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Modeling rent seeking activities: quality of institutions, macroeconomic performance, and the economic crisis

by

Tryfon Christou, Apostolis Philippopoulos and Vanghelis Vassilatos

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303 / Fax: 210 8203499
76, Patission Street, Athens 104 34 Greece.
Tel.: (+30) 210 8203303 / Fax: (+30) 210 8203499
E-mail: econ@aueb.gr / www.aueb.gr

Modeling rent seeking activities: quality of institutions, macroeconomic performance, and the economic crisis

Tryfon Christou[a], Apostolis Philippopoulos[b], Vanghelis Vassilatos[c]

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Abstract

This paper studies the implications of institutional quality on macroeconomic performance. For this reason, we augment the standard real business cycle (RBC) model with rent seeking competition. The idea is that agents allocate a part of their effort time competing with each other for a fraction of a contestable prize. Our analysis considers alternative contestable prizes like government transfers, total tax revenue and firms' produced output. We calibrate the respective models to 12 Eurozone countries over the period 2001-2016. Our task is to evaluate the ability of the alternative ways of modeling the contestable prize to match the data and to compare second moment properties in the data vis-a-vis each model. An interesting finding is that, in terms of the second moment properties, we observe notable differences between core and periphery countries in the data. We find that all models perform in a similar way; yet both qualitative and quantitative differences arise in second moment properties among core and periphery countries. The model with rent seeking activities is closer to periphery countries. Also, motivated by the changes in fiscal policy instruments observed in the data in response to the outburst of the 2007-8 world crisis, we investigate how this affected macroeconomic performance and quality of institutions distinguishing among the two sub-periods preceding and following the crisis. We find that firstly, the repercussions of the crisis have been milder in countries with better quality of institutions and secondly, countries with poor quality of institutions before the crisis, suffered a further deterioration in this quality in the crisis years.

Keywords: Rent seeking, property rights, institutions, economic fluctuations, Eurozone
JEL classification: E32, E65, D7, O43, O57

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[a] Athens University of Economics and Business, Athens, Greece, email: christoutry@aueb.gr
[b] Athens University of Economics and Business, Athens, Greece and CESifo, Munich, Germany, email: aphil@aueb.gr
[c] Athens University of Economics and Business, Athens, Greece, email: vvassila@aueb.gr

1 Introduction

The economic and social consequences of the recent crisis that started in 2007-08 have been more severe and deep in countries of Southern Europe compared to countries of Northern Europe. What could lie behind this observation? A possible candidate could be the role and quality of institutions, since this provides the rules of the game and determine the framework where economic and social activity takes place. Moreover, there is ample evidence in the literature that institutions matter for macroeconomic performance. For example, as stressed by North, a crucial channel through which institutional quality interacts with macroeconomic performance is through the decrease of uncertainty in the economy and the reduction of the cost of transactions. The importance of institutions for economic performance is well established in the literature. For example, Aron (2000) and Efendic et al. (2001), support through empirical studies the importance of institutions on the macroeconomic performance of each country. Acemoglu et al. (2005) suggest that political activity and the nature of politics in a country can explain differences in terms of institutions and a country's economic results. Moreover, Alesina et al. (1996) find a negative correlation between political instability and growth.

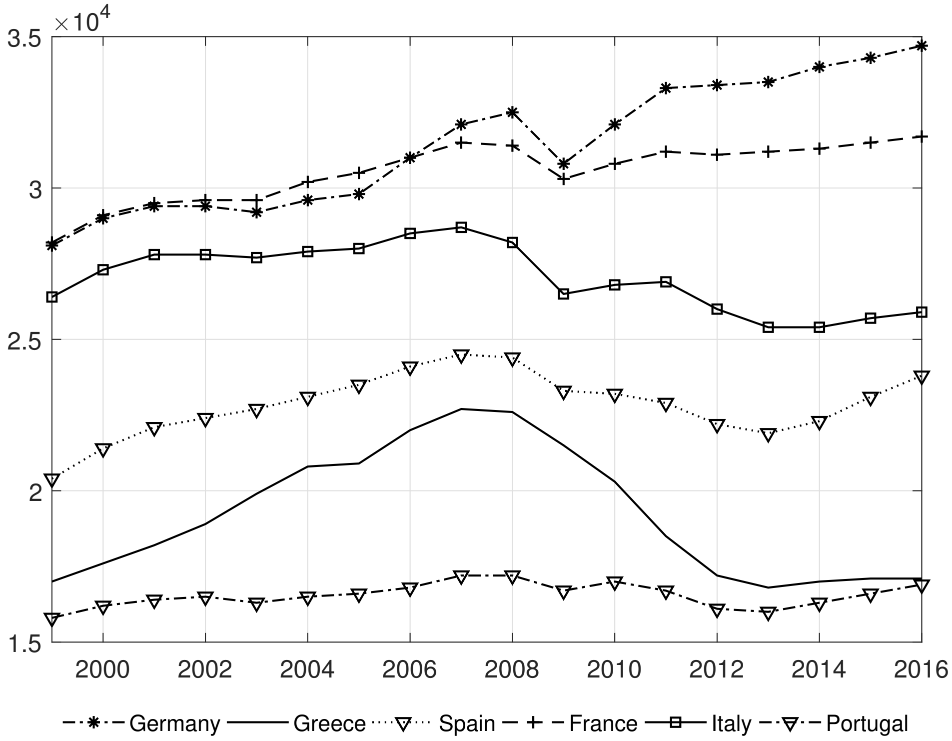

Figure 1: Real per capita GDP, Eurostat

In this paper, we incorporate institutions in a dynamic general equilibrium macroeconomic framework in order to explain discrepancies in macroeconomic performance observed in the data between 12 Eurozone countries. In particular, we build on the concept of rent seeking introduced by Tullock (1967) and the work by Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) and Park et al. (2005) and introduce institutions in the form of rent seeking activities. Under this specification, agents are engaged in rent seeking activities and compete with each other in order to extract a fraction of a contestable prize. Park et al. (2005) study the effects of the size of government sector under the assumption of rent seeking from state coffers. Furthermore, Angelopoulos et al. (2009) use this framework as to capture the social cost of rent seeking in Europe. Angelopoulos et al. (2011) study how rent seeking competition affects emerging markets, like in Mexico, where property rights are weakly protected.

Our model is a standard real business cycle model with distortionary taxation where we further assume that agents allocate a fraction of their non-leisure time competing with each other for a fraction of a contestable prize; we consider three different contestable prizes, namely, public transfers, total tax revenue and the economy-wide output. In the terminology of Chari et al. (2007), we observe that rent seeking in our model introduces an additional friction to the standard RBC model with distortionary taxation that induces wedges which distort agents decisions and depend apart not only on the level of distortionary taxation but on the level of institutional quality also. We calibrate each case of contestable prize for 12 Eurozone countries which we group into two groups: core countries consisting by Austria, Belgium, Germany, Finland, France and Netherlands and periphery countries consisting of Cyprus, Greece, Ireland, Italy, Portugal and Spain. The calibration of the model to 12 Eurozone countries for the period 2001-2016 leads to considerable differences between core and periphery countries especially in the respective parameter of the extraction of the contestable prize, indicating higher extraction of the contestable prize and thus lower institutional quality in periphery countries.

We then use this frameworks focusing on second moment properties and impulse response function analysis in order to answer the following questions: firstly, what are the implications of the introduction of institutions in an otherwise standard neoclassical growth model. Secondly whether the introduction of institutions helps the model to better explain macroeconomic behavior. To answer this, we evaluate for all 12 Eurozone countries the ability of each of the three contestable prize cases to match the second moment properties in the data. To do so, we solve and simulate each case of contestable prize as to generate series for all endogenous variables. We then compare their statistical properties to the ones of the relevant series in the data.

An interesting finding is that, in terms of the second moment properties, we observe notable differences between core and periphery countries in the data. Not surprisingly, given the resembling underlying propagation mechanisms, all contestable prize cases generate, for each country, data series with a similar qualitative behavior in terms of second moment properties. On the other hand, given the contestable prize case, both qualitative and quantitative differences arise among core and periphery countries in terms of second moment properties; however the model with rent seeking activities generates series with second moment properties closer to what we find in the data for periphery countries. Looking at the dynamic implications of the introduction of institutions in a simple real business cycles model with distortionary taxation, we find that all three cases of contestable prize share similar qualitative characteristics of impulse responses; yet a shock in total factor productivity reveals a more persistent behavior in periphery countries when compared to core countries.

We also investigate what our model predicts on the interaction between macroeconomic performance, fiscal policy and institutional quality in view of the recent economic crisis. To this end, taking into account the observed changes in fiscal policy in the years following the economic crisis, we examine whether and how these changes played a significant role in the level of institutions and on the macroeconomic performance of each country. We thus, distinguish among the two sub-periods preceding and following the crisis (2001-2008 and 2009-2016, respectively), substitute the respective policy instruments averages in our calibrated model for each case of contestable prize, and compute the respective long-run equilibria for each case/sub-period. We find that the repercussions of the crisis have been milder in countries with better quality of institutions. That is, the post-crisis period for the periphery countries is characterized by a considerably sharper and more persistent drop in output, compared to what is observed for core countries, where the fall in output was milder and less protracted. In addition, periphery countries in the period following the economic crisis suffered a deterioration in institutional quality whereas core countries suffered little or no decrease. This suggests that the repercussions of the crisis have been milder in countries with better quality of institutions and that countries with poor quality of institutions before the crisis, suffered a further deterioration in this quality in the crisis years. Consequently, countries with weak institutional framework can benefit from an improvement in institutional quality.

The paper is organized as follows: in Section 2, we discuss the data regarding the macroeconomic performance and institutional quality. In Section 3, we present each case and solve the problems of individual households, firms and the government followed by the comparison of the respective Decentralized Competitive Equilibrium (DCE). In Section 4, we discuss the methodology we use when taking the model to the data. In Section 5 we present the calibration procedure of each case and in Section 6 we discuss the long-run solution (steady state). Finally, in Section 7 we present the second moment properties of each case of contestable prize, in Section 8 the impulse responses of the key endogenous variables of the model and in Section 9 our findings on the interaction between fiscal policy, macroeconomic performance and institutional quality.

2 Macroeconomic performance and institutions

We begin our analysis by introducing a selection of 6 Eurozone countries from our sample, representing the core and periphery countries. These include the following countries: Germany, Greece, Spain, France, Italy and Portugal. In Figure 1, we see that all countries experienced an increase in real per capita GDP up until the economic crisis of 2007-08.

The interesting point regarding this figure is that despite the decrease in real per capita GDP observed in all countries in the wake of the economic crisis, Greece simply seems to strike out by being the country with the largest drop. What is even more striking is that Greece remains the only country that its real per capita GDP levels have not yet returned to its pre-crisis levels, rather have dropped even further. In Figure 2 we see a series for total factor productivity (TFP) from the St. Louis FED. This depicts the efficiency of production in the countries of our sample relative to United States being equal to 1. We notice that around 2002 all countries in our sample, apart from Germany, experience a decrease in TFP. The levels of TFP become lower in periphery countries than core countries, indicating an

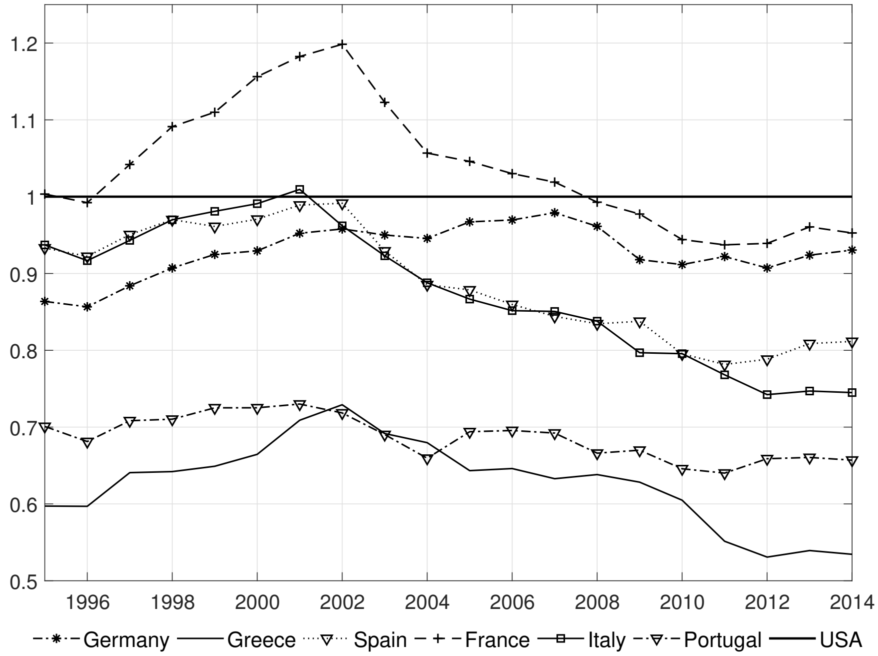

Figure 2: Total factor productivity (USA=1), St. Louis FED

inefficiency in utilizing inputs in production. After the economic crisis, periphery countries stabilize around their low levels in TFP, with the exception of Greece and Italy that suffer a continuous decrease.

In what institutions are concerned, Figure 3 shows the International Country Risk Guide (ICRG), for the years 1994-2015, produced by the Political Risk Services (PRS) Group. This is a widely used index regarding the quality of institutions and is comprised using 22 variables of risk evaluation. The index has an upper level of 100 where higher values indicate better institutional quality. We see that in this sample, Germany and Greece set the upper and lower bound respectively. It is also clear that Greece has suffered a continuous decrease in the level of institutional quality in the ICRG since 1998, with the lowest level to be in the crisis years in 2010 and 2012. It should not come as a surprise that this index shows an increase in the quality of institutions for Greece after 2012. This is due to the fact that Greece was under an economic adjustment program that reduced the risk of default, thus, increasing the index's value for the years after 2012.

A better picture emerges if we look at specific indicators more closely related to what we usually think of as institutions. Thus, we present 6 components of a different source of evaluation of institutional quality. In Figure 4 we present the World Governance Indicators as given from the World Bank. These indicators are the government effectiveness (captures the quality of public and civil services), regulatory quality (considers the implementation of policies to promote private sector development), rule of law (if the quality of contract enforcement and property rights is well established), control of corruption (whether public power is used for private use), voice and accountability (captures freedom of expression, free media and citizens ability to select their government) and political stability (considers the

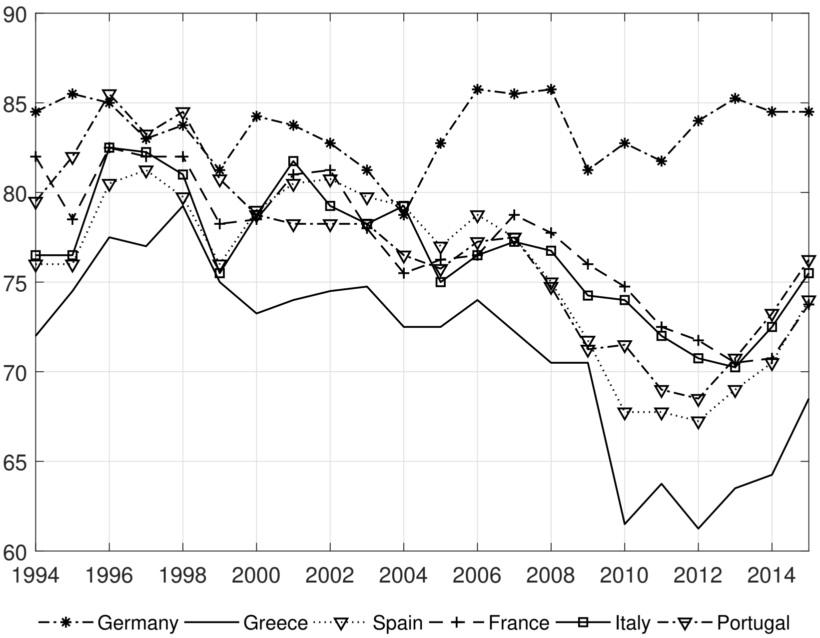

Figure 3: International country risk guide, PRS Group

likelihood of political instability). All components sum to 100 points, where higher values capture an increase in the quality of each component. What we observe is that Germany is the country with the highest points meaning a better institutional quality overall. In contrast, it is clearly shown that Greece holds the lower positions in our sample indicating bad institutional quality in all indicators. Compared to the ICRG index, these indicators reveal that the deterioration continued even after the economic crisis years, especially in government effectiveness, rule of law and regulatory quality.

3 Theoretical model

3.1 Description of the model

In this paper we build upon Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) and incorporate rent-seeking activities in a standard RBC model. We consider three alternative cases of contestable prizes: government transfers (Case I), total tax revenues (Case II) and firm's output (Case III). We assume that in the economy there is an equal number of identical households and identical firms and the government. The population size is N_t, where $N_{t+1} = \gamma_n N_t$, $\gamma_n \geq 1$ and $N_0 > 0$ are exogenously given constant parameters. Households, indexed by $h = 1, 2, \ldots, N_t$, own capital and labour which they supply to firms and choose in addition to consumption, leisure, and investment in capital, how to allocate their non-leisure time between productive work and rent seeking activities. Firms, indexed by $f = 1, 2, ..., N_t$, produce a homogeneous product using capital and labor. Government uses tax revenues and bonds to finance government consumption

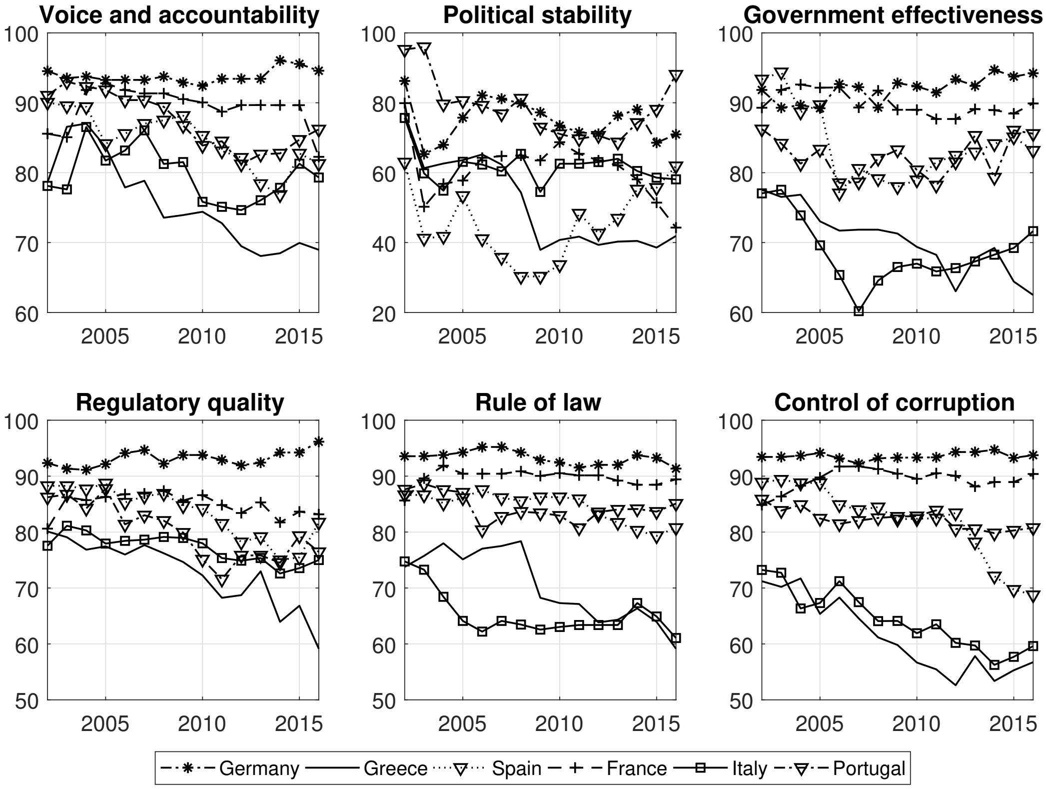

Figure 4: World governance indicators, World Bank

and government transfers. In what follows we present our standard RBC model with rent seeking activities focusing on the equations that are affected given the choice of contestable prize.[1]

3.2 Households

The expected discounted lifetime utility of household h is given by:

$$E_0 \sum_{t=0}^{\infty} {\beta^*}^t U(C_t^h + \psi \bar{G_t^c}, L_t^h) \tag{1}$$

where E_0 denotes rational expectations conditional on the information set available at time zero, the time discount factor is $\beta^* \in (0,1)$, C_t^h is household $h's$ consumption at time t, $\bar{G_t^c}$ is government consumption of goods and services provided by the government for each household at time t, L_t^h is household $h's$ leisure time at time t and ψ is a parameter that measures the degree of substitutability between private and government consumption in utility.[2]

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[1] The detailed models for the three cases of contestable prize namely Cases I, II and III are presented in Appendices A, B and C respectively.

[2] If $\psi = 0$ then the household receives no utility from government consumption.

We assume that in all three cases of contestable prize the instantaneous utility function for each household h takes the following form:

$$U(C_t^h + \psi \bar{G}_t^c, L_t^h) = \frac{\Big((C_t^h + \psi \bar{G}_t^c)^{\mu} (L_t^h)^{1-\mu}\Big)^{1-\sigma}}{1-\sigma} \tag{2}$$

where $0 < \mu < 1$ and $\sigma \geq 0$ are parameters.

The household has one unit of time in each period allocated to either leisure, L_t^h, or non-leisure time, H_t^h. Thus, the time constraint of the household h is:

$$L_t^h + H_t^h = 1 \tag{3}$$

Following Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) the household further divides its non-leisure time, H_t^h, between productive work, $\eta_t^h H_t^h$, and rent-extracting or seeking activities, $(1-\eta_t^h)H_t^h$, where $0 < \eta_t^h \leq 1$ and $0 \leq (1-\eta_t^h) < 1$ denote the fractions of non-leisure time that the household allocates to productive work and rent extraction or rent seeking activities respectively. Thus, in each period non-leisure time is:

$$H_t^h = \eta_t^h H_t^h + (1-\eta_t^h)H_t^h \tag{4}$$

The household receives income from labor, $w_t Z_t \eta_t H_t^h$, where w_t is the wage rate, Z_t is a labour augmenting technology variable evolving according to $Z_{t+1} = \gamma_z Z_t$, $\gamma_z \geq 1$ and $Z_0 > 0$ are exogenously given constant parameters. Each household h decides to invest in capital, I_t^h, and government bonds, D_t^h. This gives each household an interest income $r_t^k K_t^h$ and $r_t^b B_t^h$ from capital and government bonds respectively, where r_t^k and r_t^b are the gross returns to capital and bonds, K_t^h and B_t^h. Additionally, each household receives a share of profits, Π_t^h, and a share of lump-sum government transfers given to all households irrespective of their rent seeking activities. Consumption and both sources of income are taxed at the rates $0 \leq \tau_t^c < 1$ and $0 \leq \tau_t^y < 1$ respectively.

The choice of contestable prize directly affects the household budget constraint.[3] Hence, when the contestable prize is government transfers (Case I), the budget constraint of household h is:

$$\begin{aligned}(1+\tau_t^c)C_t^h + I_t^h + D_t^h = \\ (1-\tau_t^y)(r_t^k K_t^h + w_t Z_t \eta_t^h H_t^h + \Pi_t^h) + r_t^b B_t^h + \bar{G}_t^{t,E} + \frac{(1-\eta_t^h)H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t G_t^t\end{aligned} \tag{5-I}$$

where $\bar{G}_t^{t,E}$ are lump-sum transfers given to every household h irrespective of rent seeking activities (i.e. effortlessly), G_t^t are total government transfers and $0 \leq \theta_t < 1$ is the economy-wide degree of extraction (defined in subsection 3.5).

When the contestable prize is tax revenues (Case II), the budget constraint of household h becomes:

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[3] The respective equations of the three cases of contestable prize are labeled in parenthesis as I, II and III respectively.

$$(1+\tau_t^c)C_t^h + I_t^h + D_t^h = \\ (1-\tau_t^y)(r_t^k K_t^h + w_t Z_t \eta_t^h H_t^h + \Pi_t^h) + r_t^b B_t^h + \bar{G}_t^t + \frac{(1-\eta_t^h)H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t R_t \quad \text{(5-II)}$$

where $\bar{G}_t^t$ denote lump-sum transfers given to every household and we define tax revenues, R_t, to be by:

$$R_t = \tau_t^c \sum_{h=1}^{N_t^h} C_t^h + \tau_t^y \sum_{h=1}^{N_t^h}(w_t^h Z_t \eta_t^h H_t^h + r_t^k K_t^h + \Pi_t^h) \quad (6)$$

Finally, when the contestable prize is the economy-wide firms' output Y_t (Case III), the budget constraint of household h is:

$$(1+\tau_t^c)C_t^h + I_t^h + D_t^h = \\ (1-\tau_t^y)(r_t^k K_t^h + w_t Z_t \eta_t^h H_t^h + \Pi_t^h) + r_t^b B_t^h + \bar{G}_t^t + \frac{(1-\eta_t^h)H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t Y_t \quad \text{(5-III)}$$

The last term in each budget constraint (5-I),(5-II) and (5-III) indicates that given the respective contestable prize, a self-interested agent attempts to obtain a share of the prize.

The law of motion of private holding of government bonds evolves according to:

$$B_{t+1}^h = B_t^h + D_t^h \quad (7)$$

where the initial B_0^h is given.

The law of motion of private holding of capital evolves according to:

$$K_{t+1}^h = (1-\delta)K_t^h + I_t^h \quad (8)$$

where the parameter $0 < \delta < 1$ is a depreciation rate and the initial K_0^h is given.

Each household h acts competitively by taking prices, government policy and economy-wide variables as given and chooses $\{C_t^h, H_t^h, \eta_t^h, K_{t+1}^h, B_{t+1}^h\}_{t=0}^{\infty}$ to maximize lifetime utility Eq.(1) given the definition of instantaneous utility Eq.(2) and subject to the relevant budget constraint depending on the contestable prize (i.e. either (5-I), (5-II) or (5-III)), the time constraints (3) and (4), and K_0^h, B_0^h given.[4] [5]

3.3 Firms

Each firm f uses private capital K_t^f and private labor Q_t^f in order to produce a homogeneous product Y_t^f according to the production function:

$$Y_t^f = A_t(K_t^f)^{\alpha}(Q_t^f)^{1-\alpha} \quad (9)$$

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[4] See Appendices A, B and C for the first order conditions of the household's maximization problem for the three cases of contestable prize.

[5] We assume that each individual household h takes as given the economy-wide variables (i.e. contestable prize (G_t^t, R_t and Y_t), total rent seeking time in the economy $\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h$ and θ_t).

where $A_t > 0$ is the stochastic total factor productivity (see subsection 3.6 for its law of motion) and $0 < \alpha < 1$ is a parameter.

Each firm f acts competitively by taking prices, policy, and economy-wide variables as given and chooses K_t^f and Q_t^f in order to maximize a series of static profit problems subject to the production function, Eq.(9). In the contestable prize Cases I and II the profit function of firm f is given by:

$$\Pi_t^f = Y_t^f - r_t^k K_t^f - w_t Q_t^f \tag{10-I, II}$$

whereas in Case III, where a fraction of the firm's output is extracted by rent seekers due to weak property rights protection, the profit function becomes:[6]

$$\Pi_t^f = (1-\theta_t) Y_t^f - r_t^k K_t^f - w_t Q_t^f \tag{10-III}$$

3.4 Government

The government taxes consumption at the rate $0 \le \tau_t^c < 1$ and total income at the rate $0 \le \tau_t^y < 1$. The collected tax revenues, R_t, as well as new bonds, B_{t+1}, are used in order to finance government consumption, G_t^c, and government transfers, G_t^t.[7] Depending on the case of contestable prize the government budget constraint becomes:

$$G_t^c + G_t^t + (1 + r_t^b) B_t = B_{t+1} + \tau_t^c C_t + \tau_t^y Y_t \tag{9-I}$$

$$G_t^c + G_t^t + (1 + r_t^b) B_t = B_{t+1} + (1-\theta_t)(\tau_t^c C_t + \tau_t^y Y_t) \tag{9-II}$$

$$G_t^c + G_t^t + (1 + r_t^b) B_t = B_{t+1} + \tau_t^c C_t + (1-\theta_t)\tau_t^y Y_t \tag{9-III}$$

3.5 Economy-wide rent extraction

As mentioned previously, θ_t is a variable denoting economy-wide rent extraction: higher values of θ_t indicate that the rent-seeking technology becomes more efficient and therefore a larger fraction of the contestable prize can be extracted. We consider θ_t to be a proxy for the quality of institutions in the economy where lower values indicate better institutions. As mentioned in the following subsection we shall assume θ_t to be exogenous.[8]

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[6] See Appendices A, B and C for the first order conditions of the firm's maximization problem for the three cases of contestable prize.

[7] In Case I, we assume that a fraction of government transfers is extracted by rent seekers, $G_t^{t,RS} = \theta_t G_t^t$, whereas the remaining government transfers, $G_t^{t,E} = (1-\theta_t) G_t^t$ are lump-sum transfers given to all households (i.e. given irrespective of rent-seeking activities), thus, $G_t^t = G_t^{t,RS} + G_t^{t,E} = \theta_t G_t^t + (1-\theta_t) G_t^t$.

[8] Alternatively, one could assume that θ_t is endogenous and increases with per capita rent-seeking activities $\theta_t = \phi_t \frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t}$. Furthermore, it could also depend on the fraction of output that the government allocates in securing property rights, s_t^p, (i.e. expenditures on policing, law enforcement etc.), e.g. $\theta_t = \phi_t (s_t^p)^{-\xi_2} \left(\frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t} \right)^{\xi_1}$; ϕ_t, ξ_1 and ξ_2 are parameters related to the quality of institutions.

3.6 Exogenous stochastic variables

The exogenous stochastic variables in our model are the aggregate productivity, A_t, the economy-wide degree of rent extraction, θ_t, as well as the shares over GDP of government consumption and government transfers (i.e. $s_t^c = \frac{G_t^c}{Y_t}$ and $s_t^t = \frac{G_t^t}{Y_t}$ respectively). They all follow a univariate stochastic AR(1) process:

$$lnA_{t+1} = (1 - \rho_a)lnA_0 + \rho_a lnA_t + \epsilon_{t+1}^a \tag{10}$$

$$ln\theta_{t+1} = (1 - \rho_\theta)ln\theta_0 + \rho_\theta ln\theta_t + \epsilon_{t+1}^\theta \tag{11}$$

$$lns_{t+1}^t = (1 - \rho_t)lns_0^t + \rho_t lns_t^t + \epsilon_{t+1}^t \tag{12}$$

$$lns_{t+1}^c = (1 - \rho_c)lns_0^c + \rho_c lns_t^c + \epsilon_{t+1}^c \tag{13}$$

where A_0, θ_0, s_0^t and s_0^c are means of the stochastic process, $\rho_a, \rho_\theta, \rho_t$ and ρ_c are the first-order autocorrelation coefficients and $\epsilon_{t+1}^\alpha, \epsilon_{t+1}^\theta, \epsilon_{t+1}^t$ and ϵ_{t+1}^c are i.i.d. shocks. The tax rates, τ_t^c and τ_t^y, are assumed to be constant over time.

