

Fiscal Spending Shocks and the Price of Investment: Evidence from a Panel of Countries

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Abstract

The effects of fiscal spending shocks are estimated by the introduction of a measure of fiscal policy into the neoclassical growth model via a parametric function that distorts the value of newly created capital. The model is estimated by Method of Simulated Moments (MSM) via conditional moments (IRFs) from a panel of countries. We find that fiscal spending distortions cannot be rejected as an important determinate for deviations in the relative price of investment for the OECD countries. An implication is that a one-standard error shock to fiscal spending can increase GDP by as much as 1.12% over an eight year horizon. Alternatively, the price of investment seems not to be affected by fiscal policy shocks in less developed countries

Key words: General Equilibrium Dynamics; Fiscal Spending Shocks; Method of Simulated Moments.

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1 Introduction

In theoretical exercises Easterly (1993), Chari, Kehoe, and McGrattan (1997), and McGrattan and Schmitz (1999) examine investment distortions that affect capital accumulation. They find that roughly four-fifths of the variation of cross-country incomes can be accounted for by these distortions to the capital accumulation process. The primary motivation for the theoretic exercises is that there are empirically large differences in real investment prices, as found by Barro (1991) and Easterly (1993). Thus, the implication is that investment distortions can account for the significant cross-country differences in growth.

This paper is concerned with a complementary issue – in a mix of countries how does the relative price of investment behave at business cycle frequencies and are deviations in fiscal spending policy quantitatively important for generating this behavior? This issue appears non-trivial because the relationship between the capital formation process and the public sector has been found to be statistically important by the empirical work of Benhabib and Spiegel (1994). They found, using cross-country estimates of physical capital stocks, that capital positively affects economic growth. But when the capital is taken out, previously insignificant variables – that include measures of the size of public institutions – become significant.

There is a large literature on the theoretic contributions of exogenous deviations in the relative price of investment to an economy’s business cycle behavior. In these cases, the price is exogenous and represents investment-specific technological change. The first paper on the subject is Greenwood, Hercowitz, and Huffman (1988). Other papers that have followed on the business cycle implications of investment-specific technological change are Christiano and Fisher (1998), Fisher (1997), Greenwood, Hercowitz, and Krusell (2000), and Fisher (2002). The main finding is that investment-specific technology shocks account for about 30 to 40 percent of the cyclical variations in output (Greenwood, Hercowitz, and Krusell, 2000; and Fisher, 2002). Though, much is known about the business cycle impacts of investment specific technology shocks, little knowledge exists so far about whether these shocks are indeed pure technology.¹ Therefore, this paper adds to the literature by determining, via theoretical modeling and estimation, the contribution of fiscal policy to movements in the price of investment.

In the theoretical modeling, fiscal spending affects capital by entering the intertemporal Euler equations via a parametric function that distorts the value of newly created capital. Because the Euler equations relate the current costs and future discounted benefits for capi-

¹Fisher (2002) notes this point.

tal investments, the fiscal policy variable acts as a tax wedge, thus affecting the steady-state level of capital through the relative price of investment. In addition, the tax wedge process is an ad-hoc specification and thus has an uncertain component; another term is included to account for uncertainty in the actual process that governs the distortions that includes, presumably, technological change. Because technological change can not be observed directly and enters the Euler equations in a non-additive fashion, General Method of Moments (GMM) will be inoperable as an estimation technique.²

Toward this end, and as a key to the analysis, we employ a version of the estimation algorithm outlined by Rotemberg and Woodford (1997) and used recently by Fuhrer (2000), Amato and Laubach (2003), and Auray and Gallès (2002). Specifically, the reduced-form processes for capital, consumption, investment price, and fiscal policy are estimated by a state-space model (SSM) to obtain empirical estimates of the conditional distributions describing these variables. The SSM is then used to generate separate sets of simulated time series for the computation of the empirical distribution of impulse response functions (IRFs). Next, the theoretical relationships between the population IRFs implied by the linearized intertemporal Euler equations are replaced by the averaged simulated IRFs. In the final step of the algorithm, the simulated linearized Euler equations are summed, squared, and minimized with respect to the structural parameters of the model.

There are two important features of this algorithm to note. First, because the method minimizes a squared metric between simulated and sample values, the Method of Simulated Moments (MSM) of McFadden (1989) and Pakes and Pollard (1989) is being used. Operating in an MSM environment allows for the computation of the asymptotic variance-covariance matrix for the parameters and, hence, conducting hypothesis tests in the usual way. Second, not only is the estimated SSM a benchmark to test the theoretical model, the SSM is directly used in the computation of the theoretical parameters. Therefore, the estimation procedure is relatively efficient since the higher order moments contained in the IRFs of the SSM are used directly.

The results can be quickly summarized. For the OECD countries, fiscal spending shocks cannot be rejected as an important determinant for deviations in the relative price of investment. Specifically, using data on a panel of countries, the estimated effect of a 1 percent increase in the size of government is found to decrease the relative price of investment by 36%. Additionally, deviations in fiscal spending immediately increases national income by 0.13% percent, followed by a slow damping. The persistence of the effects on GDP imply income rises by 1.12% over an eight year horizon. Alternatively, the Non-OECD estimation

²This argument is forcefully made by Sill (1992).

and modeling appear not to be consistent with investment shocks.

The remainder of the paper is as follows. Section 2 describes the data and lists the empirical facts. Section 3 describes the theoretical model. Section 4 presents the estimation methods. Section 5 presents the main results. The last section concludes.

2 The Data

This section reports some empirical facts related to fiscal spending observed in a large sample of countries. The data used for the estimation is from a panel of 71 countries. Additionally, a dynamic factor model in state-space form is estimated to extract the co-movements of the capital-output ratio, consumption growth, and investment price following a shock to the government-consumption/output ratio that is to be our measure of fiscal policy.

2.1 Definitions and Empirical Facts

The sample variables come from the Penn World tables (PWT) version 6.0 and form a 72 country panel of macroeconomic data.³ The variables are further classified as Organization for Economic Cooperation and Development (OECD) and Non-OECD countries. To keep the panel relatively balanced and to eliminate the effects of different exchange rate regimes, only the years from 1973 through 1998 are used for the summary statistics and estimation models.

Following Chari *et al.* (1997), Y , which stands for Gross Domestic Product (GDP), is constructed by using real GDP per capita in constant dollars (RGDPCH) and multiplying this by population (POP). The variable per capita consumption is constructed by using the consumption share of RGDP, where RGDP is real per capita GDP in constant prices based on the Laspeyres method. The log of consumption growth from period $t - 1$ to t is denoted as $\Delta \tilde{c}_t = \log(C_t/C_{t-1}) - \log(N_t/N_{t-1})$.

To construct the K/Y variable, the capital-output ratio, the study makes use of the investment share of real per capita GDP (RGDPL). The initial capital-output ratio is constructed according to the formula employed by Chari *et al.* (1997), that is, $(X/Y)/(n+g+\delta)$, where X/Y is the average investment output ratio from 1961 to 1998 and n is the average rate of growth of the work force over the same period. The variable g is the common world rate of technical change. It is set at 2.3 percent per year, and δ is the rate of depreciation,

³The choice of variables is intended to capture the essential features of our theoretical model presented in the next section. An appendix to this paper lists all countries.

which is assumed to be 6 percent per year. The initial capital stock is constructed so that the capital-output ratio in 1961 equals the capital-output ratio in 1998. Based on the initial capital stock, all following figures for the capital stock are constructed using the perpetual inventory method. Finally, we define the log capital-output ratio as $\tilde{k} = \log(K/Y)$.

The measure of fiscal spending is defined as the ratio of government share of real gross domestic product (KG). The log of the fiscal spending variable is denoted by $\tilde{\theta}^f$. The final variable identified from the macroeconomic database is the relative price of investment, defined by the price of investment (PI) divided by the price of consumption (PC); the log value is denoted by $\tilde{p} = \log(PI/PC)$.

