

## **Intermediate Goods Trade and Macroeconomic Volatility: The Case of Iran-China Trade Relations**

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### **Abstract**

This paper tries to analyze the impacts of intermediate goods trade on production, consumption, investment, net exports, employment, labor wage and capital rent of Iran in its bilateral trade relations with China. This analysis has been done by modeling, solving and calibrating an international real business cycles (IRBC) model in period 1980-2009. The results show that when elasticity of substitution between domestic and imported intermediate goods is low, increasing the share of Iran's imported intermediate goods from China increases volatility of Iran's macroeconomic variables. The value of an increase in volatility of Iran's macroeconomic variables depends on elasticity of substitution between domestic and imported intermediate goods, when the elasticity of substitution between domestic and imported intermediate goods is low, an increase in the share of Iran's imported intermediate goods from China leads to a further increase in the volatility of macroeconomic variables. These results indicate that imports of intermediate goods are an important path through for transmission of shocks between main bilateral trade partners.

**Keywords:** Intermediate Goods, International Real Business Cycles, General Equilibrium Model, Calibration.

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## **1. Introduction**

Given the stronger growth in trade relative to production after 1950s, the share of imported intermediate goods in total inputs increased strikingly over this time period. Kleinert (2003) has explained this phenomenon by three reasons: (1) growing trade in intermediate goods results from the fact that companies use foreign cost advantages more intensively by buying inputs from the cheapest supplier (global sourcing); (2) growing trade in intermediate goods is related to company's outward FDI activities (outsourcing); and (3) growing trade in intermediate goods results from an increasing importance of multinational enterprise (MNE) networks.

Antràs and Helpman (2004) have classified and nominated different kinds of strategy for producing an intermediate good: A firm that chooses to keep the production of an intermediate input within its boundaries can produce it at home or in a foreign country. When it keeps it at home, it engages in standard vertical integration. And when it makes it abroad, it engages in foreign direct investment (FDI) and intra-firm trade. Alternatively, a firm may choose to outsource an input in the home country or in a foreign country. When it buys the input at home, it engages in domestic outsourcing. And when it buys it abroad, it engages in foreign outsourcing, or arm's-length trade.

Feenstra (2004), and Feenstra and Taylor (2012), have mentioned that Production Sharing is a good name for concept of International Outsourcing. The term production sharing was conducted by management consultant Peter Drucker in Wall Street Journal, March, 1977. Hence, a variety of expressions are used for this conception by different economists.

Growth in exports in the 1990s was mostly in exports of technology and human capital-intensive production. They grew by around 17 percent per year as against 9 percent growth for all exports. In contrast, export growth in the 2000s was much more balanced between sophisticated goods and goods more in line with India's static comparative advantage, natural resources and unskilled labor. In the 2000s, however, services exports with much higher human-capital intensity took off with growth of 18 percent per year. The sources of global trade growth provide no strong reasons for export pessimism. In recent years before the global crisis, high-income country imports have grown faster than GDP, driven by differentiation of goods and outsourcing of some elements of production. Developing country exports, in contrast, have risen faster than global

GDP because of continuing economic integration, fragmentation of production, and specialization in globalized production networks (Shephard et al. 2011). Hummels et al. (2001) have shown that growth of trade in intermediate goods is more rapid than trade in final goods.

For developing countries, trade, investment, and knowledge flows that strengthen international outsourcing can provide mechanisms for rapid learning, innovation and industrial upgrading (Lall, 2000; Humphrey and Schmitz, 2002). Global value chains (GVCs) can provide better access to information, open up new markets, and create opportunities for fast technological learning and skill acquisition. Because GVC-linked transactions and investments typically come with quality control systems and prevailing global business standards that exceed those in developing countries, suppliers and individuals in developing countries can be “pushed” to acquire new competencies and skills through their participation in GVCs. In the most deeply linked developing countries, these business process improvements can sometimes be felt far beyond exporting firms and sectors.

At the same time, local firms in developing countries can achieve greater success in their own markets by combining domestic and foreign intermediate inputs and creating economies of specialization that leverage cross-border complementarities. For example, border-spanning GVC linkages can potentially bring local firms into closer contact with “open innovation” systems (Teece et al. 1997 cited in Ketels and Memedovic, 2008), where firms draw on and contribute to freely available technologies and standards. Local firms can also take advantage of specialized knowledge garnered through participation in GVCs to export or set up production abroad, either directly or through contractors and suppliers.

As Wellman and Frasco (2010) have mentioned, China and Iran enjoy an extensive economic relationship. The two cooperate in various different sectors, including energy and construction. China has emerged as a top economic partner of Iran, investing heavily in the energy sector. In 2009, China became Iran's most significant trade partner, with bilateral exchanges worth \$21.2 billion compared to \$14.4 billion three years earlier. In 2011, volume of bilateral trade between Iran and China is increased to \$45.09 billion. According to official data, Iran imported 13% of its imports (\$7.9 billion) from China in 2009. In 2009, China imported \$3.12 billion worth of Iranian non-oil goods, making it Iran's second

largest export market. In 2011, this digit increased to \$5.652 billion, making it Iran's largest export market.

This paper plans to analyze the impacts of trading intermediate goods on Iran's macroeconomic variables volatility in its bilateral trade relations with China. Macroeconomics variables include production, consumption, investment, net exports, employment, labor wage and capital rent. This analysis has been done by modeling, solving and calibrating an international real business cycles (IRBC) model in period 1980-2009.

This paper is structured as follows: Section 2 illustrates the literature review of research. Section 3 explains the research model by details. In section 4, the model will be calibrated and the results of model will be analyzed. In section 5, sensitivity analysis with respect to share of trading intermediate goods will be done. Finally section 6 will focus on concluding remarks which meet the main objective of this paper.

## **2. Research Literature Review**

There is limited empirical analysis on the relationship between intermediate goods trade and macroeconomic volatility. Some studies, however, are devoted to the link between macroeconomic volatility and trade openness in general. Typically, the latter is measured as the sum of imports and exports of goods and services over GDP. As trade in intermediates is part of this measure, the findings clearly bear some relevance for our analysis. With a few exceptions (e.g. Buch et al. 2005), most researchers such as Karras and Song (1996), Kose et al. (2001) and Kose et al. (2006) establish a positive and significant relationship between trade openness and output volatility. This directly leads to the question: Is trade in intermediates any different? Or is it even a driving force behind the link found in the data? Our theoretical and empirical analysis is an attempt at tackling this problem for two developing countries including Iran and China.

Steger and Bretschger (2005) have stated that a large number of endogenous growth models assign intermediate goods a prominent role in the production process. Especially important in this context are the gains from specialization. By combining intermediate goods with other input factors (capital and labor), firms can take advantage of specialization. As a consequence, the productivity of capital and labor increases (e.g. Romer 1990; Grossman and Helpman, 1991). Moreover, the use of intermediate

goods enables an additional roundaboutness in production (von Böhm-Bawerk, 1921), which might increase the productivity of the complementary factors.

