Assessing the Impact of Potential Sudden Reduction of the Supply of Petroleum on the Different Sectors of the Iranian Economy*

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Abstract

The import of petroleum constitutes more than 40 percent of domestic production and drains more than 8 billion U.S. Dollars of the foreign exchange of Iran per years. In order to control domestic energy consumption, on reduce the import dependence, and finally decrease the burden of the annual drained foreign exchange of the country, the government has recently resorted to the quota system. But this is not the whole issue: The potential of petroleum embargo is another issue facing the Iranian economy. To what extent such a potential threat would damage the different sectors of the Iranian economy is not clear to many analysts and policy makers is Iran. The main concern of this paper is to quantitatively assess the impact of the potential sudden supply shortage of petroleum on the different sectors of the Iranian economy. From the methodological point of view, the conventional Leontief's and Ghosh's type models are not suitable to deal with such an issue, therefore a combination of the two in the framework of mixed variables or mixed models is proposed. For this purpose, we use a 147×147 IO Table of Iran for the year 2001.

Key words: Economic Embargo, Mixed Models, Supply-Side, Demand-Side.

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1- **Introduction**

Recent estimates of the World Bank show that the price of fuel products in Iran are only 10 percent of the world prices and fuel product subsidies are 18 percent of the GDP in Iran (World Bank 2002). The other estimates reveal that Iran with one percent of the total world population, consumes 9 percent of world fuel and 36 percent of petroleum in the Middle East. Besides, on an average, Cars in Iran consume 11 liters per 100 km whereas in Germany and Japan consume 2.5 liters and U.S.A 7.3 liters per 100 km. Every 10 years, fuel consumption in Iran increases two times whereas in the world this happens every 50 years. Energy subsidies are estimated to be 37 billion dollars which is second in the world and per capita energy consumption in Iran is five times that of Indonesia, two times that of China and four times that of India (Arman, Daily News paper, 2010)

As a remedial measure to promote better and more efficient use of energy, to compensate the budget deficit in the current fiscal year (2009-2010), and also to reduce the burden of the drain of 8 billion U.S dollars of the import of petroleum per year, the government has opted not only to eliminate energy product subsidies, but has also imposed quota system for some energy products like petroleum [1]. The aim of this policy is to encourage households and industries to be more efficient in using energy. The following Table reveals the proposed increase in prices of fuel and non-fuel products by the government.

Table 1- Proposed increase in the prices of fuel and non- fuel products

Energy and non-energy products	Rials / per Litre per cm^3 and per kwh	Scenario one: Increase in terms of Rials and percentage	Scenario two: Increase in terms of Rials and percentage
Petroleum	1000	40000 (300%)	40000 (300%)
Gasoline	165	2700 (1536%)	3500 (2010%)
Natural Gas	120	750 (525%)	1300 (983%)
Electricity	167	800 (379%)	1000 (448%)

Source: Etemad Melli, (Daily Newspaper, 2009 page) Exchange rate: Rials 10000 = 1 USD

From the above Table, we observe that the proposed increase in the prices of the four fuel and non-Fuel products varies between 300% in the case of petroleum and 2021% in the case of gasoline. The impact of the subsidies elimination and / or increase in prices of fuel and non fuel products on the increase in price indices of different economic sectors as well as on the welfare of the different household groups has been worked out by individual analysts and different government institutions using IO, SAM and CGE Models [2].

The central focus of this paper is not to analyze the socio-economic aspects of the cost-push inflation due to the elimination of subsidies in fuel and non-fuel products, but also to assess quantitatively the impact of the potential threat of embargo on the sudden reduction of the supply of petroleum on the outputs of the different sectors of the Iranian economy, suggesting a combination of Leontief and Ghosh's type Models.

For this purpose, the contents of this paper are structured as follows: In section 1, we briefly review the relevant literature. In section 2, we briefly explore the methodology of the mixed variables, mixed models or supply constrained models. Data base and adjustments are covered in section 3. In section 4, we present the empirical results and limitations. In the last section, we end with the summary and conclusions.

