
Price Transmission and Industrial Linkage

—A theoretical explanation of inter-sectoral price transmission based on input-output coefficients

Abstract: Price transmission is one of the key issues in both economic theories and policies, but most research of price transmission just depicts some features and phenomena rather than explores the deeper reason lying behind. Using time correlation and cointegration analysis methods, this paper tests the existence and strength of price transmission between 35 Chinese manufacturing sectors from 2007 to 2016. Moreover, this paper, for the first time, raises several theoretical propositions and constructs a possible theoretical explanation of inter-sectoral price transmission based on industrial linkage by using input-output coefficients. Results of empirical tests show that price transmission relations beyond regular upstream and downstream concepts between manufacturing sector exist and the existence, strength and time lag of transmission relations can be explained by input-output coefficients, that is, industrial linkage. Further results show that the type of price transmission between manufacturing sectors is supply-push, which holds true through 2007-2016. Conclusions above have values on price prediction as well as policy making about supply-side reform.

Key Words: Industrial Linkage; Price Transmission; Input-Output Analysis; Inflation

1. Introduction

The so-called inter-industry price transmission refers to the phenomenon that the price level of one or some industrial products fluctuates and the price level of other industrial products changes accordingly. This phenomenon has always been the focus of academic attention. On the one hand, the theoretical explanation of price transmission phenomenon can better reveal the development and evolution of inflation, and provide a dynamic perspective of the theoretical explanation for inflation. On the other hand, exploration of price transmission will contribute to clarify the main drivers of price changes in economy and distinguish the different roles that upstream and

downstream industries play in inflation. In this case, the types of inflation can be determined and price control recommendation would be provided based on the analysis. Therefore, it is theoretically as well as practically significant to study the price transmission.

Existing research has been paying attention to price transmission for decades. From the research object, there are studies on the phenomenon of price transmission in a single industry as well as macroeconomics. Research on a single industry focused on industries such as agriculture and energy. For example, Chen et al. (2005) explored the price transmission of crude oil to gasoline, Shrinivas and Gómez (2016) studied the integral price transmission in the cotton industry. Producer price index (PPI) and consumer price index (CPI) are generally introduced to analyze the price transmission in macroeconomy. Silver and Wallace (1980), Caporale and Pittis (2002), He et al. (2008) and Zhang (2010) pointed out it would be more clearly to analyze the price transmission of upstream and downstream industries after the refinement of production, circulation and consumption process. In addition, the raw material purchase price index and the enterprise commodity transaction price index were involved into the original framework with PPI to CPI and the impact of monetary policy has also been considered. In contrast, Serra et al. (2006) studied the price transmission of poultry market in the US from geographical perspective rather than the industrial chain. Apart from the price transmission in the real economy, existing research, such as Rui et al. (2004) and Su (2009) also studied the price transmission problem in the stock market.

In terms of the research content, most of the research mainly focused on the description of price transmission characteristics. Early research, represented by Silver and Wallace (1980), focused on the direction of price transmission to explore whether price conduction was unilateral or bilateral. Kinnucan and Forker (1987) first proposed the issue of asymmetry in price transmission. In other words, responses to the price increase and decline would be different. Since then, Chen et al. (2005), Zlatcu et al. (2015), and McLaren (2015) have examined the asymmetry of price transmission and the threshold effect was also be incorporated.

From the perspective of research methods, the paradigm of time series analysis occupies the absolute mainstream, that is, first establish a vector autoregressive model for the price index or establish a vector error correction model based on the cointegration analysis, and then use the Granger causality test method. Determining the direction of price transmission, Caporale and Pittis (2002), Chen et al. (2005), He Liping (2008), Zhang Chengsi (2010), and Zerihun (2012) all adopt this research paradigm; Sexuality often introduces a threshold effect in the model. In recent years, some authors have adopted non-parametric methods to improve the above methods using nonlinear time series models, such as Serra et al. (2006) and Yang Zihui (2013). Different from the above analysis paradigm lacking the theoretical framework, McLaren (2015) studies the price transmission of agricultural products export market based on the relationship between market supply and demand, based on the asymmetric market position of wholesalers and farmers, and carried out a theoretical model. Empirical test. From the perspective of analyzing methods, the paradigm analysis of time series has always led the mainstream. Specifically, a vector autoregressive model for the price index or a vector error correction model based on the cointegration analysis would be first established, and then Granger causality test method would be introduced to determine the direction of price transmission. Caporale and Pittis (2002), Chen et al. (2005), He et al. (2008), Zhang (2010) and Zerihun (2012) all adopted the research to make research. The threshold effect can usually be incorporated into theoretical framework considering the asymmetry of price transmission. In recent years, some authors have applied the non-parametric method and nonlinear time series model to make improvement, such as Serra et al. (2006) and Yang et al. (2013). The theoretical framework of above analysis is not perfect, so McLaren (2015) constructed a theoretical model by studying the price transmission of agricultural export market based on the relationship between market supply and demand, according to the asymmetric market position of wholesalers and farmers. In addition, an empirical test was carried out to make further study.