Table 1 contains descriptive statistics for the variables that are used in the study. According to Table 1, the capital-output ratio is significantly larger for the countries in the OECD grouping. Second, the relative price of capital is smaller in OECD countries. Together, these facts are consistent with the literature in which the price of capital has been found to be, in general, distorted in low growth economies (Easterly, 1993; Chari, Kehoe, and McGrattan, 1997; McGrattan and Schmitz, 1999; and Barro, 1991). Next, Table 1 indicates that on average, OECD countries spend less as a fraction on income on government consumption; governments in Non-OECD are about 2 percentage points bigger. As the results of Benhabib and Spiegel (1994) suggest, fiscal spending may be acting as a distortion that is working through to the physical capital accumulation process.

Finally, the macrovariables are more volatile in Non-OECD countries. Additionally, the higher volatility in Non-OECD government's share is positively correlated with higher volatility in the relative price of investment. Figure 2 displays the cross-section standard deviations of government's share and the relative price of investment. We see a significant and positive relationship; the correlation coefficient is 0.416.

2.2 State-Space Estimation

The state-space model (SSM) is used for the empirical estimate of the impact of changes in fiscal spending. The SSM, described in Harvey (1989) and Hamilton (1994), is given by the equations:

$$\begin{array}{ll} \text{(measurement equations)} & \mathbf{y}_t = \mathbf{B}\mathbf{x}_t + \mathbf{H}\boldsymbol{\theta}_t + \mathbf{w}_{t+1} \\ \text{(state equations)} & \boldsymbol{\theta}_{t+1} = \mathbf{F}\boldsymbol{\theta}_t + \mathbf{v}_{t+1} \end{array}, \quad (1)$$

where \mathbf{y}_t and \mathbf{x}_t denote $(n \times 1)$ and $(b \times 1)$ vectors of observed variables. Alternatively, the $(r \times 1)$ vector $\boldsymbol{\theta}_t$ are latent variables. The matrices \mathbf{B} , \mathbf{F} , and \mathbf{H} are parameters of dimension $(n \times b)$, $(r \times r)$, and $(n \times r)$, respectively. The vectors \mathbf{w}_t and \mathbf{v}_t are independent

random variables defined, for all t , by $\mathbf{w}_t \sim N(\mathbf{0}, \mathbf{R})$ and $\mathbf{v}_t \sim N(\mathbf{0}, \mathbf{Q})$, and $E(\mathbf{w}_t \mathbf{w}_{t+i}) = E(\mathbf{v}_t \mathbf{v}_{t+i}) = \mathbf{0}$ for all $i \neq 0$. The variance matrices \mathbf{R} and \mathbf{Q} are of size $(n \times n)$ and $(r \times r)$, respectively. The variables in \mathbf{y} are to be the logged capital-output ratio; the logged growth of per capita real consumption; the logged price of investment; and the log of government's share of real gross domestic product. More formally, in vector form the variables are written as: $\mathbf{y}'_t = [\tilde{k}_t, \Delta \tilde{c}_t, \tilde{p}_t, \tilde{\theta}_t^f]$. The variables in \mathbf{x}_t are a constant and a time trend.

The modeling of the states is intended to capture the unobserved factors that determine the investment price. The first factor represents government policy's affect. Estimation of this variable is achieved by restricting the first element of the last row of \mathbf{H} to one; the corresponding variable is denoted θ_t^f . The second and third states are to represent technological change that exogenously and directly affects the value of newly created capital. More specifically, the second state is to be an autoregressive stationary process that is denoted θ_t^a ; its persistence is given by the magnitude of the parameter in the second row and column of \mathbf{F} . The third state is to represent an exogenous permanent (stochastic trend) component of technological change. In this case, the third row and column of \mathbf{F} is set to one. Further, the third row, second and third columns in \mathbf{H} are set to one.

Because consumption is in terms of growth, the states are represented in deviation form in the consumption growth equation. More specifically, lags are included for all the sates thus allowing \mathbf{H} to be augmented; this is accomplished by stacking \mathbf{F} with the identity matrix \mathbf{I} . It is also common in the literature (Kim and Piger, 2001) not to include the stochastic trend directly in the consumption growth equation; it enters indirectly via \mathbf{w}_{t+1} . In this case, the estimated second row and column of \mathbf{R} represents the variance of the shock to the trend times the squared direct effect of θ_t^p on consumption (denoted $h_{2,3}$). Next, when the price of investment has a stochastic trend then the capital-output can be made stationary by multiplication of the exponential to the stochastic trend (Fisher, 2002). In terms of logs, the stationary restriction is incorporated by setting the first row, third column of \mathbf{H} to minus one. Finally, the capital series has been constructed by the perpetual inventory method and, as a result, is most likely noisy. In this case, the first element in \mathbf{w}_{t+1} is to a represent the possibility of measurement error in the capital stock series.

In total, the unobserved states are given by $\boldsymbol{\theta}'_t = [\theta_t^f, \theta_t^a, \theta_t^p, \theta_{t-1}^f, \theta_{t-1}^a, \theta_{t-1}^p]$ with the

parameter matrices for the observation equations being:

$$\mathbf{H} = \begin{bmatrix} h_{1,1} & h_{1,2} & -1 & 0 & 0 & 0 \\ h_{2,1} & h_{2,2} & 0 & -h_{2,1} & -h_{2,2} & 0 \\ h_{3,1} & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \quad \mathbf{R} = \begin{bmatrix} r_{1,1}^2 & 0 & 0 & 0 \\ 0 & h_{2,3}^2 q_{3,3}^2 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}.$$

The parameter matrices for the state equations are:

$$\mathbf{Q} = \begin{bmatrix} \mathbf{Q}_1 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}, \quad \mathbf{F} = \begin{bmatrix} \mathbf{F}_1 & \mathbf{0} \\ \mathbf{I} & \mathbf{0} \end{bmatrix},$$

where

$$\mathbf{F}_1 = \begin{bmatrix} f_{1,1} & f_{1,2} & 0 \\ 0 & f_{2,2} & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{Q}_1 = \begin{bmatrix} q_{1,1}^2 & 0 & 0 \\ 0 & q_{2,2}^2 & 0 \\ 0 & 0 & q_{3,3}^2 \end{bmatrix}.$$

Estimation of and inference in the model are conducted in three steps. The first step is to compute the coefficients of the model for each country. For any country, one could apply a generalized version of least squares to (1) for the set of parameter vectors. Alternatively, a Kalman filtering approach is typically easier to implement and more intuitive. For the given parameters of the model, the filter provides the prediction error, $\boldsymbol{\eta}_{t|t-1}$, and its variance, $\mathbf{f}_{t|t-1}$. The sample log likelihood for the state-space model is then represented by:

$$L(\boldsymbol{\Psi}^i) = \sum_{t=1}^T \ln((2\pi)^{-n/2} |\mathbf{f}_{t|t-1}|^{-1/2}) - \frac{1}{2} \sum_{t=1}^T \boldsymbol{\eta}'_{t|t-1} (\mathbf{f}_{t|t-1})^{-1} \boldsymbol{\eta}_{t|t-1},$$

which can be maximized with respect to the unknown parameters of country i (denoted by $\boldsymbol{\Psi}^i$) given initialization of the filter.

Initialization of the estimation algorithm is by definition of the matrices $\boldsymbol{\theta}_{0|0}$ and $\mathbf{P}_{0|0}$. The unconditional mean and covariance matrix of $\boldsymbol{\theta}_t$ are employed as initial values for the stationary states and are:

$$\boldsymbol{\theta}_{0|0} = (\mathbf{I} - \mathbf{F})^{-1} E[\mathbf{v}_0], \quad \text{vec}(\mathbf{P}_{0|0}) = (\mathbf{I} - \mathbf{F} \otimes \mathbf{F})^{-1} \text{vec}(\mathbf{Q}).$$

When $\boldsymbol{\theta}_t$ is non-stationary, we can treat $\boldsymbol{\theta}_{0|0}$ as a parameter to be estimated. Because $\boldsymbol{\theta}_{0|0}$ is no longer a random variable, $\mathbf{P}_{0|0}$ should be set to set equal to 0 in the non-stationary rows and columns (Harvey, 1989). Once the parameters are estimated, the algorithm may

be re-initialized by setting $\boldsymbol{\theta}_{0|0} = \hat{\boldsymbol{\theta}}_{0|0}$ and $\mathbf{P}_{0|0} = cov(\hat{\boldsymbol{\theta}}_{0|0})$.