Wong and Eng (2010) have explained that business cycle co-movements across countries, for which vertical and sequential trade in intermediate input is empirically found to be one of the most important explanations, have been documented. They reevaluate the Bayesian estimated two-country real business cycle model with traded intermediates and New Keynesian model that incorporates vertical specialization using observable series of nine East and Southeast Asian economies, and generate counterfactual moments. They extend two-country New Keynesian model by considering three processing stages to authentically embrace vertical and sequential linkage at traded intermediate inputs. The Bayesian estimated model has been able to replicate the autocorrelation, cross and contemporaneous correlations over a large set of macroeconomic variables spectacularly well.

Explaining macroeconomic co-movement across countries has been a longstanding task in international macroeconomics. Abrupt fall in world economy following the most recent U.S. recession has vividly demonstrated how countries across regions are tightly linked. A pressing question is thus to know what explains the business cycle co-movement. International trade is certainly one of the empirically most established determinants of business cycle synchronization. Ever since Frankel and Rose (1998), and Clark and van Wincoop (2001), the profession generally agrees that countries that trade more to each other are more likely to co-move. Baxter and Kouparitsas (2005) add to the literature by proving that bilateral trade is one of the only few significant and robust determinants of business cycle co-movement. Of all the types of trade, particularly in between developed and developing nations, trade in intermediates is potentially a mechanism too important to dispense with in accounting for the interaction between trade and business cycle co-movement. As a matter of fact, it has no lack of empirical support on the role of vertical linkages. Based on a panel of 55 countries with 28 manufacturing over four decades, di Giovanni and Levchenko (2010), for instance, reach the conclusion that bilateral trade significantly enhances co-movement should cross-border manufacturing pairs use each other as intermediate input. In particular, they infer that vertical trade can explain 73 percent of trade-comovement nexus among the advanced-developing

country pairs (see, also, Burstein et al., 2008; Tesar, 2008).

Burstein et al. (2008) in a study with title “trade, production sharing and the international transmission of business cycles” have illustrated countries that are more engaged in production sharing exhibit higher bilateral manufacturing output correlations. They use data on trade flows between US multinationals and their affiliates as well as trade between the United States and Mexican maquiladoras to measure production-sharing trade and its link with the business cycle. They then develop a quantitative model of international business cycles that generates a positive link between the extent of vertically integrated production-sharing trade and internationally synchronized business cycles. Their model extends the framework of Backus et al. (1995) to allow for these links in production. A key assumption in the model is a relatively low elasticity of substitution between home and foreign inputs in the production of the vertically integrated good.

Takeuchi (2011) in a study with title “The role of production fragmentation in international business cycle synchronization in East Asia” analyzes factors contributing to the observed increase in international business cycle synchronization between eight East Asian developing countries and the major developed economies of Japan and the United States. To this end, a two-country dynamic general equilibrium model is proposed which focuses on the role of production fragmentation among these countries. The parameters of the model are calibrated using actual data of the countries included. Model simulations are conducted for two periods (1993–1997 and 1999–2005), before and after the Asian financial crisis, showing that the increase in business cycle synchronization can be attributed mainly to the growing fragmentation of production activities.

### 3. The Model

The structure of this research is a two country Real Business Cycle model based on Backus, et al. (1992, 1994 and 1995), Kose and Yi (2001, 2006) and Takeuchi (2011). There are two countries; home and foreign. Each country is inhabited by a continuum of infinitely-lived, identical households with mass unity. The representative agents in each country  $i$  maximize their expected utility as below:

$$U_i = \max E_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}, 1 - n_{it}) \quad (0 < \beta < 1), \quad (1)$$

Where,  $\beta$  is the subjective discount Factor,  $c_i$  and  $n_i$  are per capita consumption and per capita employment in country  $i = H, F$ .

Utility function is specified as:

$$u(c, 1 - n) = \frac{1}{1-\sigma} [c^\mu(1 - n)^{1-\mu}]^{1-\sigma} \quad (0 < \mu < 1, \quad \sigma > 0) \quad (2)$$

$u(\cdot)$  is second-order differentiable, strictly concave, strictly increasing with respect to consumption ( $c_i$ ) and leisure ( $1 - n_i$ ). This form of utility function guaranties substitutability between consumption and leisure.  $\sigma$  shows intertemporal elasticity of substitution.  $\mu$  represents the share of household's consumption with respect to total intratemporal utility.

Each country specializes in the production of one intermediate good. Per capita output of the intermediate good  $z_i$  requires inputs of domestic labor  $n_i$ , and capital  $k_i$ , and is affected by country-specific aggregate productivity( $s_i$ ), which changes stochastically over time. The production function of the intermediate good is given by

$$z_{i,t} = s_{i,t} (k_{i,t})^\alpha (n_{i,t})^{(1-\alpha)} \quad i = H, F \quad (3)$$

The parameter  $\alpha$  denotes the share of capital in value added.  $S_i = (S_{H,t}, S_{F,t})$  is the vector of aggregate productivity shock. It follows an AR(1) process. Intermediate good producer use capital and labor for maximizing profit in each period:

$$\begin{aligned} \text{Max } Z_i - r_i k_i - w_i n_i \\ k_i, n_i \geq 0 \quad i = H, F \end{aligned} \quad (4)$$

Where  $w_i$  and  $r_i$  are labor's wage and capital rent in two countries. First Order Conditions for maximizing intermediate good producer's profit with respect to labor and capital are:

$$\begin{aligned} w_H &= s_H (k_H)^\alpha (n_H)^{(1-\alpha)} (1-\alpha) / n_H \\ r_H &= s_H (k_H)^\alpha (n_H)^{(1-\alpha)} \alpha / k_H \\ w_F &= s_F (k_F)^\alpha (n_F)^{(1-\alpha)} (1-\alpha) / n_F \\ r_F &= s_F (k_F)^\alpha (n_F)^{(1-\alpha)} \alpha / k_F \end{aligned} \quad (5)$$

Production of final goods  $y_{i,t}$  combines local and imported

intermediate goods according to the following Armington aggregator:

$$y_{H,t} = (\theta_H (a_{H,t})^{(\varepsilon-1)/\varepsilon} + (1-\theta_H)(b_{H,t})^{(\varepsilon-1)/\varepsilon})^{\varepsilon/(\varepsilon-1)} \theta_H \geq 0 \quad (6)$$

$$y_{F,t} = (\theta_F (b_{F,t})^{(\varepsilon-1)/\varepsilon} + (1-\theta_F)(a_{F,t})^{(\varepsilon-1)/\varepsilon})^{\varepsilon/(\varepsilon-1)} \theta_F \geq 0 \quad (7)$$

Actually,  $z_{i,t}$  that is produced by  $n_{it}$  and  $k_{it}$  according to (3) can be used as an intermediate good ( $a_{H,t}, a_{F,t}, b_{H,t}, b_{F,t}$ ) in (6) and (7). These variables are defined as follows:

$a_{H,t}$ : Amount of intermediate good that is produced and used in home country.

$b_{H,t}$ : Amount of intermediate good that is produced in foreign country and imports into home country.

$b_{F,t}$ : Amount of intermediate goods that is produced and used in foreign country.

$a_{F,t}$ : Amount of intermediate goods that is produced in home country and exports into foreign country.

The parameter  $(1 - \theta)$  reflects the importance of imported intermediate goods in the production of composite  $y_i$ . Symbol  $\varepsilon$  shows the elasticity of substitution between domestic and imported intermediate inputs.

