Iran. Econ. Rev. Vol.19, No.1, 2015. p.107-122

Trade-based technology transfer and Its Impact on the Iranian Economy: Using a CGE model

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Received: 2015/01/05 Accepted: 2015/10/12

Abstract

The purpose of this study is to evaluate the impact of import of technology on Iranian Economy. We have used multi-sectoral and multi–regional computable general equilibrium GTAP model. Transfer of technology from one region to another is another factor effecting productivity. Trade is one of the channels that speeds the transfer of technology. The effect of a ten percent productivity shock, in high-tech industries of industrial countries have been tracked on economic sectors of Iran. The result show that productivity of high technology industrial sectors in Iran has increased by 3.6%, GDP has increased by 0.52%, while inflation decreased by 1.19% in the Iranian economy. The findings also include increases in real sectoral outputs and decrease in the imports.
Keywords: CGE Model Iran, GTAP, Technology Absorption, Trade-Based Technology Transfer.
JEL classification: O4, O33, D58, D28, C68

1. Introduction

Taking into consideration the scarcity and high costs, of inputs, instead of increasing the consumption of stocks and new investments for production and economic growth, every country try to concentrate on available inputs, increase efficiency and productivity and utilize its existing capacity optimally (Shimizu, 1997). Improvement of methods and techniques is of immense importance. According to the new growth theories, technology is considered to be a public goods which is transferred among countries with low prices (for example: Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991). Technology is transferred to developing countries through exports of the intermediate and capital goods or by way of foreign direct investment (FDI) (Coe, et al., 1995). The effects of transfer and spillover of

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technology in the economies are generally studied by CGE model (Van Meijil and Van Tongeren, 1998; Das and Powell, 2000) and or GTAP model (Das, 2011). In this study we have followed Van Meijl and Van Tongeren (1999), assuming that technology is transferred from source to a target country by the way of importing intermediate goods and transfer of technology. Evaluating the effects of technology transference is done by GTAP model which uses a multi-sect oral and multi-regional CGE model. Moreover, the role of absorption capacity and structural similarity has been considered as two effective factors on transfer and spillover of technology in an empirical model. After this introduction, we shall discuss transfer channels and spillover of technology, in the section three we shall introduce multi-regional general equilibrium GTAP Model**,** in section 4, Methodology and Data are discussed**.** Analysis of findings is presented in section 5 and finally in section 6, we shall conclude our discussion.

2. Transfer Channels and spillover of technology

While the importance of technology transfer from developed to developing countries are very well recognized, the important issues in this regards are transfer channels and its spillover in the economy of receiving technology. It is generally believed that there are three known channels through which technology can be transferred. These basic channels are: international trade, foreign direct investment and licensing (e.g. Keller, 2004). We shall explain below, these three transfer channels briefly.

2.1. International trade

In new trade theories, international trade play a significant role in the technology transfer to receiving countries .It is argued that, international trade enables a country to use different kinds of intermediate and capital goods as required for its production and increase its productivity. It is also an important source of learning technology, Production and organizational methods and marketing. Countries may import technical equipment for producing new and innovative goods. Import of modern technology help technological development and spillover leading to increase in productivity and efficiency (Coe and Helpman, 1993; Ethier, 1982; Markusen, 1989; Grossman and Helpman, 1991). Countries can gain from international trade not only through imports but also through exports, where to compete in international markets, exporters are forced to reduce costs and increase their quality. Also exporters can gain through “learning by exporting” (Greenway and Kneller, 2007).

