Study on import price transmission with time lag based on non-competitive input-output model

Abstract: With the deepening of China's integration into the global value chain, the transmission of price fluctuation of imported products has become an important part of the industrial economic research, while traditional research methods cannot reflect the time lag in price transmission. This paper established a non-competitive input-output price model and measured the biggest potential impact of price changes of imported products on the prices of various sectors in China based on the Chinese input-output table of 2012. Furthermore, by introducing the factor of production time lag, this paper gave the discrete state iterative equation of import price transmission. Results show that the import prices of mining and electrical and electronic sectors have the highest influence on the domestic market, and the degree of influence is distributed on the timeline. Also, some policy suggestions were discussed accordingly.
Keywords: price transmission, non-competitive input-output model, time lag

I. Introduction

Currently, the international industrial division of labor is deepening and the global economy is integrating through various channels such as international trade, foreign investment, and technological cooperation. At the same time, the degree of interdependence and mutual influence of all major economies is deepening along with the cooperation. In 2017, the value of China's import and export of goods totaled 27.79 trillion yuan. China's foreign trade has gained opportunities and development, and its international competitiveness has significantly enhanced, but is also more vulnerable to the external environment of global economy and faced with more serious challenges. As China continues to deepen the degree of integration into the global value chain, one of the important issues to be concerned about is the international price transmission between industrial sectors—the price fluctuations of imported products may directly affect the level of domestic prices.

In the national economy, the fluctuation of product price of each sector will transmit through the upstream and downstream relationship of the production chain, causing price changes in related sectors. This price transmission mechanism works for import products too, which is an important part of the economic research and the focus of the government to prevent inflation and conduct economy regulation. Today, China is still in the mid-to-late stage of industrialization, and its dependence on imported products has been persistently high, especially large commodities such as crop, oil and mineral resources. As basic material support in the new industrial transformation stage, the import volume will still remain high for a long time. When the prices of these imported products fluctuate, it is likely to cause price changes in the domestic sectors and even instability of the domestic economy as a whole. The risk of resource supply will still exist for a long period of time. If we can understand the role of various imported products play in the domestic economic system and the rules of their operation, so as to monitor and predict the impact of imported products on domestic prices, we will be able to provide effective guidance for the formulation of various economic policies.

From the beginning of global economy integration, there has been literature focusing on the impact of external shocks on the domestic price level. Phillip Cagan studied the inflation in the United States from 1973 to 1974 and argued that "the rise in prices in the US in the mid-1970s was mainly attributed to foreign shocks"(Cagan, 1978). Through literature review, we find that econometric and time series methods are more focused on analyzing the impact of commodity price fluctuation on the macro price index. For example, Minot used Error Correction Model to analyze the price conduction of food prices in African countries (Minot, 2010). Gao L et al. used VAR model to estimate the effect of international oil price shocks on the price index of various sectors in the United States (Gao et al., 2014). The input-output method, proposed by the American economist W.W. Leontief (1986), can fully reflect the links between various manufacturing sectors in the economic chain. Based on its advantages in the analysis of production structure, it can reflect the variation of price in various sectors in addition to the overall price level, therefore suitable for the study of price calculation, price impact and ripple effect (Chen et al., 2011).

Since Leontief proposed the first cost-price structure price model in 1947, the research on the application of input-output technology to price conduction has gained considerable development, both in the expansion of the model itself and the perspective of research. Hawkins (1948) first proposed the dynamic input-output price model, where the price of the commodity equals to its current production cost plus the cost of new capital needed. Bazzazan et al. (2003) established an extended partial-closed input-output price model based on previous studies, which included the income of the resident sector (salary). Zhang (2008) made a further improvement with the model and introduced the two new variables, the influence of supply and demand and the government regulation. Valadkhani et al. (2002) made oil price exogenous, simulated the impact of its increase on Australian price indices and compared the results of the 1970s and 1990s.

In the classic input-output price model, some factors are not taken into accounts such as the elasticity of demand, the time lag of transmission and the hedging of the profits, so the calculation results are often referred to as the biggest potential impact. Nonetheless, the impact of import price change is not instantaneous, but through layers of transmission between sectors on the industrial chain, which causes the responses of each sector happening in sequence. Therefore, the regulation of the government should take into account the time lag of such price transmission, and pay more attention to timeliness and pertinence, especially when the prices of international import products fluctuate greatly in a short time. The traditional input-output method cannot deal with the time lag in price transmission between industries. Tong (2010) established a time-lag price transmission model by introducing the price response period; Wang et al. (2011) constructed the price transmission network model with the introduction of temporal dimension; Xu et al. (2011) introduced the price viscosity theory and constructed an input-output price viscosity model; Shang (2017) used the discrete state equation to establish a time-lag price transmission input-output model. However, there is no calculable and concise model for the import price transmission with the time lag.