2- Brief Review of the Relevant Literature.

Miller and Blair advocate that in certain situations the application of usual from of the standard Leontief model (demand-side input-output model) and the alternative standard Ghosh model (supply-side input-output model) are not suitable, but rather a mixed type of input-output model may be more appropriate to deal with the specific economic situations (Miller and Blair 2009). For example, due to a Strike of a major supplier, imposing the quota system and or economic embargo on certain commodities, output from a particular sector might be fixed at the amount currently on hand in warehouses, awaiting transportation and delivery to buyers, or in a planned economy a target might be to increase agricultural output by a certain percent by the end of the next planning period. From the methodological point of view, many analysts reached the conclusion that usual from of the standard demand-side and / or supply-side input-output models are suitable and therefore, suggesting a combination of the two which is generally known as mixed input-output mixed variables or supply constrained models. These Models have been applied in empirical studies in both agricultural and resource economics. Some of these research works are briefly reviewed as follows:

- Agriculture [Johnson and Kulshreshtha, 1982 (Economic importance of different farm types); Findeis and Whittlesey, 1984 (Impacts of two irrigation development projects); Tanjuakio, Hastings and Tytus, 1996 (contribution of agriculture to Delaware economy); Papadas and Dahl, 1999 (Relative importance of 16 different US farm commodities); Roberts, 1994 (effects of milk production quotas)].
- Mining, Petkovich and Ching, 1978 (Effects of partial elimination of mining in Nevada due to ore depletion)].

- Fisheries, Leung and Pooley, 2002 (Impacts of reduction in fishing areas in order to protect certain turtle population).

Kerschner and Hubacek, after reviewing the methodology, literature and empirical applications of the mixed models, observe that "it has become evident that it is a prime candidate for analysing the impact of sudden output reductions of the oil sector (petroleum and natural gas extraction sectors) on the different sectors" (Kerschner and Hubacek, 2009). The two sectors were chosen to reflect the constraints experienced by an economy due to peak oil. These sectors were subjected to a 10% reduction in total output which is in the same range as historical reduction of World oil and gas output during past oil shocks: Suez Crisis (1956) -10.1% Arab-Israel War (1973) -7.8% ; Iranian Revolution (1978) -8.9% ; Iran-Iraq War (1980) -7.2% ; Persian Gulf war (1990) -8.8% .

For this purpose, they have used IO tables of a net oil exporter-United Kingdom and the two net oil importers-Japan and Chile.

Our main aim in this paper is to analyze the impact of the sudden reduction of petroleum output due to the potential of petroleum imports embargo on the outputs different sectors of the Iranian economy, taking petroleum as a constrained sector.

3- The Methodology: Demand side, supply side and Mixed Models.

Table 2 shows the structure of a simple IO table, partitioned in terms of non-constrained and constrained sectors. The static demand side Leontief model is derived entirely by the final demand matrix [Y]. This matrix determines total outputs [X], intermediate inputs [Z] and primary inputs [W] through a set of technical coefficients. In application of demand side IO modeling, we usually seek to answer the following question: If final demand from one or more of the exogenous sectors like households, government and / or exports is planned to increase or decrease in the future, how would this affect total output throughout the economy?

The workability of such modeling depends on the assumption that input requirements for production of some exogenously given demand will automatically and instantaneously within an accounting period (i.e. given statistical year) be met. Such workability of the modeling is justifiable, if there exist unused capacity and also very elastic supply of factors (Giarration, 1976) which usually under the certain specific situations, discussed in the previous section, will not be the case. Under these situations, modeling the standard demand side approach is unsuitable for the analysis of the supply constraints. As an alternative, the supply side approach which was proposed by Ghosh (Ghosh, 1958) is considered to be the most suitable approach for such analysis. The basic idea behind this approach is that if, for example, less of a scare input (e.g. labor) is fed into the system, its ripple effects will result in output decreases throughout all economic sectors. Therefore, as compared to the standard demand-side model, the supply matrix [W], appears to be the driving force in determining the endogenous variables Z, Y and X. The implicit assumption in this approach is perfect substitutability between factors. In addition to that, at the level of the whole economy the model assumes perfect elasticity of demand, which means that final (households, government, exports, etc) and intermediate (inter industry) demand will adjust smoothly to any changes in supply. In this respect, Oosterhaven observes that it is very unlikely that for example, sales of cars would increase if fuel was not available (Oosterhaven, 1988).

