The Greek Great Depression from a Neoclassical Perspective

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Abstract

This paper follows the great depression methodology of Kehoe and Prescott (2002, 2007) to study the importance of total factor productivity (TFP) in the Greek economic crisis over the period 2008-2017. Using growth accounting and the neoclassical growth model, the paper shows that exogenous changes in TFP are crucial for the Greek depression. The theoretical model reproduces quite well the decline in economic activity over 2008-2013 and the subsequent period of slow recovery found in the data. Nevertheless, it is less successful in predicting the magnitude of the decline in output and the labour factor. In addition, including financial frictions and risk shocks into the neoclassical growth model, does not significantly improve the model's performance.

JEL classification: D81, G01, G21, G33, E44, E52, E58

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1. Introduction

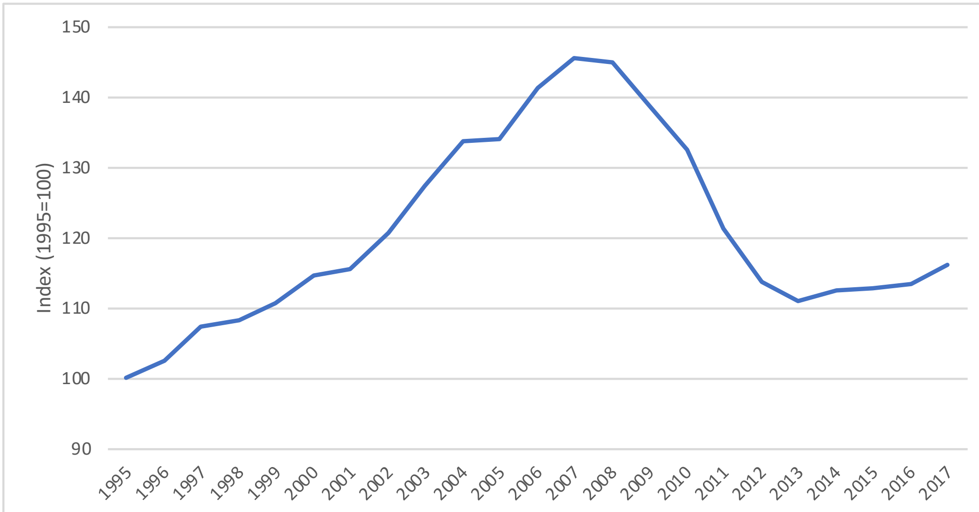
Greece experienced an increase in the real per capita GDP by around 45% over the period 1995-2007 with an average growth rate of 3.48%. As Figure 1 illustrates, this boom was followed by a dramatic economic downturn. Notably, real per capita output dropped about 26% from 2008 to 2013. In fact, Greece suffered one of the longest and deepest recessions of advanced economies to date.

This paper studies the importance of total factor productivity (TFP) in the Greek economic crisis over the period 2008-2017 following the great depression methodology developed by Kehoe and Prescott (2002, 2007). According to this methodology, the period 2008-2017 can be characterized as a *great depression*. The approach we follow can be summarized as follows. First, we examine the growth accounting characteristics of the actual data over the 2000-2017 period and decompose the changes in output into three factors: changes in inputs of labour, changes in capital inputs and changes in TFP. Then, we employ two widely known macroeconomic models: the basic neoclassical growth model (NG hereafter) and the neoclassical growth model augmented to include financial frictions and risk shocks in the spirit of Bernanke, Gertler, and Gilchrist (1999) (BGG hereafter). We calibrate the models and solve for the competitive equilibrium. We then feed the observed TFP series into each model and generate artificial data for the main aggregate economic variables over the period 2000-2017. Finally, we compare the growth accounting characteristics of the actual data to those of the artificial economies.

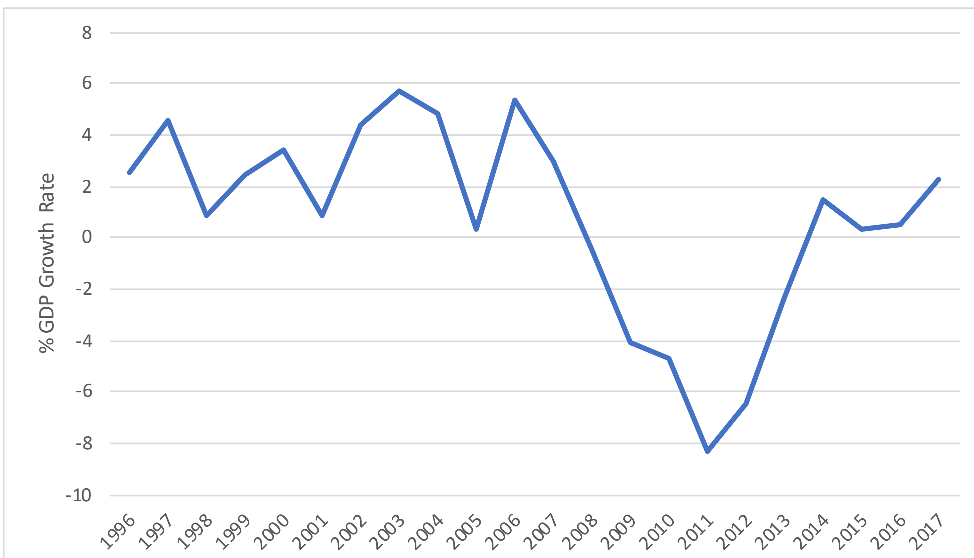
The results suggest that the TFP factor is crucial in accounting for the Greek depression over 2008-2017. The labour factor also played an important role, especially after 2012. The NG model reproduces quite well the decline in economic activity over 2008-2013 and the subsequent period of slow recovery found in the data. However, the magnitude of the decline in output and the labour factor is smaller than in the data. In addition, we augment the basic model to include financial frictions and risk shocks. Our goal is to examine whether the presence of financial frictions and changes in aggregate uncertainty can improve the performance of the model.[1] Results remain very close to the predictions of the basic model. Finally, both models perform quite well in capturing the rise in output observed in the pre-crisis period (2000-2007).

Many academic studies have recently focused on the Greek crisis. In the context of Dynamic Stochastic General Equilibrium (DSGE) models, Gourinchas, Philippon, and Vayanos (2017) find that fiscal consolidation accounted for approximately 50% of the output drop. They also show that much of the remainder drop (around 40%) can be explained by the increase in funding costs for the private sector and the sovereign crisis. In a similar spirit, Chodorow-Reich, Karabarbounis, and Kekre (2019) find that lower external demand for traded goods and contractionary fiscal policies account for the largest fraction of the Greek depression. Furthermore, they show that a decline in total factor productivity substantially amplified the depression. Economides, Papageorgiou, and Philippopoulos (2017) suggest that the fiscal policy mix adopted in the years 2000-2009,

[1] Hardouvelis, Karalas, Karanastasis, and Samartzis (2018) show that economic uncertainty explains a large fraction of the decline in GDP during the crisis.



(a)



(b)

Fig. 1. (a) Real per capita GDP; (b) Real per Capita GDP Growth Rate

jointly with the deterioration in institutional quality and, specifically, in the degree of protection of property rights, can explain essentially all the total loss in GDP between 2010 and 2015 (around 26%). Dellas, Malliaropulos, Papageorgiou, and Vourvachaki (2017) show that the fiscal consolidation measures in Greece can explain most of the decline in GDP when the informal sector is taken into account. The existence of an informal sector significantly amplifies the effects of fiscal policy.[2]

[2]For studies related to the Greek crisis see among many others Ardagna and Caselli (2014), Ioannides and Pissarides (2015), House and Tesar (2015), Kollintzas, Papageorgiou, Tsionas, and Vassilatos (2018a); Kollintzas, Papageorgiou, and Vassilatos (2018b) and the references therein.

We are interested in examining the role of productivity growth in the Greek crisis because it has been found as an important determinant in the majority of depression episodes in the twentieth century that are comparable in magnitude to Greek one. As already mentioned, most studies on the Greek crisis rely on DSGE models and adopt a number of exogenous shocks such as productivity shocks, financial shocks, interest rate shocks, trade shocks etc. in order to identify the drivers of the recession. Compared to these studies, our work follows the great depression methodology that relies on general equilibrium models and growth accounting that decomposes changes in output to changes in labour and capital inputs and productivity growth. Additionally, relative to previous work we also examine the role of financial frictions and changes in the aggregate uncertainty by incorporating a financial accelerator mechanism and risk shocks. The paper extends the literature on great depressions and the analysis provides a diagnostic tool to determine the factors that could increase our understanding regarding the Greek crisis. The fact that the economic downturn in Greece is driven to a large extent by the drop in TFP and the labour factor, indicates the need to identify the factors that shaped the decline in TFP and employment. The study most related to this paper is the work of Gogos, Mylonidis, Papageorgiou, and Vassilatos (2014). They use the neoclassical growth model and employ the great depression methodology for Greece over the period 1979-2001. They find that this period can be characterised as a great depression and that changes in TFP are crucial in accounting for the Greek great depression.

2. The Definition of Great Depressions

According to Kehoe and Prescott (2002), a downturn of real per capita GDP over the time period $D = [T_0, T_1]$ can be labelled as a great depression if *three conditions* relating output to its trend are met.

Let us first define de-trended real per capita GDP in period $t, \tilde{y}_t$, as the ratio of real per capita GDP, y_t, over trend real per capita GDP, $g^{t-T_0} y_{T_0}$,

$$\tilde{y}_t = \frac{y_t}{g^{t-T_0} y_{T_0}} \tag{1}$$

where g is the gross trend growth rate, T_0 is the starting year of the de-trending period and y_{T_0} is the real per capita GDP at T_0. We define the trend growth rate g as the average growth rate in the full sample period (1995:2017) which is 0.74%.

The three conditions that need to be fulfilled for an economic downturn to be labelled a great depression are:

1. The deviation of the per capita GDP from its trend must be sufficiently negative (20% or larger). That is, there is some year t in such that:

$$\frac{y_t}{g^{t-T_0} y_{T_0}} \leqslant 80\%.$$

2. The deviation must occur rapidly (with a negative deviation of 15% in the first

decade). That is, there is some year $t \leqslant T_0 + 10$ such that:

$$\frac{y_t}{g^{t-T_0} y_{T_0}} \leqslant 85\%.$$

3. The deviation must be sustained, in the sense that real per capita GDP cannot return to trend growth rate for a decade. That is, there are no T'' and T' in D, $T'' \geqslant T' + 10$, such that

$$\frac{y_{T''}}{g^{T''-T'} y_{T'}} \geqslant 100\%.$$

As can be seen in Figure 2, the Greek economy during the period 2008-2017 strictly meets all the above criteria. The year 2008 is identified as the starting year of the depression. This is also clear from the two previous graphs, indicating the year 2008 as the peak of the business cycle. According to our terminology, $T_0 = 2008$. Real per capita GDP is characterized by a sharp and large fall following 2008. By 2013, real per capita GDP has decreased about 26.18% below its trend. Furthermore, by 2011 the drop of real per capita GDP was already more than 15% below its trend (notably 18.02%). Therefore both the first and second criteria are met. The third criterion requires that real per capita GDP should not grow at the trend growth rate of 0.74% during any decade over the depression period. Although the data available is up to the year 2017, it is clear that on average the real per capita GDP does not grow at a 0.74% growth rate. Looking at Figure 2 confirms that this criterion is also met. Consequently, the Greek economy for the period 2008-2017 meets all the aforementioned criteria identifying this period as a great depression.