In addition, most of the input-output tables used by scholars on this issue are competitive, with no distinction between domestic and imported intermediate use. In order to study the influence of price fluctuation of imported intermediate products on domestic prices more precisely, this paper established a non-competitive input-output price model using customs trade data. The remainder of this paper is organized as follows: in section 2 we deduce the formula for the domestic transmission of import intermediate price change in non-competitive input-output price model and calculate the biggest potential impact of a price increase of 10% of each imported intermediate product on various sectors in China. In section 3 we expand further by using iterative discrete state equations to construct a price transmission model with the time lag and measure the impact of import intermediate price change on domestic price on the timeline. The results of the two parts both have some practical significance.

II. Static analysis on import intermediate price transmission

1. Non-competitive input-output import price model

We use trade data to break up the intermediate flow in the competitive IO table into the use of domestic products (with the superscript D) and imported products (with the superscript M), thus obtaining the non-competitive input-output table, as shown in Table 1.

Table 1 Non-competitive input-output table

		Intermediate use	Final demand	Total output (Total import)
		Sector1 Sector 2 ⋯ Sector n		
Domestic input	Sector 1	Z^D	F^D	X
	Sector 2			
	⋯			
	Sector n			
Imports	Sector 1	Z_1^M	F^M	X^M
	Sector 2	Z_2^M		
	⋯	⋯		
	Sector n	Z_n^M		
Value added		V'		
Total input		X'		

From the input (vertical) perspective, the non-competition table does not change the total input of each sector but differentiates the domestic product and the imported product in the input structure. The column equation of the table is

$$e'Z^D + \sum_i Z_i^M + V' = X' \tag{1}$$

We set up the price impact model based on the non-competitive input-output framework to learn the influence of the price change of an imported product on the price of all domestic products from the perspective of the production cost of each sector. Assuming that the price of the imported product of the ith sector goes up by ΔP_i^M, under the condition that the production technology does not change, the cost of unit production value in the jth sector will rise by $\Delta P_i^M a_{ij}^M$. If the costs rising are fully conductive in the production system, the price increase of each sector of the domestic market is: $\Delta P = \Delta P_i^M \cdot A_{i\bullet}^M + \Delta P \cdot A^D$, in which $A^D = Z^D \cdot \hat{X}^{-1}$ is the direct consumption coefficient matrix of domestic products, and $A_{i\bullet}^M = Z_{i\bullet}^M \cdot \hat{X}^{-1}$ is the consumption row vector of each sector of the ith sector imports per unit output. The simplified equation is:

$$\Delta P = \Delta P_i^M A_{i\bullet}^M (I - A^D)^{-1} \tag{2}$$

It can be seen from the equation that the fluctuation of domestic price depends on the range of import price change, the direct consumption coefficient of imported goods, and the domestic product's Leontief inverse matrix. Since the direct input coefficient and Leontief inverse matrix reflect the current production technology level and remain short-term stable, therefore the price of the imported product determines the prices of domestic products.

In addition, the impact of price changes of different types of import intermediate on domestic products is directly related to the direct consumption coefficient of the imported intermediates and the depth of value chain transmission (reflected in the Leontief inverse matrix). This shows that if the dependence on a certain kind of imported intermediates is higher, or a kind of imported intermediates is primarily invested in the upstream sector, this kind of import intermediates has a stronger effect on the price transmission of domestic products. This will be confirmed in the empirical analysis later.

In equation (2), $(I - A^D)^{-1}$ can be broken down into $I + A^D + A^{D2} + \cdots$:

$$\Delta P = \Delta P_i^M A_{i\bullet}^M + \Delta P_i^M A_{i\bullet}^M A^D + \Delta P_i^M A_{i\bullet}^M A^{D2} + \cdots \tag{3}$$

This can be interpreted as follows: the price increase of an import product directly leads to the price increase of sectors that use it as an intermediate input, which increases the cost of production in various sectors, and in turn, leads to a new round of price increases; by this analogy, each successive round of price increases will cause a new round of price increases, eventually resulting in the price rise of each sector.

2. Data sources

At present, the Chinese national input-output tables published by National Bureau of Statistics of China are competitive, i.e. without distinction between domestic input and imported inputs. To compile the non-competitive table, we used the Chinese input-output table capturing processing trade (abbreviated as DPN table) of 2012. The DPN table was compiled by the global value chain research group of the Academy of Mathematics and Systems Science, Chinese Academy of Sciences. At the same time, we aggregated the original table with 139 industries into the one with 15 sectors, mainly based on the similarity in the character of the production process of each product. The other purpose to aggregate is to reduce the computational complexity and make the results more concise and clear. The sector classification is shown in Table 2.