3.7 Decentralized Competitive Equilibrium (DCE)

We solve for the DCE, where given market prices (w_t, r_t^k, r_t^b), government policy $(s_t^c, s_t^t, \tau_t^c, \tau_t^y)$ and economy-wide variables (A_t, θ_t): (i) each individual household, $h = 1, 2, \dots, N_t$, solves its problem defined in section (3.2), (ii) each individual firm, $f = 1, 2, \dots, N_t$, solves its problem defined in section (3.3), (iii) all markets clear and (iv) all constraints are satisfied.[9] Given that our economy convergences to a balanced growth path where consumption, output, capital and investment grow at the rate $\gamma_n \gamma_z$, we express the DCE in terms of variables expressed in per capita and efficient labor units (per capita in the case of labor).[10] Thus, we end up for each case of contestable prize with a system of eight equations in eight unknown endogenous variables $y_t, c_t, h_t, \eta_t, i_t, r_t^b, b_{t+1}$ and k_{t+1}, given the paths for A_t, θ_t, and the four policy instruments $s_t^c, s_t^t, \tau_t^c, \tau_t^y$. These are presented in detail in Appendices A, B and C. In what follows, we focus on the DCE equations that are affected given the choice of contestable prize, namely the first order conditions with respect to effort, η_t, non-leisure time, h_t, and capital, k_{t+1}, as well as the government budget constraint. For comparison reasons we also present the respective conditions of the simple RBC model (labelled as RBC) as well as the simple RBC model with distortionary taxation (labelled as RBCT), both without any rent seeking activities (i.e. $\theta_t = 0$ and η_t is not a choice variable).

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[9] The market clearing conditions are: $\sum_{f=1}^{N_t} Y_t^f = \sum_{h=1}^{N_t} Y_t^h$ in the product market, $\sum_{f=1}^{N_t} Q_t^f = Z_t \sum_{h=1}^{N_t} \eta_t^h H_t^h$ in the labor market, $\sum_{f=1}^{N_t} K_t^f = \sum_{h=1}^{N_t} K_t^h$ in the capital market and $\sum_{f=1}^{N_t} \Pi_t^f = \sum_{h=1}^{N_t} \Pi_t^h = 0$ in the dividend market.

[10] We transform the model in per capita and efficient unit terms to make them stationary and define that for any economy-wide variable X_t, $X_t \equiv (Y_t, C_t, K_t, B_t, G_t^c, G_t^t)$, $x_t = \frac{X_t}{N_t Z_t}$, and that $h_t = \frac{H_t}{N_t}$ is per capita non-leisure time.

Thus, for each of the three cases of contestable prize the first order condition with respect to effort, η_t, is:

$$\eta_t = 1 - \theta_t \frac{s_t^t}{(1-\tau_t^y)(1-\alpha)\frac{y_t}{\eta_t h_t}} \frac{y_t}{h_t} \tag{14-I}$$

$$\eta_t = 1 - \theta_t \frac{\tau_t^c \frac{c_t}{y_t} + \tau_t^y}{(1-\tau_t^y)(1-\alpha)\frac{y_t}{\eta_t h_t}} \frac{y_t}{h_t} \tag{14-II}$$

$$\eta_t = 1 - \theta_t \frac{1}{(1-\tau_t^y)(1-\theta_t)(1-\alpha)\frac{y_t}{\eta_t h_t}} \frac{y_t}{h_t} \tag{14-III}$$

the first order condition with respect to non-leisure time, h_t, is:[11]

$$\left(\frac{1-\mu}{\mu}\right)\left(\frac{c_t + \psi s_t^c y_t}{1-h_t}\right) = (1-\alpha)\frac{y_t}{h_t} \tag{15-RBC}$$

$$(1+\tau_t^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c_t + \psi s_t^c y_t}{1-h_t}\right) = (1-\tau_t^y)(1-\alpha)\frac{y_t}{h_t} \tag{15-RBCT}$$

$$(1+\tau_t^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c_t + \psi s_t^c y_t}{1-h_t}\right) = \Big[(1-\tau_t^y) + \frac{\theta_t s_t^t}{1-\alpha}\Big](1-\alpha)\frac{y_t}{h_t} \tag{15-I}$$

$$(1+\tau_t^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c_t + \psi s_t^c y_t}{1-h_t}\right) = \Big[(1-\tau_t^y) + \frac{\theta_t(\tau_t^c \frac{c_t}{y_t} + \tau_t^y)}{1-\alpha}\Big](1-\alpha)\frac{y_t}{h_t} \tag{15-II}$$

$$(1+\tau_t^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c_t + \psi s_t^c y_t}{1-h_t}\right) = \Big[(1-\tau_t^y)(1-\theta_t) + \frac{\theta_t}{1-\alpha}\Big](1-\alpha)\frac{y_t}{h_t} \tag{15-III}$$

the first order condition with respect to capital, k_{t+1}, which is the same for the simple RBC model with distortionary taxation, Cases I and II, i.e. Eq. (16-RBCT, I, II), but different for the simple RBC model, Eq. (16-RBC) and Case III, Eq. (16-III):

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[11] This is the standard condition equating the marginal rate of substitution of consumption to leisure to the marginal product of labor, i.e. $MRS_{c,l} = w_t$ in the simple RBC model, $MRS_{c,l} = (\frac{1-\tau_t^y}{1+\tau_t^c})w_t$ in the simple RBC model with distortionary taxation, $MRS_{c,l} = (\frac{1-\tau_t^y}{1+\tau_t^c})w_t\eta_t + \frac{\theta_t s_t^t}{1+\tau_t^c}\frac{y_t}{h_t}$ in Case I, $MRS_{c,l} = (\frac{1-\tau_t^y}{1+\tau_t^c})w_t\eta_t + \frac{\theta_t(\tau_t^c \frac{c_t}{y_t} + \tau_t^y)}{1+\tau_t^c}\frac{y_t}{h_t}$ in Case II and $MRS_{c,l} = (\frac{1-\tau_t^y}{1+\tau_t^c})(1-\theta_t)(1-\alpha)\frac{y_t}{h_t} + \frac{\theta_t}{1+\tau_t^c}\frac{y_t}{h_t}$ in Case III, where $MRS_{c,l} = \frac{U_l(c_t+\psi s_t^c y_t, 1-h_t)}{U_c(c_t+\psi s_t^c y_t, 1-h_t)} = (\frac{1-\mu}{\mu})(\frac{c_t+\psi s_t^c y_t}{1-h_t})$ in all cases.

$$\left(\frac{c_{t+1}+\psi s^c_{t+1}y_{t+1}}{c_t+\psi s^c_t y_t}\right)^{1-\mu(1-\sigma)}\left(\frac{1-h_t}{1-h_{t+1}}\right)^{(1-\mu)(1-\sigma)} \quad = \quad \beta\left[\alpha\frac{y_{t+1}}{k_{t+1}} \ + \ 1 \ - \ \delta\right] \tag{16-RBC}$$

$$\left(\frac{c_{t+1}+\psi s^c_{t+1}y_{t+1}}{c_t+\psi s^c_t y_t}\right)^{1-\mu(1-\sigma)}\left(\frac{1-h_t}{1-h_{t+1}}\right)^{(1-\mu)(1-\sigma)} = \beta\left(\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\right)\left[\alpha(1-\tau^y_{t+1})\frac{y_{t+1}}{k_{t+1}}+1-\delta\right] \tag{16-RBCT, I, II}$$

$$\left(\frac{c_{t+1}+\psi s^c_{t+1}y_{t+1}}{c_t+\psi s^c_t y_t}\right)^{1-\mu(1-\sigma)}\left(\frac{1-h_t}{1-h_{t+1}}\right)^{(1-\mu)(1-\sigma)} = \beta\left(\frac{1+\tau^c_t}{1+\tau^c_{t+1}}\right)\left[\alpha(1-\theta_{t+1})(1-\tau^y_{t+1})\frac{y_{t+1}}{k_{t+1}}+1-\delta\right] \tag{16-III}$$

and finally, the government budget constraint, which is the same for the simple RBC model with distortionary taxation and Case I, Eq. (17-RBCT, I), but different for the simple RBC model, Eq. (17-RBC), Case II, Eq. (17-II), and Case III, Eq. (17-III):

$$s^c_t + s^t_t + (1+r^b_t)\frac{b_t}{y_t} = \gamma_n\gamma_z\frac{b_{t+1}}{y_t} \tag{17-RBC}$$

$$s^c_t + s^t_t + (1+r^b_t)\frac{b_t}{y_t} = \gamma_n\gamma_z\frac{b_{t+1}}{y_t} + \tau^c_t\frac{c_t}{y_t} + \tau^y_t \tag{17-RBCT, I}$$

$$s^c_t + s^t_t + \theta_t(\tau^c_t\frac{c_t}{y_t} + \tau^y_t) + (1+r^b_t)\frac{b_t}{y_t} = \gamma_n\gamma_z\frac{b_{t+1}}{y_t} + \tau^c_t\frac{c_t}{y_t} + \tau^y_t \tag{17-II}$$

$$s^c_t + s^t_t + \theta_t\tau^y_t + (1+r^b_t)\frac{b_t}{y_t} = \gamma_n\gamma_z\frac{b_{t+1}}{y_t} + \tau^c_t\frac{c_t}{y_t} + \tau^y_t \tag{17-III}$$

Note that in the previous equations we substitute the factor prices which, depending on each model are:

$$r_t = \alpha \frac{y_t}{k_t} \tag{18-RBC, RBCT, I, II}$$

$$r_t^k = (1-\theta_t)\alpha \frac{y_t}{k_t} \tag{18-III}$$

$$w_t = (1-\alpha)\frac{y_t}{\eta_t h_t} \tag{19-RBC, RBCT, I, II}$$

$$w_t = (1-\theta_t)(1-\alpha)\frac{y_t}{\eta_t h_t} \tag{19-III}$$

The introduction of frictions (i.e. distortionary taxation, market power, sticky prices and sticky wages) in the simple RBC model manifests itself in the terminology of Chari et al. (2007) as wedges affecting labor, investment and government consumption outcomes. In our model, we introduce a friction in the form of rent seeking that implies a wedge similar to a labor, an investment and a government consumption wedge in Chari et al. (2007). To see this we compare the respective DCE conditions implied by each case of contestable prize with the ones from the simple RBC model with distortionary taxation.

In the case of $\theta_t = 0$ (i.e. in the absence of rent seeking activities), our model is nothing but a simple RBC model with distortionary taxation. When $\theta_t > 0$, it is evident from Eqs. (14-I), (14-II) and (14-III), that the existence of rent seeking activities reduces the effort level, η_t. In Cases I and III the dynamic behaviour of the effort level, η_t, is driven by the behaviour of the exogenous variables only (θ_t in Case I and θ_t and s_t^t in Case III), i.e. in the absence of a shock in θ_t and s_t^t, η_t remains constant over time. On the other hand when the contestable prize is tax revenues (Case II), the dynamic behaviour also depends on the behaviour of the endogenously determined variables c_t and y_t. Hence, in this case the effort level, η_t reacts to a shock in A_t via its effects on consumption, c_t, and output, y_t, implying a richer propagation mechanism.[12] Moreover, comparing the first order condition for non-leisure time, h_t, of the simple RBC with distortionary taxation, Eqs. (15-RBCT), with the respective conditions of the three cases of contestable prize, Eqs.(15-I), (15-II) and (15-III), we see that θ_t affects all cases of contestable prize positively. In the framerwork of Chari et al. (2007), the fraction $(1-\theta_t)$ in Eq. (15-III) and Eq. (19-III) induces a wedge that resembles a labor tax, that further distorts the marginal rate of substitution between consumption and leisure. Moreover, in Case III the household's decision with respect to capital deviates from the standard condition of the simple RBC with distortionary taxation (Eq. 16-RBCT), in the fraction $(1-\theta_t)$ which works like an investment tax in Chari et al. (2007) and induces a wedge in the intertemporal marginal rate of substitution.[13]

Finally, the government budget constraint in Case I coincides with that of the simple RBC model with distortionary taxation. However, Cases II and III differ in the following

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[12] See Tables 8-I, 8-II and 8-III in Appendix G for the impulse response of η following a shock in A_t in Cases I, II and III respectively.

[13] See Tables 9-I, 9-II and 9-III in Appendix G for the response of h_t and k_{t+1} to a positive shock in θ_t in Cases I, II and III respectively.

way: in Case II, a fraction $(1-\theta_t)$ of total tax revenues is extracted compared to Case III where a fraction $(1-\theta_t)$ of tax revenues from total income is extracted due to weak property rights protection of firms' total output. Thus, the introduction of rent seeking activities in our model in the terminology of Chari et al. (2007) introduces an extra government wedge. Apart from the shocks in government consumption we have an additional wedge in transfers and an additional wedge for Cases II and III due to weak institutional quality that work in the same direction like a positive shock in government spending.

To summarize, the introduction of rent seeking induces a labor, an investment and a government wedge which are richer compared to the simple RBC model with distortionary taxation and depend not only on distortionary taxation but also on the level of institutional quality.

4 Taking the model to the data

To match the variables of our closed economy model for each case of contestable prize with the variables observed in the data we follow usual practise (e.g. see Kehoe and Prescott (2002, 2007) and Conesa et al. (2007)), and define output in our model to be the real gross domestic product in the data. We also allocate real net exports to real consumption in the data, and investment and capital in our model to be total investment and total capital respectively in the data.[15]

The fraction of effort time allocated to productive work, η_t, and thus hours allocated to productive work, $\eta_t h_t$, are not recorded in the data. To address this issue we assume that rent seeking takes place while agents are at work. That is, we assume that hours at work, which are actually recorded in the data, include both productive hours at work, $\eta_t h_t$, and hours allocated to rent-seeking activities, $(1-\eta_t)h_t$.

Naturally, data on government transfers do not distinguish whether government transfers are associated or not with rent-seeking activities. Hence, in Case I the sum of G_t^{RS} and G_t^{E} in our model, i.e. government transfers extracted by rent seekers, $G_t^{RS} = \theta G_t^t$, and effortless government transfers, $G_t^{t,E} = (1-\theta_t)G_t^t$, coincides with the government transfers we observe in the data, $G_t^t = G_t^{t,RS} + G_t^{t,E} = \theta_t G_t^t + (1-\theta_t)G_t^t$.

5 Calibration of the model

We calibrate our model to 12 Eurozone countries which we group into two sets: a) Core countries, consisting of Austria (AT), Belgium (BG), Germany (DE), France (FR), Finland (FI), Netherlands (NL) and b) Periphery countries, consisting of Cyprus (CY), Greece (GR), Ireland (IR), Italy (IT), Portugal (PT) and Spain (ES). Data are of annual frequency and cover the period 2001-2016. Our data sources are Eurostat, Total Economy Database, St. Louis FED and AMECO.[14]

Following usual practise in the literature, we set the curvature parameter in the utility function, σ, equal to 2 and the degree of substitutability between private and government

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[14] See Appendic D for a detailed description of the data sources and series we use.

Table 1: Calibration of the model

	Countries											
Parameters	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
α	0.41	0.32	0.31	0.40	0.37	0.38	0.35	0.26	0.31	0.39	0.29	0.38
A_0	0.98	0.94	1.18	0.63	0.86	1.03	0.84	0.77	1.05	0.87	0.68	0.84
γ_n	1.01	1.00	1.02	1.00	1.02	1.01	1.01	1.02	1.00	1.01	1.00	1.00
β	0.97	0.98	0.96	0.94	0.96	0.97	0.97	0.96	0.97	0.97	0.97	0.97
δ	0.07	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.06	0.06

Note $\sigma = 2$, $\gamma_z = 1.024$, $\psi = 0$, $Z_0 = 1$ $\rho_\theta = 0.99$, $\rho_t = \rho_c = 0.95$, $\sigma_t, \sigma_c, \sigma_\theta = 0.01$ for all countries.
α: capital share (Calibrated), A_0: long-run aggregate productivity (Set)
σ: curvature parameter in the utility function (Set), β: discount factor (Calibrated)
γ_n: population growth rate (Set), γ_z: labour-augmenting technology growth rate (Set)
ψ: substitutability between private and government consumption (Set)
Z_0: initial level of technical progress, δ: capital depreciation rate (Set)

consumption in the utility function, ψ, equal to zero.[15] Next, we set the population growth, γ_n, to the average growth rate of the population of each country and the growth rate of the exogenous labor-augmenting technology to 1.024, equal to the average growth rate of the United States. We follow King and Rebelo (1999) and normalize the initial level of technical progress, Z_0, to 1 and set the level of long-run aggregate productivity, A_0, of each country to its average value of the period 2001-2014 of the Total Factor Productivity series from the St. Louis FED. [16] Using data on capital series from AMECO, we calibrate the annual rate of depreciation rate, δ, of each country. To calibrate the time preference rate, β, we use data on real interest rates for each country and the Euler equation of government bonds. Then, we calibrate the capital share in production, α, from the Euler equation for capital using data on investment to output ratio for each country. Furthermore, we set the persistence parameters ρ_θ to 0.99, ρ_t and ρ_c to 0.95, and the standard deviation of the shocks $\sigma_t, \sigma_c, \sigma_\theta$ to be 0.01 whereas we choose ρ_α and σ_a in order to match the volatility and persistence of the output series generated by the model with the volatility and persistence of the GDP series in the data for each country.[17]

The long-run value of the economy-wide degree of extraction, θ_0, and the value of the consumption weight in the utility function, μ, is different depending on each case of contestable prize in our model. In addition to the great ratios from the data (See Table 3 below), the calibrated parameter of α and the average values of $\tau_0^y, \tau_0^c, s_0^t$, this also requires the calibration of η (i.e. the fraction of non-leisure time allocated to productive work time) which is not reported in the data. We thus work as follows. Following usual practice used in the construction of many ICRG indices, we first rank and assign each country to a group of countries according to the Composite Risk Rating of the ICRG index. Then we assign values of η for each country according to their ranked group and then calibrate θ_0 using the first order condition with respect to the effort level, η_t.[18]

Finally, given the calibrated value of θ_0 we calibrate μ for the three cases of contestable

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[15] We assume that government consumption provides no utility to the household.

[16] The series we use for the Total Factor Productivity from St. Louis FED, is an index where USA take the value 1.

[17] See Appendix D for the calibration procedure we use for the model.

[18] See Appendices A, B and C for the first order condition with respect to effort level, η_t.

Table 2: Calibration of θ_0 and μ

		Countries											
Cases	Parameter	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
	η	0.95	0.95	0.95	0.80	0.85	0.90	0.90	0.90	0.95	0.95	0.85	0.95
I	θ_0	0.07	0.09	0.22	0.57	0.46	0.17	0.20	0.52	0.12	0.09	0.53	0.10
	μ	0.46	0.38	0.42	0.47	0.40	0.41	0.48	0.41	0.36	0.47	0.41	0.47
II	θ_0	0.02	0.02	0.03	0.10	0.07	0.04	0.04	0.06	0.02	0.02	0.09	0.02
	μ	0.46	0.39	0.43	0.50	0.42	0.42	0.49	0.43	0.36	0.47	0.43	0.48
III	θ_0	0.02	0.02	0.03	0.10	0.07	0.04	0.04	0.06	0.02	0.02	0.08	0.02
	μ	0.45	0.38	0.44	0.50	0.41	0.41	0.48	0.43	0.36	0.46	0.43	0.47

Note η: assigned effort level (Set)

θ_0: extraction parameter (Calibrated), μ: Consumption weight in utility (Calibrated)

prize using the respective first order condition for hours at work, h_t. We present the calibrated values of θ_0 and μ in Table 2 for each case in our model where we observe that in all three cases of contestable prize the periphery countries (Greece, Portugal, Spain, Cyprus, Ireland and Italy) have the highest long-run levels of the economy-wide degree of extraction indicating a more efficient rent-seeking technology and therefore higher extraction of the contestable prize and lower institutional quality.

6 Long-run equilibrium

In Table 3 we report the long-run equilibrium and the respective values from the data for the core and periphery countries for the three cases of contestable prize. In Table 4 we also report the long-run equilibrium and the respective data averages for the two countries that are characterized by the lowest and highest calibrated values of the extraction parameter θ_0, i.e. Germany and Greece respectively.[19] We obtain the unique solution for each case using the parameter values of Table 1 and 2 in the respective equations of the long-run equilibrium of each case and solve for the eight endogenous variables $y, k, c, i, h, \eta, b, r^b$.[22] In this solution, we set the long-run government debt-to-GDP ratio, $\frac{b}{y}$, to 0.90 on an annual basis and allow the long-run consumption-to-GDP ratio, s^c, to be endogenously determined.

The long run solution is very similar for the three cases of contestable prize given each country, yet we observe differences when we compare core to periphery countries. In the three cases, η is 0.94 on average in core countries, whereas in periphery countries this is around 0.88. This indicates higher rent seeking activities in periphery countries since agents allocate twice the amount of time to rent seeking when compared to core countries.

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[19] In Appendix D we present the long-run equilibrium of each case of contestable prize for all countries.

Table 3: Data averages and long-run equilibrium

	Data		Case I		Case II		Case III	
Variables	Core	Periphery	Core	Periphery	Core	Periphery	Core	Periphery
c/y	0.56	0.60	0.49	0.55	0.51	0.61	0.51	0.58
i/y	0.22	0.21	0.22	0.21	0.22	0.21	0.21	0.2
h	0.3	0.37	0.33	0.38	0.32	0.36	0.33	0.37
η	Na	Na	0.94	0.88	0.94	0.87	0.94	0.88
k/y	2.95	3.01	2.48	2.44	2.48	2.44	2.48	2.44
s^c	0.22	0.19	0.29	0.23	0.27	0.18	0.28	0.22
r^b	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.04

Table 4: Data averages and long-run equilibrium

	Data		Case I		Case II		Case III	
Variables	Germany	Greece	Germany	Greece	Germany	Greece	Germany	Greece
c/y	0.61	0.60	0.57	0.64	0.58	0.73	0.58	0.67
i/y	0.20	0.19	0.20	0.19	0.20	0.19	0.19	0.17
h	0.27	0.41	0.29	0.39	0.28	0.36	0.29	0.37
η	Na	Na	0.95	0.80	0.95	0.79	0.95	0.80
k/y	2.95	3.78	2.39	2.62	2.39	2.62	2.39	2.62
s^c	0.19	0.20	0.24	0.17	0.22	0.08	0.23	0.15
r^b	0.03	0.06	0.03	0.06	0.03	0.06	0.03	0.06

7 Solving the model and second moment properties

7.1 Linearized decentralized competitive equilibrium

We linearize the DCE of each case of contestable prize around its respective long-run solution. The linearized DCE can be written in the form $E_t[A_1\widehat{x}_{t+1} + A_0\widehat{x}_t + B_1\widehat{z}_{t+1} + B_0\widehat{z}_t] = 0$, where we define $\widehat{x_t} = (lnx_t - lnx)$, $\widehat{x_t} \equiv [\widehat{y_t}, \widehat{c_t}, \widehat{i_t}, \widehat{\eta_t}, \widehat{h_t}, \widehat{r^b_t}, \widehat{k_t}, \widehat{b_t}]$, $\widehat{z_t} \equiv [\widehat{A_t}, \widehat{\theta_t}, \widehat{s^t_t}, \widehat{s^c_t}]$, and A_1, A_0, B_1, B_0 are constant matrices of dimension 8x8, 8x8, 8x4 and 8x4 respectively. The elements of $\widehat{z_t}$ follow the AR(1) processes in Eqs. (10)-(13), and tax rates are assumed to be constant. Thus, for all three cases we end up with a linear stochastic difference equation system in eight variables; two are predetermined $(\widehat{k_t}, \widehat{b_t})$ and the remaining six are forward-looking $(\widehat{y_t}, \widehat{c_t}, \widehat{i_t}, \widehat{\eta_t}, \widehat{h_t}, \widehat{r^b_t})$, which given the calibrated parameter values is characterized by saddle-path stability in all cases of contestable prize.

We evaluate for all 12 Eurozone countries the ability of each of the alternative ways of modeling the contestable prize to match the data and we compare second moment properties in the data vis-a-vis each model. To do so, we solve and simulate each case as to generate series for each of the eight endogenous variables. We choose ρ_α and σ_a as to match the volatility and persistence of the output series generated by the model with the volatility and persistence of the GDP series in the data.[20] We calculate the trend using the HP filter

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[20] In Appendix F we present our results on the second moment properties in the data and of the series generated in the three cases of constestable prize.

with a smoothing parameter of 100 and then obtain the cyclical component. We calculate the second moment properties (relative volatility with respect to output, persistence and co-movement with output) of the series in the data and the ones generated by each case. We then compare their statistical properties to the ones of the relevant series in the data. The second moment properties for the key variables (y, c, i, h, k and η) in the data as well as in the model for the three contestable prize cases for all countries are presented in Appendix F, whereas in Tables 5, 6 and 7 we present the second moment properties for the group of core and periphery countries.

Table 5: Relative volatility, $x \equiv s_x/s_y$

	Data		Case I		Case II		Case III	
x	Core	Periphery	Core	Periphery	Core	Periphery	Core	Periphery
c	0.9339	0.7758	0.4905	0.7385	0.4896	0.7489	0.4948	0.7557
i	2.6575	3.4807	2.2722	1.7123	2.3124	1.7528	2.3149	1.7444
h	0.4223	0.2694	0.4231	0.1903	0.4141	0.1751	0.4180	0.1776
k	0.3430	0.4006	0.3186	0.2709	0.3244	0.2777	0.3246	0.2765
η	Na	Na	0.0516	0.0588	0.0367	0.0432	0.0373	0.0446
s_y	0.0161	0.0343	0.0162	0.0343	0.0162	0.0344	0.0161	0.0342

Not surprisingly, given the resembling underlying propagation mechanisms, all contestable prize cases generate, for each country, data series with a similar qualitative behavior in terms of second moment properties.[21] However, given the case of contestable prize, both qualitative as well as quantitative differences arise among countries.

We first look at the second moment properties in the data. In what concerns volatility and relative volatility with respect to output, a key observation is that, in the data, output in periphery countries is on average much more volatile than in core countries. Observe that in Cyprus, Greece, Ireland and Spain output is more than twice as volatile compared to the country where output is least volatile, i.e. Belgium. When it comes to the relative volatility of consumption to output series in the data, we see that consumption is less volatile than output and that, on average, consumption in periphery countries (0.78) is less volatile than in core countries (0.93). Investment is more volatile than output in all countries, yet investment is more volatile in periphery (3.48) compared to core countries (2.66). Also for all countries, hours at work are less volatile than output. Moreover, relative volatility of hours at work in periphery countries is much less volatile (0.27) compared to core countries (0.42). Capital series for all countries is less volatile than output. The ranking among core and periphery countries is more mixed here but still on average relative volatility of capital is slightly higher in periphery countries.

Looking at the persistence of the output series in the data we observe that output is more persistent in periphery countries than in core countries. More specifically, the average persistence of output in periphery countries is 0.68 whereas in core countries the average is 0.42. The picture is the same for investment and capital where periphery countries are characterized by relatively higher persistence. This becomes most evident in the case of in-

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[21] The only exception is the co-movement of the effort level with output, where the cross correlations are qualitatively similar in all cases but in Case 2 are relatively bigger.

vestment where periphery countries top the list with respect to the persistence value with the average being almost double relative to the average persistence of investment in core countries. When it comes to consumption series in the data, we observe that in Greece, Italy and Spain consumption is up to 3 times more persistent relative to Belgium where consumption is least persistent. Hours at work are considerably more persistent in periphery compared to core countries with the respective average values being 0.47 and 0.22 respectively.

Finally, in what concerns cross-correlations of key macroeconomic variables with output, Germany, Ireland, Austria, Finland and Italy behave in a similar way. More specifically, consumption, investment and hours at work are contemporaneously procyclical and capital is lagging procyclically. Moreover, the remaining correlations (i.e. with respect to a lead or a lag) are also qualitatively similar. Procyclicality with output for all variables is a feature shared by the remaining countries as well; however this procyclicality may either have a leading or lagging feature. Notable exceptions are Cyprus and Portugal, where consumption is countercyclical.

Table 6: Persistence, $\rho(x_t, x_{t-1})$

	Data		Case I		Case II		Case III	
x	Core	Periphery	Core	Periphery	Core	Periphery	Core	Periphery
y	0.4216	0.6786	0.3986	0.4789	0.3993	0.4811	0.3994	0.4804
c	0.4500	0.4508	0.4906	0.4975	0.4946	0.4996	0.4925	0.4979
i	0.4394	0.6598	0.3813	0.4639	0.3819	0.4645	0.3813	0.4634
h	0.2227	0.4685	0.3862	0.4559	0.3839	0.4556	0.3839	0.4564
k	0.7664	0.8443	0.7983	0.8434	0.7987	0.8440	0.7986	0.8441
η	Na	Na	0.4669	0.4659	0.4603	0.4668	0.4666	0.4683

We now come to the second moment properties of the series generated by our model for all three cases of contestable prize. Starting with the volatility of consumption, although less volatile than output for all countries and for all cases of contestable prize, consumption is considerably more volatile in the periphery countries as compared to core countries. Also, although more volatile than output for all countries, investment is considerably less volatile in periphery countries as compared to core countries. In all countries and for all cases of contestable prize, our model generates series for hours at work that are less volatile (0.50 or less) than output. However, the relative volatility of hours at work is considerably lower in all periphery countries (0.25 or less). For all cases of contestable prize, our model generates series for capital that are less volatile than output and more or less quantitatively similar for all countries (around 0.82). Finally, for all cases of contestable prize and for all countries, our model generates series for the effort level that are considerably less volatile than output (0.10 or less).

In general, our model for all contestable prize cases and for all countries with the exception of Germany, generate output persistence of similar magnitude, ranging from 0.40 to 0.48[22]. Nevertheless, persistence in periphery countries is relatively higher (0.48 compared to 0.40 in core countries). When it comes to consumption the differences among countries are negligible taking values around 0.50. In what concerns investment though, the model

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[22] Germany is characterized by considerably lower persistence (0.20)

generates series that are on average more persistent in periphery countries than in core countries. The opposite holds for hours at work where the series generated by our model for all cases of contestable prize are less persistent in core countries relative to periphery countries. Capital is persistent for all countries (more than 0.69), but relatively more persistent in the periphery relative to core countries (0.84 compared to 0.80). Finally, for all countries and all cases of contestable prize our model generates series for the effort level taking values around 0.47.

The cross-correlations of the c, i, h, k with output generated by our model are similar for all cases of contestable prize and all countries. Consumption, investment and hours at work are contemporaneous procyclical, whereas capital lags procyclically. The correlations with respect to leads or lags are qualitatively similar for all countries. When it comes to the effort level in all cases of contestable prize and for all countries this is contemporaneous procyclical. However, in Cases 1 and 3 (the contestable prize is government transfers and firms' output respectively), the cross-correlations are small ranging from 0 to 0.1, whereas in Case 2 (the contestable prize is total tax revenues) the magnitude of the cross-correlation is considerably higher (ranging from 0.2 to 0.4).

