

# A STOCHASTIC DYNAMIC GENERAL EQUILIBRIUM MODEL FOR GREECE

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Discussion Paper No. 1518  
November 1996

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## ABSTRACT

### A Stochastic Dynamic General Equilibrium Model for Greece\*

In this paper we develop a stochastic dynamic general equilibrium model of the Greek economy, in the real business cycle modelling tradition. Household preferences depend on private and public consumption and leisure. Government finances its investment, consumption and transfer payments by means of a proportional income tax rate. Households buy and sell foreign assets in an international capital market and also receive transfer payments from abroad. The volatility, persistence, and co-movement properties of the business cycle component of the data generated by the model are broadly consistent with the actual behaviour of the corresponding actual data of the Greek economy, in 1960–92. We use the model to investigate the response of major macroeconomic variables to temporary and permanent changes in government policy variables, foreign transfers and the rate of return on foreign assets.

JEL Classification: E1, E3, E6, F3

Keywords: growth, business cycles, taxes, small open economy

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\*This paper is produced as part of a CEPR research programme on *Globalization and Regionalism: Policy-making in a Less National World*, supported by a grant from the Ford Foundation (no. 920–1265–1). We are grateful to Evi Pappa for expert research assistantship, to the European Union for financial support (HCM grants: CHRX–CT94–0458, CHRX–CT94–0465 and CHRX–CT94–0658), and to seminar audiences at IMOII, the 1996 Annual

Meetings of the Society for Economic Dynamics and Control at Mexico City, the 1996 EEA Summer School on Computational Methods for the study of Dynamic Economics at the EUI and the 1996 HCM Workshop at Matagne-la-Petite, for helpful comments.

Submitted 15 October 1996

## NON-TECHNICAL SUMMARY

In several recent empirical papers on the business cycle properties of various OECD economies over the last 40 years or so, Lucas' (1977) conjecture that the business cycle has more or less the same pattern across countries has been validated. On the other hand, the theoretical business cycle literature has been characterized by the great success of the so-called real business cycle (RBC) models in accounting for most major stylized facts of business cycles in the United States. These two outcomes suggest that RBC models could be used to study the business cycles of other OECD countries as well. Despite some notable exceptions for Canada, France, and Portugal, however, this has not been the case so far. The reasons that are typically mentioned for the reluctance of researchers to adapt RBC models to study the business cycles of other OECD countries are:

- I. The lack of appropriate and/or reliable data.
- II. The notion that most OECD economies other than the United States should be modelled as small open economies and, in several cases, with capital market imperfections.
- III. The notion that in most OECD economies other than the United States, the role of the public sector is crucial in the workings of the economy.
- IV. The great differences observed in labour market behaviour.

In this paper, we build an RBC model for a country that: is thought to have problems with (I) above; is typically modelled as a small open economy; has a public sector which for the last three decades amounts to about one-third of its GDP; and has a labour market that is believed to be heavily influenced by the annual contract between an umbrella labour union ( $\Gamma\Sigma\text{EE}$ ) and an industry guild ( $\Sigma\text{EB}$ ) – Greece.

Our first objective is to investigate whether an RBC-type model that tries to capture these features has any success in accounting for the stylized facts of business cycles of post-war Greece. Thus, we develop an RBC model for Greece that is calibrated on several stylized facts of economic growth from 1960 to 1992. Household preferences depend on private and public consumption and leisure. Government finances its consumption, invests in capital, and engages in transfer payments to the private sector by way of a proportional income tax. An international capital market exists where

households can buy and sell foreign assets. Households also receive transfer payments from abroad.

The second objective of the paper is to investigate, if the descriptive power of the model allows, the response of the Greek economy to various changes in government policy and transfers from abroad. In this model government policy changes are not neutral since they affect the effective income tax rate, introducing incentive effects for capital accumulation and work effort. Thus, one of the questions we are interested in is whether the increase in government consumption and domestic transfer payments, and the decrease in government investment along with the increased foreign transfers that characterized the economy over the last 20 years, affected output, consumption, investment, work, etc. Other than applying the model to the Greek economy, our contribution lies with the fact that unlike Mendoza (1991), we model the public sector. And, unlike Correia *et al* (1995), we do not assume lump-sum taxes. The latter assumption would have greatly simplified the solution to the model.

Our simple model does quite well in reproducing several of the key stylized facts of the Greek business cycle. One source of the problems that remains is the fact that foreign transfers are assumed (as a tractable device to solve the model) proportional to GDP, which they are not. One of the surprising properties of the model is that it is consistent with what some believe to be an idiosyncrasy of the Greek economy – the fact that increases in foreign transfers lead to less output and work and more consumption and foreign investment.

The effects of both temporary and permanent increases in total factor productivity are the typical responses found in RBC models. The response of an increase in the GDP share of foreign transfers increases consumption, foreign assets and the trade balance, and decreases work, investment output and both private and public capital. The main effect of a decline in the international interest rate is to reduce foreign asset holdings and the trade balance and to increase domestic private investment.

Our model predicts that increases in the GDP share of government consumption have adverse effects on output and the factors of production and tend to increase foreign asset holdings. As can be seen from the impulse response function diagrams, a 1% permanent increase in the GDP share of government consumption leads to an 8% fall in output. Increases in the GDP share of government investment increase output and the factors of production and lower foreign asset holdings. The response of an increase in the GDP

share of domestic transfers is qualitatively similar, but quantitatively smaller, to an increase in the GDP share of government consumption.

Thus our model suggests that the increases in the shares of government consumption, and foreign and domestic transfers over the last 20 years have worked to reduce the performance of the Greek economy both with respect to its steady state and its transition to it (see Kollintzas and Vassilatos (1996)). The primary mechanisms behind this result are the distortions on the incentives to save and work.

Although our model's prediction for the volatility, persistence and co-movement properties of the key macroeconomic variables were insensitive to the value of  $\theta$ , this was not the case for the impulse response functions (especially for labour).

The transition towards the steady state was captured by choosing the appropriate initial values. In future work it would be interesting to calibrate the economy in two periods (before and after 1974) thus achieving a closer fit with real data characteristics. Presumably, the model would be able to better account for most of these stylized facts if we calibrated the model in two steady states, each being associated with a different set of values for the tax policy variables, and then follow the usual procedure.

## 1. Introduction

In several recent empirical papers on the business cycle properties of various OECD economies over the last forty or so years (See, e.g., Kydland and Prescott (1990), Backus and Kehoe (1992), Danthine and Donaldson (1993), Fiorito and Kollintzas (1994) and Christodoulakis, Dimelis and Kollintzas (1995)), Lucas' (1977) conjecture that the business cycle has more or less the same pattern across countries has been validated. On the other hand, the theoretical business cycle literature has been characterized by the great success of the so-called real business cycle (RBC) models (See, e.g., Kydland and Prescott (1982, 1988, 1991), Hansen (1985), Greenwood, Hercowitz, and Huffman (1988), King, Plosser, and Rebelo (1988), Benhabib, Rogerson, and Wright (1991), Backus, Kehoe, and Kydland (1992), Baxter and King (1993), Baxter and Crucini (1993), and McGrattan (1994).) in accounting for most major stylized facts of business cycles in the United States. These two outcomes would suggest that RBC models would be used to study the business cycles of other OECD countries as well. However, despite some notable exceptions (e.g., Mendoza (1991) for Canada; Bruno and Portier (1995) for France, and Correia, Neves and Rebelo (1995) for Portugal) this has not, so far, been the case. The reasons that are typically mentioned for the reluctance of researchers to adapt RBC models to study the business cycles of other OECD countries are:

- (i) The lack of appropriate and/or reliable data.
- (ii) The notion that most OECD economies other than that of the United States should be better modeled as «small open economies» and, in several cases, with capital market imperfections (See, e.g., Mendoza (1991, p.815)).
- (iii) The notion that in most OECD economies other than that of the United States the role of the public sector is crucial in the workings of the economy.
- (iv) The great differences observed in labor market behavior (See, e.g., Danthine and Donaldson (1993, pp.29-30) and Fiorito and Kollintzas (1994, p.259-260)).

In this paper, we build an RBC model for a country that is thought to have problems with (i), typically modeled like a «small open economy», has a public sector which for the last three decades amounts to about one third of its GDP, and its labor market is believed to be heavily influenced by the annual contract (See, e.g., Petrakis and Vlassis (1996).) between an umbrella labor union ( $\Gamma\Sigma\text{EE}$ ) and an industry guild ( $\Sigma\text{EB}$ ) - Greece. Our first objective is to investigate whether an RBC - type model that tries to capture these features has any success in accounting for the stylized facts of business cycles of post war Greece. Thus, we develop an RBC model for Greece that is calibrated on several stylized facts of economic growth from 1960 to 1992. Household preferences depend on private and public consumption and leisure. Government finances its consumption and makes investment in capital, engages in transfer payments to the private sector by way of a proportional income tax. An international capital market exists where

households can buy and sell foreign assets. Households also receive transfer payments from abroad.

The second objective of the paper is to investigate, if the descriptive power of the model allows, the response of the Greek Economy to various changes in government policy and transfers from abroad. In this model government policy changes are not neutral since they affect the effective income tax rate introducing incentive effects for capital accumulation and work effort. Thus, one of the questions we are interested is whether the increase in government consumption and domestic transfers payments and the decrease in government investment along with the increased foreign transfers that characterized the economy over the last twenty years affected output, consumption, investment, work, etc. Other than the application to the Greek economy, our contribution lies with the fact that unlike Mendoza (1991), we do model the public sector. And, unlike Correia et al. (1995), we do not assume lump sum taxes. The latter assumption would have greatly simplified the solution to the model.

The plan of the paper is as follows: Section 2 presents the model. Section 3 defines and solves for the competitive equilibrium and characterizes the steady state growth path. Section 4 calibrates the model and looks at the descriptive power of the simulated data. Section 5 discusses the results from the investigation of the response of major macroeconomic variables to temporary and permanent changes in government policy, foreign transfers, and return on foreign assets. Section 6 concludes the paper.

## 2. The Model

The economy is populated by a large number of identical households,  $N_t$ , who act as price takers in the fully competitive markets in which they interact. Population grows according to the deterministic law of motion:

$$N_{t+1} = \gamma_n N_t ; \quad \gamma_n \geq 1, \quad N_0 > 0. \quad (1)$$

### 2.1 Preferences

Household preferences are characterized by the lifetime utility function:

$$\sum_{t=0}^{\infty} \beta^{*t} u(C_t, L_t); \quad \beta^* \in (0,1); \quad (2)$$

where:

$$C_t = C_t^p + \vartheta C_t^s ; \quad \vartheta \in [-1,1]; \quad (3)$$

and

$$u(C,L) = \frac{(C^\gamma L^{1-\gamma})^{1-\sigma} - 1}{1-\sigma}; \quad \gamma \in [0,1], \quad \sigma \geq 0 \quad (4)$$



$C_t^p$  is aggregate private consumption in period  $t$ ;  $C_t^g$  is aggregate government consumption in period  $t$ ;  $L_t$  is the fraction of aggregate time devoted to leisure activities in period  $t$ ;  $u(\dots)$  is a temporal utility function;  $\beta^*$  is the fixed discount factor.

Government expenditures influence private sector utility through the parameter  $\theta$ . If  $\theta > 0$ , the marginal utility of consumption decreases with an increase in  $C_t^g$ . If  $\theta < 0$ , the opposite is true. More specifically, if  $\theta > 0$  public and private consumption are perfect substitutes (e.g., private security services and police). On the other hand, when  $\theta < 0$  government consumption is harmful (e.g., low quality public education requiring additional time and money for private courses, students' protection, etc.). When  $\theta=0$  the household's preferences are lexicographic with respect to private consumption.

## 2.2 Technology

An homogeneous final product,  $Y_t$ , is produced using private capital,  $K_t^p$ , labor,  $H_t$ , and government capital,  $K_t^g$ . Technology is characterized by:

$$Y_t = A_t K_t^{p\alpha} (Z_t H_t)^{1-\alpha} \left[ \frac{K_t^g}{Z_t N_t} \right]^\zeta; \quad A_t > 0, \alpha \in (0,1), \zeta \geq 0; \quad (5)$$

$$Z_{t+1} = \gamma_z Z_t; \quad \gamma_z \geq 1, \quad Z_0 > 0, \text{ given.} \quad (6)$$

$Z_t$  characterizes non-stochastic labor augmenting technology;  $A_t$  characterizes stochastic total factor productivity;  $H_t/N_t$  stands for the fraction of time devoted by the representative private agent to income earning activities in period  $t$  (i.e., total time is equal to one).

The dependence of aggregate or individual firm output on the effective, per capita public capital incorporates the hypothesis that the economy's infrastructure (e.g., roads, railroads, harbors, airports, etc.) affects total factor productivity, irrespectively of the quality of the labor input involved. We surmise that a similar formulation has been adopted by Baxter and King (1993).

Private capital evolves according to:

$$K_{t+1}^p = \varphi \left( \frac{I_t^p}{K_t^p} \right) K_t^p + (1 - \delta^p) K_t^p; \quad \delta^p \in (0,1), K_0^p \text{ given.} \quad (7)$$

$I_t^p$  is aggregate private investment and  $\varphi(\cdot)$  incorporates the hypothesis of internal adjustment costs on gross investment (Lucas and Prescott (1971)). The function  $\varphi(\cdot)$  is positive and increasing at a decreasing rate. We also assume that adjustment costs are absent and that Tobin's  $q$ -ratio is one in the steady state growth path:

$$\varphi(\gamma_z \gamma_n - 1 + \delta) = \gamma_z \gamma_n - 1 + \delta$$

and

$$\varphi'(\gamma_z \gamma_n - 1 + \delta) = 1$$

where  $\gamma_z \gamma_n - 1 + \delta$  is the ratio of investment to capital in the steady state. This is the formulation adopted by Correia et al. (1995).

### 2.3 International borrowing and lending

Mendoza (1991) formalizes the small open economy hypothesis by endogenizing the rate of time preference. Bruno and Portier (1995) assume that foreign financial assets enter negatively in the utility function (i.e. domestic households prefer national assets). Cardia (1991) follows the Blanchard(1985)-Yaari(1965) finite lifetime set-up which however cannot be applied to a stochastic setting. Here we close the model differently. Motivated by the various capital flow controls that characterized the Greek economy until 1992(See, e.g., Alogoskoufis (1995) and Christodoulakis and Karamouzis (1995).), we introduce transaction costs in the foreign sector. Thus, foreign asset holdings of households evolve according to:

$$p_t^f \Psi(K_t^f, K_{t+1}^f) K_{t+1}^f = K_t^f + X_t + T_t^f \quad (8)$$

where:

$$p_t^f = \frac{1}{1 + r_t^*} \quad (9)$$

and

$$\lim_{t \rightarrow \infty} E_0(\prod_{s=0}^t p_s^f) K_{t+1}^f = 0 \quad (10)$$

$K_t^f$  denotes the net aggregate holdings of foreign assets in period  $t$ ;  $X_t$  denotes the net exports in period  $t$ ;  $T_t^f$  denotes the aggregate foreign transfers in period  $t$ ; if  $r_t^*$  is the international rate of return, then  $r_t^* = 1/p_t^f - 1$ . That is,  $p_t^f$  is the price of an asset which delivers one unit of consumption in the next period.