Table 2 The classification of 15 product sectors

Number	Sector Name	Sector Description
1	Agriculture	Agriculture, forestry, animal husbandry, fishery products and related services
2	Mining	Oil, natural gas, coal, mineral mining and related services
3	Manufacture of food	Manufacture of food products, beverage, and tobacco
4	Textile and paper printing	Textiles, leather and feather products, wood, paper printing and educational and sports goods
5	Petrochemical industry	Petroleum, coking, chemical products, medicine, and non-metallic mineral products
6	Metal products	Metal smelting, rolling processed and products
7	Manufacture of machinery	Manufacture of machinery and equipment
8	Transportation equipment	Manufacture of transportation equipment
9	Electrical and electronic industry	Manufacture of electrical machinery and equipment and electronic devices
10	Energy supply	Electricity, heat, gas, water production, and supply
11	Construction	Houses and civil construction
12	Transportation	Transportation, storage, and postal services
13	Business services	Wholesale and retail, accommodation and catering, leasing and business services
14	Information and financial industry	Information technology, financial, insurance and real estate
15	Public services	Scientific and technical services, public services, education, health, recreation and social services

3. Estimation results and their implications

After obtaining the non-competitive input-output table of 15 sectors, according to equation (2), we can calculate the biggest potential impact on the price of domestic products of the import price increase of each sector. This impact is called the biggest without considering the elasticity of demand, the time lag of transmission and the hedging of the profits etc.

The price change of each sector is weighted by the total output value of the sector, thus obtaining the overall impact of import products on the domestic market. Assuming that the prices of import products of each sector are up by 10% respectively, using MATLAB software to calculate, we obtain the biggest potential impact on domestic prices.

The results are listed in Table 3, ranked in order of the highest impact on domestic price.

Table 3 Biggest potential impact of import price of each department

Ranking	Sector	Impact	Ranking	Sector	Impact
1	Mining	0.52%	9	Business services	0.04%
2	Electrical and electronic industry	0.42%	10	Manufacture of food	0.03%
3	Petrochemical industry	0.27%	11	Transportation equipment	0.02%
4	Metal products	0.13%	12	Information and financial industry	0.01%
5	Agriculture	0.07%	13	Public services	0.01%
6	Textile and paper printing	0.05%	14	Energy supply	0.00%
7	Manufacture of machinery	0.05%	15	Construction	0.00%
8	Transportation	0.04%			

The import products with the highest potential impact on the overall domestic price are from the mining industry and electrical and electronic manufacturing respectively. When the import price of these two sectors increases by 10%, respectively, the ranking of the top 6 most affected sectors and their price changes are shown in Table 4.

Table 4 Top 6 most affected sectors by mining and electrical and electronic industry and their price changes

Ranking	Responses to mining imports		Responses to electrical and electronic imports	
1	Petrochemical industry	1.24%	Electrical and electronic industry	2.47%
2	Metal products	1.23%	Manufacture of machinery	0.72%
3	Construction	0.64%	Transportation equipment	0.55%
4	Energy supply	0.61%	Metal products	0.42%
5	Manufacture of machinery	0.50%	Energy supply	0.37%
6	Transportation equipment	0.44%	Construction	0.28%

The import intermediate of mining products ranking No.1 confirmed that the price transmission effect of imported intermediates that are mainly used in the upstream sector is stronger. In order to measure the upstream and downstream relationship of each industry in the production chain, we use the upstreamness index proposed by Antràs (Antràs et al, 2012). The further the product sector is from final consumption, the higher the upstreamness degree is. By equation (4), the upstreamness index adjusted in open economy can be calculated using the direct consumption coefficient in the non-competitive input-output table:

$$U = [I - \Delta]^{-1} \cdot e \tag{4}$$

U represents the column vector of upstreamness of each industry; $\Delta = \hat{X}^{-1} A^D \hat{X}$; e is the unit column vector.From the non-competitive input-output table of 15 sectors in 2012, the upstreamness of each sector are shown in Table 5:

Table 5 Upstreamness of 15 sectors

Number	Sector	Upstreamness	Number	Sector	Upstreamness
1	Agriculture	2.66	9	Electrical and electronic industry	2.13
2	Mining	4.47	10	Energy supply	4
3	Manufacture of food	2.28	11	Construction	1.12
4	Textiles and paper printing	2.5	12	Transportation	2.85
5	Petrochemical industry	3.29	13	Business services	2.31
6	Metal products	3.28	14	Information and financial industry	2.36
7	Manufacture of machinery	2.15	15	Public services	1.53
8	Transportation equipment	1.93			

The mining intermediate import are mainly used in the domestic petrochemical sector (59%) and the metal products sector (34%). The upstreamness of the two sectors are 3.29 and 3.28 respectively, ranking 3rd and 4th in 15 sectors. It indicates that the imported intermediates are basic inputs, involved in long production chain, and the price fluctuation will have a wide influence on the downstream sectors.

China’s external dependency on oil, iron ore and other minerals are rather high: in 2016 China's crude oil external dependency rose to 67.4% and is expected to exceed 70% by 2020; there are more than 10 kinds of minerals with more than 50% of external dependence, and domestic supply capacity is greatly influenced by the market. The price fluctuations of such commodities in the international market are much likely to hurt some domestic producers' and consumers' interests. Attention should be given to the affordability of all aspects of society to the impact of energy price increases, focusing on low-income groups. At the same time, enterprises should be encouraged to gradually "go out" and optimize the allocation of resources globally, thus improving the overall stability of macroeconomy.

