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The Behavior of Households Using the Dynamic Stochastic General Equilibrium Model: Alternative Models

(*Gelagat Isi Rumah Menggunakan Model Keseimbangan Umum Stokastik Dinamik: Model Alternatif*)

Hamid Reza Izadi
Chabahar Maritime University

ABSTRACT

This paper endeavors to present a dynamic stochastic general equilibrium (DSGE) model that can assay and check the traces of changes in utility in Iran's economy by defining different utility functions for households. It uses data from 1998 to 2020 and assays Iranian households' behavior within the framework of a DSGE model. A number of modifications to the standard model have been introduced to enforce stationarity and household behavior. To this aim, this rummage, with a glimpse at the existing economic literature, will present a DSGE model for a small open economy with changing utility function. Three different characteristics are considered for this purpose, namely an endogenous discount factor model, a debt-elastic interest-rate premium model, and a portfolio adjustment costs model. The results show that all models assert virtually identical dynamics at business-cycle frequencies as measured impulse response functions. The notable difference among the alternative models is that the debt-elastic interest-rate premium model and the portfolio adjustment costs model have dynamic changes.

Keywords: Debt; dynamic stochastic general equilibrium; household behavior; open economic model

ABSTRAK

Artikel ini berusaha untuk membentangkan model keseimbangan umum stokastik dinamik (DSGE) yang boleh menguji dan menyemak kesan perubahan utiliti dalam ekonomi Iran dengan mentakrifkan fungsi utiliti yang berbeza untuk isi rumah. Ia menggunakan data dari 1998 hingga 2020 dan menguji tingkah laku isi rumah Iran dalam rangka kerja model DSGE. Beberapa pengubahsuaian kepada model piawai telah diperkenalkan untuk memastikan tingkah laku isi rumah dan pegun. Untuk tujuan ini, dengan melihat sekilas literatur ekonomi sedia ada, akan membentangkan model DSGE untuk ekonomi terbuka yang kecil dengan fungsi utiliti yang berubah-ubah. Tiga ciri-ciri berbeza dipertimbangkan untuk tujuan ini, iaitu model faktor diskaun endogen, model premium kadar faedah anjal hutang, dan model kos pelarasan portfolio. Keputusan menunjukkan bahawa semua model menegaskan dinamik yang hampir sama pada frekuensi kitaran perniagaan sebagai fungsi tindak balas dorongan yang diukur. Perbezaan ketara antara model alternatif ialah model premium kadar faedah anjal hutang dan model kos pelarasan portfolio mempunyai perubahan dinamik.

Kata kunci: Hutang; keseimbangan umum stokastik dinamik; gelagat isi rumah; model ekonomi terbuka
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INTRODUCTION

Dynamic stochastic general equilibrium (DSGE) models, which have played a significant role in modern discussions of macroeconomics, in my judgment, fail to serve the functions expected from a well-designed macroeconomic model. Early models of the real business cycle made the assumption that the representative consumer acted in perfectly competitive markets. Technology shocks are the only source of uncertainty in these models. To investigate how actual shocks to the economy could cause business cycle fluctuations, RBC theory establishes the neoclassical growth model under the notion of flexible prices. The representative consumer premise can be interpreted either literally or as a Gorman aggregation[1] of diverse individuals experiencing unique income shocks and full markets for whole assets. These models are based on the premise that shifts in overall economic activity are in fact the economy's efficient reaction to external shocks (Backus et al. 1992).

These models are criticized for several reasons. First, microeconomic data cast doubt on some of the key roles of the models, such as perfect credit markets and insurance markets and perfectly frictionless labor markets. Second, they have difficulty accounting for some main traits of the aggregate data, including the perceived volatility in hours worked and the equity premium. Third, open-economy prescriptions of these models fail to account for observations such as the cyclical demeanor of consumption and output among countries and the hardly high correlation across nominal and real exchange rates. Finally, they are mute on numerous policy-related matters of dimension to macroeconomists and policymakers, including the outcomes of different monetary policy rules for aggregate economic acting (Lucas *1976).*

In the present paper, we develop a DSGE model for an open economy and calibrate it on data from the Iranian context. In more accurate terms, we modify the closed economy DSGE model formulated by Christiano et al. (2005) through consociating open economy phases. The DSGE model proposed in this paper incorporates their closed economy context elements with some specifications and detections in the new open economy macroeconomics**.**

