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Abstract

We examine the macroeconomic and household welfare consequences of oil sanctions in Iran. We use social accounting matrix (SAM) and develop a computable general equilibrium (CGE) model to simulate selected scenarios in which the exportation of oil from Iran to the rest of the world is banned. Our main results show that higher income households are losing more significantly under oil sanctions. Total imports, exports, private consumption, and GDP fall in response to oil sanctions. Interesting is the increase of net indirect taxes at the time of oil revenues fall. Real exchange rate appreciates in the oil sanction crisis. In addition, labor income increases while the capital income falls in response to oil sanctions in Iran. These simulations are in line with reality of the Iranian economy in post-oil sanction period.

Keywords: oil, sanctions, CGE model, social accounting matrix, Iran

1. Introduction

We investigate the economic and welfare consequences of oil export sanctions[1] on the Iranian economy. The idea of this paper is motivated by the U.S encouragement of an international pressure on Iran to change the political behavior of the government. The research aims to answer the following questions: a) what will be the effects of oil sanctions on the Iranian macro-economic variables? and b) what will be the effects of oil sanctions on the Iranian households' welfare? These are key questions which need to be addressed in a quantitative framework. After all, senders of sanctions want to see if the imposed restrictions have had any significant economic impact or not.

Economic pressures following sanctions can be a key driver behind changing in political behavior of target state. Hufbauer et al. (2007) show that the success to failure ratio of sanctions in changing political behavior of target country reduces significantly in the long run. The success to failure ratio is 2.4 during the first year after sanction shock, reaching to 2.3 in 2 years after sanction and staying at 0.6 beyond 2 years (Dizaji and van Bergeijk, 2013).[2] The reason for falling success ratio of sanction is adjusting process of targeted economy to new equilibrium. Indeed, an economy under sanction tries to offset the reducing in its revenues (e.g., oil revenues in Iran) by increasing the tax efforts or reforming subsidies. If such painful policies can be managed well and do not lead to political instability, then in long run the sanctions lose their effectiveness.

The recent sanctions on Iran began since 2006 and presidency of Mr. Ahmadinejad. Between 2006 and 2010, the sanctions mostly aim to ban supply of heavy weapons and technologies

[1] We follow definition of Askari et al. (2003, p.14) in defining the sanctions: "…economic sanctions are *coercive measures imposed by one country or coalition of countries, against another country, its government or individual entities therein, to bring about a change in behavior or policies*".

[2] For a historical review of economic sanctions see Daoudi and Dajani (1983) and Hufbauer et al. (2007).

which could be used also in the Iranian military and nuclear projects. They were not targeting the Iranian economy in a particular way. One of the main signals for possible sanctioning of Iranian oil was sent by the United Nation Security Council (UNSC) Resolution 1929.[3] While recognizing Iranian government right to diversify its energy portfolio, the resolution emphasized that "chemical process equipment and materials required for the Iranian petrochemical industry have much in common with those required for certain sensitive nuclear fuel cycle activities". This resolution was the basis of subsequent practical oil embargos against Iran.

Iranian government underestimated the feasibility of such treat: "*From right and from left, they adopt sanctions, but for us they are annoying flies, like a used tissue*" (Mr. Ahmadinejad, on an official visit in Tajikistan, The Telegraph, 10 June 2010)[4]. Soon, however, the European Union (EU) reacted to the UNSC Resolution 1929 by asking member states to ban sale and supply of equipment and technologies which can be used in the Iranian petrochemical industry. In July 2012, the EU banned imports, purchase and transport of the Iranian crude oil. Also oil sanctions combined with international financial, banking, and insurance sanctions which have amplified the destructive effects of sanctions for the Iranian economy.

The response of Iranian oil production to such sanctions was visible: it has reduced by around 1 million bbl/d, namely from more than 4 million in 2005 to about 3 million in 2012/2013.[5] According to the Iran Economics and Finance Minister, Ali Tayebnia, in 2013 Iranian GDP reduced by 5.8%, taking into account the population growth rate this means a 7% reduction in per capita income of Iranians in one year.[6] Furthermore, there are ongoing debates for

[3] http://www.iaea.org/newscenter/focus/iaeairan/unsc_res1929-2010.pdf
[4] http://www.telegraph.co.uk/news/worldnews/middleeast/iran/7816395/Iran-dismisses-new-UN-sanctions-as-a-used-hanky.html
[5] http://www.eia.gov/todayinenergy/detail.cfm?id=11011
[6] the interview with Tayebnia is available at: http://www.bbc.co.uk/persian/business/2014/03/140306_tayebniya_economy_iran.shtml (in Farsi)

suggestions a new proposal: the Iranian-Oil-Free Zone[7]. The idea has recently received some attention in the US congress. The proposal aims to ban the whole export of Iranian oil worldwide.[8]

We deviate from existing empirical studies of Iran economic sanctions (see section 2) by applying the computable general equilibrium (CGE) model and Social Accounting Matrix (SAM) of Iran. We estimate the impact of oil sanctions on a set of key macroeconomic indicators and household welfare. Our main results show that under the scenario of oil sanction by the EU and Japan (scenario three, which is the most realistic scenario than the others), we observe a dampening effect on the Iranian GDP by 2.2%, reducing total imports and exports by 20.0% and 16.5%, respectively, while private consumption also decreases by 3.9%. Furthermore, such a sanction on Iran increases net indirect taxes in Iran by almost 23.6%, real exchange rate by 13.0% and labor income by 8.7%. Finally, our results show that richer households are losing more under oil sanctions in Iran.

The remainder of the paper is structured as follows: Section 2 discusses the existing literature on the economic sanctions with particular attention to the case of Iran. In Section 3 we present and discuss our empirical strategy and the data. Section 4 shows and explains the empirical evidence and some robustness analyses. Section 5 concludes the paper.

2. Review of literature on sanction

Overall, the literature is not conclusive about the effectiveness of economic sanctions in changing political behavior of target country. Some studies such as Eaton and Engers (1992, 1999) and Hufbauer et al. (2007) suggest that sanctions can be effective tools. Others such as

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[7] http://www.defenddemocracy.org/media-hit/the-case-for-an-iranian-oil-free-zone/

[8] http://www.defenddemocracy.org/media-hit/frustrated-with-diplomacy-some-in-congress-seek-total-ban-on-irans-oil/. Also Farzanegan and Raeisian Parvari (2014) have examined this proposal and the response of international oil prices to such policy.