Resource constraints in two countries are:

$$\omega_H z_{H,t} = \omega_H a_{H,t} + \omega_F a_{F,t} \quad (8)$$

$$\omega_F z_{F,t} = \omega_H b_{H,t} + \omega_F b_{F,t} \quad (9)$$

Where  $\omega_H$  and  $\omega_F$  are the shares of two countries (Iran and China), where  $\omega_H + \omega_F = 1$ . Gross Domestic Production in two countries is:

$$GDP_{H,t} = P_{a_H} z_{H,t} \quad (10)$$

$$GDP_{F,t} = P_{b_F} z_{F,t} \quad (11)$$

Where  $P_{a_H}$  is price of domestic produced intermediate goods ( $a_H$ ) and  $P_{b_F}$  is the price of foreign produced intermediate goods ( $b_F$ ) in equations (10) and (11).

Let  $NX_{H,t}$  and  $NX_{F,t}$  denote the net exports for two countries as a

fraction of GDP:

$$NX_{H,t} = \frac{P_{a_H} a_{F,t} - P_{b_H} b_{H,t}}{GDP_{H,t}} \quad (12)$$

$$NX_{F,t} = \frac{P_{b_F} b_{H,t} - P_{a_F} a_{F,t}}{GDP_{F,t}} \quad (13)$$

Let  $TOT_{H,t}$  and  $TOT_{F,t}$  denote the terms of trade, defined as the price of imports into country  $i$  relative to the price of exports from country  $i$ . The Armington aggregator in equations (6) and (7) according to Zimmermann (1997) imply:

$$TOT_{H,t} = \frac{P_{b_H}}{P_{a_H}} = \frac{\partial y_{H,t} / \partial b_{H,t}}{\partial y_{H,t} / \partial a_{H,t}} = \frac{1 - \theta_H}{\theta_H} \left( \frac{a_{H,t}}{b_{H,t}} \right)^{1/\varepsilon} \quad (14)$$

$$TOT_{F,t} = \frac{P_{a_F}}{P_{b_F}} = \frac{\partial y_{F,t} / \partial a_{F,t}}{\partial y_{F,t} / \partial b_{F,t}} = \frac{1 - \theta_F}{\theta_F} \left( \frac{b_{F,t}}{a_{F,t}} \right)^{1/\varepsilon} \quad (15)$$

Let  $IR_{i,t}$  denotes the import ratio for country  $i$ , defined as the ratio of intermediate goods imports to non-traded domestic intermediate goods production:

$$IR_{H,t} = \frac{b_{H,t}}{a_{H,t}} \quad (16)$$

$$IR_{F,t} = \frac{a_{F,t}}{b_{F,t}} \quad (17)$$

By substituting (16) in (14) and (17) in (15), the terms of trade for two countries are given by:

$$TOT_{H,t} = \frac{1 - \theta_H}{\theta_H} (IR_{H,t})^{-1/\varepsilon} \quad (18)$$

$$TOT_{F,t} = \frac{1-\theta_F}{\theta_F} (IR_{F,t})^{-1/\varepsilon} \quad (19)$$

Equations (18) and (19) imply the relationship between the terms of trade and the import ratios.

Final good ( $y_{i,t}$ ) in two countries is composite of consumption ( $c_{i,t}$ ), investment ( $i_{i,t}$ ), and government purchases ( $g_{i,t}$ ):

$$y_{H,t} = c_{H,t} + i_{H,t} + g_{H,t} \quad (20)$$

$$y_{F,t} = c_{F,t} + i_{F,t} + g_{F,t} \quad (21)$$

The capital formation process is according to

$$k_{H,t+1} = (1-\delta_H)k_{H,t} + i_{H,t} - \frac{\varphi}{2}(k_{H,t+1} - k_{H,t})^2 \quad (22)$$

$$k_{F,t+1} = (1-\delta_F)k_{F,t} + i_{F,t} - \frac{\varphi}{2}(k_{F,t+1} - k_{F,t})^2 \quad (23)$$

Where,  $\delta$  is the depreciation rate and  $\frac{\varphi}{2}(k_{i,t+1} - k_{i,t})^2$  denotes the adjustment costs to changes in the capital stock.

The four shocks to our model are governed by independent bivariate autoregressions. The technology shocks in two countries  $S_t = (S_{H,t}, S_{F,t})$  follow

$$S_{H,t} = A_H S_{H,t-1} + \varepsilon_t^{SH} \quad (24)$$

$$S_{F,t} = A_F S_{F,t-1} + \varepsilon_t^{SF} \quad (25)$$

Where  $\varepsilon^{SH}$  and  $\varepsilon^{SF}$  are distributed normally and independently over time with variances  $V_{SH}$ , and  $V_{SF}$ , similarly shocks to government purchases in two countries  $g_t = (g_{H,t}, g_{F,t})$  are governed by

$$g_{H,t} = B_H g_{H,t-1} + \varepsilon_t^{gH} \quad (26)$$

$$g_{F,t} = B_F g_{F,t-1} + \varepsilon_t^{gF} \quad (27)$$

Where,  $\varepsilon^{gH}$  and  $\varepsilon^{gF}$  are distributed normally and independently over time with variances  $V_{gH}$ , and  $V_{gF}$ .

An equilibrium is characterized in this two countries model by exploiting the equivalence between competitive equilibria and Pareto

optima. Since the utility functions are concave, any optimum can be computed as the solution to a planning problem of the following form, maximize:

$$\omega_H \sum_{t=0}^{\infty} \beta^t u(c_{H,t}, 1 - n_{H,t}) + \omega_F \sum_{t=0}^{\infty} \beta^t u(c_{F,t}, 1 - n_{F,t}) \quad (28)$$

Subject to the constraints for some choice of  $0 < \omega_H, \omega_F < 1$ , with  $\omega_H + \omega_F = 1$ ,

$$y_{H,t} + y_{F,t} = (c_{H,t} + i_{H,t} + g_{H,t}) + (c_{F,t} + i_{F,t} + g_{F,t}),$$

$$k_{H,t+1} = (1 - \delta)k_{H,t} + i_{H,t} - \frac{\varphi}{2}(k_{H,t+1} - k_{H,t})^2,$$

$$k_{F,t+1} = (1 - \delta)k_{F,t} + i_{F,t} - \frac{\varphi}{2}(k_{F,t+1} - k_{F,t})^2,$$

Where  $k_{H,0}$  and  $k_{F,0}$  are given.

