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The impact of human capital accumulation on growth in Algeria using DSGE models

Chahrazed Belhadj-Amara

Department of Economic Sciences, Faculty of Economic, Commercial and Management Sciences, University of Yahia Fares, Medea, Algeria, Sustainable Local Development Laboratory
Email: belhadjamara.chahrazed@univ-medea.dz

Mohamed Saoudi

Department of Economic Sciences, Faculty of Economic, Commercial and Management Sciences, University of Yahia Fares, Medea, Algeria, Sustainable Local Development Laboratory
Email: saoudi.mohamed@univ-medea.dz

Abstract--This study aims to estimate the relationship between economic growth and human capital, based on a dynamic stochastic general equilibrium (DSGE) model. It utilizes macroeconomic data for Algeria from 1970 to 2022, relying on six real series including consumption, investment, the consumer price index, GDP, financial expenditure, and interest rates, all aligning with the DSGE model. The results showed that the accumulation of human capital in Algeria, through a productivity shock function, does not significantly affect economic growth in Algeria.

Keywords--Economic Growth, Human Capital, DSGE, Productivity Shock Function.

Theoretical Background

The classical school since the first half of the 19th century has regarded human capital as important due to its scientific qualifications, which contribute to economic and social development through innovations and discoveries. This view was supported by Mac Culloch and later by Simon Kuznets (1966) and William Petty, who considered that an increase in population means a higher likelihood of geniuses. In the new economy¹, human capital is seen as a source of value creation².

The classical economic growth theory assumes diminishing marginal returns to capital (Solow, 1956), implying that poorer countries will grow faster than rich countries and that capital will flow from rich to poor countries, leading to a convergence of per capita income levels (Barro, 1991). However, income disparity between countries persists, and there is little evidence of absolute convergence. The richer effects come from the development of endogenous growth theory based on Arrow's work in 1962, and further enhanced by the critical role of human capital introduced by second-generation growth theory pioneers such as Romer (1986), Lucas Jr (1988), Prescott (1998), and Zhang & Wan (2021).

Schultz's concept of investment in human capital is a significant contribution to the field of economics, as it expressed the need to treat personal skills and knowledge as a form of human capital investment³.

Theoretical Background (continued)

During this period, efforts began to move beyond superficial ideas about the human factor. The perspective shifted from viewing human capital merely as a contributor to production through work hours to recognizing its role in driving technological development and progress. This is achieved by leveraging the knowledge, ideas, experiences, and skills that the human factor-especially the workforce-brings to the production process. Consequently, the concept of investing in human capital emerged, which includes investments in education, training, learning by doing, and health⁴.

Theoretical Background (continued)

It is well known that a growth model relying solely on the accumulation of physical capital is unsustainable. This fact, first proposed by Solow in 1956, emphasizes that the diminishing returns are the main obstacle to capital accumulation. New economic growth literature indicates strong links between national income growth and spending on education and health. This investment in human capital directly enhances workforce efficiency and provides significant externalities for growth. Therefore, economic growth is fueled by two interdependent sources: education and the accumulation of capital in research and development.

Key Studies on the Topic:

- **Pardo Clara, Cotte Poveda Alexander, Rangel Correa Alejandro (2021):** "Economic Growth and Human Capital: A Dynamic Stochastic General Equilibrium Modelling Approach for Colombia" This paper shows a long-term positive relationship between human capital and economic growth in Colombia. The analysis indicates that the quality of education affects growth, with a causal relationship between per capita GDP and higher education enrollment rates. The model focuses only on households and firms, suggesting expansion to include the external sector, government, and other factors to enhance the analysis.
- **Dargahi Hassan, Beiranvand Amin (2018)⁶:** "Examining the Relationship between Social Damages and Iran's Economic Growth with an Emphasis on

Human Capital in an Endogenous Growth Model: DSGE Approach" This study examines the relationship between social damages and economic growth in Iran, emphasizing human capital within an endogenous growth model using a DSGE approach.

This paper shows that social damages such as divorce, addiction, and crime negatively impact economic growth in Iran. By analyzing data from 1991 to 2014, the model demonstrates that increases in poverty, unemployment, and inflation exacerbate social damages, which in turn reduce human capital and productivity. The study emphasizes that economic improvement is essential to mitigate these social damages and ensure sustainable economic growth.