Clawson (1998), Askari et al. (2001), and Torbat (2005) have the opposite view. Dashti-Gibso et al. (1997) examine the determinants of the success of economic sanctions empirically.

Naghavi and Pignataro (2013) highlight the role of religious ideology in economic sanctions-politics nexus. Their theoretical modeling shows that "… *sanctions increase the magnitude and the persistence of religious ideology in the target country*". They explain that sanctions increase the legitimacy of ruling state among religious population and thus "(sanctions) *at times defeat its own purpose by strengthening the regime in power*".

There is an increasing attention in the literature to measure the political economy consequences of sanctions on Iran. Farzanegan (2011) investigates the response of Iranian government in allocating its budget to different functions such as military and non-military to negative oil revenues shocks. As a proxy for oil sanctions he uses the negative shocks on oil revenues of Iran. Using the unrestricted VAR models and annual data from 1959 to 2007, his impulse response analyses show that military and domestic security spending show a statistically significant negative response to negative oil shocks. In other words, there is a chance in changing the budget allocation behavior of Iranian state through oil sanctions which reflect itself in falling oil revenues. Military and security spending also react positively and significantly at the time of increasing oil revenues shocks while other non-military spending (e.g. education, health and culture) do not show such a positive and statistically significant response.

In another study and using VAR models and Granger causality analysis, Farzanegan also finds a significant interaction between economic growth and military spending in Iran. Economic sanctions by reducing military spending also cause lower economic growth in Iran due to strong linkages between military and economy in Iran (Farzanegan, 2014).

How about effects of sanctions on political institutions? Can sanctions improve the political openness in Iran by increasing the economic costs of misconduct? Dizaji and van Bergeijk (2013) examine this issue by using democracy indicators in Iran (e.g. Polity and Vanhanen indicators) and their response to oil revenues shocks as proxy for oil sanctions. Their finding shows that sanctions are successful to change the political behavior of Iran in short run. In other words, lifting the sanctions may have a negative short term consequences for political rights in Iran. In a subsequent analysis, Dizaji, Farzanegan, and Naghavi (2015) show that political institutions are important drivers of allocation of government budget to military spending in Iran. Their results imply that a *shock in positive changes of democratic quality of institutions leads to negative and statistically significant response of military spending and positive and statistically significant response of education expenditures in short term*. If, as Dizaji and van Bergeijk (2013) suggest, sanctions are successful to change the political behavior of Iran in short run, then we can also expect to see a reduction in allocated budget for military in Iran. Sanctions do not *only* affect the formal economy of Iran. They also shape the informal (shadow) economy of Iran.[9] Farzanegan (2013) explains how the sanctions have increased the size of the shadow economy in Iran.

Our methodological approach namely Computable General Equilibrium (CGE) in the case study of Iranian oil sanction is new and can add to our understanding of challenges and opportunities of the sanctions for the Iranian economy. Siddig (2011) emphasizes that "simulation of economic sanctions using the CGE approach is particularly rare." Some studies on economic sanctions using CGE models are McDonald and Roberts (1998), Hubbard and Philippidis (2001), Philippidis and Hubbard (2005), and Siddig (2009 and 2011). In addition, use of CGE model, as

[9] See Bloomberg report: http://www.bloomberg.com/news/2012-07-25/iranian-smugglers-feel-the-pressure-as-western-sanctions.html

a useful tool in trade policy contexts, by researchers concerning Iran is increasing. For instance, Sadeghi et al. (2010 and 2011), Daneshjafari and Barghi Oskuei (2009), and Mehrara and Barkhordari (2007) employ CGE model based on a Standard Computable General Equilibrium (CGE) Model in GAMS, hereafter SCGE, by Lofgren et al. (2002).

3. Data and model

This section presents an overview of our model. It also explains how we model the effects of oil sanctions, explaining the applied dataset and elasticities.

Model Overview

The multi-sectorial characteristic of SCGE together with entirely specified trade-side of economy is a rich model that facilitates the analysis of economic policies. Therefore, we employ SCGE as the basic model in this paper. Our contributions are parameterizing SCGE on Iranian data and adjusting it to show how oil sanctions work.

The model is static and written as a collection of linear and non-linear equations. Nature of the model is neo-classical, and it follows a Walrasian general equilibrium theory inside a small open country. It reflects the interactions between different performers in economy at the same time. Such performers are activities (represented as producers), commodities, factors, households, government, enterprises, and rest of the world.[10] The whole system of equations also has to meet a set of constrains covering macroeconomic aggregates and markets.

Optimal decisions about the amount of productions are driven by activities maximizing their profits as the difference between their revenues and expenses on factors and intermediate inputs. Activities are not restricted to produce only one commodity, thus one or more commodities can be produced by an activity simultaneously. In addition, commodities can be sold for domestic uses or can be exported. The model assumes that commodity and factor markets are completely

[10] For a complete description of SCGE see Lofgren et al. (2002).

competitive. Factors are mobile and fully-employed where the total supply amount of factors is fixed at the level they are observed.

Institutions in our paper are households, enterprises, government, and the rest of the world. Maximizing their utility function subject to budget constraints, households derive their amount of consumption as a result of optimization process. After paying direct taxes, households pay for marketed and non-marketed commodities, save, and transfer some amount to other institutions. Selling factors to activities is the main source of households' income. Other income sources are transfers from other institutions such as enterprises. Enterprises do not consume. They save, pay direct taxes, and receive from and transfer to other institutions. Government receives transfers from other institutions and tax revenues in order to save, buy commodities, and make transfers to other institutions as well. The last institution is rest of the world known as the counterparty which is destination of Iranian export and origin of Iranian import. Except for export and import, all other transfers from and to rest of the world are fixed in foreign currency. The difference between total foreign spending and receipts shows the foreign savings.

Three macroeconomic balances which should be satisfied by whole system are government, external, and saving-investment balances. Here, we follow "Johansen closure (Johansen, 1960)." Regarding the government balance, the real government expenditure is fixed, while the government saving is flexible as the difference between government earning and spending. For external balance, whereas foreign saving is fixed in foreign currency, real exchange rate is flexible. The trade balance and all transfers between rest of the world and other institutions are also fixed at foreign currency. Finally, the macroeconomic closure about saving-investment assumes that the quantities of real investment are fixed, thus domestic nongovernment institutions (households and enterprises) have to adjust their saving rates to equalize the savings needed to finance investment costs.[11] Although many macro closures can be implemented in SCGE models, macro closures used in our static analysis are "preferable for simulations that explore the equilibrium welfare changes of alternative policies," (Lofgren et al. 2002) because it "avoids the misleading welfare effects."