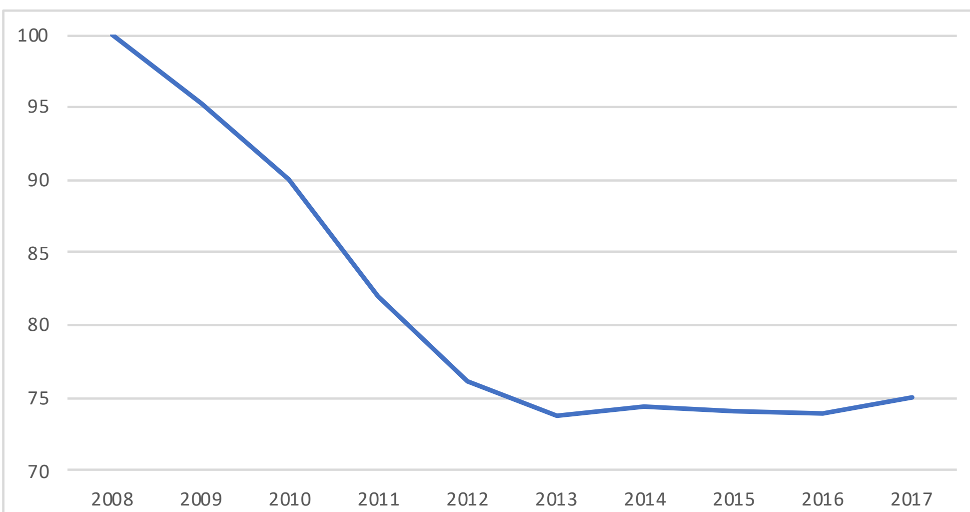


Fig. 2. Detrended Real per Capita GDP 2008-2017

3. The Model

In this section we present the two models that are employed in the study. The presentation here takes advantage of the similarities the two models share. Section 3.1 describes the NG model while Section 3.2 presents the financial frictions BGG model. In both models, the only exogenous source of fluctuations is the total factor productivity (TFP). In addition, the agents have perfect foresight, which means that they fully anticipate the future paths of productivity.

3.1. The Neoclassical Growth Model

In the canonical neoclassical growth model there are two types of agents: households and firms. Firms' role in the model is to produce consumption goods by combining capital and labour borrowed from the households. Households are the owners of capital which they lend to the firms at a cost specified from the rental rate of capital and they also work in the production firm where their compensation is their marginal product of labour.

Households. — There is a continuum of households with identical preferences. Households work and get their labour wage, invest in capital receiving the rental rate of capital, and retain the profits of the non-financial firms.

The preferences of the representative household take the mostly standard following form:

$$\sum_{i=0}^{\infty} \beta^i [\ln(C_{t+i}) - \frac{\chi}{1+\epsilon} L_{t+i}^{1+\epsilon}], \tag{2}$$

C_t denotes the per capita consumption of the household members and L_t the supply of labour. $\beta \in [0, 1]$ is the discount factor, ϵ is the inverse Frisch elasticity of labour supply, $\chi > 0$ is the relative utility weight of labour and $t + i$ is the time subscript.

The household allocates funds to consumption and transfers wealth across time and states by investing I_t. We assume that the holding capital bears no risk and we call the rental rate of capital Z_t. The household's financial resources originate from its labour income, W_t is the real wage, capital returns and the net payouts to the household from ownership of both non-financial firms Π_t. The budget constraint of the representative household is:

$$C_t + I_t = W_t L_t + \Pi_t + Z_t K_t. \tag{3}$$

Furthermore, the law of motion of capital is:

$$K_{t+1} = I_t + (1 - \delta) K_t. \tag{4}$$

The problem of the representative household is to choose C_t, L_t, K_{t+1} in order to maximize its utility (2) subject to the budget constraint (3) and the law of motion of capital (4) at every period.

Let $u_{c,t}$ denote the marginal utility of consumption and $\Lambda_{t,t+1}$ denote the household's discount factor (the intertemporal marginal rate of substitution):

$$\Lambda_{t,t+1} \equiv \beta \frac{u_{c,t+1}}{u_{c,t}}, \tag{5}$$

$$u_{c,t} = C_t^{-1}.$$

Let λ be the Lagrange multiplier associated with the household problem, the Lagrangian is

$$\mathcal{L} = \sum_{i=0}^{\infty} \beta^i \big\{ \ln(C_{t+i}) - \frac{\chi}{1+\epsilon} N_{t+i}^{1+\epsilon} + \lambda_t [W_t L_t + \Pi_t + Z_t K_t - (C_t + K_{t+1} - (1-\delta)K_t)] \big\}.$$

The first order conditions yield:

$$\frac{\partial \mathcal{L}}{\partial C_t} : u_{c,t} - \lambda_t = 0 \tag{6}$$

$$\frac{\partial \mathcal{L}}{\partial K_{t+1}} : -\lambda_t + \beta \lambda_{t+1}(Z_{t+1} + (1-\delta)) = 0 \tag{7}$$

$$\frac{\partial \mathcal{L}}{\partial L_t} : -\chi L_t^{\epsilon} + \lambda_t W_t = 0 \tag{8}$$

Combining (6) and (7) we get the two standard intertemporal and intratemporal equations of the NG model: namely the Euler equation

$$\Lambda_{t,t+1}[Z_{t+1} + (1-\delta)] = 1 \tag{9}$$

and by combining (6) and (8) the optimality condition for labour supply

$$u_{c,t} W_t = \chi L_t^{\epsilon}. \tag{10}$$

Production. — The production process is limited to the production of a consumption good.

Goods Producers.— Goods producers combine capital and labour both rented from households to produce goods under a constant returns to scale production function. Production is subject to a total factor productivity shock A_t.

$$Y_t = A_t (K_t)^{\alpha} L_t^{1-\alpha}. \tag{11}$$

The decision problem of the goods producers is to choose K_t and L_t in order to maximize their profits. Profit maximization implies standard input demands for labour and capital:

$$W_t = (1-\alpha)\Big(\frac{K_t}{L_t}\Big)^{\alpha}$$

$$Z_t = \alpha \Big(\frac{L_t}{K_t}\Big)^{1-\alpha}.$$

Resource Constraint.— The resource constraint of the model implies aggregate demand to be equal with aggregate supply:

$$Y_t = C_t + I_t.$$

Lastly, to be consistent with the BGG framework that follows, we call the gross return on capital net of depreciation as $R_{k,t} = Z_t + (1 - \delta)$.

3.2. The Financial Frictions Model

The economy of the financial frictions model, a version of the Bernanke et al. (1999), is populated by five agents: Households, entrepreneurs, bankers, capital and consumption good producers. Contrary to the NG model, the representative household is not the direct owner of capital which is now being intermediated by banks from households to entrepreneurs. Households hold bank deposits which are the only source of bank funding and banks provide loans to the entrepreneurs which use credit to buy capital. Put it simply, households are the lenders of the entrepreneurs with banks acting as an intermediary.

What gives rise to the financial accelerator mechanism, is the addition of the capital goods producers and the non-linear adjustment costs. Tobin's q, the price of capital, creates an extra feedback mechanism in the perturbations of the model, namely the financial accelerator. In detail, the financial accelerator mechanism describes a feedback process between price of capital and entrepreneur's net worth. Think of a negative shock in aggregate demand which leads to a fall in entrepreneur's net worth. The entrepreneur now is unable to buy the amount of capital purchased before the shock due to lower equity. This leads to a reduction in the capital price. The feedback mechanism is turned on because lower capital price leads to a further reduction to net worth. This process continues until the economy reaches a new equilibrium with lower capital price and net worth value.

Households.— There is a continuum of households with preferences defined in a similar manner as in the NG model by (2). Household members are divided according to their occupation. Within each household there are two different member types: ϖ workers and $(1 - \varpi)$ entrepreneurs. Household members differ in the way they obtain earnings. Workers supply labour and entrepreneurs manage the non-financial firms. All return their earnings back to their families.[3] Lastly, within the family there is perfect consumption insurance.

The household allocates funds to consumption and bank deposits D_t. We assume that deposits bear no risk and we call the riskless gross return to deposits, R_t (the interest factor). The rest of the household income sources are the wage income and the profits from the non-financial corporations. Therefore, the budget constraint of the representative household is:

$$C_t + D_{t+1} = W_t L_t + \Pi_t + R_t D_t. \tag{12}$$

[3]This approach follows Gertler and Kiyotaki (2010) and allows for within-household heterogeneity but also sticks to the representative approach representation. Abstracting from the entrepreneurs' consumption makes the model presentation simpler.

The problem of the representative household is to choose C_t, L_t, D_t in order to maximize its utility (2) subject to the budget constraint (12) at every period.