The function  $\Psi(\cdot)$  implies the existence of transaction costs that affect the price of foreign assets. These are assumed to be a positive function of the level of transactions. We assume that function  $\Psi(\cdot)$  has the form:

$$\Psi(K_t^f, K_{t+1}^f) = 1 + \frac{\psi}{2} \left( \frac{K_{t+1}^f - K_t^f \gamma_n \gamma_z}{K_t^f} \right)$$

where  $\psi$  is a positive constant.

Foreign transfers are determined by:

$$T_t^f = S_t^f Y_t \quad (11)$$

The way in which  $S_t^f$  evolves is given in Section 2.5.

## 2.4 Government Behavior

The government budget constraint is given by:

$$C_t^g + I_t^g + T_t = \tau_t Y_t \quad (12)$$

Government capital evolves according to:

$$K_{t+1}^g = I_t^g + (1 - \delta^g) K_t^g; \quad \delta^g \in (0,1) \quad (13)$$

$I_t^g$  is aggregate public investment in period  $t$ ;  $T_t$  denotes domestic transfers in period  $t$ ;  $\tau_t$  is the period  $t$  income tax rate<sup>1</sup>.

Naturally, an increase in the ratio of government spending to GDP implies higher tax rates and increasing tax distortions.

Government consumption, government investment, and domestic transfers are determined by:

$$G_t = S_t^c Y_t \quad (14)$$

$$I_t^g = S_t^i Y_t \quad (15)$$

$$T_t = S_t^t Y_t \quad (16)$$

The way in which  $S_t^c$ ,  $S_t^i$ , and  $S_t^t$  evolve is given below. It should be mentioned, however, that government is "passive." In particular, it does not select  $S_t^c$ ,  $S_t^i$  and  $S_t^t$  in any optimizing sense.

Clearly, we disregard government deficits and public debt. At first sight, this would seem like a blatant omission for a country with a public debt of more than 120% of its GNP. For reasons explained in Barro (1974), however, the class of models such as ours is characterized by a form of Ricardian Equivalence. That is, given an unchanged tax rate path ( $\tau$ ), the increase in public debt is equivalent to a decrease in domestic transfers. Moreover, if an increase in government spending is associated with increases in public debt and distortionary taxation, our formulation, which focuses on the effects of distortions due to increased tax rates, is fairly similar to the crowding-out effects stemming from the increased interest rates due to the higher level of public debt.

Our choice of channel through which higher government spending affects the economy, is dictated by the lack of appropriate and reliable data on the level, interest and maturity of the public debt<sup>2</sup>.

<sup>1</sup> See Baxter and King (1993) for a detailed description of these distortions and their consequences.

<sup>2</sup> The true figures on Greek public debt should comprise the central government and the non-central government public sector (greater public sector - central government). The former is well documented but the latter, although estimated to be quite substantial, is not. For example, the financial charges concerning the cost of default of nationalised enterprises is not included in the corresponding interest rate charges.

### 2.5 Stochastic Environment

We assume the following univariate laws of motion for the stochastic processes of the model:

$$\ln A_{t+1} = (1 - \rho_A) \ln A + \rho_A \ln A_t + \varepsilon_{t+1}^A \quad (17)$$

$$\ln p_{t+1}^f = (1 - \rho_p) \ln p^f + \rho_p \ln p_t^f + \varepsilon_{t+1}^p \quad (18)$$

$$\ln S_{t+1}^f = (1 - \rho_f) \ln S^f + \rho_f \ln S_t^f + \varepsilon_{t+1}^f \quad (19)$$

$$\ln S_{t+1}^c = (1 - \rho_c) \ln S^c + \rho_c \ln S_t^c + \varepsilon_{t+1}^c \quad (20)$$

$$\ln S_{t+1}^i = (1 - \rho_i) \ln S^i + \rho_i \ln S_t^i + \varepsilon_{t+1}^i \quad (21)$$

$$\ln S_{t+1}^t = (1 - \rho_t) \ln S^t + \rho_t \ln S_t^t + \varepsilon_{t+1}^t \quad (22)$$

are the shocks in the time series of  $A_t, p_t^f, S_t^f, S_t^c, S_t^i, S_t^t$ , respectively. In particular, the where  $A, p^f, S^f, S^c, S^i$  and  $S^t$  are the means of the respective stochastic processes;  $\rho_A, \rho_p, \rho_f, \rho_c, \rho_i, \rho_t$  are the first order autocorrelation coefficients;  $\varepsilon_t^A, \varepsilon_t^p, \varepsilon_t^f, \varepsilon_t^c, \varepsilon_t^i, \varepsilon_t^t$  vector of shocks, is assumed to follow a Gaussian process with a given variance-covariance matrix.

### 3. The Solution of the Model

In the steady state all the components of the national income identity grow at the constant rate  $\gamma_n \gamma_z$ , where  $\gamma_n$  is the gross population growth rate and  $\gamma_z$  the gross growth rate of the technological change. Hereafter, low case letters denote per capita variables deflated by  $Z$ . The discount factor in the transformed (stationary) economy is  $\beta = \beta^* \gamma_n \gamma_z^{\gamma(1-\sigma)}$ .

#### 3.1 The Competitive Equilibrium

As usual, a competitive equilibrium with a non-optimizing government is a vector stochastic process of the pertinent prices and quantities, such that:

(i) The representative firm takes all prices and government policy variables as given and seeks an input-output plan so as to maximize its profits:

$$\max_{\substack{k_t^p \geq 0 \\ 0 \leq h_t \leq 1}} (A_t k_t^p{}^\alpha h_t^{1-\alpha} k_t^c{}^\zeta - p_t^h h_t - p_t^k k_t^p) \quad (23)$$

(ii) The representative household takes all prices and government policy variables as given and seeks a contingency plan for consumption, investment in domestic assets, foreign assets, leisure, and work so as to maximize its expected lifetime utility subject to its budget constraint:

$$c_t \leq (1 - \tau_t) [p_t^k k_t^p + p_t^h h_t] + l_t + l_t^f + k_t^f - \gamma_n \gamma_z \tilde{p}_t^f k_{t+1}^f - l_t^p + \mathcal{R}_t^c \quad (24)$$

where :

$$\tilde{p}_t^f = p_t^f \left[ 1 + \frac{\psi}{2} (\gamma_n \gamma_z)^2 \left( \frac{k_{t+1}^f - k_t^f}{k_t^f} \right) \right]$$

and the restrictions (1)-(4), (6)-(10), and (16)-(21).

(iii) Given the representative firm's and household's choices, prices are such that all underlying markets clear.

(iv) Given the representative firm's and household's choices, government policy variables end up being what they were expected to be. Then, given the form of the utility and production functions, the following are necessary and sufficient conditions for a competitive equilibrium:

$$p_t^h = \alpha A_t k_t^p \alpha^{-1} h_t^{1-\alpha} k_t^{\alpha} \quad (25)$$

$$p_t^k = (1 - \alpha) A_t k_t^p \alpha h_t^{-\alpha} k_t^{\alpha} \quad (26)$$

$$u_c(c_t, 1 - h_t) \varphi_t^{-1} = \frac{\beta}{\gamma_n \gamma_z} E_t u_c(c_{t+1}, 1 - h_{t+1}) \pi_{t+1} \quad (27)$$

where  $\pi_{t+1} = (1 - \tau_{t+1}) p_{t+1}^k - [\varphi_{t+1}^{-1} - \varphi_{t+1}^{-1} \gamma_n \gamma_z \frac{k_{t+2}^p}{k_{t+1}^p}]$

$$u_c(c_t, 1 - h_t) = \frac{\beta}{\gamma_n \gamma_z} \frac{1}{p_t^f} E_t u_c(c_{t+1}, 1 - h_{t+1}) \omega_t \quad (28)$$

where  $\omega_t = \frac{1 + p_{t+1}^f (\gamma_n \gamma_z)^3 \psi \left( \frac{k_{t+2}^f}{k_{t+1}^f} \right)^2 \left( \frac{k_{t+2}^f - k_{t+1}^f}{k_{t+1}^f} \right)}{1 + \frac{\psi}{2} (\gamma_n \gamma_z)^2 \left( \frac{k_{t+1}^f - k_t^f}{k_t^f} \right)^2 + \psi (\gamma_n \gamma_z)^2 \frac{k_{t+1}^f}{k_t^f} \left( \frac{k_{t+1}^f - k_t^f}{k_t^f} \right)}$

$$\frac{u_l(c_t, 1 - h_t)}{u_c(c_t, 1 - h_t)} = (1 - \tau_t) p_t^h \quad (29)$$

$$\lim_{t \rightarrow \infty} \beta^t E_0 u_c(c_t, 1 - h_t) k_{t+1}^p = 0 \quad (30)$$

$$\lim_{t \rightarrow \infty} \beta^t E_0 u_c(c_t, 1 - h_t) k_{t+1}^f = 0 \quad (31)$$

$\varphi_t^{-1}$  denotes the function  $\varphi^{-1}$  with its arguments evaluated at time  $t$  and  $\varphi_t^{-1'}$  denotes the derivative of  $\varphi^{-1}$  with respect to its arguments evaluated at time  $t$ . Conditions (25) and (26) equate rental factor prices to the corresponding marginal factor products. The next two conditions equate the current marginal cost (i.e., the value of sacrificed consumption) of invested wealth to its expected present value of next periods' marginal benefit associated with the corresponding investment. Of course, (27) pertains to domestic physical capital and (28) to investment in foreign assets. Condition (29) is the standard temporal condition that equates the after tax rental factor price of labor to the marginal value of leisure measured in output units. The next two conditions are the transversality conditions. The best way, perhaps, to interpret them is that the expected present value of domestic private capital and foreign assets held by domestic agents, at infinity (i.e., the end of the world) should be zero.

### 3.2 Steady State

The balanced growth path  $\dots = k_t^p = k_{t+1}^p = \dots = k^p$ ,  $\dots = k_t^f = k_{t+1}^f = k^f$ ,  $\dots = k_t^g = k_{t+1}^g = \dots = k^g$ , is characterized by the following equations:

$$1 = \frac{\beta}{\gamma_z \gamma_n} [(1-\tau)F_{k^p}(k^g, k^p, h) + (1-\delta^p)] \quad (32)$$

$$1 = \frac{\beta}{\gamma_z \gamma_n} \frac{1}{p^f} \quad (33)$$

$$\frac{(1-\gamma)c}{\gamma(1-h)} = (1-\tau)F_h(k^g, k^p, h) \quad (34)$$

$$c = c^p + \theta c^g \quad (35)$$

$$F(k^g, k^p, h) = c^p + c^g + i^p + i^g + x \quad (36)$$

$$\tau F(k^g, k^p, h) = c^g + i^g + i^f \quad (37)$$

$$\frac{i^p}{k^p} = (\gamma_z \gamma_n - 1 + \delta^p) \quad (38)$$

$$\frac{x + i^f}{k^f} = (\gamma_z \gamma_n p^f - 1) \quad (39)$$

$$\frac{i^g}{k^g} = (\gamma_z \gamma_n - 1 + \delta^g) \quad (40)$$

$$\tau = S^c + S^i + S^x \quad (41)$$

where  $h, c^p, i^p, c^g, i^g, x, i^f, k^f$  are the steady state values of the respective variables.

### 3.3 Linearizations and Approximate Solution

The first order necessary conditions are linearized around the logarithms of the steady state. The variables in the linearized system are expressed as percentage deviations from the respective steady state values:

$$\hat{x}_t = \ln x_t - \ln x$$

where  $x$  is the steady state value of the variable  $x_t$ .

The vector of the state variables is  $\hat{x}_t = [\hat{k}_t^p, \hat{k}_t^f, \hat{k}_t^g]'$  and the vector of the exogenous variables is  $\hat{\xi}_t = [\hat{S}_t^c, \hat{S}_t^f, \hat{S}_t^i, \hat{A}_t, \hat{p}_t, J]'$ .

The linearized Euler equations together with the linearized law of motion of government capital consist a second - order linear stochastic difference equation system of the form:

$$AE_t \hat{x}(t+2) - BE_t \hat{x}(t+1) + \beta^{-1} CE_t \hat{x}(t) = -\Gamma E_t \hat{\xi}(t+1) - \beta^{-1} \Delta E_t \hat{\xi}(t) \quad (42)$$

where  $A, B, C, \Gamma, \Delta$  are constant matrices of dimension  $3 \times 3, 3 \times 3, 3 \times 3, 3 \times 6,$  and  $3 \times 6,$  respectively.

Following Kollintzas(1986), under appropriate regularity conditions, the general solution to the above equation is given by:<sup>8</sup>

$$\hat{x}_{t+1} = T\hat{x}_t + U\hat{\xi}_t \quad (43)$$

$$\hat{\xi}_{t+1} = Q\hat{\xi}_t + \varepsilon_{t+1} \quad (44)$$

where the matrices  $T$  and  $Q$  have eigenvalues which do not exceed unity.

The characteristic polynomial of system (42) has one root equal to zero. This implies that matrix  $T$  has a zero valued eigenvalue as well. The other two eigenvalues of this matrix are less than one, which means, according to (42), that the deviations from the steady state values of private, foreign and government capital follow a flexible accelerator process. Further, we found that without adjustment costs in the foreign sector, there is one unit root in the characteristic polynomial of (42), which although admissible has counterfactual implications.<sup>9</sup> The introduction of transaction costs makes the modulus of this root greater than one.

## 4. Calibration and the Model's Descriptive Power

In this section we explore the properties and evaluate the descriptive power of our model. For this reason, we first calibrate the model using annual Greek data from 1950 to 1994<sup>10</sup> and compare the second moment properties of the actual and simulated series over the period 1960 - 1990.

<sup>8</sup> All these conditions hold for the parameter values used in the numerical solution.

<sup>9</sup> In Correia et al. (1995), consumption and output are not cointegrated while labor follows a random walk.