Moreover, there are empirical evidences which support our used closures for the case of Iran. For examples, Farzanegan and Markwardt (2009) show that the effect of oil price shocks, and hence oil revenues, on the Iranian real government expenditures are "marginal." In addition, despite the fact that the exchange rate in Iran is fixed by Iranian Central Bank in an official rate, there has always been a free market rate for exchange rate that is a reference for most of businesses; especially those who do not have access to the subsidized exchange rate.[12] In fact, the role of this free market exchange rate in Iran is so important that Bahmani-Oskooee (1996) claims that instead of the official exchange rate "it is the black market rate (for foreign currency) that is co-integrated with money, income and inflation rate." Moreover, the recent oil sanctions forced the Iranian Central Bank to increase the exchange rate which can be served as an evidence for flexibility of exchange rate as well.[13]

3.1. Modeling oil sanctions; a simple theoretical exposition

To model oil sanction, we use a two-step approach of common usage of CGE models. The first step provides us with the initial equilibrium value of oil export under no sanction condition; therefore, the amount of oil export in the model is determined endogenously. So far, there is no major change to the SCGE model. While the initial values are available, our contribution in step

[11] "Implicitly, it is assumed that the government is able to implement policies that generate the necessary private savings to finance the fixed real investment quantities" Lofgren et al. (2002).

[12] The gap between formal and informal (free) exchange rates is known as the black market premium –BMP-(see Farzanegan, 2009 and 2013 for evaluation of the BMP as a driver of the Iranian shadow economy).

[13] See Farzanegan (2013) for an economic examination of recent sanctions in Iran.

two imposes some scenarios in which the amount of oil export is decreased and considered as a fixed variable. Here, some changes to SCGE are needed to show how sanctions work.

Step One

The SCGE model employs a constant elasticity of transformation (CET) function, Eq 1, for commodity C that is both exported and sold domestically. A CET function is identical to a constant elasticity of substitution (CES) function except for the negative elasticity of substitution. Eq 1 provides the possibility to address the allocation of marketed domestic output for commodity C (QX_c), to two alternative destinations: domestic sale for commodity C (QD_c) and export for commodity C (QE_c).

$$QX_c = \alpha_c . \left(\delta_c .\ QE_C^{\rho_c} + (1-\delta_c) .\ QD_C^{\rho_c}\right)^{\frac{1}{\rho_c}} \qquad \text{Eq 1.}$$

Where:

α_c = a CET function shift parameter for commodity C

δ_c = a CET function share parameter for commodity C, and

ρ_c = a CET function exponent for commodity C

$\Omega_C = \frac{1}{1+\rho_c}$, a transformation of ρ_c, is the elasticity of transformation between the two destinations. Since $-1 < \rho_c < \infty$ and $\rho_c = 0$, Ω_C varies from infinity to zero.

In addition, for each domestically produced commodity, Eq. 2 shows sum of the values of domestic sale and export, stating marketed output value in producer price:

$$PX_c . QX_c = PDS_c . QD_c + PE_c . QE_c \qquad \text{Eq. 2}$$

Where:

PX_c = aggregate producer price for commodity C

PDS_c = supply price for commodity C produced and sold domestically, and

PE_c = export price for commodity C in local currency.

Suppliers maximize sale revenues defined in Eq. 2 for any given aggregate output level subject to the imperfect transformability between domestic sales and exports expressed by Eq. 1. Eq. 3 defines the first-order condition that is the optimal mix between domestic sales and exports given the two prices PDS_c and PE_c[14]:

$$\frac{PDS_c}{PE_c} = \left(\frac{QD_c}{QE_c^*}\right)^{\rho_c - 1} . \frac{1-\delta_c}{\delta_c} \qquad \text{Eq. 3}$$

Where:

QE_c^* = the equilibial amount of export for commodity C.

It is useful to notice that Eq. 3 assures that a decrease in the export-domestic price ratio generates a decrease in the export-domestic supply ratio, which is a shift toward the destination that offers the higher return.

Step Two

Facing oil sanctions, the country is forced to reconsider finding the amount of QE_{oil}^* endogenously. Hence, it should take into account the given quantity of oil export after those sanctions are imposed, $QE_{oil} = \overline{QE}_{oil}^{s} \leq QE_{oil}^*$, as an exogenous variable. So, the maximization process gives Eq. 4 (see appendix 1):

$$\frac{PDS_{oil}}{PE_{oil}} = \left(\frac{QX_{oil}^{\rho}}{\delta .\alpha^{\rho}} - \frac{1-\delta}{\alpha} . \ QD_{oil}^{\rho}\right)^{\frac{1}{\rho}-1} . \ \frac{\delta}{1-\delta} \ QD_{oil}^{\rho-1} \qquad \text{Eq. 4}$$

[14] This equation is the same as $\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} . \frac{1-\delta_c}{\delta_c}\right)^{\frac{1}{\rho_c - 1}}$ in the paper by Lofgren et al. (2002).

The model in step one should have the same number of single equations and variables. Due to making QE_{oil} exogenous, we have to drop one single equation in step 2 to maintain the number of single equations and variables identical. Here, we dropped Eq. 1 for oil.

We can test the correctness of the process in step two in a way that if the value of QE_{oil} is fixed at QE^*_{oil}, then the simulation results for both steps must be the same.

3.2. Data

We use the social accounting matrix (SAM) as the main dataset to provide an economy-wide micro-consistent benchmark.[15] We use a large disaggregated form of the SAM to show best the relationships between all players in Iranian economy. To this end, we use the SAM modified by Mehrara and Barkhordari (2007) for the year 2001 and aggregate it.[16] The aggregated SAM has 151 accounts: 66 accounts representing commodities, 53 accounts for activities, 20 accounts showing Iranian urban and rural households separated by income level, 2 accounts for labor and capital, 2 accounts for direct and indirect tax, and also has 4 accounts, each for enterprises, government, saving-investment, and rest of the world. Moreover, this SAM is balanced by using the iterative adjustment method provided in the SCGE.[17]

3.3 Elasticities

In studying applied general equilibrium, it is usual to use components of integrated data set as a benchmark to calibrate the parameters and exogenous variables for the base year. Although employing calibration procedure provides us with the most of coefficients and exogenous

15 For general discussions of SAMs, see Pyatt and Round (1985) and Reinert and Roland-Holst (1997); for perspectives on SAM-based modeling, see Pyatt (1988) and Robinson and Roland-Holst (1988).