Let λ be the Lagrange multiplier associated with the household problem, the Lagrangian is

$$\mathcal{L} = \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \big\{ \ln(C_{t+i}) - \frac{\chi}{1+\epsilon} N_{t+i}^{1+\epsilon} + \lambda_t [W_t L_t + \Pi_t + R_t D_t - (C_t + D_{t+1})] \big\}.$$

The first order conditions yield:

$$\frac{\partial \mathcal{L}}{\partial C_t} : u_{c,t} - \lambda_t = 0 \tag{13}$$

$$\frac{\partial \mathcal{L}}{\partial D_{t+1}} : -\lambda_t + \beta \lambda_{t+1}(R_{t+1}) = 0 \tag{14}$$

$$\frac{\partial \mathcal{L}}{\partial L_t} : -\chi L_t^{\epsilon} + \lambda_t W_t = 0 \tag{15}$$

Combining (13) and (14) we get the two standard intertemporal and intratemporal equations of the NG model; namely the Euler equation:

$$\Lambda_{t,t+1} R_{t+1} = 1 \tag{16}$$

and by combining (13) and (15) the optimality condition for labour supply

$$u_{c,t} W_t = \chi N_t^{\epsilon}. \tag{17}$$

Entrepreneurs.— Each entrepreneur i purchases raw capital $K_{i,t+1}$ from the capital goods producers at price Q_t in a competitive market and funds this purchase with equity $N_{i,t+1}^E$ and credit $LNS_{i,t+1}$ obtained from the financial institutions. The entrepreneur's balance sheet is:

$$Q_t K_{i,t+1} = LNS_{i,t+1} + N_{i,t+1}^E. \tag{18}$$

The entrepreneur transfers the purchased capital to the retail firm in order to produce goods. Capital yields its marginal product Z_{t+1}. At the end of the period, she sells the undepreciated capital back to the capital goods producer at price Q_{t+1}. Therefore, the average return per nominal unit invested in period t is:

$$R_{k,t+1} = \frac{[Z_{t+1} + (1-\delta) Q_{t+1}]}{Q_t}. \tag{19}$$

In every period t an idiosyncratic shock ψ_i transforms the newly purchased $K_{i,t+1}$ raw units of capital into $\psi_i K_{i,t+1}$ effective units of capital. It is assumed that ψ follows a unit-mean log normal distribution. The idiosyncratic shock is drawn from a density $f(\psi_t)$. Following Christiano, Motto, and Rostagno (2014) we call the standard deviation of $\log(\psi)$ denoted by σ_ψ, the *risk shock*. It is the cross sectional dispersion in ψ and it is allowed to vary over time. This will introduce another source of fluctuations in the model's perturbations in addition to the TFP.

A threshold value of ψ_i called $\bar{\psi}_{t+1}$ divides the entrepreneurs that cannot pay back the loan and interest from those who can repay. It is defined by

$$R_{l,t+1}LNS_{i,t+1} = \bar{\psi}_{t+1}R_{k,t+1}Q_tK_{i,t+1}. \tag{20}$$

$R_{l,t+1}$ is the rate to be decided in the debt contract between the entrepreneur and the banker. When $\psi_i \geqslant \bar{\psi}_{t+1}$ the entrepreneur repays the bank the amount $R_{l,t+1}LNS_{i,t+1}$ keeps the profits equal to $\bar{\psi}_{t+1}R_{k,t+1}Q_tK_{i,t+1} - R_{l,t+1}LNS_{i,t+1}$ and continues production. If $\psi_i < \bar{\psi}_{t+1}$ the entrepreneur has negative net worth resulting in bankruptcy and default. When an entrepreneur defaults, her assets are then being acquired by a bank paying also a bankruptcy cost μ to be defined momementariry. The probability of default is then given by:

$$p(\bar{\psi}) = \int_0^{\bar{\psi}} f(\psi)d\psi. \tag{21}$$

The expected net worth of the entrepreneurs is

$$[(1 - \Gamma_t(\bar{\psi}_{t+1}))R_{k,t+1}Q_tK_{i,t+1}], \tag{22}$$

where

$$\Gamma_t(\bar{\psi}_{t+1}) = \int_0^{\bar{\psi}_{t+1}} \psi f(\psi)d\psi + \bar{\psi}_{t+1}(1 - p(\bar{\psi}_{t+1})). \tag{23}$$

is the fraction of net capital received by the lender, and $1-\Gamma_t(\bar{\psi}_{t+1})$ represents the average weight of the entrepreneurs' gains.

If there was no cost to the banker to observe the idiosyncratic shock $\psi_{i,t}$, then there would be state-contingent contracts that would perfectly insure the banker. Instead, in order to make entrepreneurs' default costly for the banking sector, ψ_i is costlessly observed by the entrepreneur, but it is not observed by the lender unless he pays a fraction of their ex-post revenues. Specifically, the financial intermediary must pay a "monitoring cost" to observe the borrower's realized return on capital. This follows the "costly state verification" illustration proposed by Townsend (1979). Monitoring costs can be interpreted as legal costs that the banks pay in the case of borrowers' default. This cost destroys part of the capital produced by the project and equals a proportion μ of the gross pay-off of the firms capital, i.e. $\mu\psi_{i,t+1}R_{k,t+1}Q_tK_{i,t+1}$.

The optimal contract maximizes the expected profits of the entrepreneur under the condition that the expected return on lending is no less that the opportunity cost of lending. In other words, for the financial intermediary to continue extending credit to entrepreneurs, their expected return from credit must be always greater or equal to the opportunity cost of its funds. The opportunity cost is the riskless rate R_t. The loan contract must satisfy:

$$(1 - \mu)R_{k,t+1}Q_tK_{i,t+1}\int_0^{\bar{\psi}_{t+1}} \psi f(\psi)d\psi + (1 - p(\bar{\psi}_{t+1}))R_{l,t+1}L_{i,t+1} \geqslant R_tL_{i,t+1}. \tag{24}$$

The left hand side shows the expected gross return that the financial intermediary receives over all realizations of the shock and the right hand side the intermediary's opportunity cost of lending.

Using (18) and (23), the zero profit condition (24) becomes :

$$R_{k,t+1}Q_tK_{i,t+1}[\Gamma_t(\bar{\psi}_{t+1}) - \mu G_t(\bar{\psi}_{t+1})] \geqslant R_t(Q_tK_{i,t+1} - N^E_{i,t+1}), \tag{25}$$

where $\mu G_t(\bar{\psi}_{t+1})$ are the expected monitoring costs paid by the bank:

$$G_t(\bar{\psi}_{t+1}) = \int_0^{\bar{\psi}_{t+1}} \psi f(\psi) d\psi.$$

The optimal contract for the entrepreneur solves the entrepreneur's expected net worth (22) subject to the zero profit condition (25).

Let $\mathcal{L}$ be the Lagrangian of the maximization problem and λ^e_t the Lagrange multiplier associated with the zero profit condition.

$$\mathcal{L} = [1 - \Gamma(\overline{\psi_{t+1}})R_{k,t+1}Q_tK_{t+1}] + \lambda^e_t[R_{k,t}Q_tK_t[\Gamma(\overline{\psi_{t+1}}) - \mu G(\overline{\psi_{t+1}})] - R_{t+1}(Q_tK_t - N^e_t)].$$

The first order and Kuhn-Tucker conditions for the maximization problem are:

$$\frac{\partial \mathcal{L}}{\partial K_t} : 1 - \Gamma(\overline{\psi_{t+1}})R_{k,t+1} + \lambda^e_t[\Gamma(\overline{\psi_{t+1}}) - \mu G(\overline{\psi_{t+1}})R_{k,t+1} - R_{t+1}] = 0 \tag{26}$$

$$\frac{\partial \mathcal{L}}{\partial \overline{\psi_{t+1}}} : -\Gamma'(\overline{\psi_{t+1}}) + \lambda^e_t[\Gamma'(\overline{\psi_{t+1}}) - \mu G'(\overline{\psi_{t+1}})] = 0 \tag{27}$$

From equation (27) we get

$$\lambda_t = \frac{\Gamma'(\overline{\psi_{t+1}})}{\Gamma'(\overline{\psi_{t+1}}) - \mu G'(\overline{\psi_{t+1}})}. \tag{28}$$

Inserting (28) to (26) we get:

$$R_{k,t} = \frac{\Gamma'(\overline{\psi_{t+1}})}{(\Gamma(\overline{\psi_{t+1}}) - \mu G(\overline{\psi_{t+1}}))\Gamma'(\overline{\psi_{t+1}}) + (1 - \Gamma(\overline{\psi_{t+1}}))(\Gamma'(\overline{\psi_{t+1}}) - \mu G'(\overline{\psi_{t+1}})}R_t,$$

which gives the external finance premium as shown in the BGG:

$$R_{k,t+1} = \rho(\overline{\psi_{t+1}})R_{t+1}$$

where the external finance premium $\rho(\overline{\psi_{t+1}})$ is given by

$$\rho(\overline{\psi_{t+1}}) = \frac{\Gamma'(\overline{\psi_{t+1}})}{[(\Gamma(\overline{\psi_{t+1}}) - \mu G(\overline{\psi_{t+1}}))\Gamma'(\overline{\psi_{t+1}}) + (1 - \Gamma(\overline{\psi_{t+1}})(\Gamma'(\overline{\psi_{t+1}}) - \mu G'(\overline{\psi_{t+1}}))]}.$$

The above equation demonstrates how the assumption of financial frictions eliminates the arbitrage between the risk free rate and the capital returns. In the NG model described above $\rho(\overline{\psi_{t+1}})$ is equal to 1, and both returns are equalized. This could happen here in the limiting case of zero monitoring costs and a zero default probability when the idiosyncratic shock threshold approaches zero.

Aggregation.— At the end of the period t a fraction $\sigma_{E,t}$ of entrepreneurs continues and the rest disappears and is replaced by an equal number of workers. This assumption ensures that entrepreneurs will not fund all investments from their own accumulated capital. The probability of remaining is a constant parameter calibrated such as to target a specific leverage ratio for the entrepreneurs.[4] The new entrants receive a start up fund transferred from the old entrepreneurs which is equal to a proportion ξ_E of their wealth. By the law of large numbers the aggregate net worth for every entrepreneurs i at the end of the period t is $(1-\Gamma_{t-1})\bar{\psi}_t R_{k,t} Q_{t-1} k_{i,t}$. Integrating over all entrepreneurs we get the aggregate net worth at the end of period t where capital letters denote aggregate variables.

$$N_{t+1}^E = (\sigma_{E,t} + \xi_E)(1-\Gamma_{t-1}(\bar{\psi}_t))R_{k,t}Q_{t-1}K_t.$$

Production.— The production process is limited to the production of a consumption good. In order to introduce the price of capital, the model has the addition of the capital goods producers.

Goods Producers.— Goods producers are owned by the entrepreneurs who provide the capital needed. Producers combine the capital with labour rented from the households to produce goods under a constant returns to scale production function. Production is subject to a total factor productivity shock. We skip the formal presentation of this sector since is identical with the one of the NG model.

Capital Goods Producers.— Capital goods producers produce new capital and sell it to entrepreneurs at a price Q_t. Investment on capital I_t is subject to adjustment costs. Therefore, the new law of motion of capital is

$$K_{t+1} = I_t[1 + \tilde{f}\Big(\frac{I_t}{I_{t-1}}\Big)] + (1-\delta)K_t. \tag{29}$$

where the adjustment cost function $\tilde{f}$ captures the cost of investors to increase their capital stock:

$$\tilde{f}\left(\frac{I_\tau}{I_{\tau-1}}\right) = \frac{\eta}{2}\left(\frac{I_\tau}{I_{\tau-1}} - 1\right)^2 I_\tau$$

and η is the inverse elasticity of net investment to the price of capital. Their objective is to choose $\{I_t\}_{t=0}^{\infty}$ to solve:

$$\max_{I_\tau} \sum_{\tau=t}^{\infty} \Lambda_{t,\tau}\Big\{Q_t I_t - [1 + \tilde{f}\left(\frac{I_\tau}{I_{\tau-1}}\right) I_\tau]\Big\}.$$

[4] This follows Gertler and Kiyotaki (2010), Gertler and Karadi (2011) and Gertler, Kiyotaki, and Queralto (2012).