Table 7: Contemporaneous co-movement with output, $\rho(y_t, x_{t+1})$

	Data		Case I		Case II		Case III	
x	Core	Periphery	Core	Periphery	Core	Periphery	Core	Periphery
c	0.6683	0.3658	0.827	0.9839	0.8478	0.988	0.8388	0.9863
i	0.8497	0.9075	0.9839	0.9921	0.9858	0.9931	0.9577	0.9285
h	0.386	0.3296	0.8876	0.8872	0.8988	0.9122	0.8921	0.9025
k	0.3912	0.298	-0.0819	-0.0333	-0.079	-0.0276	-0.0786	-0.0283
η	Na	Na	0.0124	0.0201	0.2277	0.2897	0.0093	0.0122

When it comes to the comparison of the second moment properties observed in the actual data vis-a-vis the series generated by our model in each case of contestable prize, several interesting results arise. When it comes to the relative volatility of consumption it is the model calibrated for the periphery countries that generates series that quantitatively matches more closely the behavior of the actual data. The main differences in the calibration among countries lie on the parameterization of institutions. The differences in the second moment properties of the series generated by our model for each country will be mainly attributed to the differences in the calibrated values of the economy wide degree of rent extraction, θ_0.

The model can clearly match the qualitative characteristics we observe in the data when it comes to relative volatility. As in the data, the model produces for all cases of contestable prize and for all countries consumption, hours at work and capital series that are less volatile than output, whereas the investment series produced are more volatile than output. In more depth we see that the average relative volatility of consumption is closely matched for periphery countries (around 0.74 in the model and 0.78 in the data). The model also catches very well the relative volatility of investment to output of core countries; on average we find 2.27 in the model and 2.66 in the data. For non-leisure time the average value of all countries is 0.31 compared with the average value in the data, 0.35. Finally, the relative volatility of capital is closely matched with the data for the core countries (0.32 in the model and 0.34 in the data).

When we compare the persistence of the series generated by the model with the persistence of the series in the data, we see that this is closely matched. For consumption, the model generates series that are on average 0.49 persistent whereas in the data the respective persistence is 0.45. The persistence for investment series is higher for periphery (0.46 in model, 0.66 in data) compared to core countries (0.38 in model, 0.44 in data), both in the model and in the data. The picture is similar when we look at hours at work where the more persistent series are for periphery than core countries. In fact, the average persistence of the series in the model is 0.47 which is what we also find in the data. Finally, the persistence of the capital series generated by the model is closely matched with what we find in the data for all countries.

Our model, for all cases of contestable prize and for all countries implies throughout that consumption, investment, hours at work and effort are contemporaneously procyclical while capital lags procyclically. In the data the picture is more mixed. First, the model prediction that capital lags procyclically is a feature observed in the data for eleven out of the twelve countries of our sample[23]. Second, We also observe that qualitatively the model mimics the behavior or the data, yet quantitatively the contemporaneous cross-correlations with output are much higher. The contemporaneous correlation is in most cases the highest and in all cases quantitatively high implying strong contemporaneous procyclicality. The model prediction that capital lags procyclically is a feature observe in most countries in the data.

8 Impulse response functions

We compute the responses of the key endogenous variables (measured as percentage deviations from their model-consistent long-run value) to a unit shock to total factor productivity, A_t, institutional quality, θ_t, government consumption, s_t^c, and government transfers, s_t^t, in the three cases of contestable prize. In what follows we report the effects on impact for the two countries that are characterized by the lowest and highest calibrated values of the extraction parameter θ_0, i.e. Germany and Greece respectively. (See Tables 8, 9, 10 and 11).[24]

We first focus on the comparison among the three cases of contestable prize for each exogenous variable. This reveals that all three cases share the same qualitative characteristics. In what concerns the response to A_t and s_t^c, the impulse responses are qualitatively similar to those reported in Angelopoulos, Philipopoulos and Vassilatos (2009). The effects of a deterioration in institutional quality reflected on the impulse response functions of θ_t resemble to those of a negative total factor productivity shock, which is also consistent to the findings of Angelopoulos, Economides and Vassilatos (2011). In what concerns a shock in s_t^t in Case I, we observe that when it comes to the allocation of time, non-leisure time, h_t,

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[23] The exception is France where capital leads countercyclically $\rho(k_{t-1}, y_t) < 0)$; however $\rho(k_{t-1}, y_t)$ and $\rho(k_{t+1}, y_t)$ are practically the same in absolute terms.

[24] The complete set of figures and tables of the impulse response functions for all countries and cases of contestable prize is in Appendix G.

Table 8: Positive shock in A_t: Response on impact

	Case I		Case II		Case III	
Variable	Germany	Greece	Germany	Greece	Germany	Greece
y	1.55	1.11	1.56	1.11	1.55	1.1
c	0.4	0.81	0.4	0.83	0.4	0.83
h	0.81	0.18	0.82	0.17	0.82	0.17
η	0	0	0.01	0.02	0	0
i	4.81	2.12	4.96	2.19	4.95	2.15

increases whereas the effort level η_t decreases as agents observing a bigger contestable prize allocate more time towards rent seeking activities.[25] Following the decrease in η_t, productive hours at work and output also decrease. Consumption and investment follow the decrease in output and then capital decreases.

Table 9: Positive shock in θ_t: Response on impact

	Case I		Case II		Case III	
Variable	Germany	Greece	Germany	Greece	Germany	Greece
y	-0.01	-0.05	-0.01	-0.05	-0.03	-0.12
c	-0.01	-0.04	-0.01	-0.04	-0.01	-0.04
h	0.03	0.11	0.03	0.12	0.01	0.02
η	-0.05	-0.20	-0.05	-0.21	-0.05	-0.22
i	-0.02	-0.11	-0.02	-0.11	-0.09	-0.41

Table 10: Positive shock in s_t^t, Case I: Response on impact

	Variable									
	y		c		h		η		i	
	DE	GR	DE	GR	DE	GR	DE	GR	DE	GR
Country	-0.01	-0.06	-0.01	-0.03	0.03	0.10	-0.05	-0.20	-0.04	-0.16

Focusing now on the comparison among different countries reveals notable quantitative differences. As already mentioned we choose to present our results for Germany and Greece. Observe that, the effect on impact of a positive shock in A_t is considerably higher in Germany compared to Greece with the exception of consumption where the opposite holds. Similarly, the responses on impact of a government consumption shock are bigger in Germany compared to Greece with the exception of investment where the picture is more mixed. Finally, albeit quantitatively small, the effects on impact of a positive shock in θ_t, i.e. a deterioration in institutional quality, are bigger in Greece compared to Germany. A notable example is the response of the effort level to the deterioration of institutional quality; η drops by almost four times in Greece compared to Germany. A similar picture as for θ_t arises for the case of s_t^t.

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[25] In Cases II and III a change in s_t^t has no effect in the economy

Table 11: Positive shock in s_t^c: Response on impact

	Case I		Case II		Case III	
Variable	Germany	Greece	Germany	Greece	Germany	Greece
y	0.16	0.08	0.15	0.04	0.16	0.07
c	-0.18	-0.14	-0.16	-0.05	-0.17	-0.12
h	0.24	0.14	0.22	0.05	0.24	0.12
η	0	0	0.004	0.006	0	0
i	-0.05	-0.08	-0.03	-0.02	-0.04	-0.07

9 Policy and institutions interactions before and after the crisis

In Tables 12 and 13 we present the policy instrument averages for the periods before and after the economic crisis; i.e. the sub-periods 2001-2008 and 2009-2016, where we observe significant changes in policy instruments in the years following the crisis.

Table 12: Policy instruments average: 2001-2008

	Countries											
Policy instrument	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
τ^c	0.22	0.19	0.26	0.18	0.17	0.21	0.17	0.22	0.23	0.23	0.21	0.28
τ^y	0.44	0.37	0.24	0.27	0.33	0.40	0.41	0.23	0.34	0.38	0.26	0.41
s^t	0.22	0.25	0.11	0.16	0.14	0.23	0.19	0.10	0.18	0.22	0.15	0.17
s^c	0.22	0.18	0.16	0.20	0.17	0.23	0.19	0.17	0.23	0.19	0.20	0.21

Note τ^c: effective tax rate on consumption, τ^y: effective tax rate on total income
s^t: share of government transfers to GDP, s^c: share of government consumption to GDP

Motivated by these changes, we investigate whether they played a significant role in the level of institutional quality and macroeconomic performance. We thus, distinguish among the two sub-periods preceding and following the crisis (2001-2008 and 2009-2016, respectively), substitute the respective policy instruments averages (s^t, τ^c, τ^y) in our calibrated model for each contestable prize case, and compute the respective long-run equilibrium for each case/sub-period. We present our results for Case I in Table 14 for two endogenous variables of interest, output y and effort level η.[26]

When we compare the results from each sub-period, we see that the model shows that all countries except Germany, which shows even a slight increase, have a decrease in output in the period following the economic crisis with Greece experiencing the largest decrease at -12.81%. The results from Table 7 show that after the economic crisis there has been a decrease in the level of institutional quality in all countries, apart from Germany. Periphery countries like Greece, Spain, Italy, Portugal and Cyprus suffered a clear deterioration of institutions (in terms of the effort level) whereas core countries experience little or no decrease in their institutional quality. This suggests that the repercussions of the crisis have been

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[26] Cases II and III show qualitatively similar results (see Appendix E).

Table 13: Policy instruments average: 2009-2016

Policy instrument	Countries BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
τ^c	0.21	0.20	0.22	0.19	0.15	0.21	0.17	0.20	0.23	0.22	0.19	0.26
τ^y	0.46	0.37	0.23	0.30	0.32	0.44	0.45	0.25	0.35	0.39	0.28	0.42
s^t	0.25	0.24	0.15	0.22	0.18	0.25	0.22	0.13	0.22	0.23	0.19	0.21
s^c	0.24	0.19	0.17	0.21	0.20	0.24	0.20	0.17	0.26	0.20	0.19	0.24

Note τ^c: effective tax rate on consumption, τ^y: effective tax rate on total income
s^t: share of government transfers to GDP, s^c: share of government consumption to GDP

Table 14: Policy changes, institutions and macroeconomic performance: Case I

Variable	Countries BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
Policy instruments set to their pre-crisis period 2001-2008 average												
y	0.50	0.34	0.75	0.25	0.42	0.44	0.40	0.30	0.37	0.46	0.24	0.40
η	0.95	0.95	0.96	0.83	0.87	0.91	0.91	0.91	0.96	0.95	0.87	0.96
Policy instruments set to their post-crisis period 2009-2016 average												
y	0.47	0.34	0.70	0.22	0.39	0.41	0.36	0.29	0.35	0.45	0.22	0.38
η	0.95	0.95	0.94	0.77	0.83	0.89	0.89	0.89	0.95	0.95	0.83	0.94
% change in output and effort level												
y	-6.29	0.23	-6.14	-12.81	-6.25	-7.45	-8.75	-5.32	-4.94	-1.94	-8.18	-4.95
η	-0.86	0.09	-1.50	-6.78	-3.73	-1.74	-2.27	-2.70	-0.94	-0.34	-3.84	-1.05

Note y: output, η: effort level

milder in countries with better quality of institutions and that countries with poor quality of institutions before the crisis, suffered a further deterioration in this quality in the crisis years.

10 Conclusions

In this paper, we incorporated institutions in a standard RBC model with distortionary taxation in order to explain discrepancies in macroeconomic performance observed in the data between 12 Eurozone countries. In particular, we used the concept of rent seeking assuming that agents allocate a fraction of their non-leisure time competing with each other for a fraction of a contestable prize; we considered three different contestable prizes: public transfers, total tax revenue and the economy-wide output. In the terminology of Chari et al. (2007), we observe that rent seeking in our model introduces an additional friction to the standard RBC model with distortionary taxation that induces wedges which distort agents decisions and depend on the level of institutional quality.

The calibration of the model to 12 Eurozone countries for the period 2001-2016 leads to considerable differences between core and periphery countries especially in the calibrated value of the extraction parameter indicating higher extraction of the contestable prize and thus lower institutional quality in periphery countries.

In terms of second moment properties we observe differences between core and periphery countries in the data. Given the underlying propagation mechanisms, all cases of contestable prize generate series that can match the qualitative characteristics of second moment properties in the data for all countries. However, the second moment properties generated by the model with rent seeking activities, are closer to periphery countries.

Moreover, we find that all three cases of contestable prize share similar qualitative characteristics of impulse responses; yet a shock in total factor productivity reveals a more persistent behavior in periphery countries when compared to core countries.

We further investigated how changes in fiscal policy instruments observed in the data in response to the outburst of the 2007-08 world crisis, have affected macroeconomic performance and institutional quality. Our findings are the following: firstly the repercussions of the crisis have been milder in countries with better quality of institutions (core countries) and secondly, countries with poor quality of institutions (periphery countries) before the crisis, suffered a further deterioration in this quality in the crisis years. Consequently, countries with weak institutional framework can benefit from an improvement in institutional quality.

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Appendix A

Case I: Rent seeking on government transfers

1.1 Description of the model

In this paper we build upon Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) and incorporate rent-seeking activities in a standard RBC model assuming that agents allocate a fraction of their non-leisure time competing with each other for a fraction of a contestable prize; here we consider public transfers to be the contestable prize. We assume that in the economy there is an equal number of identical households and identical firms and the government. The population size is N_t, where $N_{t+1} = \gamma_n N_t$, $\gamma_n \geq 1$ and $N_0 > 0$ are exogenously given constant parameters. Households, indexed by $h = 1, 2, \ldots, N_t$, own capital and labour which they supply to firms and choose in addition to consumption, leisure, and investment in capital, how to allocate their non-leisure time between productive work and rent seeking activities. Firms, indexed by $f = 1, 2, ..., N_t$, produce a homogeneous product using capital and labor. Government uses tax revenues and bonds to finance government consumption and government transfers. In the following sections, we present the three blocks of our model: households, firms and the government, the competitive decentralized equilibrium and the long-run equilibrium.

1.2 Households

The expected discounted lifetime utility of household h is given by:

$$E_0 \sum_{t=0}^{\infty} {\beta^*}^t U(C_t^h + \psi \bar{G}_t^c, L_t^h) \tag{1}$$

where E_0 denotes rational expectations conditional on the information set available at time zero, the time discount factor is $\beta^* \in (0,1)$, C_t^h is household $h's$ consumption at time t, $\bar{G}_t^c$ is government consumption of goods and services provided by the government for each household at time t, L_t^h is household $h's$ leisure time at time t and ψ is a parameter that measures the degree of substitutability between private and government consumption in utility.

We assume that the instantaneous utility function for each household h takes the following form:

$$U(C_t^h + \psi \bar{G}_t^c, L_t^h) = \frac{\Big((C_t^h + \psi \bar{G}_t^c)^{\mu} (L_t^h)^{1-\mu}\Big)^{1-\sigma}}{1-\sigma} \tag{2}$$

where $0 < \mu < 1$ and $\sigma \geq 0$ are parameters.

The household has one unit of time in each period allocated to either leisure, L_t^h, or non-leisure time, H_t^h. Thus, the time constraint of the household h is:

$$L_t^h + H_t^h = 1 \tag{3}$$

Following Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) the household further divides its non-leisure time, H_t^h, between productive work, $\eta_t^h H_t^h$, and rent-extracting or seeking activities, $(1-\eta_t^h)H_t^h$, where $0 < \eta_t^h \leq 1$ and $0 \leq (1-\eta_t^h) < 1$

denote the fractions of non-leisure time that the household allocates to productive work and rent extraction or rent seeking activities respectively. Thus, in each period non-leisure time is:

$$H_t^h = \eta_t^h H_t^h + (1 - \eta_t^h) H_t^h \tag{4}$$

The household receives income from labor, $w_t Z_t \eta_t H_t^h$, where w_t is the wage rate, Z_t is a labour augmenting technology variable evolving according to $Z_{t+1} = \gamma_z Z_t$, $\gamma_z \geq 1$ and $Z_0 > 0$ are exogenously given constant parameters. Each household h decides to invest in capital, I_t^h, and government bonds, D_t^h. This gives each household an interest income $r_t^k K_t^h$ and $r_t^b B_t^h$ from capital and government bonds respectively, where r_t^k and r_t^b are the gross returns to capital and bonds, K_t^h and B_t^h. Additionally, each household receives a share of profits, Π_t^h, and a share of lump-sum government transfers given to all households irrespective of their rent seeking activities. Consumption and both sources of income are taxed at the rates $0 \leq \tau_t^c < 1$ and $0 \leq \tau_t^y < 1$ respectively.

Based on the above, the household $h's$ budget constraint is:

$$\begin{aligned}(1+\tau_t^c)C_t^h + I_t^h + D_t^h = \\ (1-\tau_t^y)(r_t^k K_t^h + w_t Z_t \eta_t^h H_t^h + \Pi_t^h) + r_t^b B_t^h + \bar{G}_t^{t,E} + \frac{(1-\eta_t^h)H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t G_t^t\end{aligned} \tag{5}$$

where $\bar{G}_t^{t,E}$ are lump-sum transfers given to every household h irrespective of rent seeking activities (i.e. effortlessly), G_t^t are total government transfers and $0 \leq \theta_t < 1$ is the economy-wide degree of extraction (defined in subsection 1.5). The last term in the budget constraint indicates that given the respective contestable prize, a self-interested agent attempts to obtain a share of the prize.

The law of motion of private holding of government bonds evolves according to:

$$B_{t+1}^h = B_t^h + D_t^h \tag{6}$$

where the initial B_0^h is given.

The law of motion of private holding of capital evolves according to:

$$K_{t+1}^h = (1-\delta)K_t^h + I_t^h \tag{7}$$

where the parameter $0 < \delta < 1$ is a depreciation rate and the initial K_0^h is given.

Each household h acts competitively by taking prices, government policy and economy-wide variables as given and chooses $\{C_t^h, H_t^h, \eta_t^h, K_{t+1}^h, B_{t+1}^h\}_{t=0}^{\infty}$ to maximize lifetime utility Eq.(1) given the definition of instantaneous utility Eq.(2) and subject to the budget constraint Eq.(5), the time constraints Eqs.(3) and (4), and K_0^h, B_0^h given.[1]

The first-order conditions of the maximization problem of the household h include the constraints and the following equations:

$$\frac{\partial u_t(.)}{\partial L_t^h} = \frac{1}{1+\tau_t^c}\frac{\partial u_t(.)}{\partial C_t^h}\left[(1-\tau_t^y)w_t Z_t \eta_t^h + \frac{(1-\eta_t^h)}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t G_t^t\right] \tag{8}$$

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[1] We assume that each individual household h takes as given the economy-wide variables (i.e. contestable prize (G_t^t), total rent seeking time in the economy $\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h$ and the economy-wide degree of rent extraction θ_t).

$$(1-\tau_t^y)w_t Z_t H_t^h = \frac{H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t G_t^t \tag{9}$$

$$\frac{1}{1+\tau_t^c}\frac{\partial u_t(.)}{\partial C_t^h} = \beta^* E_t\left[\frac{1}{1+\tau_{t+1}^c}\frac{\partial u_{t+1}(.)}{\partial C_{t+1}^h}\Big((1-\tau_{t+1}^y)r_{t+1}^k + 1-\delta\Big)\right] \tag{10}$$

$$\frac{1}{1+\tau_t^c}\frac{\partial u_t(.)}{\partial C_t^h} = \beta^* E_t\left[\frac{1}{1+\tau_{t+1}^c}\frac{\partial u_{t+1}(.)}{\partial C_{t+1}^h}(1+r_{t+1}^b)\right] \tag{11}$$

1.3 Firms

Each firm f uses private capital K_t^f and private labor Q_t^f in order to produce a homogeneous product Y_t^f according to the production function:

$$Y_t^f = A_t(K_t^f)^\alpha(Q_t^f)^{1-\alpha} \tag{12}$$

where $A_t > 0$ is the stochastic total factor productivity (see subsection 1.6 for its law of motion) and $0 < \alpha < 1$ is a parameter.

Each firm f acts competitively by taking prices, policy, and economy-wide variables as given and chooses K_t^f and Q_t^f in order to maximize a series of static profit problems subject to the production function, Eq.(12). The profit function of firm f is given by:

$$\Pi_t^f = Y_t^f - r_t^k K_t^f - w_t Q_t^f \tag{13}$$

The first order conditions of the maximization problem of the firm are:

$$\frac{aY_t^f}{K_t^f} = r_t \tag{14}$$

$$\frac{(1-\alpha)Y_t^f}{Q_t^f} = w_t \tag{15}$$

1.4 Government

The government taxes consumption at the rate $0 \leq \tau_t^c < 1$ and total income at the rate $0 \leq \tau_t^y < 1$. The collected tax revenues, $R_t = \tau_t^c C_t + \tau_t^y Y_t$, as well as new bonds, B_{t+1}, are used in order to finance government consumption, G_t^c, and government transfers, G_t^t.[2] The government budget constraint is:

$$G_t^c + G_t^t + (1+r_t^b)B_t = B_{t+1} + \tau_t^c C_t + \tau_t^y Y_t \tag{16}$$

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[2] In Case I, we assume that a fraction of government transfers is extracted by rent seekers, $G_t^{t,RS} = \theta_t G_t^t$, whereas the remaining government transfers, $G_t^{t,E} = (1-\theta_t)G_t^t$ are lump-sum transfers given to all households (i.e. given irrespective of rent-seeking activities), thus, $G_t^t = G_t^{t,RS} + G_t^{t,E} = \theta_t G_t^t + (1-\theta_t)G_t^t$.

1.5 Economy-wide rent extraction

As mentioned previously, θ_t is a variable denoting economy-wide rent extraction: higher values of θ_t indicate that the rent-seeking technology becomes more efficient and therefore a larger fraction of the contestable prize can be extracted. We consider θ_t to be a proxy for the quality of institutions in the economy where lower values indicate better institutions. As mentioned in the following subsection we shall assume θ_t to be exogenous.[3]

1.6 Exogenous stochastic variables

The exogenous stochastic variables in our model are the aggregate productivity, A_t, the economy-wide degree of rent extraction, θ_t, as well as the shares over GDP of government consumption and government transfers (i.e. $s_t^c = \frac{G_t^c}{Y_t}$ and $s_t^t = \frac{G_t^t}{Y_t}$ respectively). They all follow a univariate stochastic AR(1) process:

$$lnA_{t+1} = (1-\rho_a)lnA_0 + \rho_a lnA_t + \epsilon_{t+1}^a \tag{10}$$

$$ln\theta_{t+1} = (1-\rho_\theta)ln\theta_0 + \rho_\theta ln\theta_t + \epsilon_{t+1}^\theta \tag{11}$$

$$lns_{t+1}^t = (1-\rho_t)lns_0^t + \rho_t lns_t^t + \epsilon_{t+1}^t \tag{12}$$

$$lns_{t+1}^c = (1-\rho_c)lns_0^c + \rho_c lns_t^c + \epsilon_{t+1}^c \tag{13}$$

where A_0, θ_0, s_0^t and s_0^c are means of the stochastic process, $\rho_a, \rho_\theta, \rho_t$ and ρ_c are the first-order autocorrelation coefficients and $\epsilon_{t+1}^\alpha, \epsilon_{t+1}^\theta, \epsilon_{t+1}^t$ and ϵ_{t+1}^c are i.i.d. shocks. The tax rates, τ_t^c and τ_t^y, are assumed to be constant over time.

1.7 Decentralized Competitive Equilibrium (DCE)

We solve for the DCE, where given market prices (w_t, r_t^k, r_t^b), government policy $(s_t^c, s_t^t, \tau_t^c, \tau_t^y)$ and economy-wide variables (A_t, θ_t): (i) each individual household, $h = 1, 2, \ldots, N_t$, solves its problem defined in section (1.2), (ii) each individual firm, $f = 1, 2, \ldots, N_t$, solves its problem defined in section (1.3), (iii) all markets clear and (iv) all constraints are satisfied.[4] Given that our economy convergences to a balanced growth path where consumption, output, capital and investment grow at the rate $\gamma_n\gamma_z$, we express the DCE in terms of variables expressed in per capita and efficient labor units (per capita in the case of labor).[5] Thus, we end up with a system of eight equations

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[3] Alternatively, one could assume that θ_t is endogenous and increases with per capita rent-seeking activities $\theta_t = \phi_t \frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t}$. Furthermore, it could also depend on the fraction of output that the government allocates in securing property rights, s_t^p, (i.e. expenditures on policing, law enforcement etc.), e.g. $\theta_t = \phi_t(s_t^p)^{-\xi_2}\left(\frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t}\right)^{\xi_1}$; ϕ_t, ξ_1 and ξ_2 are parameters related to the quality of institutions.

[4] The market clearing conditions are: $\sum_{f=1}^{N_t} Y_t^f = \sum_{h=1}^{N_t} Y_t^h$ in the product market, $\sum_{f=1}^{N_t} Q_t^f = Z_t \sum_{h=1}^{N_t} \eta_t^h H_t^h$ in the labor market, $\sum_{f=1}^{N_t} K_t^f = \sum_{h=1}^{N_t} K_t^h$ in the capital market and $\sum_{f=1}^{N_t} \Pi_t^f = \sum_{h=1}^{N_t} \Pi_t^h = 0$ in the dividend market.

[5] We transform the model in per capita and efficient unit terms to make them stationary and define that for any economy-wide variable X_t, $X_t \equiv (Y_t, C_t, K_t, B_t, G_t^c, G_t^t)$, $x_t = \frac{X_t}{N_t Z_t}$, and that $h_t = \frac{H_t}{N_t}$ is per capita non-leisure time.

in eight unknown endogenous variables $y_t, c_t, h_t, \eta_t, i_t, r_t^b, b_{t+1}$ and k_{t+1}, given the paths for A_t, θ_t, and the four policy instruments $s_t^c, s_t^t, \tau_t^c, \tau_t^y$.

Thus the stationary DCE will be given by Eqs. (14)-(21):

$$\eta_t = 1 - \theta_t \frac{s_t^t}{(1-\tau_t^y)(1-\alpha)\frac{y_t}{\eta_t h_t}} \frac{y_t}{h_t} \tag{14}$$

$$(1+\tau_t^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c_t + \psi s_t^c y_t}{1-h_t}\right) = \left[(1-\tau_t^y) + \frac{\theta_t s_t^t}{1-\alpha}\right](1-\alpha)\frac{y_t}{h_t} \tag{15}$$

$$\left(\frac{c_{t+1} + \psi s_{t+1}^c y_{t+1}}{c_t + \psi s_t^c y_t}\right)^{1-\mu(1-\sigma)} \left(\frac{1-h_t}{1-h_{t+1}}\right)^{(1-\mu)(1-\sigma)} = \beta\left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right)\left[\alpha(1-\tau_{t+1}^y)\frac{y_{t+1}}{k_{t+1}} + 1 - \delta\right] \tag{16}$$

$$(s_t^c + s_t^t)y_t + (1+r_t^b)b_t = \gamma_n\gamma_z b_{t+1} + \tau_t^c c_t + \tau_t^y y_t \tag{17}$$

$$\left(\frac{c_{t+1} + \psi s_{t+1}^c y_{t+1}}{c_t + \psi s_t^c y_t}\right)^{1-\mu(1-\sigma)} \left(\frac{1-h_t}{1-h_{t+1}}\right)^{(1-\mu)(1-\sigma)} = \beta\left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right)(1+r_{t+1}^b) \tag{18}$$

$$(1-s_t^c)y_t = c_t + i_t \tag{19}$$

$$\gamma_n\gamma_z k_{t+1} = (1-\delta)k_t + i_t \tag{20}$$

$$y_t = A_t k_t^\alpha (\eta_t h_t)^{1-\alpha} \tag{21}$$

where $\beta \equiv \beta^* \gamma_z^{\mu(1-\sigma)-1}$. This is an equilibrium of eight equations in the paths of eight unknown endogenous variables $i_t, c_t, y_t, r_t^b, \eta_t, h_t, b_{t+1}, k_{t+1}$, given the paths of productivity A_t, the economy-wide degree of extraction θ_t, and the four policy instruments $s_t^c, s_t^t, \tau_t^c, \tau_t^y$.

1.8 Long-run equilibrium of Case I

In the long-run, our economy reaches an equilibrium where no shocks exist and variables remain constant but grow at a constant balance growth rate. We remove time subscripts and solve for the equilibrium. Thus, all variables satisfy that $x_{t+1} = x_t = x_{t-1} = x$. The long-run equilibrium or the steady state is characterized by $Eqs.(22) - (29)$:

$$\eta = 1 - \theta \frac{s^t}{(1-\tau^y)(1-\alpha)\frac{y}{\eta h}} \frac{y}{h} \tag{22}$$

$$(1+\tau^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c + \psi s^c y}{1-h}\right) = \left[(1-\tau^y) + \frac{\theta s^t}{1-\alpha}\right](1-\alpha)\frac{y}{h} \tag{23}$$

$$1 = \beta\left[\alpha(1-\tau^y)\frac{y}{k} + 1 - \delta\right] \tag{24}$$

$$(s^c + s^t)y = (\gamma_n\gamma_z - 1 - r^b)b + \tau^c c + \tau^y y \tag{25}$$

$$(1-s^c)y = c + i \tag{26}$$

$$1 = \beta(1 + r^b) \tag{27}$$

$$(\gamma_n \gamma_z - 1 + \delta) = \frac{i}{k} \tag{28}$$

$$y = A k^{\alpha} (\eta h)^{(1-\alpha)} \tag{29}$$

The above system of equations is an equilibrium system of eight equations in eight unknown endogenous variables $y, k, c, i, h, \eta, b, r^b$. We set $b = 0.9y$ (i.e. the government debt-to-GDP ratio is 90% on an annual basis); therefore we choose the long-run government consumption-to-GDP ratio, s_0^c, to follow residually and satisfy the government budget constraint $Eq.$(25).

Appendix B

Case II: Rent seeking on total tax revenues

1.1 Description of the model

In this paper we build upon Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) and incorporate rent-seeking activities in a standard RBC model assuming that agents allocate a fraction of their non-leisure time competing with each other for a fraction of a contestable prize; here we consider total tax revenue to be the contestable prize. We assume that in the economy there is an equal number of identical households and identical firms and the government. The population size is N_t, where $N_{t+1} = \gamma_n N_t$, $\gamma_n \geq 1$ and $N_0 > 0$ are exogenously given constant parameters. Households, indexed by $h = 1, 2, \ldots, N_t$, own capital and labour which they supply to firms and choose in addition to consumption, leisure, and investment in capital, how to allocate their non-leisure time between productive work and rent seeking activities. Firms, indexed by $f = 1, 2, ..., N_t$, produce a homogeneous product using capital and labor. Government uses tax revenues and bonds to finance government consumption and government transfers. In the following sections, we present the three blocks of our model: households, firms and the government, the competitive decentralized equilibrium and the long-run equilibrium.

1.2 Households

The expected discounted lifetime utility of household h is given by:

$$E_0 \sum_{t=0}^{\infty} {\beta^*}^t U(C_t^h + \psi \bar{G}_t^c, L_t^h) \tag{1}$$

where E_0 denotes rational expectations conditional on the information set available at time zero, the time discount factor is $\beta^* \in (0,1)$, C_t^h is household $h's$ consumption at time t, $\bar{G}_t^c$ is government consumption of goods and services provided by the government for each household at time t, L_t^h is household $h's$ leisure time at time t and ψ is a parameter that measures the degree of substitutability between private and government consumption in utility.

We assume that the instantaneous utility function for each household h takes the following form:

$$U(C_t^h + \psi \bar{G}_t^c, L_t^h) = \frac{\Big((C_t^h + \psi \bar{G}_t^c)^{\mu} (L_t^h)^{1-\mu}\Big)^{1-\sigma}}{1-\sigma} \tag{2}$$

where $0 < \mu < 1$ and $\sigma \geq 0$ are parameters.