Based on the existing research, the existence of price transmission phenomenon

has been widely proved in both single industry level and macroeconomic level, but the specific characteristics of price transmission in different levels are different. For example, Zhang (2010) proved that there was significant relationship between price transmission from the upstream industries to downstream industries based on the China's price index (CPI) and the "reverse forced" mechanism can also be found. Yang et al. (2013) found that the directions of price transmission varied in different industries as well as countries.

The existing researches mainly applied time series model to describe the phenomenon of price transmission, but the theoretical explanation and corresponding empirical test for the causes and characteristics of price transmission was insufficient. In fact, the price transmission reveals a certain relationship between industries theoretically, in this case, it is necessary to incorporate it into the framework of industrial linkages. It is the complex product consumption and distribution relationship in the production of various industries that enables the price fluctuations of an industry to affect the production costs of its upstream and downstream industries, and thus the price of the products. Furthermore, the different spread directions of this influence along industrial chains have formed the so-called "supply-driven" and "demand-driven" price transmission.

This paper mainly studies the price transmission phenomenon among China's manufacturing industries. Compared with the above researches, the main innovations of this paper are as follows. Firstly, this paper analyzes the price transmission phenomenon among the 35 sub-product sectors included in the manufacturing industry and by replacing PPI with the clearly defined product sector price index, the direction of price transmission can be more clearly defined; In addition, compared with the studies of a single industry, the conclusions drawn in this paper are more universal. Secondly, this paper attempts to give a theoretical explanation of the price transmission phenomenon based on the consumption and distribution relationship in the product manufacturing process from the perspective of industrial correlation, thus solving the problem that the price transmission cause is only empirical guess and lack of empirical

support.

The rest of the paper is structured as follows. The second part proposes the theoretical hypothesis of price transmission through the analysis of price transmission phenomenon, and gives the scheme of empirical test. The third part introduces the data source and processing method used in this paper. The fourth part empirically tests the above theoretical hypothesis. Finally, the conclusions of this paper are given in the fifth part.

2. Theoretical assumptions and test methods

2.1 Theoretical Analysis of Industrial Correlation and Price Transmission

As mentioned above, in the existing researches, the focus of empirical research on price transmission among industries can be summarized as four characteristics of price transmission: whether there are long-term stable relations between the timing changes of several price indices, the intensity of price transmission, time lag of price transmission and the direction of price transmission (or the causal relationship of price conduction). The time series method can empirically analyze the above characteristics between two sets of price indices but cannot give an economic explanation for its cause. From the perspective of economics, the transmission relationship among industrial price indices should be attributed to the industrial correlation among industries because of the direct and indirect consumption of each other's products as intermediate inputs in the production process. For example, if the product of an industry is an intermediate investment of another industry and if the price of the product in the industry rises, it means that the cost of another industry increases. According to economic principles, the price of another industry product will also increase and price transmission relationship is thus produced. In this part, this study discusses the mechanism of the influence of industrial linkages on the four main characteristics of price transmission.

Hypothesis 1: The long-term stable price transmission phenomenon among the manufacturing product sectors can be explained by the industrial linkage, that is, the consumption and distribution relationship in the production process.

The rationality of this assumption is explained below. Figure 1 shows a part of a hypothetical industry chain. The direction of the arrows in the figure indicates the direction of flow of the product. Specifically, from the perspective of the source of products such as raw materials, the products of industry A will be used in the production process of industry B, and the products of industry B will be used in the production process of industry C; using the term of input-output analysis, the production of industry B consumes the product of industry A, and the production of industry C consumes the product of industry B.

It should be pointed out that due to the existence of the consumption relationship of industry B to industry A, industry C also has a consumption relationship with industry A through industry B; it is distinguished from the consumption relationship of the intermediary industry (direct consumption), and this kind of consumption relationship is called indirect consumption. From the perspective of the product destination, according to a similar analysis, the product of industry A is assigned to industry B (direct distribution), and further assigned to industry C (indirect distribution).



Figure 1 Simplified diagram of industry chain

According to the flow direction of products, industrial linkages can be divided into forward linkage and backward linkage. Taking industry B as an example, the relationship between industry A and industry B is forward linkage, and the relationship between industry C and industry B is backward linkage. Thus, the consumption of the product reflects the backward relationship, and the distribution of the product reflects the forward relationship.

