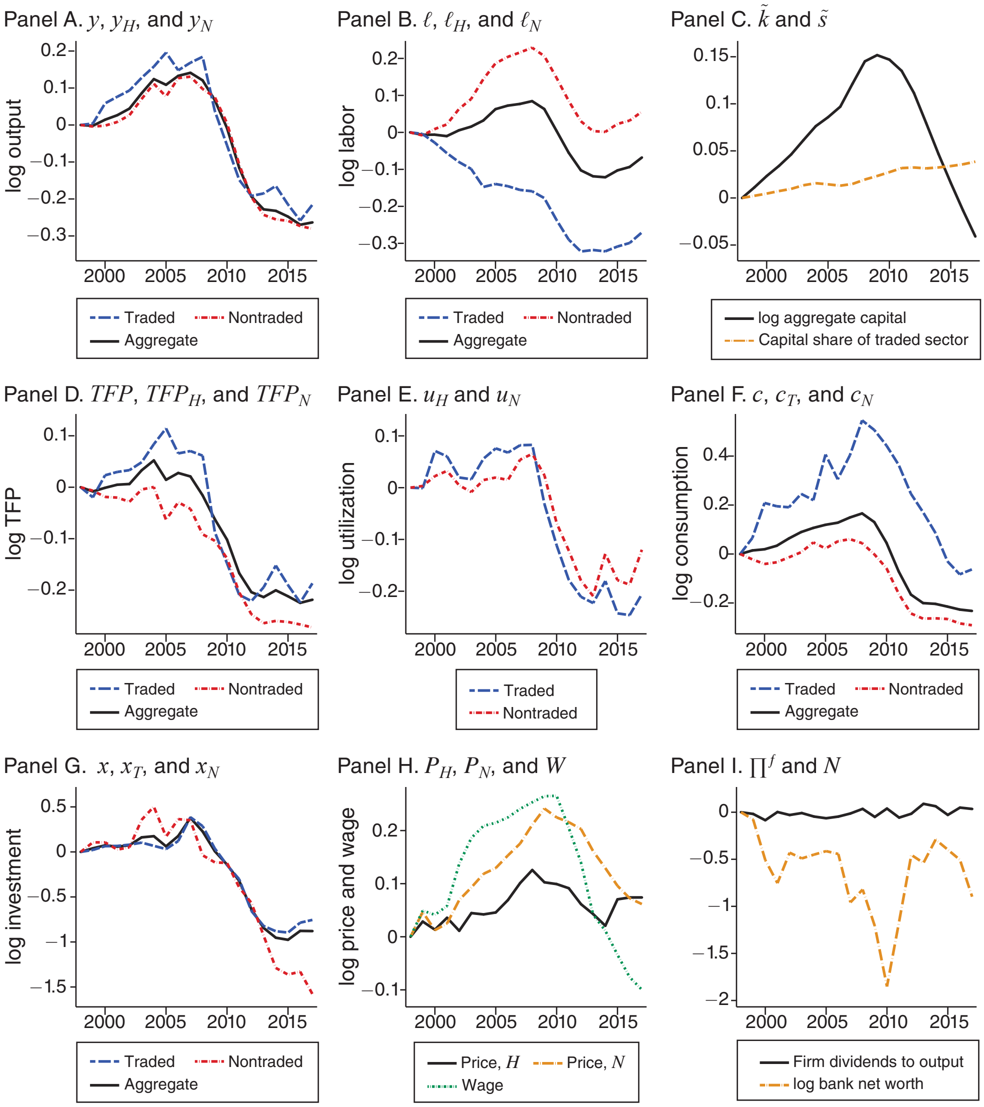

Figure 2. Outcomes

Notes: Figure 2 plots the evolution of macroeconomic variables. H denotes the traded sector for production measures, and T denotes the traded sector for consumption measures. N denotes the nontraded sector. y is output, ℓ is labor, $\tilde{k}$ is capital, $\tilde{s}$ is the share of capital allocated to the traded sector, TFP is total factor productivity, u is utilization, c is consumption, x is investment, P is price, W is wage, Π^f is firm profits, and N is net worth of banks. Quantities are detrended with 1.6 percent per year, TFP with 0.7 percent, prices with 1 percent, and wages with 2.6 percent.

that in the boom TFP in the traded sector increases and TFP in the nontraded sector decreases. Both, however, decrease substantially in the bust, and neither recovers.

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 service 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. We then aggregate within sectors to obtain u_H and u_N. Figure 2 (panel E) shows that both utilization indices increase modestly in the boom, decline substantially between 2007 and 2012, and remain depressed after.[18]

Current-price private consumption of nontraded goods equals nontraded value added minus other absorption of nontraded goods, $P_N c_N = P_N\left(y_N - x_{N,t} - g^c_{N,t} - g^x_{N,t}\right)$. 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 nonprofits. We obtain c_N using the Paasche index P_N from the underlying industry prices that compose the nontraded 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.[19] Figure 2 (panel F) displays a consumption boom until 2007 and then a significant decline and lack of recovery. Expenditure on nontraded goods composes roughly 70 percent of total expenditure, and thus, total consumption comoves more closely with nontraded consumption than with traded consumption.

Figure 2 (panel G) displays total private investment x, the part purchased from the traded sector x_T, and the part purchased from the nontraded sector x_N. We assign to nontraded investment the value-added component of structures, calculated as total investment in structures multiplied by the value added share of gross output in the construction industry. We assign all other investment to the traded sector. Both categories of investment fall more than 100 log points in the crisis, and neither recovers in the last years of the sample.

Figure 2 (panel H) displays the evolution of prices and wages. Until 2008, the relative price of nontraded goods increases, and Greek terms of trade appreciate. These trends reverse after 2010. Relative to their trend, wages increase by more than 20 log points by 2010 and then decline by more than 30 log points. We measure wages as total employee compensation divided by total employee hours. In online Appendix B.4, 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 and skill categories and throughout the wage distribution.

Finally, Figure 2 (panel I) shows the evolution of firm dividends Π^f and bank net worth N. Both series come from the Flow of Funds accounts at the

[18] The surveys do not cover agriculture or mining, for which we assume full utilization. We also depart from the survey measurement for the shipping industry, which is part of the traded sector. TFP in shipping fell by almost 70 percent between 2007 and 2017, reflecting the widespread idling of ships due to excess capacity following an investment boom (Kalouptsidi 2014). We attribute all of the fluctuations in TFP in shipping to utilization. In online Appendix C.3, we present an alternative series for utilization, based on Basu (1996), that relates unobserved utilization to the growth of material inputs. Our baseline survey measures correlate well with this alternative measure, with both measures showing a sharp decline in utilization in the bust.

[19] 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 $\left(1 + \tau^c\right)P_c$. We use our series on the consumption tax rate τ^c described below to obtain P_c from the national accounts price index.

Bank of Greece. Dividends for nonfinancial corporations are relatively stable over time. Net worth equals the difference between the market value of assets and the market value of non-equity liabilities for financial institutions. Net worth collapses between 2007 and 2010 and recovers to precrisis levels soon after that.

B. *Driving Forces*

Productivity.—Traded and nontraded productivity, z_H and z_N, equal sectoral TFP net of the contribution of utilization. Figure 3 (panel A) shows that z_N declines in the boom. Both z_N and z_H fluctuate substantially in the bust but without a clear trend.

External.—We measure external demand $\bar{a}_T$ for Greek goods by evaluating equation (14) in the symmetric equilibrium of the model:

$$P_{H,t} y_{H,t} = \gamma \left(\frac{P_{T,t}}{P_{H,t}} \right)^{\eta - 1} P_{T,t} \left(c_{T,t} + x_{T,t} + g^c_{T,t} + g^x_{T,t} \right) + (1 - \gamma) \left(\frac{P_{F,t}}{P_{H,t}} \right)^{\eta - 1} P_{F,t} \bar{a}_{T,t}. \quad (22)$$

Equation (22) decomposes expenditure on Greek-produced tradable goods into the part coming from domestic absorption (the first term) and exports (the second term). We invert this equation to solve for $\bar{a}_T$, given values $\gamma = 0.24$ and $\eta = 1.65$, which we estimate below, and data on traded value added, $P_H y_H$, traded domestic demand, $P_T(c_T + x_T + g^c_T + g^x_T)$, and prices of traded goods, P_H and P_F. Figure 3 (panel B) displays a roughly 30 log points increase in $\bar{a}_T$ from the beginning of the sample until 2008, followed by a cumulative decline of roughly 30 log points until the end of the sample. It also shows that the price of foreign traded goods, P_F, does not fluctuate significantly over time. To understand the time series of $\bar{a}_T$, note that with a trade elasticity $\eta > 1$, Greek exports increase when the terms of trade P_F/P_H depreciate. The terms of trade appreciate in the boom and depreciate in the bust. In the absence of movements in $\bar{a}_T$, the behavior of P_F/P_H would initially generate a decrease in Greek exports and then an increase. The increase and then decline in $\bar{a}_T$ rationalizes the boom and bust in exports, given the behavior of P_F/P_H.[20]

[20] Exports here refer to the value added content of exports rather than gross exports because $P_H y_H$ is value added and not gross output. Value added exports differ from gross exports as reported in the national accounts because of imports of intermediate goods used in the production of gross exports. In Greece, gross and value added exports differ primarily because of the oil-refining sector, which imports crude petroleum and exports refined petroleum products. Conceptually, the value added content of exports measures foreign demand for Greek factors of production (Johnson and Noguera 2012; Adao, Costinot, and Donaldson 2017). Using this logic, we have obtained $\bar{a}_T$ in three alternative ways, using only the second term of the right-hand side of equation (22). In the first alternative, we equate the second term to the value added content of exports obtained by applying the procedure of Johnson and Noguera (2012) to the World Input-Output Database. In the second alternative, we equate the second term to nonpetroleum gross exports. In the third alternative, we equate the second term to gross exports of shipping only. Online Appendix Figure B.7 shows that these alternative $\bar{a}_T$ series closely track each other and our baseline measure obtained using equation (22). Relative to the alternatives, our preferred measure understates the importance of $\bar{a}_T$ in the boom. The measures display similar declines in the bust, and none recovers by the end of the sample.