The household has one unit of time in each period allocated to either leisure, L_t^h, or non-leisure time, H_t^h. Thus, the time constraint of the household h is:

$$L_t^h + H_t^h = 1 \tag{3}$$

Following Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) the household further divides its non-leisure time, H_t^h, between productive work, $\eta_t^h H_t^h$, and rent-extracting or seeking activities, $(1-\eta_t^h)H_t^h$, where $0 < \eta_t^h \leq 1$ and $0 \leq (1-\eta_t^h) < 1$

denote the fractions of non-leisure time that the household allocates to productive work and rent extraction or rent seeking activities respectively. Thus, in each period non-leisure time is:

$$H_t^h = \eta_t^h H_t^h + (1 - \eta_t^h) H_t^h \tag{4}$$

The household receives income from labor, $w_t Z_t \eta_t H_t^h$, where w_t is the wage rate, Z_t is a labour augmenting technology variable evolving according to $Z_{t+1} = \gamma_z Z_t$, $\gamma_z \geq 1$ and $Z_0 > 0$ are exogenously given constant parameters. Each household h decides to invest in capital, I_t^h, and government bonds, D_t^h. This gives each household an interest income $r_t^k K_t^h$ and $r_t^b B_t^h$ from capital and government bonds respectively, where r_t^k and r_t^b are the gross returns to capital and bonds, K_t^h and B_t^h. Additionally, each household receives a share of profits, Π_t^h, and a share of lump-sum government transfers given to all households irrespective of their rent seeking activities. Consumption and both sources of income are taxed at the rates $0 \leq \tau_t^c < 1$ and $0 \leq \tau_t^y < 1$ respectively.

Based on the above, the household $h's$ budget constraint is:

$$\begin{aligned}(1+\tau_t^c)C_t^h + I_t^h + D_t^h = \\ (1-\tau_t^y)(r_t^k K_t^h + w_t Z_t \eta_t^h H_t^h + \Pi_t^h) + r_t^b B_t^h + \bar{G}_t^t + \frac{(1-\eta_t^h)H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t R_t\end{aligned} \tag{5}$$

where $\bar{G}_t^t$ denote lump-sum transfers given to every household and tax revenues, R_t, are defined by:

$$R_t = \tau_t^c \sum_{h=1}^{N_t^h} C_t^h + \tau_t^y \sum_{h=1}^{N_t^h} (w_t^h Z_t \eta_t^h H_t^h + r_t^k K_t^h + \Pi_t^h) \tag{6}$$

The last term of the budget constraint indicates that given a contestable prize denoted as $\theta_t R_t$, a self-interested agent attempts to obtain a share of the prize.

The law of motion of private holding of government bonds evolves according to:

$$B_{t+1}^h = B_t^h + D_t^h \tag{7}$$

where the initial B_0^h is given. The law of motion of private holding of capital evolves according to:

$$K_{t+1}^h = (1-\delta)K_t^h + I_t^h \tag{8}$$

where the parameter $0 < \delta < 1$ is a depreciation rate and the initial K_0^h is given.

Each household h acts competitively by taking prices, government policy and economy-wide variables as given and chooses $\{C_t^h, H_t^h, \eta_t^h, K_{t+1}^h, B_{t+1}^h\}_{t=0}^{\infty}$ to maximize lifetime utility Eq.(1) given the definition of instantaneous utility Eq.(2) and subject to the budget constraint Eq.(5), the time constraints Eqs.(3) and (4), and K_0^h, B_0^h given.[1]

The first-order conditions of the maximization problem of the household h include the constraints and the following equations:

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[1] We assume that each individual household h takes as given the economy-wide variables (i.e. contestable prize (R_t^t), total rent seeking time in the economy $\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h$ and θ_t).

$$\frac{\partial u_t(.)}{\partial L_t^h} = \frac{1}{(1+\tau_t^c)} \frac{\partial u_t(.)}{\partial C_t^h} [(1-\tau_t^y) w_t Z_t \eta_t^h + \frac{(1-\eta_t^h)}{\sum_{h=1}^{N_t} (1-\eta_t^h) H_t^h} \theta_t R_t] \tag{9}$$

$$(1-\tau_t^y) w_t Z_t H_t^h = \frac{H_t^h}{\sum_{h=1}^{N_t} (1-\eta_t^h) H_t^h} \theta_t R_t \tag{10}$$

$$\frac{1}{(1+\tau_t^c)} \frac{\partial u_t(.)}{\partial C_t^h} = \beta^* E_t [\frac{1}{(1+\tau_{t+1}^c)} \frac{\partial u_{t+1}(.)}{\partial C_{t+1}^h} \Big((1-\tau_{t+1}^y) r_{t+1}^k + 1 - \delta \Big)] \tag{11}$$

$$\frac{1}{(1+\tau_t^c)} \frac{\partial u_t(.)}{\partial C_t^h} = \beta^* E_t [\frac{1}{(1+\tau_{t+1}^c)} \frac{\partial u_{t+1}(.)}{\partial C_{t+1}^h} (1 + r_{t+1}^b)] \tag{12}$$

1.3 Firms

Each firm f uses private capital K_t^f and private labor Q_t^f in order to produce a homogeneous product Y_t^f according to the production function:

$$Y_t^f = A_t (K_t^f)^\alpha (Q_t^f)^{1-\alpha} \tag{13}$$

where $A_t > 0$ is the stochastic total factor productivity (see subsection 3.6 for its law of motion) and $0 < \alpha < 1$ is a parameter.

Each firm f acts competitively by taking prices, policy, and economy-wide variables as given and chooses K_t^f and Q_t^f in order to maximize a series of static profit problems subject to the production function, Eq.(13). The profit function of firm f is given by:

$$\Pi_t^f = Y_t^f - r_t^k K_t^f - w_t Q_t^f \tag{14}$$

The first order conditions of the maximization problem of the firm are:

$$\frac{a Y_t^f}{K_t^f} = r_t \tag{15}$$

$$\frac{(1-\alpha) Y_t^f}{Q_t^f} = w_t \tag{16}$$

1.4 Government

The government taxes consumption at the rate $0 \leq \tau_t^c < 1$ and total income at the rate $0 \leq \tau_t^y < 1$. The collected tax revenues, $R_t = \tau_t^c C_t + \tau_t^y Y_t$, as well as new bonds, B_{t+1}, are used in order to finance government consumption, G_t^c, and government transfers, G_t^t.[2]

The government budget constraint is:

$$G_t^c + G_t^t + (1 + r_t^b) B_t = B_{t+1} + (1-\theta_t)(\tau_t^c C_t + \tau_t^y Y_t) \tag{17}$$

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[2] In Case II, we assume that a fraction of total tax revenues, R_t, is extracted by rent seekers.

1.5 Economy-wide rent extraction

As mentioned previously, θ_t is a variable denoting economy-wide rent extraction: higher values of θ_t indicate that the rent-seeking technology becomes more efficient and therefore a larger fraction of the contestable prize can be extracted. We consider θ_t to be a proxy for the quality of institutions in the economy where lower values indicate better institutions. As mentioned in the following subsection we shall assume θ_t to be exogenous.[3]

1.6 Exogenous stochastic variables

The exogenous stochastic variables in our model are the aggregate productivity, A_t, the economy-wide degree of rent extraction, θ_t, as well as the shares over GDP of government consumption and government transfers (i.e. $s_t^c = \frac{G_t^c}{Y_t}$ and $s_t^t = \frac{G_t^t}{Y_t}$ respectively). They all follow a univariate stochastic AR(1) process:

$$lnA_{t+1} = (1-\rho_a)lnA_0 + \rho_a lnA_t + \epsilon^a_{t+1} \tag{10}$$

$$ln\theta_{t+1} = (1-\rho_\theta)ln\theta_0 + \rho_\theta ln\theta_t + \epsilon^\theta_{t+1} \tag{11}$$

$$lns^t_{t+1} = (1-\rho_t)lns^t_0 + \rho_t lns^t_t + \epsilon^t_{t+1} \tag{12}$$

$$lns^c_{t+1} = (1-\rho_c)lns^c_0 + \rho_c lns^c_t + \epsilon^c_{t+1} \tag{13}$$

where A_0, θ_0, s_0^t and s_0^c are means of the stochastic process, $\rho_a, \rho_\theta, \rho_t$ and ρ_c are the first-order autocorrelation coefficients and $\epsilon^\alpha_{t+1}, \epsilon^\theta_{t+1}, \epsilon^t_{t+1}$ and ϵ^c_{t+1} are i.i.d. shocks. The tax rates, τ_t^c and τ_t^y, are assumed to be constant over time.

1.7 Decentralized Competitive Equilibrium (DCE)

We solve for the DCE, where given market prices (w_t, r_t^k, r_t^b), government policy $(s_t^c, s_t^t, \tau_t^c, \tau_t^y)$ and economy-wide variables (A_t, θ_t): (i) each individual household, $h = 1, 2, \ldots, N_t$, solves its problem defined in section (1.2), (ii) each individual firm, $f = 1, 2, \ldots, N_t$, solves its problem defined in section (1.3), (iii) all markets clear and (iv) all constraints are satisfied.[4] Given that our economy convergences to a balanced growth path where consumption, output, capital and investment grow at the rate $\gamma_n \gamma_z$, we express the DCE in terms of variables expressed in per capita and efficient labor units (per capita in the case of labor).[5] Thus, we end up with a system of eight equations

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[3] Alternatively, one could assume that θ_t is endogenous and increases with per capita rent-seeking activities $\theta_t = \phi_t \frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t}$. Furthermore, it could also depend on the fraction of output that the government allocates in securing property rights, s_t^p, (i.e. expenditures on policing, law enforcement etc.), e.g. $\theta_t = \phi_t (s_t^p)^{-\xi_2} \left(\frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t}\right)^{\xi_1}$; ϕ_t, ξ_1 and ξ_2 are parameters related to the quality of institutions.

[4] The market clearing conditions are: $\sum_{f=1}^{N_t} Y_t^f = \sum_{h=1}^{N_t} Y_t^h$ in the product market, $\sum_{f=1}^{N_t} Q_t^f = Z_t \sum_{h=1}^{N_t} \eta_t^h H_t^h$ in the labor market, $\sum_{f=1}^{N_t} K_t^f = \sum_{h=1}^{N_t} K_t^h$ in the capital market and $\sum_{f=1}^{N_t} \Pi_t^f = \sum_{h=1}^{N_t} \Pi_t^h = 0$ in the dividend market.

[5] We transform the model in per capita and efficient unit terms to make them stationary and define that for any economy-wide variable X_t, $X_t \equiv (Y_t, C_t, K_t, B_t, G_t^c, G_t^t)$, $x_t = \frac{X_t}{N_t Z_t}$, and that $h_t = \frac{H_t}{N_t}$ is per capita non-leisure time.

in eight unknown endogenous variables $y_t, c_t, h_t, \eta_t, i_t, r_t^b, b_{t+1}$ and k_{t+1}, given the paths for A_t, θ_t, and the four policy instruments $s_t^c, s_t^t, \tau_t^c, \tau_t^y$.

Thus the stationary DCE will be given by Eqs. (14)-(21):

$$\eta_t = 1 - \theta_t \frac{\tau_t^c \frac{c_t}{y_t} + \tau_t^y}{(1-\tau_t^y)(1-\alpha)\frac{y_t}{\eta_t h_t}} \frac{y_t}{h_t} \tag{14}$$

$$(1+\tau_t^c)\Big(\frac{1-\mu}{\mu}\Big)\Big(\frac{c_t + \psi s_t^c y_t}{1-h_t}\Big) = \Big[(1-\tau_t^y) + \frac{\theta_t(\tau_t^c \frac{c_t}{y_t} + \tau_t^y)}{1-\alpha}\Big](1-\alpha)\frac{y_t}{h_t} \tag{15}$$

$$\Big(\frac{c_{t+1} + \psi s_{t+1}^c y_{t+1}}{c_t + \psi s_t^c y_t}\Big)^{1-\mu(1-\sigma)} \Big(\frac{1-h_t}{1-h_{t+1}}\Big)^{(1-\mu)(1-\sigma)} = \beta\Big(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\Big)\Big[\alpha(1-\tau_{t+1}^y)\frac{y_{t+1}}{k_{t+1}} + 1 - \delta\Big] \tag{16}$$

$$(s_t^c + s_t^t)y_t + \theta_t(\tau_t^c c_t + \tau_t^y y_t) + (1+r_t^b)b_t = \gamma_n\gamma_z b_{t+1} + \tau_t^c c_t + \tau_t^y y_t \tag{17}$$

$$(1-s_t^c)y_t = c_t + i_t \tag{18}$$

$$\Big(\frac{c_{t+1} + \psi s_{t+1}^c y_{t+1}}{c_t + \psi s_t^c y_t}\Big)^{1-\mu(1-\sigma)} \Big(\frac{1-h_t}{1-h_{t+1}}\Big)^{(1-\mu)(1-\sigma)} = \beta\Big(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\Big)(1+r_{t+1}^b) \tag{19}$$

$$\gamma_n\gamma_z k_{t+1} = (1-\delta)k_t + i_t \tag{20}$$

$$y_t = A_t k_t^\alpha (\eta_t h_t)^{1-\alpha} \tag{21}$$

where $\beta \equiv \beta^* \gamma_z^{\mu(1-\sigma)-1}$. This is an equilibrium of eight equations in the paths of nine unknown endogenous variables $i_t, c_t, y_t, r_t^b, \eta_t, h_t, b_{t+1}, k_{t+1}^g, k_{t+1}$, given the paths of productivity A_t, the economy-wide degree of extraction θ_t and the five independent policy instruments, $s_t^c, s_t^t, \tau_t^c, \tau_t^y$.

1.8 Long-run equilibrium: Case II

In the long-run, our economy reaches an equilibrium where no shocks exist and variables remain constant but grow at a constant balance growth rate. We remove time subscripts and solve for the equilibrium. Thus, all variables satisfy that $x_{t+1} = x_t = x_{t-1} = x$. The long-run equilibrium or the steady state is characterized by $Eqs.(22) - (29)$:

$$\eta = 1 - \theta \frac{\tau^c \frac{c}{y} + \tau^y}{(1-\tau^y)(1-\alpha)\frac{y}{\eta h}} \frac{y}{h} \tag{22}$$

$$(1+\tau^c)\Big(\frac{1-\mu}{\mu}\Big)\Big(\frac{c + \psi s^c y}{1-h}\Big) = \Big[(1-\tau^y) + \frac{\theta(\tau^c \frac{c}{y} + \tau^y)}{1-\alpha}\Big](1-\alpha)\frac{y}{h} \tag{23}$$

$$1 = \beta\Big[\alpha(1-\tau^y)\frac{y}{k} + 1 - \delta\Big] \tag{24}$$

$$(s^c + s^t)y + \theta(\tau^c c + \tau^y y) = (\gamma_n\gamma_z - 1 - r^b)b + \tau^c c + \tau^y y \tag{25}$$

$$(1 - s^c)y = c + i \tag{26}$$

$$1 = \beta(1 + r^b) \tag{27}$$

$$(\gamma_n \gamma_z - 1 + \delta) = \frac{i}{k} \tag{28}$$

$$y = Ak^{\alpha}(\eta h)^{(1-\alpha)} \tag{29}$$

The above system of equations is an equilibrium system of eight equations in eight unknown endogenous variables $y, k, c, k^g, i, h, \eta, b, r^b$. We set $b = 0.9y$ (i.e. the government debt-to-GDP ratio is 90% on an annual basis); therefore we choose the long-run government consumption-to-GDP ratio (s_0^c) to follow residually and satisfy the government budget constraint $Eq.$(25).

Appendix C

Case III: Weak property rights protection on firms' output

1.1 Description of the model

In this paper we build upon Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) and incorporate rent-seeking activities in a standard RBC model assuming that agents allocate a fraction of their non-leisure time competing with each other for a fraction of a contestable prize; here we consider the economy-wide output to be the contestable prize. We assume that in the economy there is an equal number of identical households and identical firms and the government. The population size is N_t, where $N_{t+1} = \gamma_n N_t$, $\gamma_n \geq 1$ and $N_0 > 0$ are exogenously given constant parameters. Households, indexed by $h = 1, 2, \ldots, N_t$, own capital and labour which they supply to firms and choose in addition to consumption, leisure, and investment in capital, how to allocate their non-leisure time between productive work and rent seeking activities. Firms, indexed by $f = 1, 2, ..., N_t$, produce a homogeneous product using capital and labor. Government uses tax revenues and bonds to finance government consumption and government transfers. In the following sections, we present the three blocks of our model: households, firms and the government, the competitive decentralized equilibrium and the long-run equilibrium.

1.2 Households

The expected discounted lifetime utility of household h is given by:

$$E_0 \sum_{t=0}^{\infty} {\beta^*}^t U(C_t^h + \psi \bar{G}_t^c, L_t^h) \tag{1}$$

where E_0 denotes rational expectations conditional on the information set available at time zero, the time discount factor is $\beta^* \in (0, 1)$, C_t^h is household $h's$ consumption at time t, $\bar{G}_t^c$ is government consumption of goods and services provided by the government for each household at time t, L_t^h is household $h's$ leisure time at time t and ψ is a parameter that measures the degree of substitutability between private and government consumption in utility.

We assume that the instantaneous utility function for each household h takes the following form:

$$U(C_t^h + \psi \bar{G}_t^c, L_t^h) = \frac{\left((C_t^h + \psi \bar{G}_t^c)^{\mu} (L_t^h)^{1-\mu}\right)^{1-\sigma}}{1-\sigma} \tag{2}$$

where $0 < \mu < 1$ and $\sigma \geq 0$ are parameters.

The household has one unit of time in each period allocated to either leisure, L_t^h, or non-leisure time, H_t^h. Thus, the time constraint of the household h is:

$$L_t^h + H_t^h = 1 \tag{3}$$

Following Angelopoulos, Philippopoulos, Vassilatos (2009) and Angelopoulos, Economides, Vassilatos (2011) the household further divides its non-leisure time, H_t^h, between productive work,

$\eta_t^h H_t^h$, and rent-extracting or seeking activities, $(1-\eta_t^h)H_t^h$, where $0 < \eta_t^h \leq 1$ and $0 \leq (1-\eta_t^h) < 1$ denote the fractions of non-leisure time that the household allocates to productive work and rent extraction or rent seeking activities respectively. Thus, in each period non-leisure time is:

$$H_t^h = \eta_t^h H_t^h + (1-\eta_t^h)H_t^h \tag{4}$$

The household receives income from labor, $w_t Z_t \eta_t H_t^h$, where w_t is the wage rate, Z_t is a labour augmenting technology variable evolving according to $Z_{t+1} = \gamma_z Z_t$, $\gamma_z \geq 1$ and $Z_0 > 0$ are exogenously given constant parameters. Each household h decides to invest in capital, I_t^h, and government bonds, D_t^h. This gives each household an interest income $r_t^k K_t^h$ and $r_t^b B_t^h$ from capital and government bonds respectively, where r_t^k and r_t^b are the gross returns to capital and bonds, K_t^h and B_t^h. Additionally, each household receives a share of profits, Π_t^h, and a share of lump-sum government transfers given to all households irrespective of their rent seeking activities. Consumption and both sources of income are taxed at the rates $0 \leq \tau_t^c < 1$ and $0 \leq \tau_t^y < 1$ respectively.

Based on the above, the household $h's$ budget constraint is:

$$\begin{aligned}(1+\tau_t^c)C_t^h + I_t^h + D_t^h = \\ (1-\tau_t^y)(r_t^k K_t^h + w_t Z_t \eta_t^h H_t^h + \Pi_t^h) + r_t^b B_t^h + \bar{G}_t^t + \frac{(1-\eta_t^h)H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t Y_t\end{aligned} \tag{5}$$

where $\bar{G}_t^t$ are lump-sum transfers given to every household h and $0 \leq \theta_t < 1$ is the economy-wide degree of extraction (defined in subsection 1.5). The last term in the budget constraint indicates that given the respective contestable prize; here the economy-wide output, a self-interested agent attempts to obtain a share of the prize.

The law of motion of private holding of government bonds evolves according to:

$$B_{t+1}^h = B_t^h + D_t^h \tag{6}$$

where the initial B_0^h is given.

The law of motion of private holding of capital evolves according to:

$$K_{t+1}^h = (1-\delta)K_t^h + I_t^h \tag{7}$$

where the parameter $0 < \delta < 1$ is a depreciation rate and the initial K_0^h is given.

Each household h acts competitively by taking prices, government policy and economy-wide variables as given and chooses $\{C_t^h, H_t^h, \eta_t^h, K_{t+1}^h, B_{t+1}^h\}_{t=0}^{\infty}$ to maximize lifetime utility Eq.(1) given the definition of instantaneous utility Eq.(2) and subject to the budget constraint Eq.(5), the time constraints Eqs.(3) and (4), and K_0^h, B_0^h given.[1]

The first-order conditions of the maximization problem of the household h include the constraints and the following equations:

$$\frac{\partial u_t(.)}{\partial L_t^h} = \frac{1}{(1+\tau_t^c)}\frac{\partial u_t(.)}{\partial C_t^h}[(1-\tau_t^y)w_t Z_t \eta_t^h + \frac{(1-\eta_t^h)}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t Y_t] \tag{8}$$

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[1] We assume that each individual household h takes as given the economy-wide variables (i.e. contestable prize (G_t^t), total rent seeking time in the economy $\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h$ and θ_t).

$$(1-\tau_t^y)w_t Z_t H_t^h = \frac{H_t^h}{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}\theta_t Y_t \tag{9}$$

$$\frac{1}{(1+\tau_t^c)}\frac{\partial u_t(.)}{\partial C_t^h} = \beta^* E_t[\frac{1}{(1+\tau_{t+1}^c)}\frac{\partial u_{t+1}(.)}{\partial C_{t+1}^h}((1-\tau_{t+1}^y)r_{t+1}^k + 1 - \delta)] \tag{10}$$

$$\frac{1}{(1+\tau_t^c)}\frac{\partial u_t(.)}{\partial C_t^h} = \beta^* E_t[\frac{1}{(1+\tau_{t+1}^c)}\frac{\partial u_{t+1}(.)}{\partial C_{t+1}^h}(1+r_{t+1}^b)] \tag{11}$$

1.3 Firms

Each firm f uses private capital K_t^f and private labor Q_t^f in order to produce a homogeneous product Y_t^f according to the production function:

$$Y_t^f = A_t(K_t^f)^\alpha(Q_t^f)^{1-\alpha} \tag{12}$$

where $A_t > 0$ is the stochastic total factor productivity (see subsection 3.6 for its law of motion) and $0 < \alpha < 1$ is a parameter.

Each firm f acts competitively by taking prices, policy, and economy-wide variables as given and chooses K_t^f and Q_t^f in order to maximize a series of static profit problems subject to the production function, Eq.(12). Due to weak property rights protection, each firm can only appropriate a fraction of its produced output. Thus, the profit function is:

$$\Pi_t^f = (1-\theta_t)Y_t^f - r_t^k K_t^f - w_t Q_t^f \tag{13}$$

The first order conditions of the maximization problem of the firm are:

$$\frac{a(1-\theta_t)Y_t^f}{K_t^f} = r_t \tag{14}$$

$$\frac{(1-\alpha)(1-\theta_t)Y_t^f}{Q_t^f} = w_t \tag{15}$$

1.4 Government

The government taxes consumption at the rate $0 \leq \tau_t^c < 1$ and total income at the rate $0 \leq \tau_t^y < 1$. The collected tax revenues, $R_t = \tau_t^c C_t + \tau_t^y Y_t$, as well as new bonds, B_{t+1}, are used in order to finance government consumption, G_t^c, and government transfers, G_t^t.[2]

The government budget constraint is:

$$G_t^c + G_t^t + (1+r_t^b)B_t = B_{t+1} + \tau_t^c C_t + (1-\theta_t)\tau_t^y Y_t \tag{9-I}$$

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[2] In Case III, we assume that a fraction of the economy-wide output is extracted by rent seekers.

1.5 Economy-wide rent extraction

As mentioned previously, θ_t is a variable denoting economy-wide rent extraction: higher values of θ_t indicate that the rent-seeking technology becomes more efficient and therefore a larger fraction of the contestable prize can be extracted. We consider θ_t to be a proxy for the quality of institutions in the economy where lower values indicate better institutions. As mentioned in the following subsection we shall assume θ_t to be exogenous.[3]

1.6 Exogenous stochastic variables

The exogenous stochastic variables in our model are the aggregate productivity, A_t, the economy-wide degree of rent extraction, θ_t, as well as the shares over GDP of government consumption and government transfers (i.e. $s_t^c = \frac{G_t^c}{Y_t}$ and $s_t^t = \frac{G_t^t}{Y_t}$ respectively). They all follow a univariate stochastic AR(1) process:

$$lnA_{t+1} = (1-\rho_a)lnA_0 + \rho_a lnA_t + \epsilon_{t+1}^a \tag{10}$$

$$ln\theta_{t+1} = (1-\rho_\theta)ln\theta_0 + \rho_\theta ln\theta_t + \epsilon_{t+1}^\theta \tag{11}$$

$$lns_{t+1}^t = (1-\rho_t)lns_0^t + \rho_t lns_t^t + \epsilon_{t+1}^t \tag{12}$$

$$lns_{t+1}^c = (1-\rho_c)lns_0^c + \rho_c lns_t^c + \epsilon_{t+1}^c \tag{13}$$

where A_0, θ_0, s_0^t and s_0^c are means of the stochastic process, $\rho_a, \rho_\theta, \rho_t$ and ρ_c are the first-order autocorrelation coefficients and $\epsilon_{t+1}^\alpha, \epsilon_{t+1}^\theta, \epsilon_{t+1}^t$ and ϵ_{t+1}^c are i.i.d. shocks. The tax rates, τ_t^c and τ_t^y, are assumed to be constant over time.

1.7 Decentralized Competitive Equilibrium (DCE)

We solve for the DCE, where given market prices (w_t, r_t^k, r_t^b), government policy $(s_t^c, s_t^t, \tau_t^c, \tau_t^y)$ and economy-wide variables (A_t, θ_t): (i) each individual household, $h = 1, 2, \ldots, N_t$, solves its problem defined in section (1.2), (ii) each individual firm, $f = 1, 2, \ldots, N_t$, solves its problem defined in section (1.3), (iii) all markets clear and (iv) all constraints are satisfied.[4] Given that our economy convergences to a balanced growth path where consumption, output, capital and investment grow at the rate $\gamma_n \gamma_z$, we express the DCE in terms of variables expressed in per capita and efficient labor units (per capita in the case of labor).[5] Thus, we end up with a system of eight equations

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[3] Alternatively, one could assume that θ_t is endogenous and increases with per capita rent-seeking activities $\theta_t = \phi_t \frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t}$. Furthermore, it could also depend on the fraction of output that the government allocates in securing property rights, s_t^p, (i.e. expenditures on policing, law enforcement etc.), e.g. $\theta_t = \phi_t (s_t^p)^{-\xi_2} \left(\frac{\sum_{h=1}^{N_t}(1-\eta_t^h)H_t^h}{N_t} \right)^{\xi_1}$; ϕ_t, ξ_1 and ξ_2 are parameters related to the quality of institutions.

[4] The market clearing conditions are: $\sum_{f=1}^{N_t} Y_t^f = \sum_{h=1}^{N_t} Y_t^h$ in the product market, $\sum_{f=1}^{N_t} Q_t^f = Z_t \sum_{h=1}^{N_t} \eta_t^h H_t^h$ in the labor market, $\sum_{f=1}^{N_t} K_t^f = \sum_{h=1}^{N_t} K_t^h$ in the capital market and $\sum_{f=1}^{N_t} \Pi_t^f = \sum_{h=1}^{N_t} \Pi_t^h = 0$ in the dividend market.

[5] We transform the model in per capita and efficient unit terms to make them stationary and define that for any economy-wide variable X_t, $X_t \equiv (Y_t, C_t, K_t, B_t, G_t^c, G_t^t)$, $x_t = \frac{X_t}{N_t Z_t}$, and that $h_t = \frac{H_t}{N_t}$ is per capita non-leisure time.

in eight unknown endogenous variables $y_t, c_t, h_t, \eta_t, i_t, r_t^b, b_{t+1}$ and k_{t+1}, given the paths for A_t, θ_t, and the four policy instruments $s_t^c, s_t^t, \tau_t^c, \tau_t^y$.

Thus the stationary DCE will be given by Eqs. (14)-(21):

$$\eta_t = 1 - \theta_t \frac{1}{(1-\tau_t^y)(1-\theta_t)(1-\alpha)\frac{y_t}{\eta_t h_t}} \frac{y_t}{h_t} \tag{14}$$

$$(1+\tau_t^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c_t + \psi s_t^c y_t}{1-h_t}\right) = \left[(1-\tau_t^y)(1-\theta_t) + \frac{\theta_t}{1-\alpha}\right](1-\alpha)\frac{y_t}{h_t} \tag{15}$$

$$\begin{aligned}\left(\frac{c_{t+1} + \psi s_{t+1}^c y_{t+1}}{c_t + \psi s_t^c y_t}\right)^{1-\mu(1-\sigma)} \left(\frac{1-h_t}{1-h_{t+1}}\right)^{(1-\mu)(1-\sigma)} &= \\ &\beta\left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right)\left[\alpha(1-\theta_{t+1})(1-\tau_{t+1}^y)\frac{y_{t+1}}{k_{t+1}} + 1 - \delta\right]\end{aligned} \tag{16}$$

$$(s_t^c + s_t^t)y_t + \theta_t \tau_t^y y_t + (1+r_t^b)b_t = \gamma_n \gamma_z b_{t+1} + \tau_t^c c_t + \tau_t^y y_t \tag{17}$$

$$(1-s_t^c)y_t = c_t + i_t \tag{18}$$

$$\left(\frac{c_{t+1} + \psi s_{t+1}^c y_{t+1}}{c_t + \psi s_t^c y_t}\right)^{1-\mu(1-\sigma)} \left(\frac{1-h_t}{1-h_{t+1}}\right)^{(1-\mu)(1-\sigma)} = \beta\left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right)(1+r_{t+1}^b) \tag{19}$$

$$\gamma_n \gamma_z k_{t+1} = (1-\delta)k_t + i_t \tag{20}$$

$$y_t = A_t k_t^{\alpha} (\eta_t h_t)^{(1-\alpha)} \tag{21}$$

where $\beta \equiv \beta^* \gamma_z^{\mu(1-\sigma)-1}$. This is an equilibrium of eight equations in the paths of eight unknown endogenous variables $i_t, c_t, y_t, r_t^b, \eta_t, h_t, b_{t+1}, k_{t+1}$, given the paths of productivity A_t, the economy-wide degree of extraction θ_t and the five independent policy instruments, $s_t^c, s_t^t, \tau_t^c, \tau_t^y$.

