Geoeconomics, Structural Change and Energy Use in Iran: A SAM-Based CGE Analysis with Some Geoeconomic and Geopolitical Considerations

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Abstract:

In this paper we present a structural CGE model for analyzing the energy situation in Iran and to draw some tentative economic policy and geopolitical conclusions. An important feature of the Iranian economy is its constant intensification of energy use per unit of labor. At the same time, Iran shows only slow improvement in energy intensity i.e. the use of energy per unit of output.

Our structural computable general equilibrium (CGE) model for Iran is based on 3- aggregate productive activities input-output structure- agriculture, energy and industry ---within a social accounting matrix for Iran. Four simulation exercises are conducted using this model---industrial investment demand increase, industrial wage increase, exchange rate depreciation, and government spending increase in industry. Our results show that structural change associated with raising industrial labor productivity and employment share are likely to result in simultaneous intensification of per worker energy-use and slight reduction of energy productivity in Iran. Industrial wage increase can create cost-push inflation and output contraction through a decrease in input use and increase in imports. Exchange rate devaluation is expansionary. Furthermore, when industrial output is insulated from foreign-domestic relative price effects, devaluation too becomes contractionary and wage increase results in a slight contraction in real GDP due to the "forced saving" effect. The model illustrates some of policy challenges Iran faces in its attempt to achieve "green growth" objective with high level of employment. To implement socially beneficial, capabilities-enhancing wage-led growth, Iran has to first successfully rebalance from its export-oriented growth path, which might require the government providing better social safety net for its citizens and increase their purchasing power across the board and generate further productive capacity in the Agricultural sector rather than generate inflation by increasing just the industrial sector wage. This would require a careful crafting of guaranteed income esp. for the Agricultural sector and government programs and incentives for increasing supply and productivity by enhancing both physical infrastructure, technical change and human capabilities.

Geopolitically, Iran’s current competition with Saudi Arabia and Turkey diverts valuable economic resources from development to political purposes. Satisfying legitimate security concerns rationally while reorienting the geopolitical concerns to a peaceful commercial relation to North and East of Iran including Japan will lead to much more stable and prosperous economic conditions than Iran experiences at present. However, provocations such as the June 2017 Qatar crisis provoked by Saudi Arabia and its “Islamic NATO” alliance makes geopolitical complexities more acute for Iran. Still Iran needs to avoid sanguinary conflicts and try to isolate Saudi Arabia politically. Geopolitical, 2023 moves for reconciliation via China and Russia seem to indicate a northward and eastward direction of energy and other related policies of both Iran and Saudi Arabia.

Key words: Energy , Geoeconomics, geopolitics, Iran, Saudi Arabia, Russia, China, CGE modeling

Structural Change and Energy Use in Iran: A SAM-Based CGE Analysis with Some Geo-economic and Geopolitical Considerations

I. Introduction

Despite the signing of the historical Joint Comprehensive Plan of Action (JCPOA) in July 2015 and the economic opportunities connected to it, the Iranian economy has grown at a slow pace over the past year. The minimal growth can be attributed to the fact that Iranian economic activity and government revenue remain dependent on oil revenues and therefore are highly unstable.[1] Iran now ranks among the world's largest energy producing and consuming countries, as well as a major CO_2 emitter. Its patterns of energy consumption and production are constantly affecting energy and environment related issues such as resource depletion, geopolitical conflicts, and climate change around the world. Furthermore, Iran will continue to be affected by global fluctuations in energy supply and demand, as well as the environmental consequences of production. The cost of environmental degradation for Iran reached 4.8 to 10 percent of its GDP already in 2002 (World Bank, 2005), which ironically was nearly equal to its real GDP growth rate that year.

In a country like Iran, economic growth to a large extent depends on industrialization, and the latter necessitates the increasing use of fossil fuel energy as an input for production. The intensification of energy use consequently leads to a series of negative externalities with the most obvious one being CO_2emission. Energy inputs in Iran are both imported and domestically produced; in the final analysis the energy production and consumption are determined by Iran's production structure. Given its significance for Iran, it is important to set the energy sector at the center of the stage in a macroeconomic model for conducting relevant policy analyses. It is also important to look at the geopolitical factors (Khan 2003, 2011). As Khan(2011) shows , the geopolitical factors are also important in analyzing domestic and foreign policies and assess whether these policies accelerate or retard the reaching of important developmental goals such as human development. Our technical modeling exercise is a preliminary and empirically reliable way based on the best available model and theory.[2]The geopolitical analysis offered here is preliminary and can be thought of only as a modest beginning that is rooted in most modern techniques of geo-economic

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[1] For a good historical and political economic analysis of oil producers like Iran, see Hossein Askari, *Collaborative Colonialism: The Political Economy of Oil in the Persian Gulf* (Palgrave MacMillian, September 2013)

[2] Implicit in this statement is a commitment to a version of scientific realism and causal depth. See Khan(2008).

modeling. A more detailed geopolitical analysis based on the best currently available economic modeling is the subject of a future paper.[3]

This paper presents a 3-sector social accounting matrix (SAM) based macroeconomic model of Iran in the tradition of structural computable general equilibrium (CGE) analysis with the energy sector explicitly modeled. Using this model, we conduct simulation for four scenarios: industry investment demand increase, industry wage increase, exchange rate depreciation, government spending increase in industry, and energy export contraction. These scenarios are either common policy instruments the Iranian government tends to adopt or scenarios that are likely to arise in the future as Iran continues to develop. These simulation exercises enable us to observe various effects of macroeconomic structural[4] and policy changes[5] on the patterns of energy production and consumption in Iran in a *ceteris paribus* environment.

Section 2 discusses some stylized facts about the pattern of energy use in Iran's development process. Section 3 presents the 3-sector model and its properties. Section 4 illustrates and discusses the simulation results of the aforementioned four scenarios. Section 5 concludes the paper with some policy implications.

II. Growth and Energy Use in Iran: Some Stylized Facts

A reasonable place to start is a simple stylized fact about the overall relationship between industrial growth and energy-use over time in Iran.