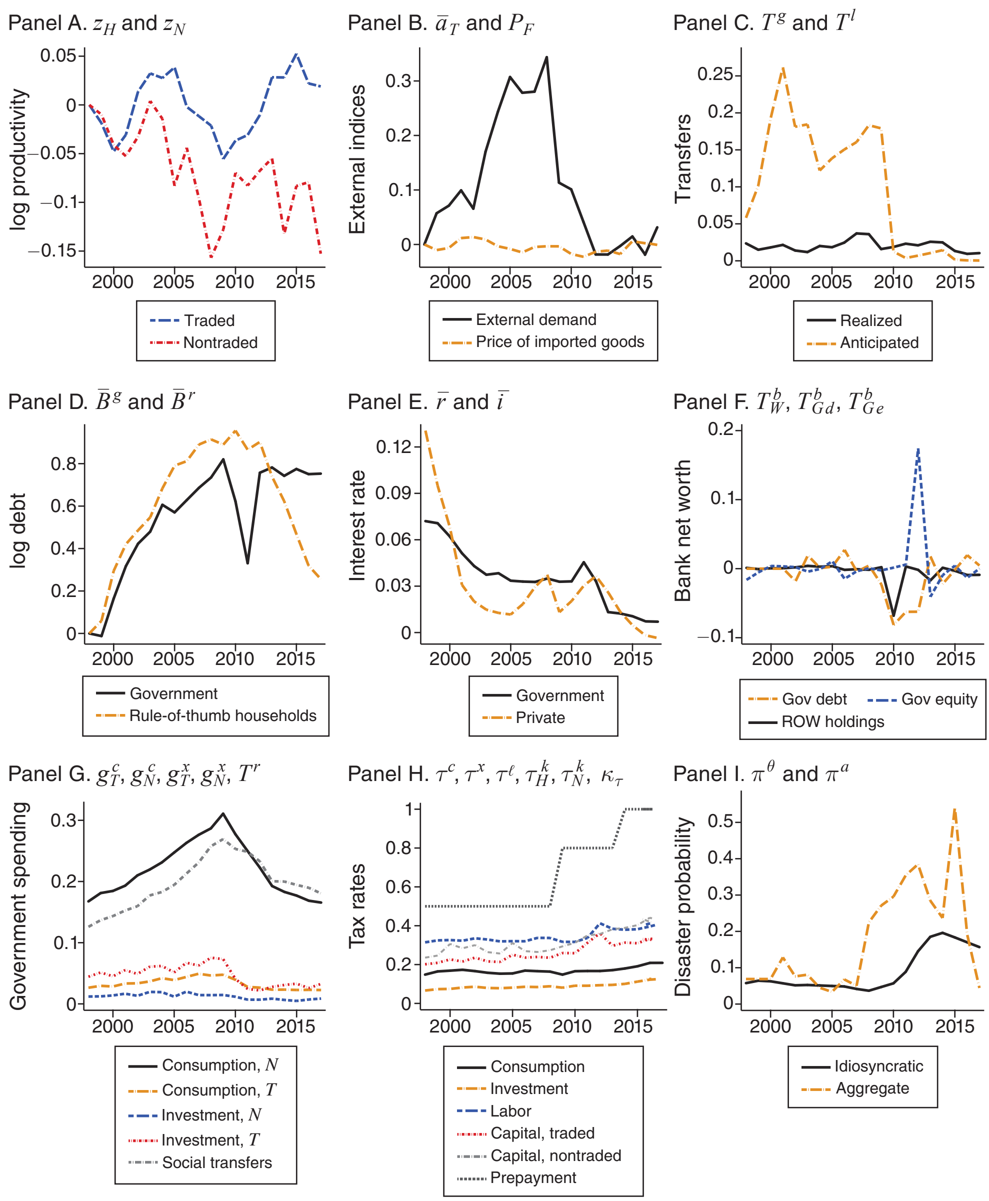

FIGURE 3. DRIVING FORCES

Notes: Figure 3 plots the evolution of driving processes. H denotes the traded sector for production measures, and T denotes the traded sector for consumption measures. N denotes the nontraded sector. z is productivity; $\bar{a}_T$ is external demand; P_F is the price of foreign goods; T^g is realized transfers from structural funds; T^l is anticipated transfers; $\bar{B}^g$ is government debt held by the rest of the world; $\bar{B}^r$ is the borrowing limit of the rule-of-thumb household; $\bar{r}$ is the government interest rate; $\bar{i}$ is the private interest rate; T^b_W, T^b_{Gd}, and T^b_{Ge} are changes in bank net worth from values of rest-of-the-world assets, holdings of government debt, and equity injections; g^c_T, g^c_N, g^x_T, and g^x_N are government spending on consumption and investment; T^r is transfers to the rule-of-thumb household; τ^c, τ^x, τ^ℓ, τ^k_H, and τ^k_N are tax rates on consumption, investment, labor income, and capital income; κ_τ is the fraction of taxes firms prepay; π^θ is the probability of idiosyncratic disaster; and π^a is the probability of aggregate disaster.

How does the behavior of $\bar{a}_T$ align with fluctuations in the demand for Greek products? Greece is a major global freight shipper, with this industry accounting for 30 percent of Greek gross exports in 2008. The path of $\bar{a}_T$ follows closely the boom and bust in global shipping demand (as we show more formally in online Appendix C.5). Strong growth in global trade between 2003 and 2007, and especially in raw material imports from China, resulted in high global shipping demand, a sharp increase in freight rates, and a wave of investment in new ships (Greenwood and Hanson 2014). Given significant time to build and low scrapping value of ships, the 2008 crisis led to substantial overcapacity in shipping, persistent declines in freight rates, and the idling of the existing fleet (Kalouptsidi 2014). The increase in $\bar{a}_T$ during the early part of the sample also coincides with the entry of Greece into the euro area and the hosting of the Olympic Games, both of which increased demand for Greek output in the boom.

Figure 3 (panel C) plots the paths of realized and anticipated foreign transfers to the Greek government. Realized transfers T^g are the sum of transfers to Greek regions from structural funds. They average roughly 2 percent of trend output in the boom and decline somewhat in the bust.

Anticipated transfers T^l measure perceived changes in household wealth when the Greek government misreports its deficit and debt. We measure T^l_t as the difference between gross debt of the general government (Maastricht Treaty definition) at the end of year t as reported in April of $t+1$ to the European Commission and the value reported for year t in 2019.[21] The difference between these two series constitutes an anticipated transfer because it represents the financing of the Greek government debt that workers did not believe would require higher future tax revenues. As seen in Figure 3 (panel C), Greece consistently understated its debt throughout the 2000s, with the understatement exceeding 25 percent of trend output in 2001 and 15 percent on the eve of the crisis. We note that 25 percent and 15 percent should be understood as the equivalent of a one-time transfer. In October 2009 the incoming government announced the misreporting of its budget statistics, prompting T^l to fall essentially to zero beginning in 2010. To operationalize these transfers in our model, we split them into a persistent component $\bar{T}^l$ and a transitory component $\hat{T}^l$ and feed them as a news shock that arrives in each period t but does not materialize in $t+1$.

Financial.—Figure 3 (panel D) shows the evolution of government debt held by the rest of the world, $\bar{B}^g$, and debt of the rule-of-thumb household, $\bar{B}^r$. Both series are from the Flow of Funds. Debt $\bar{B}^g$ is the market value of government debt and loans net of assets, currency held, and deposits, and $\bar{B}^r$ is household short-term liabilities in loans and other payables. The decline in $\bar{B}^g$ in 2011 reflects the 20 percent haircut in the net present value of bond holdings of private lenders to the Greek government. The increase in $\bar{B}^g$ after 2012 reflects long-term loans

[21] We obtain the historical reported values from https://bit.ly/3vtDHG1 and from past editions of the OECD Economic Outlook. The sources of understatement varied across years, but many involved improperly keeping some liabilities "off balance sheet." In 2002, the government restated its debt to include convertible and exchangeable bonds and the absorption of the liabilities of a state-owned company. In 2004, it recognized delayed interest payments as debt and corrected the accounting of debt owned by the social security fund. The 2009 and 2010 restatements reflected numerous changes, including putting a number of additional state-owned enterprises on budget, incorporating the market value of off-market swaps in debt, and correcting misreporting in several categories.

from the European Union and the International Monetary Fund under the second bailout program.

Figure 3 (panel E) plots the evolution of government, $\bar{r}$, and private, $\bar{i}$, interest rates. We measure $\bar{r}$ as an effective interest rate on government debt by dividing government (net) interest payments by the market value of debt. The interest rate $\bar{i}$ is the rate on deposits with maturity less than one year at Greek banks. Both interest rates decline over time, consistent with the experience of other southern economies (Gopinath et al. 2017).[22]

Figure 3 (panel F) plots the evolution of the three exogenous components of bank net worth. Component T_W^b equals the change in the market value of rest-of-world assets held by banks less net purchases. This variable remains close to 0 until 2010, when banks experienced a decline of 7 percent of output on their holdings of foreign assets.

We measure the mark-to-market gain or loss on holdings of Greek government debt, T_{Gd}^b, by comparing the market value from the Flow of Funds with the book values of these holdings from the Bank of Greece. To this unrealized gain or loss, we add the realized write-downs that occurred as part of the banks' participation in the 2011 securities exchange program.[23] Our measure of T_{Gd}^b shows that banks experienced cumulative losses of around 20 percent of output from their holdings of government debt between 2009 and 2012. Government equity injection T_{Ge}^b equals the value of bank shares held by the government. This series has small fluctuations, except in 2012 when the government injected equity of roughly 20 percent of output.

Government Spending.—Government consumption, g_T^c and g_N^c, includes purchases of market goods for consumption and own-account production. We allocate government purchases of market goods to g_T^c and g_N^c using the share of intermediate inputs purchased from each sector by public administration, education, and health and social work in the input-output tables. We allocate all other government consumption, which consists primarily of employee compensation, to the nontraded sector. We allocate the value added component of government investment in structures to g_N^x and all other investment to g_T^x. Transfers to the rule-of-thumb household T^r include pensions (accounting for more than 70 percent of T^r), health insurance, disability insurance, unemployment insurance, and in-kind benefits. Figure 3 (panel G) shows that g_N^c and T^r are the largest shares of government spending, with both exceeding 25 percent of trend output at their peak. All categories of spending rise in the boom and contract in the bust.

Tax Policy.—Our methodology for measuring tax rates builds on Mendoza, Razin, and Tesar (1994), who calculate effective tax rates using national income

[22] In Greece, the financial cycle for firm borrowing occurred mainly 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 nonfinancial firms in that year barely exceeded 6 percent. We interpret the endogenously determined borrowing cost i_t as a shadow cost that encompasses these financial developments.

[23] The Bank of Greece's statistics do not report interest income separately for holdings of government debt. The coupons on the securities were sufficiently small relative to the capital losses that ignoring interest income has a small impact. Nor do the data report realized gains or losses at sale separately for government debt, but banks sold relatively few of their holdings between 2009 and 2012.

and product accounts. There are two reasons we prefer to use effective rather than statutory tax rates. First, tax evasion in Greece is rampant (Artavanis, Morse, and Tsoutsoura 2016). Effective tax rates capture changes in tax compliance over time that would otherwise 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" (Eurostat 2013, pp. 106–07). 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 richest micro datasets.

Greece levies taxes on transactions, individuals, corporations, and property (see online Appendix C.7 for more details). We allocate all tax receipts and actual social contributions into taxes on consumption, investment, labor, and capital. 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 to consumption the part that unambiguously falls on consumption and allocate the residual to consumption and investment in proportion to their expenditure shares. Figure 3 (panel H) shows that τ^c and τ^x increased 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).

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). We measure the labor income tax rate τ^{ℓ} as the sum of the tax rate on social security contributions and the tax rate on labor income net of social security contributions. Labor income equals compensation of employees and an adjustment for the income of the self-employed. The labor income tax rate τ^{ℓ} is adjusted for the gap between the average marginal tax rate and the average average tax rate. Figure 3 (panel H) shows that τ^{ℓ} increased by roughly 10 percentage points between 2010 and 2012. In online Appendix Figure B.9, we document that the timing of these increases coincides with the increases in statutory income tax rates.