In the models for a small open economy proposed by Eichenbaum (1997), Schmitt-Grohe and Uribe (2004), Domeij and Heathcote (2004), and more recently, Izadi and Marzban (2016), Marzban et al. (2016), Marzban et al. (2018), Izadi (2018), Izadi and Marzban (2019), and Izadi (2021), the researchers have surveyed the effect of equilibrium dynamics to study and accurately forecast the equilibrium path dynamics using the modifications made to standard models. Such changes in the structure and framework of the model will lead to accurate determination of the characteristics and behavior of these models. Hence, the main focus of the present paper is to appraise how and to what extent changes in the household utility function and its variables will affect the equilibrium dynamics and the direction of variables during business cycles.

This paper compares the business cycle properties by considering three models. The first model assumes an endogenous discount factor (Uzawa 1968). Recent studies using this characteristic comprise Obstfeld (1990), Mendoza (1991), Uribe (1997), Schmitt-Grohe (1998), Neumeyer and Perri (2005), Abdullah Yusof et al. (2015), Azlina et al. (2018), Ngadiman et al. (2019), Chang et al. (2020), Santoso and Sriyana (2020), and Baharudin et al. (2021).

In this model, the subjective discount factor, typically denoted by β, is considered to decrease consumption. Agents become more impatient as they consume more. This modification makes the steady-state independent of initial conditions clear from inspection of the Euler equation $\lambda_t = \beta(C_t)(1+R)\lambda_{t+1}$. Here, λ_t denotes the marginal utility of wealth, and r means the world interest rate. In the steady-state, this equation is reduced to $\beta(C)(1+R) = 1$, which pins down the steady-state level of consumption solely as a function of r and the parameters defining the function $\beta(.)$. Kim and Kose (2003) compare the business-cycle implications of this model to those implied by a model with a constant discount factor. Also, the present paper considers a briefed explanation of Uzawa's preferences, where the discount factor is assumed to be a function of aggregate per capita consumption rather than individual consumption.

The second model takes into account a debt-elastic interest-rate premium. This stationarity inducing method has been used, among others, in research by Senhadji (1994), Mendoza and Uribe (2000), and Schmitt-Grohe and Uribe (2001). In this model, domestic agents are supposed to face an interest rate increase in the country's net foreign debt. To see why this device induces stationarity, let $p(D_t)$ denote the premium over the world interest rate paid by domestic habitants and d_t the foreign debt stock. Then in the steady-state, the Euler equation connotes that $\beta = \left(1 + R + p(D)\right) = 1$. This explanation defines the steady-state net foreign asset situation as a function of r and the parameters that determine the premium function $p(.)$ only.

The third model investigates portfolio adjustment costs. Neumeyer and Perri (2005) recently used this way of convincing stationarity. In this model, the cost of increasing asset holdings by one unit is greater than one because it includes the marginal cost of adjusting the size of the portfolio. The Euler equation thus becomes $\lambda_t(1 - \psi'(D_t)) = \beta(1+r)\lambda_{t+1}$, where ψ (.) is the portfolio adjustment cost. In the steady-state, this statement is simplified to $\left(1 - \psi'(D)\right) = \beta(1+r)$, which mentions a steady-state level of foreign debt that depends only on the model's parameters.

In fact, by reviewing economics literature and small open economy models, we conclude that since such a study has never been undertaken in Iran, this research can be a basis for policy-making and modelling. Many studies have examined economic variables' dynamics by introducing several different models. Since Iran does not have the same economic and geographical conditions as other countries, introducing different models and examining the dynamics of the paths of economic variables and comparing them with the results of other studies can be used as a pattern. Then if the results of this research are similar and close to the results of the studies conducted in other countries, policymakers can use the findings of those studies as a pattern for Iran's economy.

The present paper is organized into four sections. After the *Introduction*, the three models are presented in the second section. The third section will examine the research model and its equations and will discuss the research's empirical results. The fourth section will present the conclusion of such empirical findings.