The second step is to group the estimates to form a consistent estimator for an average country. That is, we average the parameters for the mean group (MG) estimator which has been shown by Pesaran and Smith (1995) to be the consistent estimator when parameter heterogeneity and lagged dependent variables are present. The estimators for the mean and parameter variances are defined as:

$$\boldsymbol{\Psi}^{mge} = \frac{1}{m} \sum_{i=1}^m \boldsymbol{\Psi}^i, \quad var(\boldsymbol{\Psi}^{mge}) = \frac{1}{m(m-1)} \sum_{i=1}^m (\boldsymbol{\Psi}^i - \boldsymbol{\Psi}^{mge})(\boldsymbol{\Psi}^i - \boldsymbol{\Psi}^{mge})',$$

where m is the number of countries in the grouping. Three sets of MG parameter estimates are presented: (i) the entire sample; (ii) the OECD countries; and (iii) the Non-OECD countries.

The third and final step of the modeling process is intended to help us infer the importance of the contemporaneous effects not obvious by inspection of the parameter matrices. This is accomplished by deriving the impulse response functions. The impulse response function of variable y is formally defined as the difference

$$h_t^y(j, i) = E_t[y_{j+1}] - E_{t-1}[y_{j+1}].$$

Thus, the impulse response function represents the change in the expected value of all future time j variables from a time t shock generated from the i 'th equation. For estimation of the IRFs, the generalized method of Pesaran and Shin (1997) is employed, which is characterized by the fact that the simulation results do not depend on the ordering of the equations or variables in the system. All impulse response functions track the effects of a one-standard error shock to the fiscal policy equation.⁴

2.3 The State-Space Results

The SSM estimation results are present in Table 2. First, the results for the OECD countries show that the fiscal policy variable is statistically important in the determination of the variables in \mathbf{y}_t . We see that *all* the coefficients in the first column of \mathbf{H} , that represent the factor loadings for θ^f , can not be rejected as significant at the 15% level. The process that governs θ^f , found in the estimates of \mathbf{F} and \mathbf{Q} , are also significant with, in addition, the government policy variable being somewhat persistent as indicated by its autoregressive

⁴Note that the impulse response function resulting of variable y from a time t change in the random variable v_t^f , where f denotes the fiscal policy equation is given by $h_t^y(j, f)$.

parameter of 0.731. In Non-OECD countries the estimates that represent the effects of the θ^f roughly match the OECD estimates and are significant with the exception of $h_{3,1}$; fiscal policy's factor loading on the investment price.

For the purpose of highlighting differences in the evolution of the co-variates, Figure 2 displays the IRFs for the variables after a one-standard error fiscal spending shock. The first panel shows that the capital-output variable increases while the growth in consumption and the investment price initially fall. The capital-output ratio and investment price demonstrate a gradual response for several years. Alternatively, after the initial shock, consumption growth is negative, followed immediately by a large positive jump and decay. Note that the decay in consumption growth is slowly damping towards zero. The implication is that consumption is below its mean but increasing back towards its unconditional mean.

The second and third panel in Figure 2 indicate that the variables in OECD and Non-OECD countries adjust differently. Specifically, an OECD fiscal policy shock significantly alters the price of investment (negative); in the Non-OECD countries the price variable does not appear to respond. Thus, the dynamic effects of OECD fiscal spending shocks are important in our understanding of movements in the investment price series – this is a direct effect of the significant of the parameters in **H**.

Now consider the effects of an increase in the price of investment caused by an increase in θ^p ; a permanent decrease in the level of investment specific technology. According to Table 2 an increase in θ^p significantly alters the capital-output ratio (negative by restriction), price of investment (positive by restriction), and the growth of consumption (positive). Note that these predictions match the OECD results for a decrease in θ^f . That is, the effects of fiscal spending shocks are consistent with the estimated dynamics of a positive investment specific shock. There are a wide variety of spending programs that can presumably alter the value of newly created capital. For example, it is believed that fiscal spending on, for example, the internet has increased the productivity of newly created capital. For the Non-OECD, fiscal policy appears not to affect the investment price. In these countries fiscal spending may be characterized, as stressed by Barro (1997), by collective enactments of rich-to-poor redistribution of income that presumably have no effects on the price of investment.

What effects will an increase in θ^f have on other macroeconomic aggregates (*e.g.*, capital, output, labor)? We know that capital should increase to be consistent with the macroeconomic theory of a positive investment specific shock (Greenwood, Hercowitz, and Huffman, 1988; Greenwood, Hercowitz, and Krusell, 2000). More specifically, temporary shocks to the value of investment will have two effects: an intertemporal substitution and an income effect. In the intertemporal substitution effect, the productivity of newly produced capital

increases, causing households to shift out of consumption and into next period's capital. In the income effect, consumption and capital investment are persuaded to increase.

Though capital appears to have increased, it is unclear what has happened to output and labor effort. Because the estimation is conducted in reduced form, we are unable to determine the relative elasticity of labor and capital and hence their dynamics. Additionally, theory does not offer more guidance. As noted by Greenwood *et al.* (1988), when θ^f is serially correlated, the exact theoretical dynamic effects on consumption, output, and labor effort from changes in the price of investment are ambiguous. That is, a numerical model must be used in analytical predictions of the dynamic effects of distortions from government policy. Toward this end, the next several sections introduce a structural model that is to be estimated and solved for effects of government policy when it distorts the price of investment.

3 The Model

The model economy is assumed to have three types of economic institutions: households, firms, and the public sector. In the model, time evolves in discrete units, called periods (which are specified to be one year long in the quantitative results reported later on). Each period, households make decisions on consumption, supply labor, and physical capital investments. The investment choice is assumed to be distorted by the public sector by making the price of newly produced capital a function of fiscal policy.

3.1 The Households

Households' problem is to maximize lifetime utility given the choice between consumption, labor hours, and loans of capital. They maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, \ell_t),$$

subject to the budget constraints and capital accumulation processes:

$$\begin{aligned} C_t + P_t X_t &\leq (1 - \tau_t)[R_t K_t + W_t \ell_t], \\ K_{t+1} &= (1 - \delta)K_t + X_t, \end{aligned}$$

where β is the discount factor. Additionally, C_t is consumption, X_t is physical capital investment, ℓ_t is labor choice, K_t is capital stock, R_t is the capital rental rate, W_t is the wage

rate, τ_t is an income tax, and P_t is the real value of newly created capital.

Since there is no trend in hours worked in the data, but there is a trend in wages, we choose the momentary utility function that implies constant relative risk aversion with respect to consumption. Second, preferences for labor are assumed to be additive separable from consumption, giving a utility function of:

$$u(C_t, \ell_t) = \frac{C_t^{1-\rho}}{1-\rho} + \omega_{1,t} \frac{(1-\ell_t)^{1-\omega_2}}{1-\omega_2},$$

where the ω 's give the elasticity for labor. This utility function is consistent with balanced growth only if one of the following two conditions hold: (i) $\rho = 1$ and $\omega_{1,t} = \omega_1$; or (ii) $\omega_{1,t}$ grows at the rate of technological progress.