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 nontraded sector. Property taxes paid by corporations are allocated to each sector in proportion to its share of nonresidential 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. Figure 3 (panel H) shows a significant increase in both tax rates after 2012. The increase in τ_N^k exceeds the increase in τ_H^k, reflecting the significant increase in taxes falling on the residential sector after 2011. As in the case of labor income taxes, the timing of these increases coincides with increases in statutory rates.

Finally, we use tax laws 2238/1994, 3697/2008, and 4334/2015 to measure the fraction of income taxes that firms are required to prepay, κ_{τ}. Figure 3 (panel H) shows that κ_τ is 50 percent before the crisis, rises to 80 percent in 2009, and rises to 100 percent in 2014.

Disaster Risk.—The stochastic process for individual income in equation (4) captures permanent changes in income. Motivated by the long-term unemployed's significant income losses upon reemployment (Schmieder, von Wachter, and Bender 2016), we measure the time-varying probability of a permanent decline in income, π^θ, with the fraction of the labor force unemployed for 12 months or more. We choose unemployment as our measure of idiosyncratic risk because this captures both increased job separations and lower job finding rates in recessions. We choose 12 months, as it is the maximum duration of regular unemployment benefits. Figure 3 (panel I) shows that the long-term unemployment rate averages around 5 percent in the boom. It increases to almost 20 percent during the crisis and remains elevated until the end of the sample.

For the aggregate disaster probability π^a, we follow Barro and Liao (2021) and use 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 significant amount, so the price of such an option provides information about the probability of a disaster occurring (in which case the option becomes in the money), the size of a disaster conditional on one occurring, and risk aversion. Online Appendix Section C.6 details our implementation of the Barro and Liao (2021) procedure for Greece. We estimate monthly averages of daily disaster probabilities and then annualize and average in a year to arrive at our series for π^a in Figure 3 (panel I). Online Appendix Figure B.8 reports the monthly series and shows that the peaks of the disaster probability coincide with major political and economic events during the crisis period.

III. Parameterization

Parameters Set without Solving the Model.—In panel A of Table 1, the coefficient of relative risk aversion is $\sigma = 3$, consistent with the choice of σ by Barro and Liao (2021) and our implementation of their methodology for recovering the aggregate disaster probability. Using their methodology, we estimate $\varphi^a = 0.24$ so that the economy scales down by $\exp(-\varphi^a) = 0.79$, conditional on an aggregate disaster. Goods and labor demand elasticities, ε_p and ε_w, are such that markups equal 10 percent in the flexible price and wage equilibrium, consistent with the range of estimates reported by Basu and Fernald (1997). We estimate average depreciation rates, $\bar{\delta}_H = 0.08$ and $\bar{\delta}_N = 0.05$, using sectoral accounts data on depreciation and capital.

We estimate a trade elasticity of $\eta = 1.65$ (with a standard error of 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. Online Appendix C.8 presents details of our estimation procedure. Our η estimate is comparable to the value of 1.5 found in Backus, Kehoe, and Kydland (1994) and used extensively in the literature. The preference weight $\gamma = 0.24$ equals the sample average ratio of domestic absorption of domestic traded goods to domestic absorption of all traded goods.

Table 1—Parameter Values: Without Solving the Model

		Value	Rationale
Panel A. Parameter			
σ	Risk aversion	3.00	Barro and Liao (2021)
φ^a	Size of aggregate disaster	0.24	Estimation of Barro and Liao (2021) 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, nontraded	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 traded	0.24	Absorption of home to all traded
Panel B. Mean of exogenous process			
z_H	Productivity, traded	1.00	Normalization
P_F	Price of foreign traded goods	1.00	Normalization
T^g	Capital transfer	0.02	Sample average 1998–2007
$\bar{T}^l$	Transfer anticipation, persistent	0.00	Sample average 1998–2007
$\hat{T}^l$	Transfer anticipation, transitory	0.00	Sample average 1998–2007
$\bar{B}^g$	Government debt	0.89	Sample average 1998–2007
$\bar{r}$	Government interest rate	0.05	Sample average 1998–2007
$\bar{i}$	Private interest rate	0.04	Sample average 1998–2007
T^b_W	Rest of the world asset valuation	0.00	Sample average 1998–2007
T^b_{Gd}	Sovereign debt valuation	0.00	Sample average 1998–2007
T^b_{Ge}	Bank equity injection	0.00	Sample average 1998–2007
g^c_T	Government consumption, traded	0.03	Sample average 1998–2007
g^x_T	Government investment, traded	0.05	Sample average 1998–2007
g^c_N	Government consumption, nontraded	0.18	Sample average 1998–2007
g^x_N	Government investment, nontraded	0.01	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	0.33	Sample average 1998–2007
τ^k_H	Tax rate on capital, traded	0.26	Sample average 1998–2007
τ^k_N	Tax rate on capital, nontraded	0.26	Sample average 1998–2007
κ_τ	Prepayment fraction	0.50	Sample average 1998–2007
π^θ	Probability of idiosyncratic disaster	0.05	Sample average 1998–2007
π^a	Probability of aggregate disaster	0.07	Sample average 1998–2007

Panel B of Table 1 displays means of exogenous processes that drive the model.[24] We normalize the mean of traded productivity and foreign price to one. The means of all other exogenous processes equal their sample average between 1998 and 2007. Mean values of debt and government spending are relative to the value

[24] Online Appendix Table C.1 displays estimates of the persistence and standard deviation of the autoregressive processes using ordinary least squares between 1998 and 2017.

of output, $P_y y$, as our choice of parameters implies that $P_y = y = 1$ in the steady state of the model.

Parameters Calibrated Such that the Model Matches Targets in Steady State.—Panel A of Table 2 presents values of parameters calibrated from steady-state conditions involving endogenous variables. Some parameters are chosen to normalize output, utilization, and the price of traded and nontraded goods to one in the steady state of the model. The other parameters are chosen so that the model reproduces average values of endogenous variables between 1998 and 2007. The targets include expenditure shares of traded goods, the capital-output ratio, the labor share of income, debt-output ratios, interest rates, and net worth in the banking sector.[25]

Estimated Parameters.—Panel B of Table 2 presents parameters estimated with Bayesian techniques. We use 16 variables collected in the following vector:

$$(23)\quad \mathbf{y} = \Big(\log \ell_H, \log \ell_N, \log TFP_H, \log TFP_N, \log u_H, \log u_N, s, \log c, \log\big(P_N c_N\big), \log x_T, \log x_N, \log P_H, \log P_N, \log W, \Pi^f/\big(P_y y\big), \log N\Big).$$

We estimate 16 parameters using as observables in the estimation both the outcome variables **y** and the exogenous processes **z**. Crucially, we feed the time series of **z** as measured in the data without adding to them measurement error. This strategy disciplines our exercise because it restricts the freedom of shocks to account for the behavior of outcome variables. For the estimation, we instead add measurement errors to the outcome variables **y**. We subsequently remove the measurement error component when evaluating the performance of the model and in counterfactual analyses.[26]

Starting from a prior mean of 0.5 (Hall 2009), we estimate an intertemporal elasticity of substitution $\rho = 0.97$ with a tight confidence interval. A value of $\rho < 1$ implies that aggregate disaster risk π^a increases the stochastic discount factor of the optimizing household and that consumption and labor comove stronger than with a separable utility function. The estimates do not favor a ρ significantly lower than one because π^a mean reverts quickly, whereas consumption and labor remain persistently depressed until the end of the sample. We estimate a high elasticity between traded and nontraded goods, $\phi = 3.17$, starting from a prior mean of 0.44

[25] Following Schmitt-Grohé and Uribe (2003), we induce stationarity of net foreign assets by adding a small endogenous component to the interest rate $\bar{\imath}_t$ faced by the optimizing household and banks. Letting $\bar{\imath}_t^*$ temporarily denote the deposit rate we feed in as a driving force, we write $\bar{\imath}_t = \bar{\imath}_t^* + \psi_b\Big\{\exp\Big[B_{t+1}/\big(P_{y,t}y_t\big) - \bar{b}\Big] - 1\Big\}$, where $B_t = \zeta\bar{B}_t^r + (1-\zeta)B_t^o + B_t^f + \bar{B}_t^g = \bar{B}_t^b + (1-\zeta)B_t^o + \bar{B}_t^g$ is total external debt. We set $\psi_b = 0.001$ and choose $\bar{b}$ to target the average debt to output. The in-sample gap between $\bar{\imath}_t$ and $\bar{\imath}_t^*$ is negligible, and we ignore their distinction throughout the paper.

[26] Online Appendix Table C.2 presents details on the parameter priors used in the estimation. Online Appendix Table C.3 and online Appendix Figure C.1 demonstrate the stability of our results with respect to the prior means for price and wage adjustment costs. We assume that measurement errors of observables are drawn from the same prior and are uncorrelated with each other and over time. Online Appendix Figures C.2, C.3, and C.4 show that changing the prior of the variances of either all measurement errors or the measurement errors on prices and wages has negligible impact on the time series of outcome variables. Parameter estimates, time series of outcomes, and the sources of the boom and the bust do not change significantly when we estimate the model allowing for serially correlated measurement errors (online Appendix Table C.4, online Appendix Figure C.5, online Appendix Table C.5, and online Appendix Table C.6) and contemporaneously correlated measurement errors (online Appendix Table C.7, online Appendix Figure C.6, online Appendix Table C.8, and online Appendix Table C.9).

Table 2—Parameter Values: Solving the Model

			Value	Target
Panel A. Parameters calibrated from steady state				
χ	Disutility of labor		2.22	$y = 1$
$\bar{\xi}_H$	Utilization constant, traded		0.23	$u_H = 1$
$\bar{\xi}_N$	Utilization constant, nontraded		0.18	$u_N = 1$
$\bar{a}_T$	External demand		0.35	$P_T = 1$
z_N	Mean productivity, nontraded		0.89	$P_N = 1$
ω_c	Weight on traded goods, consumption		0.22	$(p_T c_T)/(P_c c) = 0.22$
ω_x	Weight on traded goods, investment		0.77	$(p_T x_T)/(P_x x) = 0.77$
α	Capital elasticity		0.44	$(Q k_N)/(P_N y_N) = 3.83$
q_ℓ	Firm labor subsidy		0.02	$(W\ell)/(Py) = 0.52$
$\bar{B}^r$	Mean debt of rule-of-thumb		0.41	$(\zeta \bar{B}^r)/(P_y y) = 0.14$
T^r	Mean transfers to rule-of-thumb		0.29	$c^r = c^o$
β^o	Discount factor, optimizing		0.97	$\bar{i} = 0.04$
β^r	Discount factor, rule-of-thumb		0.95	Carroll, Slacalek, and Tokuoka (2014)
κ_b	Diversion of funds, bankers		0.53	$B^f/(P_y y) = 0.35$
ω_b	Endowment, new bankers		0.17	$N/(P_y y) = 0.25$
$\bar{b}$	Steady-state debt		1.01	$B/(P_y y) = 1.01$
κ_y	Available fraction of output		0.19	Multiplier $= 0$ on constraint (12)
		Prior mean	Posterior mean	90 percent interval
Panel B. Parameters estimated from time series				
ρ	Intertemporal elasticity of substitution	0.50	0.97	[0.81, 1.14]
ϕ	Traded-nontraded elasticity	0.44	3.17	[2.22, 4.16]
ϵ	Frisch elasticity	1.50	1.16	[0.44, 1.88]
κ_x	Working capital, investment	0.50	0.59	[0.39, 0.80]
κ_ℓ	Working capital, labor	0.50	0.06	[0.01, 0.10]
ζ	Fraction rule-of-thumb	0.23	0.34	[0.21, 0.47]
φ^θ	Size of idiosyncratic disaster	0.20	0.16	[0.14, 0.17]
ξ_H	Utilization elasticity, traded	7.00	3.12	[2.89, 3.34]
ξ_N	Utilization elasticity, nontraded	7.00	3.75	[3.30, 4.16]
δ_b	Exit rate, bankers	0.50	0.70	[0.53, 0.90]
ψ_π	Adjustment cost, profits	0.50	0.60	[0.14, 1.04]
ψ_x	Adjustment cost, investment	7.00	6.28	[3.71, 8.74]
ψ_ℓ	Adjustment cost, labor	1.00	1.52	[1.00, 2.02]
$\psi_{H,p}$	Adjustment cost, prices traded	40.0	79.3	[39.5, 119.0]
$\psi_{N,p}$	Adjustment cost, prices nontraded	40.0	36.5	[18.3, 53.7]
ψ_w	Adjustment cost, wages	40.0	78.4	[43.1, 112.5]