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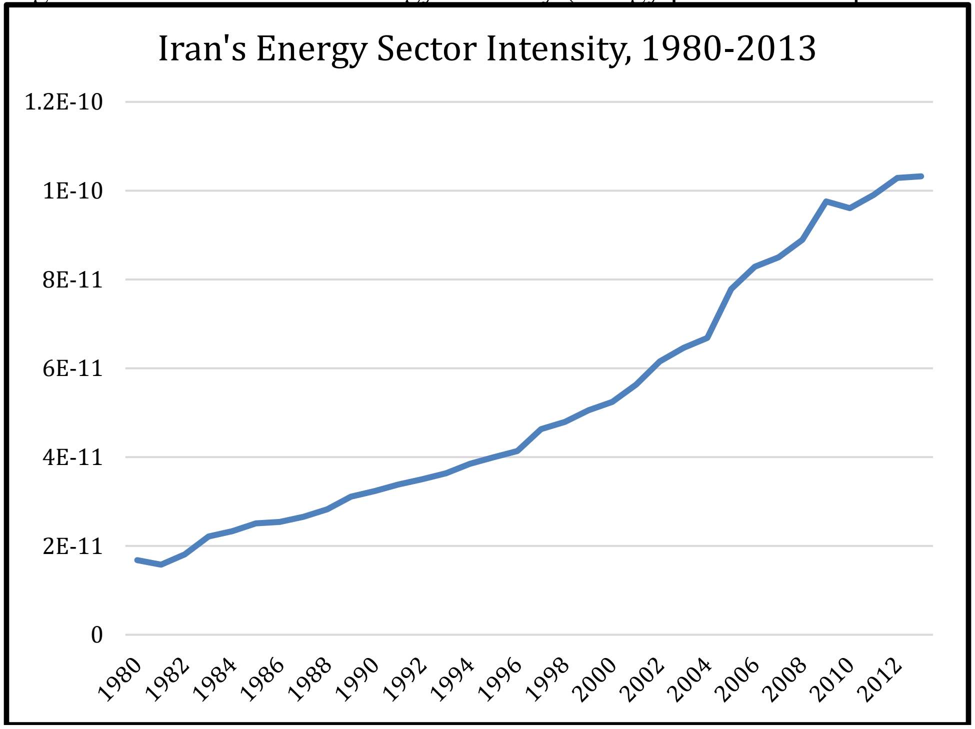
[3] For background to our geopolitical approach rooted in a critical version of Realism, see Amirahmadi(2013, 2014),Gause,III(2010), Buzan(1991),Buzan and Waever(2003), Lake and Morgan(1997), Abd al-Khaleq Abdulla(1998),Idris(2000),Adib-Moghaddam(2006), Klare(2004),Brzezinski(1983,2007), Bush and Scowcroft(1998), Milani(2013) among others.

[4] For example, labor transfer from the agricultural to the industrial sector

[5] For a recent example using a neoclassical modeling approach, see Gharibnavaz, Mohammad Reza; Waschik, Robert. *Food and Energy Subsidy Reforms in Iran: A General Equilibrium Analysis. Journal of Policy Modeling*, September-October 2015, v. 37, No. 5.

Figure 1: Iran’s Industrial Energy Intensity (energy per unit of output on the y-axis)



Sources: EIA, International Energy Statistics (2013), World Bank, World Development Indicators Database (2015)

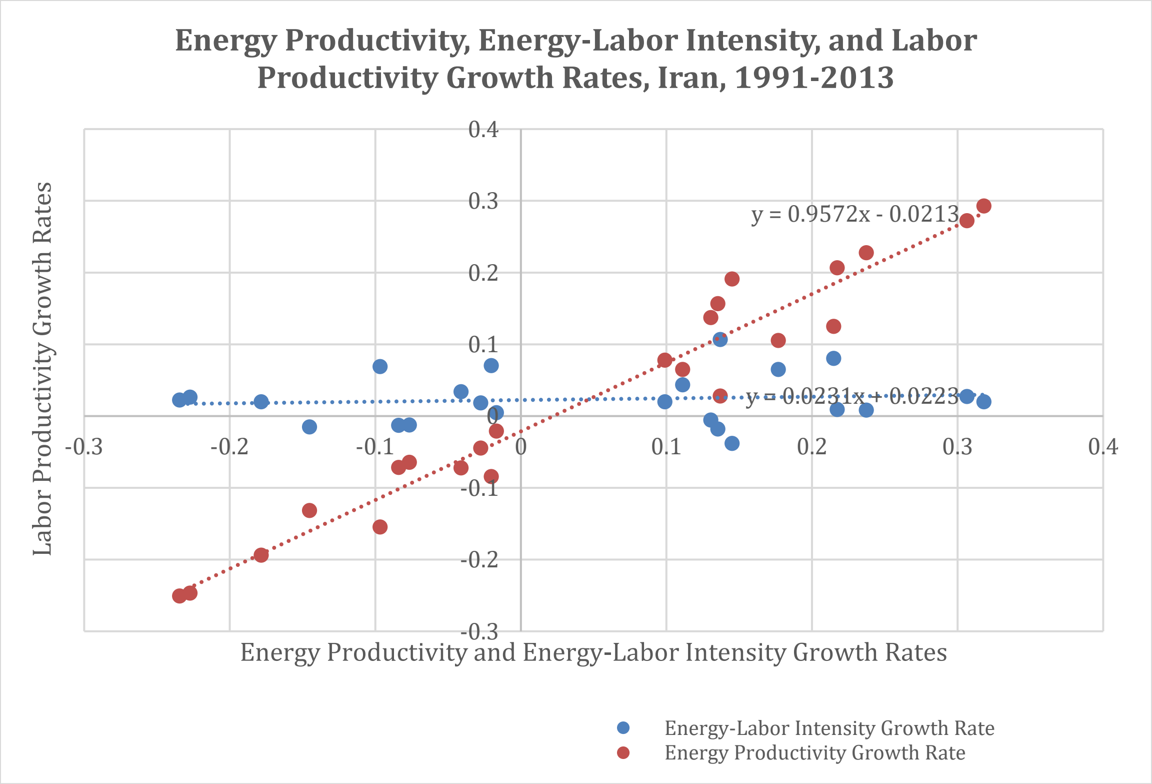
Figure 1 above is a plot of Iran's industrial real energy intensity over time. Industrial energy intensity here is measured as the ratio between total energy consumption and total real value-added in Iranian industrial sectors, and the quantity of "energy" here is measured in Quad btu. Essentially, this energy-output intensity (EOI) reveals how much energy is required for each unit of industrial outputs produced. At the first glance Iran's energy problem seems dire. Economic growth in Iran seems to be accompanied by the steady growth in the intensification of energy-use. At the same time, the inverse of energy intensity is the output-energy ratio, which is called *energy productivity*, hence the counterpart of figure 1 must be the steady decrease of Iranian energy productivity over time. Although Iran has gone through a period of decreasing energy-output intensity (increasing energy productivity) in the mid-2000s due to favorable supply and demand conditions, the unstable price of oil and other energy sources as well as the increase in the use of alternative energy has led to an upward trend for industrial energy output intensity in Iran.