<sup>10</sup> These series are available on request.

#### 4.1 Calibration

The data set we used to calibrate our model comprises of annual data at constant 1970 prices (when relevant). Our main source were the OECD data for Greece. The series for private and public capital are from ΚΕΠΕ. The series for hours of work is computed as in Correia et al.(1995) on the assumption that there are 7x14 hours per week and the average work week is 40 hours. Thus the series of labor is equal to the employment rate multiplied by the population and the factor 40/(7x14). The value of the tax rate in the steady state is taken to be the sum of the mean of the shares of government consumption, investment, and domestic transfers (from equation (41)). The two physical depreciation rates,  $\delta^p$  and  $\delta^k$  were estimated via a GMM procedure from ΚΕΠΕ's series of private and government capital, with lagged investment and capital as the instruments.

The value of  $\gamma_z$  was set equal to 1.04, so as to match the average growth rate of per capita GDP for the corresponding period. We, thus, assume that during this period the Greek economy was near its steady state growth path and therefore its rate of growth, as required by our model, is characterized by the growth rate of the exogenous labor augmenting technical progress<sup>11</sup>. The value of  $\gamma_n$  was computed from the population data.

Following Correia et al (1995), we set  $\sigma = 2$ . We assume that parameter  $\theta$  takes alternatively the values  $\theta = -1/2$ ,  $\theta = 0$  and  $\theta = 1/2$ . Parameter  $\gamma$ , which varies according to the value of  $\theta$ , was calibrated from the condition with respect to labor (34). See Table 1, below. Parameters  $\alpha$ ,  $\beta$  and  $\rho^f$  are jointly calibrated from equations (32) and (33). More specifically, the average user cost of private capital in the Greek economy during the period under consideration was 11% (Dimelis et al. (1996)). Given our value of  $\delta^p$ , this implies from (32) a value of  $\alpha$  equal to 0.4376. This value is slightly lower compared to the average share of capital reported in Dimelis et al. (1993). Via equations (32) and (33), this also implies that the steady state rate of return on foreign assets must be 11%. That is,  $r^* = 11\%$  or  $\rho_f = 0.9009^{12}$ . Given the values of  $\gamma_z$  and  $\gamma_n$  and via (33), this gives  $\beta = 0.9428$ . Given, further, the values of  $\sigma$  and  $\gamma$ ,  $\beta^*$  is also computed. See Table 1, below.

The Parameters  $\rho_A, \rho_{p^f}, \rho_f, \rho_c, \rho_i, \rho_t$ , were estimated from their respective stochastic processes. The same applies to the standard deviations of these variables  $\sigma_A, \sigma_{p^f}, \sigma_c, \sigma_i, \sigma_t$ . These series for  $A_t$  was computed from the production function. The values of  $A, S^f, S^c, S^i$  and  $S^t$  were set equal to their respective mean values over the period 1960-1994.

<sup>11</sup> This is questioned in Dimelis et al. (1996). On this issue, we will return in the last section.

<sup>12</sup> Following a different calibration method, Correia et al (1995) also conclude to a value of  $r^* = 11\%$ . This value of  $r^*$  is higher than the average LIBOR rate for the corresponding period (7.5%). It should be noted here that the mean value of  $\rho^f$  from the data corresponds to a very low value of  $\alpha$ .



The presence of  $K^{\alpha}$  in the production function implies increasing returns with respect to capital and labor. For this reason to ensure the convergence of the economy to a steady state growth path the parameter  $\zeta$  has to be restricted accordingly. We follow Baxter and King in setting the value of  $\zeta$  equal to the share of public investment  $s^g$  so as the multiplier of an increase in government investment that leaves private capital and labor unchanged is unity<sup>13</sup>. That is, effectively we assume that the increase in the private factors of production brought about by the increase in their marginal products due to the increase in public capital is just balanced by the reduction in their products stemming from the associated increase in the tax rate.

We set  $\psi=1/20$ . This implies fairly small costs in international transactions. The incorporation of adjustment costs in the foreign sector, which as already mentioned is necessary for the spectral factorization property, is independently motivated by the elaborate system of capital controls that prevailed in Greece in the period under consideration (See Christodoulakis and Karamouzis (1993)).

The formulation of our model does not require a specific functional form for the adjustment costs in private capital formation. Following Correia et al. we set  $\xi=1/30$ , which implies fairly small adjustment costs (about 1% of GDP loss). The values of  $p^f$ ,  $S^f$ , as well as the mean value of  $X/Y$  over the period 1960-1994 imply from equation (39) that  $K^f$  in Greece is positive and amounts to an average 70% of GDP. This value seems rather reasonable taking into account the number of Greek ships in the high seas and the substantial foreign assets of repatriated immigrants.

Table 1 summarizes the baseline model parameter values.

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<sup>13</sup> The mean share in GDP of Government investment over the period 1960-1994 is equal to 3.5%.

Table 1: Calibration

Parameter	Value		
$\alpha$	0.4376		
$\beta$	0.9428		
$\theta$	-1/2	0	1/2
$\beta^*$	0.9509	0.9517	0.9525
$\gamma$	0.2196	0.2405	0.2602
$\sigma$	2		
$\delta_P$	0.0279		
$\delta_x$	0.0312		
$\zeta$	0.06		
$\xi$	-1/30		
$\gamma_n$	1.0063		
$\gamma_z$	1.04		
$S^c$	0.1564		
$S^i$	0.0345		
$S^r$	0.1162		
$S^f$	0.0394		
$P$	0.9009		
$A$	10.1204		
$P_c$	0.9622		
$P_i$	0.8842		
$P_t$	0.9368		
$P_r$	0.9534		
$P_p$	0.8013		
$P_A$	0.9699		

#### 4.2 The Descriptive Power of the Model

Following usual practice, the descriptive power of our model is evaluated through the comparison of the second moment properties found in the series generated by the model, with those characterizing the actual Greek data. This is carried out for the baseline parameterization described in Section 4.1 complemented with a sensitivity analysis with respect to the parameter  $\theta$  (i.e., we consider the three alternative values  $\theta=-1/2$ ,  $\theta=0$ ,  $\theta=1/2$ ).

To reveal the business cycle behavior of the various series, we first take logarithms and then apply the Hodrick-Prescott filter with a smoothing parameter 100. In what concerns the Trade Balance which takes throughout negative values, we simply follow the same procedure but on the reverse signed series.

We made two sets of experiments. In the first, we pinned down the variability of the shock in Total Factor Productivity ( $A$ ) so as the actual and artificial (simulated) series for GDP have the same variance. This was achieved for standard deviation values of the shock to total Factor Productivity equal to 0.1835, 0.187 and 0.19 for  $\theta=-1/2$ ,  $\theta=0$  and  $\theta=1/2$ , respectively. Total Factor Productivity accounts for 65.44%, 66.09% and 67.77% of the variability of GDP, respectively.

In the second exercise, we constrained both the persistence and volatility of the Solow residual so that the model reproduces exactly not only the volatility but also the serial correlation of output as well. Thus instead of using the estimated value  $\rho^A=0.97$ ,  $\rho^A$  was set equal to 0.77 implying lower persistence for the shock on Total Factor Productivity.

In Tables 2,3, and 4 we report the autocorrelations, relative volatility and cross correlations for the actual Greek data as well as the simulated (with respect to the baseline parametrization) data, for the first experiment. The respective results for the second experiment are given in Tables 2' 3' and 4'.

From the inspection of Table 3 we can see that our model does fairly well in predicting the variability of the key macroeconomic variables when  $\rho^A=0.97$ . The volatility of investment is the same as that found in the data while the volatilities of the other variables, with the exception of the Trade Balance are equally well captured. In contrast with Correia et al. whose model predict that the Trade Balance is much less volatile than in reality, our model indicates that its volatility is higher compared to the actual data.

The general characteristics with respect to relative volatility remain more or less unchanged when  $\rho^A=0.77$  with only notable exceptions the fall in the variability of the Trade Balance and Private Consumption which now are considerably closer to the real data (see Table 3').

As far as the persistence properties we can see from Table 2 that when  $\rho^A=0.97$  our model produces satisfactory results throughout. Our model manages to capture the positive sign although with an upward bias. The behavior of private investment is similar to the one found in Correia et al. The first order serial correlation coefficient of GDP predicted from our model has an upward bias.

As seen from Table 2', when  $\rho^A=0.77$  the model reproduces exactly the same behavior for GDP and labor as in the real data. The general characteristics for the remaining variables remain unchanged with the exceptions of private investment and Trade Balance. Thus, with the persistence of the shock on Total Factor Productivity being lower, our model now predicts a practically zero value for the autocorrelation coefficient of private investment (implying a white noise type behavior) which is not consistent with the data show. On the other hand, while the first order serial correlation characterizing the actual series for the Trade Balance is practically zero, this is not the case for our model which predicts a higher value. Therefore, the decline in the persistence of the shock in Total Factor Productivity lowers the predicted persistence of private investment and raises that of the Trade Balance. In both cases, the discrepancy from the real data becomes larger.

From the inspection of Table 4, we can see that when  $\rho^A=0.97$  our model does well in reproducing the comovement properties of the various variables, with the exceptions of private capital and hours of work. In both these cases our model produces opposite sign results for the

relations of past and present capital and work with GDP and overestimates the relation of current GDP with future capital and work. On the other hand one should stress the success of our model in reproducing the general behavior of private investment and the Trade Balance. Our model does worse in predicting the way current GDP affects future investment and net exports but nearly excels in what concerns the way past and current investment and net exports relate to current GDP. Equally satisfactory are the results for private consumption and government capital.

The main characteristics of the comovement of GDP with the various variables of the model for the  $\rho^A=0.77$  (See Table 4') are qualitatively the same with the exceptions again of private investment and the Trade Balance. Our model predicts no more a positive relation between current GDP and future investment (recall that from Table 4, this coefficient was low but positive), while the relation of past net exports with current GDP is found to be practically zero (instead of a small value - but positive and very near real data, for the  $\rho^A=0.97$  case).

Therefore, overall, our simple model does quite well in reproducing several of the key stylized facts of the Greek Business Cycle. The only exception is the labor market, which for reasons already mentioned, does not seem to follow well the Walrasian framework. Clearly, more work is needed towards this issue. It should be interesting to integrate the RBC methodology with the dynamic firm-union bargain set-up (See Eberwein and Kollintzas (1995)). One other source of the still existing problems must be due to the fact the foreign transfers were assumed (as a tractable device to solve the model) proportional to GDP which are certainly not.

Table 2: First Order Serial Correlations ( $\rho^A=0.97$ )

	Actual Data	Simulated Data		
		$\theta=1/2$	$\theta=0$	$\theta=1/2$
$k^p$	0.73	0.68	0.68	0.68
$k^f$	-	0.59	0.59	0.58
$k^e$	0.83	0.82	0.80	0.79
$y$	0.32	0.55	0.55	0.55
$h$	0.28	0.56	0.55	0.55
$c^p$	0.43	0.50	0.48	0.46
$j^p$	0.46	0.10	0.10	0.10
$x$	0.03	0.13	0.13	0.13

Table 2: First Order Serial Correlations ( $\rho^A=0.77$ )

	Actual Data	Simulated Data		
		$\theta=-1/2$	$\theta=0$	$\theta=1/2$
$k^p$	0.73	0.70	0.70	0.70
$k^r$		0.62	0.62	0.63
$k^e$	0.83	0.87	0.86	0.85
$y$	0.32	0.32	0.32	0.32
$h$	0.28	0.27	0.28	0.29
$c^p$	0.43	0.50	0.53	0.55
$i^p$	0.46	0.01	0.003	-0.001
$x$	0.03	0.24	0.26	0.27

Table 3: Relative Volatility ( $\rho^A=0.97$ )

$$sd(X) / sd(y)$$

	Actual Data	Simulated Data		
		$\theta=-1/2$	$\theta=0$	$\theta=1/2$
$k^p$	0.74	0.64	0.65	0.66
$k^r$	-	2.37	2.44	2.50
$k^e$	0.62	0.41	0.45	0.47
$y$	1.00	1.00	1.00	1.00
$h$	0.38	0.48	0.48	0.47
$c^p$	0.68	0.81	0.81	0.82
$i^p$	4.33	4.32	4.27	4.22
$x$	6.73	9.11	9.23	9.36

Table 3: Relative Volatility ( $\rho^A=0.77$ ) $sd(X) / sd(y)$ 

	Actual Data	Simulated Data		
		$\theta=-1/2$	$\theta=0$	$\theta=1/2$
$k^p$	0.74	0.57	0.58	0.59
$k^f$	-	1.86	1.89	1.92
$k^e$	0.62	0.35	0.37	0.39
$y$	1.00	1.00	1.00	1.00
$h$	0.38	0.53	0.52	0.51
$c^p$	0.68	0.61	0.59	0.56
$i^p$	4.33	4.29	4.30	4.31
$x$	6.73	6.98	6.89	6.82

Table 4: Correlation between  $y(t)$  and  $X(t-i)$  ( $\rho^A=0.97$ )

X	Actual Data			Simulated Data								
	$X(t-1)$	$X(t)$	$X(t+1)$	$\theta=-1/2$			$\theta=0$			$\theta=1/2$		
	$X(t-1)$	$X(t)$	$X(t+1)$	$X(t-1)$	$X(t)$	$X(t+1)$	$X(t-1)$	$X(t)$	$X(t+1)$	$X(t-1)$	$X(t)$	$X(t+1)$
$k^p$	-0.19	-0.004	0.37	0.49	0.70	0.72	0.49	0.70	0.71	0.48	0.69	0.70
$k^f$	-	-	-	-0.11	-0.23	-0.29	-0.10	-0.22	-0.28	-0.10	-0.20	-0.26
$k^e$	0.06	0.18	0.38	0.32	0.31	0.31	0.30	0.29	0.29	0.29	0.28	0.28
$y$	0.32	1	0.32	0.55	1	0.55	0.55	1	0.55	0.55	1	0.55
$h$	-0.39	-0.01	0.14	0.28	0.57	0.42	0.26	0.52	0.41	0.24	0.47	0.39
$c^p$	0.31	0.76	0.39	0.53	0.91	0.44	0.52	0.90	0.42	0.52	0.89	0.40
$i^p$	0.36	0.72	0.42	0.33	0.61	0.10	0.33	0.62	0.02	0.33	0.63	0.02
$x$	0.07	0.25	-0.02	0.11	0.30	-0.25	0.11	0.30	-0.25	0.11	0.31	-0.25

Table 4: Correlation between  $y(t)$  and  $X(t-i)$  ( $\rho^r=0.77$ )

