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Sectoral Impacts of an Oil Price Shock: An Updated Input-Output Approach

Recent rise in oil prices once again fuelled fears over country's vulnerability to widening current account gap and rising inflation. The ongoing debate is mostly about "How and to what extent oil price shocks will impact the Turkish economy?" Measuring the impact of oil prices on the overall economy, however, is quite difficult since an accurate quantification of transmission mechanisms is a daunting task.

In this study, we choose to focus on the direct inflationary effects of an oil price shock rather than model the indirect/overall economic impacts. We use the input-output (*IO, hereafter*) analysis to investigate the relationship between oil prices and general price level.

Input-output tables provide the most comprehensive and consistent information on the industrial structure of an economy for a given period. An IO table displays the flows of goods and services between industries/sectors of the economy. For a brief representation of these relationships, please see our earlier Occasional Macro Note: **Thinking Inside the Box: Input-Output**

Unfortunately, the latest IO table belongs to 2002 and therefore should be updated in order to account for developments in the Turkish economy since then. There is a vast literature on IO table updating techniques and we will use a version of the most common method known as Generalized RAS (*GRAS*) approach. The method is developed and popularized by Junius, T. and J. Oosterhaven and displayed in detail in "The Solution of Updating or Regionalizing a Matrix with both Positive and Negative Entries", *Economic Systems Research*, 15, 87–96, 2003.

This approach is well grounded in information theory, and provides a basis on which to solve the problem of adjusting matrices with negative entries. However, the formulated objective function in Junius and Oosterhaven (2003) was later on criticized as an incomplete representation of the *minimum information loss principle*. Therefore, we use an improved version of the objective function as suggested by Huang, W., S. Kobayashi and H. Tanji in "Updating an Input–Output Matrix with Sign-Preservation: Some Improved Objective Functions and their Solutions". *Economic Systems Research*, 20, 111–123, 2008.

We use the following Improved GRAS (*IGRAS*) objective function as suggested by Huang et al. (2008):

$$\textit{Minimize:}\quad f(R)=\sum_i\sum_j\left|IO_{ij}^{old}\right|*\left[r_{ij}*\left(\ln(r_{ij})-1\right)+1\right]$$

We prefer to continue our analysis in the form of a *constrained optimization* model mainly due to lack of data availability which is crucial for the updating procedure. We had to compile the data from various sources, which is a process that introduces incompatibility issues. In order to overcome these problems, we followed a unified approach and combined all the information we gather in a consistent and coherent fashion. The model also has the flexibility property that it is fairly easy to feed newly available information into current structure. We optimize the above nonlinear objective function with respect to the following **feasibility constraints**:

1) $\sum_j z_{ij}^{new}+c_i^{new}+g_i^{new}+i_i^{new}+e_i^{new}-m_i^{new}=x_i^{new}$

2) $\sum_i z_{ij}^{new}+v_j^{new}+t_j^{new}=x_j^{new}$

3) $\sum_i c_i^{new}=C_{new}^{GDP},\sum_i g_i^{new}=G_{new}^{GDP},\sum_i i_i^{new}=I_{new}^{GDP},$

$\sum_i e_i^{new}=E_{new}^{GDP},\sum_i m_i^{new}=M_{new}^{GDP}$

4) $m_p^{new}=m_p^{old}*\dfrac{M_{p,new}^{TRADE}}{M_{p,old}^{TRADE}}\qquad p<i$

5) $\sum_i\sum_j z_{ij}^{m,new}=\sum_i\sum_j z_{ij}^{m,old}*\dfrac{RM_{i,new}^{TRADE}}{RM_{i,old}^{TRADE}}$

6) $\sum v_{j,k}^{new}=\sum v_{j,k}^{old}*\dfrac{V_{k,new}^{GDP}}{V_{k,,old}^{GDP}}\qquad k<j$

7) $\sum_j t_j^{new}=T_{new}^{GDP}$

8) $x_i^{new}=x_j^{new}=x_i^{old}*\dfrac{x_{i,new}^{SURVEY}}{x_{i,old}^{SURVEY}}$

9) $r_{ij}=\dfrac{IO_{ij}^{new}}{IO_{ij}^{old}}\geq 0$

Here, ***IO*** is the Input-Output table for the relevant year. x_i and x_j are the total supply and use figures and represent the total (domestic) production of the sector. Benchmark figures for the updated year are obtained from various sources. Agricultural production values, for instance, are taken from TURKSTAT's *Agricultural Structure* publication. We use *Annual Business Statistics* for the production values of subsectors of Mining, Manufacturing and Services. z_{ij} denotes the inter-industry sales by sector *i* to sector *j*. c_i, g_i, i_i, e_i and m_i indicate final demand categories for sector *i*.

v_j and t_j denote value added and tax-subsidy for sector *j*. ***C*** (consumption), ***G*** (government), ***I*** (investments and stock changes), ***E*** (exports of goods and services) and ***M*** (imports of goods and services) are final demand categories of GDP by expenditures. M_p is total imports of sector *p* and figures are taken directly from trade statistics by ISIC. Since the number of sectors in trade statistics are smaller than that of an IO table, $p<i$. Here, we mainly use mining and manufacturing subsectors.

z^m denotes the import component of intermediate consumption in the IO table. ***RM*** represents imports of raw materials and figures are taken directly from the trade statistics by BEC. V_k is value added of sector *k* and corresponds to relevant categories of GDP by production. Since further breakdown of GDP figures for manufacturing sector is not available, $k<j$. Also taxes-subsidies, ***T***, is taken directly from GDP by production. Finally, r_{ij} is the decision variable and defined as the ratio of new value of each cell in the updated IO table to the old one.