(Stockman and Tesar 1995). The high substitutability allows the model to fit more closely the declines in consumption, prices, and wages in the bust. We estimate a Frisch elasticity of labor supply of $\epsilon = 1.16$ with a wide confidence interval, starting from a prior mean of 1.5. Our estimate is within the range found in studies discussing the role of the extensive margin and the gap between micro and macro estimates (Chetty et al. 2012).

We estimate a low fraction of the wage bill, $\kappa_\ell = 0.06$, and a high fraction of investment expenditures, $\kappa_x = 0.59$, that require working capital. Both estimates come with tight confidence intervals. As a comparison, the value of $\kappa_\ell = 1$ is found in Jermann and Quadrini (2012) in their study of financial sources in US business cycles and in Neumeyer and Perri (2005) in their study of interest rate shocks in emerging markets. 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 requiring a high κ_ℓ. On the other hand, the model requires a high κ_x to account for the significant decline in investment in the bust.

Using a prior mean of 0.23 from the evidence of Carroll, Slacalek, and Tokuoka (2014) on the marginal propensity to consume in Greece, we estimate that a fraction $\zeta = 0.34$ of households are rule-of-thumb. The existence of the rule-of-thumb household helps the model generate a comovement between consumption and labor income, as observed in both the boom and the bust. Our estimate of ζ falls within the typical range of 0.25 (Drautzburg and Uhlig 2015) to 0.5 (Mankiw 2000; Galí, Lopez-Salido, and Valles 2007) in the literature. Martin and Philippon (2017) calibrate a value of $\zeta = 0.65$ for Greece, based on the fraction of households with liquid assets below two months of income. Our estimated value is lower partly because our model generates a significant consumption drop of the optimizing household during the bust, in response to the rise of uninsurable idiosyncratic risk. Our estimate for the decline in consumption upon an idiosyncratic disaster is $\varphi^\theta = 0.16$, with a tight confidence interval. This value is consistent with studies documenting declines between 15 and 25 percent of consumption upon unemployment (Chodorow-Reich and Karabarbounis 2016).

We estimate elasticities of utilization of $\xi_H = 3.1$ and $\xi_N = 3.8$, with small standard errors. Lower values of ξ_H and ξ_N imply lower responsiveness of depreciation rates to utilization and therefore larger responsiveness of utilization to fluctuations in the marginal revenue product of capital. The estimated low values of ξ_H and ξ_N reflect the sharp decline in utilization in the bust.

We discuss in more detail the identification of the adjustment cost parameters and the exit rate of bankers in Section IVC by demonstrating how the model's time series change as we vary selected parameters. To summarize the most important results, we characterize the estimated exit rate of bankers, $\delta_b = 0.7$, as high because it generates significant fluctuations in the borrowing cost in response to shocks in bank net worth. We characterize price and wage rigidities as moderate. The evolution of quantities and prices between 2007 and 2017 under the estimated parameters $\psi_{H,p} = 79$, $\psi_{N,p} = 37$, and $\psi_w = 78$ is similar to their evolution when setting $\psi_{H,p} = \psi_{N,p} = \psi_w = 0$. However, the evolution of quantities and prices between 1998 and 2007 under the estimated parameters is different than their evolution when setting $\psi_{H,p} = \psi_{N,p} = \psi_w = 0$.

IV. Quantitative Results

We compare the time series generated by the model to their data counterparts. Next, we assess the importance of driving forces and model elements for generating these time series.

A. *Model Fit*

In the first row of Figure 4, we present aggregate measures of production.[27] Output in the model matches the data in terms of the timing of the boom and the bust, the magnitude of the bust, and the lack of recovery after 2012. The model generates a boom and a bust in capital but underestimates the magnitude of the boom and overestimates the magnitude of the bust. The model also accounts well for the evolution of TFP, although not for the last years of the sample. The driver of TFP in the model is variable utilization, with the model generating sectoral utilizations that match almost perfectly with their data counterparts, as shown in online Appendix Figure C.7.

In the second row of Figure 4, we see that the model performs well in terms of matching the time series of expenditures. Consumption and investment increase in the boom and collapse in the bust by roughly as much as in the data. Similar to their counterparts in the data, domestic absorption in the model increases by more than domestic production, and net exports decline during the boom. The model also generates a sudden stop at the onset of the bust. As in the data, net exports rise by more than 10 percentage points of GDP after 2009 and remain high until 2017.[28]

The bottom rows present the evolution of sectoral output, sectoral prices, labor, and wages. The model is successful in accounting for the comovement observed in the data, with both sectors experiencing a boom until 2007, followed by a persistent decline after. The model also generates an increase in sectoral prices in the boom and a decline in the bust but to a smaller extent than the data. Finally, similar to the data, the model generates a boom and bust in labor and wages. Quantitatively, the model accounts more closely for the time series of labor, as it underestimates the increase in wages in the boom and misses by two years their turning point. The lag in the turning point of wages in the data is consistent with a stronger downward wage rigidity in the early part of a recession, as suggested by Schmitt-Grohé and Uribe (2017).[29]

[27] To plot endogenous variables, we feed the exogenous processes **z** into the policy functions evaluated at the parameters' posterior mean. Online Appendix Table C.10 presents the correlation between data and model variables and R^2 coefficients from regressions of the data on the model variable. The correlation is around or above 90 percent for all variables, except for the two price indices for which it is roughly 60 percent. The model accounts for more than 90 percent of the variation of observables, except for capital (73 percent), wages (73 percent), price of nontraded goods (34 percent), and price of traded goods (32 percent).

[28] The value of net exports in the model is $P_H y_H - P_T(c_T + x_T + g_T^c + g_T^x) - \textit{adjustment\_costs}$. Net exports and the current account comove very closely in our model. We focus our analysis on net exports because the current account does not include valuation effects from foreign asset holdings, which impact banks' balance sheets in our model, and includes items that we do not model but are important for its deterioration during the boom period in the data, such as income earned by foreigners in Greek investments and remittances. Greece had an export deficit of around 10 percent of GDP in 1998. Because we initiate the model in steady state, model net exports are close to zero in 1998. To ease the presentation of the results, we thus normalize net exports over GDP to zero in 1998 both in the data and in the model.

[29] 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 because this specification facilitates the use of standard perturbation methods to solve the model and the estimation of its parameters. We acknowledge that downward nominal wage rigidity may have played a role in the initial years of the recession. In online Appendix Figure C.8, we display the path of endogenous variables using an alternative specification in which nominal wage adjustment costs are infinite between 2008 and 2010. As the figure shows, this specification is more aligned with the timing of the decline in wages in the data, though it features a decline in output, labor, and consumption that precedes the declines observed in the data by one to two years. Importantly, online Appendix Table C.11 shows that the changes in endogenous variables through 2017 and

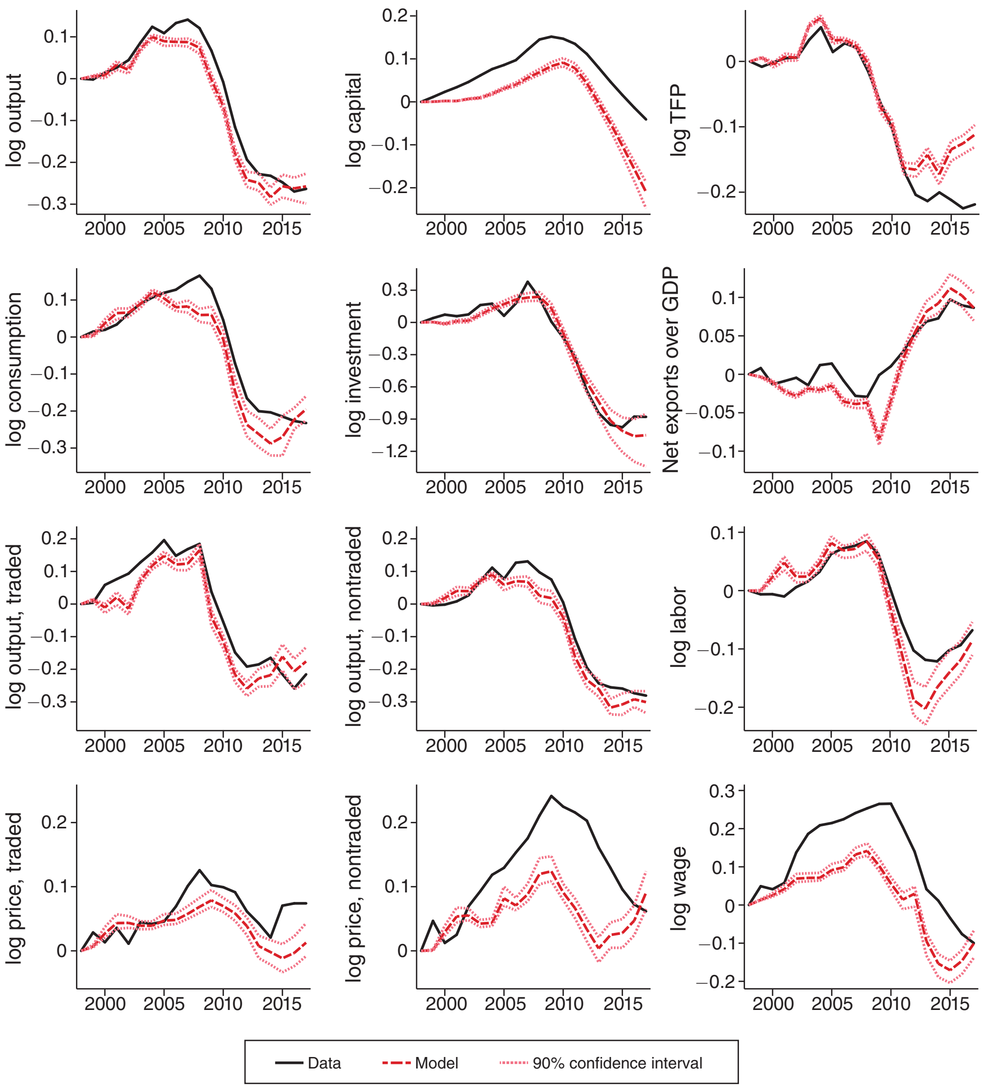

Figure 4. Time Series Comparison between Model and Data

Notes: Figure 4 plots the evolution of macroeconomic variables in the data (solid line) and the model (dashed line). In both the data and the model, quantities are detrended with 1.6 percent, TFP with 0.7 percent, prices with 1 percent, and wages with 2.6 percent. All series are normalized to zero in 1998.