The solution to the decision problem of the investors yields the competitive price of capital:

$$Q_t = 1 + \left(\eta \frac{I_\tau}{I_{\tau-1}}\left(\frac{I_\tau}{I_{\tau-1}} - 1\right) + \frac{\eta}{2}\left(\frac{I_\tau}{I_{\tau-1}} - 1\right)^2 - \eta \Lambda_{t,\tau} \frac{I_{\tau+1}^2}{I_\tau^2}\left(\frac{I_\tau}{I_{\tau-1}} - 1\right)\right).$$

Banks. — Each bank j allocates its funds to credit $LNS_{j,t+1}$. It funds its operations by receiving deposits from households $D_{j,t+1} = LNS_{j,t+1}$ remunerated at the discount rate R_t. From the above specification and by the law of large numbers, it follows that the bank's balance sheet is:

$$LNS_{t+1} = D_{t+1}. \tag{30}$$

Resource Constraint. — The resource constraint of the economy is:

$$Y_t = C_t + I_t + \mu G_t(\bar{\psi}_t) R_{k,t} Q_t K_t.$$

Final output may be either transformed into consumption good, invested or used up in monitoring (bankruptcy) costs. All the model's equations are presented in Appendix C.

4. Data & Calibration

In this section we describe the data and the calibration procedure for the two models. The data sources are Eurostat and the Bank of Greece, unless otherwise indicated and span the period 1995-2017.

4.1. Data

In order to apply the great depression methodology, we need to match some of the model's variables with the data. The first step is to construct a time series for the capital stock and total factor productivity that we use for the growth accounting exercises.

4.1.1. Capital Stock

In order to obtain a time series for the real capital stock, K_t, we follow the procedure described in Conesa, Kehoe, and Ruhl (2007). Taking as given the equation for the law of motion of capital:

$$K_{t+1} = I_t + (1 - \delta) K_t, \tag{31}$$

we need data on real investment expenditure, a value for the depreciation rate, δ, which we assume to be constant, and an initial value for the real capital stock, K_0.

To obtain δ we need the series of average consumption of fixed capital-to-GDP ratio observed in the data. The value of this ratio over the period 2000-2017 is 16.29%, that is:

$$\frac{1}{23} \sum_{t=2000}^{2017} \frac{\delta K_t}{Y_t} = 16.29\%. \tag{32}$$

The initial value for the capital-to-output ratio is chosen to be equal to the average of the ratio for the period 1995-2000:

$$\frac{K_{1995}}{Y_{1995}} = \frac{1}{5}\sum_{t=1996}^{2000} \frac{K_t}{Y_t}. \tag{33}$$

We use the period 1995-2000 to obtain the initial value for the capital stock as in a way that minimizes the impact of the ad-hoc initial value on the constructed series. Given that the period of interest is the 2008-2017, the impact of the capital starting value is small. Equations (31), (32) and (33) constitute a system of 24 equations in 24 unknowns ($K_{1995}, K_{1996}, ...K_{2017}$ and δ). The solution to this non-linear system yields an annual depreciation rate equal to $\delta = 0.051$.

4.1.2. Labour Share

To compute the labour share in output $(1-\alpha)$, we add total compensation of the self-employed to total compensation of employees and then divide this number with GDP at factor prices (that is GDP minus taxes less subsidies on production and imports). Then we take the average for the period 1995-2008:

$$1-\alpha = \frac{TCE^{DE} + TCE^{SE}}{Y_t - NIT},$$

where TCE^{DE} is total compensation of employees, TCE^{SE} is the imputed total compensation of the self-employed, and NIT is net indirect taxes. This yields an annual capital share in output $\alpha = 0.45$. That is in line with previous estimates for the Greek economy (see e.g. Gogos et al. (2014) and Papageorgiou (2012)).

4.1.3. TFP

Having constructed the capital stock series and given the data for real GDP, Y_t, hours of work, L_t, and the value for the capital share parameter, α, calculated above, the TFP is computed as a residual from the aggregate production function (11):

$$A_t = \frac{Y_t}{K_t^{\alpha} L_t^{1-\alpha}}.$$

4.2. Calibration

The model is calibrated to the Greek economy at an annual frequency using data from the period 1995-2008, the pre-crisis period. The parameters of the NG model are a subset of the parameters of the BGG. We treat the BGG as our main model and we calibrate it to match certain data characteristics. As a result, the common parameters of the two models have the same values for both models. All the calibrated parameters are summarized in Table 1. Most of the parameters are calibrated so that the model yields the average values of the Greek economy macro variables in the data.

The discount factor, β, is parametrized such that the model yields a 5.1% annual risk free interest rate which corresponds to the average of the benchmark 10 year Greek bond from 1995-2008. We compute the depreciation rate, δ, and the capital share, α, following the two procedures analysed above. This yields an annual depreciation rate of capital equal to 0.051 and a capital share equal to 0.45. Finally, we set the inverse Frisch elasticity of labour, ϵ, and the inverse elasticity of net investment to the price of capital (the capital adjustment cost parameter) η as in Balfoussia and Papageorgiou (2016).

The preference parameter χ, which is the weight given to consumption relative to leisure, is calibrated consistent with a labour allocation equal to 22% of time which is the average value of per capita hours of work in the data.[5]. This yields χ equal to 11.781 for the BGG model and 6.86 for the NG model. Regarding the parameters that are related to the model with financial frictions, we calibrate the monitoring costs parameter, μ, so that the model produces an external finance premium for non-financial corporations (NFCs) equal to 1.912%. This is the average difference between banks' interest rates on new business loans and a weighted average interest rate on new deposits from non-financial corporations up to 2008. The implied value of μ is 0.0025. We calibrate the distributed income of the exiting to the new entrepreneurs, E, as the annual distributed income of non-financial corporations relative to their net worth, which is 3.4% in the data. Next, we calibrate the volatility of the idiosyncratic risk shock, σ^*_ψ, assuming a default rate for NFCs equal to 3%, which is in the range of estimates found in Charalambakis (2015). The value of the idiosyncratic shock is found to be equal to 0.954. Finally, we set the fraction of entrepreneurs that continue to the next period to 0.912 so that the model produces the loan-to-GDP ratio found in data and which is equal to 64.8%.

5. Growth Accounting

For our growth accounting analysis we follow the approach of the great depressions methodology literature (see Conesa et al. (2007) and Kehoe and Prescott (2007)). We proceed by calculating each factor from the actual data and then we plot the factors against the real per capita GDP path.

The aggregate production function can be written as:

$$\frac{Y_t}{N_t} = A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} \frac{L_t}{N_t} \tag{34}$$

and in natural logarithms:

$$\ln\frac{Y_t}{N_t} = \frac{1}{1-\alpha}\ln A_t + \frac{\alpha}{1-\alpha}\ln\frac{K_t}{Y_t} + \ln\frac{L_t}{N_t}. \tag{35}$$

[5]For the series of per capita hours work to be compatible with the model economy, we assume that the time endowment is (365 days* 16 hours per day) = 5840 hours per year)

Parameters	Value	Definition
		Households
β	0.951	Discount rate
χ	11.781 (BGG)	Relative utility weight of labour
	6.864 (NG)	
ϵ	0.500	Inverse Frisch elasticity of labour supply
		Entrepreneurs
μ	0.0025	Monitoring Costs
σ_E	0.912	Fraction of entrepreneurs survived
σ_ψ^*	0.954	Steady-state cross sectional dispersion of ψ
ξ_E	0.034	Entering entrepreneurs initial capital
		Firms
δ	0.051	Depreciation of capital
α	0.456	Capital share
		Capital Goods Producers
η	1.500	Inverse elasticity of net investment to the price of capital

Table 1: Parameter Values

where N_t is the working age population. We decompose real per capita GDP into three factors: The TFP factor, $A_t^{\frac{1}{1-\alpha}}$, the capital factor, $(\frac{K_t}{Y_t})^{\frac{\alpha}{1-\alpha}}$ and the labour factor, $\frac{L_t}{N_t}$.

To enhance understanding, tables 2 and 3 show the growth accounting characteristics of the data. Table 2 shows the data levels of the four factors at the end of each sub-period considered. The values are normalized with the value of each variable at the beginning of each period. Table 3 presents the average annual growth of each variable of interest for the three sample sub-periods.

Components	Data
2007 (2000 = 100)	
Detrended Real per Capita GDP	120.60
TFP Factor	108.96
Capital Factor	95.21
Labour Factor	107.18
2017 (2008 = 100)	
Detrended Real per Capita GDP	74.99
TFP Factor	86.70
Capital Factor	117.12
Labour Factor	88.68

Table 2: Data Growth Accounting (levels)

Components	Data
2000-2007	
Real per Capita GDP	3.41
TFP Factor	2.23
Capital Factor	0.20
Labour Factor	0.99
2008-2017	
Real per Capita GDP	-2.46
TFP Factor	-2.88
Capital Factor	1.76
Labour Factor	-1.33
2000-2017	
Real per Capita GDP	0.07
TFP Factor	-0.88
Capital Factor	1.20
Labour Factor	-0.25

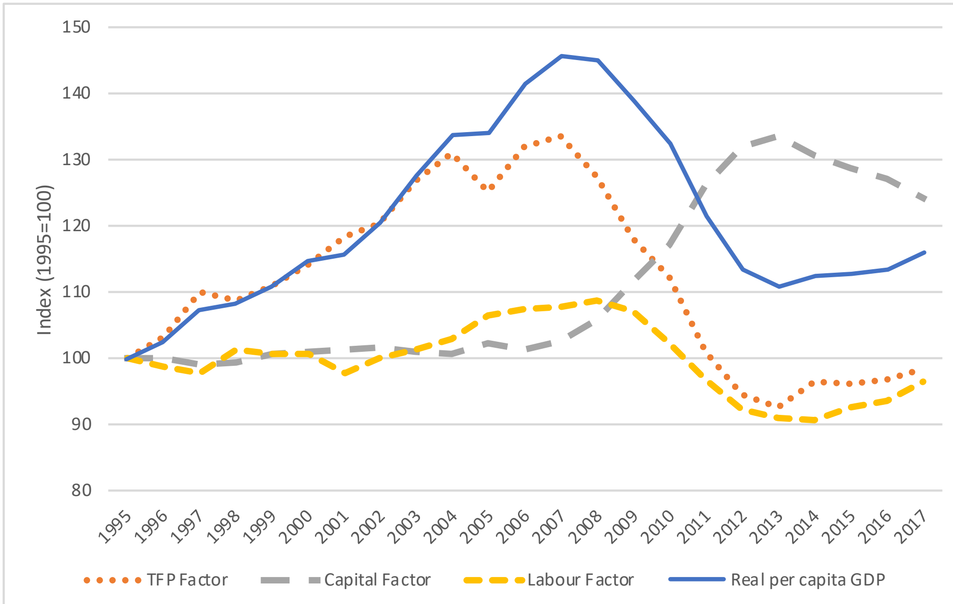
Table 3: Data Growth Accounting (average annual changes)

Figure 3 shows the evolution of the real per capita GDP together with the three growth accounting factors. The top part of Figure 3 shows the evolution of the variables spanning the time 1995-2017 normalized by the value of each factor at 1995. The bottom part of Figure 3 shows the evolution of the factors in the period 2008-2017 normalized by each factors' value at the year 2008, the onset of the great depression in Greece.