X	Actual Data			Simulated Data								
	$X(t-1)$	$X(t)$	$X(t+1)$	$\theta=-1/2$			$\theta=0$			$\theta=1/2$		
	$X(t-1)$	$X(t)$	$X(t+1)$	$X(t-1)$	$X(t)$	$X(t+1)$	$X(t-1)$	$X(t)$	$X(t+1)$	$X(t-1)$	$X(t)$	$X(t+1)$
$k^r$	-0.19	-0.004	0.37	0.34	0.46	0.71	0.34	0.46	0.71	0.33	0.46	0.71
$k^f$	-	-	-	0.01	0.05	-0.01	0.01	0.07	0.02	0.02	0.09	0.04
$k^z$	0.06	0.18	0.38	0.37	0.36	0.41	0.34	0.34	0.39	0.31	0.33	0.37
$y$	0.32	1	0.32	0.32	1	0.32	0.32	1	0.32	0.32	1	0.32
$h$	-0.39	-0.01	0.14	0.20	0.83	0.17	0.20	0.81	0.16	0.20	0.80	0.16
$e^r$	0.31	0.76	0.39	0.36	0.92	0.39	0.37	0.91	0.40	0.38	0.89	0.41
$i^r$	0.36	0.72	0.42	0.15	0.71	-0.11	0.15	0.72	-0.10	0.15	0.73	-0.10
$x$	0.07	0.25	-0.02	-0.01	0.21	-0.28	-0.01	0.19	-0.27	-0.02	0.17	-0.26

### 5. Impulse Response Analysis

As we have shown in Subsection 3.3 the vector with the deviations of the logarithms of the endogenous state variables of the transformed economy (i.e., in efficient, per capita units) from their respective steady state values,  $\hat{x}_t$ , follows the linear law of motion (43); while the vector with the deviations of the logarithms of the exogenous state variables from their corresponding mean values,  $\hat{\xi}_t$ , follows the AR(1) law of motion (44). Combining these two laws of motion, gives an MA( $\infty$ ) representation of the endogenous state variables in terms of the innovations of the exogenous state variables. That is,

$$\hat{x}_{t+1} = \sum_{k=0}^{\infty} \gamma_k \varepsilon_{t-k}$$

$$\text{where } \gamma_k = \sum_{i=0}^k T^i U Q^{k-i}$$

This enables us to compute the response of any of the endogenous variables (i.e., both state and control variables) to any change in the exogenous variables.

We follow standard practice in plotting the responses (i.e., impulse response functions) of the above mentioned deviations of various endogenous variables to one-period (i.e., temporary) and infinite-period (i.e., permanent) unitary increases in the innovations in each and every one of the above mentioned deviations of the exogenous variables. Further, we do this for all three

different values of the parameter  $\theta$  examined. The plots reveal the usual hump shape responses with a few exceptions however of even more complex type behaviors.

### *5.1 The effects of shocks to Total Factor Productivity, $A_t$*

The effects of both temporary and permanent increases to total factor productivity are the typical responses found in RBC models. That is, a temporary increase in total factor productivity causes a wealth effect that tends to increase both current consumption and current leisure, moreover via the consumption smoothing channel it tends to affect in a similar way future consumption and leisure. The last effect is strengthened by the expectations effect brought about by the nearly random walk behavior of total factor productivity. On the other hand, the increase in total factor productivity raises the wage rate and creates a substitution effect that tends to decrease leisure. The total effect on leisure (labor) is negative (positive) one in the short run. The increase in future consumption implies an increase in savings and investment so as to build sufficient capital in order to satisfy the former. This, of course, is the primary propagation mechanism of the initial shock. The increase in consumption and investment increases output in a similar fashion. Moreover, the increase in output causes an increase in government consumption and government investment, that further increases output, and government capital which increases the productivities of the factors of production and enhances the propagation mechanism described earlier. Now, the increase in domestic total factor productivity causes a substitution effect between foreign and domestic capital generating a current account deficit (i.e., foreign capital holdings decline). As domestic capital increases, its return falls so as to end up below the steady state value of the return in foreign assets. This in turn, eventually causes an increase in foreign capital. This is responsible for the underlying overshooting in the behavior of foreign assets. However, the movement of the trade balance in the short run is opposite to that of the current account, unlike Backus, Kehoe, and Kydland (1992). This is because in our formulation the increase in foreign transfers due to the increase in domestic output dominates the decrease in the trade balance.

The basic difference between the above responses and those generated by a permanent increase in productivity is that the former dies out as the steady state of the economy remains the same while in the later case they persist, leading to a new steady state where although all great ratios have the same values, all capital stock variables and labor have higher values.

### *5.2 The effects of shocks to the Share of Government Consumption, $S_t^c$*

A temporary increase in the share of GDP that goes to government consumption increases the effective tax rate of the economy. This increase sets into motion two types of mechanisms. First it increases the amount of distortions, thereby creating deadweight losses in the economy. The second mechanism operates in a manner similar, but with opposite effect, to the increase in



the Total Factor Productivity just studied. The increase in the effective tax rate operates through a negative income effect that tends to reduce current consumption and leisure, and moreover via consumption smoothing it tends to affect in a similar way future consumption and leisure. Again, the last effect is strengthened by the expectations effect brought about by the nearly random walk behavior of the GDP share of government consumption. On the other hand, the increase in the effective tax rate lowers the wage rate and creates a positive substitution effect that tends to increase leisure. The total effect on leisure (work) is negative (positive) in the short run. Although the effect on consumption is always negative for all values of  $\Theta$  the effect on work is always negative for  $\theta=1/2$  and  $\theta=0$  and mixed for  $\theta=-1/2$ . This is apparently happens because of the relatively strong negative interaction between private and public consumption that causes a quite strong income effect necessary to ameliorate the negative utility impact from the increase in public consumption.

The decrease in future consumption implies a decrease in savings and investment so as to reduce capital temporarily. The drop in private capital is certainly due to the combination of both these mechanisms. The drop in public investment, transfers and public capital is due to the ensuing fall in output. Further, the increase in the domestic tax rate causes a substitution effect between domestic and foreign capital generating a current account surplus (i.e., an increase in foreign capital). As domestic capital decreases its return raises so as to end up above the steady state value of the return in foreign assets. This in turn, eventually causes a decrease in foreign capital. Furthermore, these changes in foreign capital and domestic output imply a negative effect in the trade balance and foreign transfers.

Similar comments apply to the differences in the effects of temporary and permanent changes in the share of GDP that goes to government consumption as in the total factor productivity case.

It should also be mentioned that this behavior of government consumption and output is not inconsistent with a positive but less than one value of the multiplier as typical RBC models predict (See, e.g., Christiano and Eichenbaum, and Baxter and King). However, given the set up of our model it is impossible to disentangle the effect of a change in the government consumption share from a lump sum change in government consumption. Our results are different from Correia et al. where all taxes are lump sum taxes thereby breaking the channel between increased government consumption and increased taxation.

### *5.3 The effects of shocks to the Share of Government Investment, $S$*

The response of the economy to an increase in the share of GDP that goes to public investment is more complicated than the corresponding response to a change in the share of government consumption. To the two mechanisms mentioned above we now have to add a third one - the increase in public capital brought about by the increase in government investment. This

increase in public capital increases the marginal productivities of both factors stimulating demand for both capital and labor. Thus, the response of the economy to a change in the share of GDP that goes to public investment in the very short run resembles that of a change in the share of GDP that goes to government consumption. But as time goes by the third mechanism becomes dominant increasing consumption, investment and output.

The response of foreign capital is even more complicated. The initial rise is brought about by the distortions caused by the increase in the effective income tax rate. The subsequent fall arises mostly from the increase in the private capital return due to the increase in government capital. The new rise in foreign capital is mainly due to the eventual decline in public capital caused by its physical depreciation. The final convergence of foreign capital towards its previous steady state is mostly shaped from the eventual increase in the return of private capital.

#### *5.4 The effects of shocks to the Share of Domestic Transfers*

The response of an increase in the GDP share of domestic transfers is qualitatively similar but quantitatively smaller to an increase in the GDP share of government consumption. The only notable exception concerns the behavior of private consumption in the  $\theta=1/2$  and  $\theta=0$  cases where the initial response is positive. This positive response of consumption takes place as the negative income effect from the increase in the effective tax rate is counterbalanced by the positive income effect brought about by the increase in domestic transfers.

#### *5.5 The effects of shocks to the Share of Foreign Transfers*

The response of an increase in the GDP share of foreign transfers increases consumption, foreign assets and the trade balance and decreases work, investment output and both private and public capital. This perhaps paradoxical response of output can be simply explained by the fact that the positive income effect induced by the increase in foreign transfers, increases consumption and leisure and reduces both savings (investment) and work.

Several authors have argued that this was the response of the Greek economy to the transfers from the so called Delors I package (see e.g. Alogoskoufis 1995)<sup>14</sup>.

While the effects of the temporary increase in the GDP share of foreign transfers eventually die out, in the permanent increase case the economy converges to a new steady state where the corresponding responses last forever.

#### *5.6 The effects of shocks to the Return to foreign assets*

The main effect of an increase in  $p$  (i.e., decline in  $r^*$ ) is of course to reduce foreign asset holdings and the trade balance and increase domestic private investment. Part of the decrease in

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<sup>14</sup> In our model, this will not be the case if the increase in foreign transfers is in tandem with an increase in public investment as is presumably the case under the so called Delors II package.

foreign asset holdings is being channeled to domestic investment and part of it to consumption and leisure (i.e., reduction in work). The overall impact on income is negative.

## 6. Conclusions

In this paper we develop a stochastic dynamic general equilibrium model that is consistent with several stylized facts of growth of the Greek Economy from 1960 to 1990, in the RBC tradition. Household preferences depend on private and public consumption and leisure. Government makes investment in capital, engages in government consumption, and provides transfer payments to the private sector while maintaining a balanced budget. An international capital market exists where households can buy and sell foreign bonds and receive net transfers from abroad. The volatility, persistence and comovement properties of the data generated by the model are broadly consistent with the actual behavior of the Greek Economy, from 1960-1992. We use the model to investigate the response of major macroeconomic variables to temporary and permanent changes in government policy variables, foreign transfers, and the international interest rate.

Our simple model does quite well in reproducing several of the key stylized facts of the Greek Business Cycle. The only exception is the labor market, which for reasons already mentioned, does not seem to follow well the Walrasian framework. Clearly, more work is needed towards this issue. It should be interesting to integrate the RBC methodology with the dynamic firm-union bargain set-up (See Eberwein and Kollintzas (1995)). One other source of the still existing problems is due to the fact the foreign transfers were assumed (as a tractable device to solve the model) proportional to GDP which are certainly not.

One of the surprising properties of the model is that is consistent with what some believe to be an idiosyncrasy of the Greek Economy - the fact that increases in foreign transfers leads to less output and work and more consumption and foreign investments.

The effects of both temporary and permanent increases to total factor productivity are the typical responses found in RBC models. The response of an increase in the GDP share of foreign transfers increases consumption, foreign assets and the trade balance and decreases work, investment output and both private and public capital. The main effect of an increase in  $p$  (i.e., decline in  $r^*$ ) is to reduce foreign asset holdings and the trade balance and increase domestic private investment.

Our model predicts that increases in the GDP share of government consumption have adverse effects on output and the factors of production and tend to increase foreign asset holdings. As can be seen from the impulse response function diagrams a 1% permanent increase in the GDP share of government consumption leads to an 8% fall in output. Increases in the GDP share of government investment increase output and the factors of production and lower

foreign asset holdings. The response of an increase in the GDP share of domestic transfers is qualitatively similar but quantitatively smaller, to an increase in the GDP share of government consumption.

Thus our model suggests that the increases in the shares of government consumption, and foreign and domestic transfers over the last 20 years have worked to reduce the performance of the Greek economy both with respect to its steady state and its transition to it (See Kollintzas and Vassilatos (1996)). The primary mechanism behind this result is the distortions on the incentives to save and work.

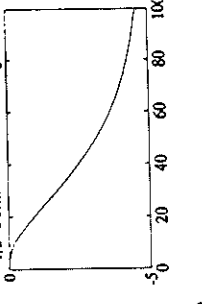
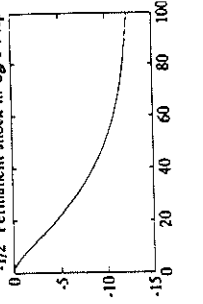
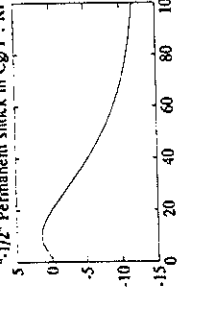
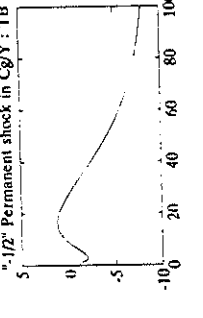
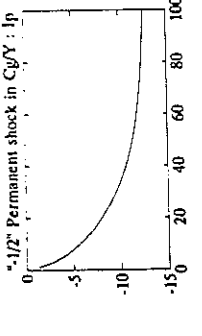
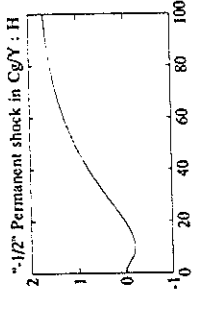
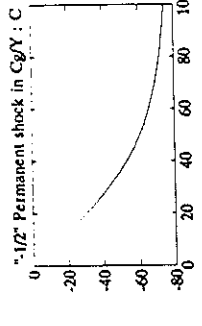
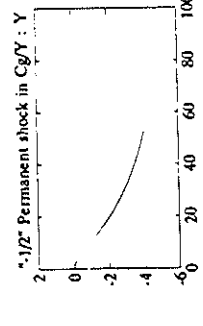
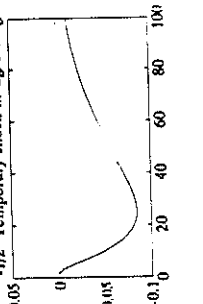
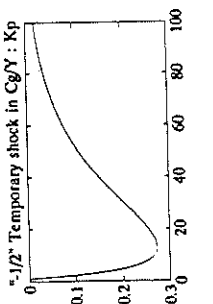
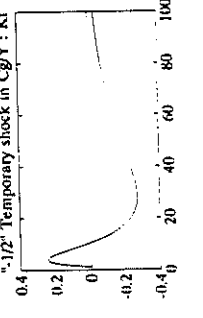
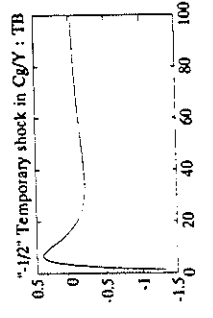
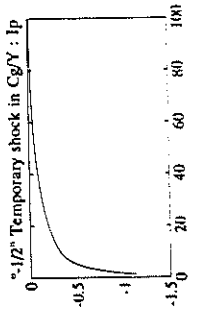
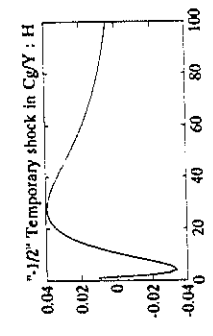
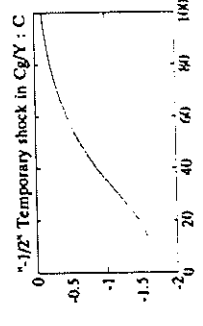
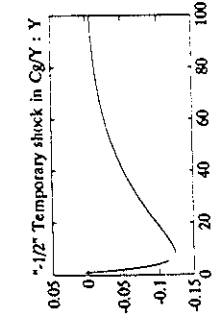
Although, our model's prediction for the volatility, persistence and comovement properties of the key macroeconomic variables were insensitive to the value of  $\theta$ , this was not the case for the impulse response functions (specially for labor).