We will attempt to construct a dynamic general equilibrium model for a small open economy with multiple sectors and without nominal rigidity for an oil-exporting economy. The model is based on the real business cycle (RBC) model for an open economy adapted from Meenagh (2010)⁷, which builds on the work of Chari et al. (2002)⁸, and is expanded to capture sector-specific characteristics in the Algerian economy as in Santacreu (2005)⁹. It is assumed that each sector of the economy faces a specific productivity shock. Modeling the economy in this manner is crucial, especially given Algeria's significant oil sector and a non-tradable sector. Thus, the model will explore the impact of relevant productivity shocks on these different sectors of the economy, with a focus on the effect of human capital accumulation. The stability of net foreign assets (NFA) is imposed in the model using a flexible interest rate on external debt as in Schmitt-Grohe and Uribe (2003)¹⁰.

Practical Aspect

To incorporate the internal economic growth rate into DSGE models, researchers have relied on three designs: technology accumulation, creation of new institutions, and human capital accumulation. Our study adopts the human capital accumulation model for its comprehensive approach to improving technology, institutions, and labor capabilities. Inputs rely on the joint investment of physical capital and labor, both serving as inputs for the production of new human capital, as indicated in studies by Maffezzoli¹¹ and Novales et al¹². Empirical evidence shows that improving education and increasing human capital enhance economic growth and productivity.

1. Building the DSGE Model

The DSGE model we are constructing represents a local economy interacting with a foreign economy without mutual influence on major economic variables. The model is based on a representative firm that aims to maximize profits through production and participation in a competitive market. We assume a consumer who seeks to maximize utility under budget and time constraints. Companies produce intermediate goods that require the employment of labor and physical and human capital. The model includes a human capital accumulation equation in households, a public goods production function, and improved financial expenditure, which determine the internal economic growth rate. The model heavily relies on the methodology of Smets and Wouters¹³.

1-1 Household Sector

The DSGE model consists of a continuum of households, each of which seeks to maximize a utility function that includes consumption and labor. The fundamental equation for this utility is:

$$\varepsilon_t^{pf} \frac{(C_{i,t})^{1-\theta_c}}{1-\theta_c} (\varepsilon_t^L L_{i,t}^S)^{1+\theta_L}$$

where $C_{i,t}$ represents household consumption, θ_c is the coefficient of relative risk aversion, and $L_{i,t}^S$ is the labor service. The labor service is divided into labor for producing new human capital $L_{i,t}^{hc}$ and labor used by firms $L_{i,t}^f$. ε_t^{pf} represents the intertemporal preference shock, and ε_t^{pf} represents the labor supply shock. The shocks are assumed to follow a first-order autoregressive process:

$$\varepsilon_t^L = \rho^L \varepsilon_{t-1}^L + v_t^L, \quad \varepsilon_t^{pf} = \rho^{pf} \varepsilon_{t-1}^{pf} + v_t^{pf}$$

The household budget constraints are determined by the equation:

$$\begin{aligned} C_{i,t} + INV_{i,t} + TX_{i,t} + \frac{BG_{i,t}}{\varepsilon_t^{bg} r_t^{bg}} + \mathcal{A}(\mu_t) K_{i,t-1}^S \\ = \frac{BG_{i,t-1}}{\pi_t} + r_t^k \mu_t K_{i,t-1}^f + (L_{i,t}^f + L_{i,t}^{gv}) w_t HC_{i,t-1} + DIV_{i,t} \end{aligned}$$

where the variables represent household consumption, investment, taxes, government debt, inflation rate, capital utilization rate, wage for labor, and net equity payments. The accumulation of human capital is calculated by the equation:

$$\begin{aligned} HC_{i,t} = (1 - \delta_{hc}) HC_{i,t-1} \\ + \varepsilon_t^{hc} \chi^{hc} (\mu_t K_{i,t-1}^{hc})^{\alpha_{hc}} (L_{i,t}^{hc} HC_{i,t-1})^{1-\alpha_{hc}} \end{aligned}$$