3.2 The Firms

The representative firm rents capital and hires labor. The firm produces consumption goods via a neoclassical constant returns to scale production function and chooses $\{K_t, \ell_t\}$ to maximize: $\pi_t = F(K_t, A_t N_t \ell_t) - W_t N_t \ell_t - R_t K_t$, where A_t is a labor-augmenting technological process parameter. The firm takes as given $\{R_t, W_t\}$. In equilibrium, the factors of production are paid their marginal products:

$$F_K(t) = R_t, \quad F_\ell(t) = W_t,$$

where $F_K(t) \equiv \partial F(K_t, A_t N_t \ell_t) / \partial K_t$, for example. The Cobb-Douglas form is chosen for the production technology because it is consistent with the relative constancy of income shares:

$$Y_t = K_t^\alpha (A_t N_t \ell_t)^{1-\alpha}.$$

The capital shares are assumed to satisfy $0 < \alpha < 1$. Finally, technology and population are assumed to be described by the following processes:

$$A_t = A(1+g)^t, \quad N_t = N(1+n)^t .$$

3.3 The Public Sector

The public sector represents the channels through which government distorts the economy. First, income is distorted by the following tax rate:

$$\tau_t = \exp(\tilde{\tau} + \theta_t^f).$$

We then let the logged tax rate be defined as: $\log(\tau_t) \equiv \tilde{\tau}_t = \tilde{\tau} + \theta_t^f$. Second, the value of physical capital is assumed a function of θ_t^f and is to follow the parametric form:

$$P_t = \exp(\phi_0 + \phi_1 \theta_t^f + \theta_t^a + \theta_t^p), \quad (2)$$

where θ_t^f is the log of time t ratio of government share of real gross domestic product. The variables θ_t^a and θ_t^p are intended to represent persistent and permanent shifts, other than fiscal policy, that alter the price of investment. The exponential assures that the relative price of capital is always positive.

The effects of fiscal spending are determined by the sign and magnitude of ϕ_1 . If increased spending is associated with increases (decreases) in the productivity of newly produced capital, then we expect $\phi_1 < 0$ ($\phi_1 > 0$); a temporarily bigger government implies less (more) distortions to the price of investment.

3.4 Characterization of the Equilibrium

The conditions for optimality for the above dynamic programming problems can be written as stochastic Euler equations:

$$-u_\ell(t) = (1 - \tau_t)W_t u_c(t), \quad (3a)$$

$$P_t u_c(t) = E_t \{ \beta u_c(t+1) [R_{t+1}(1 - \tau_{t+1}) + P_{t+1}(1 - \delta)] \}, \quad (3b)$$

where $u_c(t) = \partial u(C_t, \ell_t) / \partial C_t$ and $u_\ell(t) = \partial u(C_t, \ell_t) / \partial \ell_t$. Since interpretation of the Euler Equations will be critical to understanding the method of estimation, we take a moment to discuss the meaning of the equations above (despite their being standard conditions). The household's intratemporal first-order condition, (3a), relates the benefit of increasing labor by one unit, $W_t u_c(t)$, to marginal cost of the lost leisure time, $-u_\ell(t)$. The intertemporal Euler equation, (3b), equates the marginal loss in utility from saving ϵ more today, $P_t u_c(t)$, and the expected marginal benefit from consuming it tomorrow, where the second terms in brackets are the after-tax return on an ϵ of additional savings in physical capital.

The model estimation and solution methods require that all variables be stationary. It is easy to show that the following transformations return stationary variables:

- $\mathcal{C}_t = C_t/Z_t$, $\mathcal{K}_t = K_t \exp(\theta_{t-1}^a)/Z_{t-1}$, $y_t = Y_t/Z_t$, and $k_t = K_t \exp(\theta_{t-1}^a)/Y_t$;
- $p_t = P_t/\exp(\theta_t^a)$, $w_t = W_t/Z_{t-1}$, and $r_t = R_t/\exp(\theta_{t-1}^a)$;

where $Z_t = A_t N_t e^{-\alpha/(1-\alpha)\theta_t^a}$.

Rearranging the intertemporal condition (3b) and assuming CES utility gives the stationary Euler Equation:

$$p_t = E_t \left\{ \beta e^{-\rho(\Delta\tilde{c}_{t+1}+n)} e^{v_{t+1}^p} \left[\alpha e^{-\tilde{k}_{t+1}} [1 - e^{\tilde{r}+\theta_{t+1}^f}] + p_{t+1}(1-\delta) \right] \right\},$$

where $\Delta\tilde{c}_{t+1} = \log(C_{t+1}/C_t) - \log(N_{t+1}/N_t)$ and $\tilde{k}_{t+1} = \log(K_{t+1}/Y_{t+1}) + \theta_t^p$. Then, the log-linearized intertemporal Euler equation gives:

$$\gamma_1 \theta_t^f + \theta_t^a = E_t \left\{ \gamma_2 \Delta\tilde{c}_{t+1} + \gamma_3 \tilde{k}_{t+1} + \gamma_4 \theta_{t+1}^f + \gamma_5 \theta_{t+1}^a + \gamma_6 v_{t+1}^p \right\}, \quad (4)$$

where the γ 's are functions of the model's parameters,

$$\psi = [g, n, \beta, \rho, \alpha, \delta, \phi_0, \phi_1, \omega_1, \omega_2],$$

and the linearization of the Eulers is achieved by expansion around the model's theoretical steady state.

Additionally, after a fiscal spending shock, (4) holds on expectation⁵ from time $t-1$, implying

$$\gamma_1 h_t^f(0, f) = \left\{ \gamma_2 h_t^c(1, f) + \gamma_3 h_t^k(1, f) + \gamma_4 h_t^f(1, f) \right\}, \quad (5)$$

where the h 's are the impulse response functions defined by $h_t^x(1, i) = E_t x_{t+1} - E_{t-1} x_{t+1}$ and $h_t^x(0, i) = x_t - E_{t-1} x_t$ after a shock from the i 'th state. Also, note that $h_t^a(0, f) = h_t^a(1, f) = \dots = 0$ and $h_t^v(0, f) = h_t^v(1, f) = \dots = 0$ by exogeneity of θ_t^a and θ_t^p . Equation (5) links the contemporaneous response of the government size variable to future responses of consumption growth, physical capital, and government size. One period after the shock, equation (5) is:

$$\gamma_1 h_t^f(1, f) = \left\{ \gamma_2 h_t^c(2, f) + \gamma_3 h_t^k(2, f) + \gamma_4 h_t^f(2, f) \right\}, \quad (6)$$

⁵This discussion follows Auray and Gallès (2002).

where $h_t^x(2, i) = E_t x_{t+2} - E_{t-1} x_{t+2}$. Normalizing all the coefficients so that $\gamma_1 = 1$ and substituting (6) into (5) we see that

$$h_t^f(0, f) = \left\{ \begin{array}{l} \hat{\gamma}_2 h_t^c(1, f) + \hat{\gamma}_3 h_t^k(1, f) + \\ \hat{\gamma}_4 \left[\hat{\gamma}_2 h_t^c(2, f) + \hat{\gamma}_3 h_t^k(2, f) + \hat{\gamma}_4 h_t^f(2, f) \right] \end{array} \right\},$$

where the “hats” indicate a parameter has been divided by γ_1 . Continuing for N periods, an equation for each t can be formed:

$$h_t^f(0, f) = \sum_{i=1}^N \hat{\gamma}_4^{(i-1)} \hat{\gamma}_2 h_t^c(i, f) + \sum_{i=1}^N \hat{\gamma}_4^{(i-1)} \hat{\gamma}_3 h_t^k(i, f) + \hat{\gamma}_4^{(N)} h_t^f(N, f) ; \quad (7)$$

this equation forms the basis for the estimation strategy presented in the next section.

4 Estimation and Solution Methods

In this section the structural coefficients estimation and model solution methods are discussed. Note that each period, the households are assumed to realize the true relative price of investment and hence the true $\theta_t^a + \theta_t^p$. However, to the econometrician, this is an unobserved variable; we can at best use a noisy measure. Thus, GMM will most likely give biased results since $\theta_t^a + \theta_t^p$ enters, and hence measurement error, into the structural equations in non-additive fashions.

Towards this end, the estimation method follows the procedure outlined in Rotemberg and Woodford (1997) and used recently by Fuhrer (2000), Amato and Laubach (2003), and Auray and Gallès (2002) where the structural equations have been linearized. Then, the method relies on estimation through the conditional moments (IRFs) implied by these linearized intertemporal Euler equations. The solution method solves the log-linearized Euler equations by the method of undetermined coefficients described in Campbell (1994).