When the statistics obtained from surveys or other sources do not overlap or are not fully consistent with the IO table, growth rates are preferred over raw figures. Moreover, if the information on a certain sector turns out to be insufficient or unreliable, then the corresponding constraint for that sector is loosened. ***New*** and ***old*** correspond respectively to years **2008** and **2002** in this study. Number of sectors used in the analysis is **38** and the full list is given in the **Appendix**.

Our model has **3272** free parameters to be estimated along with **123** equations/identities. The main issue is to minimize the amount of information imposed upon the a priori distribution in order for the adjusted matrix to verify the proposed constraints. Since the objective function is nonlinear, several *global optimization routines* are applied to obtain the best solution.

Once we have updated the IO table so as to represent the inter-industrial relationships as of 2008, one final adjustment is needed in terms of price developments. Domestic and foreign price changes are incorporated into the updated IO table via three ways. GDP deflators, Producer Price Indices (PPI) and unit value indices of imports (*in TL*) are used for the purpose:

$$z_{ij} = z_{ij}^{d} + z_{ij}^{m}$$

$$\frac{P_i^{2010}}{P_i^{2008}} = \frac{P_i^{d,2010}}{P_i^{d,2008}} * \frac{P_i^{m,2010}}{P_i^{m,2008}}$$

$$z_{ij}^{d,2010} = z_{ij}^{d,2008} * \frac{P_i^{d,2010}}{P_i^{d,2008}}$$

$$z_{ij}^{m,2010} = z_{ij}^{m,2008} * \frac{P_i^{m,2010}}{P_i^{m,2008}}$$

$$v_j^{2010} = v_j^{2008} * \frac{P_i^{d,2010}}{P_i^{d,2008}}$$

$$t_j^{2010} = t_j^{2008} * \frac{P_i^{d,2010}}{P_i^{d,2008}}$$

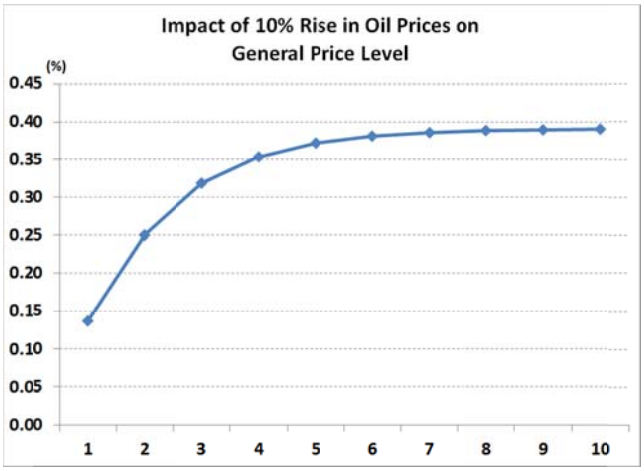
$$x_j^{2010} = \sum_i z_{ij}^{d,2010} + \sum_i z_{ij}^{m,2010} + v_j^{2010} + t_j^{2010}$$

Now we have an updated IO table that has the (estimated) technological structure of 2008 expressed in 2010 prices.

We prefer to use the iteration method rather than the Leontief's inversion method to analyze the effect of oil price increases on the price level of sectors. A similar exercise was carried out by Kibritcioglu, A. and B. Kibritcioglu, 1999: "Inflationary Effects of an Increase in Prices of Crude Oil and Fuel Products (*in Turkish*)", Working Paper Series No: 21, Undersecreteriat of Treasury.

The immediate impact of an oil price shock will be significant on Refined Petroleum (NACE 23) and Electricity-Gas-Water Supply (NACE 40-41) sectors as expected, since imports of crude oil constitute an important share in their production. Other sectors mostly use refined petroleum in the production process and therefore are not influenced by the oil price increases at first stage. However, the sectors that experience a cost increase will carry it forward to other sectors to which they are considered to be a supplier.

After the initial shock, each sector adjusts itself to the cost increase imposed by increasing input prices and the process continues successively until the general price level stabilizes. The chart below depicts the impact of 10% permanent rise in crude oil prices on the general price level. Overall inflationary impact of oil price shock on the economy is estimated as **0.39%**. Convergence is quite high; most of the price changes are observed during first **five periods/steps** and level off after **ten periods/steps**.



Sectoral breakdown of the impact of a10% shock in oil prices by the end of ten periods is presented in **Table-1** in the **Appendix**. Since the relationship is linear, one can calculate the impact of a, say, 20% shock by simply doubling the figures presented in the last column of the table.