The capital accumulation function is expressed as:

$$K_{i,t}^S = (1 - \delta_k) K_{i,t-1}^S + \varepsilon_t^{inv} [1 - S(\cdot)] INV_{i,t}$$

where $S(\cdot)$ is a convex adjustment cost function. The differentiated labor service is converted into aggregate labor input using:

$$L_t = \left[\int_0^1 (L_{i,t}^S)^{1+\lambda_w} di \right]^{1+\lambda_w}$$

Households face a constant probability of resetting their nominal wage each period, leading to the derivation of optimal conditions for wage stickiness through the Lagrangian function:

$$\mathcal{E}_{\text{wage}} = E_t \sum_{s=0}^{\infty} (\xi_w \beta)^s \left\{ \begin{aligned} & \varepsilon_{t+s}^{pf} \frac{(C_{i,t+s})^{1-\theta^c}}{1-\theta^c} (\varepsilon_{t+s}^L L_{i,t+s}^s)^{1+\theta^L} + \Xi_{t+s} [(L_{i,t+s}^f + L_{i,t+s}^{gv}) w_{i,t+s} HC_{i,t+s-1}] \\ & + \Xi_{t+s}^{hc} [-HC_{i,t+s} + (1-\delta_{hc}) HC_{i,t+s-1} + f(\varepsilon_{t+s}^{hc}, \chi^{HC}, \mu_{t+s}, K_{i,t+s-1}^{hc}, L_{i,t+s}^{hc}, HC_{i,t+s-1})] \end{aligned} \right\}$$

$$\text{s.t. } L_{i,t+s}^s = \left(\frac{\mathcal{X}_{t,s}^w \tilde{W}_{i,t}}{w_{t+s}} \right)^{-\frac{1+\lambda_w}{\lambda_w}} L_{t+s}$$

$$w_{i,t+s} = \mathcal{X}_{t,s}^w \tilde{W}_{i,t}$$

$$\mathcal{X}_{t,s}^w = \begin{cases} 1 & s = 1 \\ \frac{\prod_{\ell=1}^s \pi^{1-tw} \pi_{t+\ell-1}^{ww}}{\prod_{\ell=1}^s \pi_{t+\ell}} & 1 < s < \infty \end{cases}$$

1-2- Firm Sector:

The firm sector is divided into two types: final goods producing firms and intermediate goods producing firms. Intermediate firms operate in a monopolistically competitive market where price adjustments are not immediate.

1-2-1 Final Goods Producing Firms: These firms operate in a perfectly competitive market and use differentiated intermediate goods. The production function and the relationship between prices can be written as follows:

$$Y_t = \left[\int_0^1 (Y_{j,t}^f)^{\frac{1}{1+\lambda_p}} dj \right]^{1+\lambda_p}$$

such that: λ_p is the price markup. To maximize profit, the relationship between the price $p_{j,t}$ of intermediate good j and the price P_t of the final good can be written as follows:

$$Y_{j,t}^f = \left(\frac{p_{j,t}}{P_t} \right)^{\lambda_p} Y_t \quad P_t = \left[\int_0^1 (p_{j,t})^{\frac{1}{\lambda_p}} dj \right]^{\lambda_p}$$

1-2-2 Intermediate Goods Producers: They use technology to produce intermediate goods:

$$Y_{j,t}^f = \varepsilon^A \left[\alpha_k (K_{j,t}^f)^{1-\eta} + \alpha_{gv} (K_{j,t}^{gv})^{1-\eta} + (1 - \alpha_k - \alpha_{gv}) \right]^{\frac{1}{1-\eta}} (L_{j,t}^f HC_{t-1})^{1-\eta}$$

Since ε^A represents the productivity shock of the company, $K_{j,t}^f$ is the capital allocated to the company, $L_{j,t}^f$ is the labor employed by the company, and $K_{j,t}^{gv}$ is the public goods provided by the government. The profit function for company j is given by.

and the profit function is calculated by:

$$DIV_{j,t}^f = Y_{j,t}^f - r_t^k K_{j,t}^f - r_t^{gv} K_{j,t}^{gv} - w_t L_{j,t}^f$$

1-3 Government and Monetary and Fiscal Policies: The government aims to maximize public benefits by using labor (L_t^{gv}) and fiscal spending (G_t):

$$K_t^{gv} = \varepsilon_t^{gv} \cdot (G_t \varepsilon_t^g)^{\alpha_{gv}} (L_t^{gv} H C_{t-1})^{1-\alpha_{gv}}$$