16 Source of the SAM which Mehrara and Barkhordari (2007) modified is the SAM for 2001 issued by the former Iranian Organization of Management and Planning.

17 The SAM is available upon the request from authors.

variables in our analysis, SCGE requires that we introduce Armington and CET elasticities[18], elasticity of substitution between factors (bottom of technology nest), elasticity of substitution between aggregate factors and intermediate inputs (top of technology nest), output aggregation elasticity for commodities, Frisch parameter[19], and expenditure elasticity of goods. Therefore, we get help of other studies especially those which concern Iran to apply these elasticities. Most studies which use CGE models have employed a number between 2 to 3 as the elasticity for Armington function (for example, see McCalla and Nash, 2007 and Sadeghi and Hassanzadeh, 2011). Therefore, we choose 3 for the Armington elasticity in our analysis. For CET function, 2 and 3 was used by Sadeghi and Hassanzadeh (2011) and Jensen and Tarr (2003) respectively. Consequently, we use 2.5 for CET elasticity. Studies such as Khodadadkashi and Jani (2011) and Akbarian and Rafiei (2006) show that the elasticity of substitution between factors and the elasticity of substitution between factors and intermediate inputs such as energy are non-elastic. Hence, we make use of 0.8 and 0.6 for elasticity of substitution between factors and elasticity of substitution between aggregate factors and intermediate inputs, respectively. AlShehabi (2013), De Melo and Tarr (1992), Jensen and Tarr (2003), and Rutherford et al (1997) employ 6 for output aggregation elasticity, AlShehabi (2013) uses -1 for Frisch parameter, and AlShehabi (2013) and Jensen and Tarr (2003) apply 1 for expenditure elasticity of most goods. Hence, we set output aggregation elasticity at 6, Frisch parameter at -1, and expenditure elasticity of goods at 1.

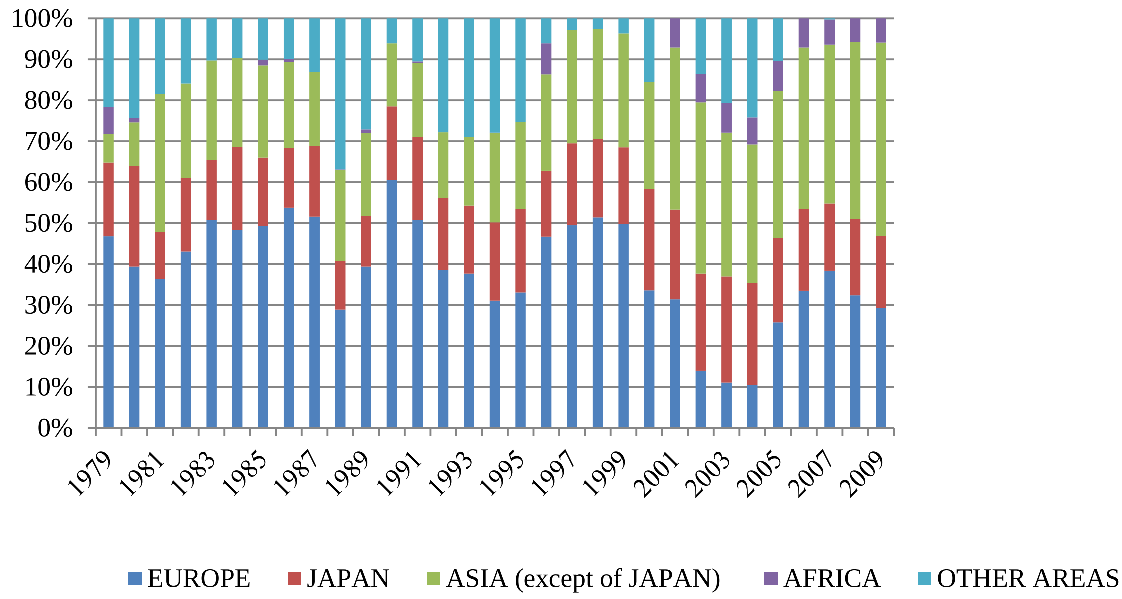
[18] In SCGE, a CES aggregation function that shows domestic market demand captures imperfect substitutability between imports and domestic output. This function is often called Armington function, named after Paul Armington who first introduced using of CES function for this purpose (Armington 1969).
[19] Frisch parameter measures the elasticity of the marginal utility of income with respect to income.

4. Scenarios and analysis

4.1. Scenarios

Geographical distribution of destinations of Iranian oil export from 1979 to 2009 is depicted in Fig. 1. It can be seen that during this period Europe is approximately the most important destination for Iranian oil export with nearly importing 39% of the Iranian oil. After Europe, The greatest major importing areas are Asia, except of Japan, with an average of 26% importing of Iranian oil export and then Japan with nearly 18% of it. The remaining regions are categorized as Africa and other areas.

Fig. 1. Geographical distribution of Iranian oil export (1979 – 2009)



Source: CBI (2012)

In this paper, to show the effects of sanctions on the Iranian economy, ***three scenarios*** are built on the assumptions that the EU and Japan cut the whole importing of oil from Iran, and given finding another source of supply by the EU and Japan we observe no major effect on the world oil price; hence, the world price of oil in foreign currency is fixed.[20] The total amount of Iranian oil export to the EU and Japan fluctuates from one year to another and thus we use the average quantity of oil export to these regions to model sanctions.

In the ***first and second scenarios***, it is assumed that the amount of Iranian oil export, QE_{oil}, decreases by 39% and 18% due to sanctions by the EU and Japan, respectively. The ***third scenario*** considers that both EU and Japan execute sanctions at the same time, so the reduction in the amount of oil export will be 57%.

4.2. Simulation results

Table 1 shows the impacts of the scenarios on macro indicators in our general equilibrium model. Results are represented for ***three conceptual scenarios***: sanctions by Japan, the EU, and both Japan and the EU. As it is expected, the results indicate that the shock of oil sanctions in scenario three is bigger than the shock due to sanctions by the EU, and these shocks are more significant than the shock implemented by Japan.