Along with point estimates for the model's time series, Figure 4 shows 90 percent confidence intervals (credible sets), which we construct by drawing vectors of parameters from their joint posterior distribution. The confidence intervals are generally tight and tend to become wider toward the end of the sample. The tightness reflects that crucial parameters for the model's dynamics are estimated precisely and

the contribution of the shocks to these changes are robust to this specification of adjustment costs. The reason is that wages eventually drop in the data, by 17 percent from 2010 to 2017 (when not detrended), and the model generates a substantial fraction of this decline.

parameters that are estimated imprecisely are not crucial for the model's dynamics. To give some examples, the utilization elasticities are estimated tightly and are crucial for the dynamics of variables, whereas the nominal rigidity parameters are not estimated precisely, but the path of variables is not too sensitive to reasonable changes in their values. The widening of the confidence intervals toward the end of the sample arises because confidence intervals cumulate the effects of earlier shocks and shocks are larger in the bust.

B. *The Sources of the Greek Boom and Bust*

Table 3 documents the sources of the boom (1998–2007) and Table 4 documents the sources of the bust (2007–2017). The first row of each table reports changes in variables in the data, and the second row reports changes in the model. In other rows, we shut off the time evolution of particular exogenous processes by setting them equal to a constant. A positive entry indicates that the exogenous process contributes to an increase in a particular variable. Up to rounding, the contributions of all exogenous processes sum up to the reported sum in the model row.

Beginning with Table 3, we find that essentially all of the boom in production is accounted for by two demand shifters, the increase in external demand for traded goods $\bar{a}_T$ and the increase in government spending that mostly falls on nontraded goods g_N^c. The economics are fairly straightforward, as the increase in the demand for Greek goods raises the marginal revenue product of factors and firms accommodate the increase in demand by employing more labor and capital. By contrast, we find limited or no contribution to the production boom from productivity, financial conditions, tax policy, and disaster risk.

The consumption boom comes from both the rule-of-thumb and the optimizing household. Workers in the rule-of-thumb household increase their consumption alongside their labor income. Workers in the optimizing household increase their consumption for two reasons. First, in response to an increase in realized transfers, T^g, and anticipated transfers, T^l, their perceived wealth increases. Second, in response to the decline in idiosyncratic disaster risk, π^θ, workers in the optimizing household lower their precautionary saving. The demand boom is accompanied by an increase in prices and wages. Quantitatively, external factors ($\bar{a}_T$, T^g, and T^l) account for the largest fraction of the boom in prices and wages. Net exports deteriorate in the boom despite the increase in external demand, as the combination of lower borrowing cost, transfers to workers, and government spending causes an even larger import boom.

Table 4 presents the sources of the Greek bust. Tax policy is the most important driver of the bust in production. An increase in the fraction of taxes firms are required to prepay, κ_τ, can be accommodated by either an increase in borrowing or a decrease in expenditures for labor and capital. Firms in the model respond to the increase in κ_τ by mostly cutting their demand for labor and capital because the supply of loans from banks is not perfectly elastic, and thus i increases in response to an increase in loan demand. The increase in capital taxes in the nontraded sector, τ_N^k, also plays an important role for the bust in production, as it lowers after-tax marginal revenue products of labor, capital, and utilization. Finally, the increase in

Table 3—Sources of Macroeconomic Dynamics: Boom Period, 1998–2007

	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log TFP$	$\log c$	$\log P_H$	$\log P_N$	$\log W$	NX/GDP
Data	0.14	0.08	0.12	0.02	0.15	0.10	0.18	0.24	−0.03
Model	0.09	0.07	0.06	0.02	0.08	0.06	0.09	0.13	−0.04
Productivity	0.00	0.01	0.00	−0.01	0.00	0.00	0.00	0.00	0.00
$\log z_H$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\log z_N$	0.00	0.01	0.00	−0.01	0.00	0.00	0.00	0.00	0.00
External	0.04	0.03	0.02	0.02	0.05	0.05	0.06	0.08	0.00
$\log \bar{a}_T$	0.04	0.04	0.01	0.02	0.01	0.03	0.03	0.04	0.02
$\log P_F$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T^g	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	−0.01
T^l	0.00	−0.01	0.01	0.00	0.01	0.01	0.01	0.02	−0.01
Financial	0.00	−0.01	0.01	0.00	0.01	0.01	0.01	0.02	−0.01
$\log \bar{B}^g$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\log \bar{B}^r$	−0.01	−0.01	−0.02	0.00	0.00	0.01	0.01	−0.01	0.01
$\bar{r}$	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00
$\bar{\imath}$	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.02	−0.01
T^b_W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T^b_{Gd}	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
T^b_{Ge}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gov. spending	0.04	0.03	0.03	0.01	0.00	0.00	0.00	0.01	−0.02
$\log g^c_T$	0.00	0.00	0.00	0.00	−0.01	0.00	0.00	−0.01	−0.01
$\log g^c_N$	0.02	0.02	0.00	0.00	−0.03	0.00	0.00	0.00	0.00
$\log g^x_T$	0.01	0.00	0.02	0.00	0.00	−0.01	−0.01	0.00	−0.01
$\log g^x_N$	0.00	0.00	0.01	0.00	0.00	0.00	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	−0.01
Tax policy	−0.01	0.00	−0.01	0.00	−0.01	0.00	0.01	0.01	0.00
τ^c	0.00	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	0.00
τ^ℓ	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
τ^k_H	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
τ^k_N	−0.01	−0.01	−0.01	0.00	−0.01	0.00	0.01	0.00	0.00
κ_τ	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Disaster risk	0.01	0.00	0.00	0.01	0.03	0.01	0.01	0.02	−0.01
π^θ	0.01	0.00	0.00	0.01	0.03	0.01	0.01	0.02	−0.01
π^a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

labor income taxes τ^ℓ accounts for a significant fraction of the decline in labor by reducing workers' labor supply.[30]

[30] We clarify that the role of all driving forces is assessed relative to the least expensive way to balance the government's budget, which is to adjust lump-sum transfers. Thus, the contribution of tax rates should be thought of as an upper bound. When estimating the model, we prefer the assumption that lump-sum transfers adjust to balance the government's budget because this assumption allows us to match the path of taxes and government spending as observed in the data. Online Appendix Tables C.12 and C.13 present the sources of the boom and the bust under the alternative assumption that government spending adjusts to balance the budget and lump-sum transfers to the

In the bust, the declines in $\bar{a}_T$ and g_N^c also account for a significant fraction of the output and labor declines. Financial drivers play a moderate role in accounting for the bust in production. However, as we discuss in the context of the bailouts in Section VC, this result masks the observation that losses from holdings of sovereign bonds T_{Gd}^b and foreign assets T_W^b are offset by the equity injection to banks T_{Ge}^b.[31]

With respect to the bust in consumption, quantitatively the most important factors are the increase in uninsurable idiosyncratic risk and taxes. To understand the role of idiosyncratic risk, we define the effective discount factor, $\tilde{\beta}_t^o$, of the optimizing household as the product of all exogenous components of the expected stochastic discount factor $\Lambda_{t,t+1}^o$ (which we present in online Appendix B):

$$\tilde{\beta}_t^o = \underbrace{\beta^o e^{\left(1-\frac{1}{\rho}\right)\mu}}_{\text{discount factor}} \times \underbrace{\left(1 - \pi_t^a + \pi_t^a e^{(\sigma-1)\varphi^a}\right)^{\frac{\frac{1}{\rho}-1}{\sigma-1}}}_{\text{aggregate risk}} \times \Bigg[\underbrace{\left(1-\pi_t^\theta\right) e^{-\sigma \log\left(\frac{1-\pi_t^\theta e^{-\varphi^\theta}}{1-\pi_t^\theta}\right)} + \pi_t^\theta e^{\sigma\varphi^\theta}}_{\text{idiosyncratic risk}}\Bigg]. \tag{24}$$

An increase in the effective discount factor $\tilde{\beta}_t^o$ is isomorphic to an increase in the discount factor β^o because both increase the willingness of the household to postpone consumption for the future. Beginning with the aggregate risk term in parentheses, we note that a higher probability of disaster π^a increases the effective discount factor only if the elasticity of intertemporal substitution $\rho < 1$. Because we estimate ρ close to one, aggregate disaster risk does not matter quantitatively for the time series of the model. By contrast, for the idiosyncratic risk term in brackets, a higher probability of disaster π^θ unambiguously increases the effective discount factor, with the effect being stronger the larger is risk aversion σ. As a result, the rise of idiosyncratic risk increases precautionary saving, lowers consumption, and improves the trade balance.

The rise of idiosyncratic risk acts simultaneously as a negative demand disturbance and as a positive labor supply disturbance, depressing both prices and wages. The rise of idiosyncratic risk accounts for 10 percentage points of the decline in prices and 18 percentage points of the decline in wages. By contrast, increased taxes act as a negative supply disturbance and increase prices and wages in the bust.

optimizing household are constant. The differences relative to our baseline, in which lump-sum transfers adjust, are relatively small. Tax policy still makes the largest contribution to the bust, but its contribution to the output bust declines to 15 percentage points instead of 18 percentage points. Tax rates by themselves contribute 6 percentage points to the decline in output, a contribution that is closer to that in Section V, in which we adjust government spending to balance the budget.

[31] Online Appendix Table C.14 documents the contribution of exogenous processes in the earlier years of the bust (2007–2012). Relative to the results discussed in Table 4, those in online Appendix Table C.14 show a somewhat larger role for external demand $\bar{a}_T$ and losses from holdings of sovereign bonds T_{Gd}^b and somewhat smaller roles for fiscal policies.