Table 2- The Structure of a Simple IO in Terms of Constrained and Non-Constrained Sectors

From (i)	To (j)						Total output (X)
Processing sectors (Z) (i×j) non-constrained	Processing sectors				Purchase sectors final demand (y)		
	Non-constrained Agri	manuf	ser	constrained Energy (petrol)	Households, etc	exports	
Agriculture	z_{11}	z_{12}	z_{13}	z_{14}	h_1	e_1	x_1
manufacturing	z_{21}	z_{22}	z_{23}	z_{24}	h_2	e_2	x_2
services	z_{31}	z_{32}	z_{33}	z_{34}	h_3	e_3	x_3
constrained energy sector (petroleum)	z_{41}	z_{42}	z_{43}	z_{44}	h_4	e_4	x_4
Payment sectors (W) Value added	w_1	w_2	w_3	w_4			
Imports (M)	m_1	m_2	m_3	m_4			
Total outlays (X')	x_1	x_2	x_3	x_4			

Kershner and Hubacek, accepting the criticism made by Oosterhaven on plausibility of supply-side IO models that the supply-driven models may be unsuitable for both, that is general descriptions of the working of an economy and for analyzing the effects of supply constraints. They believe that there may be circumstances, where these problematic assumptions might be less unrealistic and the subject may merit further analysis (Kershner and Hubacek, 2009) [3].

The second alternative to the standard demand-side model is the supply constrained or mixed IO Model. As mentioned above, exogenous variables were either final demand [Y] in the demand side or value added [W] in the supply-side model. This restricts the scientific efforts to observe the impact on total output [X] of either changes in final demand (due to changing consumer tastes, government spending, etc) or value added due to certain specific situations like strike, import embargo of certain products (like potential threat of petroleum embargo in Iran) respectively. This is particularly restrictive for impact studies [4] of supply shortages such as in the case of potential threat of petroleum embargo in Iran. Under this specific situation, it may be desirable to exogenous the sector that is potentially causing the disruption. In order to deal with such a specific situation, IO models with mixed exogenous and endogenous variables known as mixed Model is suggested in this paper [5].

In these models, instead of estimating changes in sectoral outputs due to changes in final demand as in the traditional Leontief model or value added as in the standard Ghoshian model, mixed model estimates the impacts on unconstrained sectors given some reduced outputs of the supply constrained sectors. This approach allows the final demand of some sectors and the gross output of the remaining sectors to be specified exogenously.

The procedure of the mixed models is well explained in (Miller and Blair, 2009; Roberts, 1994; Steinback, 2004; Kerschner and Hubacek, 2009).

To begin with, the IO system is basically partitioned into non-supply constrained and supply constrained sectors. This is illustrated for a simple four sector commodity economy with output restricted petroleum due to the potential threat of petroleum embargo in Table 2. Using basic matrix algebra for partitioned matrices, one can derive the following general equation for an n-sector economy.

$$\begin{bmatrix} (I - A^{(k)}) & O \\ -A_{21} & -I \end{bmatrix} \begin{bmatrix} x_{no} \\ y_{co} \end{bmatrix} = \begin{bmatrix} I & A_{12} \\ O & -(I - A_{22}) \end{bmatrix} \begin{bmatrix} x_{no} \\ y_{co} \end{bmatrix} \quad (1)$$

Where $x_{no} = \begin{bmatrix} x_1 \\ \vdots \\ x_k \end{bmatrix}$ for an n-sector case, assume that sectors have been labeled so that the first k sectors are non-constrained or endogenous, and the corresponding final demands of non constrained sectors are exogenous, i.e. $y_{no} = \begin{bmatrix} y_1 \\ \vdots \\ y_k \end{bmatrix}$.