2.2. Foreign direct investment

Foreign direct investment is not only help transfer of technology but also managerial skills and technical knowledge. Spillover of technology from foreign firm residing in host country to the rest of the economy can occur horizontally and vertically. Horizontal spillover refers to a process during which technical knowledge spillovers from foreign firms to the rest of the economy. The inflow of foreign firms may cause technologically side effects for the domestic firms. Using new technologies by multi-nationals firms and imitating it by domestic firm is an important technology transfer channel (Wang and Blomstrom, 1992). Adopting new technology by domestic firms may be slow due to high costs and risks and uncertain result. However, observing the success of multi-nationals in using new technology persuades domestic firms to imitate it (Krespo and Fentora, 2006). Teaching by foreign firms to domestic and local firms is the second channel of the technology transfer (Meyer, 2003). Thirdly, competition resulting from presence of foreign firm, may force domestic firms to adopt better technology, increase their productivity and efficiency and reduce their costs. If foreign firms have better technology than the domestic one, competition pressure of foreign firms can force domestic firms to improve quality of goods use new management methods to increase their market shares. However, competition may have negative effect on local firms if it leads to crowding-out domestic investment (Damijan et al., 2007).

Exports of multi-national firms are another channel from which multi-national firms can be beneficial for the domestic firms. We know that exports require good infrastructure, distribution network, advertisement i and marketing research. The mentioned costs may be lesser for the multi-national firms because of their knowledge and experience in foreign markets. These worthy information and benefits can spill over to the domestic firms. In other words the domestic firms can gain familiarity with the international markets. The existence of big multi-national firms with good international trade networks and recognized reputation in international markets can help domestic firms to overcome their information deficiency and barriers on foreign markets.

Vertical spillover is the result of inter-industry linkages. Inter-industry linkage refers to the connection between foreign and domestic firms. Vertical productivity spillover can occur through forward and backward linkages.

Backward linkages occur when foreign firms in the downstream industry demand raw and intermediate goods from the domestic firms of upstream industries. Providing these inputs by domestic firms increases the competition among active domestic firms. Producing intermediate input for multi-national firms mostly requires high technical knowledge and transfer of updated technology. These requirement, forces the domestic firms to increase their skills and technology and update and adapt their technology accordingly (Javorcik, 2004). Meyer (2003) explains that backward linkages may increase the spillover of technology to the domestic firms from different channels. Firstly, domestic firms because of buying intermediate goods and machineries from foreign firms can produce higher quality and cheaper products. Secondly, foreign direct investment in infrastructures and trade services increase domestic producers' productivity. Thirdly, domestic firms may receive services in the form of teaching and learning in the field of selling techniques from foreign firms.

2.3. Licensing

Firms can acquire technology via licensing contracts from abroad. Licensing includes buying the product and property right for one commodity and goods and the required technical information and knowledge for its production (see Markusen, 1995; Dunning, 1993). Patent grant of technology, allows countries to access the developed technology, quickly and cheaply. Importing Technology is relatively easier than developing a new one, because developing a new technology, requires technological mastery while its importing doesn't need it. (Westphal, 1982). Lall (2000) is of the view that that the imported technology provides the most important primary input for the technological learning in developing countries. Therefore according to him, imported technology is crucial for technological progress. Patent grant can benefit the concessionaire and also other firms in the country. Westphal (1982) has shown that mastery in one technology causes the increase of the productivity but most of its effects spill over to the related activities. However; most technologies are not accessible through licensing. The important reason of firms which acquire their most technology through other methods is that they want to overcome the problems of writing and implementing the patent grant.

3. Introduction of multi-regional general equilibrium GTAP Model

General equilibrium models covere the whole economy in its multi-sectoral form. They give the axial role to the prices systems. These characteristics differentiate it from other types of modeling, including the whole economy input-output modeling (McDougall, 1995). Multi-regional general equilibrium models are preferred to other models including regional general equilibrium model because of its advantages: It is able to help understanding the linkages among sectors, countries and production factors in the global scale. It, therefore, shows that any changes in one of the parts of the system have consequences for the whole parts and countries. In other words implementing any policy or causing a shock in any part of the system affect the whole economy. Through its backward and forward linkages (Fracois et al., 1997). Since it is generally believed that technology transfer and spillover, it can affect other regions and sectors through linkage among sectors and economic factors and also linkage of different regions. Therefore, GTAP multi-regional model is a suitable choice for measuring the effect of spillover of foreign direct investment in Iran.