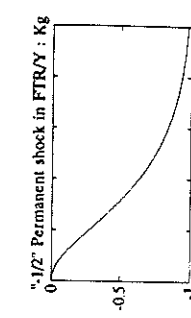
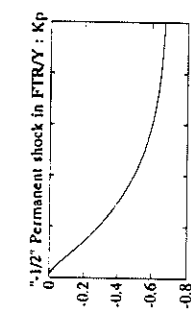
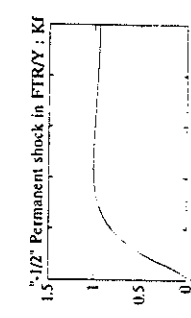
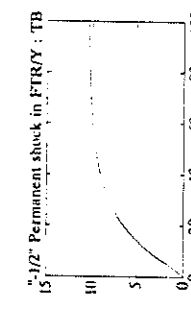
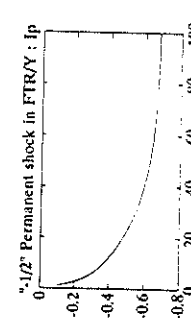
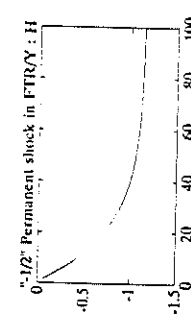
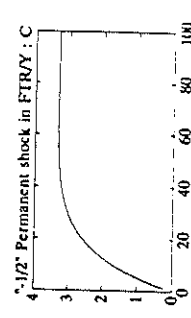
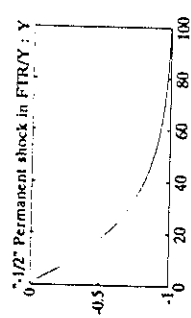
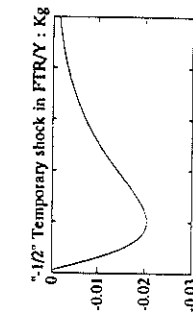
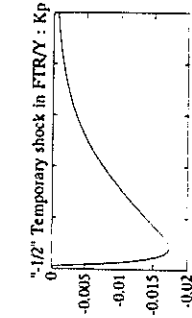
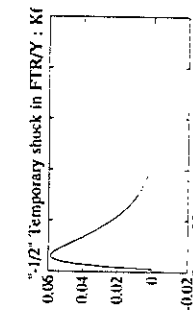
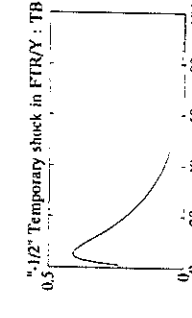
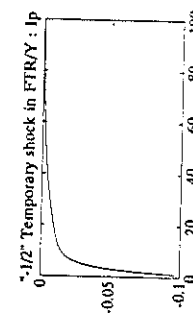
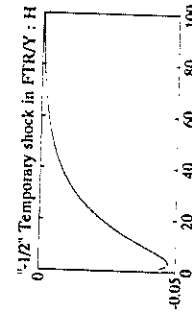
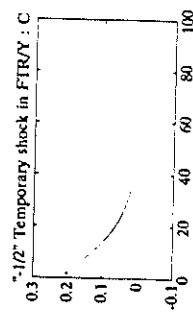
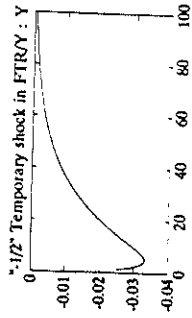
The transition towards the steady state was captured by choosing the appropriate initial values. In future work it would be interesting to calibrate the economy in two periods (before and after 1974) thus achieving a closer fit with real data characteristics. Presumably, the model would be able to better account for most of these stylized facts if we calibrated the model in two steady states each one being associated with a different set of values for the tax policy variables and then follow the usual procedure.

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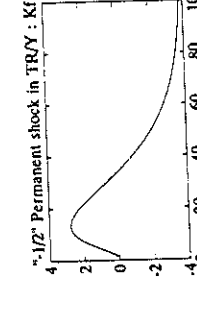
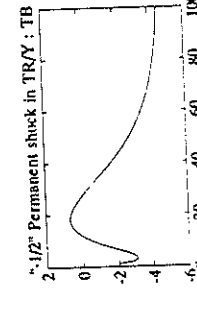
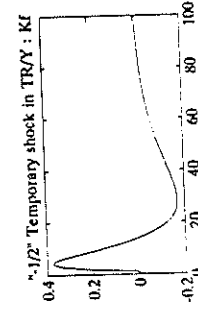
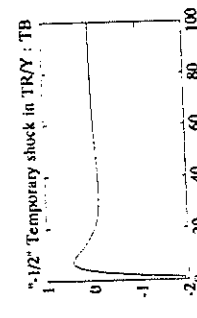
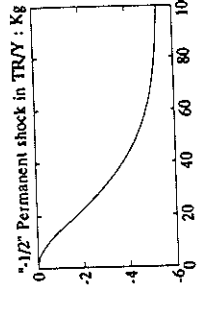
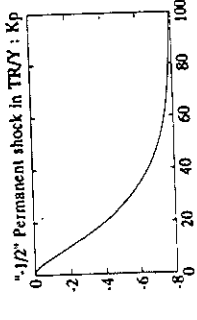
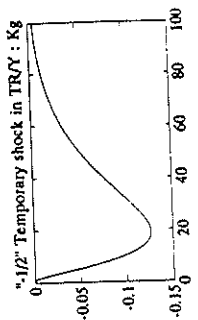
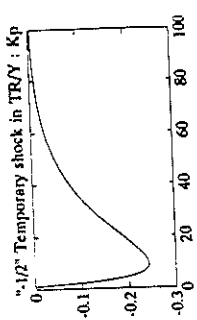
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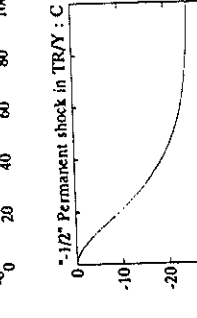
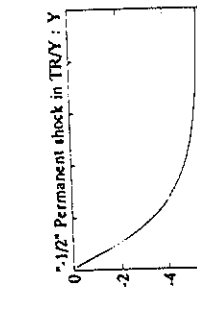
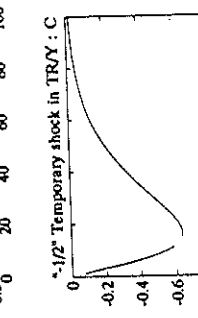
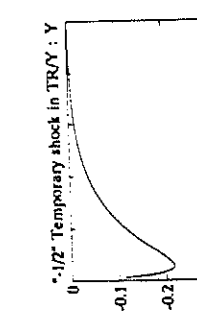
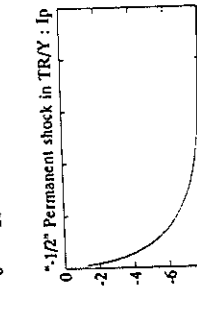
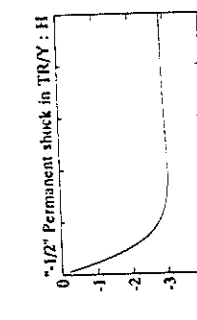
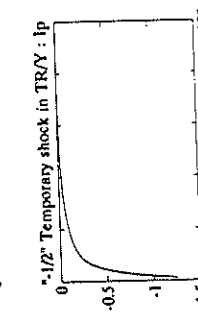
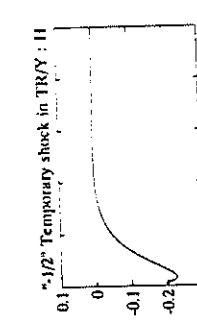




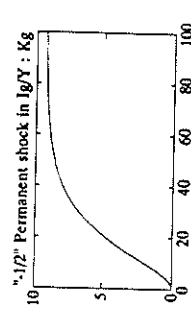
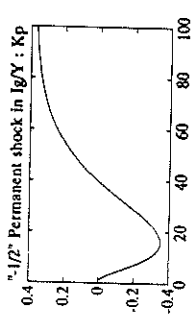
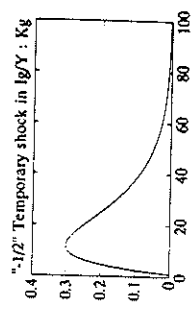
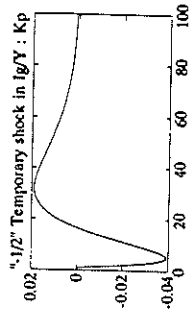
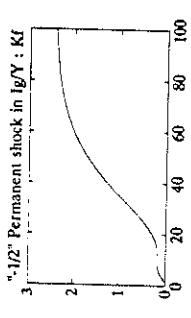
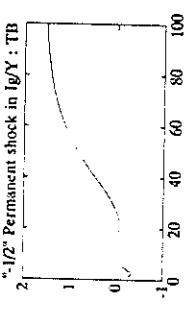
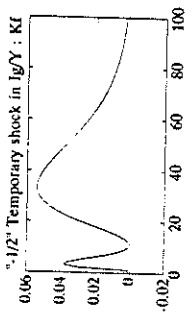
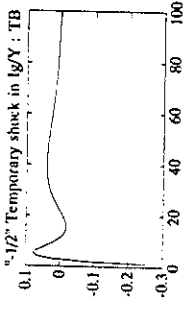
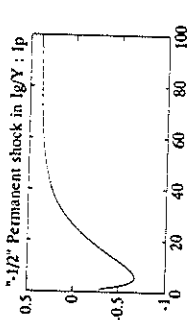
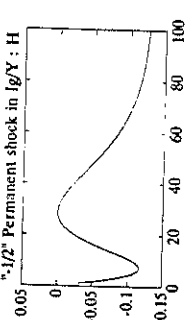
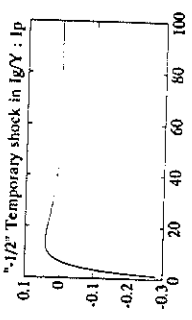
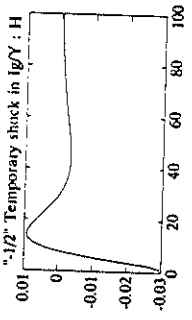
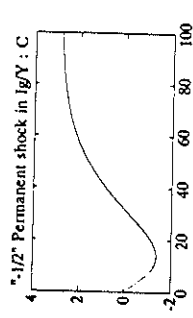
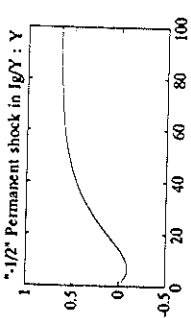
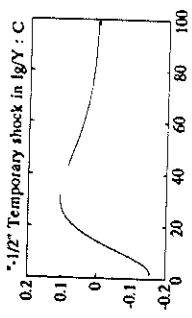
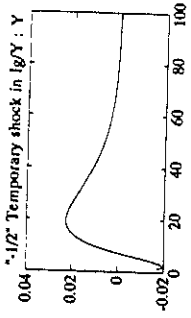


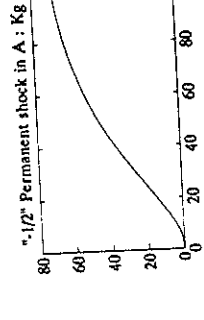
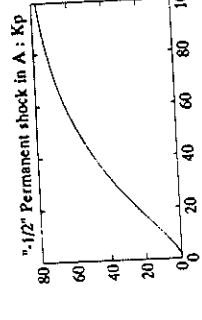
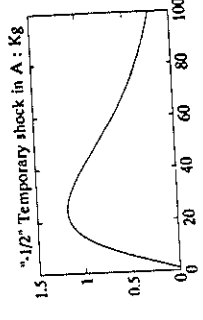
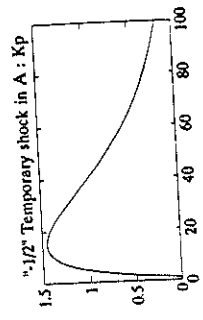


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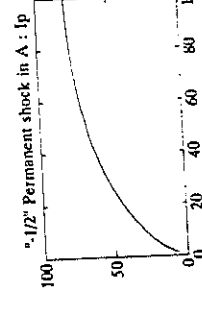
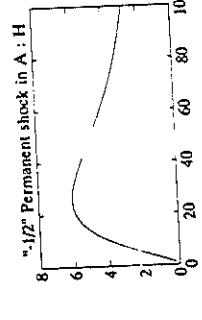
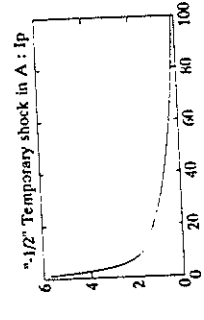
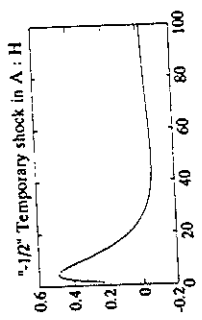
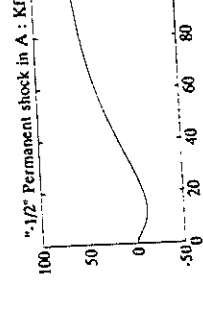
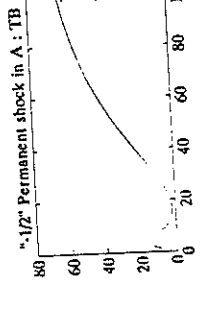
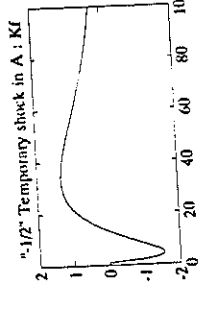
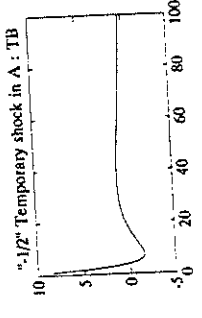