Without loss of generality, suppose an exogenous shock at a certain moment causes the price level of industry B to rise. Its increase in the price level of industry C is intuitive. In the short term, enterprises are limited by their production technology, and it is difficult to adjust various production inputs, so that the increase in the price level of industry B has led to an increase in the production cost of industry C. When the cost is high enough to exceed the cost of the enterprise price adjustment (such as menu

cost, etc.), the price level of the industry C will also rise. Since the price level of industry C is increased due to the increase of production cost, the price transmission can be called “cost-driven”. It is the product distribution relationship of industry B to industry C, that is, the forward direction that leads the price transmission.

However, the rise in the price level of Industry B may also lead to an increase in the price level of Industry A. Assume that the impact of the increase in the price level of the industry B is the demand shock, and the rise in the price level stimulates the capacity expansion of the industry B. Then, the production process of the industry B will consume more products of the industry A. Since the production capacity adjustment of the industry A takes a certain period of time, the price level of the industry A will also rise before the capacity expansion is completed. Since the price level of industry A is increased due to more demand for its products, the price transmission can be called “demand-driven” type. It is the product consumption relationship of industry B to industry A, that is, the backward direction that leads the price transmission.

In this way, it explains how the existence of industrial linkages explains the formation and persistence of price transmission relationships among industries.

Further, examine two characteristics of price transmission - the intensity and time lag of price transmission. If Hypothesis 1 is established, both of these features can be reasonably interpreted within the framework of industry linkages. The so-called intensity of price transmission refers to the extent to which the price level of the transmitted industry changes when the price level of an industry changes. The greater the degree of change in the price level of the transmitted industry, the greater the intensity of price transmission. The time lag of price transmission refers to how long it takes for the change of the price level of an industry leads to the change of the price level of the transmitted industry. In short, the intensity of price transmission is concerned with the magnitude of price transmission, while the time lag of price transmission is the speed of price transmission. The following is a discussion of the relationship between the intensity of price transmission and industry linkages.

Hypothesis 2: The intensity of price transmission is positively related to the

closeness of the industries, i.e. the intensity of the consumption or distribution relationship.

Under the premise of the establishment of Hypothesis 1, the rationality of this hypothesis is obvious. Closer industrial linkages mean more product consumption and distribution, which leads to an increase in the intensity of price transmission. Specifically, from the perspective of forward linkage, the more products of industry B consumed in the production of products of industry C, the higher increase of the production cost of industry C, and the higher increase of the price level of industry C. From the perspective of backward linkage, the more consumption of industrial A products in the production of industry B, the greater the demand for products of industry A, which leads to a greater rise of the price level of industry A. In other words, the strength of the forward linkage in the previous path affects the production function $f(x)$ and the cost function $c(\mathbf{r}, x)$ of the enterprises of industry C, where \mathbf{r} represents the price vector of inputs. The strength of the backward linkage in the latter path affects the demand function $q(p, \mathbf{s})$ faced by the enterprises of industry A, where \mathbf{s} represents the price vector of downstream product.

In addition, the strength of the industry linkages will also affect market expectations. The strength of industrial linkages determines the degree of difficulty that can be observed, and stronger industrial linkages are more easily recognized by the market. When the price level of industry B rises, industry A and industry C which are in the same industrial chain may regard it as a signal for the expansion of demand in the whole industry chain, that is, the demand curve of the whole industry chain is expected to shift to the right, resulting in the rise of the price level of industry A and industry C. Conversely, weaker industrial linkages may not directly affect the expectations of the firms. For example, it is difficult for manufacturers in industry D which is outside the above-mentioned industrial chain to regard the price level of industry B as the signal of demand expansion and Manufacturers may react less to the increase in the price level of industry B. Thus, the direct impact of the rising price level of industry B on the price level of industry D may be minimal.

Next, the relationship between the time lag of price transmission and industry linkage is discussed.

Hypothesis 3: The time lag of price transmission is negatively related to the closeness of the industries, i.e. the intensity of the consumption or distribution relationship.

At present, the main schools of macroeconomics such as New Keynesian generally believe that price adjustment is not immediate, and price stickiness still exists even under the conditions of rational expectations. The most famous theory is the price adjustment cost theory represented by menu cost and so on. The theory holds that manufacturers will maintain the price level when the increase in profits brought about by price adjustments cannot compensate for the increase in costs caused by price adjustments. Whether it is a stronger forward linkage or a stronger backward linkage, it helps to shorten the time lag of price transmission.