However, the issue becomes even more complicated and the outlook less optimistic when we consider dynamical structural change. It has been empirically established that labor productivity growth is the major contributing factor to economic growth, especially for developing countries [Khan (1982a,b; 1983; 1997a,b; 2002; 2004; 2006a,b; 2013; Khan and Thorbecke 1988,1989; Khan and Sonko 1994; Taylor (1992)]. Moreover, Miroski (1989), Martinez-Alier and Schlupmann (1991) and later Ocampo, Taylor and Rada (2009) have pointed out that raising labor productivity is necessarily associated with the deepening of mechanization of production (more generally capital deepening), hence increasing the likelihood of increasing per worker energy use. Since labor productivity ξ_L is the output-labor ratio, it can be decomposed as output-energy ratio ξ_E (which is essentially energy productivity) times energy-labor ratio ε. ε is also called energy-labor intensity or ELI (Khan, 1982 a,b, 1983, 1985, 1997a,b,1998), as the ratio that gives the energy use per unit of labor. Thus, the growth rate of labor productivity must be the sum of energy productivity and energy-labor intensity growth rates:

$$\widehat{\xi_L} = \widehat{\xi_E} + \hat{\varepsilon} \qquad (1)$$

The hat in equation (1) represents the growth rate. Essentially, this decomposition tells us that labor productivity growth can be driven by the growth of energy-labor intensity (ε) as mentioned earlier, and/or the growth of energy-productivity (ξ_E).

Figure 2: Growth rates for Energy Productivity, Energy-Labor Intensity, and Labor Productivity

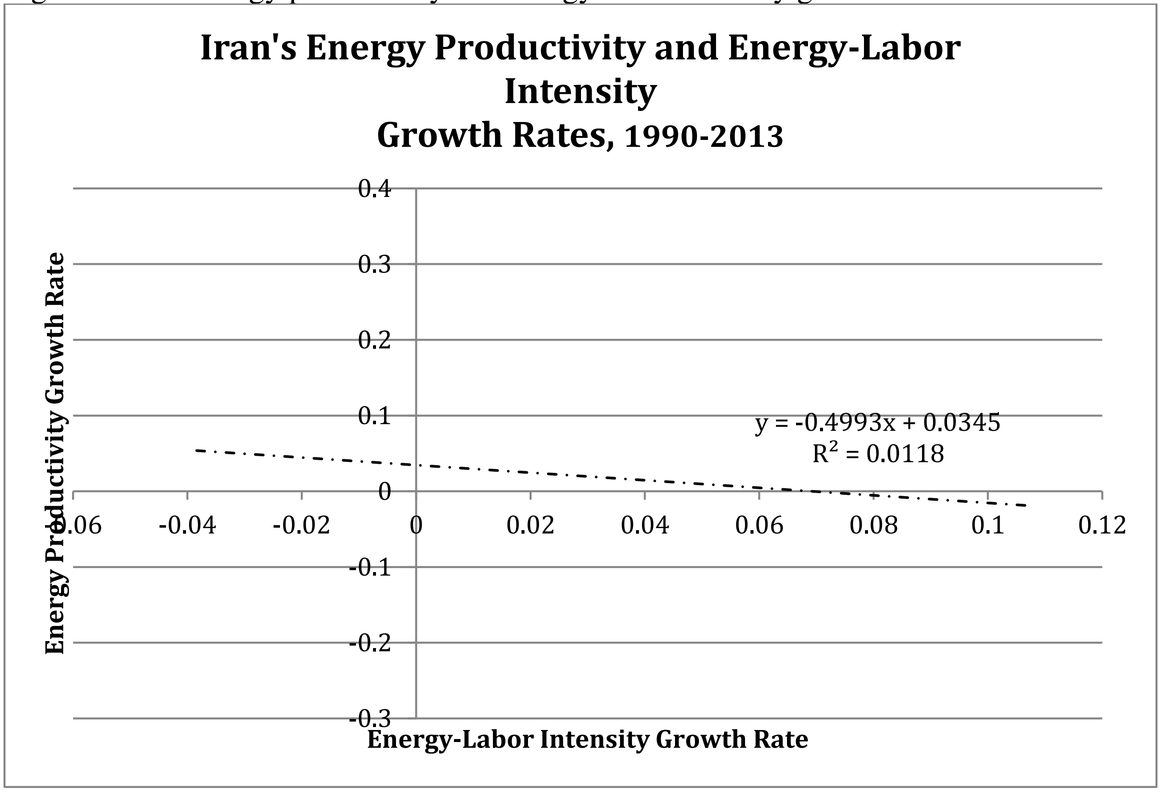


Sources: World Bank, World Development Indicators (2015), Energy Information Administration, International Energy Statistics

Figure 2 above is the scatter plot for Iran's energy productivity and energy-labor intensity growth rates on the horizontal axis against its labor productivity growth rates on the vertical axis. It is clear that, for the case of Iran, labor productivity growth tends to be driven by the growth of energy productivity rather than energy-labor intensity overtime with the linear fitted line for $\widehat{\xi_L}$ and $\hat{\varepsilon}$ exhibiting steeper slope and higher R^2 relative to $\widehat{\xi_E}$. Thus, despite the slight increase in energy-labor intensity as implied in figure 1, the effect of increasing or decreasing energy productivity has been historically dominating Iran's developmental process from the perspective of labor productivity growth.