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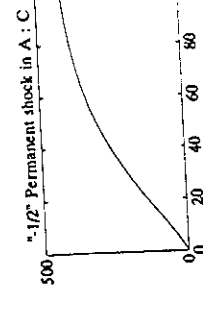
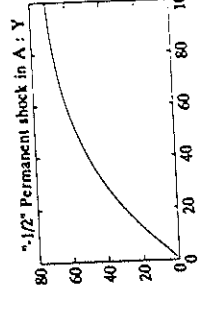
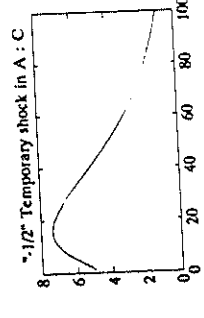
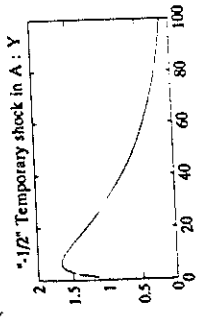


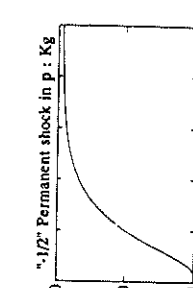
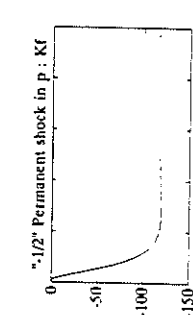
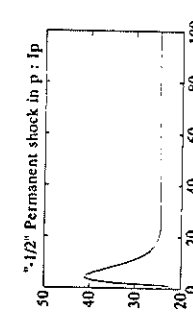
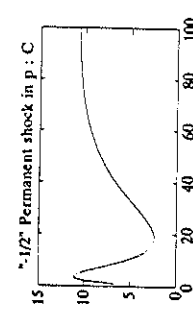
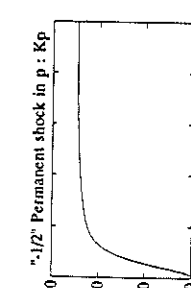
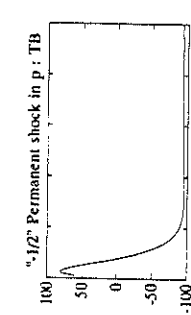
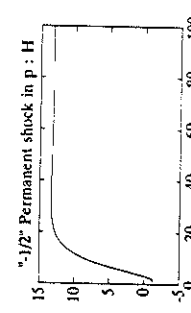
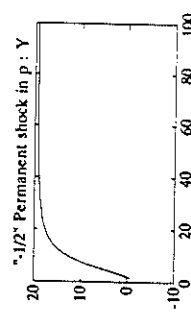
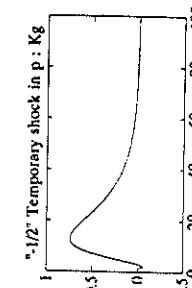
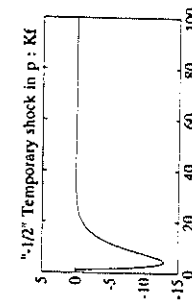
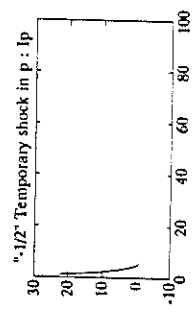
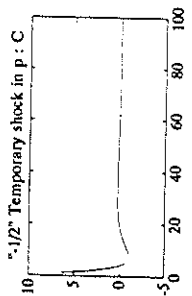
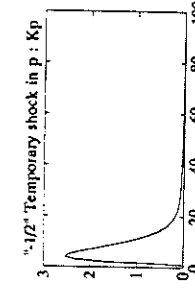
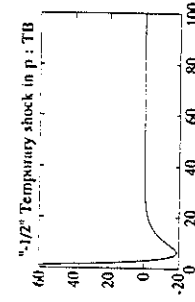
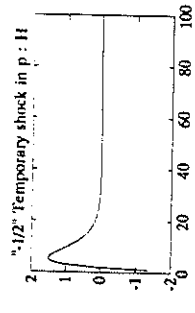
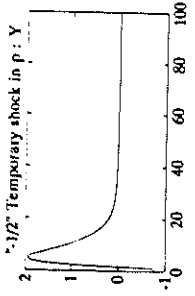


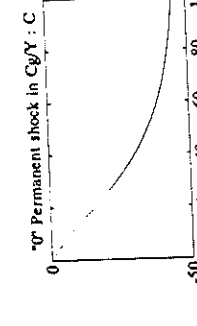
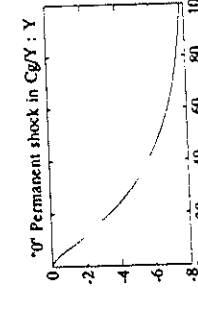
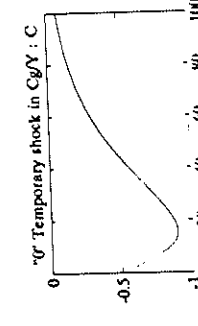
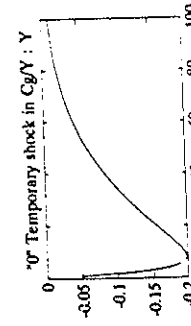
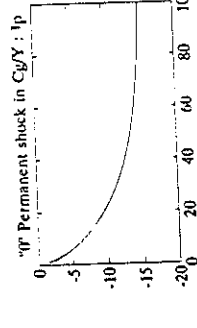
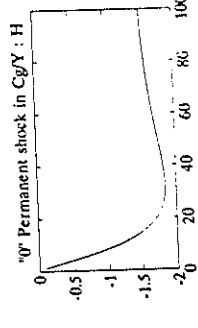
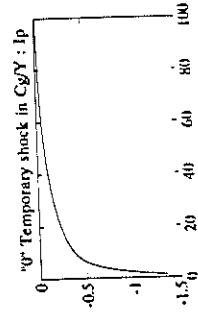
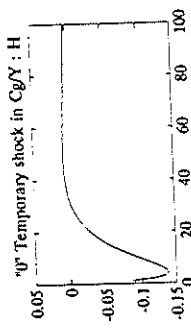
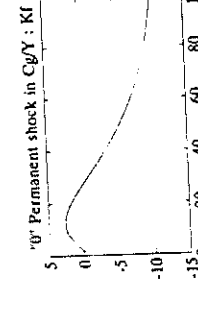
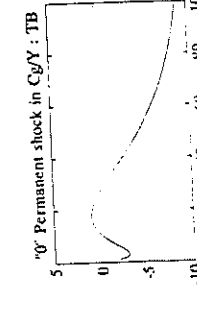
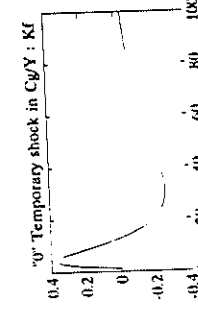
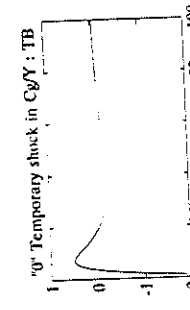
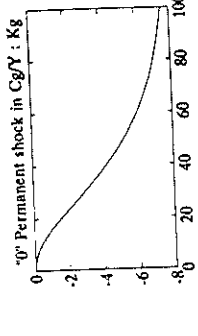
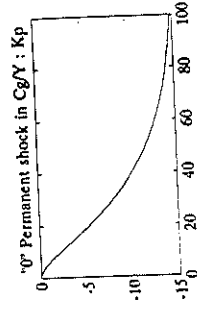
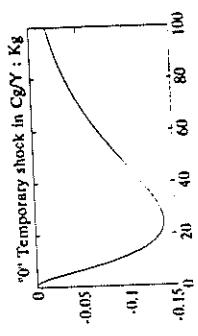
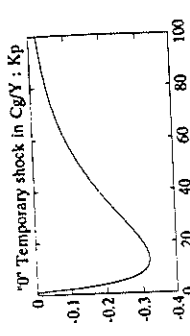
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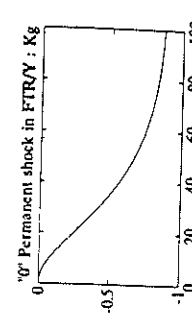
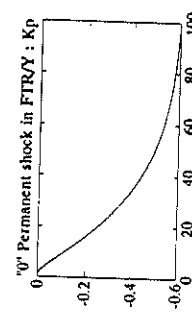
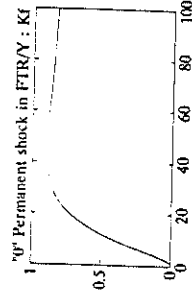
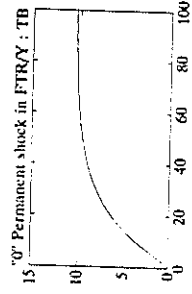
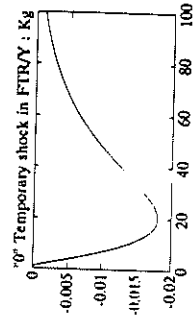
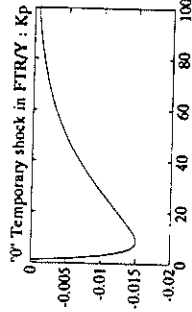
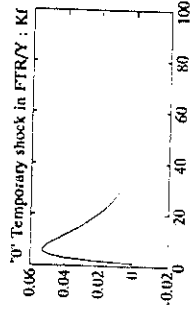
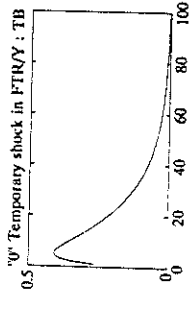
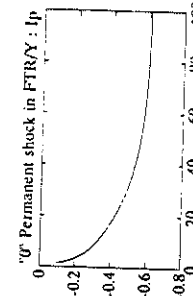
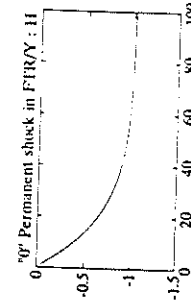
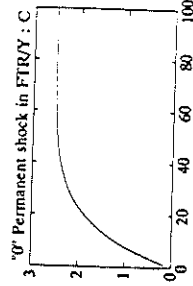
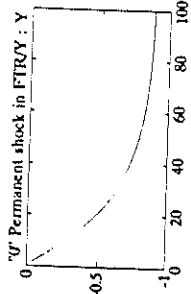
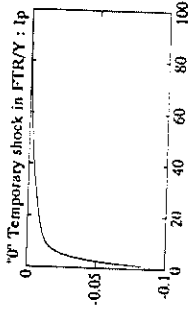
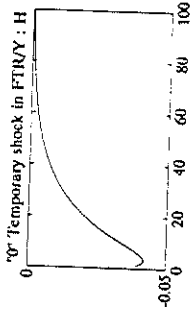
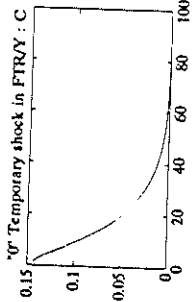
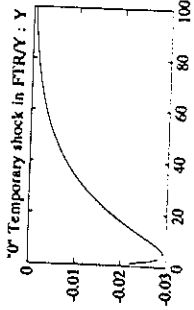


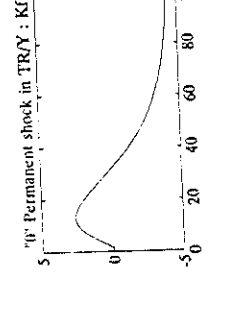
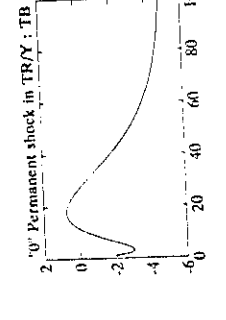
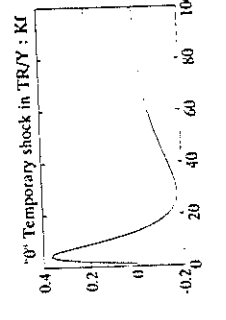
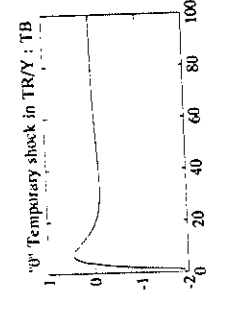
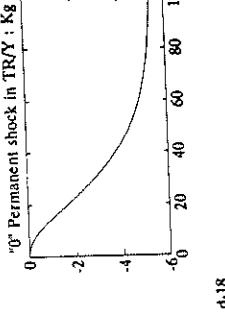
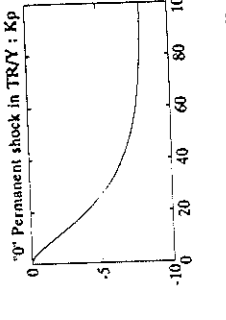
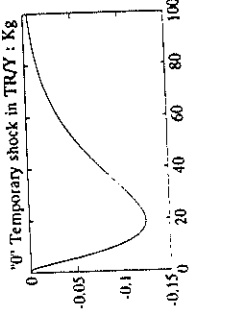
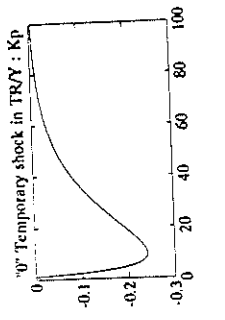
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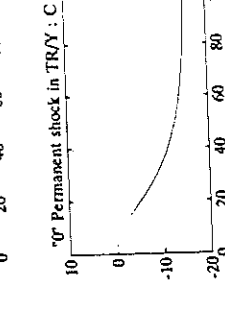
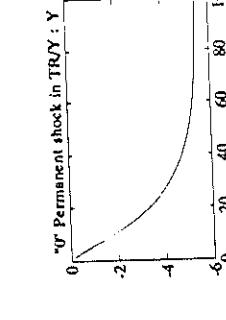
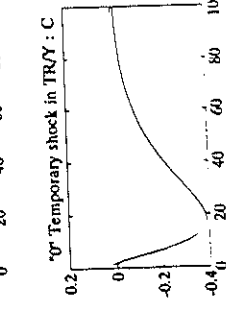
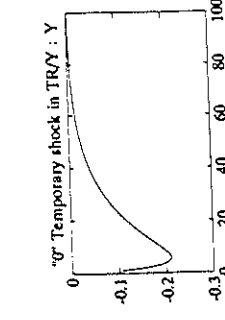
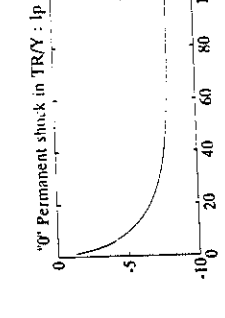
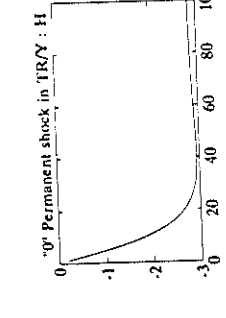
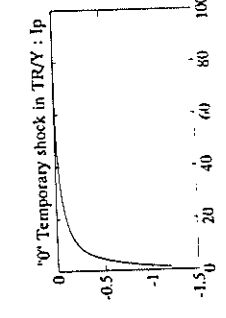
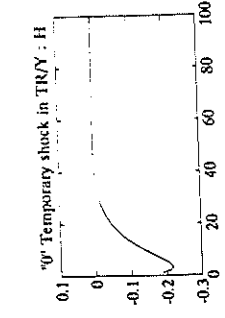