1.8 Long-run equilibrium: Case III

In the long-run, our economy reaches an equilibrium where no shocks exist and variables remain constant but grow at a constant balance growth rate. We remove time subscripts and solve for the equilibrium. Thus, all variables satisfy that $x_{t+1} = x_t = x_{t-1} = x$. The long-run equilibrium or the steady state is characterized by $Eqs.(22) - (29)$:

$$\eta = 1 - \theta \frac{1}{(1-\tau^y)(1-\theta)(1-\alpha)\frac{y}{\eta h}} \frac{y}{h} \tag{22}$$

$$(1+\tau^c)\left(\frac{1-\mu}{\mu}\right)\left(\frac{c + \psi s^c y}{1-h}\right) = \left[(1-\tau^y)(1-\theta) + \frac{\theta}{1-\alpha}\right](1-\alpha)\frac{y}{h} \tag{23}$$

$$1 = \beta\left[\alpha(1-\theta)(1-\tau^y)\frac{y}{k} + 1 - \delta\right] \tag{24}$$

$$(s^c + s^t)y + \theta \tau^y y = (\gamma_n \gamma_z - 1 - r^b)b + \tau^c c + \tau^y y \tag{25}$$

$$(1-s^{c})y = c + i \tag{26}$$

$$1 = \beta(1+r^{b}) \tag{27}$$

$$(\gamma_n\gamma_z - 1 + \delta) = \frac{i}{k} \tag{28}$$

$$y = Ak^{\alpha}(\eta h)^{1-\alpha} \tag{29}$$

The above system of equations is an equilibrium system of eight equations in eight unknown endogenous variables $y, k, c, i, h, \eta, b, r^{b}$. We set $b = 0.9y$ (i.e. the government debt-to-GDP ratio is 90% on an annual basis); therefore we choose the long-run government consumption-to-GDP ratio (s_0^c) to follow residually and satisfy the government budget constraint $Eq.$(25).

Appendix D

Long-run equilibrium

Table 12: Long-run equilibrium

CASE I

	Countries											
Variable	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
y	0.57	0.38	0.69	0.30	0.45	0.55	0.46	0.34	0.44	0.55	0.27	0.49
c/y	0.46	0.57	0.53	0.64	0.51	0.50	0.50	0.56	0.53	0.49	0.58	0.44
i/y	0.22	0.20	0.24	0.19	0.25	0.22	0.20	0.20	0.20	0.23	0.20	0.22
h	0.34	0.29	0.38	0.39	0.36	0.32	0.40	0.39	0.29	0.37	0.37	0.38
η	0.95	0.95	0.95	0.80	0.85	0.90	0.90	0.90	0.95	0.95	0.85	0.95
k/y	2.25	2.39	2.31	2.62	2.76	2.48	2.36	2.21	2.36	2.92	2.35	2.46
s^c	0.31	0.24	0.23	0.17	0.24	0.28	0.31	0.24	0.26	0.28	0.21	0.34
r^b	0.03	0.03	0.05	0.06	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03

CASE II

	Countries											
Variable	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
y	0.56	0.37	0.67	0.27	0.41	0.53	0.45	0.32	0.42	0.53	0.25	0.46
c/y	0.48	0.58	0.55	0.73	0.58	0.53	0.53	0.62	0.55	0.51	0.66	0.45
i/y	0.22	0.20	0.24	0.19	0.25	0.22	0.20	0.20	0.20	0.23	0.20	0.22
h	0.33	0.28	0.37	0.36	0.33	0.30	0.38	0.37	0.28	0.36	0.35	0.37
η	0.95	0.95	0.95	0.79	0.85	0.90	0.90	0.90	0.95	0.95	0.85	0.95
k/y	2.25	2.39	2.31	2.62	2.76	2.48	2.36	2.21	2.36	2.92	2.35	2.46
s^c	0.30	0.22	0.21	0.08	0.18	0.25	0.27	0.19	0.24	0.26	0.13	0.33
r^b	0.03	0.03	0.05	0.06	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03

CASE III

	Countries											
Variable	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
y	0.55	0.38	0.67	0.26	0.41	0.52	0.44	0.32	0.43	0.54	0.25	0.48
c/y	0.47	0.58	0.54	0.67	0.54	0.52	0.52	0.59	0.54	0.50	0.62	0.45
i/y	0.22	0.19	0.23	0.17	0.23	0.21	0.19	0.19	0.20	0.23	0.19	0.22
h	0.34	0.29	0.38	0.38	0.35	0.31	0.39	0.38	0.28	0.36	0.36	0.37
η	0.95	0.95	0.95	0.80	0.85	0.90	0.90	0.90	0.95	0.95	0.85	0.95
k/y	2.25	2.39	2.31	2.62	2.76	2.48	2.36	2.21	2.36	2.92	2.35	2.46
s^c	0.31	0.23	0.23	0.15	0.22	0.27	0.29	0.23	0.26	0.27	0.20	0.34
r^b	0.03	0.03	0.05	0.06	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03

Note y: output, c/y: consumption to output ratio, i/y: investment to output ratio
h: hours at work, η: fraction of non-leisure time allocated to productive work
k/y: capital to output ratio, s^c: government consumption to output ratio
r^b: return to government bonds (annually)

Appendix E

Macroeconomic policy and institutions interaction before and after the crisis

Table 13: Policy changes, institutions and macroeconomic performance: Case II

	Countries											
Variable	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
Policy instruments set to their pre-crisis period 2001-2008 average												
y	0.56	0.38	0.67	0.26	0.41	0.52	0.44	0.32	0.43	0.54	0.25	0.48
η	0.95	0.95	0.95	0.80	0.85	0.91	0.91	0.90	0.95	0.95	0.85	0.95
Policy instruments set to their post-crisis period 2009-2016 average												
y	0.52	0.38	0.65	0.24	0.40	0.48	0.40	0.30	0.41	0.52	0.23	0.46
η	0.95	0.95	0.95	0.78	0.85	0.90	0.90	0.90	0.95	0.95	0.84	0.95
% change in output and effort level												
y	-6.99	-0.22	-2.98	-10.03	-2.40	-8.32	-9.17	-4.21	-4.94	-2.60	-6.35	-5.50
η	-0.35	-0.16	0.22	-3.26	0.78	-1.10	-1.46	-0.59	-0.29	-0.14	-1.45	-0.16

Note y: output, η: effort level

Table 14: Policy changes, institutions and macroeconomic performance: Case III

	Countries											
Variable	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
Policy instruments set to their pre-crisis period 2001-2008 average												
y	0.55	0.38	0.67	0.26	0.41	0.52	0.44	0.32	0.43	0.54	0.25	0.45
η	0.9508	0.9503	0.9495	0.8036	0.8489	0.9023	0.9030	0.9012	0.9504	0.9504	0.8524	0.9504
Policy instruments set to their post-crisis period 2009-2016 average												
y	0.51	0.38	0.65	0.24	0.39	0.48	0.40	0.31	0.41	0.52	0.23	0.45
η	0.9492	0.9497	0.9499	0.7963	0.8512	0.8975	0.8968	0.8986	0.9496	0.9496	0.8475	0.9496
% change in output and effort level												
y	-6.90	-0.15	-3.18	-8.62	-2.97	-8.00	-8.67	-4.03	-4.83	-2.56	-5.82	-5.47
η	-0.17	-0.06	0.04	-0.90	0.27	-0.53	-0.68	-0.28	-0.09	-0.07	-0.58	-0.08

Note y: output, η: effort level

Appendix F

Second moment properties

1.9 Relative volatility $x \equiv \frac{s_x}{s_y}$

	Belgium				Germany			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
s_y	0.0117	0.0118	0.0118	0.0118	0.0156	0.0156	0.0157	0.0156
c	1.0662	0.4391	0.4328	0.4397	0.8775	0.2809	0.2772	0.2808
i	3.3621	2.3463	2.3833	2.3891	2.7486	3.1736	3.2516	3.2627
h	0.4463	0.5125	0.5039	0.5092	0.4576	0.5642	0.5598	0.5648
k	0.4376	0.3783	0.3842	0.3858	0.3496	0.3415	0.3482	0.3505
η	Na	0.0548	0.0383	0.0393	Na	0.0416	0.0300	0.0297

	Ireland				Greece			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
s_y	0.0662	0.0659	0.0664	0.0661	0.0460	0.0459	0.0461	0.0459
c	0.9510	0.7339	0.7381	0.7411	0.6508	0.7272	0.7471	0.7564
i	2.9088	1.6097	1.6248	1.6217	2.7938	1.9286	1.9921	1.9750
h	0.2382	0.1736	0.1702	0.1702	0.1958	0.1760	0.1581	0.1583
k	0.1888	0.2958	0.3004	0.2988	0.3236	0.2581	0.2670	0.2650
η	Na	0.0098	0.0083	0.0071	Na	0.0567	0.0452	0.0437

	Spain				France			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
s_y	0.0251	0.0253	0.0252	0.0250	0.0120	0.0123	0.0122	0.0122
c	0.6662	0.7366	0.7496	0.7583	0.7594	0.7687	0.7723	0.7782
i	3.6178	1.5539	1.5911	1.5847	2.6467	1.5520	1.5732	1.5692
h	0.2155	0.1976	0.1794	0.1812	0.7080	0.2904	0.2588	0.2720
k	0.3784	0.2544	0.2598	0.2598	0.2566	0.2526	0.2565	0.2557
η	Na	0.0770	0.0551	0.0586	Na	0.1052	0.0746	0.0772

	Italy				Cyprus			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
s_y	0.0178	0.0179	0.0180	0.0179	0.0299	0.0299	0.0301	0.0298
c	0.8397	0.7703	0.7753	0.7807	0.9486	0.7275	0.7357	0.7416
i	2.3631	1.6113	1.6322	1.6298	5.3665	1.7922	1.8381	1.8277
h	0.3861	0.2106	0.1930	0.1991	0.3418	0.1862	0.1749	0.1776
k	0.3973	0.2467	0.2509	0.2503	0.6201	0.2888	0.2960	0.2949
η	Na	0.0722	0.0498	0.0530	Na	0.0433	0.0317	0.0325

	Netherlands				Austria			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
s_y	0.0194	0.0194	0.0195	0.0194	0.0133	0.0134	0.0134	0.0133
c	1.0981	0.7237	0.7275	0.7305	0.9328	0.3552	0.3524	0.3570
i	2.9898	1.7382	1.7550	1.7516	1.9755	2.5094	2.5586	2.5673
h	0.2659	0.2483	0.2370	0.2421	0.5192	0.4846	0.4782	0.4829
k	0.3301	0.2745	0.2776	0.2775	0.4243	0.3175	0.3251	0.3241
η	Na	0.0333	0.0237	0.0240	Na	0.0483	0.0341	0.0346

	Portugal				Finland			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
y	0.0205	0.0208	0.0208	0.0205	0.0244	0.0248	0.0245	0.0243
c	0.5983	0.7348	0.7475	0.7560	0.8695	0.3754	0.3753	0.3823
i	3.8339	1.7780	1.8386	1.8276	2.224	2.3135	2.3528	2.3493
h	0.2387	0.1979	0.1747	0.1791	0.1366	0.4386	0.4367	0.4369
k	0.4953	0.2819	0.2923	0.2901	0.2599	0.3475	0.3546	0.3539
η	Na	0.0935	0.0691	0.0725	Na	0.0261	0.0193	0.0190

1.10 Persistence $\rho(x_t, x_{t-1})$

Belgium

	Data	Case I	Case II	Case III
y	0.4127	0.4137	0.4116	0.4119
c	0.2013	0.5183	0.5225	0.5206
i	0.4812	0.3913	0.3885	0.3893
h	0.2728	0.4051	0.4013	0.4005
k	0.7625	0.8013	0.8020	0.8019
η	Na	0.4647	0.4642	0.4658

Germany

	Data	Case I	Case II	Case III
y	0.1953	0.1986	0.1958	0.1994
c	0.3192	0.4038	0.4059	0.4068
i	0.4528	0.1773	0.1753	0.1778
h	0.1985	0.1935	0.1857	0.1918
k	0.7703	0.6878	0.6850	0.6869
η	Na	0.4680	0.4431	0.4673

Ireland

	Data	Case I	Case II	Case III
y	0.7097	0.4474	0.4849	0.4830
c	0.2042	0.4999	0.5073	0.5047
i	0.7204	0.4604	0.4674	0.4657
h	0.5320	0.4481	0.4545	0.4535
k	0.7000	0.8411	0.8428	0.8416
η	Na	0.4636	0.4643	0.4669

Greece

	Data	Case I	Case II	Case III
y	0.8112	0.4802	0.4807	0.4838
c	0.5683	0.4993	0.4988	0.5004
i	0.6694	0.4641	0.4631	0.4668
h	0.3536	0.4574	0.4565	0.4600
k	0.8736	0.8456	0.8461	0.8467
η	Na	0.4696	0.4688	0.4670

Spain

	Data	Case I	Case II	Case III
y	0.7294	0.4815	0.4797	0.4802
c	0.7511	0.4973	0.4949	0.4952
i	0.7537	0.4699	0.4672	0.4680
h	0.6591	0.4603	0.4582	0.4587
k	0.8639	0.8461	0.8448	0.8465
η	Na	0.4647	0.4671	0.4690

France

	Data	Case I	Case II	Case III
y	0.5003	0.4781	0.4818	0.4824
c	0.7271	0.4911	0.4954	0.4946
i	0.4225	0.4664	0.4701	0.4706
h	0.5392	0.4647	0.4645	0.4621
k	0.7495	0.8461	0.8468	0.8467
η	Na	0.4685	0.4688	0.4668

Italy

	Data	Case I	Case II	Case III
y	0.4980	0.4766	0.4816	0.4792
c	0.5686	0.4894	0.4943	0.4916
i	0.5436	0.4661	0.4706	0.4683
h	0.4585	0.4600	0.4614	0.4608
k	0.8865	0.8451	0.8466	0.8464
η	Na	0.4656	0.4677	0.4696

Cyprus

	Data	Case I	Case II	Case III
y	0.6947	0.4776	0.4779	0.4775
c	0.3066	0.4993	0.5002	0.4983
i	0.6051	0.4598	0.4590	0.4586
h	0.6241	0.4527	0.4488	0.4511
k	0.8609	0.8407	0.8407	0.8409
η	Na	0.4657	0.4673	0.4682

	Netherlands				Austria			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
y	0.5971	0.4774	0.4801	0.4797	0.3954	0.3981	0.4001	0.3969
c	0.5481	0.4974	0.5011	0.5003	0.4308	0.5046	0.5114	0.5063
i	0.6016	0.4614	0.4641	0.4638	0.2138	0.3825	0.3846	0.3816
h	0.0828	0.4564	0.4560	0.4559	0.0924	0.3898	0.3885	0.3864
k	0.7922	0.8427	0.8432	0.8437	0.7673	0.7999	0.8016	0.7990
η	Na	0.4662	0.4668	0.4676	Na	0.4659	0.4617	0.4685

	Portugal				Finland			
	Data	Case I	Case II	Case III	Data	Case I	Case II	Case III
y	0.6289	0.4800	0.4817	0.4788	0.4285	0.4257	0.4266	0.4259
c	0.3062	0.5000	0.5020	0.4973	0.4732	0.5280	0.5313	0.5266
i	0.6665	0.4631	0.4632	0.46068	0.4646	0.4085	0.4086	0.4078
h	0.1837	0.4567	0.4544	0.4545	0.1505	0.4075	0.4071	0.4066
k	0.8807	0.8419	0.8429	0.8423	0.7568	0.8119	0.8133	0.8132
η	Na	0.4664	0.4654	0.4690	Na	0.4681	0.4571	0.4633

Data: Ranking of volatility of output and relative volatility, $x \equiv \frac{s_x}{s_y}$

	s_y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio
BG	0.0117	1.0	PR	0.5983	1.0	AT	1.9755	1.0	FI	0.1366	1.0	IE	0.1888	1.0
FR	0.012	1.0	GR	0.6508	1.1	FI	2.2224	1.1	GR	0.1958	1.4	FR	0.2566	1.4
AT	0.0133	1.1	ES	0.6662	1.1	IT	2.3631	1.2	ES	0.2155	1.6	FI	0.2599	1.4
DE	0.0156	1.3	FR	0.7594	1.3	FR	2.6467	1.3	IE	0.2382	1.7	GR	0.3236	1.7
IT	0.0178	1.5	IT	0.8397	1.4	DE	2.7486	1.4	PR	0.2387	1.7	NL	0.3301	1.7
NL	0.0194	1.7	FI	0.8695	1.5	GR	2.7938	1.4	NL	0.2659	1.9	DE	0.3496	1.9
PR	0.0205	1.8	DE	0.8775	1.5	IE	2.9088	1.5	CY	0.3418	2.5	ES	0.3784	2.0
FI	0.0244	2.1	AT	0.9328	1.6	NL	2.9898	1.5	IT	0.3861	2.8	IT	0.3973	2.1
ES	0.0251	2.1	CY	0.9486	1.6	BG	3.3621	1.7	BG	0.4463	3.3	AT	0.4243	2.2
CY	0.0299	2.6	IE	0.951	1.6	ES	3.6178	1.8	DE	0.4576	3.3	BG	0.4376	2.3
GR	0.046	3.9	BG	1.0662	1.8	PR	3.8339	1.9	AT	0.5192	3.8	PR	0.4953	2.6
IE	0.0662	5.7	NL	1.0981	1.8	CY	5.3665	2.7	FR	0.708	5.2	CY	0.6201	3.3
Averages														
Core	0.0161			0.9339			2.6575			0.4223			0.3430	
Periphery	0.0343			0.7758			3.4807			0.2694			0.4006	
All	0.0252			0.8548			3.0691			0.3458			0.3718	

Case 1: Ranking of volatility of output and relative volatility, $x \equiv \frac{s_x}{s_y}$

	s_y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio		η	Ratio
BG	0.0118	1.0	DE	0.2809	1.0	FR	1.5520	1.0	IE	0.1736	1.0	IT	0.2467	1.0	IE	0.0098	1.0
FR	0.0123	1.0	AT	0.3552	1.3	ES	1.5539	1.0	GR	0.1760	1.0	FR	0.2526	1.0	FI	0.0261	2.7
AT	0.0134	1.1	FI	0.3754	1.3	IE	1.6097	1.0	CY	0.1862	1.1	ES	0.2544	1.0	NL	0.0333	3.4
DE	0.0156	1.3	BG	0.4391	1.6	IT	1.6113	1.0	ES	0.1976	1.1	GR	0.2581	1.0	DE	0.0416	4.2
IT	0.0179	1.5	NL	0.7237	2.6	NL	1.7382	1.1	PR	0.1979	1.1	NL	0.2745	1.1	CY	0.0433	4.4
NL	0.0194	1.6	GR	0.7272	2.6	PR	1.7780	1.1	IT	0.2106	1.2	PR	0.2819	1.1	AT	0.0483	4.9
PR	0.0208	1.8	CY	0.7275	2.6	CY	1.7922	1.2	NL	0.2483	1.4	CY	0.2888	1.2	BG	0.0548	5.6
FI	0.0248	2.1	IE	0.7339	2.6	GR	1.9286	1.2	FR	0.2904	1.7	IE	0.2958	1.2	GR	0.0567	5.8
ES	0.0253	2.1	PR	0.7348	2.6	FI	2.3135	1.5	FI	0.4386	2.5	AT	0.3175	1.3	IT	0.0722	7.4
CY	0.0299	2.5	ES	0.7371	2.6	BG	2.3463	1.5	AT	0.4846	2.8	DE	0.3415	1.4	ES	0.0770	7.8
GR	0.0459	3.9	FR	0.7687	2.7	AT	2.5094	1.6	BG	0.5125	3.0	FI	0.3475	1.4	PR	0.0935	9.5
IE	0.0659	5.6	IT	0.7703	2.7	DE	3.1736	2.0	DE	0.5642	3.2	BG	0.3783	1.5	FR	0.1052	10.7
Averages																	
Core	0.0162			0.4905			2.2722			0.4231			0.3186			0.0516	
Periphery	0.0343			0.7385			1.7123			0.1903			0.2709			0.0588	
All	0.0253			0.6145			1.9922			0.3067			0.2948			0.0552	

Data: Ranking of persistence of series of y, c, i, h, k

	y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio
DE	0.1953	1.0	BG	0.2013	1.0	AT	0.2138	1.0	NL	0.0828	1.0	IE	0.7000	1.0
AT	0.3954	2.0	IE	0.2042	1.0	FR	0.4225	2.0	AT	0.0924	1.1	FR	0.7495	1.1
BG	0.4127	2.1	PT	0.3062	1.5	DE	0.4528	2.1	FI	0.1505	1.8	FI	0.7568	1.1
FI	0.4285	2.2	CY	0.3066	1.5	FI	0.4646	2.2	PT	0.1837	2.2	BG	0.7625	1.1
IT	0.4980	2.5	DE	0.3192	1.6	BG	0.4812	2.3	DE	0.1985	2.4	AT	0.7673	1.1
FR	0.5003	2.6	AT	0.4308	2.1	IT	0.5436	2.5	BG	0.2728	3.3	DE	0.7703	1.1
NL	0.5971	3.1	FI	0.4732	2.4	NL	0.6016	2.8	GR	0.3536	4.3	NL	0.7922	1.1
PT	0.6289	3.2	NL	0.5481	2.7	CY	0.6051	2.8	IT	0.4585	5.5	CY	0.8609	1.2
CY	0.6947	3.6	GR	0.5683	2.8	PT	0.6665	3.1	IE	0.5320	6.4	ES	0.8639	1.2
IE	0.7097	3.6	IT	0.5686	2.8	GR	0.6694	3.1	FR	0.5392	6.5	GR	0.8736	1.2
ES	0.7294	3.7	FR	0.7271	3.6	IE	0.7204	3.4	CY	0.6241	7.5	PT	0.8807	1.3
GR	0.8112	4.2	ES	0.7511	3.7	ES	0.7537	3.5	ES	0.6591	8.0	IT	0.8865	1.3
Averages														
Core	0.4216			0.4500			0.4394			0.2227			0.7664	
Periphery	0.6786			0.4508			0.6598			0.4685			0.8443	
All	0.5501			0.4504			0.5496			0.3456			0.8054	

Case 1: Ranking of persistence of series of y, c, i, h, k

	y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio			Ratio
DE	0.1986	1.0	DE	0.4038	1.0	DE	0.1773	1.0	DE	0.1935	1.0	DE	0.6878	1.0	IE	0.4636	1.0
AT	0.3981	2.0	IT	0.4894	1.2	AT	0.3825	2.2	AT	0.3898	2.0	AT	0.7999	1.2	ES	0.4647	1.0
BG	0.4137	2.1	FR	0.4911	1.2	BG	0.3913	2.2	BG	0.4051	2.1	BG	0.8013	1.2	BG	0.4647	1.0
FI	0.4257	2.1	ES	0.4973	1.2	FI	0.4085	2.3	FI	0.4075	2.1	FI	0.8119	1.2	IT	0.4656	1.0
IT	0.4766	2.4	NL	0.4974	1.2	CY	0.4598	2.6	IE	0.4481	2.3	CY	0.8407	1.2	CY	0.4657	1.0
NL	0.4774	2.4	CY	0.4993	1.2	IE	0.4604	2.6	CY	0.4527	2.3	IE	0.8411	1.2	AT	0.4659	1.0
IE	0.4774	2.4	GR	0.4993	1.2	NL	0.4614	2.6	NL	0.4564	2.4	PR	0.8419	1.2	NL	0.4662	1.0
CY	0.4776	2.4	IE	0.4999	1.2	PR	0.4631	2.6	PR	0.4567	2.4	NL	0.8427	1.2	PR	0.4664	1.0
FR	0.4781	2.4	PR	0.5000	1.2	GR	0.4641	2.6	GR	0.4574	2.4	IT	0.8451	1.2	DE	0.4680	1.0
PR	0.4800	2.4	AT	0.5046	1.2	IT	0.4661	2.6	IT	0.4600	2.4	GR	0.8456	1.2	FI	0.4681	1.0
GR	0.4802	2.4	BG	0.5183	1.3	FR	0.4664	2.6	ES	0.4603	2.4	ES	0.8461	1.2	FR	0.4685	1.0
ES	0.4815	2.4	FI	0.5280	1.3	ES	0.4699	2.6	FR	0.4647	2.4	FR	0.8461	1.2	GR	0.4696	1.0
Averages																	
Core	0.3986			0.4906			0.3813			0.3862			0.7983			0.4669	
Periphery	0.4789			0.4975			0.4639			0.4559			0.8434			0.4659	
All	0.4387			0.4940			0.4226			0.4210			0.8208			0.4664	

7.3 Co-movement $\rho(y_t, x_{t+1})$

Belgium

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.4253	0.3216	0.0485	0.1792	0.6732	0.4362	0.1862	0.7000	0.4520	0.1863	0.6880	0.4430
i	0.2597	0.8065	0.5077	0.4390	0.9736	0.3373	0.4383	0.9759	0.3350	0.4387	0.9742	0.3340
h	0.0258	0.5271	0.3018	0.4305	0.9055	0.2858	0.4333	0.9127	0.2828	0.4295	0.9086	0.2825
k	0.2218	0.6270	0.7644	-0.3480	-0.0488	0.5427	-0.3450	-0.0465	0.5451	-0.3430	-0.0445	0.5460
η	Na	Na	Na	0.0068	0.0117	-0.0010	0.0854	0.1763	0.0562	0.0122	0.0199	0.0098

Germany

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	-0.1400	0.5622	0.1890	-0.0070	0.7949	0.3927	-0.0064	0.8138	0.4061	-0.0066	0.8015	0.4009
i	0.3419	0.8795	0.2015	0.2321	0.9892	0.1307	0.2314	0.9902	0.1273	0.2343	0.9893	0.1297
h	0.1566	0.5903	-0.2734	0.2515	0.9752	0.1105	0.2493	0.9782	0.1048	0.2535	0.9770	0.1091
k	0.0781	0.4135	0.4016	-0.4098	-0.2003	0.5663	-0.4109	-0.2011	0.5698	-0.4094	-0.1985	0.5692
η	Na	Na	Na	0.0036	0.0091	0.0032	0.0772	0.3015	0.0337	0.0097	0.0206	0.0113

Ireland

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.4819	0.6685	0.1997	0.4468	0.9943	0.5222	0.4545	0.9947	0.5298	0.4531	0.9946	0.5266
i	0.6347	0.8610	0.8051	0.5039	0.9954	0.4263	0.5121	0.9952	0.4321	0.5100	0.9952	0.4307
h	0.2398	0.3779	0.3638	0.5308	0.9598	0.3341	0.5401	0.9612	0.3392	0.5369	0.9595	0.3381
k	-0.2452	-0.0366	0.4592	-0.3163	-0.0115	0.5254	-0.3136	-0.0062	0.5276	-0.3159	-0.0086	0.5268
η	Na	Na	Na	0.0032	0.0068	0.0048	0.3212	0.5702	0.2026	0.0021	0.00660	0.0057

Greece

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.5836	0.7700	0.7465	0.4500	0.9947	0.5218	0.4536	0.9965	0.5203	0.4579	0.9960	0.5205
i	0.7015	0.9087	0.7111	0.5117	0.9938	0.4222	0.5139	0.9933	0.4183	0.5165	0.9932	0.4227
h	0.6084	0.3132	0.1341	0.5240	0.9483	0.3451	0.5315	0.9579	0.3446	0.5370	0.9637	0.3521
k	0.0792	0.4140	0.7341	-0.3396	-0.0398	0.4932	-0.3321	-0.0324	0.4992	-0.3349	-0.0340	0.4968
η	Na	Na	Na	0.0129	0.0206	0.0088	0.2164	0.3892	0.1429	0.0151	0.0242	0.0082

Spain

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.0541	0.1748	0.0725	0.4504	0.9850	0.5123	0.4530	0.9920	0.5123	0.4527	0.9877	0.5095
i	0.7613	0.9418	0.6431	0.5024	0.9943	0.4416	0.5027	0.9956	0.4377	0.5021	0.9943	0.4384
h	-0.0173	0.0366	0.0821	0.4806	0.8806	0.3328	0.5023	0.9191	0.3425	0.4928	0.9034	0.3380
k	-0.0126	0.3354	0.7126	-0.3439	-0.0449	0.4868	-0.3421	-0.0423	0.4919	-0.3384	-0.0402	0.4905
η	Na	Na	Na	0.0141	0.0274	0.0151	0.0919	0.1677	0.0656	0.0170	0.0314	0.0100

France

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.5518	0.7141	0.4933	0.4210	0.9228	0.4744	0.4351	0.9437	0.4879	0.4318	0.9321	0.4810
i	0.1794	0.8526	0.5696	0.4916	0.9787	0.4311	0.4989	0.9842	0.4360	0.4980	0.9805	0.4349
h	-0.0863	-0.0555	-0.3696	0.3593	0.6765	0.2635	0.3826	0.7115	0.2750	0.3694	0.6935	0.2726
k	-0.5018	0.0906	0.4393	-0.3366	-0.0445	0.4791	-0.3373	-0.0416	0.4837	-0.3365	-0.0409	0.4821
η	Na	Na	Na	0.0162	0.0281	0.0137	0.0483	0.0931	0.0381	0.0179	0.0366	0.0150

Italy

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.4406	0.7592	0.3413	0.4377	0.9575	0.4876	0.4483	0.9692	0.4977	0.4443	0.9631	0.4909
i	0.3628	0.9207	0.5959	0.4937	0.9846	0.4326	0.5014	0.9884	0.4380	0.4977	0.9860	0.4345
h	0.2674	0.5850	0.1638	0.3969	0.7466	0.2874	0.4223	0.7827	0.3018	0.4056	0.7604	0.2940
k	-0.1332	0.2792	0.6079	-0.3493	-0.0554	0.4741	-0.3478	-0.0510	0.4777	-0.3449	-0.0501	0.4773
η	Na	Na	Na	0.0119	0.0216	0.0101	0.0499	0.0936	0.0340	0.0163	0.0297	0.0131

Cyprus

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.2347	-0.0153	-0.2906	0.4434	0.9880	0.5193	0.4462	0.9919	0.5214	0.4456	0.9893	0.5175
i	0.5301	0.8580	0.7088	0.5070	0.9926	0.4193	0.5092	0.9929	0.4164	0.5077	0.9923	0.4165
h	-0.1717	0.1409	0.2704	0.5075	0.9200	0.3262	0.5198	0.9393	0.3272	0.5116	0.9267	0.3256
k	0.1404	0.4545	0.7461	-0.3266	-0.0222	0.5162	-0.3222	-0.0168	0.5217	-0.3214	-0.0173	0.5199
η	Na	Na	Na	0.0024	0.0110	0.0061	0.1728	0.3101	0.1106	0.0119	0.0269	0.0139

Netherlands

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.4989	0.7379	0.2521	0.4349	0.9695	0.5088	0.4410	0.9748	0.5140	0.4395	0.9715	0.5114
i	0.5568	0.9127	0.5998	0.5032	0.9899	0.4226	0.5073	0.9908	0.4246	0.4694	0.8587	0.3137
h	0.4691	0.3217	-0.2667	0.4667	0.8558	0.3129	0.4771	0.8712	0.3184	0.4694	0.8587	0.3137
k	-0.0332	0.5158	0.7948	-0.3316	-0.0305	0.5037	-0.3292	-0.0270	0.5066	-0.3284	-0.0271	0.5054
η	Na	Na	Na	0.0003	0.0055	0.0020	0.0909	0.1656	0.0563	0.0053	0.0121	0.0053