Electrical and electronic import intermediates ranking second confirms that the price transmission effect of the imported intermediates with higher degree of dependence is stronger. The proportion of imported intermediates of electrical and electronic products is the highest among all imported intermediates, as shown in figure 1.

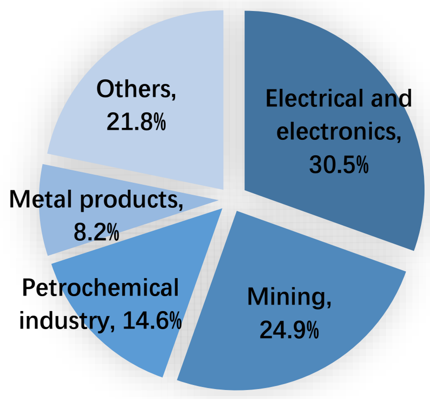

Fig. 1 The proportion of each kind of imported intermediates

Electrical and electronic sector includes electrical equipment, household appliances, computers, telecom devices and other electronic equipment and components. China's dependence on such imports is high, and their prices affect the production downstream. Among the four most affected sectors, the proportion of imported products in electrical and electronic intermediates is shown in Figure 2.

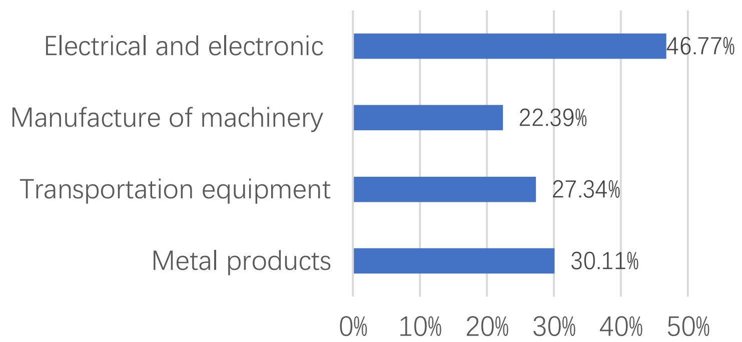

Figure 2. Import proportion of electrical and electronic intermediates of four sectors

With the improvement of the technical level of the industry and the rise of labor costs, the shift of manufacturing from labor-intensive to technology-intensive is imperative. Due to the growing demand of downstream firms for automated production equipment, China's electrical and electronic manufacturing industry has achieved rapid development, with industrial policies implemented effectively and market environment optimized. At the same time, the industry is still heavily dependent on imported products, and some current problems need to be solved, such as small industrial scale, difficulty in developing high-end new equipment and insufficient ability in providing complete sets of production lines, etc.

III. Dynamic analysis on import intermediate price transmission with time lag

1. The price transmission mechanism with time lag

In the aforementioned input-output analysis, it is assumed that the fluctuation correlation between sectors is instantaneous and the analysis on the price chain reaction of various sectors only concerns with its final result, which is a static. However, in the actual economic operation, input and output cannot be realized in an instant and there is a production process that is either long or short, which is called production time lag or production cycle. The production time lag is the time it takes for the input price to actually affect the price of the output. It's reasonable to say that the time lag in production leads to the "price lag" of the output of the sector and the lagging of further cost transmission, which is an important reason for the price "stickiness".

Clearly, the production time lag is the inherent attribute of each product sector under the existing technical conditions and the price time lag is the price aspect of the production cycle. In short-term dynamic industrial relations, the production cycle is an important factor that influences the behavior of enterprises that cannot be ignored. Also, the production time lag of each sector is different, therefore it is necessary to introduce production time lag into the input-output analysis.

The production time lag of n sectors is represented by a vector $T=(t_1,t_2,\cdots t_n)$, in which $t_n = k_n \cdot d$ and k_n is a positive integer, indicating that the production time lag of the nth sector is an integer multiple of a unit time lag.

The operation of the transmission mechanism is described as an example in three industries. Assuming that the production time lag of three industries is $T=(10,2,1)$, and the unit is week, i.e. the above time lag for the three industries are 10, 2 and 1 weeks, respectively. Then the product price of the first industry is determined by the prices of all intermediate inputs at $t-10$, the second industry output price is determined by the input prices at $t-2$, and the third industry output price is determined by the input prices at the time of $t-1$.

Assuming that the imports price of the second industry increases by 10% at $t=0$, the production cost of the third industry will increase due to using the imported products as inputs, and the price of the industry will increase correspondingly at $t=1$ to keep the value added unchanged: $\Delta P_3(1)=\Delta P_2^M(0)\cdot a_{23}{}^M$

At $t=2$, the price of the second industry will increase due to cost increase: $\Delta P_2(2)=\Delta P_2^M(0)\cdot a_{22}{}^M$; while the price of the third industry will increase due to the increase in input cost caused by the increase in its domestic product price: $\Delta P_3(2) = \Delta P_3(1) \cdot a_{33}{}^D$

At $t = 3,$ the price of the second industry will increase due to cost increase caused by the price increase in the domestic product of the third industry at $t = 1$: $\Delta P_2(3) = \Delta P_3(1) \cdot a_{32}{}^D$; while the price of the third industry will increase due to the increase of product prices of the second and third industry at $t = 2$: $\Delta P_3(3) = \Delta P_2(2) \cdot a_{23}{}^D + \Delta P_3(2) \cdot a_{33}{}^D$

At $t = 10$, the price of the first industry will increase due to cost increase caused by the price increase in export of the third industry at $t = 0$: $\Delta P_1(10) = \Delta P_2^M(0) \cdot a_{21}{}^M$

In this way, a cyclical chain reaction occurs. The cumulative change of price of the three industries will gradually approach the biggest impact calculated as equation (2).