Similarly, the last n-k sectors are considered as constrained sectors whose gross outputs are exogenous: $x_{co} = \begin{bmatrix} x_{k+1} \\ \vdots \\ x_n \end{bmatrix}$ and corresponding final demands are endogenous, i.e. $y_{co} = \begin{bmatrix} y_{k+1} \\ \vdots \\ y_n \end{bmatrix}$.

Similar to the partition of gross outputs and final demands of non constrained and constrained sectors, the coefficients matrix A are also portioned as:

$A=\begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$, where $A_{11}=A^{(k,k)}$ represents the sub-matrix made up of the first k rows and the first k columns of A which in the equation (1) denotes $A^{k}, A_{12}=A^{[k,-(n-k)]}$ shows the sub-matrix made up of the first k rows and the last (n-k) columns of $A, A_{21}=A^{[-(n-k),k]}$ denotes the sub-matrix made up of the last rows and the first k columns of A, and $A_{22}=A^{[-(n-k),-(n-k)]}$ shows the sub-matrix containing the last (n-k) rows and columns.

I and O matrices are of appropriate dimensions in each case.

The solution procedure of equation (1) is the same as for any square set of linear equation,

Let $M=\begin{bmatrix} (I-A^{k}) & O \\ -A_{21} & -I \end{bmatrix}$ and $N=\begin{bmatrix} I & A_{12} \\ O & -(I-A_{22}) \end{bmatrix}$.

Substituting Matrices M and N in equation (1), we get

$$M\begin{bmatrix} x_{no} \\ y_{co} \end{bmatrix}=N\begin{bmatrix} y_{no} \\ x_{co} \end{bmatrix} \qquad (2)$$

And solution to equation (2) is:

$$\begin{bmatrix} x_{no} \\ y_{co} \end{bmatrix}=M^{-1}N\begin{bmatrix} y_{no} \\ x_{co} \end{bmatrix} \text{ or}$$

$$\begin{bmatrix} \underset{(k\times 1)}{x_{no}} \\ \underset{[(n-k)\times 1]}{y_{co}} \end{bmatrix}=\begin{bmatrix} L^{(k)} & L^{(k)}A_{12} \\ -A_{21}L^{(k)} & (I-A_{22})-A_{21}L^{(k)}A_{21} \end{bmatrix}\begin{bmatrix} \underset{(k\times 1)}{y_{no}} \\ \underset{[(n-k)\times 1]}{x_{no}} \end{bmatrix} \qquad (3)$$

Where $(I-A^{(k)})^{-1}$

Equation (3) represents a supply constrained or the mixed models in the sense that endogenous and exogenous variables (x_{no} and y_{no} respectively) for the non-constrained sectors are same as the standard demand-side model whereas opposite case holds true for non constrained sectors. This equation has been used for the impact of sudden reduction of the supply of petroleum due to the potential of petroleum embargo on the output of different non constrained sectors of the Iranian economy.

4- Data Base

In order to operationalise the mixed models, we have used a symmetric 147×147 IOT of Iran for the year 2001. This Table has been derived on the basis of the two separate use and make tables with dimensions of 147×99 (Commodity × industry) and 99×147 (industry × commodity) respectively. The symmetric table is based on commodity × commodity with industry technology assumption. For simplicity we use "sector: instead of "commodity".

5- Empirical Results and Limitations

The IOT of Iran shows that the share of petroleum in total value added is 0.4% and has a share of 0.3% in total output.