Firstly, a stronger industry linkage means that the losses caused by delaying price adjustments increase more quickly. Taking the price increase of industry B as an example, if the backward relationship between industry B and industry C is strong, it means that the increase in the price level of industry B will significantly affect the production cost of industry C. Over time, the loss without price adjustment accumulates quickly, exceeding the cost of price adjustments, prompting the price level of industry C to rise. On the contrary, the weaker backward linkage means that the production cost of industry C is less variable, and the loss is relatively small without price adjustment. It takes longer to accumulate this loss to exceed the price adjustment cost, thus generating a long time lag. For the forward linkage, the forward linkage between Industry A and Industry B is strong, indicating that the capacity expansion of Industry B will generate more significant demand for Industry A products, thus providing conditions for the substantial increase in the price level of Industry A. The weaker forward linkage is unable to provide such conditions due to insufficient demand. The so-called substantial increase here also means that the increase in profit brought by the increase in price level can be higher than the cost of price adjustment.

Secondly, the strength of the industry linkage will also act on the time lag on price adjustment through expectations. It has been pointed out in the description of Hypothesis 2 that when the price level of industry B changes, industries A and C, which are more closely related to industry A, are more likely to produce expectations of price changes, and then change their price levels, and industries with lower linkages with industry B may keep the price level unchanged. When this follow-up price level change is observed by the market, industries with strong industry linkages with industry A and C will continue to follow-up price changes. As a result, the price level changes along the industrial chain, forming a price-constrained time lag; as the degree of industrial correlation gradually weakens, the price change takes longer to transmit, that is, the lag is longer.

Hypothesis 4: The price transmission in China is mainly supply-driven.

It has been explained that the types of price transmission can be divided into two categories from the perspective of transmission direction: price transmission caused by the forward linkage of the upstream industry to the downstream industry, that is, supply-driven price transmission; and price transmission caused by the backward linkage of the downstream industry to the upstream industry, that is, demand-driven price transmission.

Although both forward linkage and backward linkage play an important role in the formation and persistence of price transmission relations, the conclusions of existing studies indicate that the role of the two is generally not symmetrical, but rather a dominant factor. Within the time range in this study (from 2007 to the present), with the weak external demand brought about by the continuous fermentation of the world economic crisis, the demand side lacks strong power to drive the price level to rise, and the deep-seated problems in China's economic structure under the new normal gradually exposed, supply factors are also the focus of research and regulation in academic and macroeconomic practices. Therefore, there is sufficient reason to believe that the current price transmission in China is mainly supply-driven.

2.2 Hypothesis testing scheme

Before testing the above four hypotheses, it is first necessary to clarify whether the price transmission relationship among industries does exist.

Price transmission relationship is a long-term stable relationship existing in industrial price series. According to Zhang Chengsi (2010), co-integration analysis can be used to test it. In terms of statistical concepts, co-integration relationship among price index sequences represents that there is a statistically significant long-term stable relationship among the sequences. If there is a co-integration relationship between the price index series of two industries, it is considered that there is indeed a price transmission relationship between the two industries.

On the basis of the existence of price conduction relationship, hypothesis 1 is first validated. According to the previous discussion, the generation and continuity of price conduction relationship are based on the strength of industrial correlation. Therefore, the following regression model can be used to verify this hypothesis:

$$transmission_{ij} = \beta_0 + \beta_1 backward_{ij}$$

$$transmission_{ij} = \alpha_0 + \alpha_1 forward_{ij}$$

Among them, $transmission_{ij}$ represents whether price conduction relation between representative industry and inter-industry exist, $forward_{ij}$ and $backward_{ij}$ represent the distribution and consumption intensity between industry i and industry j respectively. The key parameter of the test are α_1 and β_1 , when hypothesis 1 is true, both of them should be significantly positive, indicating that the stronger the industrial correlation, the greater the possibility of the existence of price transmission relationship.

Hypothesis 2 and 3 examine whether the magnitude and velocity of price transmission can be explained by industrial correlation. Similar to the hypothesis 1 test, the following regression models were used respectively:

$$pcor_{ij} = \theta_0 + \theta_1 interlink_{ij}$$

$$lag_{ij} = \lambda_0 + \lambda_1 interlink_{ij}$$

Using the first regression equation to test hypothesis 2, $pcor_{ij}$ represents the

intensity of price transmission, $interlink_{ij}$ includes $forward_{ij}$ and $backward_{ij}$, representing the intensity of industrial correlation. The key parameter is θ_1 , when hypothesis 2 is true, the coefficient should be significantly positive, which means the stronger the industrial correlation is, the stronger the price transmission relationship is. Using the second regression equation to test hypothesis 3, lag_{ij} represents the lag period of price transmission. The key parameter is λ_1 , when the coefficient is significantly negative, the stronger the industrial correlation is, the faster the price transmission speed will be, thus hypothesis 3 is established.