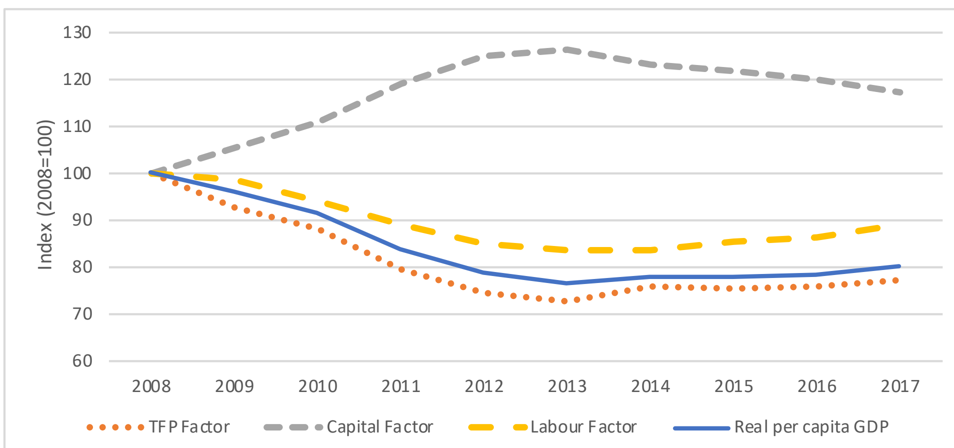
As subplot a of Figure 3 and Table 3 illustrate, the period 1995-2007 can be characterized as an expansion period during which the real per capital GDP increased by 45.45% relative to 1995 and had an average growth rate equal to 3.41% over the period 2000-2007. The growth of GDP was driven extensively by the TFP factor that increased by 33.46% (2.23% in growth terms). The labour factor also had a positive contribution, particularly in the post-2001 period, and increased by around 7.85% (0.99% in growth terms). The capital factor increased as well in the same time span by 2.54% with an average growth rate equal to 0.2%.

Turning to subplot (b) of Figure 3 and the great depression period, 2008-2017, real per capita output has been reduced by 19.86% compared to its value in 2008 with an average growth rate equal to -2.46%. The TFP factor had a significant and negative contribution equal to -2.88%. The labour factor also declined significantly (by 11.32%), and had a negative contribution to the GDP growth equal to -1.33%. By contrast, the capital factor increased this period by 17.12% with an average growth rate equal to 1.76%.

An important takeaway from the growth accounting exercise is the procyclicality of the TFP and the labour factors and the countercyclical behaviour of capital. The countercyclical behaviour of the capital factor is clear after 2001 and even more in Figure 3 showing the recession years. More specifically, the capital factor increased by 17.12%



(a)



(b)

Fig. 3. (a) Growth Accounting 1995-2017 (Index 1995=100); (b) Growth Accounting 2008-2017 (Index 2008=100)

during the period 2008-2017. It started from the value of 3.270 in 2008, reaching a first peak of 4.165 in 2013 amidst the depression episode. Then as GDP started to grow gradually the capital factor scaled down to 3.95 in 2017. Capital deepening is consistent with other studies on the Greek economy (Gogos et al. (2014)) where the authors use the same growth accounting methodology for the period 1971-2001. Other great depression episodes in other countries present the same pattern as well (see for example Hayashi and Prescott (2002) for the case of Japan, Bergoeing, Kehoe, Kehoe, and Soto (2002) for the case of Mexico, and Conesa et al. (2007) for the case of Finland).

6. Quantitative Analysis

In this section we present the findings of the perfect foresight solution of the two models, namely the NG model and the financial frictions BGG model. We split our sample in two different time spans: the "before crisis" period, 2000:2007, and the "great depression" period, 2008:2017. Lastly, we provide a full sample analysis for the period 2000:2017. We begin our analysis by presenting the two models when the only source of fluctuations is the TFP factor. Next, we show how the analysis changes when we include changes in the idiosyncratic risk of the BGG model.

We provide a number of different statistics and exercises in order to compare the predictions of the two models with the actual data. Table 4 shows the levels of GDP per capita, capital, labour and TFP factors from the perfect foresight simulation of each model along with the data levels of the same variables at the end of each sub-period. The values are normalized with the value of each variable at the beginning of each period. Table 5 presents the average annual growth of each variable from the models' simulation and the data.

Overall, the predicted variable levels and growth rates of both models are very close to the values corresponding in the data. TFP fluctuations seem to be an important factor in explaining the performance of the Greek economy in both the pre-crisis and the post-crisis periods using either the BGG or the NG models. Notably, both models can account well for the great depression episode especially in terms of the real per capita GDP. The annual average GDP growth in data for the depression period is -2.46% while BGG predicts a drop of 2.60% and the NG a 2.97% reduction. Both models also perform well in terms of the levels of the real per capital GDP, although they underestimate the decline in the level of GDP after 2013. The models' performance is less robust in the pre-crisis period with a deviation from the true real per capita GDP growth rate of almost 1 percentage point (2.02% in the BGG model compared to a 3% in the data). The two models perform equally well in predicting the capital factor values and the NG scores better in predicting the behaviour of the labour factor. This can be attributed to the lower relative utility weight of labour implied by the NG model. In general, as shown in Beaudry and Portier (2002), the elasticity of labour supply is important in capturing the behaviour of labour factor during depressions. We provide a sensitivity analysis with respect to this parameter in Appendix B.

6.1. Pre-Crisis 2000:2007

Figure 4 shows the results of the simulations together with the data for the pre-crisis period 2000-2007. All model and data variables are expressed relative to their 2000 value. For the BGG model, the reported real per capita GDP is net of default costs. The detrended real per capita Greek GDP increased by 20.6%. Clearly, both models successfully capture this increasing behaviour of Greek GDP during that period. In terms of levels, both models overestimate the rise in GDP compared to the actual data until 2004 and underestimate it after 2005, when Greek per capita GDP skyrockets. This is also evident from the average annual changes presented in Table 5. While the GDP annual

Components	Data	BGG	NG
2007 (2000 = 100)			
Detrended Real per Capita GDP	120.60	117.58	119.17
TFP Factor	108.96	108.96	108.96
Capital Factor	95.21	97.78	96.22
Labour Factor	107.18	104.59	105.99
2017 (2008 = 100)			
Detrended Real per Capita GDP	74.99	78.38	76.52
TFP Factor	86.70	86.70	86.70
Capital Factor	117.12	107.15	107.81
Labour Factor	88.68	95.29	89.38

Table 4: Data, BGG and NG models (levels)

Components	Data	BGG	NG
2000-2007			
Real per Capita GDP	3.41	2.33	2.51
TFP Factor	2.23	2.23	2.23
Capital Factor	0.20	-0.63	-0.55
Labour Factor	0.99	0.64	0.83
2008-2017			
Real per Capita GDP	-2.46	-2.61	-2.97
TFP Factor	-2.88	-2.88	-2.88
Capital Factor	1.76	0.81	1.15
Labour Factor	-1.33	-0.54	-1.25
2000-2017			
Real per Capita GDP	0.07	-1.02	-0.80
TFP Factor	-0.88	-0.88	-0.88
Capital Factor	1.20	0.11	0.37
Labour Factor	-0.25	-0.25	-0.29

Table 5: Data, BGG and NG models (average annual changes)

growth in data is 3.49%, the BGG predicts a 2.35% and the NG 2.57% growth every year. This is because both models fail to produce the behaviour of the capital factor. Notably, although the data shows that the capital factor steadily increases, both models show a gradual drop until 2004 followed by an increase after 2006, thereby generating a negative contribution of the capital factor to the GDP growth rate. In terms of the labour factor, both models predict its increase with the NG model to perform better in what concerns the predicted contribution to the GDP growth (0.83% vs 0.99% in the data).

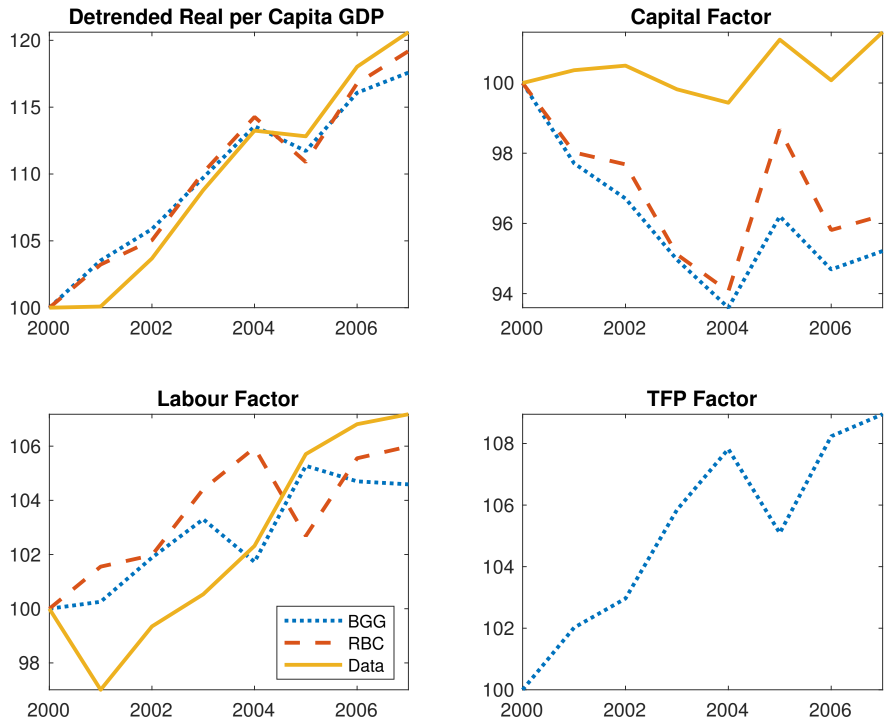


Fig. 4. Pre - Crisis Period. Index (2000=100)

6.2. *Great Depression 2008:2017*

Figure 5 shows the model and data paths of the four macro variables relative to their 2008 value. As before, for the BGG model, the reported real per capita GDP is net of default costs. The Greek great depression period is characterised by a drop of real per capita GDP of 26.3% between 2008 and 2013 and a subsequent stagnation period. Both models match those two facts relatively well. They move synchronous with the data and capture well the output drop and the timing of the subsequent output stabilization. In terms of levels, the NG model succeeds well in producing the drop in output over the 2008-2012 period, while the NGG model slightly overestimates the drop in output during this period. Nevertheless, both models do not capture the full magnitude of the output drop after 2013. The reason is that both models underestimate the large reduction in the labour factor after 2013. The NG and BGG models predict a drop in output of about 1.5 and 3 percentage point lower than in the data. In terms of output growth rates, the BGG model outperforms the NG model and produces an average growth rate equal to 2.6% (2.41% in the data). The NG model generates an average growth rate of 2.97% because it overestimates the drop in output over the period 2015-2016. On the other hand, the NG model scores better.