GTAP model is the static model and does not include any effects of dynamic technological changes, population growth and capital. Behavioral activities and its inter-sectoral and interregional exchanges consist of two basic equations: accounting relationship and behavioral equations. Accounting relationship included data in matrix table of social accounting and input-output; and behavioral equations represent the behavior of economic factors in the model which is related to production, consumption, savings and regional investment. Its mathematical model consists a set of nonlinear equations which has been extracted from the theory of microeconomics maximization by Dugan’s model and accounting relations. Every region consists of four economic factors: representative regional household, private household, government and firms. Regional household is the owner of primary factors of producing firms. Income of regional household is value added of production factors plus different kinds of taxes and tariffs which the allocation of these incomes to savings, private household and government occurs according to a cob-Douglas function. Government and private household buy their required goods and consumption services from domestic and foreign markets by receiving income from regional household. Private household demands investigated according to the functional form of “constant difference elasticity function” following Hanoch. Therefore, private household demands have a non-homothetic shape meaning thereby that the proportion of cost of different goods will not be fixed in household budget as income changes. The function of consumable demands of government is extracted by utility function of Cobb-Douglas form showing that the relative cost of different goods is fixed. Firms use intermediate goods and primary inputs such as work force, capital, labor and natural resources for producing goods and services and by combining these factors produce different kinds of goods and services. There are five production factors: labor, master work force, non-master work force, capital and natural resources. All elements except labor and natural recourses have full mobility among different sectors but none of the production factor is tradable i.e. do not have international mobility. All inputs have fix supply and full employment. Every sector or agency in economy produces a homogeneous output. The goods are sold within and out of every region. It is based on the assumption of perfect competition and constant return to scale in all goods and markets. According to standard closure of GTAP model, production of all sectors, labor, work force, capital, natural resources and all prices identified in the framework of a model i.e. they are endogenous. Two global sectors such as global transportation and banking are the completing our accounting relationship and regional equilibrium. Transportation sector is the compiler of services value which is the index of differences between CIF and FOB prices for different goods in different ways of transportation. This sector plays an intermediary role between supply and demand for international transportation services. Global banking is also an intermediate factor between global investment and savings. Therefore, if all markets are in equilibrium, all firms have zero benefit condition and equilibrium occurs on budget constraints, according to Walras savings should be equal to investment.

Since this model is not the periodic, investment does not affect the production capacity of economic sectors, but in later periods; changes in investment affect production through affecting final demand. Investment and savings level are assumed to be equal. I.e. macroeconomic closure in this model has neo-classical or saving driven closure rule. Since in behavioral function of regional household, demand system forms according to Cobb-Douglas function, saving is the constant portion of regional household income and uses for the financial support of net investment in every region. Numeracies in GTAP model is the index of global price of production factors which as usual is exogenous and the weighted average of the price of production factors in the whole regions. It should be noted that according to the kind of research different macro-closure can be assumed. Finally, solving of the model is in the form of percentage changes and all calculations have been done by GEMPACK software, following Harrison and Pearson (1996).

4. Methodology and Data

In this study we have used social accounting matrices and7th GTAP databases to examine different scenarios. Countries were aggregated into 6 Regions: European and North American countries (region one), Iran (region two), Turkey (region three), China and India (region four), south-eastern and eastern Asian countries (region five) and the rest of the world (region six). We have used European and North American countries in one group to show their relative superiority in technology and the high-tech export industries. We have also aggregated economic sectors in all regions into five sectors such as agricultural, mine, high technology industries, other industries and services. Land, labor, capital and natural resources are our factors of production.