In conclusion, when we introduce the time lag factor, the linear system that describes the input-output relationship becomes a linear difference equation system as follows:

$$\begin{cases} \Delta P_1(t) = \sum_{i=1}^{3} \Delta P_i^M (t-t_1) \cdot a_{i1}{}^M + \sum_{i=1}^{3} \Delta P_i^D (t-t_1) \cdot a_{i1}{}^D \\ \Delta P_2(t) = \sum_{i=1}^{3} \Delta P_i^M (t-t_2) \cdot a_{i2}{}^M + \sum_{i=1}^{3} \Delta P_i^D (t-t_2) \cdot a_{i2}{}^D \\ \Delta P_3(t) = \sum_{i=1}^{3} \Delta P_i^M (t-t_3) \cdot a_{i3}{}^M + \sum_{i=1}^{3} \Delta P_i^D (t-t_3) \cdot a_{i3}{}^D \end{cases} \quad (5)$$

In which $t_1 = 10, t_2 = 2, t_3 = 1$.

Given the initial import price changes $\Delta P_1^M(0), \Delta P_2^M(0), \Delta P_3^M(0)$, for any given time point t, we can calculate the price changes and the accumulated price changes of the three industries by the iterative method.

2. Data sources

Determining the production time lag of each sector is an important step to build the input-output price impact model with the time lag. In the current statistics, there are no indicators directly describing the production cycle or price response time of each sector. Therefore, this paper uses the relevant indicators that can indirectly reflect the information to estimate the production time lag.

For the agriculture sector, the proportion of the output value for each division from the IO table in 2012 is shown in Table 6.

Table 6 Proportion of output value of agriculture sub-divisions in 2012

Agricultural products	Forestry products	Animal products	Fishing products	Relevant services
52.49%	3.85%	30.41%	9.74%	3.51%

According to Table 6, the total output of agricultural and animal production accounts for over 80% in the agriculture sector. According to China Statistical Yearbook and other data sources, for the major agricultural products, the staple crops account for about 68% and the growth cycle is about 5~10 months (on average about 30 weeks); about 15% are fruit and vegetables, and the growth cycle of common vegetables is about 2~3 months (on average about 10 weeks); other cash crops (such as peanuts, rapeseed, cotton, etc.) have a growth cycle of about 4~8 months (on average about 24 weeks), so the average production cycle of agriculture is about 26 weeks. For animal products, pork accounts for about 65% of meat production, and the average growth cycle of live pigs is 25 weeks; poultry is about 25% and its growth cycle is about 7-8 weeks; the growth cycle of other livestock is about 8~18 months (on average about 52 weeks), so the average production cycle of animal is about 23 weeks. On a weighted average by output value, the average production cycle of the agriculture industry is estimated to be about 25 weeks.

For industrial manufacturing sectors, the production cycle can be indirectly estimated by inventory turnover rate. It is the ratio between the cost of goods sold and the average inventory balance in a certain period of production. This rate can be used to measure the turnover speed of enterprise inventory assets and is a measure of the efficiency of purchase, production, and sale of enterprises. Generally speaking, the faster the inventory turnover, the lower the occupancy level of inventory and stronger the liquidity. By dividing the time length by the turnover rate, it can be considered roughly the same as the production cycle. According to China Statistical Yearbook, the inventory turnover rate and estimated production cycle of the industrial sectors are as in Table 7.

Table 7 Inventory turnover and production cycle of industrial sectors

Sector	Inventory turnover	Production cycle(week)	Sector	Inventory turnover	Production cycle(week)
Mining	11.3	5	Manufacture of machinery	6.21	8
Manufacture of food	7.07	7	Transportation equipment	8.19	6
Textiles and paper printing	10.66	5	Electrical and electronic industry	8.83	6
Petrochemical industry	10.38	5	Energy supply	34.47	2
Metal products	8.76	6			

For the construction industry, we use the construction cycle of fixed asset investment projects to estimate the production cycle. The completion rate of the fixed asset investment projects in the past years from China Statistical Yearbook is shown in Table 8. The average construction period for projects is 367/7/7/0.66 =79 (weeks), which can be used as the production time lag of the Construction sector.