4.1 Estimation

As shown by Pesaran and Shin (1997), a feature of generalized impulse responses is that they are independent of the history of the economy – generalized impulse responses are said to have a history-invariance property. They do depend on, however, the size and type of shock hitting the economy. Additionally, this dependence is a known linear combination of the shock; in our case, the shock is identified with a unit value, $h_t^f(0, f) = 1$. Substitution of the shock into (7) leaves an equation in terms of the structural coefficients, ψ , and the

parameters of conditional moments implied by the SSM. The conditional moment parameters are simulated to take uncertainty into account; this is the Method of Simulated Moments (MSM) of McFadden (1989) and Pakes and Pollard (1989).

A more detailed outline of the algorithm follows.

Definition 1 (MSM Estimation Algorithm)

- *First, set $t = 0$.*
- *Second, construct S separate time series of residuals of length H from the parameter estimates of the SSM of Section 2. Denote the simulated residuals $\{\hat{\mathbf{v}}_{t+1}^{<j>}\}_{j=1}^S$ where each $\hat{\mathbf{v}}$ is of length H .*
- *Third, from the residuals and given initial conditions on θ_0 construct S sets of length H synthetic time series of states and the resulting observations denoted $\{\hat{\boldsymbol{\theta}}_{t+1}^{<j>}\}_{j=1}^S$ and $\{\hat{\mathbf{y}}_{t+1}^{<j>}\}_{j=1}^S$, respectively.*
- *Fourth, for each S use the synthetic time series of observations to estimate the vector autoregression (VAR) implied by the state and observation equations in (1). Then, use the estimates to construct a set of impulse response functions: $\{\{\hat{\mathbf{h}}_t^{<j>}(i, f)\}_{i=1}^N\}_{j=1}^S$. Also, store the set of estimated means: $\{\hat{\mathbf{B}}_t^{<j>}\}_{j=1}^S$.*
- *Finally, update t and return to the first step. Continue for T steps.*

Given the simulated impulse response functions, an MSM estimation criterion can be formed by replacing (7) with an unbiased simulator that is to be denoted:

$$\mathbf{G}_1(\psi) = \frac{1}{T \cdot S} \sum_{t=1}^T \sum_{j=1}^S g_1(\{\hat{\mathbf{h}}_t^{<j>}(i, f)\}_{i=1}^N; \psi). \quad (8)$$

The moment condition is augmented by several more moments.⁶ The second is an MSM criterion for the unconditional first moments of consumption growth, the log price of investment, and the capital-output ratio; these are their theoretical steady state values implied by the model. These equations are defined as:

$$\mathbf{G}_2(\psi) = \frac{1}{T \cdot S} \sum_{t=1}^T \sum_{j=1}^S g_2(\hat{\mathbf{B}}_t^{<j>}; \psi).$$

⁶An appendix presents the full set of moments in analytical form.

Given this setup, a consistent MSM estimator of ψ can be found by minimizing:

$$J \equiv \mathbf{G}(\psi)' \mathbf{W} \mathbf{G}(\psi),$$

where $\mathbf{G}(\psi) = [\mathbf{G}'_1(\psi), \mathbf{G}'_2(\psi)]'$ and \mathbf{W} is a positive definite weighting matrix that can be optimally chosen. Because the optimal \mathbf{W} depends on the unknown ψ , we use an iterative approach that first estimates with $\mathbf{W} = \mathbf{I}$. Then a weight matrix $\hat{\mathbf{W}}$ is computed from the inverse of the variance-covariance matrix of $\mathbf{G}(\psi)$ with the first round estimator $\hat{\psi}$ (Chapter 2 of Gouriéroux and Monfort, 1996). The asymptotic variance-covariance matrix for $\hat{\psi}$ is then defined on $\hat{\mathbf{W}}$ as:

$$Avar(\hat{\psi}) = T^{-1} \left((\partial \hat{\mathbf{G}} / \partial \psi)' \hat{\mathbf{W}} (\partial \hat{\mathbf{G}} / \partial \psi) \right)^{-1}.$$

For all simulations, we set $N = 10$, $S = 50$, and $H = 100$.

Also, the dimension of the parameter set is reduced by calibration. The depreciations are set to the values used in computation of the capital stocks, $\delta = 0.06$. The growth rate for population is set at the world's annual rate of $n = 0.02$. The rate of time preference is calibrated, as in McGrattan and Schmitz (1999), so that the subjective discount rate is 3 percent per year; this results in $\beta = 0.98$. The momentary utility from consumption is assumed to be logarithmic giving $\rho = 1$. We rely on Cho and Cooley (1994) to calibrate the labor elasticity parameter at $\omega_2 = 2$. Finally, the calibration ω_1 is made so that the steady state labor hours are 0.33.

4.2 Solution

The undetermined coefficient method, described in Campbell (1994), follows a four-step procedure to produce log-linear approximations of the scaled variables \tilde{k}_{t+1} and ℓ_t . The first step finds the values that solve the non-stochastic versions of (3a)-(3b), denoted $\{\tilde{k}, \bar{\ell}\}$, with the unconditional mean for the ratio of government's share of real gross domestic product substituted in. The second step computes the first-order Taylor series expansion of (3a)-(3b) about the capital stock, labor, θ^f and θ^a . Note that all expected values for fiscal spending policy are replaced with their estimated evolutions from the empirical SSM of the previous section. The third step substitutes linear rules (guesses) for $\{\tilde{k}_{t+1}, \ell_t\}$ into the linearized Euler Equations. The linear rules include time t capital stock and the current values of θ^f and θ^a . The final step solves for the coefficients of the rules that set the Euler Equations to zero.

5 The Modeling Results

Table 3 displays the results of the MSM estimation. The table indicates that, for all countries, fiscal spending is positively related to the relative price of capital. The relevant parameter estimates are: $\phi_1 = -0.468$ for the entire sample; $\phi_1 = -0.367$ for the OECD; and $\phi_1 = -0.512$ for the Non-OECD. Most econometric studies find values for α in the range 0.30 to 0.40. Thus, the estimate for the OECD is consistent with much of the literature; its value is $\alpha = 0.364$. Alternatively, the share of capital in output for the Non-OECD countries is low and is outside most estimates at $\alpha = 0.193$.

Figure 3 displays the model's impulse responses under both the OECD and Non-OECD estimates. The responses for the OECD countries are generally consistent with the empirical IRFs found in Figure 2. We see that the growth in consumption initially falls followed by positive but consecutively smaller growth rates. The investment price initially falls and is followed by a slow damping towards its mean. The capital-output ratio tends to be positive but the effects on the capital output ratio are small relative to Figure 2 (*or* the effects on the growth of consumption are too big).

The lack of movement in the capital-output ratio may be related to the implied falling productivity of labor that has been noted by Greenwood *et al.* (1988) and can be corrected by, presumably, making capital's utilization rate endogenous. Alternatively, the low response may be related to the model's calibration for the level of risk aversion. Increasing the level of risk aversion may induce more dynamics in capital in attempt to smooth consumption.

Given the general success of the modeling results for the OECD countries, it is important to ask what effects increases in θ^f will have on the other macroeconomic aggregates? In Figure 4 we see that capital slowly increases for six periods. After six periods, the capital stocks slowly dampens towards zero. As expected, consumption initially falls but eventually increases, by year six, to a level that is at least 1% larger than the steady state. Labor effort and, as a result, output increase. These effects are consistent with the story typically associated with productive investment technology shocks where consumers substitute out of consumption and into capital and labor effort since capital is currently more productive. Eventually, as income rises, consumers enjoy the extra consumption from the increased future output. Though the dynamics appear to be small, the cumulative sum of the percentage change in output up to the eight year is about 1.12%. Thus, fiscal policy shocks appear to have real and persistent effects on output.

The Non-OECD impulse responses of Figure 3 are, in general, not consistent with the empirical IRFs found in Figure 2. Though consumption initially falls, consumption growth

is essentially zero after the first period. In addition, the dynamics in the price of investment are too large. The price of investment initially falls by 3%; in the data the investment price does not respond to fluctuations in government policy. Finally, the theoretic capital-output ratio increases too much; after the fourth period the ratio increases to a level that is higher than θ^f .