The definition of period in this analysis is somewhat ambiguous, since it is difficult to predict the total amount of time required for a given sector to reflect the costs increases in its prices. Therefore, it is generally assumed that the whole impact will accrue within a year.

After ten periods, when the price changes become negligible, the total cost increases in the refined petroleum products and electricity-gas-water supply sectors are estimated to be **4.9%** and **2.6%**, respectively. The inflationary impact on the remaining sectors is quite limited, since all the figures are less than **1%**.

The results might seem counterintuitive or contrary to expectations at first sight. However, the share of crude oil and natural gas in Turkish production is not as high as it is commonly believed to be. Second column of **Table-2** in the **Appendix** presents share of imported raw materials in total intermediate consumption. The third column shows the share of raw materials received from crude petroleum, natural gas sector (NACE 11), coke, refined petroleum products sector (NACE 23) and electricity, gas, water supply sector (NACE 40-41) in total intermediate goods. A given figure in the third column can be considered as a proxy for the **energy usage** of a sector in its total raw material requirement.

The analysis implicitly assumes that the increase in oil prices is reflected in imports of Crude petroleum and natural gas sector. IO methodology only measures the direct impact in terms of cost increases and therefore does not account for the indirect effects that may be. Still, the analysis provides a sound and reliable basis for possible cost effects of oil price shocks on general economy with a disaggregated approach as its point of departure from other methodologies that are by nature more macro and thus aggregate.

APPENDIX

Table 1. Impact of 10% Shock after 10 periods/steps

NACE	SECTOR	T+10
1-5	Agriculture	0.18%
10	Coal and lignite	0.16%
11	Crude petroleum and natural gas	0.13%
13	Metal ores	0.31%
14	Other mining and quarrying	0.17%
15	Food and beverages	0.21%
16	Tobacco	0.26%
17	Textiles	0.48%
18	Wearing apparel	0.28%
19	Leather and leather products	0.26%
20	Wood and products of wood	0.56%
21	Pulp, paper and paper products	0.68%
22	Printed matter and recorded media	0.36%
23	Coke, refined petroleum products	4.92%
24	Chemicals, chemical products	0.59%
25	Rubber and plastic products	0.62%
26	Other non-metallic mineral products	0.50%
27	Basic metals	0.41%
28	Fabricated metal products	0.29%
29	Machinery and equipment	0.23%
30	Office machinery and computers	0.08%
31	Electrical machinery and apparatus	0.28%
32	Radio, tv and communication equipment	0.15%
33	Medial, precision and optical instruments	0.22%
34	Motor vehicles, trailers and semi-trailers	0.24%
35	Other transport equipment	0.22%
36-37	Furniture, other manufactured goods	0.20%
40-41	Electricity, gas and water supply	2.61%
45	Construction	0.29%
50-52	Wholesale and retail trade	0.07%
55	Hotel and restaurants	0.26%
60-64	Transport, storage and communication	0.11%
65-67	Financial intermediation	0.10%
70-74	Real estate, renting and business activities	0.16%
75	Public administration	0.17%
80	Education services	0.10%
85	Health and social work services	0.39%
90-95	Other services	0.23%
	TOTAL	**0.39%**

Table 2. Shares of intermediate goods

SECTOR	z^m/z	$z^{11+23+40+41}/z$
Agriculture	7.1%	9.5%
Coal and lignite	14.7%	25.1%
Crude petroleum and natural gas	5.7%	19.2%
Metal ores	10.4%	23.1%
Other mining and quarrying	9.6%	21.0%
Food and beverages	5.7%	2.3%
Tobacco	20.5%	1.7%
Textiles	22.6%	8.6%
Wearing apparel	14.9%	2.7%
Leather and leather products	35.8%	4.9%
Wood and products of wood	24.1%	8.9%
Pulp, paper and paper products	22.8%	15.3%
Printed matter and recorded media	16.2%	5.4%
Coke, refined petroleum products	61.7%	82.7%
Chemicals, chemical products	25.7%	5.9%
Rubber and plastic products	29.4%	8.5%
Other non-metallic mineral products	14.1%	16.2%
Basic metals	29.0%	10.6%
Fabricated metal products	21.1%	4.8%
Machinery and equipment	24.8%	4.7%
Office machinery and computers	54.7%	0.5%
Electrical machinery and apparatus	26.0%	4.6%
Radio, tv and communication equipment	49.6%	1.5%
Medial, precision and optical instruments	36.7%	2.2%
Motor vehicles, trailers and semi-trailers	27.7%	2.6%
Other transport equipment	21.6%	4.8%
Furniture, other manufactured goods	43.4%	1.4%
Electricity, gas and water supply	24.3%	82.7%
Construction	11.7%	7.7%
Wholesale and retail trade	8.1%	7.2%
Hotel and restaurants	3.7%	9.9%
Transport, storage and communication	8.1%	9.8%
Financial intermediation	2.9%	4.2%
Real estate, renting and business activities	7.2%	4.9%
Public administration	5.2%	9.6%
Education services	5.9%	16.3%
Health and social work services	7.3%	6.9%
Other services	5.5%	5.7%
TOTAL	**15.2%**	**12.8%**

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