Table 4—Sources of Macroeconomic Dynamics: Bust Period, 2007–2017

	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log TFP$	$\log c$	$\log P_H$	$\log P_N$	$\log W$	NX/GDP
Data	−0.40	−0.14	−0.16	−0.24	−0.38	−0.03	−0.11	−0.34	0.11
Model	−0.34	−0.16	−0.27	−0.14	−0.28	−0.04	0.00	−0.23	0.13
Productivity	−0.02	0.01	0.00	−0.02	−0.03	−0.01	0.03	0.00	0.00
$\log z_H$	0.01	0.00	0.00	0.01	0.00	−0.01	0.00	0.00	0.00
$\log z_N$	−0.02	0.01	0.00	−0.03	−0.03	0.00	0.03	0.00	−0.01
External	−0.06	−0.05	−0.01	−0.03	−0.05	−0.06	−0.07	−0.10	0.00
$\log \bar{a}_T$	−0.06	−0.06	0.00	−0.03	−0.01	−0.03	−0.04	−0.06	−0.03
$\log P_F$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T^g	−0.01	−0.01	0.01	0.00	−0.01	0.00	0.00	0.00	0.00
T^l	0.01	0.02	−0.01	0.00	−0.03	−0.03	−0.03	−0.04	0.02
Financial	−0.01	0.02	−0.05	0.01	0.03	0.02	0.03	0.01	−0.01
$\log \bar{B}^g$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\log \bar{B}^r$	0.01	0.01	−0.02	0.01	−0.01	0.00	0.00	0.01	−0.01
$\bar{r}$	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	−0.01
$\bar{i}$	0.02	0.03	0.02	0.00	0.05	0.00	0.01	0.01	−0.01
T^b_W	−0.02	−0.01	−0.03	0.00	−0.02	0.00	0.00	−0.01	0.01
T^b_{Gd}	−0.04	−0.02	−0.06	0.00	−0.02	0.02	0.02	−0.02	0.02
T^b_{Ge}	0.02	0.01	0.03	0.00	0.01	−0.01	−0.01	0.01	−0.01
Gov. spending	−0.08	−0.07	−0.05	−0.02	0.02	0.00	0.00	−0.01	0.04
$\log g^c_T$	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
$\log g^c_N$	−0.04	−0.05	0.00	−0.01	0.06	−0.01	−0.01	0.01	0.01
$\log g^x_T$	−0.02	−0.01	−0.03	0.00	0.00	0.01	0.01	0.00	0.01
$\log g^x_N$	−0.01	0.00	−0.02	0.00	0.00	0.00	0.00	−0.01	0.00
$\log T^r$	−0.01	−0.01	0.01	−0.01	−0.04	−0.01	−0.01	−0.02	0.01
Tax policy	−0.18	−0.11	−0.12	−0.06	−0.12	0.09	0.12	0.06	0.02
τ^c	−0.01	−0.01	0.00	0.00	−0.02	0.00	0.00	0.00	0.00
τ^x	−0.01	0.00	−0.01	0.00	0.00	0.01	0.01	0.00	0.00
τ^ℓ	−0.03	−0.05	0.00	0.00	−0.03	0.01	0.02	0.07	0.00
τ^k_H	−0.01	0.00	0.00	−0.01	0.00	0.01	0.00	0.00	0.00
τ^k_N	−0.05	−0.01	−0.04	−0.02	−0.03	0.01	0.06	0.00	0.00
κ_τ	−0.07	−0.04	−0.07	−0.02	−0.02	0.04	0.04	−0.02	0.02
Disaster risk	0.00	0.05	−0.03	−0.01	−0.14	−0.09	−0.10	−0.18	0.07
π^θ	0.00	0.05	−0.03	−0.01	−0.14	−0.09	−0.10	−0.18	0.07
π^a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

C. *The Importance of Structural Elements*

We discuss the mechanisms that allow the model to generate a boom and bust that resemble the Greek boom and bust in the data. The first two rows in each panel of Table 5 report changes in selected variables in the data and the baseline model for the boom (panel A) and the bust (panel B). Each other row reports changes in the same variables when we feed the same sequence of shocks but under different parameter values than those in the baseline model. This exercise also clarifies the identification of some of the estimated parameters (see online Appendix Table C.15 for additional parameters).

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 a significantly smaller bust in output and TFP. Increasing the responsiveness of utilization relative to that in the baseline ($\xi_H = \xi_N = 2.5$) 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. The tension between accounting for the behavior of quantities and prices in the bust explains why our estimated elasticities of utilization lie between these more extreme values.

Eliminating nominal price and wage rigidity ($\psi_p = \psi_w = 0$) does not affect the performance of the model in terms of the declines in quantities and prices by 2017. Nominal rigidities play an important role in generating the boom in quantities. However, increasing them to extreme values ($\psi_p = \psi_w = 1{,}000$) introduces a significant deviation of the model from the data in terms of the medium-run boom and bust in prices and wages. The trade-off between accounting for the boom in quantities and the cycle in prices and wages identifies a moderate role for nominal rigidity.

The size of idiosyncratic disasters is identified by the relative movements of consumption, prices, and labor in the bust. Without idiosyncratic disasters ($\varphi^\theta = 0$), the model generates a significantly smaller decline in consumption and prices in the bust. With larger idiosyncratic disasters ($\varphi^\theta = 0.3$), the model generates a larger decline in consumption and prices in the bust but fails to account for the drop in labor.[32]

The exit rate of bankers, δ_b, affects the responsiveness of the borrowing cost i to underlying shocks. The logic is that a higher δ_b reduces the horizon of banks to smooth negative net worth shocks. As a result, banks need to be compensated with a higher i to satisfy the incentive compatibility constraint (18). In turn, a higher i reduces firms' demand for inputs and generates upward pressure on prices. Consistent with this logic, Table 5 shows that higher values of δ_b are associated with larger movements in production and consumption, and lower values of δ_b are associated with larger price declines in the bust.

We conclude by discussing the importance of the working capital constraint, which intermediates changes in the borrowing cost i into production decisions. The decline in i during the boom and increase during the bust amplifies the boom and bust in production. Thus, in the absence of the working capital constraint, both the boom and the bust in production would have been smaller. The movements of i also affect the marginal cost of production, and therefore, the presence of a working capital constraint reduces the responsiveness of prices.

[32] Social insurance against long-term unemployment affects the size of idiosyncratic disasters φ^θ. The comparative statics of aggregate consumption with respect to φ^θ are consistent with the stabilization effects of unemployment insurance in Kekre (2022).

Table 5—Role of Structural Elements

	$\log y$	$\log \ell$	$\log \tilde{k}$	$\log TFP$	$\log c$	$\log P_H$	$\log P_N$	$\log W$	NX/GDP
Panel A. Boom: 1998–2007									
Data	0.14	0.08	0.12	0.02	0.15	0.10	0.18	0.24	−0.03
Baseline model	0.09	0.07	0.06	0.02	0.08	0.06	0.09	0.13	−0.04
$\xi_H = \xi_N = \infty$	0.06	0.10	0.06	−0.02	0.06	0.07	0.12	0.14	−0.05
$\xi_H = \xi_N = 2.5$	0.09	0.06	0.05	0.03	0.08	0.06	0.08	0.13	−0.04
$\psi_p = \psi_w = 0$	0.03	0.02	0.05	0.00	0.04	0.10	0.13	0.16	−0.05
$\psi_p = \psi_w = 1{,}000$	0.16	0.18	0.07	0.04	0.16	0.02	0.03	0.06	−0.03
$\varphi^\theta = 0$	0.08	0.07	0.05	0.02	0.06	0.05	0.08	0.11	−0.03
$\varphi^\theta = 0.3$	0.11	0.08	0.06	0.04	0.17	0.08	0.12	0.19	−0.06
$\delta_b = 0.3$	0.08	0.06	0.05	0.02	0.08	0.06	0.09	0.13	−0.03
$\delta_b = 0.9$	0.10	0.08	0.06	0.03	0.09	0.05	0.09	0.14	−0.04
No working capital	0.05	0.05	0.03	0.01	0.07	0.07	0.11	0.12	−0.03
Panel B. Bust: 2007–2017									
Data	−0.40	−0.14	−0.16	−0.24	−0.38	−0.03	−0.11	−0.34	0.11
Baseline model	−0.34	−0.16	−0.27	−0.14	−0.28	−0.04	0.00	−0.23	0.13
$\xi_H = \xi_N = \infty$	−0.24	−0.17	−0.26	−0.02	−0.18	−0.11	−0.10	−0.23	0.15
$\xi_H = \xi_N = 2.5$	−0.44	−0.15	−0.27	−0.23	−0.37	0.01	0.08	−0.25	0.11
$\psi_p = \psi_w = 0$	−0.34	−0.13	−0.26	−0.14	−0.28	−0.07	0.03	−0.24	0.12
$\psi_p = \psi_w = 1{,}000$	−0.42	−0.32	−0.26	−0.13	−0.33	0.03	0.05	−0.02	0.11
$\varphi^\theta = 0$	−0.34	−0.20	−0.23	−0.12	−0.14	0.04	0.10	−0.05	0.05
$\varphi^\theta = 0.3$	−0.36	−0.01	−0.37	−0.18	−0.72	−0.32	−0.32	−0.81	0.36
$\delta_b = 0.3$	−0.29	−0.13	−0.19	−0.13	−0.25	−0.06	−0.02	−0.21	0.10
$\delta_b = 0.9$	−0.38	−0.17	−0.31	−0.14	−0.29	−0.03	0.01	−0.25	0.14
No working capital	−0.18	−0.07	−0.10	−0.10	−0.21	−0.13	−0.08	−0.18	0.06

V. Policy Experiments

We begin our analysis by changing the mix of spending and taxes used to achieve fiscal consolidation. Next, we discuss how debt accumulation in the boom limited fiscal space in the bust. Finally, we evaluate the importance of bailouts to banks from the government and to Greece from the rest of the world. Our policy counterfactuals in this section differ from those in Tables 3 and 4, in which lump-sum transfers T^o adjust to balance the government budget, because we make the more plausible assumption that alternative policy instruments adjust to balance the budget.

A. *Fiscal Adjustment*

The Greek fiscal adjustment fell on both spending cuts and tax increases. Figure 5 evaluates the macroeconomic effects of tilting the adjustment away from increased taxes and entirely toward reduced spending.[33] In each panel, the solid

[33] Online Appendix Figure C.9 shows that for all variables the difference between the baseline and the counterfactual is statistically significant at conventional levels. To perform this counterfactual, we set all tax innovations to zero starting in 2010 and introduce innovations to government spending $\{g_T^c, g_N^c, g_T^x, g_N^x, T^r\}$ such that the government

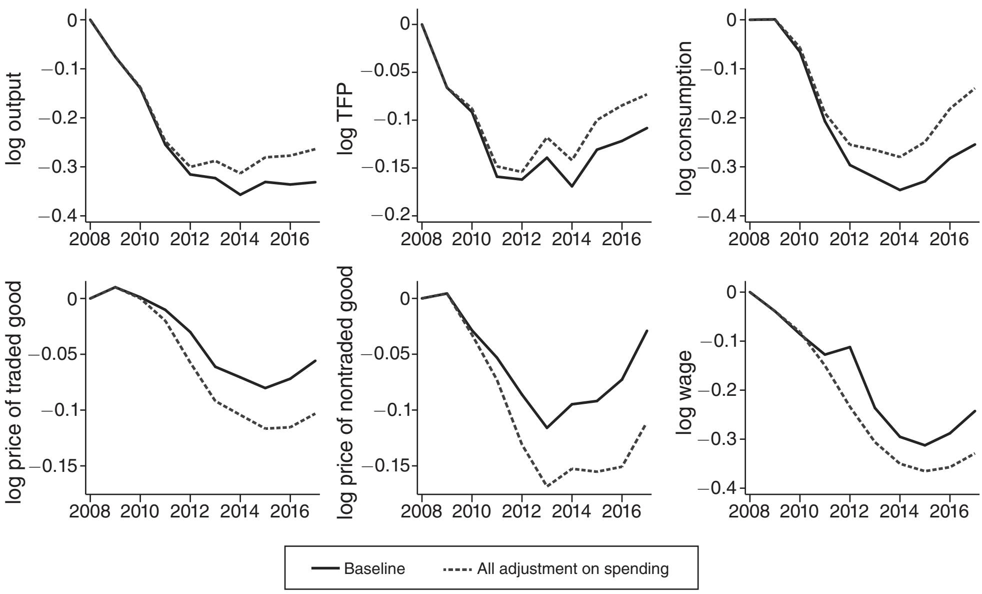

Figure 5. Tilting Fiscal Adjustment to Spending Cuts

Notes: Figure 5 plots the evolution of macroeconomic variables relative to 2008 in the model. The solid line shows the baseline path under the observed fiscal adjustment, and the dashed line shows the counterfactual path had the fiscal adjustment been concentrated entirely on spending cuts holding tax rates constant to their 2009 values.

line presents the baseline path of a variable in our model under the implemented fiscal consolidation program, and the dashed line presents the counterfactual path of a variable under the alternative program. Relative to the implemented fiscal adjustment, this alternative program would have increased output by roughly seven log points in 2017. Around one-half of the gains in output are accounted for by an increase in TFP. We also find significant gains in consumption. The second row of the figure shows that the adjustment is facilitated by a larger decline in prices and wages, as removing the increase in tax rates makes the economy more competitive.