The government collects taxes TX_t , issues debt BG_t , and sets the rent for public goods (r_t^{gv}) to finance itself:

$$K_t^{gv} = \varepsilon_t^{gv} \cdot (G_t \varepsilon_t^g)^{\alpha_{gv}} (L_t^{gv} H C_{t-1})^{1-\alpha_{gv}}$$

Were

ε_t^{gv} is the productivity shock for public goods production, and ε_t^g is the fiscal spending shock. The government collects TX_t , issues BG_t , and sets r_t^{gv} as the rent for public goods to finance itself, which is the main mechanism for the government to provide public goods. Therefore, the government budget constraints can be written as follows.

$$TX_t + \frac{BG_t}{r_t^{bg}} + r_t^{gv} K_t^{gv} = \frac{BG_{t-1}}{\pi_t} + G_t \cdot \varepsilon_t^g + w_t L_t^{gv}$$

Monetary policy relies on

$$\frac{r_t^{bg}}{r^{bg}} = \left(\frac{r_{t-1}^{bg}}{r^{bg}} \right)^{\rho_r} \left(\frac{\pi_t}{\pi} \right)^{\phi_{r\pi}} \left(\frac{Y_t}{Y} \right)^{\phi_{rY}} e^{\varepsilon_t^r}$$

Market equilibrium:

- Market equilibrium is achieved based on the identities $K_{i,t-1}^s = K_{i,t}^{hc} + K_{i,t}^f$ and $L_{i,t-1}^s = L_{i,t}^{hc} + L_{i,t}^f$, where production is equal to consumption, investment, fiscal spending, and capital adjustment cost:

$$C_t + INV_t + G_t + A(\mu_t) K_{t-1}^s = Y_t$$

Production function:

- The production function takes the following form:

$$Y_t = a_t K_t^\alpha (X_t h_t)^{1-\alpha}$$

All firms have different products, but they share the same technology represented by a Cobb-Douglas production function that includes human capital, in line with Basu and Gihman (2009)¹⁴. Here, a_t and X_t represent productivity shocks. The productivity shock follows a first-order autoregressive process:

$$\ln a_{t+1} = \rho_a \ln a_t + \varepsilon_{t+1}^a$$

The productivity shock X_t is non-stationary:

$$g_t = \frac{X_t}{X_{t-1}}$$

Estimation Methodology and Parameter Calibration

2-1 Estimation Methodology

First: Minimize the number of calibrated parameters and maximize the number of estimated parameters using Bayesian estimation. Thirty-seven parameters are estimated using the Bayesian method, excluding the discount rate β , the capital depreciation rate δ_k , and the human capital depreciation rate δ_{hc} .

- The value of β is set at 0.99.
- The value of δ_k is set at 0.025.
- The value of δ_{hc} is set at 0.03.
- If these parameters fall within specific ranges, the Bayesian estimation results for the remaining parameters will not change significantly, indicating the robustness of the model.

Second: Improve the accuracy of Bayesian estimation by repeating the Bayesian estimation process several times to ensure that the posterior distribution falls within the prior distribution period and is similar in type, ensuring that the means are convergent, which enhances the accuracy and stability of the estimation.

- The Bayesian method relies on updating old estimates with new results to obtain estimates closer to reality.
- The estimation strategy involves randomly assigning prior distributions to the parameters, then adjusting them based on the posterior distributions, and repeating this process until final stability is achieved.

2-2 Data Used

We use macroeconomic data for Algeria from 1970 to 2022, relying on six real series, including consumption, investment, the consumer price index, GDP, fiscal spending, and interest rates, which correspond to the DSGE model. All six variables are adjusted and detrended before estimation.

The human capital (HC) accumulation equation was estimated using the least squares method through variables related to spending on education and health, and the average years of schooling, according to the following equation:

$$\ln(HC) = \beta_0 + \beta_1 \ln(Y_{st}) + \mu_t$$

where:

$$HC = e^{-(r \cdot Y_{st})}$$

2-3 Parameter Calibration for Each Sector

Annual data from 1970 to 2022 were used to calibrate the model, with parameter choices aligning with the logic of the model. Some previous literature attempting to integrate calibration methodology into traditional macroeconomics includes: Manuelli and Sargent (1988)¹⁵; Gregory and Smith (1990)¹⁶; Hoover (1995)¹⁷; Hansen and Heckman (1996)¹⁸, who analyzed the calibration method as a form of "estimation by simulation."