In predicting the capital factor path, both models perform similarly, underestimating its true path given by the data by almost 10 points. The labour factor path given by the data is undoubtedly better matched by the NG model. However, the NG model cannot replicate the decrease in the labour factor after 2012. The BGG model performs poorly as regards capturing the labour factor. It is able to encapsulate only the negative sign of the labour factor growth during the great depression period. The higher implied labour elasticity for the NG model relative to the BGG model in the baseline calibration provides a potential explanation for the different predictions of the two models.

To enhance the understanding of the propagation mechanism and the role of financial frictions, Figure 6 shows the paths for the price of capital, consumption, investment and the riskless interest rate for both models. All variables except interest rates are expressed as relative deviations from their first period value. Interest rates are reported as percent deviations from the initial period. In the BGG model, there is an additional effect arising from the financial accelerator mechanism. In particular, there is a reduction in the Tobin's Q, the price of capital, that leads to a reduction in the net worth of entrepreneurs and an increase in the financial premium. This reduces the demand for capital and thus investment. At the same time, the increase in the deposit interest rate reduces consumption in the BGG model substantially more than in the NG model in which consumption increases due to the drop in interest rates. Since agents can perfectly predict the future (increasing) path of interest rates, their intertemporal substitution decision leads to more bank deposits which in this frictionless credit setting leads to a higher volume of loans. Therefore, investment falls by less than in the NG model. The reduction in consumption, in absolute terms, is even lower than the reduction in investment in the BGG model. This leads to a lower GDP per capita during the crisis predicted by the BGG. The fast recovery of investment in the BGG model after 2012, pushes higher levels of real per capita GDP to the NG.

In Appendix A we present also the same experiment for the Full Sample period 2000-2017.

6.3. The BGG Model with Exogenous Change in Risk

In the previous analysis, we showed the performance of the models when the TFP series was the only source of fluctuations. In this section, we take advantage of the BGG model's rich setting and we add one more source of exogenous disturbance in the model to see whether it improves the model's performance particularly after 2013, where the model cannot produce the big decline in the real per capital GDP. The exogenous shock we introduce is the the cross sectional dispersion in ψ, the idiosyncratic shock each entrepreneur receives. Our goal is to examine if changes in aggregate economic uncertainty had an impact on the macroeconomy. This *risk shock* as introduced by Christiano et al. (2014) is proxied by two economic uncertainty indices for Greece. The first is by Hardouvelis et al. (2018) and the other from Fountas, Karatasi, and Tzika (2018).[6] To enhance intuition both indices are plotted in Figure 7 relative to the value of the indexes in 2008. The indices behave similarly on the period 2006-2010, but they show significant differences before and after that. Furthermore, the index by Fountas et al. (2018) is much more volatile than the one of Hardouvelis et al. (2018) especially during

[6]Both indices follow the newspaper-based methods in Baker, Bloom, and Davis (2016).

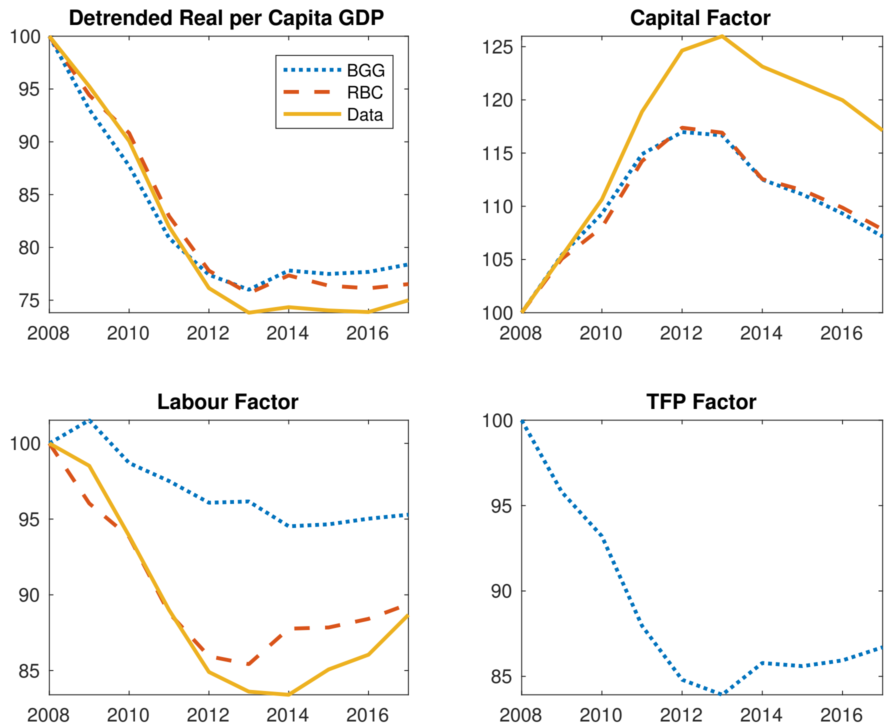


Fig. 5. Crisis Period. Index (2008=100)

the great depression period.

In the financial frictions model, when the idiosyncratic variance of the entrepreneurs increases, there is higher risk and there is substantial dispersion in the outcomes across entrepreneurs. When risk is high, the spread between the loan and the deposit rate increases and bankers are averse to providing credit. Lower credit leads to lower capital purchases by entrepreneurs and hence less investment. As a result aggregate demand falls leading to an economic downturn.

Results for the great depression period are plotted in Figures 8 for the uncertainty index of Fountas et al. (2018) and in Figure 9 for the uncertainty index of Hardouvelis et al. (2018). On the bottom right panel of the figures both the exogenous TFP and risk shocks are plotted. The more volatile, especially after 2008, index of Fountas et al. (2018) reinforces a greater economic downturn of the financial frictions model bringing it closer to the actual data. On the other hand, using the index of Hardouvelis et al. (2018) does not change the model's predictions significantly, since the index does not increase much relative to its value in 2008.

In fact, with the exception of the periods 2015-2016, its value after 2012 is lower than in 2008. In the case of Fountas et al. (2018) the value of the index almost doubles in 2015 producing a bigger downturn. Still the model cannot predict the large drop in GDP. Due to low monitoring costs of the model's calibration, we need large changes in the index so that as to have a significant impact on the economy. Sensitivity analysis suggests that an

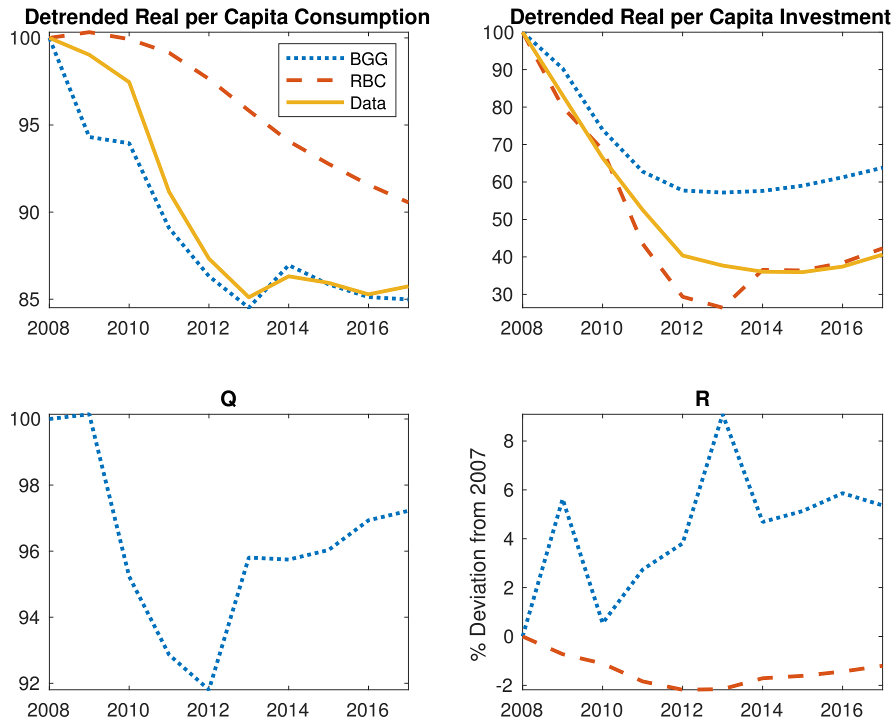


Fig. 6. Crisis Period. Index (2008=100)

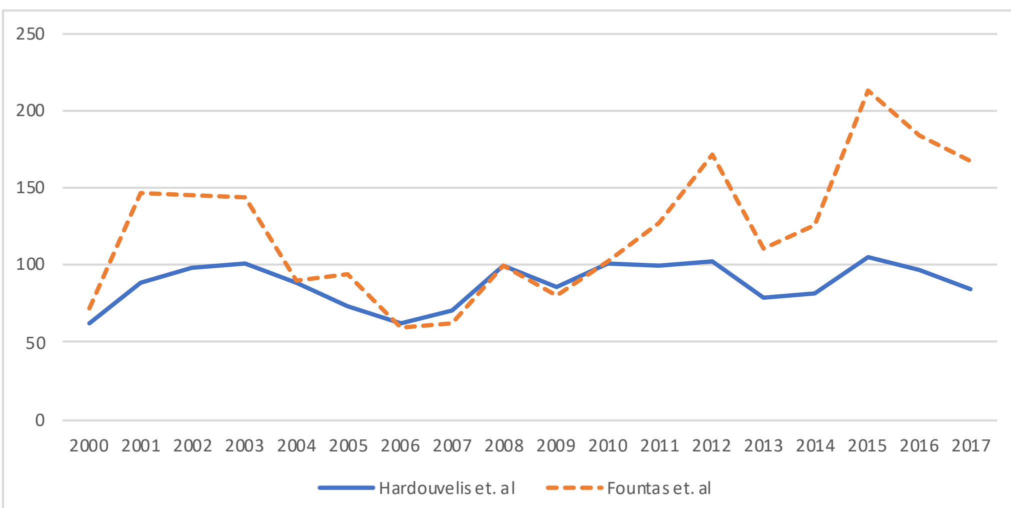


Fig. 7. Economic Uncertainty Indexes

increase in the monitoring costs increases the impact of the impact shock.[7] Additionally, since the agents have perfect foresight of the future risk shocks, this makes the impact of smaller magnitude. A departure from the perfect foresight hypothesis would enhance the

[7] Results are available by the authors upon request.

difference of the two series.