Table 8 The annual completion rate of fixed asset investment projects

2010	2011	2012	2013	2014	2015	2016	Average
62.5%	63.3%	62.0%	63.7%	68.3%	74.0%	68.5%	66.0%

For transportation services, the output value of sub-divisions from the IO table in 2012 is presented in Table 9. According to relevant data, the goods of railway transportation can be delivered at a minimum of 3 days; road transportation generally lasts 1~5 days; the average time of water transportation is longer; thus, the average time lag of transportation sector is about 1 week.

Table 9 Proportion of output value of Transportation sub-divisions in 2012

Railway transport	Road transport	Water transport	Air transport	Pipeline transport
10.29%	65.79%	11.78%	10.32%	1.82%

For the business services industries, we can use the ratio of merchandise purchase amount and ending inventory of the wholesale and retail enterprises from China Statistical Yearbook as inventory turnover (shown in Table 10). The average turnover rate is 13.2, so the average circulation period of commodity is 367/7/13. 2=4 (weeks), which can be used as the production time lag of the business services sector.

Table 10 The annual inventory turnover rate of wholesale and retail enterprises

Year	2012	2013	2014	2015	2016	Average
Inventory turnover rate	13.0	13.9	12.9	12.8	13.2	13.2

For information technology, financial, insurance, and public services, the time lag can be ignored, and the minimum value is 1 week, as there is no time lag between the input and output used for consumption like other industries.

To sum up, we obtained the estimates of the production cycles of all 15 sectors in 2012, as shown in Table 11.

Table 11 Estimated production cycles of 15 sectors in 2012

Number	**Sector**	**Production cycle**	**Number**	**Sector**	**Production cycle**
1	Agriculture	25	**9**	Electrical and electronic industry	6
2	Mining	5	**10**	Energy supply	2
3	Manufacture of food	7	**11**	Construction	79
4	Textiles and paper printing	5	**12**	Transportation	1

5	Petrochemical industry	5	**13**	Business services	4
6	Metal products	6	**14**	Information and financial industry	1
7	Manufacture of machinery	8	**15**	Public services	1
8	Transportation equipment	6			

3. Estimation results

Next, with the data of the production cycle of each sector, according to the linear difference equations (2), we can calculate iteratively the chain impact of the import price fluctuations on domestic product sectors considering time lag. The discrete state equations of 15 sectors can be expressed as:

$$\Delta P_j(t) = \sum_{i=1}^{15} \Delta P_i^M(t-t_j)\cdot a_{ij}{}^M + \sum_{i=1}^{15} \Delta P_i^D(t-t_j)\cdot a_{ij}{}^D,\ j=1,2,\cdots,15 \quad (6)$$

Given the initial import price changes $\Delta P_i^M(0)(i=1,2,\cdots,15)$, the price change of each sector at any given time point t can be calculated, as well as the cumulative value of change from time 0 to t, which would eventually approximate the biggest potential impact value calculated by the above equation (2).

We investigate the effect on domestic prices of a price increase of 10% of the imported product of two basic manufacturing industries, mining sector, and electrical and electronic sector. Set the number of iterations as 40 and calculate the price fluctuations of four most affected sectors in 40 cycles according to equation (6). The results are shown in Figure 3 and Figure 4 respectively.