The shock of sanctions on oil starts with a decrease in total export as the oil export constitutes the major part of export revenues. In our SAM, the amount of oil export is about 65% of total exports. Because oil exports are an important source of government revenues and are positively accounted in GDP, a reduction in oil income of government as well as a decrease in GDP is expected. Since most of the funding needed to import commodities in Iran are financed through petrodollars, a fall in oil revenues, and hence dollar deficiency in exchange market, results in a decline in imports together with a raise in exchange rate which worsen the situation for imports. For example, overall reduction in imports is 20% in scenario three.

[20] For a recent study on the response of international oil prices to negative shocks in Iranian oil exports see Farzanegan and Raeisian Parvari (2014).

The raise in exchange rate can have two different effects on activities' revenue. On one hand, activities that demand imports as an intermediate input for their production line face more cost of importing due to an increase in exchange rate which forces them to produce less. On the other hand, for activities that sells their products to rest of the world, the increase in exchange rate increases revenues and consequently provides the motivation to produce more[21]. The latter can be considered as a blessing of sanctions, and mitigates the huge reduction in total export; for instance total fall in export is 16.5% in scenario three.

Regarding government, due to the assumption that its real expenditure is fixed at observed level, tax rates must grow to compensate for loss in oil revenues. Finally, consumption by households representing private sector consumption decreases because imports prices have increased and their income falls, all of them due to oil sanctions.

Table 1. Percent changes in macro indicators due to oil sanctions

Indicators	Oil Sanctions by Japan	Oil Sanctions by EU	Oil Sanctions by Japan & EU
Private Consumption	-1.3	-2.8	-3.9
Exports	-6.2	-12.3	-16.5
Imports	-7.5	-14.8	-20.0
Gross Domestic Production	-0.8	-1.6	-2.2
Net Indirect Tax	10.6	19.6	23.6
Real Exchange Rate	4.3	9.1	13.0
Labor Income	2.5	5.7	8.7
Capital Income	-1.1	-2.5	-3.8

Source: own calculations

With regards to factor incomes, results in table 1 show that labor income rises by 8.7 percent while capital income falls by 3.8 percent in scenario three. The reason is that because oil sanctions limit the exportation of oil, production of oil is decreased logically to prevent a huge

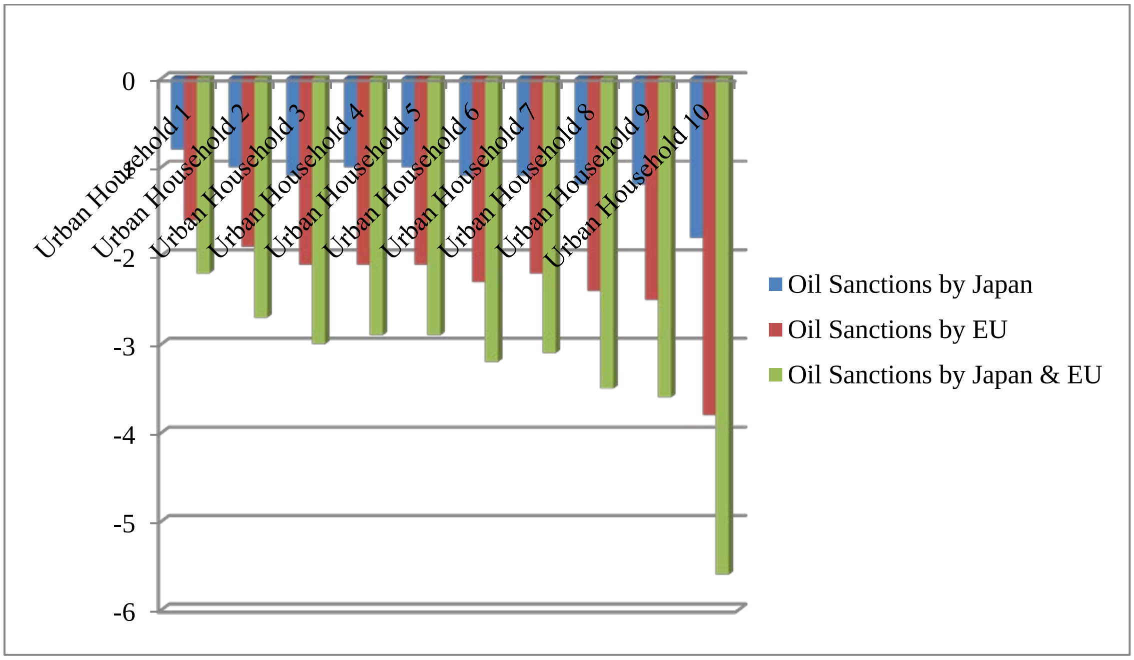
[21] It should be re-expressed that financial and banking sanctions which can offset the increase of export as an outcome of a rise in exchange rate are not of the goal of paper and not simulated.

loss to the oil industries. Therefore, producers do not need some amount of both factors anymore. Thus, those amounts are supplied in factor market. The capital-intensive nature of oil industries compare to the other industries in Iran implies that the amount of capital supplied to the factor market exceeds the mount of labor. In the SAM, the ratio of capital to the total factor employed by oil industry is about 98% and this ratio for all other industries is 76%. Consequently, under the assumption of full employment, capital price drops due to an excess of supply in capital factor market. This low-priced capital provides a good opportunity for other industries to increase the amount of their production. However, capital is not a complete substitution for labor in the technology nest, thus demand for labor rises. Finally, because the extra demand surpasses the extra supply of labor, labor wage increases which leads into a rise in labor income.

In Figures 2.a and 2.b we show the percentage changes in households' welfare because of oil sanctions. To capture welfare changes, SCGE employs Equivalent Variation (EV) indicator that, at base prices, measures the changes in income needed to avert the simulated induced changes. As it is clear, all households lose welfare due to sanctions. The reason for this relies on the fact that households have fewer earnings than before. Although labor income rises while capital income drops, the overall result is a reduction in total factor income because the share of labor income is about 20% of total Iranian factor income in our SAM.