The depreciation rate was set at 0.1 per year as in Devereux et al. (2006) and applied in some literature related to small open developing economies, notably Alguacil and Ben Khodja (2011)²⁰.

The labor supply elasticity for Frisch, ρ_2 , was set at 1.2, as in Meenagh et al. (2010). This parameter indicates the intertemporal substitution elasticity of leisure, i.e., working hours in relation to wages. The value of the elasticity determines how easily working hours are adjusted by households in response to changes in the wage rate. A higher elasticity value means that labor is more willing to smooth working hours, whereas a lower elasticity value implies that labor is less willing to adjust working hours in response to wage changes. Thus, choosing a labor supply elasticity value of 1.2 indicates that working hours change by the same proportion in response to a unit change in wages.

The coefficient of relative risk aversion, ρ_0 was set at 1.0, which is consistent with the estimates of Gandelman and Hernández-Murillo (2015)²¹ for risk aversion at the country level. Although Algeria was not included among the 80 countries mentioned in H-M work, the value reflects a standard assumption in the literature.

However, it suggests that the average coefficient that can be applied between developing countries is around 1.1, while for developed countries, it is set at 0.88. This means that higher elasticity between time periods indicates that consumption growth is highly sensitive to changes in the real interest rate²². The remaining parameters were calibrated as shown in the following table:

Table (01): Calibrated Parameters of the Model

Parameter	Γ	δ	α	Ψ	ω	θ	β	D
Calibrated Value	2	0.1255	0.32	0.01	1.6	2.24	0.9224	0.007

Source: Prepared by the student

3- Results and Discussion

3-1 Results

In this section, we will discuss the estimation results we conducted using Dynare 4.5.6 in a Matlab environment. The time unit of the model is a year, and we assigned values to the structural parameters using a combination of calibration and econometric estimation techniques. The parameters were calibrated based on long-term data in Algeria and common values in business cycle studies. Table (1) shows the calibrated parameter values, where the trade balance parameter was adjusted to achieve a small ratio of about 0.25% of output, a ratio observed in Algeria during the period from 1970 to 2022. Based on Schmitt-Grohe and Uribe (2003), a small value was assigned to the parameter that measures the sensitivity of the interest rate premium to deviations of external debt from the trend to ensure the independence of the deterministic steady-state.

The assigned depreciation rate reflects an average investment ratio of about 19%, while the assumed discount factor value reflects a relatively high real interest rate, which is reasonable for an emerging market like Algeria. Due to the lack of reliable data on the income shares of production factors in Algeria, we set the capital income share at 0.32, a value commonly used in the related literature. To ensure that households allocate about 20% of their time to market work, the appropriate parameter was determined, and the parameter that defines the curvature of the period utility function took the standard value of 2. Finally, the labor supply elasticity was calibrated at 1.6, a value frequently used in small open economy models as in Mendoza (1991)²³ and Schmitt-Grohe and Uribe (2003)²⁴.

We estimated the remaining model parameters using Bayesian methods and available data on output growth, consumption growth, investment growth, the trade balance-to-output ratio, inflation rate, fiscal spending, and the externally estimated rate of human capital accumulation during the period from 1970 to 2022. To estimate the posterior distribution, prior information was combined with the likelihood function using the Metropolis-Hastings algorithm.

The outputs of the Dynare program for dynamic stochastic general equilibrium (DSGE) models typically include a statistical analysis of the parameters used in the model. The presented table contains parameter estimates based on the prior distribution and the posterior distribution. To understand this table:

3-2 Interpretation of Results:

- **Parameter α :**

- Prior distribution: Mean of 1.015 and a standard deviation of 0.0087.
- Posterior distribution: Mean of 1.0096, mode of 1.0102, and 90% range between 1.0027 and 1.0161.
- This means that the expected growth after using actual data is slightly lower than the prior distribution but within a small dispersion range.

- **Parameter β :**

- Prior distribution: Mean of 0 and a standard deviation of 0.5716.
- Posterior distribution: Mean of 0.2367, mode of 0.4412, and 90% range between -0.4998 and 0.9342.
- This indicates an improvement in estimating the autocorrelation of growth after using the data.

- **Parameter γ :**

- Prior distribution: Mean of 0 and a standard deviation of 0.5716.
- Posterior distribution: Mean of 0.8644, mode of 0.8728, and 90% range between 0.7951 and 0.9362.
- This suggests that technological shocks have a significant and lasting impact on the economy.