The failure of the Non-OECD model may be related to the lack of a utilization choice or even misspecification of the risk aversion level via our choice of preferences. More likely, however, the failure of the model to accurately explain the empirical movements of the macrovariables is due to restrictions on the way fiscal policy enters the model. In Non-OECD countries, that include the poorer less developed countries, corruption and inefficient bureaucracies conceivably make government enhance of investment productivity unlikely; the SSM estimation results suggest this. Additionally, taxation distortions are specified as an income tax; the alternative to $\phi_1 \neq 0$ is that government affects household decisions via an income tax. Alternatively, due to the likely presence of inefficiencies in Non-OECD countries, a better specification for the effects of θ^f might include consumption taxation. The idea is that less developed countries may not have access to costly income taxation technologies. In this case, the alternative to $\phi_1 \neq 0$ is that government policy distorts the marginal rate of substitution between future and current consumption.

6 Conclusion

This paper addressed the macroeconomic effects of shocks to government policy. As stressed in the introduction, policy shocks are examined in relation to fluctuations in the price of investment because the literature finds, in general, relationships between growth rates and the price of investment. However, little is known about the actual composition of the price of investment. Fiscal policy shocks are modeled so that they affect the productivity of new capital goods and that there is parameter differences across developed and non-developed countries.

The dynamic results from our modeling show that fiscal policy shocks are an important component in fluctuations in the relative price of investment, at least for OECD countries. In terms of output, a one-standard error shock to fiscal policy implies an immediate 0.13% increase in output followed by a slow damping. Thus, these effects are transmitted over several periods resulting in an increase in GDP of 1.12% over an eight period horizon. Because consumption's intertemporal effect is too large relative to effect in the capital-output ratio, however, these results should be considered as an upper bound on policies

effects. Thus, future research is suggested for the inclusion of capacity utilization choice and higher level of risk aversions so that consumption's intertemporal effect can be altered.

Finally, the findings of the paper suggest an interesting question: why are the effects of fiscal policy shocks so different between the developed and less developed countries? The findings of Barro (1997) offer a potential answer. He finds that government type and hence their public policies relate to the level of growth. That is, the policy pursuits (what revenue is spent on) are important and must be investigated in conjunction with tax policy (revenue collection). That is, countries with the same tax rates may respond differently to perturbations in the tax policy depending on the aim of the policy change?

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Table 1: Empirical Facts: 1973-1998

<i>Variable</i>	<i>Obs.</i>	<i>Mean</i>	<i>Avg. of Std. Dev.</i>
<i>Panel A: All Countries</i>			
\tilde{k}_t	1810	0.488	0.140
$\Delta\tilde{c}_t$	1814	0.015	0.070
\tilde{p}_t	1814	0.006	0.157
$\tilde{\theta}_t^f$	1815	-1.688	0.176
<i>Panel B: OECD Countries</i>			
\tilde{k}_t	570	0.934	0.069
$\Delta\tilde{c}_t$	570	0.019	0.028
\tilde{p}_t	570	-0.001	0.142
$\tilde{\theta}_t^f$	570	-1.766	0.095
<i>Panel C: Non-OECD Countries</i>			
\tilde{k}_t	1240	0.283	0.162
$\Delta\tilde{c}_t$	1244	0.014	0.082
\tilde{p}_t	1244	0.010	0.163
$\tilde{\theta}_t^f$	1245	-1.637	0.203

Table 2: SSM Estimation Results[†]

<i>Parameter</i>	<i>All</i>	<i>OECD</i>	<i>Non-OECD</i>
$h_{1,1}$	0.662* (0.267)	0.547* (0.105)	0.714** (0.388)
$h_{2,1}$	-0.623* (0.208)	-0.425* (0.085)	-0.713* (0.300)
$h_{3,1}$	-0.093 (0.081)	-0.182 [†] (0.119)	-0.052 (0.105)
$h_{1,2}$	0.314* (0.149)	0.050 (0.132)	0.435 (0.208)
$h_{2,2}$	0.146 (0.155)	0.348 [†] (0.228)	0.055 (0.200)
$h_{2,3}$	1.017* (0.122)	0.717* (0.238)	1.154* (0.139)
$f_{1,1}$	0.698* (0.034)	0.731* (0.057)	0.683* (0.043)
$f_{1,2}$	0.268 [†] (0.179)	0.277 (0.272)	0.264 (0.231)
$f_{2,2}$	0.623* (0.037)	0.527* (0.078)	0.666* (0.040)
$q_{1,1}$	0.047* (0.005)	0.028* (0.004)	0.056* (0.007)
$q_{2,2}$	0.037* (0.005)	0.019* (0.010)	0.044* (0.006)
$q_{3,3}$	0.021* (0.002)	0.015* (0.002)	0.024* (0.002)

[†]Standard error in parentheses.

*Significant at 5%. **Significant at 10%.

[†]Significant at 15%.

Table 3: MSM Estimation Results[†]

<i>Parameter</i>	<i>All</i>	<i>OECD</i>	<i>Non-OECD</i>
g	0.016* (0.0006)	0.020* (0.0003)	0.0139* (0.0007)
ϕ_0	0.112* (0.0007)	0.107* (0.0003)	0.114* (0.0007)
ϕ_1	-0.468* (0.0193)	-0.367* (0.00001)	-0.512* (0.0204)
α	0.236* (0.0014)	0.364* (0.0012)	0.193* (0.0014)
$\bar{\tau}$	-1.940* (0.0006)	-1.874* (0.0003)	-1.970* (0.0005)

[†]Standard error in parentheses.

*Significant at 5%.

Figure 1: Scatter Plot of Investment Price and Government/Output Ratio Standard Deviations, $\rho = 0.416$. All countries.

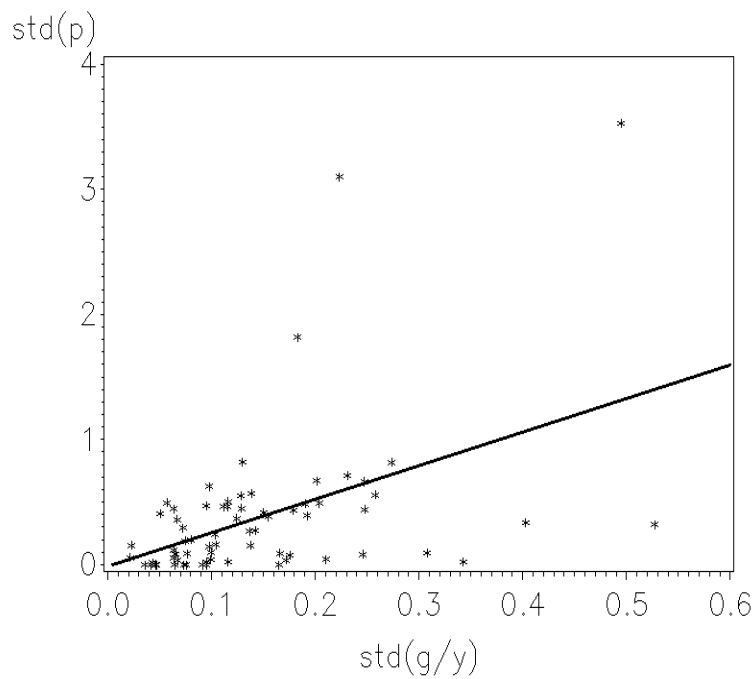


Figure 2: The Empirical Impulse Response Functions (one-standard error shock).