The percentage shares of the intermediate demand and intermediate expenditure to the total intermediate demand are 0.7% and 0.8% respectively. Oil sectors (crude oil and natural gas and other oil products) constitute 16.1% of total value added and 10.2% of total output of the country. Due to the minor share of petroleum, we expect that the impact of sudden 40% ore reduction of supply of petroleum as a constrained sector output to the reduction of non-constrained sector output is bound to be very small. In this respect since the actual percentage of the output reduction is not considered of ultimate importance here, but to contribute to a deeper understanding of the effects upon the actual economic structure of such an economy. For the same reason we are less interested in the actual magnitude of the caused reduction, than we are in the rankings of the affected sectors.

On the basis of our results, we find that the reduction of endogenous output caused in the non supply constrained sectors by the reduction of 40% of supply of petroleum output is rather mining in both absolute and relative value terms. Relative to total value added (excluding the value added of the constrained sector) is 0.19% of the total value added. Employing almost the some methodology and taking oil sectors (crude petroleum and natural gas extraction and petroleum refining) as constrained sectors for the three countries (the U.K. Japan and Chile), Kerschner and Hubacek, found that the impact of 10% reduction of oil sectors on the output of non-constrained sectors, constitutes 0.17% of total value added of the U.K. 0.028% of total value added of Japan and 0.056% of total value added of Chile. As already mentioned, it is not so much the magnitude of change itself that is of interest but to see which sectors are hit more than the others under the situation of the impact of petroleum embargo.

The results of 10 most affected sector outputs due to the reduction of 40% in supply of petroleum are arranged in Table 3.

Table 3- The 10 most affected sectors in Relative and Absolute Terms.

Relative sector change	%	Absolute sector change	Millions of Rials
Other unclassified fuel products (except petroleum products) (1)	-6.46	Crude petroleum (1)	1062120
Basic chemicals (except chemical products) (2)	-2.7	Water transport services (2)	29041
Crude petroleum (3)	-0.95	Banking services (3)	27137
Road transports (freight and passenger) (4)	0.69	Basic chemical (except chemical products) (4)	26686
Other chemical products (except soap, detergent, rubber, paints, medicine, pesticides, plastic products and etc) (5)	-0.54	Road transports (5)	21181
Distribution of natural gas and related services (6)	-0.32	Other chemical products (except soap, detergent, rubber, paints, medicine, pesticides, plastic products and etc.) (6)	16172
Natural gas (7)	-0.31	Distribution of natural gas and related services. (7)	12440
Water transport services (8)	0.3	Other financial intermediaries and related services (8)	5104
Banking services (9)	0.21	Natural gas (9)	2650
Other financial intermediaries and related services (10)	-0.19	Other unclassified fuel product (except petroleum products) (10)	2453

On the basis of the results of Table 3, we can make the following observations:

1- The results are presented in terms of the relative effects changes and the absolute effects changes due to the restriction of 40% of supply of petroleum output on the reduction of 10 most affected sector outputs. Relative effects changes are shown because they will be most important for the sector itself in terms of detrimental implications for its continuing profitable operation. Absolute effects changes, on the other hand may be significant for the whole economy as GDP may be reduced substantially. Meaning thereby that a large percentage decrease of output in a sector that contributes little to GDP may be less harmful for the whole economy than a small percentage decrease of an important sector. For example on the relative basis, we observe that other unclassified fuel products (except petroleum products), and basic chemicals (except chemical products) show 6.46 and 2.70 percent decrease in output due to the 40% reduction of supply of petroleum. Their shares in GDP are 0.008 and 0.5 percent respectively. Whereas, Crude petroleum ranks the third whose share in GDP is 15%. The results Show that in an absolute sense, crude petroleum takes the first position and appears to be not only the most vulnerable sector but also under such a specific situation may have significant impact on the reduction of the GDP of the country.

2- Hardly surprising is the relatively strong impact on the different transport sectors, given their importance in today's globalised market economy. Looking into the results of the Table, we observe that road transports (freight and passenger) and then water transport services occupies (4) and (8) position in the relative sense whereas in absolute change their ranks are (2) and (5).