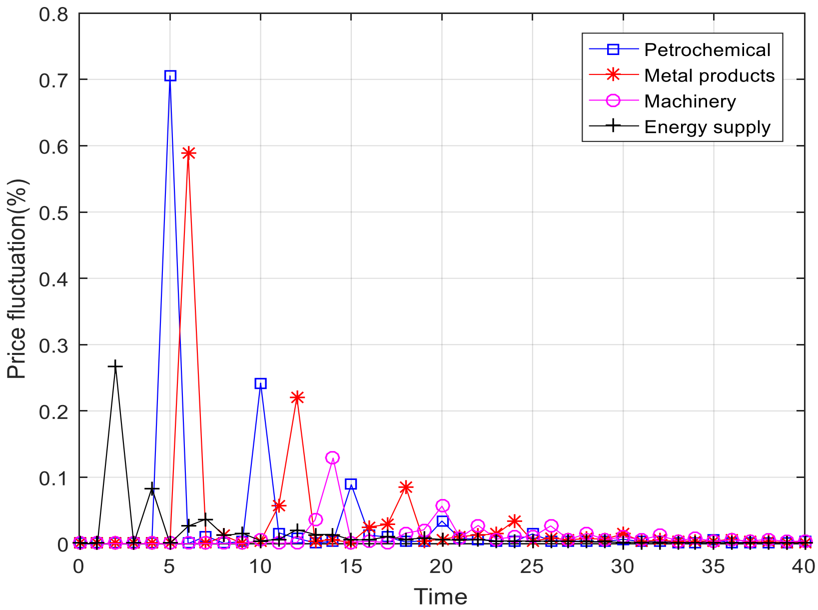

Figure 3 Price fluctuations of four sectors affected by an increase of 10%

of the import price of mining sector

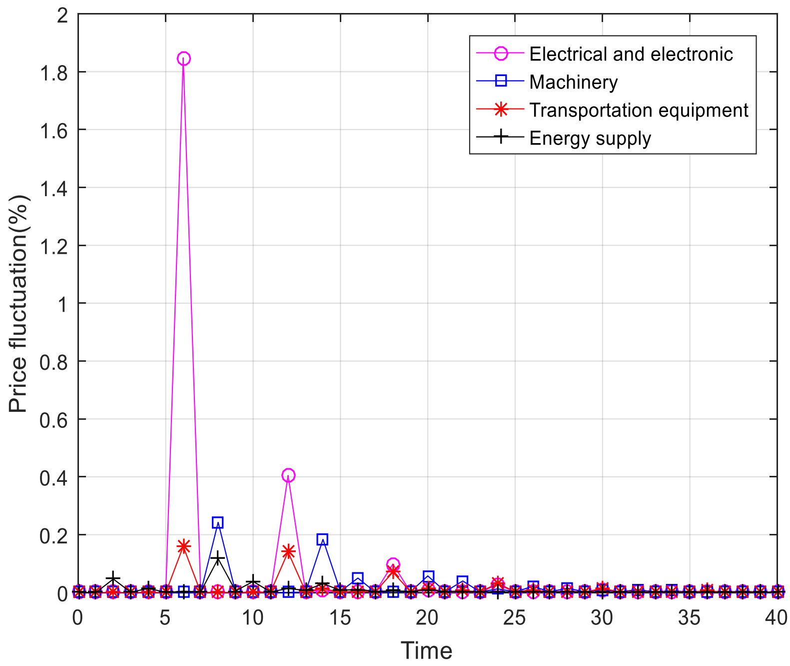

Figure 4 Price fluctuations of four sectors affected by an increase of 10% of the import price of electrical and electronic sector

From the results of the price model with the time lag, when the import price of the mining sector increases, the price fluctuations ranging from large to small, are from petrochemical industry, metal products, energy supply and machinery manufacturing, etc. As for the affected time occurred, it is, in turn, the energy supply, petrochemical, metal products, machinery manufacturing, etc. Among them, a concentration of each sector for price adjustment is in the 3rd~6th week, which will cause a relatively large impact on the overall price level.

When the price of electrical and electronic manufacturing sector increases, the most obvious influence is on itself, followed by machinery manufacturing, transportation equipment, and energy supply, etc. The transmission sequence is energy supply, Electrical and electronic industry, transportation equipment and machinery manufacturing, etc. The price chain reaction is mainly concentrated in the period between the 6th-8th week.

IV. Conclusion

In an open environment, the economy is the recipient of external prices. International commodity price fluctuations will affect the price of imported goods through trade, thus affecting domestic prices and causing uncertainty in the macroeconomy. With the development of the global value chain and the increasing openness of China, the impact of the external price on domestic economy has increased. In this paper, the static and dynamic analysis of import price transmission in a non-competitive input-output model is presented. First, we calculated the biggest potential impact of price fluctuation of imported products, then we introduced the production time lag factor and established the time-lag input-output price model, which is more consistent with the actual industrial economy. The results provide the theoretical basis for the investigation of the short-term price conduction in economic sectors.

In order to study the import price conduction effect, the corresponding model and data are obtained first. We used the Chinese DPN table in 2012 to build a non-competitive input-output table and aggregated the product sectors into 15. The key to the time-lag input-output model is to estimate the time lag of each product sector. Since there exists no such statistics, this paper processed separately with accessible data to estimate the production time lag for different industries.

By calculating the biggest potential impact of import price on domestic price, we can understand the role of all kinds of import products in the domestic production system. From the results, China has the highest import dependence on mining and electrical and electronic manufacturing industries. The fluctuation of the price of these two kinds of imported products has a great impact on the domestic economy, thus easy to generate energy and resource supply risk, challenging economic stability and security. This paper discussed some policy suggestions, that is to fully consider the ability of social parties to face the energy price fluctuations and accelerate the transition of manufacturing from labor-intensive to technology-intensive, thus improving the overall stability of macroeconomy.

In addition, we used the iterative discrete time equation to calculate the input-output price model with the time lag. The results describe the dynamic characteristics of import price transmission along the timeline and provide new ideas to control and stabilize the price fluctuations of the industrial economy.

First, due to production time lag in each sector, there exists lag in price conduction in the chain reaction. According to the iterative time-lag equation, the price changes of the industrial economic system at any time shall be jointly determined by the changes of prices of the various sectors between the maximum production lag and the preceding period. That is, the current price state of each sector reflects not only the current state of supply and demand but also the change of demand or cost factors in the past several stages.

Second, due to the lag between the input and output of the production sector in the short term, there also exists time lag between the implementation and the effect of the economic regulation measures. Therefore, it is necessary to grasp the time node and strength in the implementation of the regulation, so as to achieve greater control effect at a smaller cost. For some industries that play a key role in price transmission, such as petrochemical, metal, machinery, electric and electronics manufacturing, the average production time lag is 5, 6, 8 and 6 weeks respectively. Therefore, the price regulation measures of these sectors should be introduced the corresponding lag before the price may change.