Therefore, by solving the optimization problem with Lagrange method, the first order necessary conditions are as below:

$$c_{H,t} \rightarrow \omega_H u_{c_{H,t}}(c_{H,t}, 1 - n_{H,t}) = \lambda_t \quad (29)$$

$$c_{F,t} \rightarrow \omega_F u_{c_{F,t}}(c_{F,t}, 1 - n_{F,t}) = \lambda_t \quad (30)$$

$$n_{H,t} \rightarrow \omega_H u_{n_{H,t}} = \lambda_t (1 - \alpha_H) s_{H,t} (n_{H,t})^{-\alpha_H} (k_{H,t})^{\alpha_H} \quad (31)$$

$$n_{F,t} \rightarrow \omega_F u_{n_{F,t}} = \lambda_t (1 - \alpha_F) s_{F,t} (n_{F,t})^{-\alpha_F} (k_{F,t})^{\alpha_F} \quad (32)$$

$$k_{H,t+1} \rightarrow \lambda_t [1 + \varphi(k_{H,t+1} - k_{H,t})] = E_t \left\{ \beta \lambda_{t+1} \left[ (1 - \delta_H) + \alpha_H s_{H,t+1} (n_{H,t+1})^{1-\alpha_H} (k_{H,t+1})^{\alpha_H-1} + \varphi(k_{H,t+2} - k_{H,t+1}) \right] \right\} \quad (33)$$

$$k_{F,t+1} \rightarrow \lambda_t [1 + \varphi(k_{F,t+1} - k_{F,t})] = E_t \left\{ \beta \lambda_{t+1} \left[ (1 - \delta_F) + \alpha_F s_{F,t+1} (n_{F,t+1})^{1-\alpha_F} (k_{F,t+1})^{\alpha_F-1} + \varphi(k_{F,t+2} - k_{F,t+1}) \right] \right\} \quad (34)$$

Equations (29) and (30) of the necessary conditions interpret  $\lambda_t$  as the shadow price of wealth in each country. Merging equations (29) and (30), it's obtained:

$$\omega_H u_{c_{H,t}}(c_{H,t}, 1 - n_{H,t}) = \omega_F u_{c_{F,t}}(c_{F,t}, 1 - n_{F,t}) \quad (35)$$

Equation (35) shows marginal utility of consumption equalized across countries apart from time-invariant Negishi weight ( $\omega_i$ ). The optimal allocation is the one in which marginal utility of consumption is equalized across countries, since shadow price of  $c_{H,t}$  is equal to shadow price of  $c_{F,t}$ .

Equations (31) and (32) of the necessary conditions equalize the

marginal cost of working an additional hour to the marginal productivity of labor. Merging equations (31) and (32), the following equation is defined as:

$$\frac{\omega_H u_{n_{H,t}}}{\omega_F u_{n_{F,t}}} = \frac{(1 - \alpha_H) s_{H,t} (n_{H,t})^{-\alpha_H} (k_{H,t})^{\alpha_H}}{(1 - \alpha_F) s_{F,t} (n_{F,t})^{-\alpha_F} (k_{F,t})^{\alpha_F}} \quad (36)$$

Equation (36) shows across countries the ratio of marginal cost of labor is equal to the ratio of marginal productivity. The country with higher marginal productivity is assigned as a higher marginal cost of labor.

After removing  $\lambda_t$  in the equations (29)-(34) of the first order conditions by substitution and showing  $R_{H,t+1}$  and  $R_{F,t+1}$  as:

$$R_{H,t+1} = \left[ (1 - \delta_H) + \alpha_H s_{H,t+1} (n_{H,t+1})^{1-\alpha_H} (k_{H,t+1})^{\alpha_H - 1} \right] \quad (37)$$

$$R_{F,t+1} = \left[ (1 - \delta_F) + \alpha_F s_{F,t+1} (n_{F,t+1})^{1-\alpha_F} (k_{F,t+1})^{\alpha_F - 1} \right] \quad (38)$$

The Euler equations are obtained:

$$u_{c_{H,t}} \left[ 1 + \varphi(k_{H,t+1} - k_{H,t}) \right] = E_t \left\{ \beta u_{c_{H,t+1}} \left[ R_{H,t+1} + \varphi(k_{H,t+2} - k_{H,t+1}) \right] \right\} \quad (39)$$

$$u_{c_{F,t}} \left[ 1 + \varphi(k_{F,t+1} - k_{F,t}) \right] = E_t \left\{ \beta u_{c_{F,t+1}} \left[ R_{F,t+1} + \varphi(k_{F,t+2} - k_{F,t+1}) \right] \right\} \quad (40)$$

The Euler equations (39) and (40) are necessary conditions for optimality for any time period. They essentially represent the intertemporal efficiency conditions. The left hand sides of Euler equations represent the marginal costs in terms of utility of investing in more capital. In other words, households reduce their consumption by one unit today, allowing for one more unit investment today and thus one more unit of expected capital tomorrow. This expectedly additional unit of capital yields expectedly additional production equal to the expectedly marginal product of capital and after production  $(1 - \delta)$  unit of the expected capital still remains. Consequently, the right hand sides of the Euler equations represent discounted expected future marginal utility times the marginal productivity of capital. If it is held, then it is impossible to increase utility by moving consumption across adjacent periods. At an optimum, these costs must be equal to benefits. Adjustment costs mean this equalization happens gradually over time.

By combining equations (33) and (34) across countries and

substituting (37) and (38):

$$\frac{E_t \left\{ \pi_{t,t+1} R_{H,t+1} + \varphi(k_{H,t+2} - k_{H,t+1}) \right\}}{\left[ 1 + \varphi(k_{H,t+1} - k_{H,t}) \right]} = \frac{E_t \left\{ \pi_{t,t+1} R_{F,t+1} + \varphi(k_{F,t+2} - k_{F,t+1}) \right\}}{\left[ 1 + \varphi(k_{F,t+1} - k_{F,t}) \right]} \quad (41)$$

Where,  $\pi_{t,t+1}$  is the SDF (Stochastic Discount Factor) (pricing-kernel):

$$\pi_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t} = \beta \frac{u_c(c_{i,t+1}, 1 - n_{i,t+1})}{u_c(c_{i,t}, 1 - n_{i,t})} \quad (42)$$

Equation (41) shows apart from adjustment cost, expected marginal product of capital equalized across countries. Adjustment costs mean this equalization happens gradually over time and it is not instantly.

#### 4. Empirical Results

Empirical results are obtained by calibrating and solving the model. Data on GDP, consumption, investment, government spending, employment, exports and imports for Iran and China has been gathered from the World Development Indicators database of the World Bank. Table 1 reports productivity shocks process (24 and 25) and government shocks process (26 and 27) estimations for countries Iran and China in period 1980-2009. These estimations have been done by Microfit 4.1 software.

**Table 1: Estimation of Productivity Shocks and Government Expenditure Shocks for Iran and China**

Coefficient	Coefficient Definition	Coefficient Value	T-Statistics	Probability
$A_H$	Regression Coefficient of $S_{H,t}$ on $S_{H,t-1}$	0.74	7.11	0.000
$A_F$	Regression Coefficient of $S_{F,t}$ on $S_{F,t-1}$	0.99	55.26	0.000
$B_H$	Regression Coefficient of $g_{H,t}$ on $g_{H,t-1}$	0.95	8.83	0.000
$B_F$	Regression Coefficient of $S_{F,t}$ on $g_{F,t-1}$	0.99	42.34	0.000

Source: Authors

**Table 2: Standard Error and Correlation Coefficient of Productivity Shocks and Government Expenditures for Iran and China**

Moments	Definition	Value
$\sigma(\varepsilon^{SH})$	Regression Residual Standard Error of $S_{H,t}$ on $S_{H,t-1}$	0.0464
$\sigma(\varepsilon^{SF})$	Regression Residual Standard Error of $S_{F,t}$ on $S_{F,t-1}$	0.0198
$Corr(\varepsilon^{SH}, \varepsilon^{SF})$	Correlation Coefficient Between Two Productivity Shocks ( $\varepsilon^{SH}, \varepsilon^{SF}$ )	0.0957
$\sigma(\varepsilon^{gH})$	Regression Residual Standard Error of $g_{H,t}$ on $g_{H,t-1}$	0.071
$\sigma(\varepsilon^{gF})$	Regression Residual Standard Error of $g_{F,t}$ on $g_{F,t-1}$	0.060

Source: Authors

Standard deviations and correlation coefficients for productivity shocks and government shocks of two countries have been calculated and reported in Table 2. China’s productivity shocks coefficient value (0.99) is greater than that of Iran (0.74), that means China’s productivity shocks is more persistent. Also, China’s government expenditures shock coefficient value (0.99) is greater than that of Iran (0.95) that means greater persistence for China’s government expenditures shock.