Austria

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.2035	0.8027	0.4131	0.1905	0.7671	0.4718	0.2040	0.7920	0.4874	0.1968	0.7797	0.4776
i	0.0802	0.7483	0.4492	0.4235	0.9831	0.3383	0.4280	0.9847	0.3392	0.4241	0.9836	0.3357
h	0.0967	0.3904	-0.1818	0.4323	0.9520	0.3013	0.4355	0.9570	0.3030	0.4320	0.9548	0.2994
k	0.0545	0.4016	0.5298	-0.3910	-0.1020	0.5041	-0.3867	-0.0968	0.5072	-0.3900	-0.1005	0.5072
η	Na	Na	Na	0.0072	0.0148	0.0087	0.1145	0.2438	0.0781	0.0101	0.0187	0.0080

Portugal

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	-0.3630	-0.1622	-0.0527	0.4454	0.9841	0.5171	0.4523	0.9926	0.5220	0.4477	0.9869	0.5138
i	0.6421	0.9549	0.6158	0.5085	0.9919	0.4232	0.5128	0.9931	0.4209	0.5083	0.9914	0.4186
h	0.6903	0.5240	0.0625	0.4789	0.8676	0.3129	0.5085	0.9130	0.3233	0.4979	0.9010	0.3198
k	-0.0637	0.3413	0.7253	-0.3299	-0.0260	0.5103	-0.3214	-0.0170	0.5177	-0.3231	-0.0197	0.5150
η	Na	Na	Na	0.0178	0.0333	0.0140	0.1143	0.2074	0.0744	0.0272	0.0499	0.0222

Finland

	Data			Case I			Case II			Case III		
	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1	t-1	t	t+1
c	0.4108	0.8712	0.4073	0.2574	0.8542	0.5327	0.2608	0.8622	0.5395	0.2634	0.8600	0.5320
i	0.3452	0.8987	0.5022	0.4543	0.9886	0.3657	0.4560	0.9890	0.3651	0.4551	0.9884	0.3640
h	0.3903	0.5419	-0.2048	0.4652	0.9604	0.3192	0.4675	0.9622	0.3186	0.4651	0.9601	0.3181
k	-0.2430	0.2984	0.6768	-0.3653	-0.0652	0.5220	-0.3609	-0.0609	0.5240	-0.3592	-0.0599	0.5247
η	Na	Na	Na	0.0009	0.0048	-0.0011	0.1868	0.3859	0.1317	0.0052	0.0117	0.0063

Data: Ranking of volatility of output and relative volatility, $x \equiv \frac{s_x}{s_y}$

	s_y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio
BG	0.0117	1.0	PR	0.5983	1.0	AT	1.9755	1.0	FI	0.1366	1.0	IE	0.1888	1.0
FR	0.012	1.0	GR	0.6508	1.1	FI	2.2224	1.1	GR	0.1958	1.4	FR	0.2566	1.4
AT	0.0133	1.1	ES	0.6662	1.1	IT	2.3631	1.2	ES	0.2155	1.6	FI	0.2599	1.4
DE	0.0156	1.3	FR	0.7594	1.3	FR	2.6467	1.3	IE	0.2382	1.7	GR	0.3236	1.7
IT	0.0178	1.5	IT	0.8397	1.4	DE	2.7486	1.4	PR	0.2387	1.7	NL	0.3301	1.7
NL	0.0194	1.7	FI	0.8695	1.5	GR	2.7938	1.4	NL	0.2659	1.9	DE	0.3496	1.9
PR	0.0205	1.8	DE	0.8775	1.5	IE	2.9088	1.5	CY	0.3418	2.5	ES	0.3784	2.0
FI	0.0244	2.1	AT	0.9328	1.6	NL	2.9898	1.5	IT	0.3861	2.8	IT	0.3973	2.1
ES	0.0251	2.1	CY	0.9486	1.6	BG	3.3621	1.7	BG	0.4463	3.3	AT	0.4243	2.2
CY	0.0299	2.6	IE	0.951	1.6	ES	3.6178	1.8	DE	0.4576	3.3	BG	0.4376	2.3
GR	0.046	3.9	BG	1.0662	1.8	PR	3.8339	1.9	AT	0.5192	3.8	PR	0.4953	2.6
IE	0.0662	5.7	NL	1.0981	1.8	CY	5.3665	2.7	FR	0.708	5.2	CY	0.6201	3.3

Averages	s_y	c	i	h	k
Core	0.0161	0.9339	2.6575	0.4223	0.3430
Periphery	0.0343	0.7758	3.4807	0.2694	0.4006
All	0.0252	0.8548	3.0691	0.3458	0.3718

Case 1: Ranking of volatility of output and relative volatility, $x \equiv \frac{s_x}{s_y}$

	s_y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio		η	Ratio
BG	0.0118	1.0	DE	0.2809	1.0	FR	1.5520	1.0	IE	0.1736	1.0	IT	0.2467	1.0	IE	0.0098	1.0
FR	0.0123	1.0	AT	0.3552	1.3	ES	1.5539	1.0	GR	0.1760	1.0	FR	0.2526	1.0	FI	0.0261	2.7
AT	0.0134	1.1	FI	0.3754	1.3	IE	1.6097	1.0	CY	0.1862	1.1	ES	0.2544	1.0	NL	0.0333	3.4
DE	0.0156	1.3	BG	0.4391	1.6	IT	1.6113	1.0	ES	0.1976	1.1	GR	0.2581	1.0	DE	0.0416	4.2
IT	0.0179	1.5	NL	0.7237	2.6	NL	1.7382	1.1	PR	0.1979	1.1	NL	0.2745	1.1	CY	0.0433	4.4
NL	0.0194	1.6	GR	0.7272	2.6	PR	1.7780	1.1	IT	0.2106	1.2	PR	0.2819	1.1	AT	0.0483	4.9
PR	0.0208	1.8	CY	0.7275	2.6	CY	1.7922	1.2	NL	0.2483	1.4	CY	0.2888	1.2	BG	0.0548	5.6
FI	0.0248	2.1	IE	0.7339	2.6	GR	1.9286	1.2	FR	0.2904	1.7	IE	0.2958	1.2	GR	0.0567	5.8
ES	0.0253	2.1	PR	0.7348	2.6	FI	2.3135	1.5	FI	0.4386	2.5	AT	0.3175	1.3	IT	0.0722	7.4
CY	0.0299	2.5	ES	0.7371	2.6	BG	2.3463	1.5	AT	0.4846	2.8	DE	0.3415	1.4	ES	0.0770	7.8
GR	0.0459	3.9	FR	0.7687	2.7	AT	2.5094	1.6	BG	0.5125	3.0	FI	0.3475	1.4	PR	0.0935	9.5
IE	0.0659	5.6	IT	0.7703	2.7	DE	3.1736	2.0	DE	0.5642	3.2	BG	0.3783	1.5	FR	0.1052	10.7

Averages	s_y	c	i	h	k	η
Core	0.0162	0.4905	2.2722	0.4231	0.3186	0.0516
Periphery	0.0343	0.7385	1.7123	0.1903	0.2709	0.0588
All	0.0253	0.6145	1.9922	0.3067	0.2948	0.0552

Case II: Ranking of volatility of output and relative volatility, $x \equiv \frac{s_x}{s_y}$

	s_y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio		η	Ratio
BG	0.0118	1.0	DE	0.2772	1.0	FR	1.5732	1.0	GR	0.1581	1.0	IT	0.2509	1.0	IE	0.0083	1.0
FR	0.0122	1.0	AT	0.3524	1.3	ES	1.5911	1.0	IE	0.1702	1.1	FR	0.2565	1.0	FI	0.0193	2.3
AT	0.0134	1.1	FI	0.3753	1.4	IE	1.6248	1.0	PT	0.1747	1.1	ES	0.2598	1.0	NL	0.0237	2.9
DE	0.0157	1.3	BG	0.4328	1.6	IT	1.6322	1.0	CY	0.1749	1.1	GR	0.2670	1.1	DE	0.0300	3.6
IT	0.0180	1.5	NL	0.7275	2.6	NL	1.7550	1.1	ES	0.1794	1.1	NL	0.2776	1.1	CY	0.0317	3.8
NL	0.0195	1.7	CY	0.7357	2.7	CY	1.8381	1.2	IT	0.1930	1.2	PT	0.2923	1.2	AT	0.0341	4.1
PT	0.0208	1.8	IE	0.7381	2.7	PT	1.8386	1.2	NL	0.2370	1.5	CY	0.2960	1.2	BG	0.0383	4.6
FI	0.0245	2.1	GR	0.7471	2.7	GR	1.9921	1.3	FR	0.2588	1.6	IE	0.3004	1.2	GR	0.0452	5.4
ES	0.0252	2.1	PT	0.7475	2.7	FI	2.3528	1.5	FI	0.4367	2.8	AT	0.3251	1.3	IT	0.0498	6.0
CY	0.0301	2.6	ES	0.7496	2.7	BG	2.3833	1.5	AT	0.4782	3.0	DE	0.3482	1.4	ES	0.0551	6.6
GR	0.0461	3.9	FR	0.7723	2.8	AT	2.5586	1.6	BG	0.5139	3.3	FI	0.3546	1.4	PT	0.0691	8.3
IE	0.0664	5.6	IT	0.7753	2.8	DE	3.2516	2.1	DE	0.5598	3.5	BG	0.3842	1.5	FR	0.0746	9.0

Averages	s_y	c	i	h	k	η
Core	0.0162	0.4896	2.3124	0.4141	0.3244	0.0367
Periphery	0.0344	0.7489	1.7528	0.1751	0.2777	0.0432
All	0.0253	0.6192	2.0326	0.2946	0.3011	0.0399

Case III: Ranking of volatility of output and relative volatility, $x \equiv \frac{s_x}{s_y}$

	s_y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio		η	Ratio
BG	0.0118	1.0	DE	0.2808	1.0	FR	1.5692	1.0	GR	0.1583	1.0	IT	0.2503	1.0	IE	0.0071	1.0
FR	0.0122	1.0	AT	0.3570	1.3	ES	1.5847	1.0	IE	0.1702	1.1	FR	0.2557	1.0	FI	0.0190	2.7
AT	0.0133	1.1	FI	0.3823	1.4	IE	1.6217	1.0	CY	0.1776	1.1	ES	0.2598	1.0	NL	0.0240	3.4
DE	0.0156	1.3	BG	0.4397	1.6	IT	1.6298	1.0	PT	0.1791	1.1	GR	0.2650	1.1	DE	0.0297	4.2
IT	0.0179	1.5	NL	0.7305	2.6	NL	1.7516	1.1	ES	0.1812	1.1	NL	0.2775	1.1	CY	0.0325	4.6
NL	0.0194	1.6	IE	0.7411	2.6	PT	1.8276	1.2	IT	0.1991	1.3	PT	0.2901	1.2	AT	0.0346	4.9
PT	0.0205	1.7	CY	0.7416	2.6	CY	1.8277	1.2	NL	0.2421	1.5	CY	0.2949	1.2	BG	0.0393	5.5
FI	0.0243	2.1	PT	0.7560	2.7	GR	1.9750	1.3	FR	0.2720	1.7	IE	0.2988	1.2	GR	0.0437	6.2
ES	0.0250	2.1	GR	0.7564	2.7	FI	2.3493	1.5	FI	0.4369	2.8	AT	0.3241	1.3	IT	0.0530	7.5
CY	0.0298	2.5	ES	0.7583	2.7	BG	2.3891	1.5	AT	0.4829	3.1	DE	0.3505	1.4	ES	0.0586	8.3
GR	0.0459	3.9	FR	0.7782	2.8	AT	2.5673	1.6	BG	0.5092	3.2	FI	0.3539	1.4	PT	0.0725	10.2
IE	0.0661	5.6	IT	0.7807	2.8	DE	3.2627	2.1	DE	0.5648	3.6	BG	0.3858	1.5	FR	0.0772	10.9

Averages	s_y	c	i	h	k	η
Core	0.0161	0.4948	2.3149	0.4180	0.3246	0.0373
Periphery	0.0342	0.7557	1.7444	0.1776	0.2765	0.0446
All	0.0252	0.6252	2.0296	0.2978	0.3005	0.0409

Data: Ranking of persistence of series of y, c, i, h, k

	y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio
DE	0.1953	1.0	BG	0.2013	1.0	AT	0.2138	1.0	NL	0.0828	1.0	IE	0.7000	1.0
AT	0.3954	2.0	IE	0.2042	1.0	FR	0.4225	2.0	AT	0.0924	1.1	FR	0.7495	1.1
BG	0.4127	2.1	PT	0.3062	1.5	DE	0.4528	2.1	FI	0.1505	1.8	FI	0.7568	1.1
FI	0.4285	2.2	CY	0.3066	1.5	FI	0.4646	2.2	PT	0.1837	2.2	BG	0.7625	1.1
IT	0.4980	2.5	DE	0.3192	1.6	BG	0.4812	2.3	DE	0.1985	2.4	AT	0.7673	1.1
FR	0.5003	2.6	AT	0.4308	2.1	IT	0.5436	2.5	BG	0.2728	3.3	DE	0.7703	1.1
NL	0.5971	3.1	FI	0.4732	2.4	NL	0.6016	2.8	GR	0.3536	4.3	NL	0.7922	1.1
PT	0.6289	3.2	NL	0.5481	2.7	CY	0.6051	2.8	IT	0.4585	5.5	CY	0.8609	1.2
CY	0.6947	3.6	GR	0.5683	2.8	PT	0.6665	3.1	IE	0.5320	6.4	ES	0.8639	1.2
IE	0.7097	3.6	IT	0.5686	2.8	GR	0.6694	3.1	FR	0.5392	6.5	GR	0.8736	1.2
ES	0.7294	3.7	FR	0.7271	3.6	IE	0.7204	3.4	CY	0.6241	7.5	PT	0.8807	1.3
GR	0.8112	4.2	ES	0.7511	3.7	ES	0.7537	3.5	ES	0.6591	8.0	IT	0.8865	1.3

Averages	y	c	i	h	k
Core	0.4216	0.4500	0.4394	0.2227	0.7664
Periphery	0.6786	0.4508	0.6598	0.4685	0.8443
All	0.5501	0.4504	0.5496	0.3456	0.8054

Case I: Ranking of persistence of series of y, c, i, h, k

	y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio		η	Ratio
DE	0.1986	1.0	DE	0.4038	1.0	DE	0.1773	1.0	DE	0.1935	1.0	DE	0.6878	1.0	IE	0.4636	1.0
AT	0.3981	2.0	IT	0.4894	1.2	AT	0.3825	2.2	AT	0.3898	2.0	AT	0.7999	1.2	ES	0.4647	1.0
BG	0.4137	2.1	FR	0.4911	1.2	BG	0.3913	2.2	BG	0.4051	2.1	BG	0.8013	1.2	BG	0.4647	1.0
FI	0.4257	2.1	ES	0.4973	1.2	FI	0.4085	2.3	FI	0.4075	2.1	FI	0.8119	1.2	IT	0.4656	1.0
IT	0.4766	2.4	NL	0.4974	1.2	CY	0.4598	2.6	IE	0.4481	2.3	CY	0.8407	1.2	CY	0.4657	1.0
NL	0.4774	2.4	CY	0.4993	1.2	IE	0.4604	2.6	CY	0.4527	2.3	IE	0.8411	1.2	AT	0.4659	1.0
IE	0.4774	2.4	GR	0.4993	1.2	NL	0.4614	2.6	NL	0.4564	2.4	PR	0.8419	1.2	NL	0.4662	1.0
CY	0.4776	2.4	IE	0.4999	1.2	PR	0.4631	2.6	PR	0.4567	2.4	NL	0.8427	1.2	PR	0.4664	1.0
FR	0.4781	2.4	PR	0.5000	1.2	GR	0.4641	2.6	GR	0.4574	2.4	IT	0.8451	1.2	DE	0.4680	1.0
PR	0.4800	2.4	AT	0.5046	1.2	IT	0.4661	2.6	IT	0.4600	2.4	GR	0.8456	1.2	FI	0.4681	1.0
GR	0.4802	2.4	BG	0.5183	1.3	FR	0.4664	2.6	ES	0.4603	2.4	ES	0.8461	1.2	FR	0.4685	1.0
ES	0.4815	2.4	FI	0.5280	1.3	ES	0.4699	2.6	FR	0.4647	2.4	FR	0.8461	1.2	GR	0.4696	1.0

Averages	y	c	i	h	k	η
Core	0.3986	0.4906	0.3813	0.3862	0.7983	0.4669
Periphery	0.4789	0.4975	0.4639	0.4559	0.8434	0.4659
All	0.4387	0.4940	0.4226	0.4210	0.8208	0.4664

Case II: Ranking of persistence of series of y, c, i, h, k

	y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio			Ratio
DE	0.1958	1.00	DE	0.4059	1.00	DE	0.1753	1.00	DE	0.1857	1.00	DE	0.6850	1.00	DE	0.4431	1.00
AT	0.4001	2.04	IT	0.4943	1.22	AT	0.3846	2.19	AT	0.3885	2.09	AT	0.8016	1.17	FI	0.4571	1.03
BG	0.4116	2.10	ES	0.4949	1.22	BG	0.3885	2.22	BG	0.4013	2.16	BG	0.8020	1.17	AT	0.4617	1.04
FI	0.4266	2.18	FR	0.4954	1.22	FI	0.4086	2.33	FI	0.4071	2.19	FI	0.8133	1.19	BG	0.4642	1.05
CY	0.4779	2.44	GR	0.4988	1.23	CY	0.4590	2.62	CY	0.4488	2.42	CY	0.8407	1.23	IE	0.4643	1.05
ES	0.4797	2.45	CY	0.5002	1.23	GR	0.4631	2.64	PT	0.4544	2.45	IE	0.8428	1.23	PT	0.4654	1.05
NL	0.4801	2.45	NL	0.5011	1.23	PT	0.4632	2.64	IE	0.4545	2.45	PT	0.8429	1.23	NL	0.4668	1.05
GR	0.4807	2.46	PT	0.5020	1.24	NL	0.4641	2.65	NL	0.4560	2.46	NL	0.8432	1.23	ES	0.4671	1.05
IT	0.4816	2.46	IE	0.5073	1.25	ES	0.4672	2.67	GR	0.4565	2.46	ES	0.8448	1.23	CY	0.4673	1.05
PT	0.4817	2.46	AT	0.5114	1.26	IE	0.4674	2.67	ES	0.4582	2.47	GR	0.8461	1.24	IT	0.4677	1.06
FR	0.4818	2.46	BG	0.5225	1.29	FR	0.4701	2.68	IT	0.4614	2.48	IT	0.8466	1.24	GR	0.4688	1.06
IE	0.4849	2.48	FI	0.5313	1.31	IT	0.4706	2.68	FR	0.4645	2.50	FR	0.8468	1.24	FR	0.4688	1.06

Averages	y	c	i	h	k	η
Core	0.3993	0.4946	0.3819	0.3839	0.7987	0.4603
Periphery	0.4811	0.4996	0.4645	0.4556	0.8440	0.4668
All	0.4402	0.4971	0.4235	0.4197	0.8213	0.4635

Case III: Ranking of persistence of series of y, c, i, h, k

	y	Ratio		c	Ratio		i	Ratio		h	Ratio		k	Ratio			Ratio
DE	0.1994	1.00	DE	0.4068	1.00	DE	0.1778	1.00	DE	0.1918	1.00	DE	0.6869	1.00	FI	0.4633	1.00
AT	0.3969	1.99	IT	0.4916	1.21	AT	0.3864	2.17	AT	0.3864	2.01	AT	0.7990	1.16	BG	0.4658	1.01
BG	0.4119	2.07	FR	0.4946	1.22	BG	0.3893	2.19	BG	0.4005	2.09	BG	0.8019	1.17	FR	0.4668	1.01
FI	0.4259	2.14	ES	0.4952	1.22	FI	0.4078	2.29	FI	0.4066	2.12	FI	0.8132	1.18	IE	0.4669	1.01
CY	0.4775	2.39	PT	0.4973	1.22	CY	0.4511	2.54	CY	0.4511	2.35	CY	0.8409	1.22	GR	0.4670	1.01
PT	0.4788	2.40	CY	0.4983	1.22	NL	0.4559	2.56	IE	0.4535	2.36	IE	0.8416	1.23	DE	0.4673	1.01
IT	0.4792	2.40	NL	0.5003	1.23	PT	0.4607	2.59	PT	0.4545	2.37	PT	0.8423	1.23	NL	0.4676	1.01
NL	0.4797	2.41	GR	0.5004	1.23	IE	0.4657	2.62	NL	0.4559	2.38	NL	0.8437	1.23	CY	0.4682	1.01
ES	0.4802	2.41	IE	0.5047	1.24	GR	0.4668	2.63	ES	0.4587	2.39	ES	0.8465	1.23	AT	0.4685	1.01
FR	0.4824	2.42	AT	0.5063	1.24	ES	0.4680	2.63	GR	0.4600	2.40	GR	0.8467	1.23	ES	0.4690	1.01
IE	0.4830	2.42	BG	0.5206	1.28	IT	0.4683	2.63	IT	0.4608	2.40	FR	0.8467	1.23	PT	0.4690	1.01
GR	0.4838	2.43	FI	0.5266	1.29	FR	0.4706	2.65	FR	0.4621	2.41	IT	0.8467	1.23	IT	0.4696	1.01

Averages	y	c	i	h	k	η
Core	0.3994	0.4925	0.3813	0.3839	0.7986	0.4666
Periphery	0.4804	0.4979	0.4634	0.4564	0.8441	0.4683
All	0.4399	0.4952	0.4224	0.4202	0.8213	0.4674

Data: Co-movement with output

	c		i		h		k
PT	-0.1622	AT	0.7483	FR	-0.0555	IE	-0.0366
CY	-0.0153	BG	0.8065	ES	0.0366	FR	0.0906
ES	0.1748	FR	0.8526	CY	0.1409	IT	0.2792
BG	0.3216	CY	0.8580	GR	0.3132	FI	0.2984
DE	0.5622	IE	0.8610	NL	0.3217	ES	0.3354
IE	0.6685	DE	0.8795	IE	0.3779	PT	0.3413
FR	0.7141	FI	0.8987	AT	0.3904	AT	0.4016
NL	0.7379	GR	0.9087	PT	0.5240	DE	0.4135
IT	0.7592	NL	0.9127	BG	0.5271	GR	0.4140
GR	0.7700	IT	0.9207	FI	0.5419	CY	0.4545
AT	0.8027	ES	0.9418	IT	0.5850	NL	0.5158
FI	0.8712	PT	0.9549	DE	0.5903	BG	0.6270

Averages	c	i	h	k
Core	0.6683	0.8497	0.3860	0.3912
Periphery	0.3658	0.9075	0.3296	0.2980
All	0.5171	0.8786	0.3578	0.3446

Case I: Co-movement with output

	c		i		h		k		
BG	0.6732	BG	0.9736	FR	0.6765	DE	-0.2003	FI	0.0048
AT	0.7471	FR	0.9787	IT	0.7466	AT	-0.1020	NL	0.0055
DE	0.7949	AT	0.9831	NL	0.8558	FI	-0.0652	IE	0.0068
FI	0.8542	IT	0.9846	PT	0.8676	IT	-0.0554	DE	0.0091
FR	0.9228	FI	0.9886	ES	0.8806	BG	-0.0488	CY	0.0110
IT	0.9575	DE	0.9892	BG	0.9055	ES	-0.0449	BG	0.0117
NL	0.9695	NL	0.9899	CY	0.9200	FR	-0.0445	AT	0.0148
PT	0.9841	PT	0.9919	GR	0.9483	GR	-0.0398	GR	0.0206
ES	0.9850	CY	0.9926	AT	0.9520	NL	-0.0305	IT	0.0216
CY	0.9880	GR	0.9938	IE	0.9598	PT	-0.0260	ES	0.0274
IE	0.9943	ES	0.9943	FI	0.9604	CY	-0.0222	FR	0.0284
GR	0.9947	IE	0.9954	DE	0.9752	IE	-0.0115	PT	0.0333

Averages	c	i	h	k	η
Core	0.8270	0.9839	0.8876	-0.0819	0.0124
Periphery	0.9839	0.9921	0.8872	-0.0333	0.0201
All	0.9054	0.9880	0.8874	-0.0576	0.0163

Case II: Co-movement with output

	c		i		h		k		
BG	0.7000	BG	0.9759	FR	0.7115	DE	-0.2011	FR	0.0931
AT	0.7920	FR	0.9842	IT	0.7827	AT	-0.0968	IT	0.0936
DE	0.8138	AT	0.9847	NL	0.8712	FI	-0.0609	NL	0.1656
FI	0.8622	IT	0.9884	BG	0.9127	IT	-0.0510	ES	0.1677
FR	0.9437	FI	0.9890	PT	0.9130	BG	-0.0465	BG	0.1763
IT	0.9602	DE	0.9902	ES	0.9191	ES	-0.0423	PT	0.2074
NL	0.9748	NL	0.9908	CY	0.9393	FR	-0.0416	AT	0.2438
CY	0.9919	CY	0.9929	AT	0.9570	GR	-0.0324	DE	0.3015
ES	0.9920	PT	0.9931	GR	0.9579	NL	-0.0270	CY	0.3101
PT	0.9926	GR	0.9933	IE	0.9612	PT	-0.0170	FI	0.3859
IE	0.9947	IE	0.9952	FI	0.9622	CY	-0.0168	GR	0.3892
GR	0.9965	ES	0.9956	DE	0.9782	IE	-0.0062	IE	0.5702

Averages	c	i	h	k	η
Core	0.8478	0.9858	0.8988	-0.0790	0.2277
Periphery	0.9880	0.9931	0.9122	-0.0276	0.2897
All	0.9179	0.9894	0.9055	-0.0533	0.2587

Case III: Co-movement with output

	c		i		h		k		
BG	0.6880	IT	0.7604	FR	0.6935	DE	-0.1985	NL	0.0053
AT	0.7797	NL	0.8587	IT	0.7604	AT	-0.1005	IE	0.0057
DE	0.8015	PT	0.9010	NL	0.8587	FI	-0.0599	FI	0.0063
FI	0.8600	CY	0.9267	PT	0.9010	IT	-0.0501	AT	0.0080
FR	0.9321	AT	0.9548	ES	0.9034	BG	-0.0445	GR	0.0082
IT	0.9631	BG	0.9742	BG	0.9086	FR	-0.0409	BG	0.0098
NL	0.9715	FR	0.9805	CY	0.9267	ES	-0.0402	ES	0.0100
PT	0.9869	FI	0.9884	AT	0.9548	GR	-0.0340	DE	0.0113
ES	0.9877	DE	0.9893	IE	0.9595	NL	-0.0271	IT	0.0131
CY	0.9893	GR	0.9932	FI	0.9601	PT	-0.0197	CY	0.0139
IE	0.9946	ES	0.9943	GR	0.9637	CY	-0.0173	FR	0.0150
GR	0.9960	IE	0.9952	DE	0.9770	IE	-0.0086	PT	0.0222

Averages	c	i	h	k	η
Core	0.8388	0.9577	0.8921	-0.0786	0.0093
Periphery	0.9863	0.9285	0.9025	-0.0283	0.0122
All	0.9125	0.9431	0.8973	-0.0534	0.0107

Table 15: Relative volatility, $x \equiv s_x/s_y$

	Data			Case I		
x	Core	Periphery	All	Core	Periphery	All
c	0.9339	0.7758	0.8548	0.4905	0.7385	0.6145
i	2.6575	3.4807	3.0691	2.2722	1.7123	1.9922
h	0.4223	0.2694	0.3458	0.4231	0.1903	0.3067
k	0.3430	0.4006	0.3718	0.3186	0.2709	0.2948
η	Na	Na	Na	0.0516	0.0588	0.0552
s_y	0.0161	0.0343	0.0252	0.0162	0.0343	0.0253

	Case II			Case III		
x	Core	Periphery	All	Core	Periphery	All
c	0.4896	0.7489	0.6192	0.4948	0.7557	0.6252
i	2.3124	1.7528	2.0326	2.3149	1.7444	2.0296
h	0.4141	0.1751	0.2946	0.4180	0.1776	0.2978
k	0.3244	0.2777	0.3011	0.3246	0.2765	0.3005
η	0.0367	0.0432	0.0399	0.0373	0.0446	0.0409
s_y	0.0162	0.0344	0.0253	0.0161	0.0342	0.0252

Table 16: Persistence, $\rho(x_t, x_{t-1})$

	Data			Case I		
x	Core	Periphery	All	Core	Periphery	All
y	0.4216	0.6786	0.5501	0.3986	0.4789	0.4387
c	0.4500	0.4508	0.4504	0.4906	0.4975	0.4940
i	0.4394	0.6598	0.5496	0.3813	0.4639	0.4226
h	0.2227	0.4685	0.3456	0.3862	0.4559	0.4210
k	0.7664	0.8443	0.8054	0.7983	0.8434	0.8208
η	Na	Na	Na	0.4669	0.4659	0.4664

	Case II			Case III		
x	Core	Periphery	All	Core	Periphery	All
y	0.3993	0.4811	0.4402	0.3994	0.4804	0.4399
c	0.4946	0.4996	0.4971	0.4925	0.4979	0.4952
i	0.3819	0.4645	0.4235	0.3813	0.4634	0.4224
h	0.3839	0.4556	0.4197	0.3839	0.4564	0.4202
k	0.7987	0.8440	0.8213	0.7986	0.8441	0.8213
η	0.4603	0.4668	0.4635	0.4666	0.4683	0.4674

Table 17: Contemporaneous co-movement with output, $\rho(y_t, x_{t+1})$

	Data			Case I		
x	Core	Periphery	All	Core	Periphery	All
c	0.6683	0.3658	0.5171	0.8270	0.9839	0.9054
i	0.8497	0.9075	0.8786	0.9839	0.9921	0.9880
h	0.3860	0.3296	0.3578	0.8876	0.8872	0.8874
k	0.3912	0.2980	0.3446	-0.0819	-0.0333	-0.0576
η	Na	Na	Na	0.0124	0.0201	0.0163

	Case II			Case III		
x	Core	Periphery	All	Core	Periphery	All
c	0.8478	0.9880	0.9179	0.8388	0.9863	0.9125
i	0.9858	0.9931	0.9894	0.9577	0.9285	0.9431
h	0.8988	0.9122	0.9055	0.8921	0.9025	0.8973
k	-0.0790	-0.0276	-0.0533	-0.0786	-0.0283	-0.0534
η	0.2277	0.2897	0.2587	0.0093	0.0122	0.0107

Appendix G

Impulse response functions

a. Greece

Table 8-I-GR: Reaction to a positive shock in A_t, Case I, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	1.11	1.15	1.19	1.33	1.37	1.12	0.68
c	0.81	0.87	0.93	1.18	1.31	1.29	0.69
k	0	0.15	0.29	0.88	1.30	1.39	0.78
i	2.12	2.08	2.04	1.82	1.57	1.39	0.67
h	0.18	0.17	0.15	0.09	0.04	0.01	0.00
η	0	0	0	0	0	0	0
ηh	0.18	0.17	0.15	0.09	0.04	0.01	-0.0019
$\frac{c}{y}$	-0.30	-0.28	-0.26	-0.15	-0.06	-0.02	0.0031
$\frac{y}{h}$	0.93	0.98	1.03	1.23	1.34	1.30	0.69
r^k	1.11	1.00	0.90	0.45	0.07	-0.08	-0.10
w	0.93	0.98	1.03	1.23	1.34	1.30	0.69