3-3 Using Results to Illustrate Relationships:

From the presented table, some parameters can be used to illustrate the relationship between investment in human capital and economic growth:

1. **Parameter α :** Represents the average growth rate. The posterior growth rate of 1.0096 indicates moderate economic growth. Investing in human capital can increase this rate by improving worker productivity.

2. **Parameter γ :** Represents the autocorrelation coefficient of technological shocks. The posterior mean of 0.8644 suggests that technological shocks have a significant and lasting impact on the economy. Investment in human capital can enhance workers' ability to handle technology and innovation.
3. **Parameter δ :** Represents the elasticity parameter between labor and leisure. The posterior mean of this parameter is 4.6773, indicating that individuals have flexibility in allocating their time between work and leisure. Investment in education and training makes workers more productive, improving quality of life and increasing economic growth.

3-4 Economic Interpretation:

The economic interpretation suggests that investment in human capital boosts economic growth in multiple ways:

- **Increased productivity:** More educated and trained workers are more efficient, which increases labor productivity and contributes to economic growth.
- **Encouragement of innovation:** Education promotes innovation and new technologies, which supports long-term economic growth.
- **Labor market flexibility:** Multi-skilled workers can adapt to changes in the labor market, reducing unemployment and increasing economic growth.

Using the results presented in the table, it can be said that investment in human capital plays a crucial role in enhancing economic growth. However, according to the empirical study results, its impact was not significant. Therefore, the focus should be on improving knowledge and skills through education and training, along with investment in health, to enhance worker productivity and stimulate innovation, contributing to sustainable economic growth.

Appendices:

Table No. (02): Post and Pre-Distributions of Structural Parameters

Parameter	Tribal Distribution		Post-distribution			
	Mean	Standard deviation	Mean	Mode	Range 90%	
					The lowest	The highest
\bar{g}	1.015	0.0087	1.0096	1.0102	1.0027	1.0161
ρ_g	0.000	0.5716	0.2367	0.4412	-0.4998	0.9342
ρ_a	0.000	0.5716	0.8644	0.8728	0.7951	0.9362
ϕ	4.000	2.3094	4.6773	4.0524	2.9229	6.4042
ρ_v	0.000	0.5716	0.8657	0.8447	0.7908	0.9412
ρ_s	0.000	0.5716	0.2004	0.2900	-0.5508	0.9898
ρ_μ	0.000	0.5716	0.9063	0.9109	0.8402	0.9791
ψ	2.500	1.4434	2.6193	2.2165	1.1361	4.1298