To understand how the composition of the fiscal adjustment affects macroeconomic variables, we calculate the output and revenue effects of each fiscal instrument. The output effects are given by the fiscal multiplier of instrument $f = \left\{g_T^c, g_N^c, g_T^x, g_N^x, \zeta T^r, \tau^c, \tau^x, \tau^\ell, \tau_H^k, \tau_N^k\right\}$ at horizon h:

$$M_f^y(h) = \frac{\sum_{t=1}^h \left(1 + \bar{i}\right)^{1-t} \Delta y_t}{\sum_{t=1}^h \left(1 + \bar{i}\right)^{1-t} \Delta f_t}. \tag{25}$$

The multiplier is generated by an initial impulse ν_1^f in fiscal instrument f and its autoregressive process in equation (21). Changes in output Δy_t are calculated as the difference between the path of output given the fiscal impulse and the path of

budget constraint is satisfied at the baseline path of transfers to the optimizing household T^o. The size of the innovations in each instrument is proportional to its steady-state expenditure share. We follow the same approach in all our counterfactuals below, and when we adjust tax rates, we use revenue shares.

output in the absence of the fiscal impulse, assuming that lump-sum transfers to the optimizing household T^o adjust to balance the budget. Because output in steady state equals 1, the tax multipliers can be interpreted as the percent change in output resulting from a 1 percentage point change in a tax rate. The revenue cost is the change in lump-sum transfers T^o that balances the government budget constraint:

$$M_f^r(h) = -\frac{\sum_{t=1}^{h}\left(1+\bar{i}\right)^{1-t}\Delta(1-\zeta)T_t^o}{\sum_{t=1}^{h}\left(1+\bar{i}\right)^{1-t}\Delta f_t}. \tag{26}$$

We discount future changes at the steady-state interest rate of the optimizing household, $\bar{i} = 0.04$.

Table 6 reports cumulative multipliers at horizon $h = 7$ years to benchmark our results to the fiscal adjustment that began in 2010 (see online Appendix Table C.16 for confidence intervals and online Appendix Table C.17 for contemporaneous and infinite horizon multipliers). Dividing M_f^y by M_f^r yields the cost-based multiplier for instrument f in the last column of Table 6. For example, a cumulative 1 percentage point decrease in τ^ℓ costs 0.42 units of revenues. A unit change in revenues induced by lower τ^ℓ increases output by 0.9 units.

Table 6 highlights significant differences across fiscal instruments in their ability to raise revenues and to impact output. Revenue-based tax multipliers generally exceed revenue-based spending multipliers. As a result, shifting the burden of adjustment away from taxes as in Figure 5 increases output in the bust, holding constant the size of the fiscal consolidation.

The model generates a government spending multiplier for nontraded consumption g_N^c of 0.56.[34] Weighting the four g multipliers with their expenditure shares also yields an aggregate multiplier of 0.56 since g_N^c is the largest category of spending. The multiplier on nontraded goods exceeds the multiplier on traded goods, as the former goods are produced domestically, whereas the latter are also imported. Government spending multipliers on investment exceed the multipliers on consumption because public investment augments the capital used in production, as shown in equation (11). Finally, the multiplier on nontraded goods exceeds the transfer multiplier because transfers do not directly augment production.

How do the spending multipliers compare with those in the literature? On the theoretical side, our model contains elements 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 that belong to a currency union, such as Greece. These include nominal price and wage rigidity and liquidity-constrained workers. Despite these shared features, our model generates smaller multipliers than those in these papers for two reasons. First, this literature considers more transient changes in spending than observed in Greece.[35]

[34] This multiplier is under the assumption that lump-sum transfers T^o adjust to balance the budget constraint. Online Appendix Table C.18 reports multipliers under various alternative financing systems and at different horizons.

[35] In the presence of nominal rigidity, the most important parameter for government spending multipliers 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. We report fiscal multipliers for different parameters, different financing

Table 6—Output and Revenue Effects of Fiscal Instruments (Seven-Year Horizon)

Multiplier	Output effect	Revenue cost	Output/cost
g_N^c	0.56	0.89	0.62
g_T^c	0.14	1.04	0.14
g_N^x	1.24	0.54	2.29
g_T^x	0.62	0.85	0.73
ζT^r	0.21	0.81	0.26
τ^c	−0.27	−0.38	0.72
τ^x	−0.15	−0.12	1.25
τ^ℓ	−0.38	−0.42	0.90
τ_H^k	−0.14	−0.03	4.46
τ_N^k	−0.26	−0.10	2.71

Second, some of the theoretical literature considers complete asset markets, whereas we model Greece as 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. With incomplete asset markets, the multiplier of Nakamura and Steinsson (2014) falls from 1.4 to 0.8, and the multiplier of House, Proebsting, and Tesar (2017) falls 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 US 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. Using structural vector autoregressions, Ilzetzki, Mendoza, and Vegh (2013) report multipliers above one for countries with fixed exchange rates but lower or even negative multipliers for countries with high debt burdens, such as Greece.

Turning to taxes, we find the largest revenue-based multipliers for capital tax rates. In fact, the economy is close to the peak of the Laffer curve with respect to capital tax rates. This result again highlights the importance of variable utilization. The first-order conditions for utilization in each sector $i = \{H,N\}$ imply $u_i = \left[\frac{(1-\tau_i^k)P_i^f y_i}{\bar{\xi}_i Q^k e^{-\mu} k_i}\right]^{1/\xi_i}$. Capital taxes lower utilization and exert a negative impact on output even before capital adjusts.[36]

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

methods, and different horizons in online Appendix Tables C.22, C.21, C.20, and C.19. Lowering ρ_f from close to 1 in our baseline to 0.75 raises the g_N^c multiplier to 0.8. In their quantitative evaluation, Farhi and Werning (2016) consider spending that lasts 1.25 years, while Nakamura and Steinsson (2014) and House, Proebsting, and Tesar (2017) consider spending with an annual persistence of 0.75. Kilponen et al. (2015) reports multipliers ranging from 0.25 to 0.97 for 15 models maintained by central banks in the European System, with the Bank of Greece model at 0.87.

[36] 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.

that excludes Greece, they find that a change in tax rates resulting in a 1 percent increase in revenue to GDP over 4 years decreases GDP by 2 percent. While they do not distinguish among different types of taxes, their estimate is similar to our aggregate revenue-based tax multiplier. If we weight the different tax multipliers in Table 6 with their revenue shares in steady state, the model generates an aggregate revenue-based tax multiplier of 1.34.[37]

B. *Fiscal Discipline*

Martin and Philippon (2017) argue that reducing spending in the boom would have allowed Greece and other peripheral euro countries to adjust by less in the bust. We repeat the spirit of their exercise within our model economy by shutting off innovations in transfers to the rule-of-thumb household T^r over the entire sample. Between 1998 and 2009, government debt $\bar{B}^g$ adjusts to make the flow government budget constraint hold. We solve for the path of labor taxes τ^ℓ or capital taxes τ_H^k, τ_N^k starting in 2010 such that the flow government budget constraint holds and government debt $\bar{B}^g$ grows linearly back to its observed level in 2017. Effectively, we calculate the macroeconomic outcomes that Greece would have accomplished entering in 2010 with a lower stock of debt and using the freed-up resources to reduce distortionary taxes.

Figure 6 shows that in 2007 removing transfers lowers output by 1 log point and consumption by 3 log points (see online Appendix Figure C.10 for the confidence interval of the output and consumption effects for each counterfactual). Using the freed-up resources to lower labor income taxes would have increased output and consumption during the bust, but the effects dissipate over time, with output and consumption increasing only by two and four log points in 2017. By contrast, using the freed-up resources in 2010 to finance a reduction in capital taxes increases output by 16 log points and consumption by 12 log points by 2017. The difference between labor and capital income taxes is consistent with our findings in Table 6 that revenue-based multipliers for capital are higher than those for labor taxes. We conclude that fiscal discipline in boom years could have allowed Greece to smooth the bust in production and consumption by lowering distortionary taxes on capital.

C. *Bailouts*

Beginning in 2010, Greece received loans from four separate facilities that jointly constituted the Economic Adjustment Program (EAP). Of these loans, roughly 40 percent were earmarked at disbursement for reducing debt owed to private sector

[37] Other evidence comes from the Mertens and Ravn (2013) implementation of the Romer and Romer (2010) discretionary tax changes for the United States. They report revenue-based multipliers for personal income taxes (roughly -2.5) higher than our labor income tax multiplier (roughly -1). Their revenue-based multipliers for capital taxes are comparable to ours because in Table 6 we find small revenue effects from changing capital income taxes. Our model-based multipliers for capital income tax rates are consistent with those of Cloyne et al. (2022), who estimate a cumulative 7-year GDP multiplier of around 0.2 to 0.3 for the US corporate income tax rate. Our tax rate changes are more persistent than theirs, and thus, we do not consider the role of endogenous growth to reconcile transitory tax changes with longer-term output effects. Finally, our model-generated investment elasticity with respect to changes in the user cost induced by changes in capital tax rates is -0.3 for the traded sector and -0.6 for the nontraded sector. This elasticity falls within the range of estimates reported by Hassett and Hubbard (2002).