3- The merit of using input-output analysis is probably more obvious in the case of banking services and other financial intermediaries. In relative terms the results show that their positions are (9) and (10) respectively whereas in absolute terms, banking services fall into 3rd position and other financial intermediaries and related services appear in 8th position. Such reductions in the outputs of financial sectors are more indirect effects of 40% reduction of supply of petroleum which is considered to be the merit of IO techniques.

4- The combined changes of 12 agricultural sub-sectors show relatively higher impacts and their combined changes (0.11%) appear to be among the top 20 most affected sectors due to the sudden reduction of supply of petroleum. Such impacts are also indirect effects of the dependence of agricultural sub-sectors on artificial fertilizers and pesticides, production of both require petroleum products. These findings are not in concomitance with the findings of Kerschner and Hubacek using IOTS of the U.K. Japan and Chile (Kerschner and Hubacek, 2009). Their findings reveal that none of the agricultural sectors of the three countries appear to have higher impact due to the 10% reduction of oil sectors, but also they observe that surprisingly, even in Chile, where intensive industrial agriculture and fisheries are an important part of the economy (in particular with regard to exports) their combined changes (0.013%) are among the lowest.

5-1- Limitations

Our findings in the previous section have to be interpreted with caution as several limitations apply. These limitations which require further research are:

1- We have used a static model for a process that is inherently dynamic in nature. Since we have analyzed the changes in final demands and their further implications, but rather to assess the effects of a sudden reduction of output of petroleum under a specific situation (i.e. potential threat of petroleum embargo, and its ripple effects throughout the economy during a short period of time, static approach secms to be very suitable.

2- Kerschner and Hubacek in their paper allow imports due to the sudden 10 percent output reduction of oil sector. Allowing imports without restriction under a specific situation like economic embargo in our paper which is concentrated in final demands of the constrained sector seems to be meaning less and require further investigation.

3- The main purpose of this paper is to deal with only quantity dimension of the impact of the sudden reduction of petroleum embargo. We are aware that there is also a price dimension which we have not taken into account.

6- Conclusion

The main focus of this paper is to quantitatively assess the impact of the potential sudden shortage of petroleum on the different sectors of the Iranian economy under a specific situation namely petroleum embargo. We have shown that from the methodological point of view, the conventional Leontief and Ghosh's type models are not suitable to deal with such issue. Therefore, a combination of the two models in the framework of mixed variables, supply constrained or mixed models is proposed. Using a 147×147 IO of Iran for the year 2001 and only taking into account the quantity dimension, the vulnerability of non-constrained sectors due to the 40% reduction of petroleum output as a constraint sector has been worked out. Ten most affected sectors have been singled out. For example, while one would expect to find other unclassified fuel products, basic chemical, crude petroleum, other chemical products and also transport sectors to be highly affected, it is very interesting to a see the high ranking of banking, other financial intermediaries, and to less extent agricultural sectors whose links with petroleum are less visible. On the basis of the results we observe that the combined changes of 12 agricultural sub-sectors show relatively higher impacts and appear to be among the 20 most affected sectors.

Notes

[1]- The quota system is different for the nature of transport. For example, the quota system in the last year (2009) was 100 liters a month for each private car, allocated every three months (300 liter). This quota has been reduced to 80 liter per month this year.

[2]- Some of these works are as follows.

[3]- We are well aware of the Dietzenbacher's novel interpretation and application of the Leontief demand-driven and Ghoshian supply-driven models in terms of price models (Dietzenbacher, 1997). These aspects will not be discussed here.

[4]- Gorden, et.al. in their recent article observe that A Google-Scholar search recently found 677000 I-O hits and 87500 hits when the phrase is qualified with the words "economic impact" (Gorden, et.al. 2009).

[5]- The available literature shows that from the modeling point of view, analysts have developed and used three sets of Models:

Mixed IO models, modified mixed IO models and mixed SAM models. In this paper our main concern is to use the first set of models. The second and third sets of models are not discussed here and require a separate effort. For further information and the applications of these models please refer to:

Roberts (1994), Eiser and Roberts (2002), Thorbecke (1998) and Hartono and Resosudarmo (2008).

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