The test of hypothesis 4 need to examine both forward and backward connection to determine the main factors affecting price transmission. Therefore, the following regression model was adopted:

$$transmission_{ij} = \xi_0 + \xi_1 demand_{ij} + \xi_2 supply_{ij}$$

$$pcor_{ij} = \gamma_0 + \gamma_1 supply_{ij} + \gamma_2 demand_{ij}$$

$$lag_{ij} = \rho_0 + \rho_1 supply_{ij} + \rho_2 demand_{ij}$$

All of the regression coefficients are key parameters except intercept term. Taking the first regression equation as an example, if ξ_1 is significantly positive, ξ_2 is significantly positive but can't pass the test, indicating that backward connection plays a major role in price conduction relationship, hypothesis 4 is incorrect; on the contrary, if ξ_2 is significantly positive, ξ_1 is significantly positive but can't pass the test, indicating that forward connection plays a major role in price conduction relationship, and price conduction is indeed supply-driven, hypothesis 4 is correct. If significance of both can pass the test, it shows that both forward and backward connections play an important role in the formation of price transmission relationship. In the latter two regression equations, the test method is similar, only in the third regression equation the coefficient is expected to be negative.

On the basis of the previous discussion, it needs to specify why it is inappropriate for the traditional Granger causality test to determine whether price transmission is supply-driven or demand-driven. The reason is that the research object of this paper is no longer the transmission relationship between PPI, CPI and other comprehensive

price indices with a "clear" upstream and downstream relationship, but the price transmission relationship between segmented industries. Due to the division of labor in modern manufacturing industry, the interwoven and overlapping upstream and downstream relationships between industries are basically non-existent as shown in Figure 1. Some industries may have upstream and downstream relationships with each other. For example, the equipment produced by the general equipment manufacturing industry will be used for production by the power, thermal production and supply industries. At the same time, the production of the general equipment manufacturing industry also needs to consume the energy produced by the power, thermal production and supply industries. It is therefore impossible to determine the upstream and downstream relationship of the industry by means of visual analysis. Some industries may not have intuitive upstream and downstream relationships, such as food manufacturing, beverage manufacturing and pharmaceutical manufacturing. It is difficult to determine whether they have an upstream and downstream relationship through intuitive analysis. It is generally believed that these three industries do not have upstream and downstream relationships, but are "parallel". However, in fact, due to the widespread existence of industrial connections, there are still direct and indirect consumption and distribution relations among these industries. From the input-output table, it can be seen intuitively that manufacturing industries without direct industrial connections are very rare, and if indirect connections are considered, all industries generally have connections. In addition, the relationship between industries is not a simple non-upstream or downstream relationship, but may exist both upstream and downstream relationships. As shown in Figure 2, enterprises in the same industry (Industry E) still have some differences in production technology and product types. Some enterprises (E1) may be located in the relative upstream position, while some enterprises (E2) may be located in the relative downstream position. Therefore, compared with one enterprise in another industry (Industry F), the enterprise cluster of E1 may be located in the upstream and the enterprise cluster of E2 may be located in the upstream position. From the perspective of industry as a whole, there are both

forward and backward connections between industry E and industry F, and the relationship between upstream and downstream is not clear. In addition, Clark and Todd (1995) pointed out that there are some problems such as inconsistency of accounting caliber in PPI and CPI.

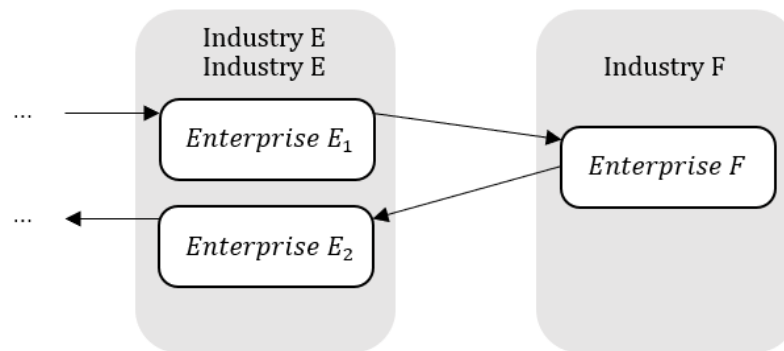


Figure 2 Complexity of upstream and downstream relationships among industries

Based on the above reasons, directly using Granger causality test can explain the sequence of price changes, but it can not clearly match the upstream and downstream relationship of the industry, so it can not clearly indicate whether price transmission is supply-driven or demand-driven. In contrast, the use of forward correlation coefficient and backward correlation coefficient among industries can not only examine the upstream and downstream relations between industries, but also quantify the upstream and downstream relations that have been qualitatively treated before, and give the intensity of industrial correlation.