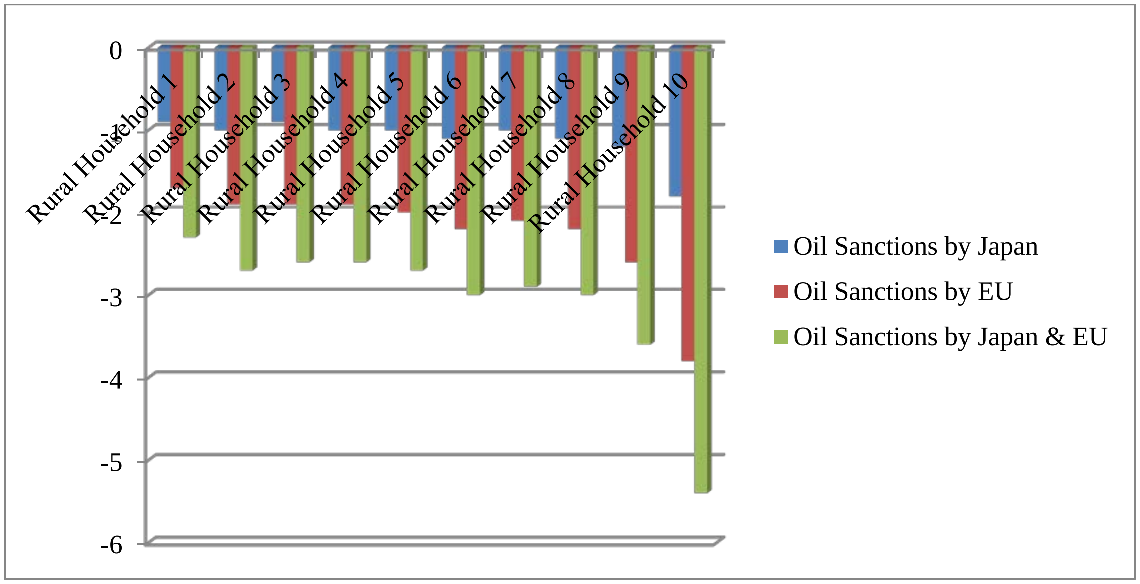
Since the major source of households' income is based on factor income, a reduction in factor income reduces their income consequently. Given that for each household the share of revenue from the factor income is fixed at base simulation, percentage falls in households' income are the same for all households. Yet, this means that the absolute fall in income for richer household is greater than poorer one, so richer households, generally, suffer more from sanctions.

Figure 2.a. Percent changes in urban households' welfare due to oil sanctions



Source: own calculations

Figure 2.b. Percent changes in rural households' welfare due to oil sanctions



Source: own calculations

The SCGE assumes that utility functions are of "Stone-Geary"[22]. Therefore, in the SCGE, first-order conditions which show the optimal household consumptions are linear functions with regards to total consumption expenditure, known as linear expenditure system (LES). One differentiable characteristic between households refers to their subsistence use of commodities. It is rational to suppose that this amount of consumption, in general, is larger for households in upper income levels. Under aforementioned circumstances, oil sanctions result in welfare falling for all households with mostly larger negative effects on households in upper income level.

4.3. Sensitivity analysis

Until now we have presented the central results upon the basic dataset included in the SAM. However, these results may be sensitive to the choice of key parameter levels or treatment of closures. How and to what extent changing previous assumptions affect the results? We present these sensitivity tests in following subsections. To investigate the sensitivity of our simulation, we consider two following questions: will the sign of results due to altering earlier assumptions differ from the central case? And, will the order of magnitudes for results change as a result of changing these assumptions?

4.3.1. Results of altering key elasticities

The key elasticities that are expected most strongly to affect the simulation results are elasticity of substitution between factors in the bottom of technology nest and Armington and CET elasticity of substitution. As it was mentioned earlier, these parameters in our core analysis are 0.8, 3 and 2.5, respectively. Second column in Table 2 gives the central results for only the scenario of oil sanctions by the EU and Japan (scenario 3); it exactly duplicates the relevant results in Table 1, Figure 2.a, and Figure 2.b. under third scenario. We use central results in

[22] For details, see Blonigen et al. 1997 (pp.223-225), and Dervis et al. 1982 (pp. 482-485).

scenario 3 as a comparing point to figure out how the results of altering key elasticities will be different. Next columns show the results where each elasticity deviates from their fixed initial level by 20% lower or higher[23].

The third and fourth columns in the table show that the results are not sensitive to the altering elasticity of substitution between factors at the bottom of technology nest (E.S.B). However, as it is expected, there are some minor changes in the results. Among them, labor and capital income changes the most. As elasticity of substitution between factors at the bottom of technology nest is in the lower level, the changes in labor and capital income are 11.2% and -4.4% respectively. Conversely, with higher elasticity of substitution between factors at the bottom of technology nest, labor income increase by 7% while capital income decreases by 3.4%. The reason is that when this elasticity is higher, factors at the bottom of technology nest can substitute more easily which mitigates the effects of oil sanctions.

The Armington (CET) elasticity reflects substitutability between commodities that are produced domestically and commodities which are imported (exported). According to the results, the sign and order of magnitude for none of the results vary from our central results. Hence, the results are considered as being insensitive to varying Armington and CET elasticities.

As results indicate, higher elasticities lower the effect of oil sanctions on macro-indicators and households' welfare, although it is rather small, and vis-à-vis for the case of lower elasticities. Meanwhile, there are two exceptional cases for each of Armington and CET elasticities. Lower Armington elasticity decreases the effect of oil sanctions on total exports and imports, where the higher elasticity increases them. In addition, lower CET elasticity decreases net indirect tax and

[23] In fact, Armington and CET elasticities of substitution are 2.4 and 2in their low level, and 3.6 and 3 in their high level respectively. For elasticity of substitution between factors in the bottom of technology nest the lower level is 0.64 and the higher level is 9.6.

labor income, whereas higher elasticity has an increasing effect on them. In sum, our results are robust when we change the initial elasticities by +/-20%.

4.3.2. Results of enforcing other closures

The treatment of government sector, exchange rate, and saving-investment ratio are the other important features of our core simulation. The current results are based on a closure regarding the government in which the tax rates and government expenditure are fixed while government saving is flexible. In the SCGE, there are two alternative closures with regards to government, Gov. 2 and Gov. 3. In both Gov. 2 and Gov. 3, government saving and expenditure are fixed, and direct tax rates of domestic institutions are adjusted endogenously to generate that fixed level of government saving. The difference between these two closures is that for Gov. 2 the same numbers of percentage points are used to adjust endogenously the base-year direct tax rate of selected domestic nongovernment institutions while for Gov. 3 the tax rates are adjusted multiplying by a flexible scalar[24]. In Table 3, under columns Gov. 2 and Gov. 3, these two closures are used to simulate the effects of sanctions for scenario one. Comparing the results to our main results shows that generally our results are not significantly affected; therefore, the simulation is not sensitive to altering the government closure[25].