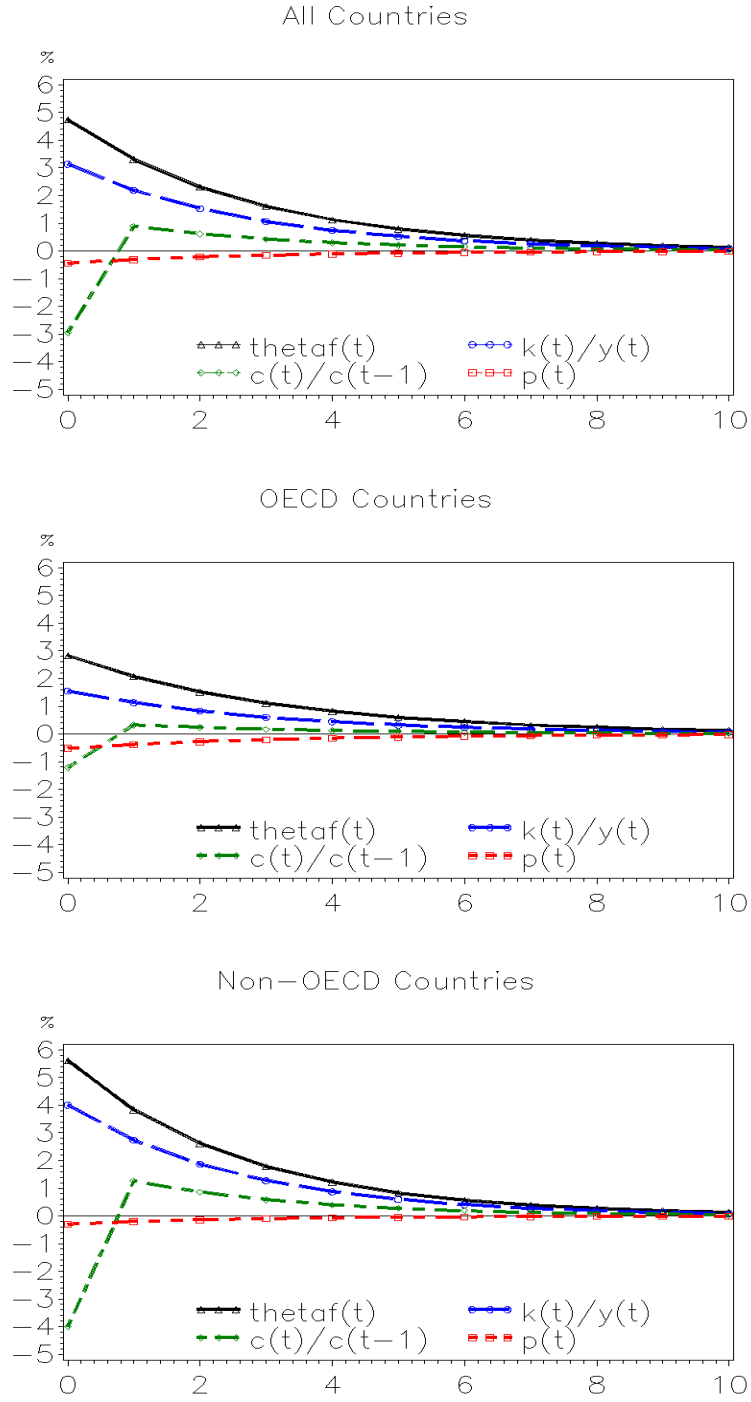


Figure 3: The Theoretical Model's Impulse Response Functions (one-standard error shock)

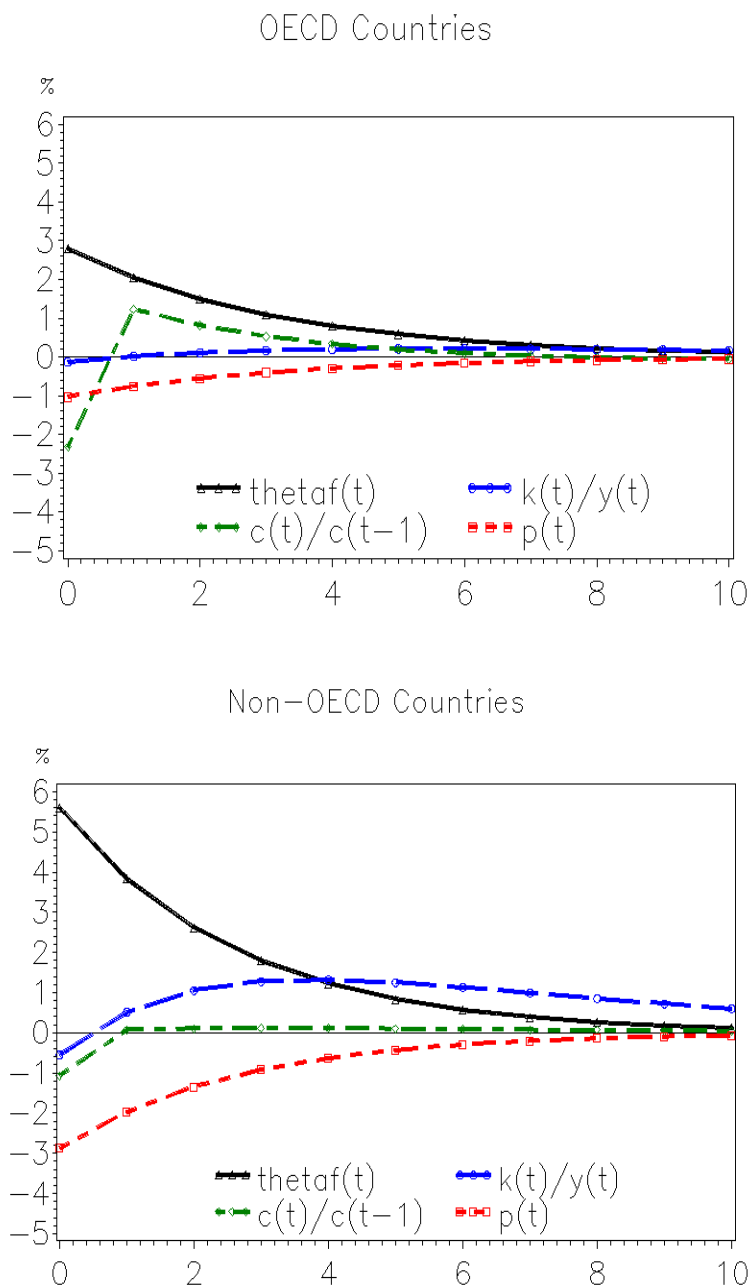
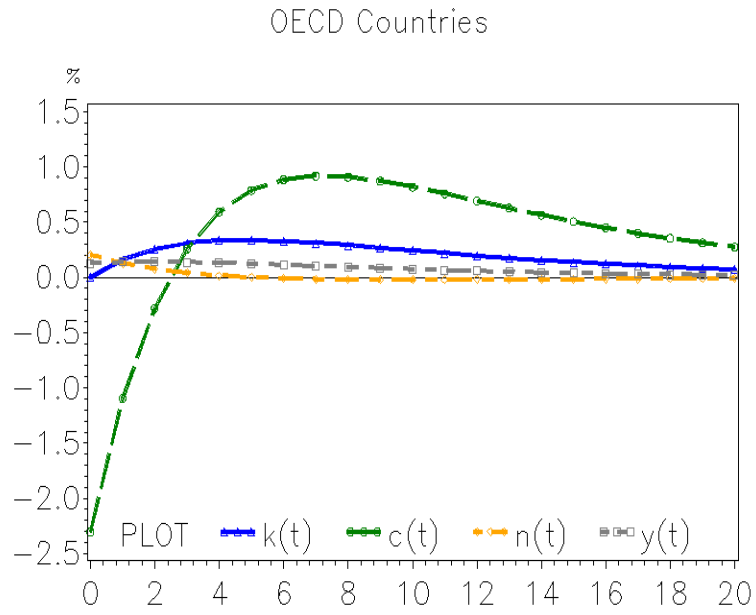


Figure 4: The Behavior of the Theoretical Model's Aggregates (one-standard error shock)



A Appendix – Not Intended for Publication.