Third, due to the existence of multiple different time lags, the price chain reaction in all sectors could be superimposed at some point in time, leading to a big fluctuation in the overall price level. In price regulation, it is necessary to grasp the above time window to improve the effectiveness of the control measures. In the time-lag model, we can obtain the overall impact of imports on domestic products by weighing the price change of all sectors by their output value, as shown in Figure 5. When imported mineral products price increases, domestic price reacts intensely between the 5th-6th week; a period of intensive price adjustment will occur in week 5-6 after the price increase of imported chemical products; when the price of electrical and electronic products increases, the price response is mainly between the 6th and 8th week. These are important references to the implementation of price control policy.

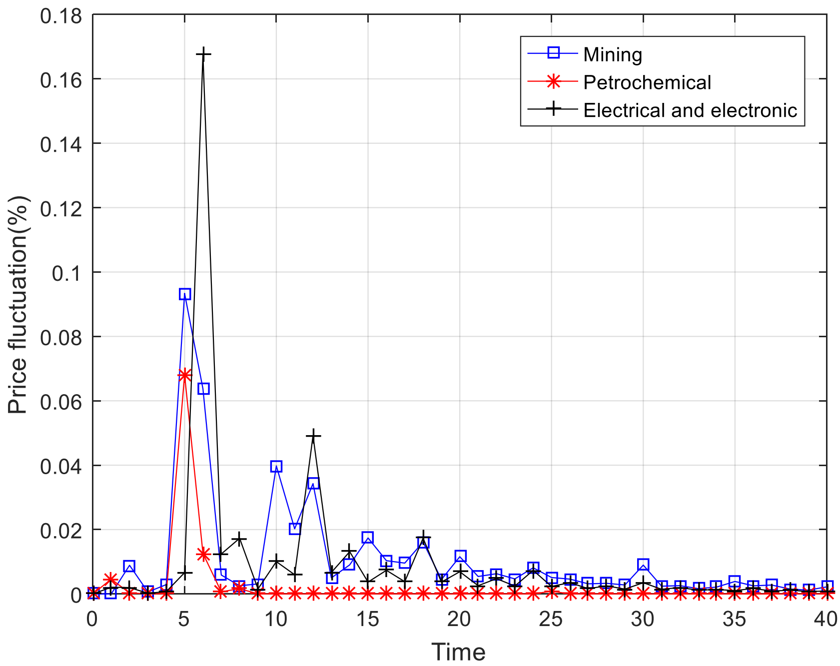

Figure 5 Price fluctuations of domestic price affected by an increase of 10% of the import price of three sectors

References

Antràs P, Chor D, Fally T, Hillberry R. Measuring the Upstreamness of Production and Trade Flows[J]. American Economic Review, 2012, 102(3):412-416.

Bazzazan F, Batey P. The development and empirical testing of extended input-output price models[J]. Economic Systems Research, 2003, 15(1): 69-86.

Cagan P. Imported inflation 1973-74 and the accommodation issue[J]. 1978.

Chen X, Cheng L K, Fung K C, et al. Domestic value added and employment generated by Chinese exports: A quantitative estimation[J]. China Economic Review, 2012, 23(4): 850-864.

Chen X, Yang C. Input-output technique[M]. Beijing: Science Press. 2011.

Gao L, Kim H, Saba R. How do oil price shocks affect consumer prices?[J]. Energy Economics, 2014, 45: 313-323.

Hawkins D. Some conditions of macroeconomic stability[J]. Econometrica: Journal of the Econometric Society, 1948: 309-322.

Leontief W. Input-Output Analysis[M]. 2nd Edition. New York: Oxford University Press, 1986: 55-64.

Minot N. Transmission of world food price changes to markets in Sub-Saharan Africa[M]. Washington: International Food Policy Research Institute, 2010.

Shang J. Study on industry price transmission based on input-output model with time delay[J]. Statistics & Information Forum (Tong Ji Yu Xin Xi Lun Tan), 2017, 32(05): 43-50.

Tong R. The price transmission model considering production delays [J]. Quantitative & technical economics (Shu Liang Jing Ji Ji Shu Jing Ji Yan Jiu), 2010, (8): 139-152.

Valadkhani A, Mitchell W F. Assessing the impact of changes in petroleum prices on inflation and household expenditures in Australia[J]. Australian Economic Review, 2002, 35(2): 122-132.

Wang Y, Tong R, Liu Y. Dynamic price transmission network model based on directed weighted network[J]. Mathematics in practice and theory (Shu Xue De Shi Jian Yu Ren Shi), 2011, 41(24): 61-68.

Xu D, Tong R. Research on an Input-Output Sticky-price Model [J]. Management Review (Guan Li Ping Lun), 2011, 23(11): 12-17.

Yang C, Dietzenbacher E, Pei J, et al. Processing trade biases the measurement of vertical specialization in China[J]. Economic Systems Research, 2015, 27(1): 60-76.

Zhang H. The development and improvement on input-output price model[J]. System Engineering Theory&Practice (Xi Tong Gong Cheng Li Lun Yu Shi Jian), 2008, 28(1): 90-94.