For external balance, our core simulation employs *flexible* real exchange rate together with fixed foreign saving. In Table 3, under the column External Balance, the other way to deal with external balance is employed; that is, the exchange rate is *fixed* whereas foreign saving is left flexible.

[24] For more clarification on difference between two alternative closures, see Lofgren et al. (2002) (p. 14, footnote 15).

[25] Unlike our sensitivity analysis on key elasticities, we decided scenario 1 as the central case to compare between closures. The reason is that making exchange rate fixed in our model has such a huge effect on the results that in scenario 3 we have not reached an equilibrial situation.

The results demonstrate that our findings are sensitive to the assumption about the *external balance*. Under this circumstance, not only the households do *not* suffer from oil sanctions, but also they *benefit* from a much higher welfare level compared to the pre-sanction situations. Results show that the changes in private consumption, import and households' welfare are positive. The reason for these surprising findings is that the huge reduction in total export due to oil sanctions are mostly compensated with an enormous increase in foreign saving, 67.71%, rather than a rise in real exchange rate, 4.3%. Consequently, factors that are not needed in oil industries are employed by other activities, and as a result, the increase in production and consumption of other commodities raises households' welfare.

Table 2. Sensitivity analysis on key elasticities

Indicator	Scenario 3	E.S.B (low)	E.S.B (high)	Arm (low)	Arm (high)	CET (low)	CET (high)
Private Consumption	-3.9	-4.0	-3.9	-4.2	-3.7	-4.5	-3.5
Exports	-16.5	-16.6	-16.5	-14.7	-18.0	-18.4	-14.9
Imports	-20.0	-20.0	-20.0	-17.8	-21.8	-22.3	-18.0
Gross Domestic Production	-2.2	-2.3	-2.2	-2.4	-2.1	-2.6	-2.0
Net Indirect Tax	23.6	24.6	22.8	27.4	21.5	20.5	25.0
Real Exchange Rate	13.0	13.0	13.0	14.4	11.9	14.8	11.7
LAB	8.7	11.2	7.0	8.7	8.7	8.6	8.9
CAP	-3.8	-4.4	-3.4	-3.8	-3.8	-3.9	-3.7
Urban Household 1	-2.2	-2.1	-2.3	-2.4	-2.1	-2.7	-1.9
Urban Household 2	-2.7	-2.6	-2.7	-2.9	-2.5	-3.2	-2.3
Urban Household 3	-3.0	-2.9	-3.0	-3.2	-2.8	-3.5	-2.6
Urban Household 4	-2.9	-2.9	-3.0	-3.1	-2.7	-3.5	-2.5
Urban Household 5	-2.9	-2.9	-3.0	-3.2	-2.8	-3.5	-2.6
Urban Household 6	-3.2	-3.2	-3.2	-3.4	-3.0	-3.8	-2.8
Urban Household 7	-3.1	-3.0	-3.1	-3.3	-2.9	-3.6	-2.7
Urban Household 8	-3.5	-3.5	-3.5	-3.7	-3.3	-4.0	-3.1
Urban Household 9	-3.6	-3.6	-3.6	-3.8	-3.4	-4.2	-3.2
Urban Household 10	-5.6	-5.8	-5.4	-5.9	-5.3	-6.3	-5.1
Rural Household 1	-2.3	-2.3	-2.3	-2.4	-2.2	-2.8	-1.9
Rural Household 2	-2.7	-2.7	-2.7	-2.8	-2.5	-3.2	-2.3
Rural Household 3	-2.6	-2.6	-2.6	-2.7	-2.4	-3.1	-2.2
Rural Household 4	-2.6	-2.6	-2.6	-2.8	-2.5	-3.1	-2.3
Rural Household 5	-2.7	-2.7	-2.7	-2.8	-2.6	-3.2	-2.3
Rural Household 6	-3.0	-3.1	-3.0	-3.2	-2.9	-3.5	-2.7
Rural Household 7	-2.9	-2.9	-2.9	-3.0	-2.7	-3.3	-2.5
Rural Household 8	-3.0	-3.1	-3.0	-3.2	-2.9	-3.5	-2.7
Rural Household 9	-3.6	-3.7	-3.5	-3.8	-3.4	-4.1	-3.2
Rural Household 10	-5.4	-5.7	-5.2	-5.7	-5.2	-6.1	-4.9

Source: own calculations

Table 3. Sensitivity analysis on other closures

Indicator	Scenario 1	Government		External balance	S-I
		Gov. 2	Gov. 3		
Private Consumption	-1.33	-1.33	-1.33	3.97	-0.05
Fixed Investment	---	---	---	---	-2.93
Exports	-6.17	-6.17	-6.17	-10.53	-6.23
Imports	-7.46	-7.46	-7.46	2.23	-7.54
Foreign Saving	---	---	---	67.71	---
Gross Domestic Production	-0.75	-0.75	-0.75	-0.41	-0.81
Net Indirect Tax	10.60	10.61	10.60	-16.84	-0.69
Real Exchange Rate	4.30	4.30	4.30	---	4.10
LAB	2.51	2.51	2.51	2.09	1.98
CAP	-1.11	-1.11	-1.11	-0.99	-0.99
Urban Household 1	-0.80	-0.90	-0.90	3.90	0.30
Urban Household 2	-1.00	-1.00	-1.00	4.00	0.20
Urban Household 3	-1.10	-1.10	-1.10	4.20	0.20
Urban Household 4	-1.00	-1.00	-1.10	4.00	0.20
Urban Household 5	-1.00	-1.10	-1.10	3.90	0.20
Urban Household 6	-1.10	-1.10	-1.10	3.90	0.10
Urban Household 7	-1.10	-1.10	-1.10	3.70	0.10
Urban Household 8	-1.20	-1.20	-1.20	3.90	0.0
Urban Household 9	-1.20	-1.20	-1.20	3.70	0.0
Urban Household 10	-1.80	-1.80	-1.80	4.50	-0.30
Rural Household 1	-0.90	-0.90	-0.90	3.40	0.20
Rural Household 2	-1.00	-1.00	-1.00	3.50	0.10
Rural Household 3	-0.90	-1.00	-0.90	3.30	0.10
Rural Household 4	-1.00	-1.00	-1.00	3.30	0.10
Rural Household 5	-1.00	-1.00	-1.00	3.30	0.0
Rural Household 6	-1.10	-1.10	-1.10	3.40	0.0
Rural Household 7	-1.00	-1.10	-1.00	3.20	0.0
Rural Household 8	-1.10	-1.10	-1.10	3.20	0.0
Rural Household 9	-1.20	-1.30	-1.20	3.50	-0.10
Rural Household 10	-1.80	-1.70	-1.70	4.60	-0.20