The issue becomes even clearer as we look at the relationship between the growth rate of energy productivity and energy-labor intensity in figure 3 below.

Figure 3: Iran Energy productivity and energy-labor intensity growth rates



Sources: IEA, International Energy Statistics; World Bank World Development Indicators Database; Authors' own calculations

The scatter plot of Iran's energy-labor intensity growth rates against energy productivity growth rates in figure 3 establishes a negative, albeit weak, linear relationship between those two variables with slope coefficient being 0.49. It implies that the increase of energy-labor intensity growth rate in Iran tends to be associated with a very slight decrease of energy productivity growth rate, which indicates the possible tradeoff between those two variables that determine labor productivity growth in equation (1). Economic growth relies on the growth of labor productivity, and the latter depends on energy productivity growth according to figure (2), and the increase of energy productivity is weakly and negatively associated with the decline of energy-labor intensity according to figure 3, which can be optimistic from the perspective of climate change. Unfortunately, due to the existence of energy surplus, Iran has been experiencing steady decline of energy productivity which is evident from figure 1, thus, historically, and certainly today, Iran faces difficulties in facilitating significant economic growth.

One way to formally model this is to use an augmented Kaldor-Verdoorn equation, which lets a country's labor productivity growth depend on its industrial sector as well as the industrial sector's energy-use per worker. (Von Arnim and Rada, 2011) The equation is written as:

$$\xi_L = \alpha Y^{\beta} \varepsilon^{\gamma} \qquad (2)$$

In equation (2), Y is the industrial sector's value-added, ε is the industrial sector's energy-use per worker, i.e. the industrial sector's ELI, β is the well-known Kaldor-Verdoorn elasticity, and γ is the labor productivity-energy-labor intensity elasticity. The specification of equation (2) is particularly relevant for the case of Iran given the aforementioned stylized facts. Although, in principle, the change of energy productivity can also affect labor productivity according to equation (1), this effect is dominated by the effect of increasing energy intensity; hence equation (2) does not include energy productivity ξ_E as an argument. Equation (2) plays an important role in the macroeconomic model to be introduced in the next section.

III. The Social Accounting Matrix (SAM)

The model features a 3-sector economy of Iran with sectors 1-3 being agriculture, energy and industry, respectively. Agricultural sector is assumed to be supply-constrained by its productive capacity but energy and industrial sectors are constrained by aggregate demand. The model is based on a 3-sector 2-household groups classification in the social accounting matrix (SAM) of Iran illustrated in table 1. The SAM is a snapshot[6] of Iran's macro-economy at a point in time with rows summarizing incomes and columns summarizing expenditures. Row and column sums are always equal, consistent with a single-entry bookkeeping rule.

-Table 1 about here-

-Table 2 about here-

Under columns 1, 2, and 3: rows 1-3 are the inter-sectoral intermediate flows amongst those three sectors; rows 5-6 are wage and profit incomes generated by the three sectors; row 6 and 7 are production tax and imported intermediate goods paid from each sector to government and rest of the world, respectively; and finally row 9 is flow of funds account, which is empty on the production side. Let's now turn to the expenditure side of each sector. To the right-hand-side of the first three rows, the first three columns are indeed the inter-sectoral intermediate flows, columns 4-6 are the consumptions of each sector's output by agriculture households, capitalist households[7], and wage-earner households. Rows 7-9 are rest of the aggregate demand for each sector's output, namely,

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[6] For a complete description of how SAM functions as a snapshot and the interconnections among the various accounts, see Khan and Thorbecke (1988, 1989), James and Khan(1993,1997) and Khan(1989, 1997).

[7] Noticing here that the SAM is constructed in such a way that capitalist households do not consume anything, which conforms the classical theory of saving.

government spending, net exports and investment demand (capital formation). Finally, the first three elements in the last column and row are each sector's total output.

The SAM above contains an input-output table, and this input-output table is the sub-matrix given by all the columns associated with rows 1-3 and all the rows associated with columns 1-3. What remains to be explained is the sub-matrix that consists of columns 4-8 and rows 4-9 of the SAM. [8]All the entries in this sub-matrix are payment flows amongst various households (agriculture, capitalist, and wage-earner) and institutions (government, foreign, and flow of fund). For the purpose of clearer illustration, let us turn to table 2, which is the symbolic counterpart of the numerical SAM in figure 4. U_{bw}, U_{gw}, and U_{fw} are the transfers from capitalist household (business), government, and foreigners to wage income. T_A, T_b, and T_w are tax revenues that flow from agriculture, capitalist and wage earner households to the government. U_{Af}, U_{bf}, U_{wf}, and U_{kf} are transfers from households and investment accounts to foreign account. S_A, S_B, S_w, and F are households and government savings that go in and out (as investment demand) of the flow of funds account. Finally, Y_A, Y_B, Y_w, Y_g and Y_f are total income (= expenditure) for all households and institutions. In our model, transfers between households, government and rest of the world denoted by $U_{i,j}$ are treated exogenously in nominal terms; however, saving and tax are proportional to household income at given tax and saving rates.

IV. Formal Structural CGE Model Setup

Let us start with output determination.

$$X_i = \sum_{j=1}^{3} a_{i,j}X_j + C_i^A + C_i^W + I_i + G_i + E_i \qquad (3)$$

In equation (3), $a_{i,j}$ is the input-output technical coefficient, $C_i^A$and $C_i^W$are agriculture and wage-earner household consumptions, respectively. Following conventional notations, I, G and E are investment, government spending and exports. Essentially, this equation simply states that output in each sector equals to the sum of intermediate inputs, consumption, investment and exports. Furthermore, in this model, we let the output of energy and industrial sectors to be determined by aggregate demand, but agricultural sector's output is fixed exogenously at $\overline{X_1}$. The limiting factor could be the productive capacity in agriculture sector such as the amount of fertile land or capital stock.