4.1. Production technology in the GTAP model

Figure 1, shows technology tree in GTAP model. In the upper part of the figure, intermediate inputs and combination of factors of production are shown assuming Leontief technology (fixed technical coefficients). In the next stage the agency extracts the optimal demand of foreign and domestic intermediate goods by a function of constant elasticity of substitution (Armington, 1969). The main advantage of Armington assumption is that complete specialization in producing a commodity by every country is impossible. It should be noted that one of the main problems of earlier models in global trade is the assumption of complete specialization of every country in producing a commodity (Whalley, 1985). In the third stage, on the one hand firms gain optimal demand of the primary factors by solving the minimizing cost by a value added function with constant elasticity substitution. On the other hand, every agency extracts the optimal demand of foreign intermediate goods by a function with constant elasticity substitution. Since this article is about investigating the effects of the present spillover of technology through the imported intermediate goods and the resultant spillover appears in the coefficients of firms' technology as an increasing productivity. Suppose the optimal combination of every kind of foreign intermediate goods is resulted from the following objective function:

$$QF_{j,s} = AF_{j,r}\left(\sum_{r=1}^{R}\delta_r\left(QFM_{j,r,s}\right)^{-\rho_f}\right)^{-\frac{1}{\rho_f}} \tag{1}$$

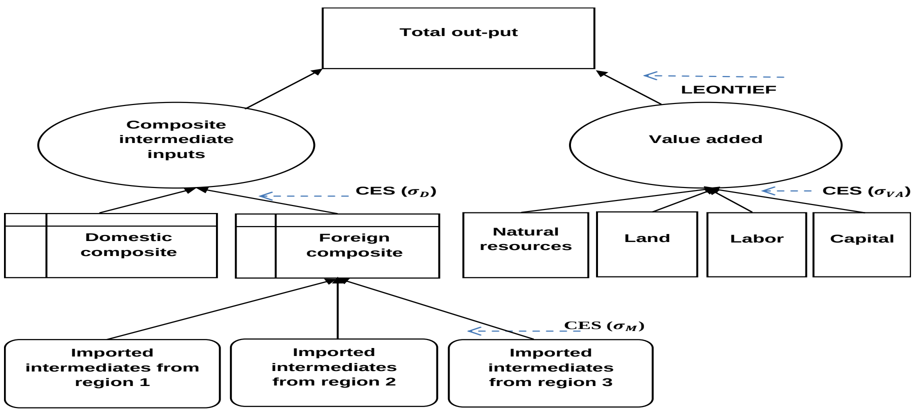

Figure 1. Technology tree in GTAP model

Source: (Hertel, 1997)

$AF_{j,r}$ is the technology coefficient of j intermediate commodity in region r, $QF_{j,s}$ is the combined intermediate commodity in region s, $\$$ are distribution parameters, PF is substitution parameter and *QFM*(*i*,*j*,*s*) is the j imported intermediate demand of region r in region s. Elasticity of substitution is fixed among different producing factors and is equal to $\sigma_M = \frac{1}{1+\rho_f}$. In this article it is assumed that the growth rate of $AF_{j,r}$ in the counterfactual equilibrium equals to 10 percent i.e. the main purpose of this article is to investigate what happens if technology coefficient of j intermediate commodity which moves from r to s region changes about 10 percent, what effect it will have on s region.

4.2. Technology Spillover and shocks Transmission channels

In this study we try to examine the impact of a 10% improvement of technology in high-tech of Northern America and European countries on a country such as Iran. In other words the main question is that if 10% improvement of technology occurs in high-tech industries of Northern

America and European countries, what effects will it has on other regions like Iran. Here we have taken High-tech industries for two reasons: firstly, this sector has high potentiality for technical improvement as compared to other sectors, so that it can have considerable effect on other sectors using it as intermediate goods. Secondly, the proportion of imports of high technology intermediate goods used by domestic sectors are relatively high, for example it is 35% in agriculture, 94% in mining sector, 33% in light industry, 90% in heavy industry and 81% in services. Therefore, it seems that imports of high tech intermediate goods provide an important channel through which technology can be transferred from of developed countries to developing countries such as Iran.

Since imports of high technology intermediate goods from region one was the highest, so in this study we have taken this region as the main source of technology transfer to other regions. Thus if a technology improvement takes place in this region, it will spread to the whole economy of this and other regions via its inter-sectoral linkages and also through international trade (linkage 3). In our model technology coefficient are considered endogenous in region one and exogenous in other regions.