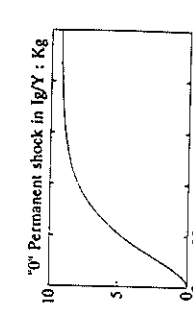
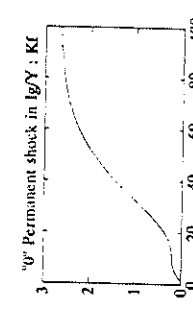
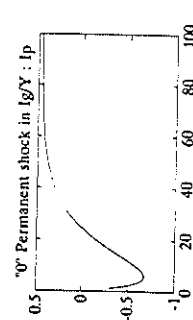
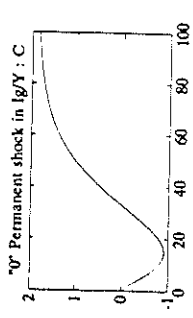
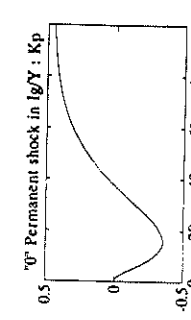
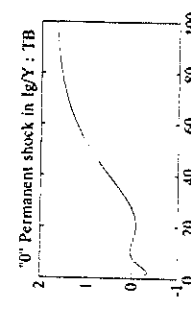
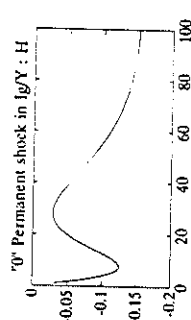
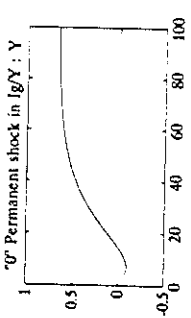
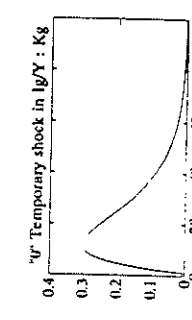
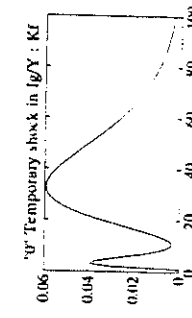
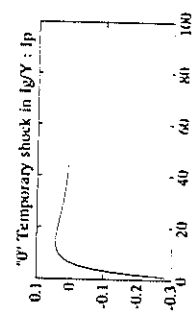
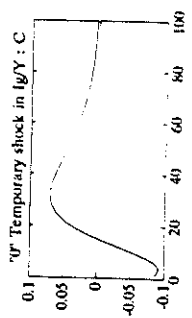
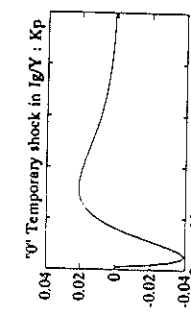
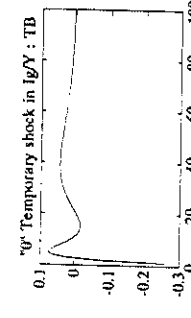
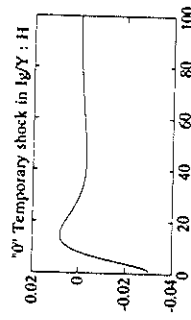
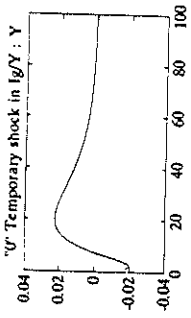




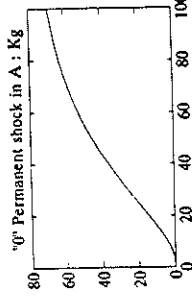
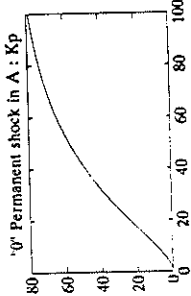
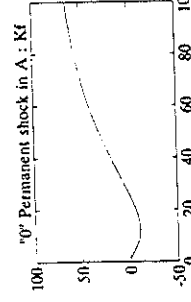
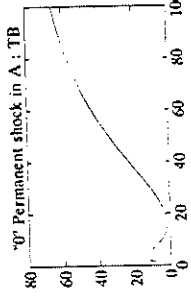
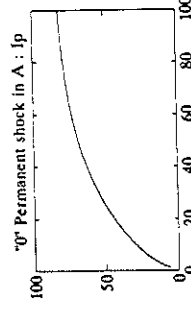
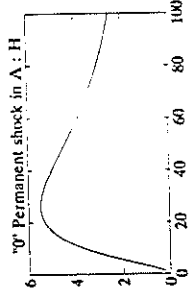
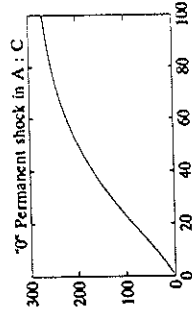
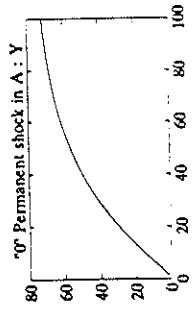
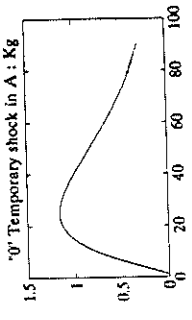
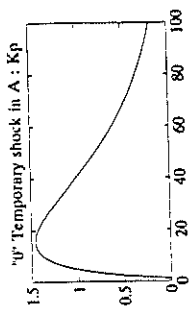
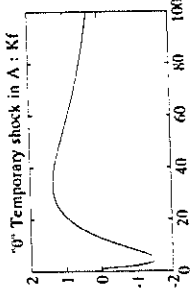
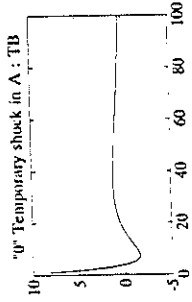
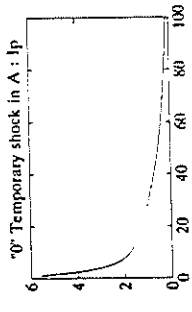
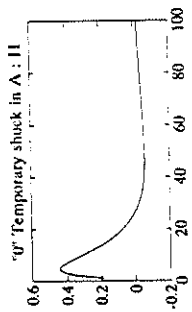
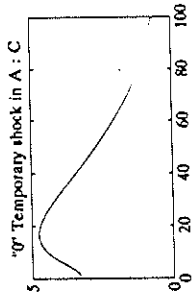
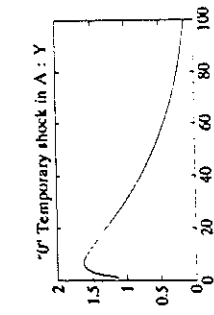
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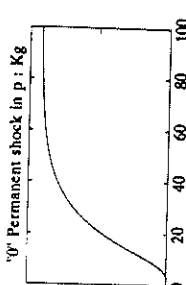
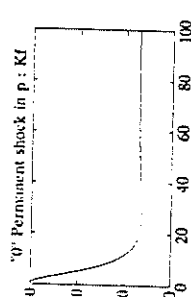
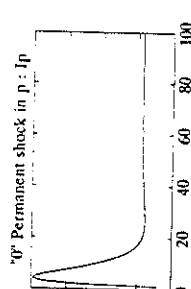
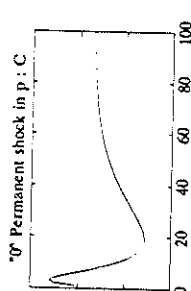
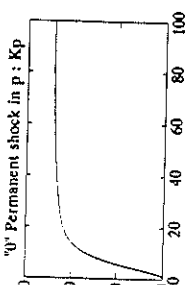
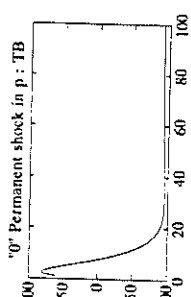
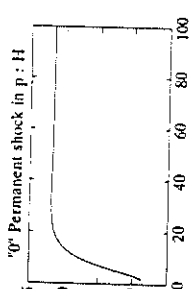
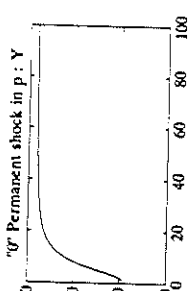
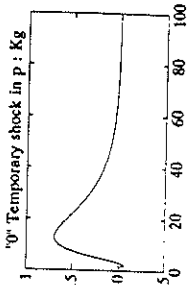
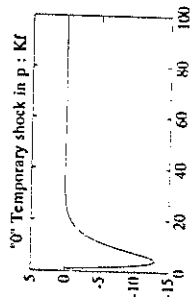
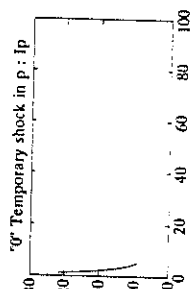
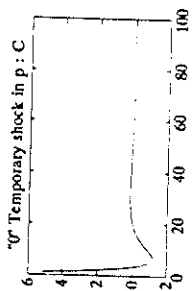
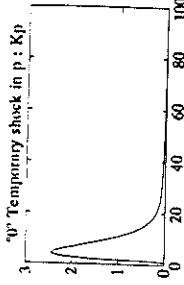
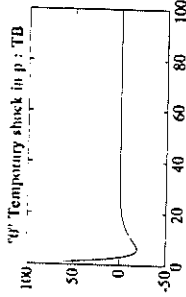
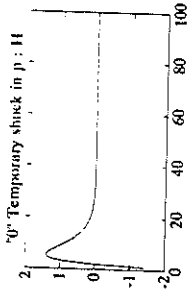
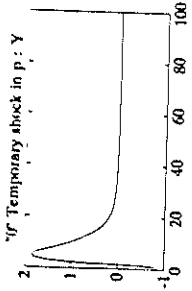


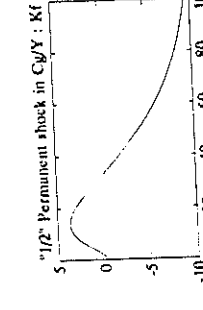
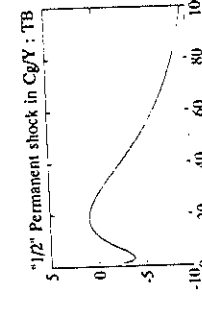
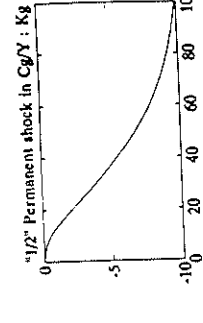
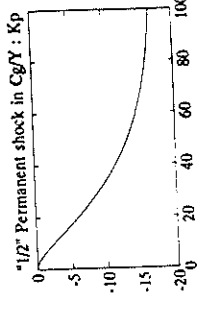
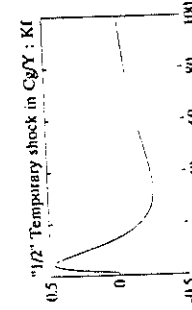
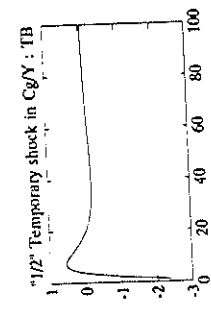
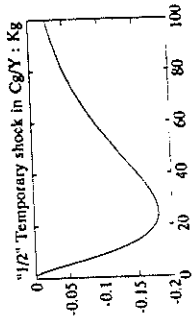
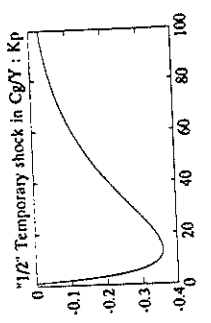
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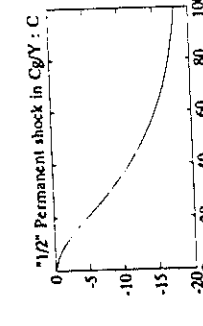
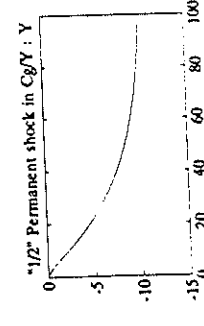
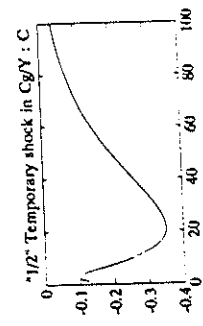
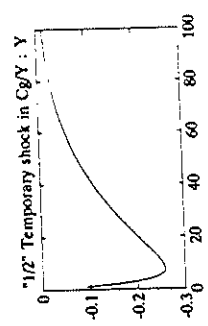
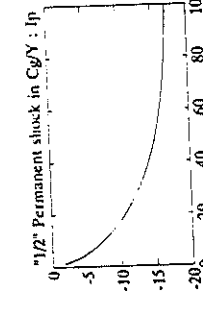
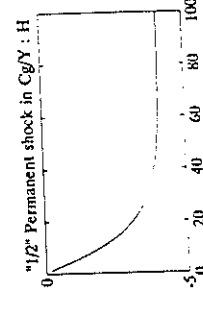
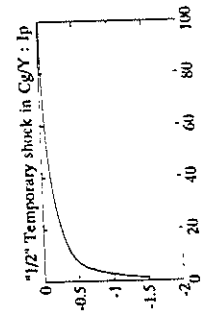
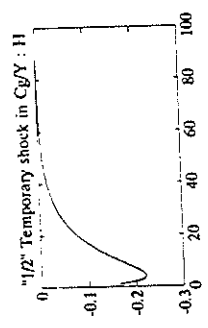