Source: Prepared by the student from Dynare outputs

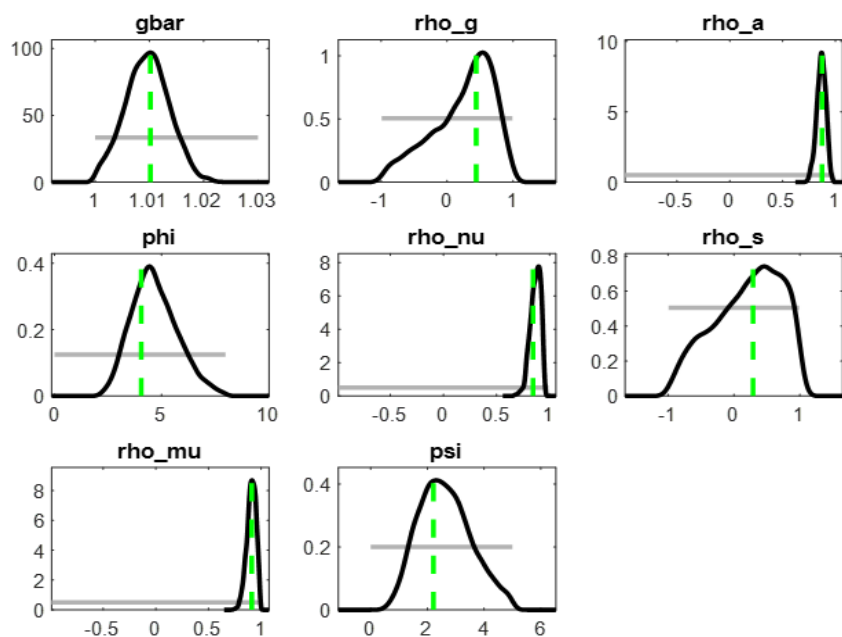
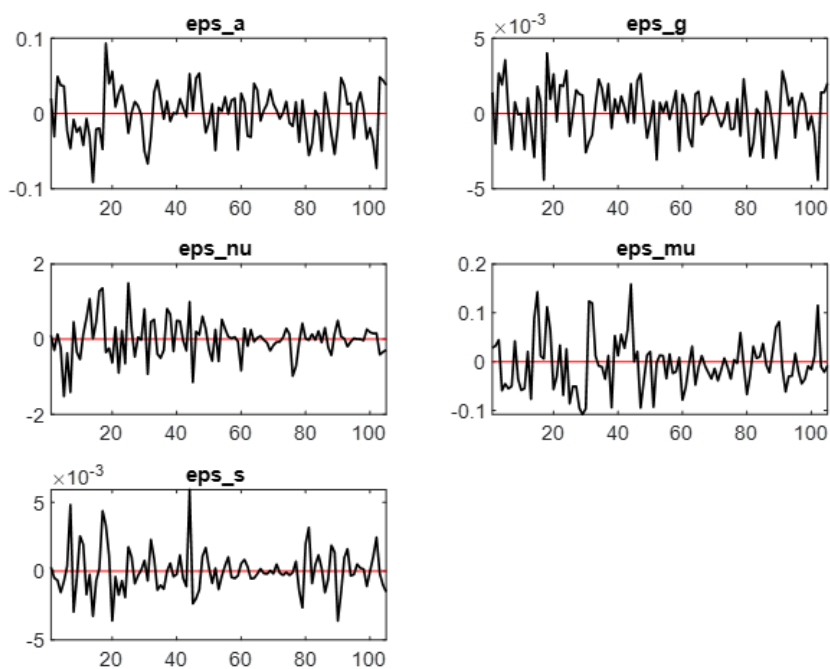
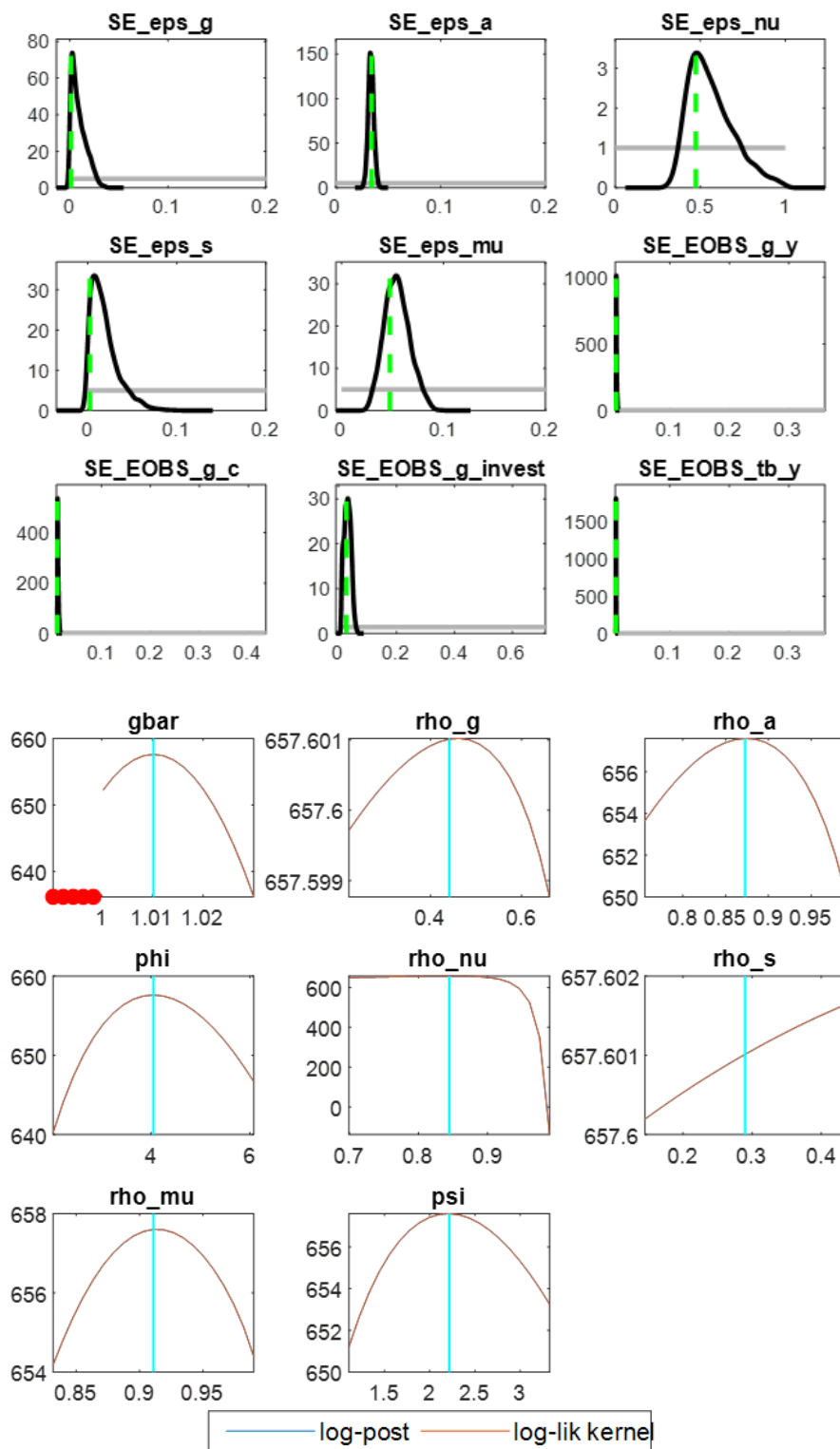