METHODOLOGY AND THE MODEL

By applying dynamic principles, DSGE models contrast with the static models studied in applied general equilibrium models and some computable general equilibrium models. DSGE models share a structure built around three interrelated "blocks": demand, supply, and monetary policy equation. Formally, the equations that define these blocks are built on micro-foundations and make explicit assumptions about the behavior of the main economic agents in the economy, i.e., households, firms, and the government. The preferences (objectives) of the agents in the economy must be specified. For example, households might be assumed to maximize a utility function over consumption and labor effort. Firms might maximize profits and have a production function, specifying the number of goods produced, depending on the labor, capital, and other inputs they employ. Technological constraints on firm decisions might include costs of adjusting their capital stocks, employment relations, or the prices of their products.
Below is an example of the set of assumptions a DSGE is built upon:

1. Perfect competition in all markets
2. All prices adjust instantaneously
3. Rational expectations
4. No asymmetric information
5. The competitive equilibrium is Pareto optimal
6. Firms are identical and price-takers
7. Infinitely lived identical price-taking households (*Sbordone et al. 2010).*

Few authors in the literature provide a comprehensive discussion about the properties of DSGE models for the economies and survey the complete description of the steady-state policy of the basic New Keynesian model for opened economies. From a theoretical perspective, the models depart from the recent literature. They are generalized for an open economy. In this intertemporal problem, the household maximizes its discounted utility by choosing current period consumption, investment, wages, bond holdings, and physical capital accumulation. The model presents adjustment costs for investment and portfolio in a brief overview from the household perspective. Household owns capital and set their wages after observing the demand for their labor. The objective of the household is to maximize the discounted value of expected utility. To achieve the objective, households in each period buy produced goods for consumption and sell their labor to satisfy the demand by the firms after the acceptance of the proposed wage. Households trade bonds in the international financial markets and accumulate capital built from produced goods to transfer wealth across periods.

The main objective of the following sub-sections is to evaluate three different models in terms of steady-state allocations with a calibration based on the literature on medium-scale macroeconomic models. The simulations compared specific moments in all models. The main goal is to understand the difference in all models and survey the responses, given the restrictions imposed by parametric assumptions. Consequently, the next sub-sections attempt to highlight differences among model 1, model 2, and model 3; and they try to explicate behavior resulting from the changes in the utility functions.

FIRST MODEL: ENDOGENOUS DISCOUNT FACTOR

The economy is assumed to be populated by a large representative family with a continuum of members. Consumption and hours worked are identical across family members. The household's preferences are defined over per capita consumption, C_t, and per capita labour H_t. The utility function is defined as follows:

$$E_0 \sum_{t=0}^{\infty} \theta_t U(C_t, H_t) \tag{1}$$

$$\theta_t = 0 \quad , \quad \theta_{t+1} = \beta(C_t, H_t)\theta_t \quad , \quad t \geq 0$$

The evolution of foreign debt D_t is given by

$$D_t = (1 + R_{t-1})D_{t-1} - Y_t + C_t + I_t + \Phi(K_{t+1} - K_t)$$

where R_t denotes the interest rate at which domestic residents can borrow in international markets in period t, Y_t denotes domestic output, C_t denotes consumption, I_t denotes gross investment, and K_t denotes physical capital. The function $\Phi(.)$ is meant to capture capital adjustment costs and is assumed to satisfy $\Phi(0) = \Phi'(0) = 0$. Output is produced employing a linearly homogeneous production function that takes capital and labor services as inputs,

$$Y_t = A_t F(K_t, H_t) \tag{2}$$

where A_t is an exogenous stochastic productivity shock. The stock of capital evolves according to

$$K_{t+1} = (1 - \delta)K_t + I_t \tag{3}$$

where δ denotes the rate of depreciation of physical capital. Households choose processes $\{C_t, H_t, Y_t, I_t, K_{t+1}, D_t, \theta_t\}_{t=0}^{\infty}$ so as to maximize the utility function subject to no-Ponzi constraint. The model includes one exogenous macroeconomic disturbance (the TFP shock). All macroeconomic disturbances are assumed to follow AR (1) processes. The law of motion of the productivity shock is given by:

$$\ln A_{t+1} = \rho_A \ln A_t + \epsilon_{t+1} \tag{4}$$

where the innovation to this shock is normally distributed zero-mean innovations. The model applies the following functional forms for preferences and technology:

$$U(C,H) = \frac{(C - \frac{H^{\omega}}{\omega})^{1-\gamma} - 1}{1-\gamma}$$
$$F(K_t, H_t) = K^{\alpha} H^{1-\alpha}$$
$$\Phi(x) = x^2 \qquad \Phi > 0$$