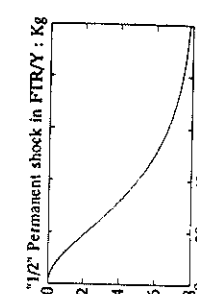
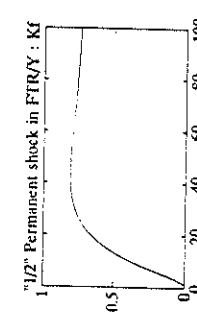
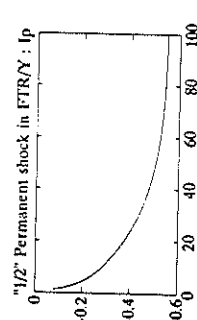
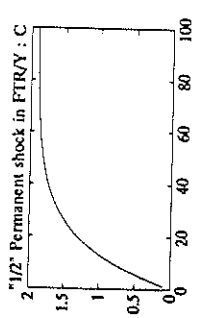
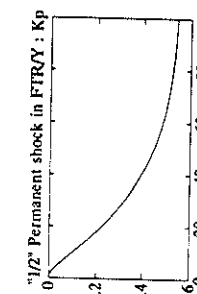
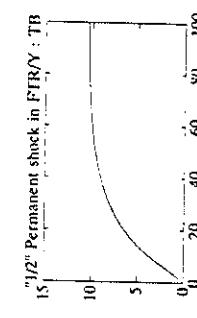
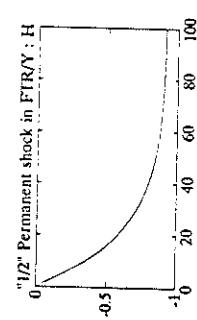
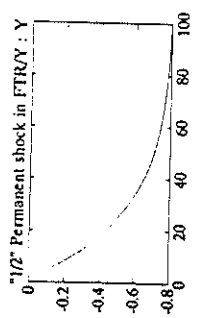
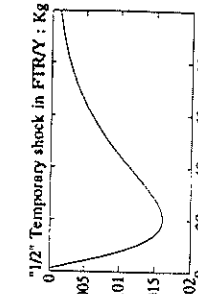
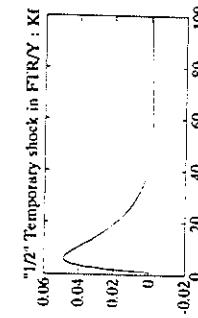
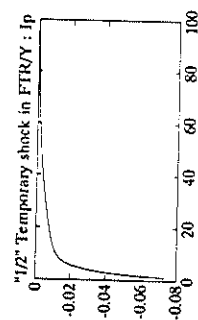
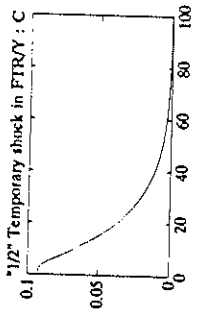
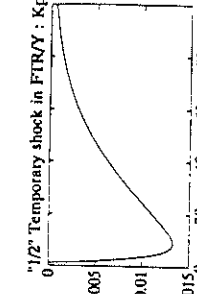
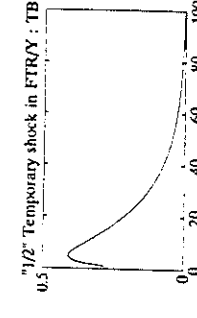
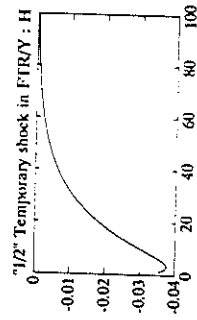
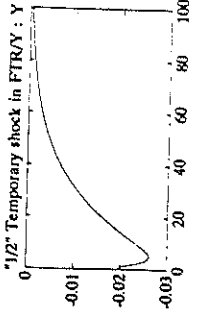


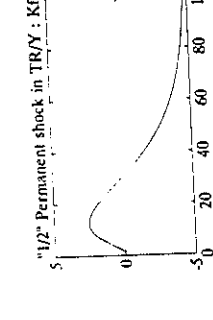
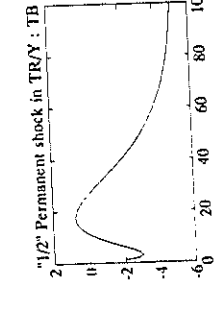
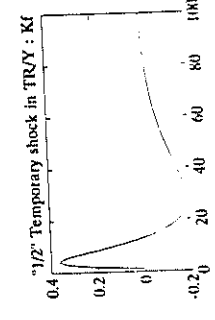
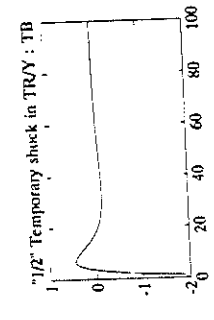
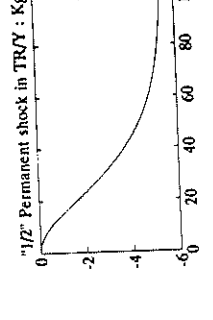
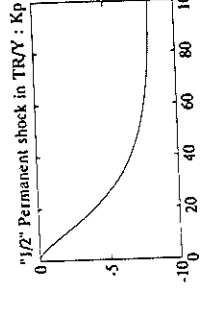
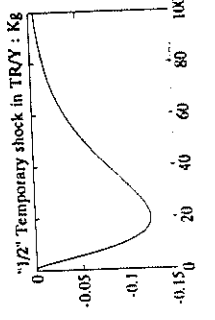
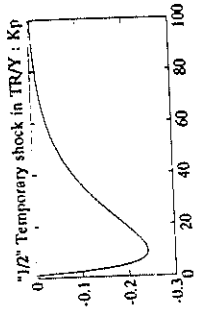


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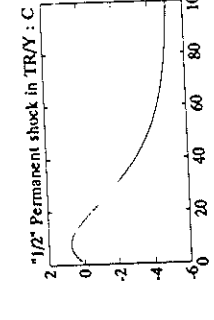
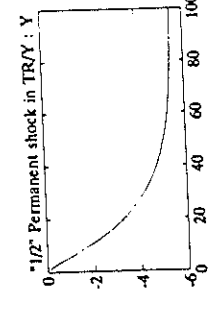
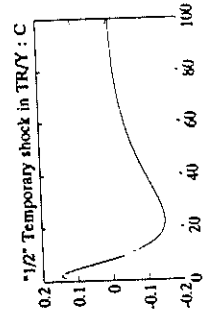
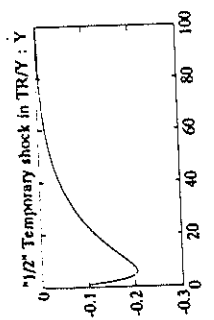
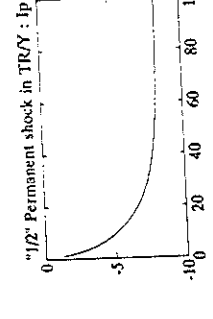
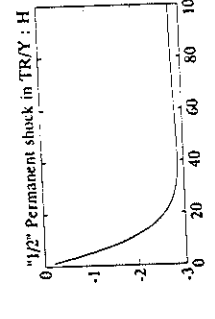
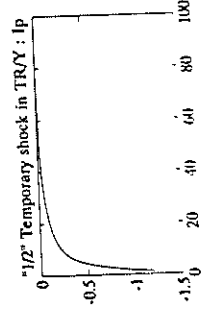
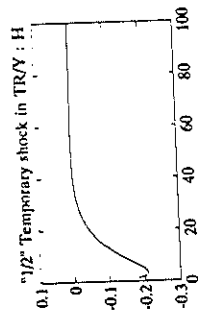


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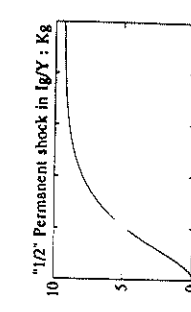
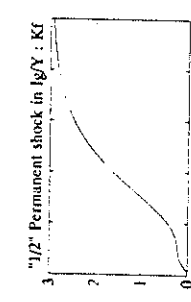
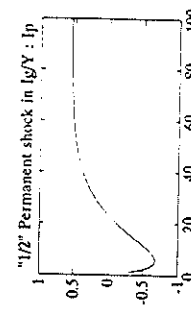
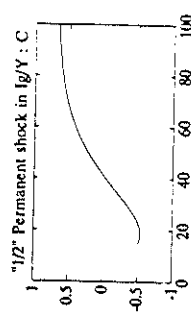
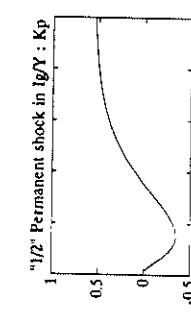
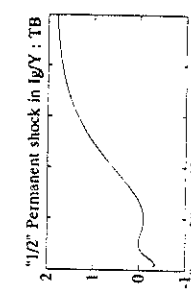
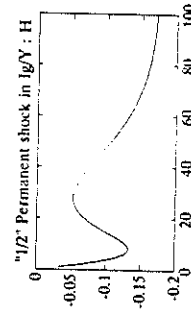
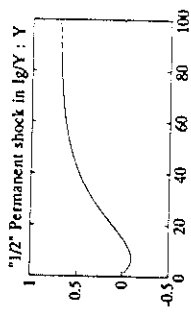
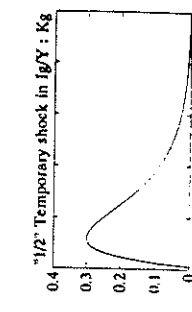
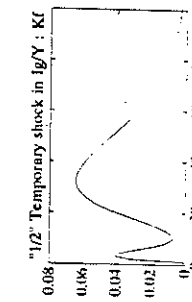
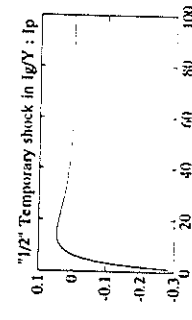
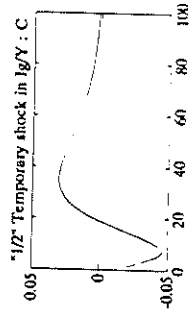
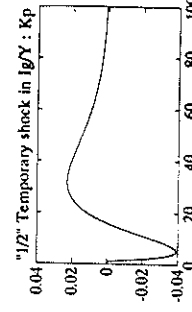
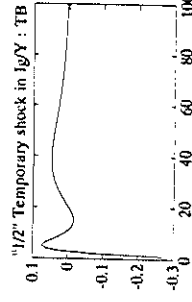
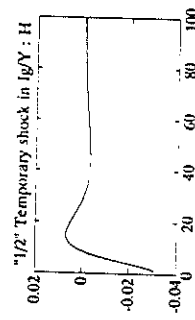
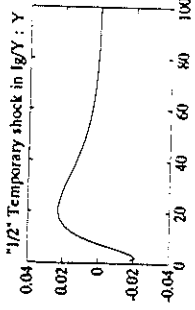


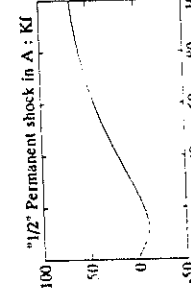
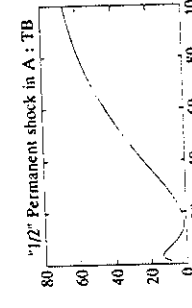
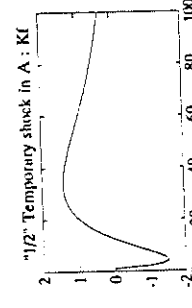
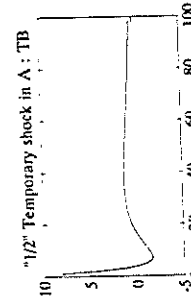
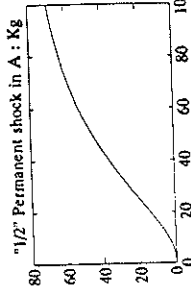
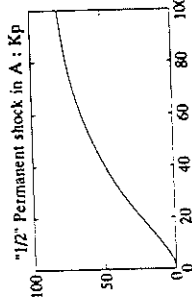
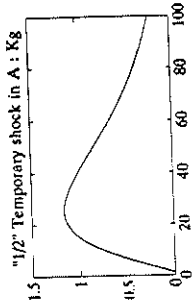
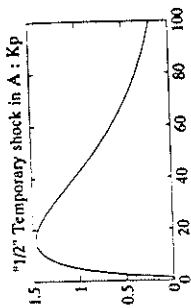


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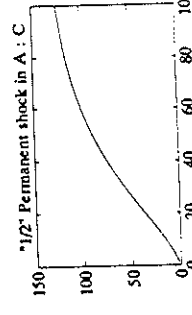
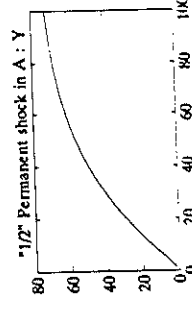
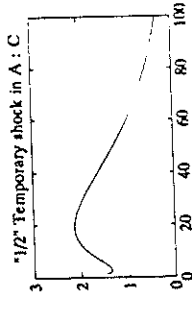
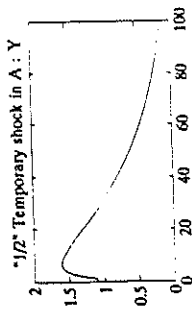
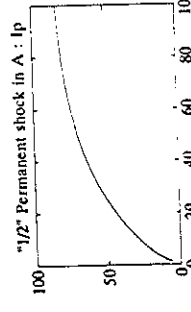
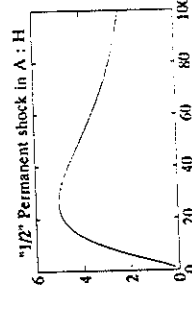
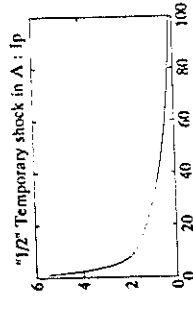
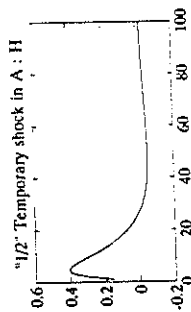


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