Table 8-II-GR: Reaction to a positive shock in A_t, Case II, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	1.11	1.15	1.19	1.33	1.38	1.32	0.68
c	0.83	0.90	0.96	1.20	1.33	1.30	0.69
k	0	0.16	0.30	0.90	1.32	1.41	0.78
i	2.19	2.14	2.09	1.86	1.58	1.39	0.67
h	0.17	0.15	0.14	0.08	0.03	0.01	-0.0016
η	0.02	0.02	0.02	0.01	0.0036	0.0013	0
ηh	0.19	0.17	0.16	0.09	0.04	0.01	-0.0018
$\frac{c}{y}$	-0.28	-0.26	-0.24	-0.14	-0.05	-0.02	0.003
$\frac{y}{h}$	0.94	1.00	1.05	1.25	1.35	1.31	0.69
r^k	1.11	1.00	0.90	0.44	0.06	-0.08	-0.10
w	0.93	0.98	1.04	1.24	1.35	1.31	0.69

Table 8-III-GR: Reaction to a positive shock in A_t, Case III

Variable	Periods						
	1	2	3	10	20	30	100
y	1.10	1.14	1.18	1.32	1.38	1.32	0.69
c	0.83	0.90	0.95	1.19	1.32	1.30	0.69
k	0	0.15	0.29	0.89	1.31	1.40	0.79
i	2.15	2.10	2.06	1.84	1.58	1.40	0.68
h	0.17	0.15	0.14	0.08	0.03	0.01	-0.0014
η	0	0	0	0	0	0	0
ηh	0.17	0.15	0.14	0.08	0.03	0.01	-0.0014
$\frac{c}{y}$	-0.27	-0.25	-0.23	-0.13	-0.05	-0.02	0.0023
$\frac{y}{h}$	0.93	0.99	1.04	1.24	1.34	1.31	0.69
r^k	1.10	0.99	0.89	0.44	0.06	-0.08	-0.10
w	0.93	0.99	1.04	1.24	1.35	1.31	0.69

Table 9-I-GR: Reaction to a positive shock in θ_t, Case I, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	-0.05	-0.06	-0.06	-0.06	-0.07	-0.06	-0.03
c	-0.04	-0.04	-0.04	-0.06	-0.06	-0.06	-0.03
k	0	-0.01	-0.01	-0.04	-0.07	-0.07	-0.04
i	-0.11	-0.11	-0.10	-0.09	-0.08	-0.07	-0.03
h	0.11	0.11	0.11	0.11	0.10	0.09	0.05
η	-0.20	-0.20	-0.20	-0.18	-0.17	-0.15	-0.07
ηh	-0.09	-0.09	-0.09	-0.08	-0.07	-0.06	-0.03
$\frac{c}{y}$	0.02	0.02	0.01	0.01	0.00	0.0019	0.00
$\frac{y}{h}$	-0.16	-0.17	-0.17	-0.17	-0.17	-0.16	-0.08
r^k	-0.05	-0.05	-0.04	-0.02	-0.0009	0.01	0.01
w	0.04	0.03	0.03	0.01	0.0006	0	0

Table 9-II-GR: Reaction to a positive shock in θ_t, Case II, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	-0.05	-0.05	-0.06	-0.06	-0.07	-0.06	-0.0326
c	-0.04	-0.04	-0.04	-0.06	-0.06	-0.06	-0.0325
k	0	-0.008	-0.015	-0.04	-0.07	-0.07	-0.04
i	-0.11	-0.11	-0.10	-0.09	-0.08	-0.07	-0.03
h	0.12	0.12	0.12	0.12	0.11	0.10	0.05
η	-0.21	-0.21	-0.21	-0.19	-0.18	-0.16	-0.08
ηh	-0.09	-0.08	-0.08	-0.08	-0.07	-0.06	-0.03
$\frac{c}{y}$	0.01	0.01	0.01	0.01	0.003	0.0016	0.0002
$\frac{y}{h}$	-0.18	-0.18	-0.18	-0.18	-0.17	-0.16	-0.08
r^k	-0.05	-0.05	-0.04	-0.02	-0.0002	0.01	0.0062
w	0.03	0.03	0.03	0.01	0.0001	-0.0044	-0.0041

Table 9-III-GR: Reaction to a positive shock in θ_t, Case III, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	-0.12	-0.13	-0.14	-0.17	-0.19	-0.18	-0.0973
c	-0.04	-0.06	-0.07	-0.12	-0.16	-0.16	-0.0889
k	0	-0.03	-0.06	-0.17	-0.25	-0.27	-0.15
i	-0.41	-0.40	-0.40	-0.35	-0.30	-0.27	-0.13
h	0.02	0.03	0.03	0.04	0.04	0.04	0.0211
η	-0.2215	-0.2193	-0.2171	-0.2044	-0.1848	-0.1672	-0.0827
ηh	-0.20	-0.19	-0.19	-0.17	-0.14	-0.13	-0.06
$\frac{c}{y}$	0.08	0.07	0.07	0.05	0.03	0.02	0.0084
$\frac{y}{h}$	-0.14	-0.15	-0.16	-0.21	-0.23	-0.22	-0.12
r^k	-0.23	-0.21	-0.19	-0.10	-0.0254	0.0041	0.0137
w	-0.03	-0.04	-0.05	-0.10	-0.13	-0.14	-0.08

Table 10-I-GR: Reaction to a positive shock in s_t^t, Case I, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	-0.06	-0.06	-0.06	-0.06	-0.05	-0.03	-0.0012
c	-0.03	-0.03	-0.04	-0.05	-0.04	-0.03	-0.0013
k	0	-0.01	-0.02	-0.06	-0.07	-0.05	-0.0023
i	-0.16	-0.15	-0.14	-0.10	-0.05	-0.03	-0.0007
h	0.10	0.10	0.09	0.07	0.05	0.03	0.0009
η	-0.20	-0.19	-0.18	-0.13	-0.08	-0.05	-0.0013
ηh	-0.10	-0.09	-0.09	-0.06	-0.03	-0.02	-0.0004
$\frac{c}{y}$	0.03	0.03	0.03	0.01	0.0026	-0.0005	-0.0001
$\frac{y}{h}$	-0.16	-0.16	-0.15	-0.13	-0.09	-0.06	-0.0021
r^k	-0.06	-0.05	-0.04	0.00	0.02	0.02	0.0011
w	0.04	0.03	0.03	0.00	-0.01	-0.01	-0.0007

Table 11-I-GR: Reaction to a positive shock in s_t^c, Case I, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	0.08	0.08	0.07	0.04	0.02	0.01	0.0001
c	-0.14	-0.14	-0.13	-0.11	-0.07	-0.05	-0.0015
k	0	-0.01	-0.01	-0.03	-0.03	-0.03	-0.0012
i	-0.08	-0.08	-0.07	-0.05	-0.03	-0.02	-0.0004
h	0.14	0.13	0.12	0.09	0.06	0.03	0.0010
η	0	0	0	0	0	0	0
ηh	0.14	0.13	0.12	0.09	0.06	0.03	0.0010
$\frac{c}{y}$	-0.23	-0.21	-0.20	-0.15	-0.09	-0.06	-0.0017
$\frac{y}{h}$	-0.05	-0.05	-0.05	-0.05	-0.04	-0.02	-0.0009
r^k	-0.05	-0.05	-0.05	-0.05	-0.04	-0.02	-0.0009
w	0.08	0.08	0.08	0.07	0.05	0.04	0.0013

Table 11-II-GR: Reaction to a positive shock in s_t^c, Case II, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	0.04	0.03	0.03	0.02	0.01	0.01	0.0001
c	-0.05	-0.05	-0.05	-0.04	-0.03	-0.02	-0.0005
k	0	-0.002	-0.003	-0.01	-0.01	-0.01	-0.0003
i	-0.02	-0.02	-0.02	-0.01	-0.01	-0.0041	-0.0001
h	0.05	0.05	0.05	0.04	0.02	0.01	0.0004
η	0.0061	0.0058	0.0055	0.0041	0.0025	0.0015	0
ηh	0.06	0.06	0.05	0.04	0.02	0.01	0.0004
$\frac{c}{y}$	-0.09	-0.09	-0.08	-0.06	-0.04	-0.02	-0.0006
$\frac{y}{h}$	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.0002
r^k	-0.02	-0.02	-0.02	-0.02	-0.0134	-0.01	-0.0003
w	0.04	0.04	0.03	0.03	0.02	0.01	0.0004

Table 11-III-GR: Reaction to a positive shock in s_t^c, Case III, GR

Variable	Periods						
	1	2	3	10	20	30	100
y	0.07	0.07	0.06	0.04	0.02	0.01	0.0001
c	-0.12	-0.12	-0.11	-0.09	-0.06	-0.04	-0.0012
k	0	-0.0048	-0.0089	-0.02	-0.03	-0.01	-0.0009
i	-0.07	-0.06	-0.06	-0.04	-0.02	-0.0125	-0.0003
h	0.12	0.11	0.11	0.08	0.05	0.03	0.0009
η	0	0	0	0	0	0	0
ηh	0.12	0.11	0.11	0.08	0.05	0.03	0.0009
$\frac{c}{y}$	-0.19	-0.18	-0.18	-0.13	-0.08	-0.05	-0.0014
$\frac{y}{h}$	-0.05	-0.05	-0.05	-0.04	-0.03	-0.02	-0.0007
r^k	-0.05	-0.05	-0.05	-0.04	-0.0306	-0.0207	-0.0007
w	0.07	0.07	0.07	0.06	0.05	0.03	0.0011

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Table 8-I-DE: Reaction to a positive shock in A_t, Case I

Variables				Periods			
	1	2	3	10	20	30	100
y	1.55	0.77	0.42	0.09	0.03	0.01	0.0000
c	0.40	0.33	0.29	0.15	0.05	0.02	0.0000
k	0	0.39	0.52	0.37	0.13	0.05	0.0000
i	4.81	2.00	0.80	-0.06	-0.02	-0.01	0.0000
h	0.81	0.31	0.09	-0.04	-0.01	-0.01	0.0000
η	0	0	0	0	0	0	0
ηh	0.81	0.31	0.09	-0.04	-0.01	-0.01	0.0000
c/y	-1.15	-0.44	-0.13	0.05	0.02	0.01	0.0000
y/h	0.74	0.46	0.32 0.13	0.05	0.02	0.0000	
r^k	1.55	0.37	-0.10	-0.27	-0.10	-0.04	0.0000
w	0.74	0.46	0.32	0.13	0.05	0.02	0.0000

Table 8-II-DE: Response to a positive shock in A_t, Case II

Variables				Periods			
	1	2	3	10	20	30	100
y	1.56	0.77	0.42	0.10	0.03	0.01	0.0000
c	0.40	0.34	0.29	0.15	0.05	0.02	0.0000
k	0	0.40	0.54	0.38	0.14	0.05	0.0000
i	4.96	2.05	0.81	-0.07	-0.03	-0.01	0.0000
h	0.82	0.31	0.09	-0.04	-0.01	-0.01	0.0000
η	0.0134	0.0050	0.0015	0	0	0	0
ηh	0.83	0.31	0.10	-0.04	-0.01	-0.01	0.0000
c/y	-1.16	-0.44	-0.13	0.06	0.02	0.01	0.0000
y/h	0.74	0.46	0.33	0.14	0.05	0.02	0.0000
r^k	1.56	0.37	-0.11	-0.28	-0.10	-0.04	0.0000
w	0.7298	0.4582	0.3277	0.1361	0.0490	0.0177	0.0000

Table 8-III-DE: Response to a positive shock in A_t, Case III

Variables	Periods						
	1	2	3	10	20	30	100
y	1.55	0.77	0.42	0.10	0.03	0.01	0.0000
c	0.40	0.33	0.29	0.15	0.06	0.02	0.0000
k	0	0.40	0.54	0.38	0.14	0.05	0.0000
i	4.95	2.05	0.81	-0.06	-0.03	-0.01	0.0000
h	0.82	0.31	0.09	-0.04	-0.01	-0.01	0.0000
η	0	0	0	0	0	0	0
ηh	0.82	0.31	0.09	-0.04	-0.01	-0.01	0.0000
c/y	-1.15	-0.43	-0.13	0.05	0.02	0.01	0.0000
y/h	0.73	0.46	0.33	0.14	0.05	0.02	0.0000
r^k	2	0.37	-0.12	-0.28	-0.10	-0.04	0.0000
w	0.73	0.46	0.33	0.14	0.05	0.02	0.0000

Table 9-I-DE: Reaction to a positive shock in θ_t, Case I

Variables	Periods						
	1	2	3	10	20	30	100
y	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.0062
c	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.0061
k	0	-0.0018	-0.0033	-0.01	-0.01	-0.01	-0.0077
i	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.0067
h	0.03	0.03	0.03	0.03	0.03	0.03	0.0131
η	-0.0500	-0.0495	-0.0490	-0.0461	-0.0417	-0.0377	-0.0187
ηh	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.0056
c/y	0.0036	0.0033	0.0030	0.0018	0.0009	0.0005	0.0002
y/h	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.0194
r^k	-0.01	-0.01	-0.01	-0.0033	0.0007	0.0020	0.0014
w	0.01	0.0049	0.0042	0.0016	-0.0003	-0.0009	-0.0007

Table 9-II-DE: Response to a positive shock in θ_t, Case II

Variables	Periods						
	1	2	3	10	20	30	100
y	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.0060
c	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.0059
k	0	0.00	0.00	-0.01	-0.01	-0.01	-0.0074
i	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.0065
h	0.03	0.03	0.03	0.03	0.03	0.03	0.0131
η	-0.0494	-0.0489	-0.0485	-0.0456	-0.0412	-0.0373	-0.0185
ηh	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.0054
c/y	0.00	0.00	0.00	0.00	0.00	0.00	0.0002
y/h	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.0191
r^k	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.0014
w	0.0054	0.0047	0.0041	0.0015	-0.0003	-0.0009	-0.0007

Table 9-III-DE: Response to a positive shock in θ_t, Case III

Variables	Periods						
	1	2	3	10	20	30	100
y	-0.03	-0.03	-0.03	-0.04	-0.04	-0.04	-0.0187
c	-0.01	-0.01	-0.02	-0.03	-0.03	-0.03	-0.0161
k	0	-0.01	-0.01	-0.04	-0.05	-0.06	-0.0299
i	-0.09	-0.08	-0.08	-0.07	-0.06	-0.05	-0.0263
h	0.01	0.01	0.01	0.01	0.01	0.01	0.0058
η	-0.0512	-0.0507	-0.0502	-0.0472	-0.0427	-0.0386	-0.0191
ηh	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.0133
c/y	0.02	0.02	0.02	0.01	0.01	0.01	0.0026
y/h	-0.04	-0.04	-0.04	-0.05	-0.05	-0.05	-0.0245
r^k	-0.05	-0.05	-0.04	-0.02	0.00	0.00	0.0029
w	-0.0081	-0.0105	-0.0126	-0.0212	-0.0261	-0.0261	-0.0138

Table 10-I-DE: Reaction to a positive shock in s_t^t, Case I

Variables	Periods						
	1	2	3	10	20	30	100
y	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.0002
c	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.0002
k	0	-0.0029	-0.0053	-0.01	-0.01	-0.01	-0.0004
i	-0.04	-0.03	-0.03	-0.02	-0.01	-0.01	-0.0002
h	0.03	0.03	0.03	0.02	0.01	0.01	0.0002
η	-0.050	-0.0475	-0.0451	-0.0332	-0.0200	-0.0119	-0.0003
ηh	-0.02	-0.02	-0.02	-0.01	-0.01	0.00	-0.0001
c/y	0.0076	0.0068	0.0061	0.0030	0.0008	0.0001	0.0000
y/h	-0.04	-0.04	-0.04	-0.03	-0.02	-0.01	-0.0004
r^k	-0.01	-0.01	-0.01	0.0012	0.0055	0.0051	0.0002
w	0.01	0.0051	0.0039	-0.0006	-0.0027	-0.0024	-0.0001

Table 10-II-DE: Response to a positive shock in s_t^t, Case II

Variables	Periods						
	1	2	3	10	20	30	100
y	0.00	0.00	0.00	0.00	0.00	0.00	0.0000
c	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
k	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
i	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
h	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
η	0	0	0	0	0	0	
ηh	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
c/y	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
y/h	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
r^k	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
w	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 10-III-DE: Response to a positive shock in s_t^t, Case III

Variables				Periods			
	1	2	3	10	20	30	100
y	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
c	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
k	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
i	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
h	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
η	0	0	0	0	0	0	0
ηh	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
c/y	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
y/h	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
r^k	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000
w	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 11-I-DE: Reaction to a positive shock in s_t^c, Case I

Variables				Periods			
	1	2	3	10	20	30	100
y	0.16	0.15	0.15	0.10	0.06	0.04	0.0009
c	-0.18	-0.17	-0.16	-0.13	-0.08	-0.05	-0.0014
k	0	-0.0038	-0.0070	-0.02	-0.02	-0.01	-0.0005
i	-0.05	-0.04	-0.04	-0.03	-0.01	-0.01	-0.0002
h	0.24	0.23	0.22	0.16	0.10	0.06	0.0016
η	0	0	0	0	0	0	0
ηh	0.24	0.23	0.22	0.16	0.10	0.06	0.0016
c/y	-0.3421	-0.3256	-0.3098	-0.2297	-0.1388	-0.0836	-0.0023
y/h	-0.08	-0.08	-0.07	-0.06	-0.04	-0.02	-0.0007
r^k	-0.08	-0.08	-0.07	-0.0586	-0.0382	-0.0240	-0.0007
w	0.16	0.1584	0.1530	0.1220	0.0795	0.0499	0.0015

Table 11-II-DE: Response to a positive shock in s_t^c, Case II

Variables	Periods						
	1	2	3	10	20	30	100
y	0.15	0.14	0.13	0.10	0.06	0.03	0.0009
c	-0.16	-0.15	-0.15	-0.11	-0.07	-0.04	-0.0012
k	0	0.00	-0.01	-0.01	-0.01	-0.01	-0.0004
i	-0.03	-0.03	-0.03	-0.02	-0.01	-0.01	-0.0002
h	0.22	0.21	0.20	0.15	0.09	0.05	0.0015
η	0.0036	0.0034	0.0032	0.0024	0.0014	0	0
ηh	0.22	0.21	0.20	0.15	0.09	0.05	0.0015
c/y	-0.31	-0.29	-0.28	-0.21	-0.12	-0.07	-0.0021
y/h	-0.07	-0.07	-0.06	-0.05	-0.03	-0.02	-0.0006
r^k	-0.07	-0.07	-0.07	-0.05	-0.03	-0.02	-0.0006
w	0.1497	0.1443	0.1390	0.1092	0.0701	0.0437	0.0013

Table 11-III-DE: Response to a positive shock in s_t^c

Variables	Periods						
	1	2	3	10	20	30	100
y	0.16	0.15	0.14	0.10	0.06	0.03	0.0009
c	-0.17	-0.16	-0.16	-0.12	-0.08	-0.05	-0.0013
k	0	0.00	-0.01	-0.02	-0.02	-0.01	-0.0005
i	-0.04	-0.04	-0.04	-0.03	-0.01	-0.01	-0.0002
h	0.24	0.22	0.21	0.16	0.10	0.06	0.0016
η	0	0	0	0	0	0	0
ηh	0.24	0.22	0.21	0.16	0.10	0.06	0.0016
c/y	-0.33	-0.31	-0.30	-0.22	-0.13	-0.08	-0.0022
y/h	-0.08	-0.07	-0.07	-0.06	-0.04	-0.02	-0.0007
r^k	-0.0763	-0.0737	-0.0712	-0.0565	-0.0366	-0.0229	-0.0007
w	0.16	0.15	0.15	0.12	0.08	0.05	0.0014

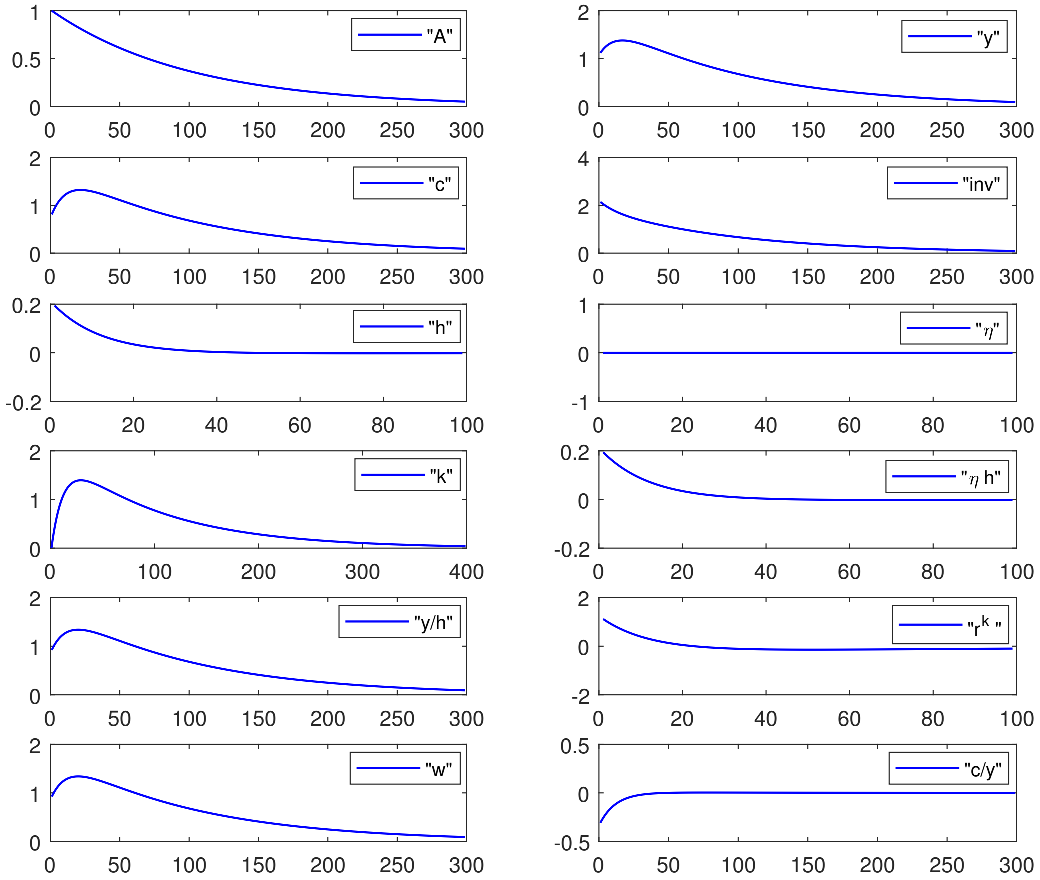

Figure 5: Case I - response to total factor productivity shock (A_t)

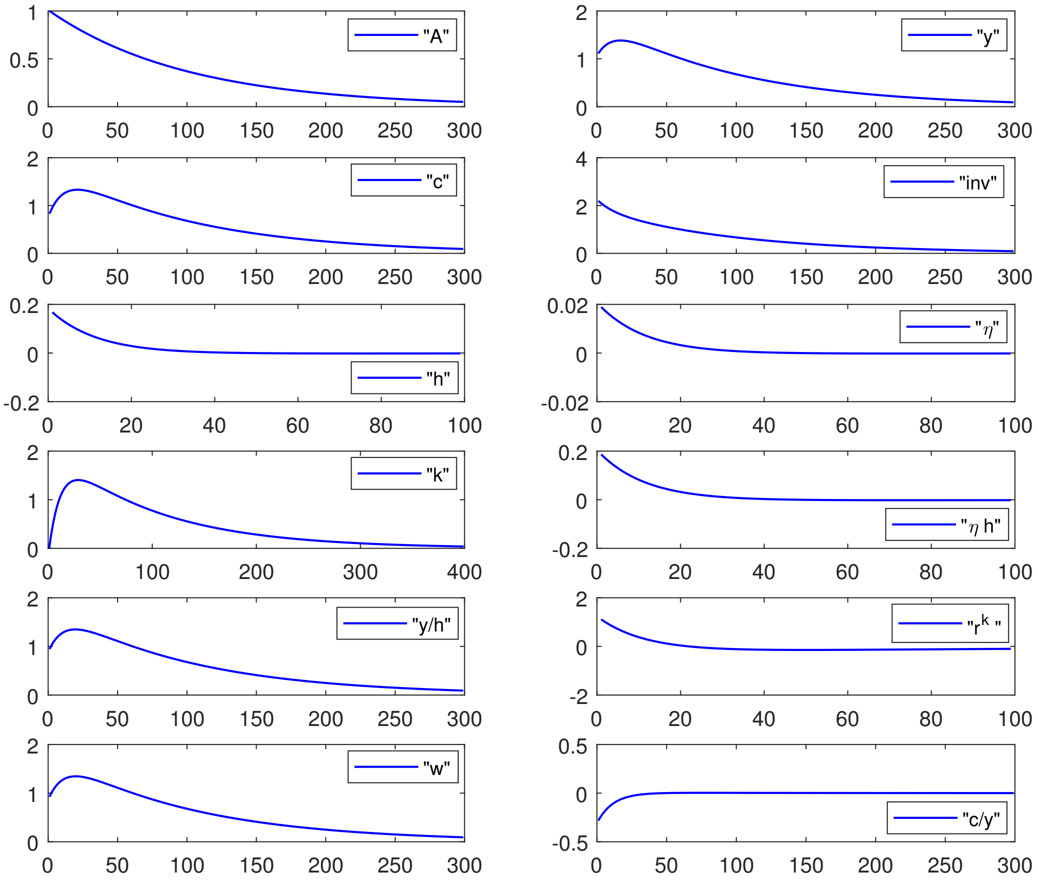

Figure 6: Case II - response to total factor productivity shock (A_t)

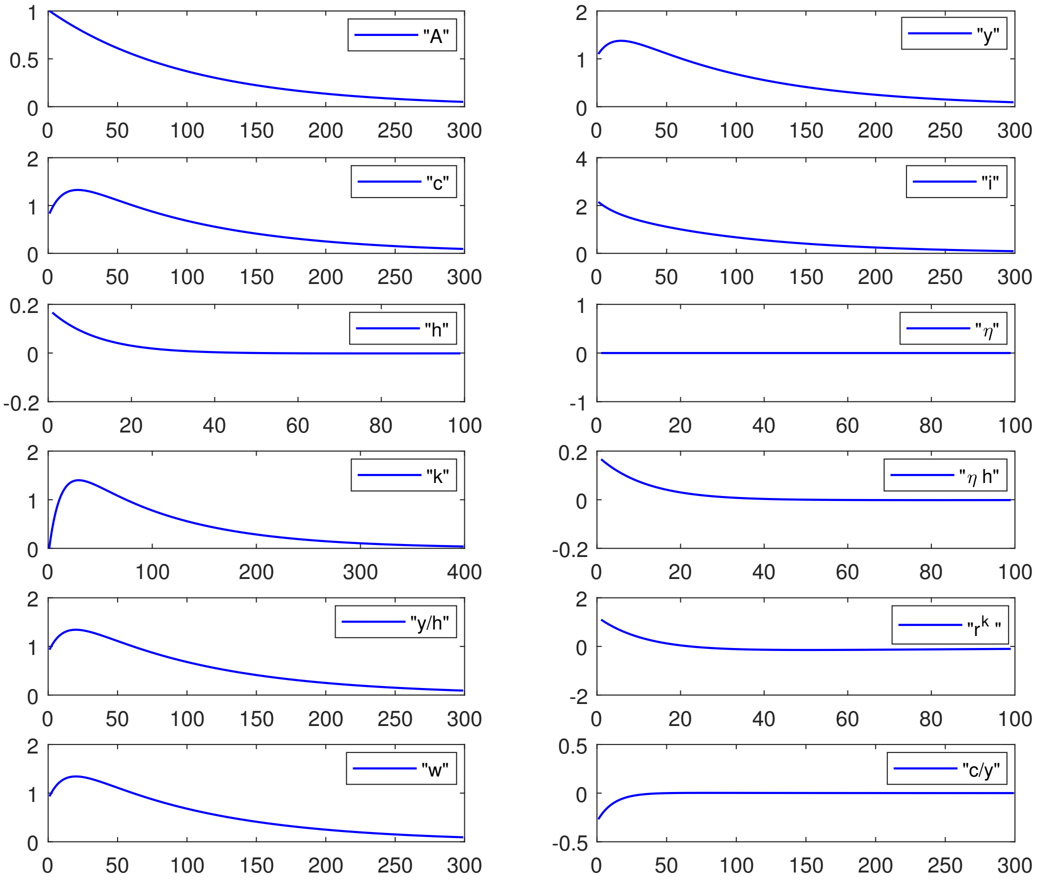

Figure 7: Case III - response to total factor productivity shock (A_t)

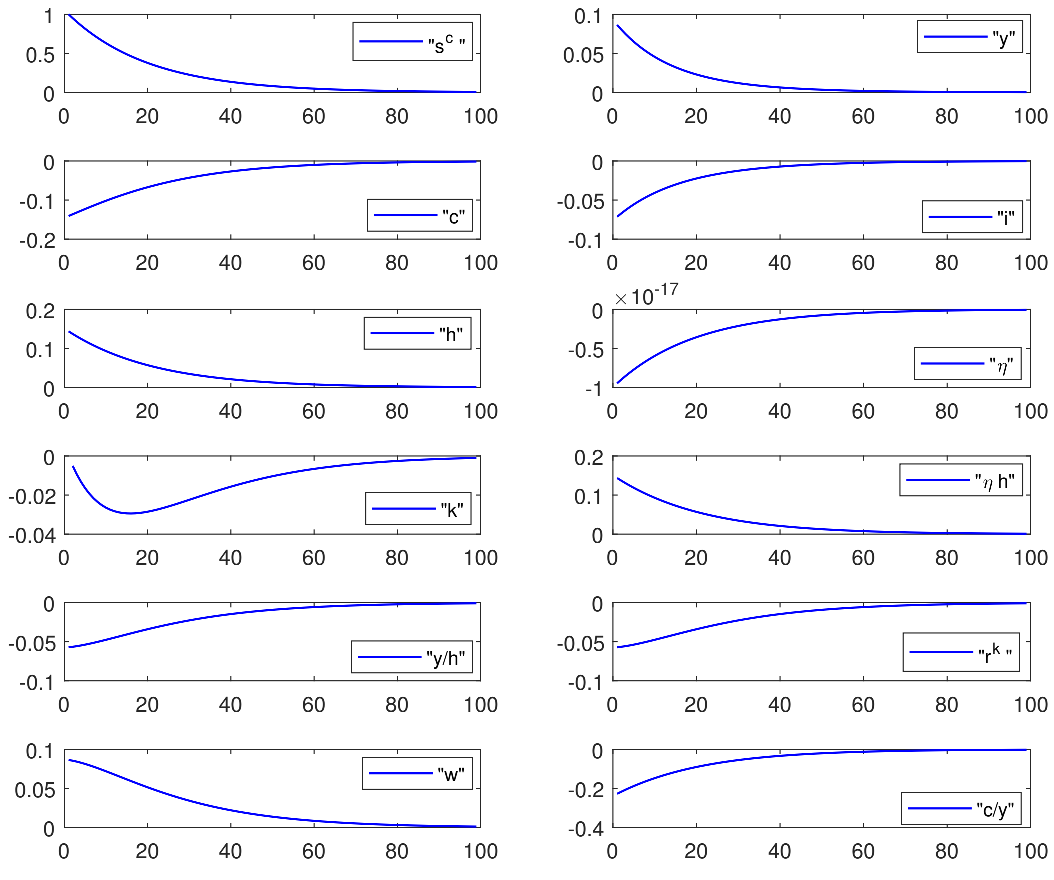

Figure 8: Case I - response to a government consumption shock (s_t^c)