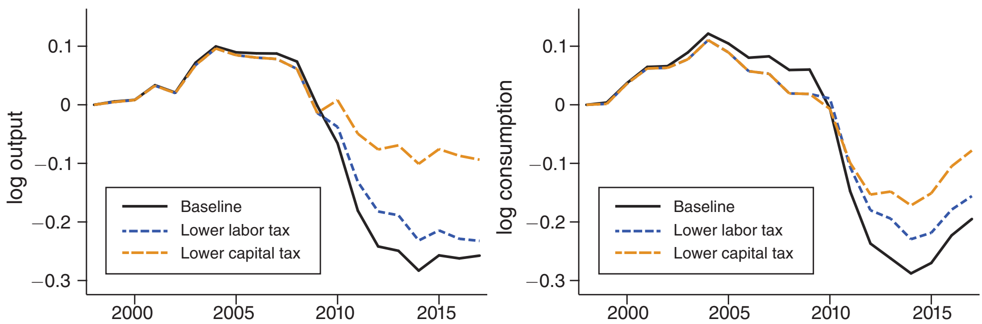

Figure 6. Reducing Transfers in the Boom and Taxes in the Bust

Notes: Figure 6 plots the evolution of output relative to 1998 in the model. The solid line shows the baseline path under the observed path of fiscal variables. The panels show the path of output and consumption in the counterfactual in which Greece had held constant transfers to the rule-of-thumb household throughout the sample and used the additional fiscal space in 2010 to either avoid increasing labor taxes (short-dashed line) or avoid increasing capital taxes (long-dashed line).

creditors, 20 percent were earmarked for equity injections into the banking sector, and the remainder was available to Greece for general budgetary needs. We use our model to assess the impact of these programs.

Constructing counterfactuals without the EAP requires answering two questions. First, since EAP loans had lower interest rates and longer maturities than Greek debt trading on secondary markets, how much of the assistance constituted a transfer of resources and how much constituted a loan? We adopt the approach of Gourinchas, Martin, and Messer (2020), who measure the transfer component as the present discounted value of the differences between disbursements and repayments (including interest), discounted using the IMF's internal rate of return. This approach assumes that institutions lending to Greece had better enforcement technology for repayment than the private sector, thus allowing Greece to borrow at lower rates but only up to the rate charged by the IMF on its programs.

Second, how would Greece have balanced its government budget without the assistance? We assume that Greece could not have raised additional private financing, as it was effectively excluded from private credit markets at the time of the programs. By the same reasoning, we exclude from the EAP resources the part used to reduce debt to private sector creditors.[38] Thus, we divide the remaining EAP disbursements in each year in the government budget constraint into a component that

[38] The Greek Loan Facility (GLF) disbursed funds in 2010 and 2011 during the first EAP, the European Financial Stability Facility (EFSF) disbursed funds between 2012 and 2014 during the second EAP, the European Stability Mechanism (ESM) disbursed funds starting in 2015 during the third EAP, and the IMF disbursed funds between 2010 and 2014 during the first and second EAPs. We obtain the time series of disbursements under the GLF from European Commission (2011); for the EFSF from Corsetti, Erce, and Uy (2017); for the ESM from https://bit.ly/3t8jiEN; and for the IMF from European Commission (2011), https://rb.gy/1hx18, and https://bit.ly/3eBC1n8. The part used to reduce debt owed to private sector creditors and hence excluded from the counterfactual exercise includes €37.1 billion from the GLF used to repay debt maturing between May 2010 and September 2011, €45.9 billion from the EFSF earmarked for the March 2012 debt exchange and December 2012 debt buyback, and €10.5 billion from the ESM earmarked to roll over other credit or pay down arrears. We also count only the part of EAP assistance earmarked for bank capital injections that Greece actually used to purchase bank equity, as measured in the Flow of Funds.

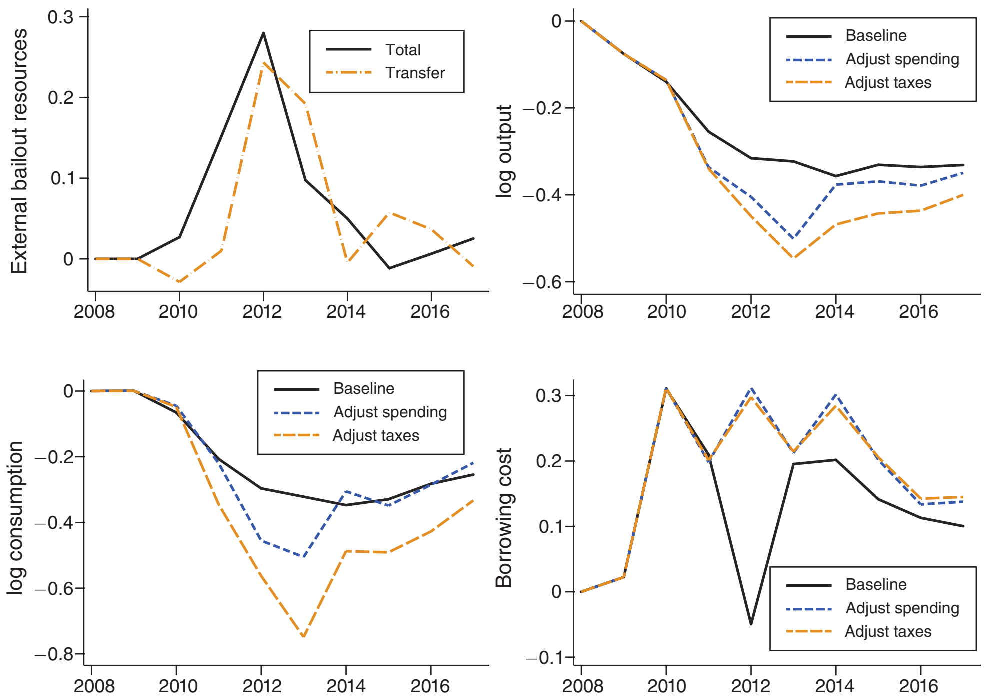

Figure 7. External Bailout of Greek Government

Notes: The first panel of Figure 7 reports the total resources from the EAP and the transfer component of the EAP in T_t^g. Without the EAP, the transfer component would be lower by roughly 20 percent of output in 2012 and 2013. The other three panels of Figure 7 show the paths of output, consumption, and the borrowing cost in a counterfactual in which we change T^g, $\bar{B}^g$, and T_{Ge}^b by the amounts due to the EAP and then balance the budget by either further reducing spending (short-dashed blue line) or further increasing taxes (long-dashed orange line). In 2013, the programs increased output by roughly 20 log points and consumption by between 20 and 40 log points, depending on whether spending or taxes adjust to absorb the forgone resources. The magnitude of these effects highlights why Greece actively considered leaving the euro and defaulting further in the absence of the bailout, an alternative that we do not consider. The last panel shows that without the EAP, the borrowing cost increases by roughly 30 percentage points in 2012. The drop in the cost of capital due to the EAP is consistent with the reversal of bank net worth by 2013 to its precrisis levels (shown previously in Figure 2, panel I). The stabilization of the borrowing cost persists throughout the sample period, leading to significant effects of the EAP on output and consumption by 2017.

augments transfers T_t^g and a component that results in a change in debt $\bar{B}_{t+1}^g$.[39] We then study alternative scenarios under which, without the programs, Greece would not have bailed out the banks and either further cut spending or further raised taxes.

The first panel of Figure 7 plots the components of the external bailout. The other three panels plot the evolution of outcome variables in the model. The solid line shows the baseline path under the observed external bailout. The short-dashed line shows the counterfactual path if Greece had not received the external bailout and instead further reduced government spending. The long-dashed line shows the counterfactual path if Greece had not received the external bailout and instead further increased tax rates.

[39]We calculate T_t^g, which is a flow transfer in the government budget constraint, as the difference between annual disbursements and the change in the present value of disbursements net of repayments (including interest) calculated using the IMF's internal rate of return.

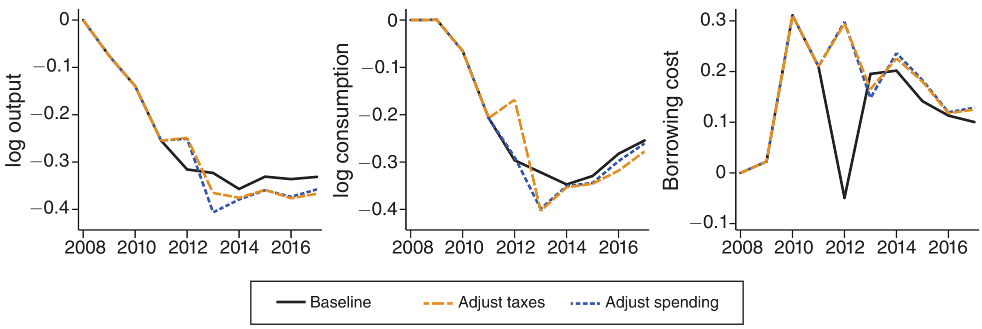

Figure 8. Bailout of Domestic Banks

Notes: Figure 8 plots the evolution of macroeconomic variables relative to 2008 in the model. The solid line shows the baseline path under the observed external bailout with some of the bailout funds being directed to inject equity to banks. The short-dashed line shows the counterfactual path under which Greece had used the equity injection resources to increase government spending. The long-dashed line shows the counterfactual path under which Greece had used the equity injection resources to decrease tax rates.

Figure 8 isolates the macroeconomic effects coming from only injecting equity into banks.[40] The counterfactual paths of output, consumption, and borrowing cost are constructed under the assumption that the resources channeled to banks through the EAP would instead have been used to either increase government spending or cut taxes. While reduced fiscal austerity stimulates output by roughly 7 log points in 2012, lower bank equity is associated with lower output and consumption by 2017. This result reflects a revenue-based multiplier for T_{Ge}^{b} over a seven-year horizon of more than five, which exceeds both the tax and spending multipliers reported in Table 6. We conclude that financial policy helped mitigate the persistence of the bust.

VI. Conclusion

Greece experienced a boom in the early 2000s, followed by a depression whose magnitude and persistence have no precedent among modern developed economies. To study this cycle, we develop and estimate a rich macroeconomic model with heterogeneous households, multiple sectors of production, a banking sector, a government sector, and an external sector. Methodologically, one contribution of our study is to discipline the shocks by feeding them directly into an estimated model without adding to them any measurement error. This approach may prove useful in future studies of particular episodes.

While the Greek experience shares some elements present in standard narratives of boom-bust cycles in small open economies with a currency peg, it differs profoundly in terms of the magnitude and the persistence of the bust in quantities and the adjustment of nominal prices and wages. For Greece, we find that increased demand from the rest of the world and the government fueled the boom in production, and realized or anticipated external transfers fueled the boom in consumption.

[40] Online Appendix Figures C.11 and C.12 present the difference in variables between the counterfactual without external assistance or bank bailouts and the baseline with these transfers. As the figures show, in general, the macroeconomic effects are statistically different from zero.

Contractionary tax policies, amplified by a decline in factor utilization and financial frictions, accounted for the largest fraction of the bust in production. The rise of idiosyncratic risk accounted for the largest fraction of the bust in consumption and prices and the sudden stop of capital flows.

The mechanisms amplifying shocks into the Greek depression and the policies mitigating them also differ from those during relatively smaller contractions. We find that Greece could have reaped substantial benefits by avoiding the debt-financed rise of household transfers in the boom and using the additional fiscal space to reduce capital taxes in the bust. Further, we find that fiscal policy amplified the depression by concentrating the burden of adjustment on taxes instead of spending and by raising the fraction of taxes that firms prepay before revenues are realized. By contrast, equity injections to banks mitigated the depression by lowering the borrowing cost.

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