4.3. Modeling process of technology transfer and shocks Transmission

Productivity parameter in spillover equations are exactly related to production function in the GTAP model. Production structure in the GTAP model can be illustrated as follow:

$$Y/A_o = min\left[AF_{i1}Q_{i1},\ldots,AF_{in}Q_{in};QVA\right] \tag{2}$$

in which Y indicated production, Q_{ij} intermediate goods and production primary factors composite or value added function of QVA. A_0 Parameter is Hickian neutral technological coefficient in production function and $AF_{i1},\ldots,AF_{in}$ are the input- output coefficients. Technological improvement via change in AF coefficients will be modeled. According to Van Meijl and Tongeren (1997) technological change in a country can be related to other countries change, endogenously. Which will appear in terms of change in technology coefficient of every intermediate goods (in Equation 1)? Spillover of trade can be shown by Equations (3) and (4) which relate productivity growth between destinations and sources of technology.

$$af_{ijs} = E_{ijrs}^{1-\delta_{rs}}.af_{ijr} \tag{3}$$

$$\gamma_{rs}\left(E_{rs}, \delta_{rs}\right) = \frac{af_{ijs}}{af_{ijr}} = E_{irs}^{1-\delta_{rs}} \tag{4}$$

af_{ijs} is growth rate of technology of I intermediate goods used by j sector in the destination region and af_{ijs} is growth rate of technology of I intermediate goods used by j sector in the source region. E_{ijrs} is the amount of embodied knowledge existed in i produced intermediate goods in region r which is exported to j sector of region$s$ which can be illustrated in the following relation:

$$E_{irs} = \left(\frac{M_{ijrs} / Y_{js}}{M_{ijrr} / Y_{jr}} \right) \tag{5}$$

in which M_{ijrs} is imports of i input from r region used in j sector of s or destination region, M_{ijrr} is domestic input of i used in j sector of r region, Y_{is} production of i part in s region and Y_{ir} production part of j in r region. The denominator in relation 4 indicates stock destination and sources coefficients from i innovator in producing j activities of the source country. The numerator in relation 4 indicates imported stock receivers and senders coefficients from i innovator in producing j activities in the target country. Therefore the equation of productivity growth in the target region can be as follows:

$$af_{ijs} = \left(\frac{M_{ijrs} / Y_{js}}{M_{ijrr} / Y_{jr}} \right)^{1-\delta_{rs}} .af_{ijr} \tag{6}$$

The basic point of the effects of trading technology spillover is that the adjustment competence and the ability of using the imported technology depends on absorption capacity of the destination region (Kohen and Levinhal, 1989) and also structural similarity between trading partners (Hayami and Ruttan, 1985). Not only the amount of imported technology but also its effective utilization in the importing country is of great importance. In other words the host country should have absorption capacity of technology and structural similarity with the country of the origin to be able to adjust its production process appropriately for adapting imported technology. In the following sections we shall elaborate on the methods of incorporating these variables in the model.

4.4. Absorption capacity index

The aim of this part is to relate absorption capacity of the destination region (h_s) into absorption capacity of the source region (h_r). Therefore the following relation has been used:

$$AC_{rs} = min\left[1, \frac{h_s}{h_r} \right] \tag{7}$$

The lower the human capital in the destination country compared to the source, the more difficult the process of absorption of new and foreign technology will be. For evaluating the amount of absorption capacity, human capital has been used as an index for competence and ability of absorption of technology by the destination country. The index of Barro and Lee (1993) which is an average of education years in every country or region has been used in this research.

4.5. Structural similarity index

Structural similarity relates to the similarity in the ratio of productions' factors between destination and source countries (Das, 2011). The rate of technology absorption and new knowledge by the destination country depends on the difference in this index. The index presented by Meijl and Tongern (1997) for structural similarity between destination and source countries is as follows:

$$SS_{rs} = exp\left[-\left|\frac{(I_r - I_s)}{d\,max}\right|\right] \tag{8}$$

I_s and I_r indicates structural characteristics in destination and source countries (Das 2011) and *dmax* is an absolute magnitude of maximum distance between I_s and I_r of destination and source countries. Meijl and Tongeren (1997) used index from the ratio of land to labor force while Das and Pawel (2000), and Das (2002, 2011) utilized the ratio of capital to labor force.