SECOND MODEL: DEBT-ELASTIC INTEREST RATE

In this model, stationarity is induced by assuming that the interest rate faced by domestic agents, R_t, increases the aggregate level of foreign debt, which we denote by $\widetilde{D}_t$. Specifically, R_t is given by

$$R_t = R + p(\widetilde{D}) \tag{5}$$

where R denotes the world interest rate, and $p(.)$ is a country-specific interest rate premium. The function p (.) is assumed to be strictly increasing. Preferences are given by Equation (1). Unlike in the previous model, preferences are assumed to display a constant subjective rate of discount, $\theta_t = \beta^t$. A competitive equilibrium is a set of processes $\{D_t, \widetilde{D}_{t+1}, C_t, H_t, Y_t, I_t, K_{t+1}, R_t, \lambda_t\}_{t=0}^{\infty}$. We adopt the same forms for the functions *U*, *F*, and Φ as in the previous model. The model uses the following functional form for the risk premium:

$$p(D) = \psi_2\left(e^{D-\bar{D}} - 1\right) \tag{6}$$

where *C* and $\bar{D}$ are constant parameters, and $\bar{D}$ equals the steady-state level of foreign debt.

THIRD MODEL: PORTFOLIO ADJUSTMENT COSTS

In this model, stationarity is induced by assuming that agents face costs of holding assets in quantities different from some long-run levels. Preferences and technology are as in the previous model. Here, it is assumed that the interest rate at which domestic households can borrow from the rest of the world is constant and equal to the world interest. The sequential budget constraint of the household is given by

$$D_t = (1 + R_{t-1})D_{t-1} - Y_t + C_t + I_t + \Phi(K_{t+1} - K_t) + \frac{\psi_3}{2}(D_t - \bar{D})^2 \tag{7}$$

where ψ_3 and $\bar{D}$ are constant parameters defining the portfolio adjustment cost function. This optimality condition states that if the household borrows an additional unit, then current consumption increases by one unit minus the marginal portfolio adjustment cost $\psi_3(D_t - \bar{D})$. The value of this increase in consumption in terms of utility is given by the left-hand side of the above equation. In the next period, the household must repay the additional unit of debt plus interest. The right-hand side gives the value of this repayment in terms of today's utility. At the optimum, the marginal benefit of a unit debt increase must equal its marginal cost. A competitive equilibrium is a set of processes $\{D_t, C_t, H_t, Y_t, I_t, K_{t+1}, R_t, \lambda_t\}_{t=0}^{\infty}$. Preferences and technology are parameterized as in the previous model.

CALIBRATION, RESULTS AND DISCUSSION

To solve the pattern, the research model was used, which includes the equations extracted from the optimization and the identities in the model. A part of the steady-state described by the model is specified by the parameters listed in Table 1, where the parameter values have been replaced by the calibration method in the software.

TABLE 1. Parameter of calibration

Parameter	Description	Value	Source
δ	depreciation rate	0.0139	Izadi (2021)
γ	risk aversion	2.0000	Marzban et al. (2016)
Φ	capital adjustment cost	7.6000	Izadi and Marzban (2019)
α	capital share	0.4400	Izadi (2018)
β	discount factor	0.9745	Marzban et al. (2018)
ψ_2	debt elastic interest rate premium	0.0060	Izadi (2021)
ω	Frisch-elasticity	2.5000	Izadi and Sayareh (2019)
ρ_A	autocorrelation TFP	0.5900	Izadi and Marzban (2016)
ε_t	standard deviation TFP	0.0164	Izadi and Sayareh (2019)
ψ_3	portfolio adjustment cost	0.0060	Izadi and Marzban (2019)
ψ_1	elasticity of the discount factor	0.1600	Izadi and Marzban (2016)
$\bar{D}$	steady-state level of foreign debt	0.4700	Marzban et al. (2018)

Table 2 compares the moments obtained from some of the model's endogenous variables with the real data moments. It shows the results of standard deviation and autocorrelation of variables. In fact, Table 2 shows the business cycle moments of the data compared with the filtered moments generated by the model (the time series path of empirical and simulated data). It lists the time series volatility and the first-order autocorrelation results. In terms of model fitting, the model does a good job matching the business cycle moments of the data, particularly output, consumption, investment, and debt.