A.1 The Kalman Filter

The basic Kalman filter is described by the seven equations:

$$\begin{array}{ll}
 \textit{Prediction} & \textit{Updating} \\
 \boldsymbol{\theta}_{t|t-1} = \mathbf{F} \boldsymbol{\theta}_{t-1|t-1}, & \boldsymbol{\theta}_{t|t} = \boldsymbol{\theta}_{t|t-1} + \mathbf{K}_t \boldsymbol{\eta}_{t|t-1}, \\
 \mathbf{P}_{t|t-1} = \mathbf{F} \mathbf{P}_{t-1|t-1} \mathbf{F}' + \mathbf{Q}, & \mathbf{P}_{t|t} = \mathbf{P}_{t|t-1} - \mathbf{K}_t \mathbf{H} \mathbf{P}_{t|t-1}, \\
 \mathbf{y}_{t|t-1} = \mathbf{A} \mathbf{x}_t + \mathbf{H} \boldsymbol{\theta}_{t|t-1}, & \\
 \boldsymbol{\eta}_{t|t-1} = \mathbf{y}_t - \mathbf{y}_{t|t-1}, & \\
 \mathbf{f}_{t|t-1} = \mathbf{H} \mathbf{P}_{t|t-1} \mathbf{H}' + \mathbf{R}, &
 \end{array}$$

where $\boldsymbol{\theta}_{t+1|t} = E[\boldsymbol{\theta}_{t+1} | \mathbf{Y}_t]$, \mathbf{Y}_t is the full information set at time t given by: $\mathbf{Y}_t \equiv (\mathbf{y}_t, \dots, \mathbf{y}_1, \mathbf{x}_t, \dots, \mathbf{x}_1)$, and $\mathbf{K}_t = \mathbf{P}_{t|t-1} \mathbf{H}' (\mathbf{f}_{t|t-1})^{-1}$ is the gain.

A.2 Steady States and Moments

The steady states are given by

$$\begin{aligned}
 \bar{k} &= -\log \left(\left[\frac{\exp(\rho(g+n))}{\beta} - (1-\delta) \right] \frac{\exp(\bar{p})}{\alpha(1-\exp(\bar{\tau}))} \right) \\
 \Delta \bar{c} &= \log(1+g) \approx g \\
 \bar{p} &= \phi_0 \\
 \bar{\tau} &= \bar{\theta}^f.
 \end{aligned}$$

The coefficients for the linearized Eulers are given by:

$$\begin{aligned}
 \gamma_1 &= \phi_1 \exp(\bar{p}), \\
 \gamma_2 &= (-\rho)\beta \exp(-\rho(\Delta \bar{c} + n)) [\alpha \exp(-\bar{k})(1-\exp(\bar{\tau})) + \exp(\bar{p})(1-\delta)] \\
 \gamma_3 &= (-1)\beta \exp(-\rho(\Delta \bar{c} + n)) [\alpha \exp(-\bar{k})(1-\exp(\bar{\tau}))] \\
 \gamma_4 &= \beta \exp(-\rho(\Delta \bar{c} + n)) [(1-\delta)\phi_1 \exp(\bar{p})] + (-1)\beta \exp(-\rho(\Delta \bar{c} + n)) [\alpha \exp(-\bar{k}) \exp(\bar{\tau})].
 \end{aligned}$$

Pesaran and Shin (1997) show that the generalized impulse response of y at horizon j from a vector representing a time t shock from the public sector equation ξ_t^f can be written as

$$h_t^y(j, f) = \mathbf{A}_j^y \xi_t^f,$$

where \mathbf{A}_j^y is a complex function of the parameters of the SSM. Then, letting $h_t^f(0, f) = \xi_t^f$, the moment equation (7) can be rewritten as:

$$\xi_t^f = \sum_{i=1}^N \hat{\gamma}_4^{(i-1)} \hat{\gamma}_2 \mathbf{A}_i^c \xi_t^f + \sum_{i=1}^N \hat{\gamma}_4^{(i-1)} \hat{\gamma}_3 \mathbf{A}_i^k \xi_t^f + \hat{\gamma}_4^{(N)} \mathbf{A}_N^f \xi_t^f.$$

Letting $\xi_t^f = 1$, the equation is simulated to form the moment condition \mathbf{G}_1 . The final set of moments, denoted $\mathbf{G}_2(\psi)$, are given by:

$$\mathbf{G}_2(\psi) = \begin{cases} \frac{1}{T \cdot S} \sum_{t=1}^T \sum_{j=1}^S \hat{k}_t^{<j>} - \bar{k} \\ \frac{1}{T \cdot S} \sum_{t=1}^T \sum_{j=1}^S \Delta \hat{c}_t^{<j>} - \Delta \bar{c} \\ \frac{1}{T \cdot S} \sum_{t=1}^T \sum_{j=1}^S \hat{p}_t^{<j>} - \bar{p} \\ \frac{1}{T \cdot S} \sum_{t=1}^T \sum_{j=1}^S \hat{\theta}_t^{f, <j>} - \bar{\theta}^f \end{cases}.$$

where \bar{k} , $\Delta \bar{c}$, \bar{p} , and $\bar{\theta}^f$ are given by their theoretical steady-states and

$$\hat{\mathbf{B}}_t^{<j>} = \begin{bmatrix} \hat{k}_t^{<j>} \\ \Delta \hat{c}_t^{<j>} \\ \hat{p}_t^{<j>} \\ \hat{\theta}_t^{f, <j>} \end{bmatrix}.$$

A.3 Country Codes

The codes and OECD status are presented in Table 4.

Table 4: Country List – Country Codes from Barro and Lee (1996)

N	Code	OECD	Country	N	Code	OECD	Country
1	3	N	Benin, BEN	2	4	N	Botswana, BWA
3	12	N	Congo, COG	4	13	N	Egypt, EGY
5	17	N	Ghana, GHA	6	21	N	Kenya, KEN
7	25	N	Malawi, MWI	8	26	N	Mali, MLI
9	28	N	Mauritius, MUS	10	31	N	Niger, NER
11	33	N	Rwanda, RWA	12	36	N	Sierra Leone, SLE
13	38	N	South Africa, ZAF	14	43	N	Tunisia, TUN
15	46	N	Zambia, ZMB	16	49	N	Barbados, BRB
17	50	Y	Canada, CAN	18	51	N	Costa Rica, CRI
19	56	N	Guatemala, GTM	20	58	N	Honduras, HND
21	59	N	Jamaica, JAM	22	60	N	Mexico, MEX
23	61	N	Nicaragua, NIC	24	62	N	Panama, PAN
25	65	N	Trinidad & Tobago, TTO	26	66	Y	United States, USA
27	67	N	Argentina, ARG	28	69	N	Brazil, BRA
29	70	N	Chile, CHL	30	71	N	Colombia, COL
31	72	N	Ecuador, ECU	32	75	N	Peru, PER
33	77	N	Uruguay, URY	34	78	N	Venezuela, VEN
35	81	N	Bangladesh, BGD	36	85	N	India, IND
37	86	N	Indonesia, IDN	38	87	N	Iran, I.R. of, IRN
39	89	N	Israel, ISR	40	90	Y	Japan, JPN
41	91	N	Jordan, JOR	42	92	N	Korea, KOR
43	94	N	Malaysia, MYS	44	97	N	Pakistan, PAK
45	98	N	Philippines, PHL	46	100	N	Singapore, SGP
47	102	N	Syria, SYR	48	104	N	Thailand, THA
49	107	Y	Austria, AUT	50	108	Y	Belgium, BEL
51	109	N	Cyprus, CYP	52	110	Y	Denmark, DNK
53	111	Y	Finland, FIN	54	112	Y	France, FRA
55	114	Y	Greece, GRC	56	116	Y	Iceland, ISL
57	117	Y	Ireland, IRL	58	118	Y	Italy, ITA
59	120	N	Malta, MLT	60	121	Y	Netherlands, NLD
61	122	Y	Norway, NOR	62	124	Y	Portugal, PRT
63	125	Y	Spain, ESP	64	126	Y	Sweden, SWE
65	127	Y	Switzerland, CHE	66	128	Y	Turkey, TUR
67	129	Y	United Kingdom, GBR	68	131	Y	Australia, AUS
69	132	N	Fiji, FJI	70	133	Y	New Zealand, NZL
71	134	N	Papua New Guinea, PNG				