3. Data and its processing

3.1 Data Sources and Departmental Adjustments

The price index used in this paper is the monthly year-on-year data of the subindustry producer's ex-factory price index from January 2007 to June 2016 published by the National Bureau of Statistics. It contains 114 observations at different time points. Industrial producer ex-factory price index (Hereinafter referred to as price index) measures the price changes of products sold by industrial enterprises measured by ex-factory price. Due to the adjustment of the statistical caliber, the data can be

divided into two sections: January 2007 to December 2013 and January 2014 to June 2016. The former section contains 39 industries, and the latter contains 41 industries. In order to obtain sufficient time series data, the industry was adjusted before the analysis, and some industries which could not be linked up in the two paragraphs were deleted. In addition, the industry corresponding to the input-output table used in the latter part deleted other mining industries, and finally retained the data of 35 industrial sectors. The industrial sectors deleted in the two paragraphs are shown in table 1. Because the data is year-on-year, as Zhang Chengsi (2010) pointed out, the data actually has the meaning of price change rate, can be regarded as year-on-year growth rate, so no seasonal adjustment is needed.

The input-output coefficients in this paper are calculated by using the input-output tables published by the National Bureau of Statistics in accordance with producer prices in the current year. There are 135 departments in the input-output tables in 2007 and 139 departments in the input-output tables in 2012. The above two tables are also summarized according to the corresponding departments of the 35 industries adjusted above, which will not be repeated here.

3.2 Treatment of Price Index

In order to verify hypothesis 2 and 3, it is necessary to find indicators to measure the intensity and time delay of price conduction relationship as test dependent variables. Here, the time difference correlation coefficient between price index series is used as a measure of intensity. In this paper, the upper limit of leading and lagging period is set to 12 periods, that is, one year, which is also consistent with the common accounting period of input-output table and most of the national economic accounting indicators. Specific calculation methods are as follows:

(a) a total of 595 groups of time difference correlation coefficients between 35 industrial price index variables are calculated in pairs, and a total of 25 correlation coefficients are obtained for each group from 12 lagged periods to 12 advanced periods. The calculation methods of time difference correlation coefficients are as follows:

$$r_l = \frac{\sum_{i=1}^n (x_{i-l} - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_{i-l} - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}} \quad l = 0, \pm 1, \dots, \pm 12$$

Among them, x, y represent the price indices of the two industries respectively, l expressed as the number of lagging periods.

(b) Choosing the largest positive correlation coefficient in each group as the description of the intensity of price conduction relationship. The time delay indexes are chosen by the period in which the maximum positive correlation coefficient is located.

The reason why we don't use time series analysis to determine the lag period based on information criteria is that we pay more attention to the economic meaning of indicators rather than statistical significance. As mentioned earlier, price stickiness exists widely in the market due to price adjustment costs, long-term contracts, production cycles and other reasons. Price adjustment takes a certain time. The largest period of relevant index can be regarded as the most representative period for enterprises to make price adjustment in the current period and of good economic significance. It is difficult to use the information criteria method to explain its economic significance. In addition, the selection of the largest positive correlation coefficient can also ensure its statistical significance to a large extent, and the vast majority of correlation coefficients in the actual test are also statistically significant.

3.3 Calculation of Industrial Relevance Coefficient

Industrial correlation coefficient is an independent variable index in the four hypothesis tests, and it is also a key index to determine the upstream and downstream relationship of industry. Among the commonly used quantitative methods, input-output method is the most convenient and accurate way to give quantitative indicators of industrial connections in many subdivisional industries. The calculation methods of forward correlation and backward correlation coefficients are introduced below.

First, explaining the meaning of the symbols in the model. Z represents the intermediate flow matrix, v represents the initial input row vector, f represents the final demand column vector, x represents the total output column vector, and its transposition is the total input row vector.