Figure (01): Outputs of Prior and Posterior Distributions
Source: Prepared by the student from Dynare outputs





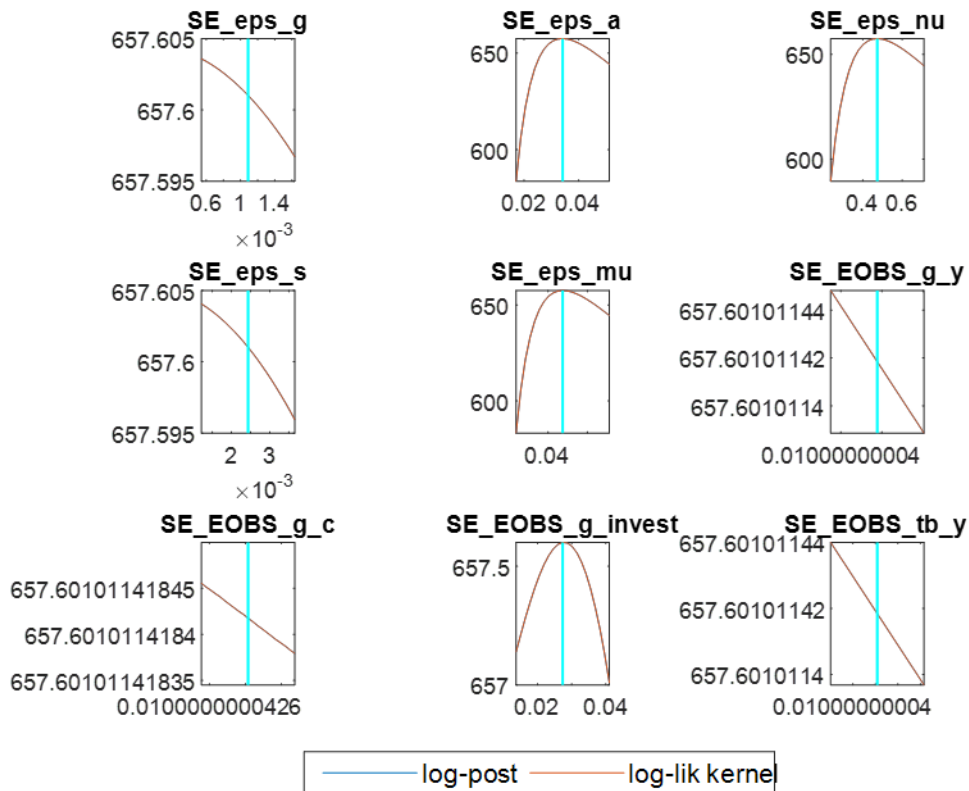


Figure (02): Outputs of Shocks and Their Distributions
Source: Prepared by the student from Dynare outputs

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