Source: own calculations

Another alternative closure that significantly affects the results is *saving-investment balance*. In the core model, an investment-driven closure is used. This closure assumes that real investment quantities are fixed. To equalize savings with investments, the base-year savings rates for households and enterprises are modified by the same number of percentage points. In Table 3, instead, under the column S-I (Saving-Investment), a saving-driven closure is employed. With a saving-driven closure, saving rates for nongovernment institutions are fixed, and to equalize between the investment cost and the savings value, a flexible scalar is multiplied to the quantity of each commodity in the investment bundle. Although real exchange rate, export, and import are not much different to that of the core simulation, the results regarding welfare level show deviations. In this case, after the shock of oil sanctions has its effects on trading sector of Iranian economy, the other parts of system react to it mostly by reducing the amount of fixed investment instead of private consumption.

Concerning welfare levels, all households are at least as well-off as pre-sanction situations, except for highest income group of urban households and two highest income groups of rural households. The overall result in private consumption is a minor reduction.

However, it is worthwhile to re-express that the results under the circumstances that exchange rate is fixed and/or saving-investment balance is saving-driven are *misleading*, especially when a single period model is used. As it was argued in section 3, used macro closures here are more in line with macro conditions in Iran. In addition, as oil sanctions are imposed, using a fixed exchange rate forces the model to raise foreign savings to reach an equilibrial solution regardless of what will happen in futures to come. The welfare gained under this circumstance is misleading because, sooner or later, this raise in foreign investment as foreign debts have to be paid back, and households will incur welfare loses. With a saving-driven closure in a single-period model also, reductions in investments due to oil sanctions do not let the model to capture welfare changes correctly. In fact, reductions in investments will reduce production capacities in the future which will eventually lead to welfare lose.

5. Conclusion

This study focuses on analyzing the economic effects of oil sanctions on Iranian economy including changes in households' welfare and macro-indicators. The framework of our analysis is CGE model based on Lofgren et al. (2002), and we use the Iranian Social Accounting Matrix (SAM) in 2001 as an economy-wide database. We modify Lofgren et al. (2002) in a manner that enables the inclusion of oil sanctions in the model. The model is closed under Johansen closure rule. Three scenarios in which the exportation of crude oil from Iran to the rest of the world is banned are developed. In addition, sensitivity analysis of results to key elasticities and other macro-closures are implemented.

The results show that the Iranian economy and households are affected enormously. The third scenario (i.e., sanctions by the EU and Japan) bans 57% of Iranian oil exports. Macro-indicators that are ***negatively*** affected in order are total import by 20%, total export by 16.5%, private consumption by 3.9%, capital income by 3.8%, and GDP by 2.2%. Other macro-indicators which ***positively*** change in order are net indirect tax by 23.6%, real exchange rate by 13%, and labor income by 8.7%.

In addition, all income groups of households in urban and rural areas suffer from oil sanctions and their welfares declines. An interesting finding is that generally richer households lose more than poorer ones. Furthermore, sensitivity analysis admits that our model is robust and insensitive to Armington and CET elasticities, and elasticity of substitution between factors at bottom of technology nest. However, although other government closures do not have a major effect on the findings, employing other closures regarding ***exchange rate*** and ***saving-investment*** take misleading effects in simulations and it also can destabilize the model.

Among many interesting applications of our model, one is the possibility to investigate the effects of lifting sanctions on the Iranian economy. Since the SAM used in this model contains income levels of both urban and rural households, this model would be useful for agents who are interested in the effects of policy implications against or for sanctions. In addition, by little changes in the model it can include sanctions on exportations and even importation of other commodities. Finally, the model can be applied to data from other countries to analyze the effects of sanctions (for example, the case of Russian sanction over Ukraine conflict). These paths are left open to further researches.

Appendix 1

Proof of Eq. 4.

Allocation of domestic output of oil (QX_{oil}) follows a CET function (Eq. B) addressing oil production between two destinations, export (QE_{oil}) and domestic use (QD_{oil}). Oil producers face sanctions and has to consider the amount of oil export as a given. Therefore, oil producer has to maximize his revenues (Eq. A) given prices (PDS_{oil}, PE_{oil} , and PX_{oil}) and subject to the CET function and a fixed quantity of domestic output (QX_{oil}) and export (QE_{oil}):

Max: $$PX_{oil} \,.\, QX_{oil} = PDS_{oil} \,.\, QD_{oil} + PE_{oil} \,.\, QE_{oil} \qquad \text{Eq. A}$$

S.T. $$QX_{oil} = \alpha \,.\left(\delta \,.\, QE_{oil}^{\rho} + (1-\delta) \,.\, QD_{oil}^{\rho}\right)^{\frac{1}{\rho}} \qquad \text{Eq. B}$$

Since Eq. B can be written as the following equation:

$$QE_{oil} = \left(\frac{QX_{oil}{}^{\rho}}{\delta\alpha^{\rho}} - \frac{1-\delta}{\delta}\, QD_{oil}^{\rho}\right)^{\frac{1}{\rho}} \qquad \text{Eq. b}$$

Then, to maximize Eq. A subject to Eq. B, we have to solve the following equation:

$$\frac{d[PDS_{oil} \,.\, QD_{oil} + PE_{oil} \,.\left(\frac{QX_{oil}{}^{\rho}}{\delta\alpha^{\rho}} - \frac{1-\delta}{\delta}\, QD_{oil}^{\rho}\right)^{\frac{1}{\rho}}]}{dQD_{oil}} = 0$$

The result is:

$$\frac{PDS_{oil}}{PE_{oil}} = \left(\frac{QX_{oil}^{\rho}}{\delta \,.\alpha^{\rho}} - \frac{1-\delta}{\alpha} \,.\, QD_{oil}^{\rho}\right)^{\frac{1}{\rho}-1} .\ \frac{\delta}{1-\delta}\, QD_{oil}^{\rho-1} \qquad \text{Eq. 4}$$

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