Leontief proposed the following model for the consumption relationship in product production to define Direct Consumption Coefficient Matrix:

$$A = Z\hat{X}^{-1}$$

Among them, the meaning of element a_{ij} in (i, j) is the amount of i industrial products consumed in the production of total products of the per industry j . Thus, A matrix reflects the consumption in inter-industry production, because this consumption relationship describes the amount of raw materials and the like directly invested in the production of the product, and is therefore referred to as the direct consumption coefficient. Furthermore, indirect consumption is also caused by the consumption of other products in the production process of these directly consumed products. Adding all the direct and indirect consumptions together, we get the complete consumption coefficient matrix

$$B = A + A^2 + A^3 + \dots = (I - A)^{-1} - I$$

I represents the unit matrix, the meaning of element b_{ij} in (i, j) of the matrix B is the amount of i industrial products consumed in the production of the final product used by the unit industry j , thus the matrix B describes the pull of the unit's final demand on the production of various sectors of the economy. On the basis of matrix B , the backward correlation coefficient is calculated.

$$backward = \frac{1}{2}(B + B')$$

The backward correlation coefficient is the result of symmetrical processing of the total consumption coefficient matrix, which reflects the average of the consumption relationship between i industry and j industry.

Leontief model is constructed by column terms. Correspondingly, Ghosh proposed input-output coefficients and models of row structure to definite Direct Distribution Coefficient Matrix

$$R = \hat{X}^{-1}Z$$

Among them, the meaning of the first element r_{ij} in (i, j) is the amount of production directly allocated to the department j in the total output of the per department i . The direct meaning here is similar to that above. From the construction

of the coefficient, we can see that the direct consumption coefficient of the list structure is concerned with the source of the products consumed in industrial production, while the direct distribution coefficient of the row structure reflects the direction of the products produced by the industry, that is, how the products are distributed to different industries. The complete distribution coefficient matrix can also be constructed.

$$D = (I - R)^{-1} - I$$

Among them, the meaning of the element d_{ij} in (i, j) is the quantity allocated to the department j for production in the initial input of the per department i . Therefore, corresponding to the demand pull represented by the total consumption coefficient, the total distribution coefficient reflects the supply push. Similarly, symmetry is used to define forward correlation coefficients.

$$forward = \frac{1}{2}(D + D')$$

This completes the definition of input-output coefficient. Using the national input-output tables of 2007 and 2012, the corresponding backward and forward correlation coefficients can be calculated after the industry adjustment mentioned above. This gives the coefficients and coefficients needed in the second part of the hypothesis test.

4. Empirical analysis

This part uses the indicators calculated in the third part to test the hypothesis of the second part. First of all, the existence of price transmission relationship is analyzed.

4.1 The existence of Price transmission relation

As mentioned earlier, it is only necessary to verify that there is a co-integration relationship between price indices to verify the existence of a price transmission relationship. For this reason, the ADF (unit root) test is used to determine the stationarity of the price index. The ADF test takes the following form. The original assumption is if there is a unit root, the sequence is not stationary. Use the following formula to perform regression:

$$\Delta X_t = \delta X_{t-1} + \sum_{i=1}^m \phi_i \Delta X_{t-i} + u_t$$

The selection of lag period in the test is determined according to the Akaike information criterion (AIC). The results of ADF test show that the price index series of 35 industries are non-stationary, and after the first-order difference, all the series are stationary series. Therefore, 35 price index sequences can be considered as first-order single integral sequence.

On this basis, we examine whether there is a co-integration relationship between the above sequences. The existence of co-integration shows that there is a long-term stable equilibrium relationship between sequences. Here we use the Engle-Granger two-step test for 35 sequences, and we use this method instead of a Johnson cointegration test for all price index variables. The main consideration is that the Engle-Granger two-step method can clearly give the test results of the co-integration relationship between the two groups of variables. In 595 sets of tests, we found that there is a cointegration relationship between the groups of variables. 481 groups, accounting for 80.84% of the total; A further observation of non-co-integration variables shows that there is a tendency of industrial concentration to a certain extent (see figure 3). This shows that, except for a very few industries, there is a common co-integration relationship among the price indices of the vast majority of industries. That is, the price transmission relationship in the manufacturing industry is widespread.