**4.1. Parameters Values**

Following the strategy widely used for dynamic stochastic general equilibrium model, some of the parameters are chosen to match empirical results from microeconomic studies or long-term averages. Parameters values were reported in Table 3. Capital depreciation rate for Iran’s economy is chosen ( $\delta_H = 0.0412$ ) based on Amini et al.(2005) research. Discount factor for Iran’s economy is chosen ( $\beta_H = 0.962$ ) based on Shahmoradi et al. (2010) estimation.

If it is assumed that each person works 8 hours per a day, work time for a unit of time ( $n = 0.33$ ) is selected. In the steady state, there is a relation among  $\mu_i$  and other model parameters:

$$\mu_i = \frac{n_i (r_i + \alpha_i \delta_i)}{\alpha_i (r_i + \delta_i) + (1 - \alpha_i) n_i r_i} \tag{43}$$

According to (43), consumption shares in utility functions ( $\mu_H$  and

$\mu_F$ ) are calculated respectively 0.4 and 0.38. The curvature of the utility function  $\sigma$  is fixed at 2. To determine the elasticity of substitution between domestic and imported intermediate goods ( $\varepsilon$ ) in Armington aggregator, it is selected from Sendhaji (1998), that has been used for some developing countries.

Each country's share in the two countries model has been chosen based on the share of population living in each country by Canova and Ubide (1998). Takeuchi (2011) has calculated share of countries using real GDP data on a purchasing power parity basis. The share of countries in this research has been calculated using average real GDP data on a purchasing power parity basis in 1980-2009. Iran's share of the total two countries model ( $\omega_H$ ) has been calculated 0.12, and that of China ( $\omega_F$ ) has been calculated 0.88. These values are reported in Table 3.

Johnson and Noguera (2012) have combined input-output and bilateral trades data to compute the value added content of bilateral trade. The ratio of value added to gross exports (VAX ratio) is a measure of the intensity of production sharing. The VAX ratio for a country can be thought of as a metric of the "domestic content of exports". They have calculated this measure for more than one hundred countries including Iran and China. Its value for Iran 0.7 and for China 0.95 has been calculated. Multiplying "share of Iran's imports from China to total Iran's imports" by the China's VAX, a proxy for the share of Iran's intermediate goods imports from China ( $1-\theta_H$ ) can be introduced, which is calculated 6 percent. Also, multiplying "share of China's imports from Iran to total China's imports" in the Iran's VAX ratio, a proxy for the share of China's intermediate goods imports from Iran ( $1-\theta_F$ ) can be introduced, which is calculated 1.42 percent. These values are reported in Table 3.

It hasn't been found any estimation of capital adjustment cost ( $\varphi$ ) for Iran and China. So, value 0.9 that has good results in the structure of model has been chosen. This value is chosen based on approximation between moments of real data and moments of simulated data.

**Table 3: Parameters Values based on Economic Studies and Authors Calculation**

Parameter	Parameter Definition	Value	Source
$\alpha_H$	Capital Share in Iran's Intermediate Goods Production Function	0.412	Shahmoradi (2008)
$\alpha_F$	Capital Share in China's Intermediate Goods Production Function	0.438	Meshcheryakova (2005)
$\beta_H$	Discount Factor in Iran's Utility Function	0.962	Shahmoradi et al. (2010)
$\beta_F$	Discount Factor in China's Utility Function	0.9615	Meshcheryakova (2005)
$\delta_H$	Iran's Rate of Capital Depreciation	0.0412	Amini and Neshat (2005)
$\delta_F$	China's Rate of Capital Depreciation	0.035	Meshcheryakova (2005)
$\varepsilon$	Elasticity of Substitution in Armington Aggregator	0.5	Sendhaji (1998)
$\mu_H$	Consumption Share in Iran's Utility Function	0.4	Authors Calculation
$\mu_F$	Consumption Share in China's Utility Function	0.38	Authors Calculation
$(1-\theta_H)$	Share of Iran's Intermediate Goods Imports from China	6%	Authors Calculation
$(1-\theta_F)$	Share of China's Intermediate Goods Imports from Iran	1.42%	Authors Calculation
$\omega_H$	Iran's Share of the Total Two Countries Model	0.12	Authors Calculation
$\omega_F$	China's Share of the Total Two Countries Model	0.88	Authors Calculation
$\varphi_H$	Iran's Capital Adjustment Costs Coefficient	0.9	Authors Calculation
$\varphi_F$	China's Capital Adjustment Costs Coefficient	0.9	Authors Calculation

Source: Compiled by Authors

**4.2. Evaluation and Comparison of Model Output with Real Data**

To evaluate the explanatory power of the model, the results of model are compared with real data. These results are reported in Table 4. The cyclical component of GDP, consumption, investment, government expenditure and net export are extracted from the raw time series data for

both countries Iran and China in 1980-2009. Hodrick-Prescott (HP) filtering is used for isolating the cyclical component of time series. All variables are in the natural logarithm except for net exports. All real and simulated data sampled at an annual frequency, so assume a value of  $\lambda$  of 100.

Table 4 compares autocorrelation coefficients in first and second lags and standard deviation of real data and that of simulated data. The comparison of these statistical characteristics is a usual method to evaluate simulation of model in DSGE researches. If simulated values are closer to corresponding real data, the simulation of model will be more acceptable. Table 4 shows that simulation is acceptable because statistical characteristics of real and simulated data are close enough.

**Table 4: Statistical Characteristics of Real and Simulated Data**

Simulated and Real Data		Autocorrelation in Lags				Standard Deviation	
		Real Data		Simulated Data		Real Data	Simulated Data
Variable	Definition	First	Second	First	Second	Data	d Data
$GDP_H$	Gross Domestic Production	0.580	-0.027	0.437	-0.054	0.0388	0.0397
$C_H$	Consumption	0.488	-0.011	0.442	-0.060	0.0172	0.0189
$I_H$	Investment	0.520	-0.157	0.443	-0.028	0.0191	0.0215
$G_H$	Government Expenditures	0.515	0.217	0.500	0.103	0.060	0.062
$NX_H$	Net Exports	0.517	0.134	0.548	0.188	0.0185	0.0193

Source: Authors

### 4.3. Analysis of Variables Characteristics

The real business cycles models emphasize on three characteristics including volatility, persistence and co-movement of variables. Volatility, persistence and co-movement are respectively measured by standard deviation, first lag autocorrelation and correlation coefficient of the series. Higher standard deviation of the series indicates higher volatility. Greater autocorrelation coefficients imply higher persistence of variables. Positive correlation coefficient between two variables show co-movement of those variables and higher correlation coefficient implies higher degree of co-movement between two variables. Also, according to DSGE models literatures a variable is pro-cyclical when it has a positive correlation with output. By contrast, a variable is countercyclical when it

has a negative correlation with output.