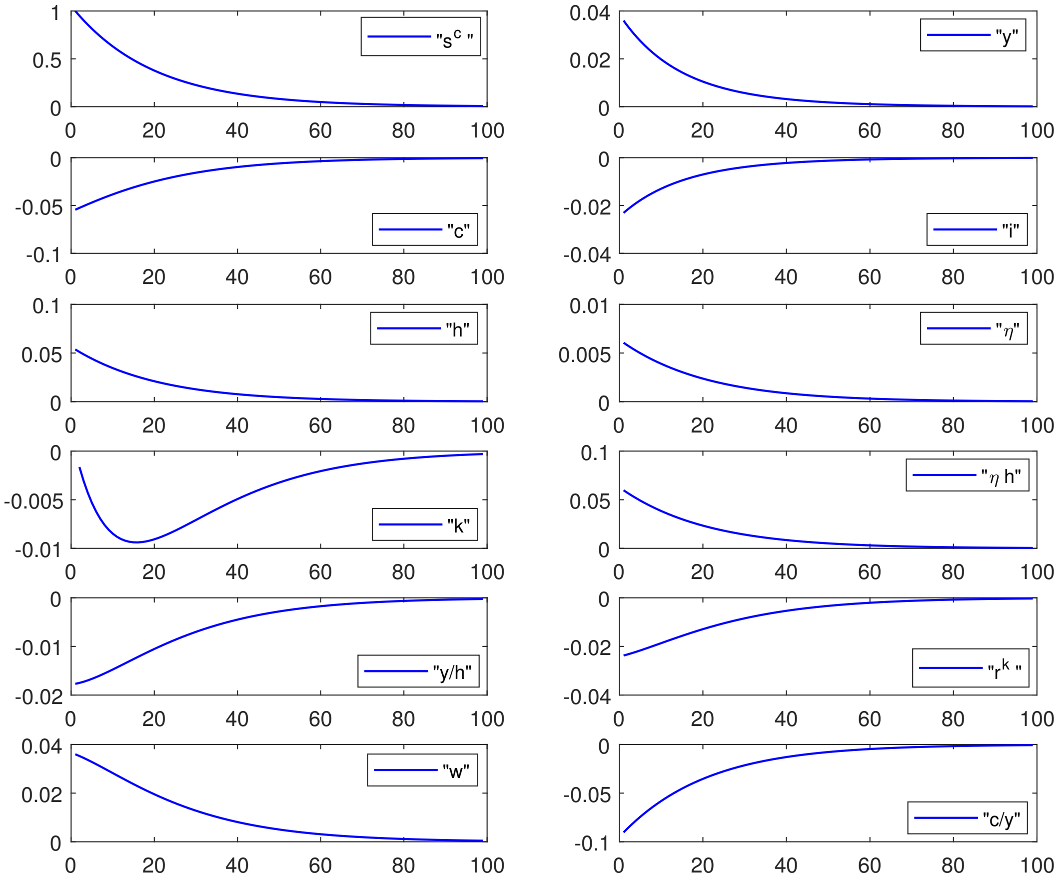

Figure 9: Case II - response to a government consumption shock (s_t^c)

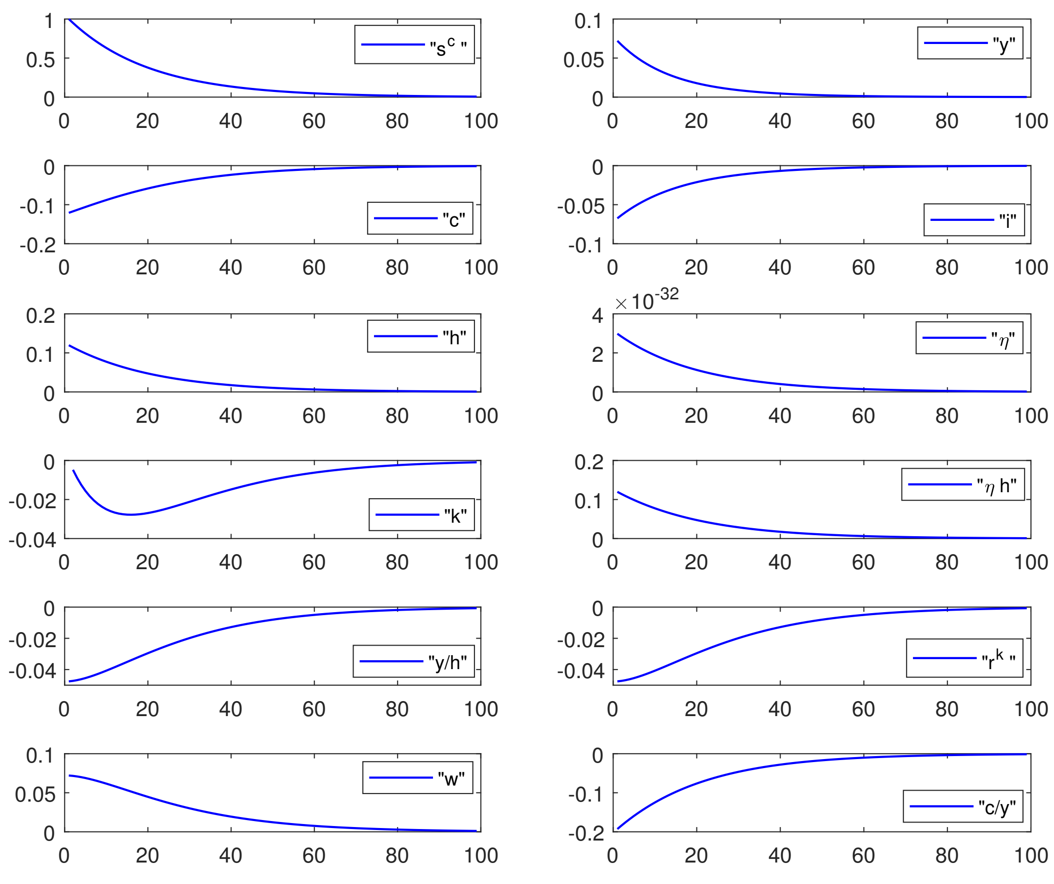

Figure 10: Case III - response to a government consumption shock (s_t^c)

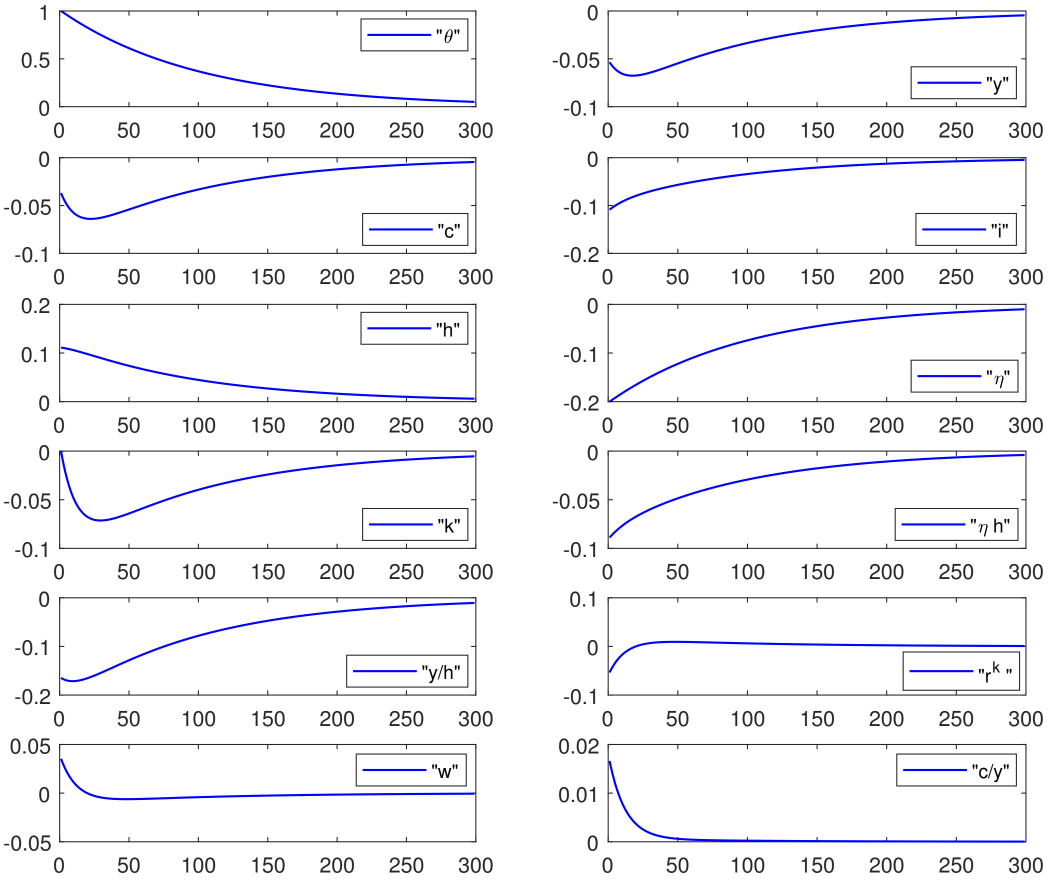

Figure 11: Case I - response to a shock institutions (θ_t)

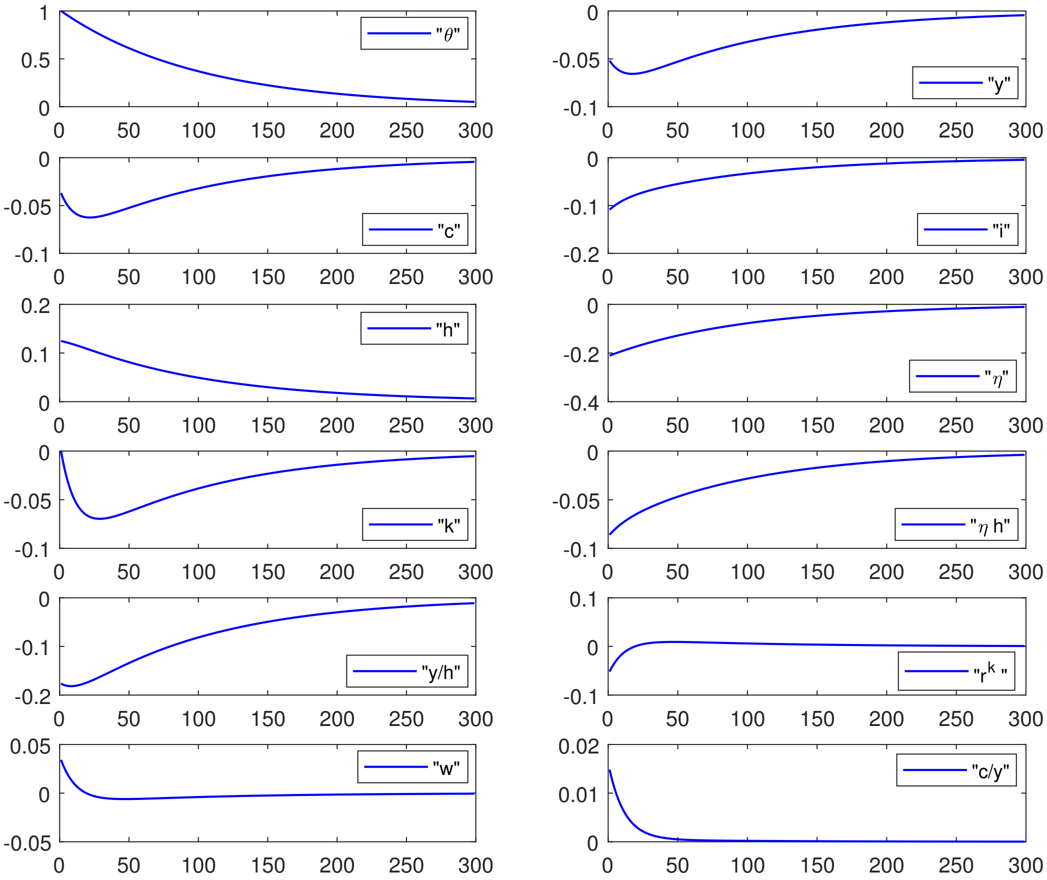

Figure 12: Case II - response to a shock institutions (θ_t)

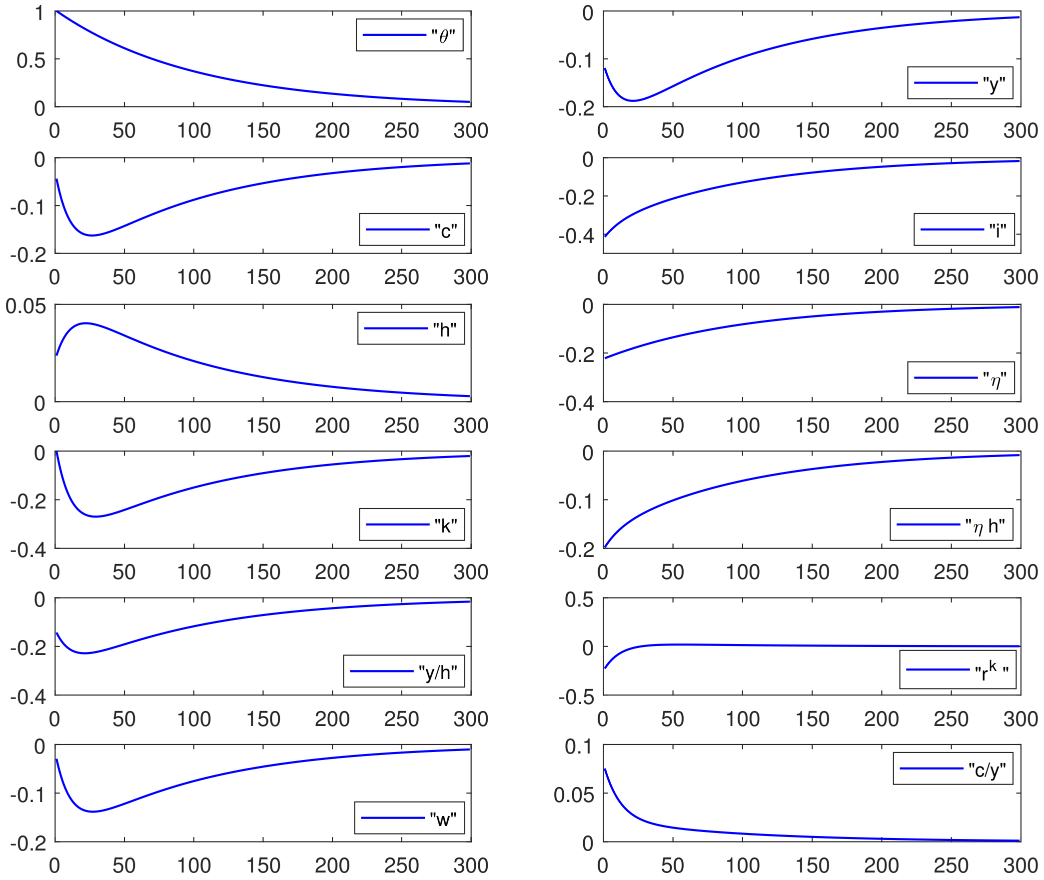

Figure 13: Case III - response to a shock institutions (θ_t)

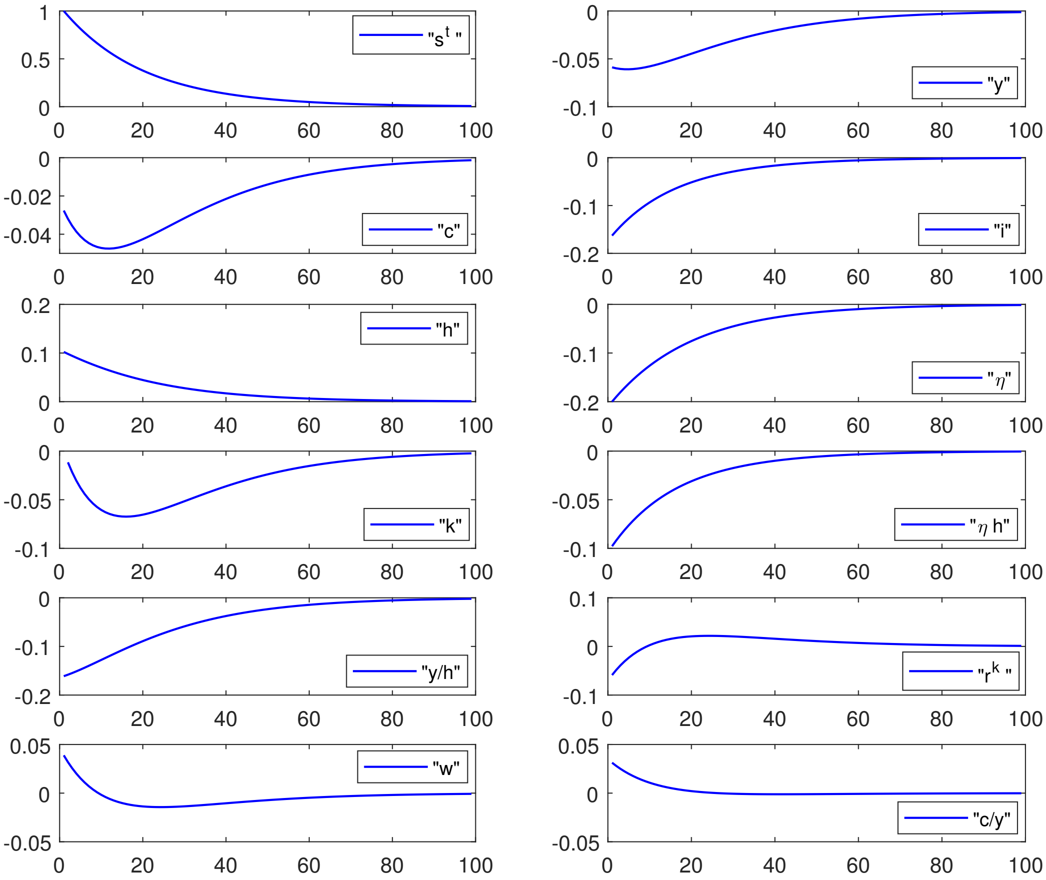

Figure 14: Case I - response to a government transfers shock (s_t^t)

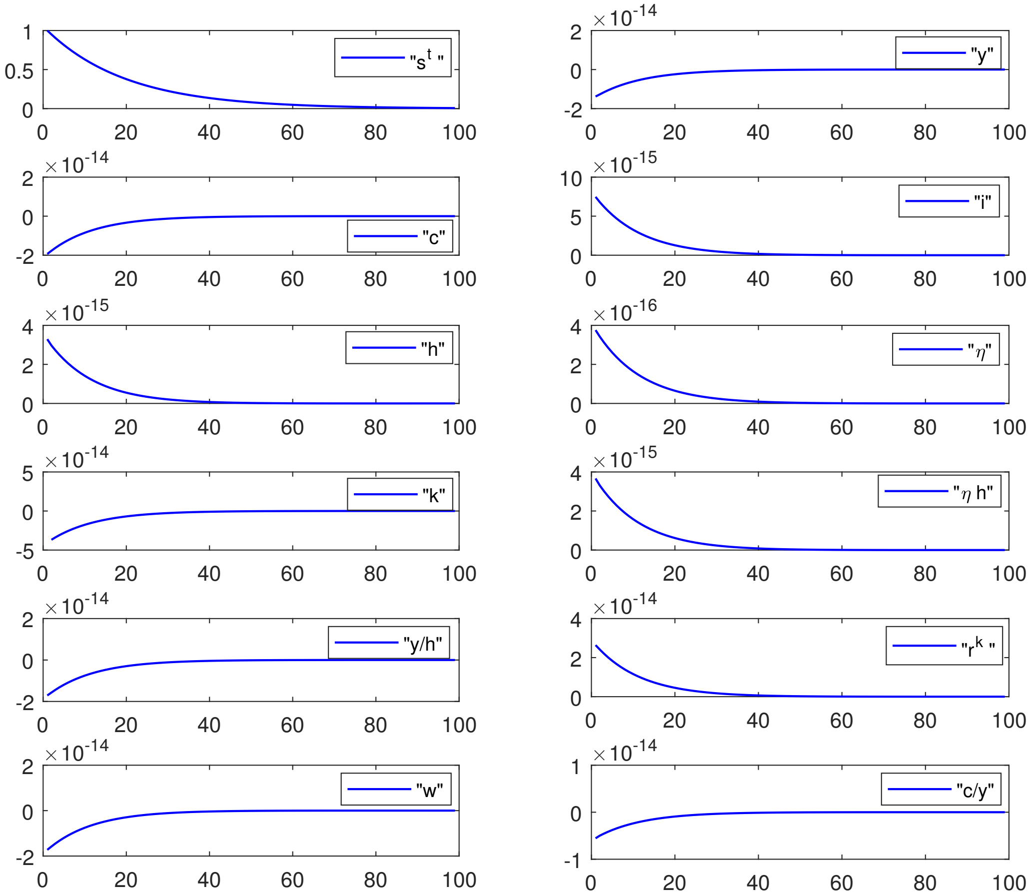

Figure 15: Case II - response to a government transfers shock (s_t^t)

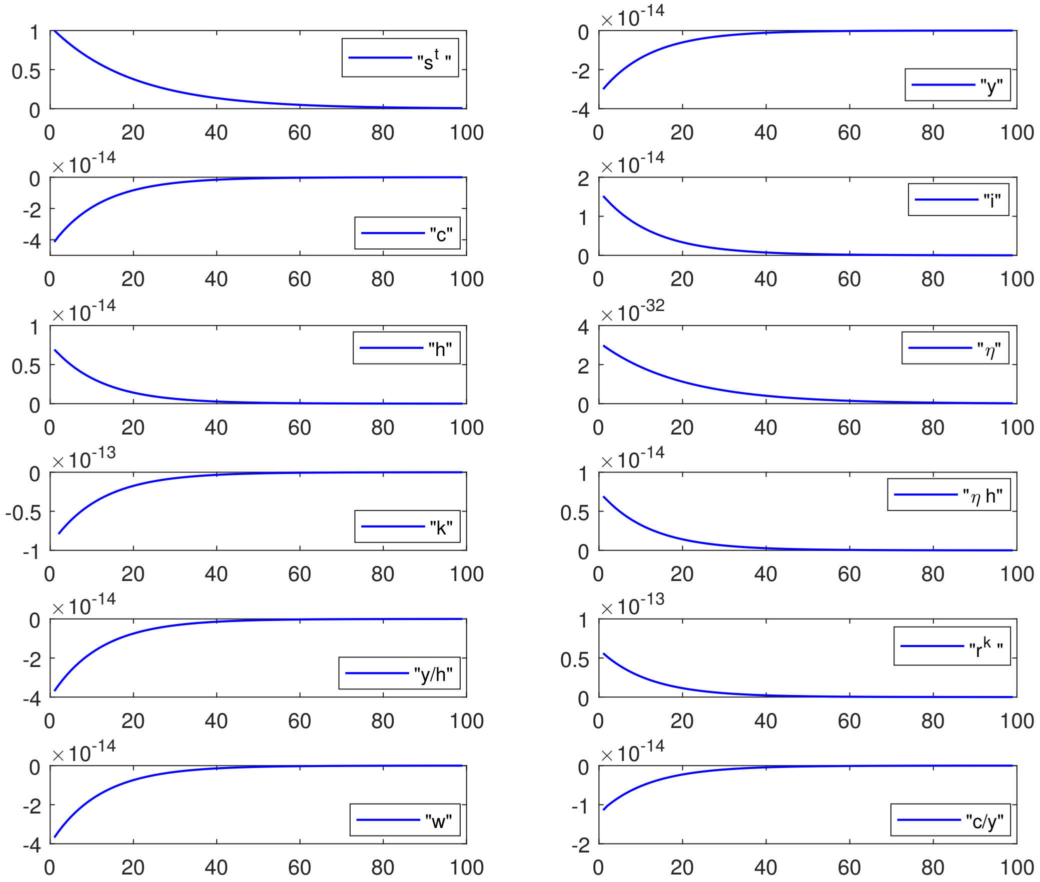

Figure 16: Case III - response to a government transfers shock (s_t^t)

Appendix H

Data

We consider the following two two sets of countries: a) Core countries, consisting of Austria (AT), Belgium (BG), Germany (DE), France (FR), Finland (FI), Netherlands (NL) and b) Periphery countries, consisting of Cyprus (CY), Greece (GR), Ireland (IR), Italy (IT), Portugal (PT) and Spain (ES). Data are of annual frequency and cover the period 2001-2016. Our main data source for macroeconomic variables is Eurostat. We also use data from the Total Economy Database, the St. Louis FED and AMECO, the International Country Risk Guide from the PRS Group and the World Governance Indicators from the World Bank.

To find the share of hours at work in available time, h_t, we use the ratio of the 'annual hours worked per worker' series to the 'total available time per worker' from the Total Economy Database.[6] We use the 'Net Capital stock' series from AMECO for real capital in our model. For the calibration of the depreciation rate, δ we series on real capital and real gross fixed capital formation from AMECO and the law of motion of capital , $K_{t+1} = (1 - \delta)K_t + I_t$.[7]

Table 40: Data

Code	Variable	Unit	Source
D.1	Gross domestic product	Millions of euros	Eurostat
D.2	Gross domestic product	Millions of 2010 euros	Eurostat
D.3	Final consumption expenditure	Millions of euros	Eurostat
D.4	Gross fixed capital formation	Millions of euros	Eurostat, AMECO
D.5	Consumption of fixed capital	Millions of euros	Eurostat
D.6	Net capital stock	Millions of 2010 euros	AMECO
D.7	Exports of goods and services	Millions of euros	Eurostat
D.8	Imports of goods and services	Millions of euros	Eurostat
D.9	Final consumption expenditure of	Millions of euros	Eurostat
D.10	general government		
D.11	Gross fixed capital formation of	Millions of euros	Eurostat
D.12	general government		
D.13	Social benefits other than social transfers	Millions of euros	Eurostat
D.14	in kind and social transfers in kind		
	purchased market production, payable		
D.15	Population	Thousands of people	TED
D.16	Annual hours worked per worker	Hours	TED
D.17	Total annual hours worked	Hours	TED
D.18	EMU convergence criterion bond yields	Rate	Eurostat
D.19	Total factor productivity (USA=1)	Index	St. Louis FED
D.20	Composite Risk Rating	Index	ICRG, PRS Group

To match the variables of our closed economy model for each case of contestable prize with the variables observed in the data we follow usual practise (e.g. see Kehoe and Prescott (2002, 2007) and Conesa et al. (2007)), and define output in our model to be the real gross domestic product

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[6] Total available time per worker is calculated as 52 weeks x 14 hours x 7 days.

[7] We use the GDP deflator to transform nominal variables to real variables.

in the data. We also allocate real net exports to real consumption in the data, and investment and capital in our model to be total investment and total capital respectively in the data.[15]

Table 41: Taking the model to the data

Code	Description	Variable
$DC.1 = I_t$	Total investment	$I_t = D.4\frac{D.1}{D.2}$
$DC.2 = C_t$	Total consumption	$C_t = [D.2 + (D.7 - D.8)]\frac{D.1}{D.2}$
$DC.3 = H_t$	Hours at work	$H_t = \frac{D.16}{52\times14\times7}$

Table 42: Data averages, 2001-2016

	Countries											
Variable	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
h	0.31	0.27	0.36	0.41	0.34	0.30	0.35	0.36	0.28	0.33	0.37	0.33
$\frac{c}{y}$	0.54	0.61	0.60	0.60	0.56	0.54	0.61	0.63	0.55	0.57	0.59	0.55
$\frac{i}{y}$	0.22	0.20	0.24	0.19	0.25	0.22	0.20	0.20	0.20	0.23	0.20	0.22
$\frac{k}{y}$	2.65	2.95	2.49	3.78	3.33	2.96	3.12	2.40	2.80	3.45	2.95	2.91

Note h: hours at work, $\frac{c}{y}$: consumption to output ratio, $\frac{i}{y}$: investment to output ratio
$\frac{k}{y}$: capital to output ratio

Table 43: Policy instruments: 2001-2016

	Countries											
Policy instrument	BE	DE	IE	GR	ES	FR	IT	CY	NL	AT	PT	FI
τ^c	0.21	0.19	0.24	0.18	0.16	0.21	0.17	0.21	0.23	0.22	0.20	0.27
τ^y	0.45	0.37	0.23	0.28	0.32	0.42	0.43	0.24	0.34	0.39	0.27	0.42
s^t	0.23	0.24	0.13	0.19	0.16	0.24	0.21	0.12	0.20	0.22	0.17	0.19
s^c	0.23	0.19	0.16	0.20	0.19	0.23	0.19	0.17	0.24	0.20	0.20	0.23

Note τ^c: effective tax rate on consumption, τ^y: effective tax rate on total income
s^t: share of government transfers to GDP, s^c: share of government consumption to GDP

To calibrate the value of η_t, needed for the calibration of θ_0, we follow usual practice used in the construction of many ICRG indices and rank and assign each country to a group of countries according to the rank of the Composite Risk Rating of the ICRG index. Then we assign values of η for each country according to their ranked group.

Effective tax rates

We construct the effective tax rates of consumption, τ^c, and of total income, τ^y, following Mendoza et al. (1994) and Papageorgiou et al. (No. 235, BoG, 2017).[8]

Tax rate on personal income

$$\tau^h = \frac{HY}{(WSSE - SSCH - SSCER) + (GOSMIH - CFCH) + (IYRH - IYPH)} \tag{30}$$

Effective tax rate on employed labor income

$$\tau^l = \frac{\tau^h(WSSE - SSCH - SSCER) + SSCH + SSCER}{WSSE} \tag{31}$$

Effective tax rate on capital income

$$\tau^k = \frac{\tau^h(GOSMIH - CFCH + IYRH - IYPH) + CAPT}{GOSMIT - CFCT} \tag{32}$$

where $CAPT = TFCT + CAT + TLG + (OTP - TLBS - TWP) + STAMP + CTC + OTPN + CORY$ are capital income tax revenue.

Effective tax rate on consumption

$$\tau^c = \frac{CT}{HC + GIC - CT} \tag{33}$$

where CT = TP - STAMP - TLG - OTP are total tax revenue from indirect taxation.

where HY: taxes on individual or household income including holding gains, WSSE: compensation of employees, SSCH: households' actual social security contributions, SSCER: employers' actual social security contributions, GOSMIH: gross operating surplus and mixed income of households, CFCH: consumption of fixed capital of households, IYRH: interest income received by households, IYPH: interest income paid by households, HC: household and NPISH final consumption expenditure, GIC: government intermediate consumption.

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[8] The effective tax rate of total income is a weighted average of the effective tax rates on employed labor income and the effective tax rate on capital income.