TABLE 2. Observed and implied second moments

	Theoretical Moments		Coefficients of Autocorrelation	
Variable	Data	Model	Data	Model
C	0.0376	0.0236	0.9210	0.8942
I	0.0040	0.0015	0.8121	0.8285
D	0.4348	0.5051	0.9767	0.9971
Y	0.0248	0.0263	0.5966	0.5949
K	0.0053	0.0012	0.9662	0.9929

Source: Research calculations

Comparison of real data and software-derived moments show that the research model has been able to simulate the periodic behavior and fluctuations of variables well.

In the following, considering the model's assumptions, the effects of the productivity shock on the economy are examined. The total factor productivity (TFP) is investigated as a shock on the economy and then compared to the behavior of variables in the other models. The effects of this shock are investigated according to the figures below.

Evaluation of Figure 1 shows that consumption and utility can be expected to increase due to increased productivity. Figure 1 demonstrates that models 1–3 also imply virtually identical impulse response functions to a technology shock on consumption and utility variables. For consumption and utility variables, the only small but noticeable difference is given by the responses of consumption and utility in the debt-elastic interest-rate model and portfolio adjustment costs model. In response to a positive technology shock, consumption increases less when the endogenous discount factor model is selected than when the debt-elastic interest-rate model or the portfolio adjustment costs model is selected. This, in turn, leads to a bigger increase in the utility in the period in which the technology shock occurs.

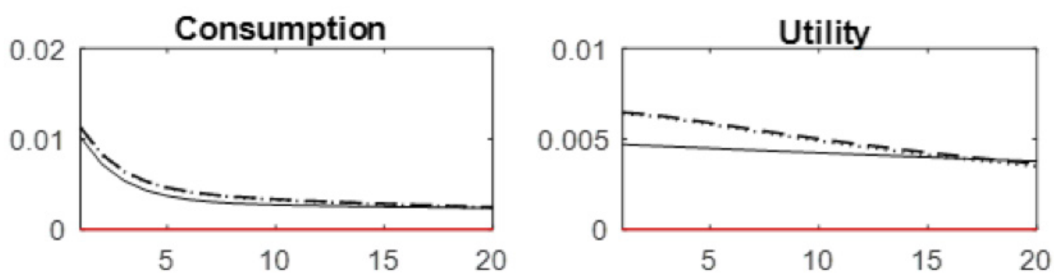

FIGURE 1. Impulse response to a unit technology shock on consumption and utility variables

Solid line: Endogenous discount factor model; Dashed line: Debt-elastic interest-rate model; Dotted line: Portfolio adjustment cost model.

Source: Research calculations

Evaluation of Figure 2 related to the response functions shows that the amount of debt raises due to the raised productivity shock. Figure 2 illustrates that models 1–3 also imply virtually identical impulse response functions to a technology shock on output and debt variables. For the output variable in the three models, the impulse response functions are so similar that the graph appears to show just a single line to the naked eye. For the debt variable, the big difference is given by the responses of debt in the debt-elastic interest-rate model and portfolio adjustment costs model. In response to a positive technology shock, debt increases when the debt-elastic interest-rate model or the portfolio adjustment costs model is selected compared to the endogenous discount factor model. It leads to a bigger increase in the utility in the period in which the technology shock occurs. In the second and third models, debt appears to be more sensitive to wide variations in the parameter of adjustment cost controlling the stationarity of the model, and the adjustment cost determines the stationarity of their respective models.

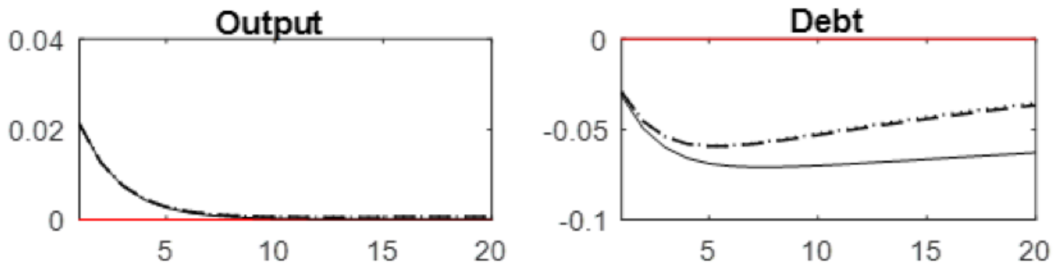

FIGURE 2. Impulse response to a unit technology shock on output and debt variables.