**Table 5: Volatility and Persistence of Simulated Variables Data**

Variable Definition	Variable	Volatility (SD) <sup>*</sup>	Relative Volatility (Relative SD)	Persistence (Autocorrelation)
Gross Domestic Production	$GDP_H$	3.97	1	0.43
Consumption	$C_H$	1.89	0.47	0.44
Employment	$N_H$	0.39	0.09	0.45
Investment	$I_H$	2.15	0.54	0.44
Government Expenditures	$G_H$	6.20	1.56	0.50
Net Exports	$NX$	1.93	0.49	0.54
Wage	$W_H$	6.75	1.70	0.48
Capital Rent	$R_H$	0.44	0.11	0.46
Iran's Intermediate Imports from China	$b_H$	4.93	1.24	0.80
Iran's Intermediate Exports to China	$a_F$	0.73	0.18	0.47

Source: Authors, <sup>1</sup> Standard Deviations are measured in percentage points

Table 5 reports standard deviation, relative volatility and first lag autocorrelation of simulated variables. Standard deviation and relative volatility (standard deviation divided by that of GDP) indicate measures of volatility. Volatility of government expenditures and Iran's intermediate goods imports from China is greater than that of Iran's GDP. The main source of Iran's government expenditures comes from oil exports, while this variable has high volatility because of oil price fluctuations. Hence, volatility of oil exports income explains higher volatility of government expenditure rather than output. Motavaseli et al. (2010) explained role of oil income shock and other shocks including growth rate of money shock, productivity shock and government expenditures shock as sources of Iran's business cycles volatilities.

According to Table 6, correlation coefficients between all components of aggregate demand except for government expenditures (including consumption, investment and net exports) and output are positive implying these variables are co-movement. Consumption co-movement is confirmed by all consumption theories in which there is a

positive relationship between total income and consumption. Investment co-movement is consistent with theories such as acceleration theory and neoclassical theory of investment. The coefficient correlation between net export and GDP is positive, so that net export variable is a co-movement variable while the correlation coefficient value is low. The correlation coefficient between Iran's intermediate goods import from China and output is positive though low. The correlation coefficient between Iran's intermediate exports to China and output (0.36) is positive and greater than that between Iran's intermediate imports from China and output (0.0043), thus increasing Iran's GDP coincidence with increasing Iran's intermediate exports and imports, but Iran's tendency to export intermediate goods to China is higher than that of imports during booms.

**Table 6: Correlation Coefficients of Simulated Variables Data**

Variable Definition	Variable	$GDP_H$	$C_H$	$N_H$	$I_H$	$G_H$	$NX$	$W_H$	$R_H$	$b_H$	$a_H$
Output	$GDP_H$	1	0.97	0.94	0.98	0.0004	0.11	0.94	0.95	0.13	0.09
Consumption	$C_H$	0.97	1	0.85	0.91	-0.20	0.09	0.89	0.89	0.015	0.29
Employment	$N_H$	0.94	0.85	1	0.99	0.29	-0.39	0.91	0.95	0.29	-0.19
Investment	$I_H$	0.98	0.91	0.99	1	0.18	-0.29	0.93	0.96	0.23	-0.08
Government Expenditure	$G_H$	0.0004	-0.20	0.29	0.18	1	-0.96	0.07	0.09	0.63	-0.99
Net Exports	$NX$	-0.11	0.09	-0.39	-0.29	-0.96	1	-0.25	-0.26	-0.44	0.92
Wage	$W_H$	0.94	0.89	0.91	0.93	0.07	-0.25	1	0.98	-0.07	0.05
Capital Rent	$R_H$	0.95	0.89	0.95	0.96	0.09	-0.26	0.98	1	-0.008	0.02
Iran's Intermediate Imports	$b_H$	0.13	0.015	0.29	0.23	0.63	-0.44	-0.07	-0.008	1	-0.69
Iran's Intermediate Exports	$a_H$	0.09	0.29	-0.19	-0.08	-0.99	0.92	0.05	0.02	-0.69	1

Source: Authors

## 5. Sensitivity Analysis

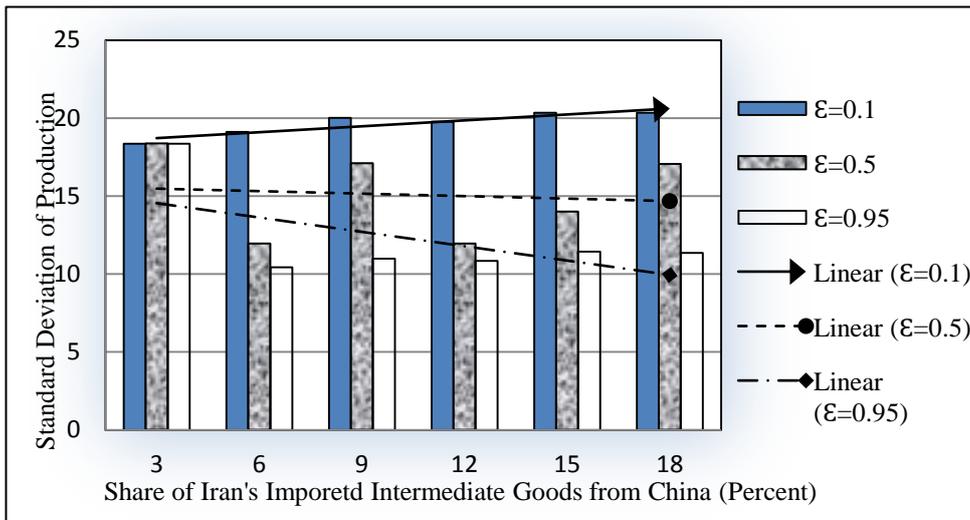
In order to analyze trading intermediate goods in association with volatilities in macroeconomic variables, we use an empirical model to solve for different shares of Iran's intermediate goods imports from China. To this end, the Dynare software is applied. An important factor

in this context is to measure elasticity of substitution between domestic and imported intermediate goods ( $\varepsilon$ ), so that the model has been solved for three scenarios dealing with different values of the elasticity. The benchmark value for the elasticity (that is,  $\varepsilon=0.5$ ) is used in the first scenario. The second scenario takes a lower value of  $\varepsilon=0.1$ . The third scenario is conducted to take a higher value, that is  $\varepsilon=0.95$ . The model is thus solved through each of these scenarios regarding different share values of Iran's intermediate goods imports from China. The share of Iran's intermediate goods imports from China ( $1-\theta_H$ ) changes in a range of 3% - 18%., as the benchmark takes a value of 6%.