Assuming the input-output coefficients are fixed during a particular time period, the value-added for each sector is determined by the fixed value-added coefficient v, which is given by the next equation:

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[8] Khan(1989) gives an explanation of how to build a SAM step-by-step starting with an input-output table in the context of an input-output table and SAM for South Africa. Khan(1997a, 1983, 1982a,b) describes how to disaggregate and link energy sectors to the rest of the economy. To link distribution and production in nonlinear SAM-based models, see Khan(2002a,b,c) and Khan(2004).

$$v_i = \frac{V_i}{X_i} = 1 - \sum_{j=1}^{3} a_{i,j} - t_i - m_i\epsilon \quad (4)$$

where V is total value-added, t is the indirect tax rate, m is the propensity to import with given total output (that is M/X), and ϵ is the exchange ratio that converts import value into domestic currency. It is important to note that the value-added coefficient v here is not fixed; instead it varies with import propensity and real exchange rate.

Government spending and investment are assumed to be fixed exogenously during a particular period following the Keynesian tradition. Exports for agriculture and industry sectors, and imports are modeled after the standard textbook version of trade functions:

$$M_i = \phi_i^0 \rho_i^{-\phi_i} X_i = \phi_i^0 (\frac{\epsilon P_i^*}{P_i})^{-\phi_i} X_i \quad (5)$$

$$E_i = \chi_i^0 \rho_i^{\chi_i} X_i^f = \chi_i^0 (\frac{\epsilon P_i^*}{P_i})^{\chi_i} X_i^f, i = 1,3 \quad (6)$$

In equations (5) and (6), ϕ_i and χ_i are price-elasticity of imports and exports, respectively. ρ is the relative price ratio between foreign to domestic price, P^* is the foreign price, and X_i^f is the world import demand for all countries' sector i's outputs for Iran's product. Thus, the product of the first two items on the right hand side of equation (6) should give us the share of world demand for sector i's outputs that goes to Iran. We assume that energy exports are given exogenously by external demand. This leaves the possibility for conducting experiment with short-run energy export contraction (or energy export sanction) shocks later.

Capitalist household's consumption is assumed to be zero in this model, following the classical tradition[9]. Consumption of agricultural and wage-earning household is characterized by the linear expenditure system below:

$$C_1 = (c_2 + c_3)C_F + \frac{(1 - c_2 - c_3)Y_d}{P} \quad (7)$$

$$C_2 = c_2 \frac{Y_d - P_1 C_F}{P_2} \quad (8)$$

$$C_3 = c_3 \frac{Y_d - P_1 C_F}{P_3} \quad (9)$$

Where the c_2 and c_3 are the consumption shares for the respective sectors, C_F is the floor level of consumption, which we assume are from the consumption of agriculture goods

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[9] This assumption is also reflected in the SAMs in tables 1 and 2 where capitalist household (K-house) consumption accounts are all zero.

such as food. Y_d is the household disposable income, which is determined by following the accounting identity from the SAM.

$$Y_d = \left(\sum_{j=1}^{3} L_j w_j + U \right) (1 - s - \tau) \quad (10)$$

Equation (10) states: each household's disposable income equals to their wage income (which equals to employment (L) times wage (w)) plus all the income transfers (U) from government, firms, and foreigners, and minus saving and income tax. Thus s and τ are saving and tax rates from household income inflows.

Let L be the total labor force of the economy, employment in agricultural sector simply equals the residual of the labor force that is not absorbed by the energy and industrial sectors, thus: $L_1 = L - L_2 - L_3$. However, energy and industrial sectors' employment equals the ratio of total value-added to labor productivity in each sector, that is:

$$L_i = \frac{V_i}{\xi_i}, \qquad i = 2,3 \quad (11)$$

In these sectors, labor productivity (ξ) increase will displace workers via labor-saving technical change, but aggregate demand increase will increase value-added (V) which generates employment. Thus, in this model, when additional employment is generated in energy or industrial sector, there is "labor transfer" from agriculture to those two sectors following the Kaldor-Verdoorn law of growth.[10] However, when there is employment contraction, labor gets transferred back to the agricultural sector (Khan, 2006). Some of these transferred workers might be unemployed; others would be underemployed, or find informal employment.

Labor productivity is exogenously fixed for the energy sector. However, for the industrial sector, labor productivity is endogenously determined by the augmented Kaldor-Verdoorn equation motivated by equation (2) in the beginning of this paper. In the context of the current model, we can rewrite the equation in following way:

$$\xi_{L,3} = \alpha V_3^{\beta} (\frac{a_{2,3} X_3}{L_3})^{\gamma} \quad (12)$$

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[10] Notice the subtle difference between this model and models of dualism. In the latter, there is surplus labor in the traditional-agriculture to begin with and even in Harris-Todaro model the movement is in response to perceived job opportunities that may not necessarily correspond to an actual increase in labor demand in the non-agricultural sectors. For a historically motivated analysis of various dualistic models see Khan(1997, ch. 2) and for a model with more sectors and households that modifies the Harris-Todaro model, see Khan(2006).

In this new expression, $a_{2,3}$ is the input-output coefficient for the flow of energy sector's outputs to industrial sector as intermediate inputs. $(a_{2,3}X_3)/L_3$ is therefore industrial sector's energy-labor intensity measured as the ratio between energy use per unit of labor. Labor productivity in agricultural sector simply equals the ratio of value-added to employment.

$$\xi_{L,1} = \frac{V_1}{L_1} \qquad (13)$$

The determination of agricultural labor productivity essentially follows Kaldor's third law of growth (Thirwall, 1983). Since agricultural output is exogenously fixed by its productive capacity in the model, agricultural employment expansion will decrease its labor productivity, and vice versa with the labor transference from agricultural to other sectors, therefore decreasing returns to labor is a built-in feature for agricultural sector. In the industrial sector however, there will be increasing returns to scale[11] because labor productivity is positively determined by industrial value-added according to equation (12).