4.6. Interaction between structural similarity and absorption capacity indices

Having either high absorption capacity or structural similarity alone in a country of receiving technology may not be enough for the spillover of technology. Not only must a country be able to utilize new knowledge effectively, but also both structural similarity as well as high absorption capacity is required for successful technology transfer. Thus, Meijl and Trongeren (1997) incorporated these two variables into the technology spillover model (Figure 2).

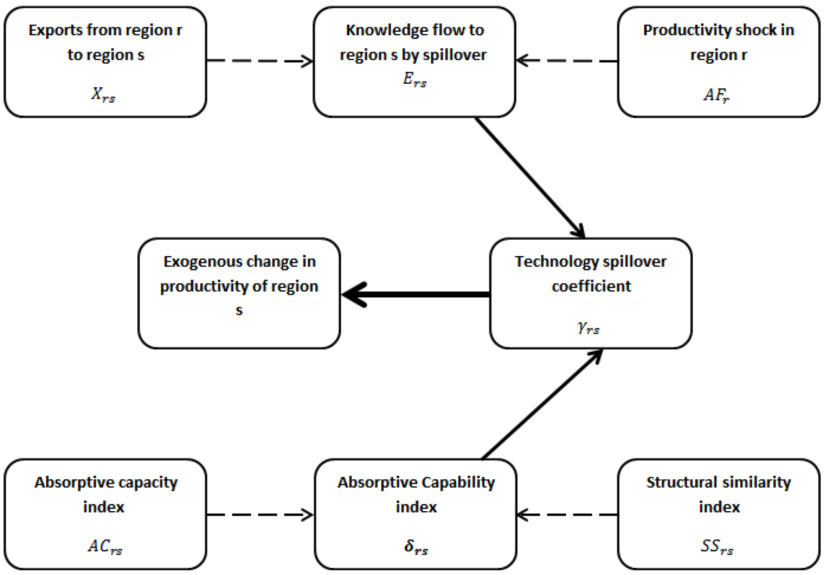

Figure 2.

Source: Authors

4.7. Summary of indices by region

For identifying the amount of absorption capacity and structural similarity, to identify the power of adaptation of foreign technology in every region, the numerical value of different indices has been presented in Table 1.

Table 1. Summary of Indices by Region

	Structural similarity index	Absorption capacity	Barro-Lee index	M_{ijrs}/Y_{js}	Effectiveness
Region 1(North America)	1	1	11.4	----	1
Region 2(Iran)	0.72	0.75	8.6	0.09	0.55
Region 3 (Turkey)	0.82	0.61	7.01	0.15	0.5
Region 4 (China and India)	0.37	0.58	6.64	0.041	0.22
Region 5 (East Asian)	0.99	0.81	9.2	0.043	0.8
Region 6 (Rest of the World)	0.59	0.59	6.8	0.071	0.35

Source: Research Findings based on data from Statistical Centre of Iran, Statistical Yearbook, Various Issues and Central Bank of Iran, Annual Reports and Balance Sheets Various Issues

The second column of above table shows the imports of high technology intermediate goods by every region from region one. It is assumed that region one is the main source of technology transfer to other regions. As an example the proportion of imports of high technology intermediate goods in total production of j sector in Iran equals to 0.09. The numerical value of the index of absorption capacity has been extracted by using relation “6” and the index of structural similarity by using relation “7”. The effectiveness indexes which are the product of structural similarity and absorption capacity of each and every regions are also shown in the table.

5. Empirical results

We have examined the impact of technological spillover and shocks of a 10 percent improvement in high-tech industries of North American and European countries, on other regions specially our emphasize has been on Iran. For having a vivid picture of the absorption capacity and the ability to adjust to foreign technology in every region, the numerical value of various related indices are depicted in table 2.