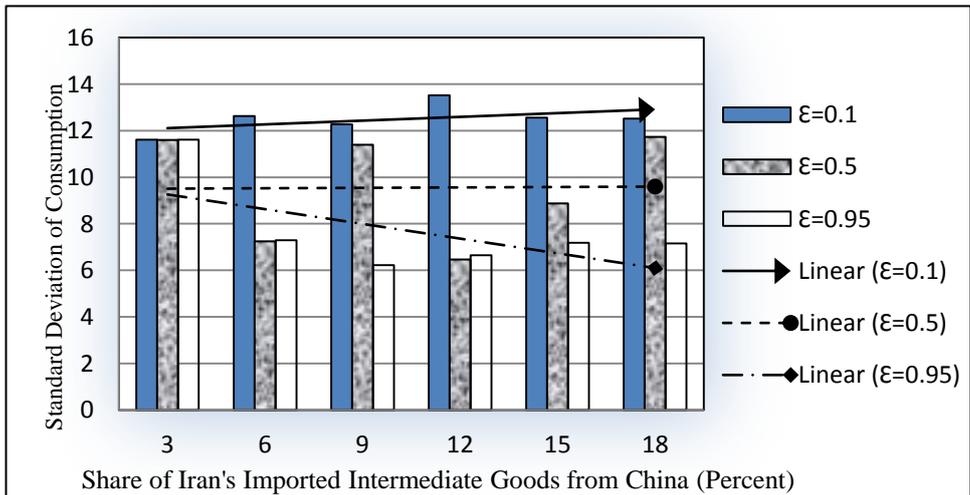
The volatility of simulated variables is calculated in three scenarios by six values for the share of Iran's intermediate goods imports from China. Hence, the model has been solved with 18 iterations. Histograms and trend lines for standard deviations of simulated variables data have been drawn in Figures (1-7). The horizontal axis is devoted to the share of Iran's intermediate goods imports from China that is involved in a range from 3% to 18%. The vertical axis of the Figures shows standard deviation of simulated data for each variable (Percent). In Figure 1, histograms indicate the simulated status of the standard deviations of the production data through which the share of Iran's intermediate goods imports increases from 3% to 18%, while the trend lines (indicating the general trend) is almost constant in the first scenario ( $\varepsilon = 0.5$ ), increasing in the second scenario ( $\varepsilon = 0.1$ ) and declining in the third scenario ( $\varepsilon = 0.95$ ). Figure 2 and Figure 3 show that volatilities of consumption and investment are almost similar to that of output, and the increasing share of Iran's imported intermediate goods from China is coincidence with increasing Iran's consumption and investment.

Figure 4 shows that the simulated net exports data have zero slope in the first scenario ( $\varepsilon = 0.5$ ), negative slope in the third scenario ( $\varepsilon = 0.95$ ) and positive slope in the second scenario ( $\varepsilon = 0.1$ ). Also, Figure 5 shows that, based on the share increasing of Iran's imported intermediate goods from China, the line of standard deviation trend of simulated employment has zero slope in the first scenario ( $\varepsilon = 0.5$ ), negative slope in the third scenario ( $\varepsilon = 0.95$ ) and positive slope in the second scenario ( $\varepsilon = 0.1$ ). When the share is 18 percent, reducing the elasticity of substitution between domestic and imported intermediate goods from 0.95 to 0.1

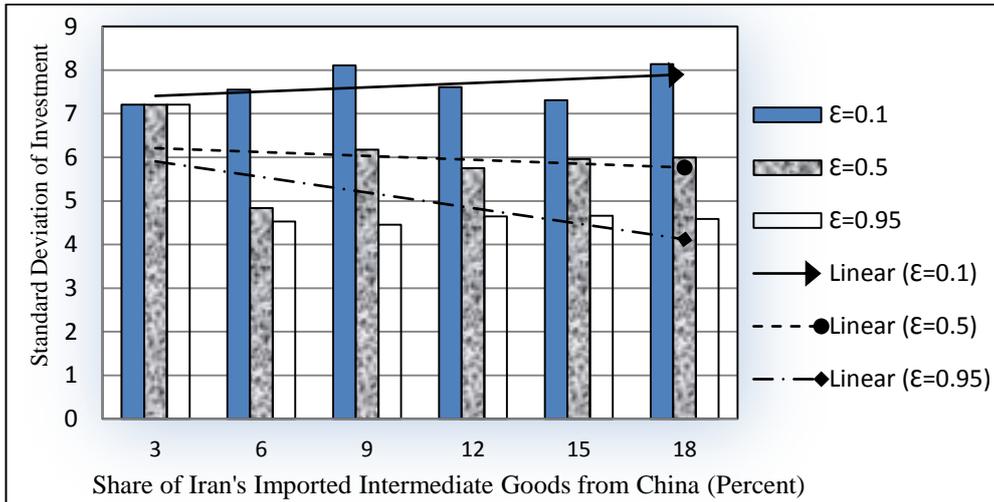
leads the standard deviation of employment to increase from 0.838 percent to 1.104 percent.



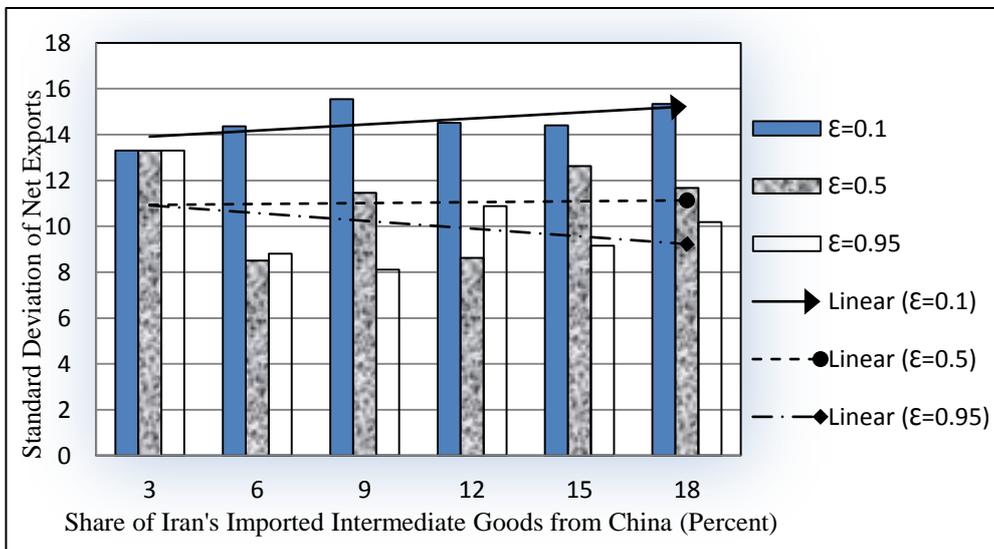
**Figure 1: Standard Deviation of Simulated Production Data for Different Shares of Iran's Imported Intermediate Goods from China.** Source: Authors.