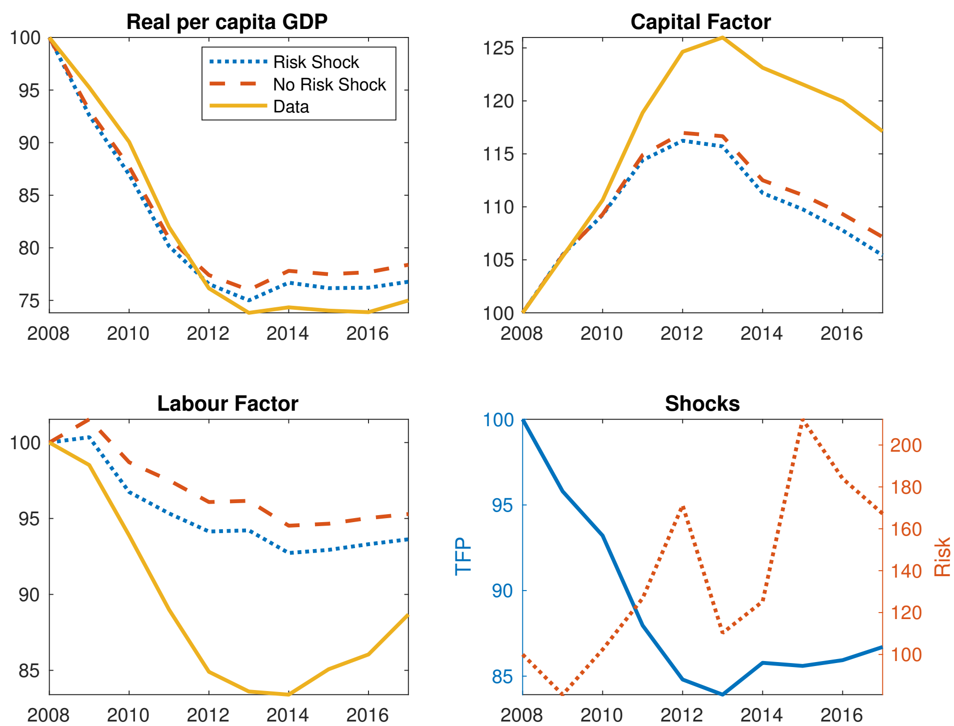


Fig. 8. Predictions: Economic Uncertainty Index Fountas et. al

7. Conclusion

Greece, at the onset of the financial crisis, experienced a severe recession. Greek real per capita output dropped by around 26 percent from 2008 to 2013. In this paper we identify and investigate Greece's great depression episode in 2008-2017 from a neoclassical perspective following the literature commenced by Kehoe and Prescott (2002). To pursue this we employ the neoclassical growth model. We assess the predictive power when the TFP is exogenous. Our results suggest that changes in TFP are important in accounting for the Greek great depression. Given the exogenous path of TFP both models predict a big decline in economic activity since 2008 and until 2013, and a relatively slow recovery for the period 2013-2017 as found in the data. When we add uncertainty shocks, the results do not change significantly. However, both models predict a lower than actually observed decline in output and the labour factor. Our analysis provides a diagnostic tool to determine the factors that could increase our understanding regarding the Greek crisis and provide directions for future research. The fact that the economic downturn is driven to a large extent by the drop in TFP and the labour factor, signals the need to identify the factors that shaped the decline in these variables. In this respect, the

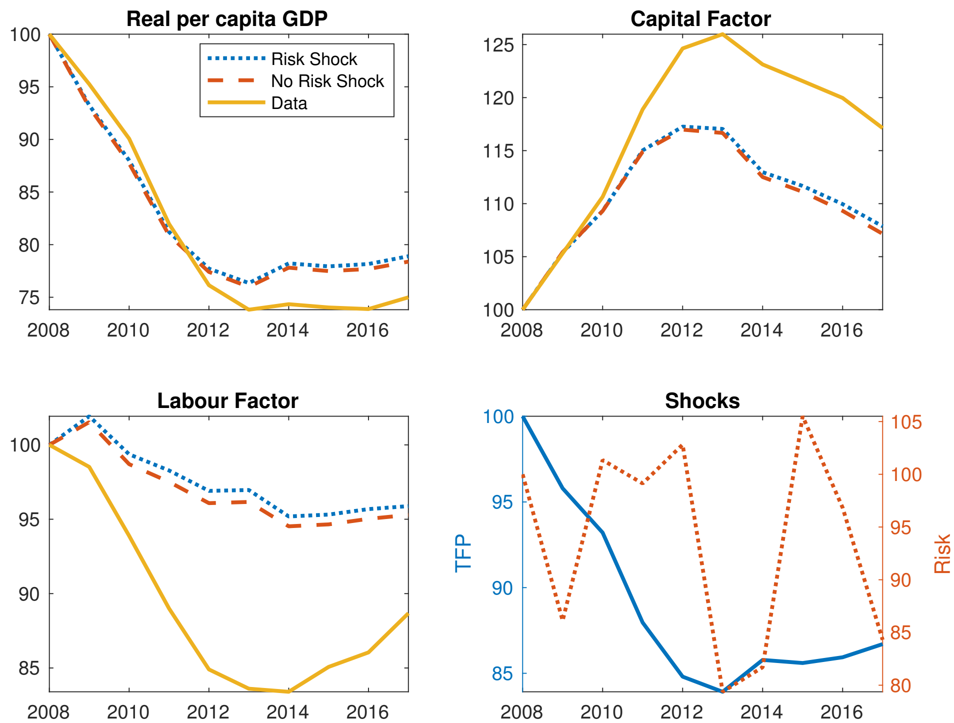


Fig. 9. Predictions: Economic Uncertainty Index Hardouvelis et. al

quality of institutions, fiscal policy, the structure of the banking system and labour market regulations are important candidates. Effectively this could be a big demand shock from tight fiscal policy stance and monetary policy stance. We leave all of these for future research.

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Appendix A Model Predictions: Full Sample 2000-2017

In this Appendix section we provide the results of our main experiment for the full sample 2000-2017. Observing the full sample we can have a more complete insight of how the two models perform relative to the data. Figure 10 shows the path of per capita GDP, capital, labour and TFP factor for the period 2000:2017. All variables are expressed in terms of their 2008 value. Both models perform well in capturing the recession as we have already seen in the Great Depression section. At the same time both models overestimate the increase of the 2000:2008 period when GDP is plotted relative to its 2008 value. As we've already seen, both models lack in their prediction of the capital factor and, especially during crisis, labour factor is predicted better by the NG.

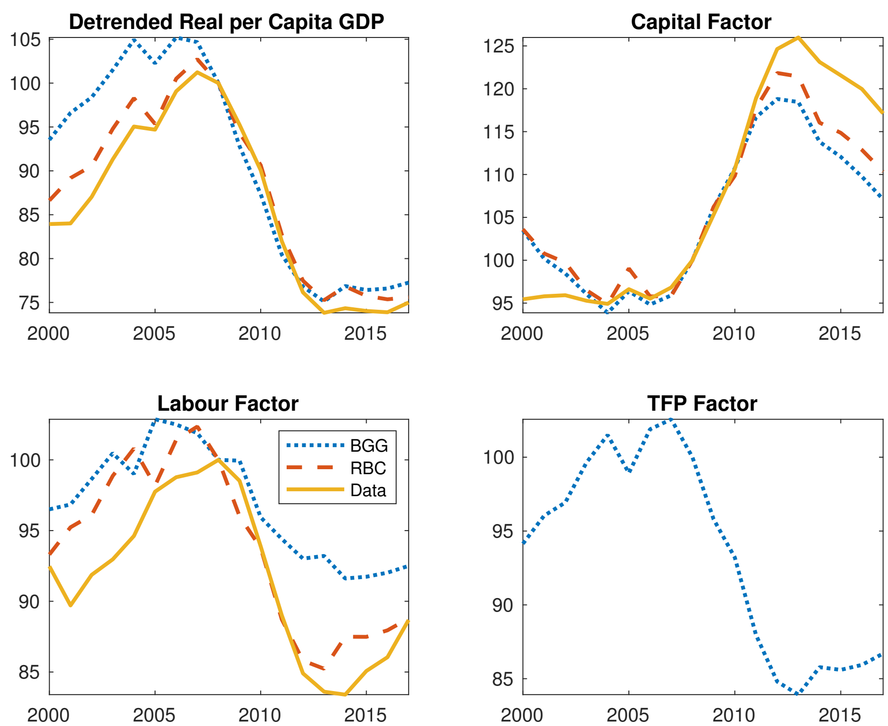

Fig. 10. Full Sample. Index (2008=100)

Appendix B Sensitivity Analysis: Changes in the Elasticity of Labour Supply

The elasticity of labour supply is of particular interest in contemporary macroeconomic models since it crucially determines how employment, and hence output, responds to fluctuations in productivity. There is a long-standing debate between macro and micro-estimates of the labour supply elasticity.[8] Micro studies typically estimate small labour supply elasticities (0-0.5) while macro models' calibration imply a higher number for this elasticity (around 2-4).

Determining the robustness of the predictions of the two models is a crucial point for our analysis. In this section, we present the models' simulations for different values of the intertemporal elasticity of substitution in labour supply. Comparisons between different model calibrations regarding the labour supply elasticity are motivated by Beaudry and Portier (2002) who perform a similar exercise for the French Depression in the 1930's using a similar methodology. They find that the two versions of their model with low and high labour elasticity produce very different results.