Let us now turn to prices and the distribution of income. Agricultural price fluctuates to clear the excess aggregate demand or supply in the market. In other words, it is an endogenous variable in the macroeconomic system as a whole. Energy and agricultural prices are cost-determined by the weighted average of the cost of each component in its unit output, namely, intermediate inputs, value-added, and imports.

$$P_2 = \sum_{j=1, j\neq 2}^{3} \frac{a_{j,2}}{1 - t_2 - a_{2,2}} P_j + \frac{v_2}{1 - t_2 - a_{2,2}} P_{v,2} + \frac{m_2}{1 - t_2 - a_{2,2}} \epsilon P_2^* \qquad (14)$$

$$P_3 = \sum_{j=1, j\neq 2}^{3} \frac{a_{j,3}}{1 - t_3 - a_{3,3}} P_j + \frac{v_3}{1 - t_3 - a_{3,3}} P_{v,3} + \frac{m_3}{1 - t_3 - a_{3,3}} \epsilon P_3^* \qquad (15)$$

P_v is the price of value-added, which we will discuss later. It is clear from the equations above that the "weights" that are applied to the cost of each component in the unit output are the relative contribution of each component to a unit of final output.

For the value-added prices, conventionally, they are determined by the neoclassical marginal productivity principle. However, this paper follows the structuralist tradition and computes value-added prices for energy and industrial sectors by the markup-pricing rule. Let us first look at agriculture sector, since its price functions to

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[11] It can be demonstrated in structural models of economies modeled either in Banach or Vector Lattice that increasing returns can produce multiple equilibriums. (Khan,1998, 2002a,b,c) Given the base year social accounting matrix, we identify one equilibrium among many.

clear the market, its value-added price ($P_{v,1}$) simply clears its cost decomposition in following equation:

$$P_{v,1} = \frac{1 - t_1 - a_{1,1}}{v_1} P_1 - \sum_{j=2}^{3} \left(\frac{a_{j,1}}{v_1} P_j \right) \qquad (16)$$

For the energy and industrial sectors, their value-added prices follow the markup pricing equation below:

$$P_{v,i} = \frac{L_i w_i}{V_i \omega_i} \qquad (17)$$

Where ω is the wage share of value-added, and $1 - \omega$ is therefore the profit share. The price of value-added (P_v) is considered as the result of wage bill (Lw) plus the markup at a rate of τ, which happens to be $1/\omega$.

Finally, energy and industry sectors' wages are exogenously given; however, agriculture wage is determined by the ratio between wage bill (income) and employment, that is:

$$w_1 = \frac{P_{v,1} \omega_1 V_1}{L_1} = \omega_1 P_{v,1} \xi_1 \qquad (18)$$

Essentially the second half of equation (18) tells us that agriculture wage is proportional to the agriculture labor productivity ξ_1.

Overall, the model features 38 equations with 38 endogenous variables and 60 exogenous variables. With correct calibrations, the solution of the system should return to us a set of values for those endogenous variables that exactly matches the values in the SAM. Furthermore, simulation exercises can be conducted by solving the system after altering some of those exogenous variables. However, the variables of interest here are those directly related to possible policy measures.

V. Calibrations

Most of the parameters in this model are calibrated based on the SAM accounting relationships as exhibited in tables 1 and 2. Sectoral employment data is imputed from the Iranian SAM and World Bank’s World Development Indictors (WDI) in following way. The Iranian SAM reports sectorial compensation to employees, and the WDI reports the number of employees in agricultural sector as well as the rest of the economy. Dividing the sum of non-agricultural compensation to employees by the sum of non-agricultural employees, we obtain the average non-agriculture wage. Then, dividing compensation to employees in industrial and energy sectors by the average non-agriculture wage will give us a rough estimate of employment in each of these sectors. For the consumption functions, we assume that the floor level of consumption for wage earner and agriculture households are 20% and 60% of their total consumption, respectively. All floor-level consumptions are consumptions of agricultural outputs. The consumption shares (c_i) are obtained by solving for the linear expenditure system independently. For the augmented Kaldor-Verdoorn equation, the Kaldor-Verdoorn elasticity is assumed to be 0.4, and the energy-intensity elasticity is assumed to be 0.3, following Von Arnim and Rada (2011). Finally, trade elasticity for agricultural, energy and industrial sectors are assumed to be 0.1, 0.2, and 0.75, respectively.

VI. Simulation Results

The correctly calibrated model is then used to conduct simulations for four relevant scenarios, namely, 10% increase in industry investment demand, 10% increase in industry wage, 10% exchange rate depreciation, 10% increase government spending in the industrial sector, and 10% contraction of energy exports. The simulation results are shown in table 1 below.

Table 1. Baseline Simulation Results

	10% Δ $I_{ind.}$	10% Δ $w_{ind.}$	10% Δ ϵ	10% Δ $G_{Ind.}$	-10% Δ E_2
Inflation	0.083	6.235	0.07	-0.014	-0.056
Growth	4.372	-2.73	0.07	1.393	-2.025
Δ S-I (to GDP)	-2.079	-1.188	0.021	0.392	-0.822
Δ T-G (to GDP)	0.373	-0.359	0.027	-0.943	-0.334
Δ X-M (to GDP)	-0.885	-0.48	0.069	-0.288	-1.76
Δ Ind. L Share	2.228	-1.777	-0.062	0.712	-0.157
Δ Ind. X Share	-0.284	0.863	-0.001	-0.077	0.837
Δ Ind. ξL	2.852	-1.49	0.284	0.909	-0.203
Δ Ind. ξE	0.297	-1.831	-0.732	0.101	-0.017
Δ Ind. E/L	2.547	0.347	1.023	0.807	-0.186
Δ Agr. ξL	13.641	-8.547	-1.621	3.98	-3.265
Δ Agr. ξE	-0.19	-0.012	-1.376	-0.058	0.021
Δ Agr. E/L	13.858	-8.536	-0.249	4.041	-3.286

With a 10% increase in industrial investment (which could either be stimulated by government or the result of further industrialization and structural change in Iran---a mixture of accelerator effects and other factors), the overall economy-wide effect is expansionary with slight inflation (measured by Fisher's index[12]) and rapid GDP growth, and these effects are in part built in the Keynesian demand-driven feature of this model. The private balance ($S - I$) falls, which might trigger other exogenous changes such as interest rate hike to bring saving and investment into balance in the longer run. Public balance ($T - G$) improves slightly due to the increased tax revenue as the result of economic growth. External balance ($X - M$) declines because of the increase of domestic price relative to foreign price due to the expansion. The extent of the decline depends on export and import elasticities. Structural change triggers labor transfer from agricultural sector to industrial sector as suggested by Kaldor-Verdoorn, hence leading to an increase in the industry employment share. It might seem surprising that the industrial sector's output share (Ind. X share) out of total output declines instead of increasing. But a closer