Table 2. Summary of Indices by Region

Indices	Absorption capacity Index	Structural similarity Index	Effectiveness Index
Region 1	1.0	1.0	1.0
Region 2	0.75	0.72	0.55
Region 3	0.61	0.82	0.5
Region 4	0.58	0.37	0.22
Region 5	0.81	0.99	0.8
Region 6	0.59	0.59	0.25

Source: Research Findings based on data from Statistical Centre of Iran, Statistical Yearbook, Various Issues and Central Bank of Iran, Annual Reports and Balance Sheets Various Issues

The numerical value of the absorption capacity index has been estimated by using relation 6 while that of structural similarity from relation 8. The effectiveness index as defined by the product of absorption capacity and structural similarity is also estimated and presented the result in table 2. Assuming as before that region one is the main source of technology transfer to other regions. It can be seen that despite the fact that Iran's effectiveness index is better than Turkey, since import of high-tech intermediate goods is higher in Turkey than in Iran (0.15 in comparison to 0.09), therefore the effectiveness of Turkey is higher than Iran, the impact of a 10% improvement of the productivity of high-tech industries in the first region leads to relatively higher productivity growth in Turkey than Iran, the percentage change was 4.4 and 3.6 respectively. In order to understand better the impact of technology spillover and shocks on Iranian economy, we have calculated this impact and presented the result in table 3.

Table 3. Sectoral Responses of Iranian Economy to a 10 Percent Exogenous Technological Shocks

	Prices	Production	Exports	Imports
Agriculture	-0.47	1.35	2.52	-2.82
Mining	-2.35	1.11	-1.17	-1.27
High-tech	-3.88	0.94	0.28	-3.65
Others	-1.01	2.17	3.23	-1.56
Services	-0.97	0.255	10.9	-4.75

Source: Research findings based on data extracted from statistical center of Iran and Central Bank of Iran various issues.

It is expected that technological improvement lead to decline in prices and increase in output of not only the sector concerned but also to other sectors through spillover and intersectoral linkages, both at home and abroad. Thus, improvement of productivity in advanced countries leads to production increase and supply of goods in various sectors especially in sectors and industries of receiving countries having high imported intermediate goods. This in turn leads to increase in output and supply and fall in prices. As productivity improvement occurs in high technology industries, the highest percent of price change is also happens within that sector. Our result show that this in the case of Iran result in increase in production and reduction of prices in almost all sectors and industries. For example output of high tech industries increase by 0.94 percent while prices in this industry decline by about 3/88%. Other sectors will also have different price reduction depending on their proportion of intermediate imports with high technology. Production also has experienced sharp increase in almost all sectors. These changes enhanced Iran s competitiveness as shown in table 2. With the decrease of prices the power of compatibility increases, which ultimately leads to increases in exports and decreases in imports in different sectors. As more production needs more intermediate goods, it is expected that with more production imports would increase in different sectors. In addition there is a considerable fall in prices. Altogether, the effect of price decrease is more than the effect of production, and as result import is faced with considerable decrease.

6. Conclusion and Policy Recommendations

The purpose of this study has been to investigate quantitatively the possibilities and effects of technology transfer through the imports of intermediate goods from developed to developing countries with the main emphasize on Iranian economy. For this purpose we have used a CGE model. The results show that a hypothetical technology improvement in intermediate goods industries of advanced trade partner will have positive effects in productivity improvement of Iran through its intermediate imports. Our findings show that technology transfer embodied in Iran's imports of intermediate goods leads to increase in outputs and decrease in prices. Factors such as absorptive capacity, structural similarity and effectiveness were contributed to these spillover effects of technological improvements in Iran. Despite positive spillover effects of technology imports, its extent, however, was limited mainly because of relatively small shares and fluctuations of intermediate imports. These results indicate that Iran has high potentiality for increasing its imports of intermediated goods.

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