Solid line: Endogenous discount factor model; Dashed line: Debt-elastic interest-rate model; Dotted line: Portfolio adjustment cost model.

Source: Research calculations

Evaluation of figure 3 related to the response functions of the positive productivity shock effect shows that the economy has faced a large increase in capital accumulation. Figure 3 indicates that models 1–3 also imply virtually identical impulse response functions to a technology shock on investment and capital variables. For the two variables, the impulse response functions are similar. The big and noticeable difference is given by the responses of investment and capital in the debt-elastic interest-rate model and the portfolio adjustment costs model. The capital variable increases when the second and third models are selected in response to a positive technology shock. In turn, it leads to a bigger increase in investment in the period in which the technology shock occurs.

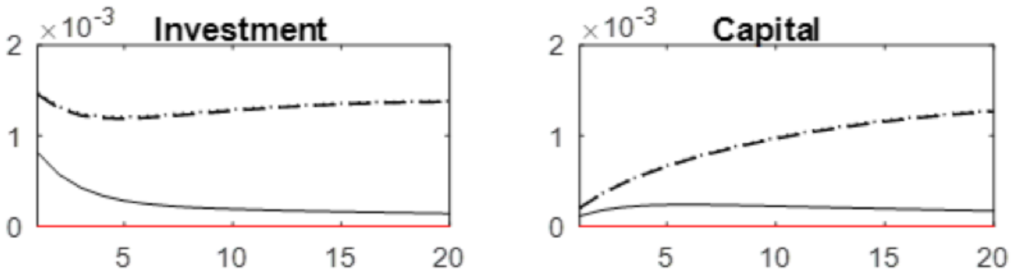

FIGURE 3. Impulse response to a unit technology shock on investment and capital variables.

Solid line: Endogenous discount factor model; Dashed line: Debt-elastic interest-rate model; Dotted line: Portfolio adjustment cost model.

Source: Research calculations

In general, despite the differences among Iran's economy and those of other countries, the results of the current study are in line with the results previously obtained in the context of real business cycle models by Obstfeld (1990), Schmitt-Grohe (1998), and Chang et al. (2020). The difference in the dynamic effects of the models designed in this research was not significant compared to the existing studies in this field, and the behavior of the models has been almost similar. Therefore, in view of these similar findings, it is possible to use the findings of the studies conducted in other countries as a pattern for implementing government policies in Iran.

CONCLUSIONS

This paper presents three alternative ways of making the open economy real business cycle model stationary: first, the model of an endogenous discount factor; second, the model of a debt-elastic interest-rate premium; and third, the model of portfolio adjustment costs. The main finding of the present study is that once the whole three models are made for sharing the same calibration, their quantitative predictions regarding the behavior of key macroeconomic variables, as measured by impulse response functions, are virtually identical. Evaluation of figures in models 1–3 related to the response functions shows that due to the raised productivity shock, the illustrated changes are given by the responses of variables in the debt-elastic interest-rate model and portfolio adjustment costs model. We can say when the debt-elastic interest-rate model or the portfolio adjustment costs model is selected compared to when the endogenous discount factor model is selected, the household behavior due to changes in the utility function leads to a noticeable increase in the variables in the period in which the technology shock occurs. Thus, the second and third models appear to be more sensitive to variations.

Since the introduction of different economic models can show the dynamic paths of different variables and introduce the appropriate model, the government can target its policies by implementing the most favorable and appropriate model and then observe the greatest effect of its policies on society.

In this paper, we developed a stochastic dynamic general equilibrium (DSGE) model for Iranian economy. It should be noted adding blocks to DSGE models and modifying them is very difficult and time-consuming. Therefore, it is impossible to add any desired block to the intended model easily, and this has been the researcher's most important limitation.

Due to the importance of sources of uncertainty in each country's economy, this research could be extended to additional sources of uncertainty such as domestic shocks (government preferences and shocks) and external shocks (world interest rate and terms of trade shocks).

NOTE

1. Gorman polar form is an economics functional form for indirect utility functions. The researcher can consider a society of utility-maximizers as though it were made up of a single "representative" person by applying this form to utility. Gorman demonstrated that for this condition to hold, the function must assume the Gorman polar form.

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Hamid Reza Izadi
Department of Economics
Faculty of Management and Humanities
Chabahar Maritime University, IRAN.
E-mail: izadi@cmu.ac.ir