**Figure 2: Standard Deviation of Simulated Consumption Data for Different Shares of Iran's Imported Intermediate Goods from China.** Source: Authors



**Figure 3: Standard Deviation of Simulated Investment Data for Different Shares of Iran's Imported Intermediate Goods from China.** Source: Authors



**Figure 4: Standard Deviation of Simulated Net Exports Data for Different Shares of Iran's Imported Intermediate Goods from China.** Source: Authors

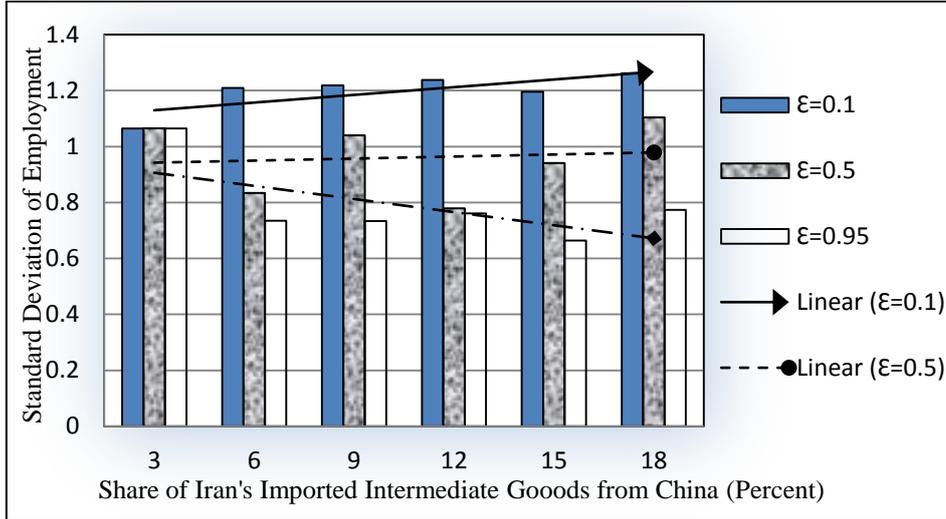


Figure 5: Standard Deviation of Simulated Employment Data for Different Shares of Iran's Imported Intermediate Goods from China. Source: Authors

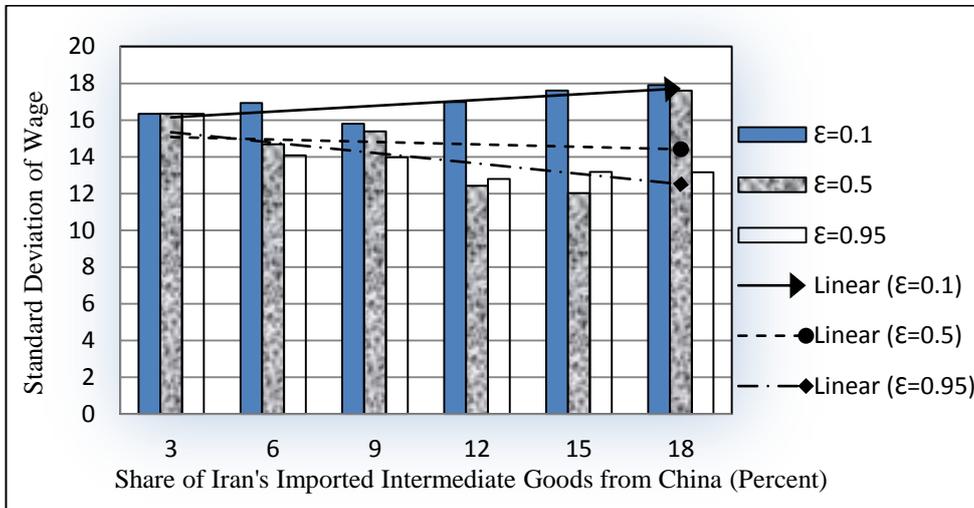
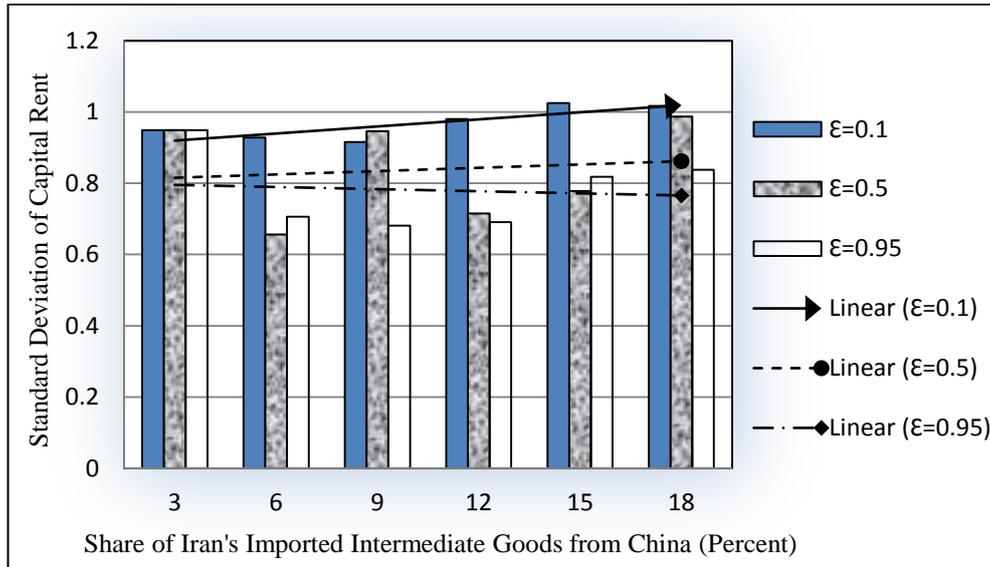


Figure 6: Standard Deviation of Simulated Wage Data for Different Shares of Iran's Imported Intermediate Goods from China. Source: Authors



**Figure 7: Standard Deviation of Simulated Capital Rent Data for Different Shares of Iran's Imported Intermediate Goods from China.** Source: Authors

Figure 6 shows that with increasing the share of Iran's imported intermediate goods from China, trend line of wage volatility is similar to that of employment. For example in second scenario ( $\epsilon = 0.1$ ), trend line of wage volatility and that of employment is increasing, and increasing wage volatility is coincidence with increasing employment volatility.

Figure 7 shows that increasing the share of Iran's imported intermediate goods from China, trend line for volatility of simulated capital rent data in third scenario has slope of zero, in first and second scenario is increasing, and trend line is steeper than others in second scenario.

Zorell (2008) has achieved same results for increasing macroeconomic variables volatility including production, consumption, investment, employment and wage after increasing share of imported intermediate goods. Also, Kleinert and Zorell (2010) have found that intermediate goods trade has an important role on macroeconomic volatility.

### 6. Conclusion

This research has analyzed the impacts of intermediate goods trade on Iran's macroeconomic variables in its bilateral trade relations with China.

This analysis has been done by modeling, solving and calibrating an international real business cycles (IRBC) model in period 1980-2009.

In order to analyzing intermediate goods trade on macroeconomics variables volatility, research model has been solved for different share of Iran's intermediate goods imports from China. An important factor in this context is elasticity of substitution between domestic and imported intermediate goods ( $\varepsilon$ ), so model has been solved for three scenarios with three amount of elasticity ( $\varepsilon$ ).

The results show that correlation coefficients between all components of aggregate demand except government expenditures (including consumption, investment and net exports) and output is positive. This indicates the presence of co-movement among these variables. Consumption co-movement is confirmed by all consumption theories. It means that there is a positive relation between total income and consumption. Investment co-movement is confirmed by theories such as acceleration theory and neoclassical theory of investment.

When elasticity of substitution between domestic and imported intermediate goods is low, increasing the share of Iran's imported intermediate goods from China increases volatility of Iran's macroeconomic variables. The value of increasing in volatility of Iran's macroeconomic variables depend on elasticity of substitution between domestic and imported intermediate goods, so that when the elasticity of substitution between domestic and imported intermediate goods is low, the increase in the share of Iran's imported intermediate goods from China lead to a further increase in the volatility of macroeconomic variables. These results indicate that intermediate goods trade is an important path through for transmission of shocks between main bilateral trade partners such as Iran and China.

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