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[12] Fisher's index is the geometric mean of the Laspeyres and Passche price indices.

examination reveals that it is the result of relative price-effect. Since the industrial output share is measured as: $P_3X_3/(P_1X_1 + P_2X_2 + P_3X_3)$, while the increase in industrial investment indeed increases the real term X_3, such structural change also triggers high agriculture price (P_1) inflation due to the supply constraint in the agricultural sector; thus the industrial output share declines despite of the increase in industry's real output[13]. Industrial labor productivity (Ind. ξ_L) increases following the Kaldor-Verdoorn effect. Interestingly, in this model, both industrial energy productivity (Ind. ξ_E) and energy-labor intensity ELI (E/L) increase (in fact, the earlier grows much faster than the latter), which is quite different from the case of China (Jiang and Khan, 2016) and Egypt (Von Arnim and Rada, 2011), where the result of labor productivity increase due to investment-led expansion is always associated with the decline of energy productivity. Agricultural labor productivity (Agr. ξ_E) increases because labor outflow combined with fixed agricultural output results in higher value-added to labor ratio. Finally the increase of agricultural productivity results rapid increase of ELI and slight decline of ξ_E in agricultural sector.

Industrialization and structural change are always associated with money wage increase. Holding everything else constant, a 10% wage increase in Iran results in contractionary effects on the economy with declining real GDP and cost-push inflation. These are expected results given the structure of the model. However, the extent of the contractionary effect of wage increase depends on the value of trade elasticities. With high trade elasticities, wage increase and cost-push inflation is likely to generate severe deterioration of trade balance; hence the economy severely contracts due to its demand constraint. Private and public balances deteriorate due to the reduction of real income, and external balance falls because of higher domestic price. Industrial employment share declines indicating unemployment or underemployment in that sector, but as discussed before, the unemployed may find informal employment in the agriculture sector. [14] The fall in overall aggregate demand to some extent releases the agricultural constraint, and the result is the rapid fall of agriculture price (P_1). The relative price effect is then set in motion which increases the nominal industry output share while the real industry output actually declines. Labor productivity falls in industrial sector due to the contraction and it also falls in agriculture sector because of the "reverse labor transfer". Industrial wage increase also results simultaneous *decline* of energy productivity, real GDP, and *increase* of energy-labor intensity in industrial sector. Agricultural energy use shows the pattern of increasing both energy productivity and energy-labor intensity.

Since the Iranian economy heavily depends on energy exports, but in this model, energy exports are given exogenously, a 10% devaluation results very small export-led expansion because rest of the Iranian economy has very low trade dependency. Since the simulation results show very small economy-wide effects, discussions of these results are omitted here.

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[13] In fact, the strength of the inflationary response in agriculture, to a large extent, depends on the size of the floor level of consumption in the linear expenditure system of the model. High consumption floor limits household's ability to shift away from foodstuff during a positive demand shock, henceforth the high agriculture inflation. It is a feature of structuralist CGE models.

[14] This is similar to the dual-dual model mechanism verified for Africa by Stifel and Thorbecke and for South Asia by Khan.

The results of 10% government spending increase are similar to the 10% industrial investment shock discussed earlier with a few exceptions. The overall price level is stable with very small deflation. As the result of small deflation, we see slight improvement of external balance. The private balance improves due to the windfall income gains from government spending-led expansion, and public balance declines as the direct result of autonomous government spending increase.

Finally, with 10% energy exports contraction due to some sort of sanctions, we observe the economy-wide contraction. The real GDP falls by 2% along with slight deflation. Private, public and external balances deteriorate. There is a slight decline of industrial labor productivity accompanied with slight decline of both industrial energy productivity and energy-labor intensity. The decline of agricultural labor productively is relatively large (3.3%), and it is accompanied with the slight increase of agricultural energy productivity and rapid decline of agricultural energy-labor intensity.

IV. Conclusions: Geopolitical, Geoeconomic and Policy Implications

In this paper we examine the impact of Iran's structural change on a number of important variables -- most importantly on the use of energy in relation to both output and labor. Methodologically, we follow the general approach of structuralist economic theory. In order to examine the key issues for Iran, we construct a structuralist computable general equilibrium (SCGE) model based on a 3- productive activities -- agriculture, energy and industry – captured consistently in relation to factorial and household incomes and expenditure, transfers, capital account and external trade etc. by the social accounting matrix for Iran. Four simulation exercises are conducted using this model--- industrial investment demand increase, industrial wage increase, exchange rate depreciation, and government spending increase in industry. Our results show that structural change associated with raising industrial labor productivity and employment share are likely to result in simultaneous intensification of energy-use and slight reduction of energy productivity in Iran. Industrial wage increase creates cost-push inflation and output contraction caused by a decrease in exports, and devaluation is expansionary. Furthermore, when industrial output is insulated from foreign-domestic relative price effects, devaluation becomes contractionary and wage increase results in a slight contraction in real GDP due to the "forced saving" effect. Essentially our model illustrates some of the challenges Iran faces in its attempt to achieve more significant economic growth in the face of unstable global energy supply and demand.

From a policy perspective, we can conclude that the current growth strategy can be both ecologically and socially burdensome. Natural capital is being depleted while the quality of life for the great majority suffers. Furthermore, the already existing inequalities can worsen if a green growth strategy is not combined with a distribution-sensitive approach. Thus policy moves for wage-led growth and energy productivity and agricultural productivity increase need to be pursued in tandem. To have wage-led growth, Iran has to first successfully rebalance from its export-oriented growth path, which might require the government providing better social safety net for its citizens and increase their purchasing power across the board and generate productive capacity in the Agricultural sector rather than generate inflation by increasing just the industrial sector wage. This would require a careful crafting of guaranteed income esp. for the Agricultural sector and government programs and incentives for increasing supply and productivity by enhancing both physical infrastructure, technical change and human capabilities.