Our baseline calibration implies a labour supply elasticity of 2 (ϵ is 0.5), consistent to recent studies calibrated to the Greek economy. We perform four different simulations for each of the two models reducing each time the labour supply elasticity. Equivalently, bringing its value closer to the micro estimates. The Frisch inverse elasticity of labour supply varies from 0.5 (baseline) to 2 meaning a range of the labour supply elasticity from 2 to 0.5. Our goal is to identify the importance the elasticity plays in our models' predictions. Results for the Greek great depression period are plotted in Figure 11 for the NG model and in Figure 12 for the BGG.

Not surprisingly, a small change in the labour supply elasticity changes both models' path. We firstly focus on the NG model performance shown in Figure 11. Under our baseline calibration, the main predictive advantage of the NG model relative to the BGG was the estimation of the labour factor path. Up to 2012, the predicted path was very close to the true one with a small deviation of 3 points until 2017. In the present exercise, as the parameter dictating the labour elasticity increases and the labour elasticity declines this predictive ability is no longer present, at least in the same level. A change of 0.5 in ϵ (from 0.5 to 1) changes the predicted labour factor path by 5 points. As the elasticity continues to decrease, the deviation of the predicted labour factor from the true path increases. This has direct effects on the estimation of per capita GDP. The predicted path for the per capita GDP underestimates the recession as elasticity increases. Lastly, the change in the parameter is bringing capital factor path slightly closer to the data.

The performance of the BGG model, (Figure 12) is also affected by the elasticity changes but significantly less than the NG. In particular, in contrast to the NG, the estimates of the real per capita GDP are very stable along the parameter space. The deviations from the true path of the labour factor increase as the elasticity goes up while capital factor is brought closer to the true path.

[8] See Chetty, Guren, Manoli, and Weber (2011), Keane and Rogerson (2012) among others.

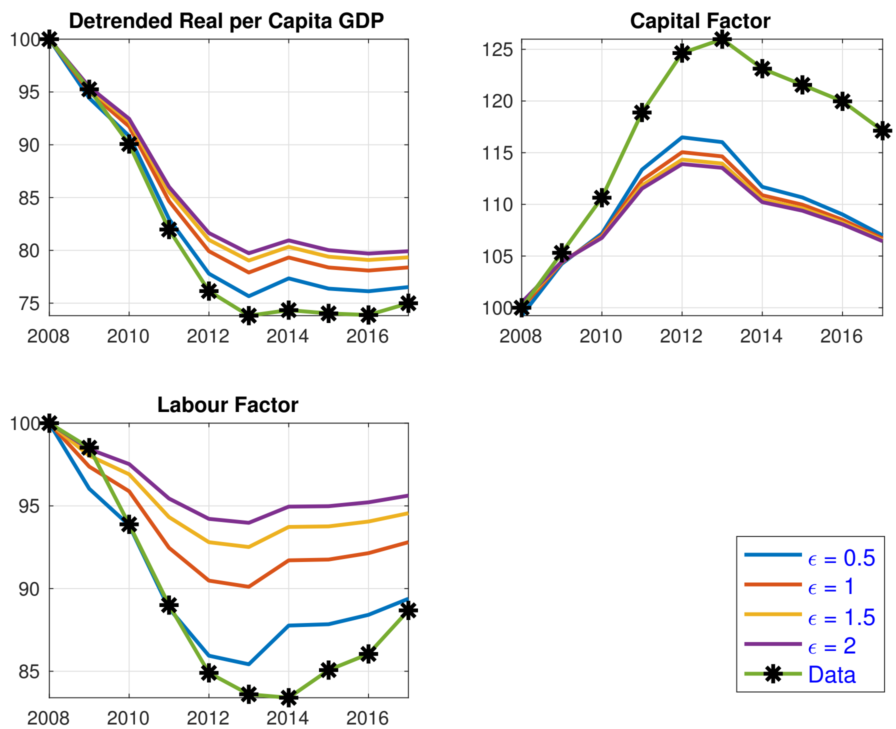

Fig. 11. Changes in the labour supply elasticity : NG

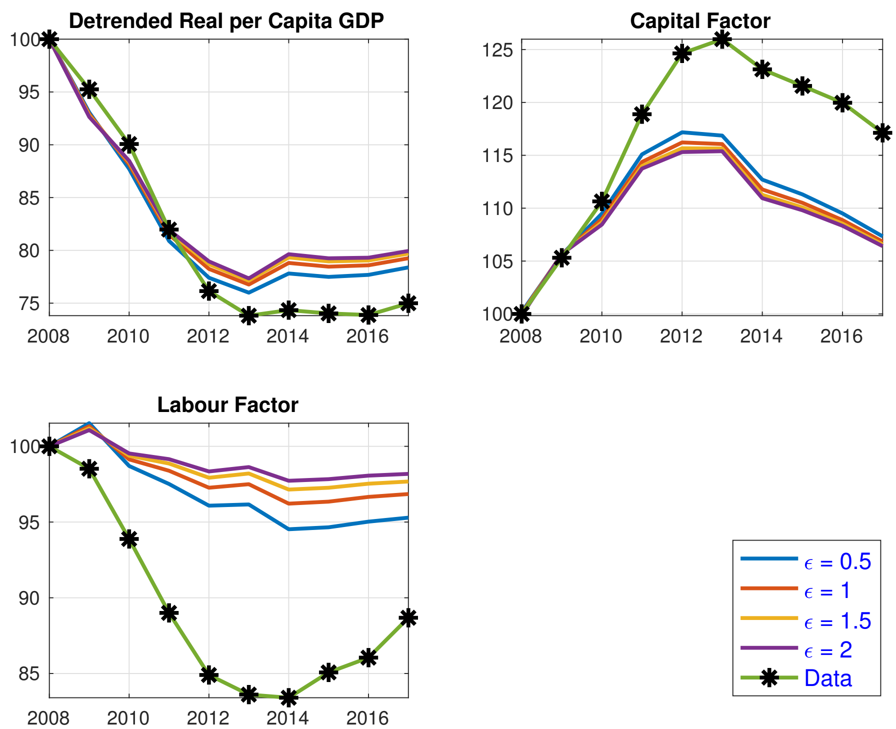

Fig. 12. Changes in the labour supply elasticity : BGG

Appendix C Model Equations

Financial Frictions Model

Production

$$
\begin{aligned}
K_{t+1} &= I_t + (1-\delta)K_t \\
Y_t &= A_t K_t^{\alpha} L_t^{1-\alpha} \\
W_t &= (1-\alpha)\left(\frac{K_t}{L_t}\right)^{\alpha} \\
Z_t &= \alpha\left(\frac{L_t}{K_t}\right)^{1-\alpha} \\
Q_t &= 1 + \left(\chi\frac{I_\tau}{I_{\tau-1}}\left(\frac{I_\tau}{I_{\tau-1}}-1\right) + \frac{\chi}{2}\left(\frac{I_\tau}{I_{\tau-1}}-1\right)^2 - \chi\Lambda_{t,\tau}\frac{I_{\tau+1}^2}{I_\tau^2}\left(\frac{I_\tau}{I_{\tau-1}}-1\right)\right. \\
R_{k,t+1} &= \frac{[Z_{t+1}+(1-\delta)Q_{t+1}]}{Q_t}
\end{aligned}
$$

Households

$$
\begin{aligned}
u_{c,t} &= (C_t)^{-1} \\
\Lambda_{t,t+1} &\equiv \beta\frac{u_{c,t+1}}{u_{c,t}} \\
\Lambda_{t,t+1}R_{t+1} &= 1 \\
u_{c,t}W_t &= \chi N_t^{\epsilon}
\end{aligned}
$$

Entrepreneurs & Debt Contract

$$
\begin{aligned}
Q_tK_t &= LNS_t + N_t^E \\
N_t^E &= R_{k,t}Q_tK_{i,t} - R_{l,t}LNS_t \\
R_{l,t}LNS_t &= \bar{\psi}_t R_{k,t}Q_tK_t \\
N_t^E &= (\sigma_{E,t}+\xi^e)(1-\Gamma(\bar{\psi}_{t+1}))R_{k,t+1}Q_tK_{t+1} \\
N_t^E\phi_t^E &= Q_tK_t \\
R_{k,t}Q_tK_t[\Gamma(\bar{\psi}_{t+1}) - \mu G(\bar{\psi}_{t+1})] &\geqslant R_{t+1}(Q_tK_t - N_t^E) \\
R_{k,t+1} &= \mathbb{E}_t\,\rho(\bar{\psi}_{t+1})R_{t+1} \\
p(\bar{\psi}_t) &= \int_0^{\bar{\psi}_t} f(\psi, -0.5(\sigma_\psi)^2, \sigma_\psi^2)d\psi \\
\Gamma(\bar{\psi}_t) &= G(\bar{\psi}_t) + \bar{\psi}_t(1-p)
\end{aligned}
$$

$$G(\bar{\psi}_t) = \int_0^{\bar{\psi}_t} \psi f(\psi, -0.5(\sigma_\psi)^2, \sigma_\psi^2) d\psi$$

$$\Gamma'(\bar{\psi}_t) = (1 - p\bar{\psi}_t)$$

$$G'(\bar{\psi}_t) = \frac{1}{\sigma_\psi \sqrt{\pi}} \exp\Big[- \frac{(\log(\bar{\psi}) + 0.5\sigma_\psi^2)^2}{2\sigma_\psi^2} \Big]$$

$$\rho(\bar{\psi}_{t+1}) = \frac{\Gamma'(\bar{\psi}_{t+1})}{[(\Gamma(\bar{\psi}_{t+1}) - \mu G(\bar{\psi}_{t+1}))\Gamma'(\bar{\psi}_{t+1}) + (1 - \Gamma(\bar{\psi}_{t+1})(\Gamma'(\bar{\psi}_{t+1}) - \mu G'(\bar{\psi}_{t+1}))]}$$

$$LNS_t = D_t$$

Resource Constraint

$$Y_t = C_t + I_t + \mu G(\psi_t) R_{k,t} Q_t K_t$$

Neoclassical Growth Model

Production

$$K_{t+1} = I_t + (1 - \delta) K_t$$

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha}$$

$$W_t = (1 - \alpha) \left(\frac{K_t}{L_t} \right)^\alpha$$

$$Z_t = \alpha \left(\frac{L_t}{K_t} \right)^{1-\alpha}$$

$$R_{k,t+1} = R_{t+1} = Z_{t+1} + (1 - \delta)$$

Households

$$u_{c,t} = (C_t)^{-1}$$

$$\Lambda_{t,t+1} \equiv \beta \frac{u_{c,t+1}}{u_{c,t}}$$

$$\Lambda_{t,t+1} R_{t+1} = 1$$

$$u_{c,t} W_t = \chi N_t^\epsilon$$

Resource Constraint

$$Y_t = C_t + I_t$$