Secondly, to prevent the effect of forced-saving caused by agriculture constraint, the government needs to ensure that Iran's agricultural sector is not lagging behind as the country goes through structural change. Furthermore, it is important to emphasize that moving towards green energy and away from fossil fuels requires explicit directives in the state sector and moral suasion plus price and other incentives for the private sector. (Khan, 2010)

Consistent with the above point, Iranian geo-economics and geopolitics for further oil and gas acquisition needs to be changed. This is in line with the optimal development trajectory that even a country like China which enjoys relatively more geopolitical and geo-economic advantages must follow (Khan, 2010; Christoffersen, 1998) in the direction of moving away from fossil fuel use and more regional cooperation. Some steps have already been taken in moving in the direction of green growth with increased regional cooperation. Iran's involvement in the Arab world and its rivalry with Saudi Arabia and Turkey make little sense from a sober geo-economic and geopolitical perspective. Rather a shift to the north and to the east with closer cooperation with central Asia, India, China, Russia and Japan make more sense in the long run. To pursue this shift which to some extent has already taken place willy-nilly, Iranian poicy makers need to disengage from Syria, Lebanon and Yemen without putting Iranian people's national interest and security in jeopardy. This requires bold and imaginative leadership that the current regime may not be able to provide. We do not pursue this point further here since in addition to considerations of the international relations theory of realism, a close analysis of the internal politics of Iran and its socio-economic bases is necessary and is beyond the scope of this paper.

We just wish to make one final point acknowledging the complexities of geopolitics in the middle east and the difficulties Iran faces in the region. As illustrated in June 2017by the Qatar crisis, Iran is surrounded by hostile reactionary middle eastern powers. Provocations such as the June 2017 Qatar crisis provoked by Saudi Arabia and its “Islamic NATO” alliance makes geopolitical complexities more acute for Iran. Still Iran needs to avoid sanguinary conflicts and try to isolate Saudi Arabia politically.

If the above economic policy directions are to be formulated in a detailed manner for implementation throughout the economy consistently, then issues of growth, energy use and distribution need to be integrated in a more disaggregated model that can be used for detailed macro, meso and micro policies. (Khan, 2010, 1997b; Khan and Sonko, 1994). Furthermore, linking the financial sector to the real sectors including energy sectors in a disaggregated structural CGE model (Khan, 2003, 2004) also looms as an urgent task for the policy-relevant research agenda.

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Table 1: Iran’s Numerical SAM 2011

	Agriculture(1)	Energy(2)	Industry(3)	A-Household(4)	K-Household(5)	W-Household(6)	Government (G)(7)	RoW (F)(8)	Inv (I)(9)	Totals (H)(10)
Agriculture(1)	155 805 687	2 105 994	295 189 731	78 650 586	0	199 273 116	6 933 807	67 087 976	138 060 488	943 107 386
Energy(2)	6 111 863	41 710 970	358 928 086	19 646 671	0	90 870 343	0	1 112 717 907	-63 965 390	1 566 020 450
Industry (3)	198 421 907	55 490 384	2 630 958 006	506 497 839	0	2 064 457 039	6.74788×10^8	727 017 363	2 128 847 197	8 986 477 407
Wage (W)(4)	447 466 747	193 772 546	2 162 474 029	0	695 770 735	0	315 426 345	8 417 971	0	3 823 328 374
Profit (π)(5)	60 752 824	1 259 046 543	2 085 758 688	1 194 959	0	2 761 043	0	19 852 182	0	3 429 366 239
Government (G) (6)	-1 808 036	10 664 649	120 366 951	697 155	857 961 871	2 748 967	0	0	0	990 631 558
RoW (F)(7)	76 356 394	3 229 364	1 332 801 916	1 586 628	13 712 366	10 614 167	0	0	496 792 564	1 935 093 400
Inv (I)(8)	0	0	0	168 994 504	1 861 921 267	675 335 354	-6 516 265	0	0	2 699 734 860
Totals (H)(9)	943 107 386	1 566 020 450	8 986 477 407	777 268 345	3 429 366 239	3 046 060 029	990 631 558	1 935 093 400	2 699 734 860	0

Table 2: Iran’s Algebraic (Symbolic) SAM

	Agriculture(1)	Energy(2)	Industry(3)	A-Household(4)	K-Household(5)	W-Household(6)	Government (G)(7)	RoW (F)(8)	Inv (I)(9)	Totals (H)(10)
Agriculture(1)	$P_1 X_1 a_{1,1}$	$P_2 X_2 a_{1,2}$	$P_3 X_3 a_{1,3}$	$C_A P_1$		$C_w P_1$	$G_1 P_1$	$P_1 E_1$	$P_1 I_1$	$P_1 X_1$
Energy(2)	$P_1 X_1 a_{2,1}$	$P_2 X_2 a_{2,2}$	$P_3 X_3 a_{2,3}$	$C_A P_2$		$C_w P_2$		$P_2 E_2$	$P_2 I_2$	$P_2 X_2$
Industry (3)	$P_1 X_1 a_{3,1}$	$P_2 X_2 a_{3,2}$	$P_3 X_3 a_{3,3}$	$C_A P_3$		$C_w P_3$	$G_3 P_3$	$P_3 E_3$	$P_3 I_3$	$P_3 X_3$
Wage (W)(4)	$L_1 w_1$	$L_2 w_2$	$L_3 w_3$		U_{bw}		U_{gw}	U_{fw}		Y_w
Profit (π)(5)	$K_1 r_1$	$K_2 r_2$	$K_3 r_3$	U_{Ab}		U_{wb}		U_{fb}		Y_π
Government (G) (6)	T_1	T_2	T_3	T_A	T_b	T_w				Y_g
RoW (F)(7)	$\in M_1 P_{f1}$	$\in M_2 P_{f2}$	$\in M_3 P_{f3}$	U_{Af}	U_{bf}	U_{wf}			U_{kf}	Y_f
Inv (I)(8)				S_A	S_b	S_w	F		$-U_{kg} - P_1 I_1 - P_2 I_2 - P_3 I_3$	0
Totals (H)(9)	$P_1 X_1$	$P_2 X_2$	$P_3 X_3$	Y_A	Y_b	Y_w	Y_g	Y_f	0	