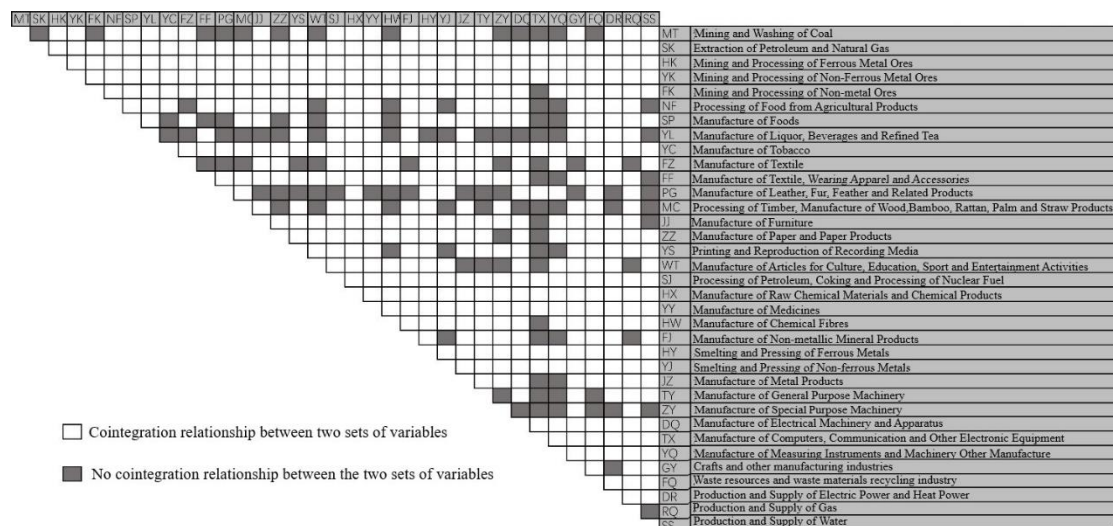


Figure 3 results of co-integration test of inter-industry price index

4.2 Test of hypothesis 1

According to the second part of the analysis, the Boolean variable representing co-

integration, that is, the existence of inter-industry price transmission, is defined as $transmission_{ij}$. The result of Logit regression using $transmission_{ij}$ as dependent variable is shown in Table 1. When using forward correlation coefficient and backward correlation coefficient as distribution relation intensity, consumption relation intensity and price conduction relation existence, the regression coefficient is significantly positive, and the forward relation coefficient is stronger. This shows that the long-term stable price transmission between manufacturing product sectors can indeed be achieved through product generation. The explanation of the relationship between consumption and distribution in production, that is, hypothesis 1 passes the test.

Table 1 Logit regression between the existence of Price transmission relation and the intensity of Industrial correlation

	(1)	(2)	(3)	(4)
forward07	8.6294*** (2.91)			
forward12		8.3592*** (2.79)		
backward07			7.5521** (2.58)	
backward12				7.3201** (2.46)
constant	1.1163*** (7.99)	1.1472*** (8.50)	1.1649*** (8.30)	1.1962*** (8.83)
LR chi2	13.24*** (0.000)	13.27*** (0.000)	8.66*** (0.003)	7.91*** (0.005)

(the value in the regression argument brackets is the value of the z-test statistic, and the value in the parentheses below the chi-square statistic is the p value)

4.3 Test of hypothesis 2 and hypothesis 3

The following test of industrial relevance to the strength of price transmission and lag of the explanatory power. In this paper, we first use the time difference correlation coefficient between price index series and the forward correlation coefficient and the backward correlation coefficient to carry on the regression result as shown in Table 2.

Table 2 Regression between interdepartmental price index correlation coefficient and input-output coefficient

	(1)	(2)	(3)	(4)
forward07	0.3183*** (3.75)			
forward12		0.2975***		

		(3.97)		
backward07			0.3820***	
			(2.52)	
backward12				0.4605***
				(2.99)
constant	0.6594***	0.6606***	0.6591***	0.6574***
	(73.52)	(75.71)	(64.51)	(66.15)

(the value in parentheses is the value of the t-test statistic)

The regression results show that both forward and backward correlation coefficients have a significant positive correlation with the price index correlation coefficient, in which the forward correlation coefficient is in two years (2007, There was no significant difference in size between the regression results in 2012. This shows that there is a close relationship between the intensity of industrial association and the intensity of price transmission, and it is reasonable to analyze price transmission by using industrial correlation relationship, so it can be considered that hypothesis 2 is valid.

Next, in order to verify whether the lag of price transmission can be explained by the intensity of industry correlation, the number of lag periods is used as a dependent variable, and the regression results are shown in Table 3.

Table 3 regression between the number of delay periods of price conduction and the input-output coefficient

	(1)	(2)	(3)	(4)
forward07	-3.7383**			
	(-2.51)			
forward12		-3.1663**		
		(-2.40)		
backward07			-4.3009	
			(-1.62)	
backward12				-4.6490*
				(-1.72)
constant	3.4213***	3.3917***	3.4175***	3.4160***
	(21.70)	(22.08)	(19.10)	(19.59)

(the value in parentheses is the value of the t-test statistic)

Compared with the strength of price conduction, the test results show that the effect of using forward correlation is better than that of backward correlation, that is, the greater the strength of supply-driven, the shorter the delay of price conduction. The

regression results also show that the backward correlation intensity and time delay may also be negative correlation, but there is no good statistical significance. In other words, suppose 3 should be expressed as a negative correlation between the time delay of price conduction and the intensity of the distribution relationship.

4.4 Test of hypothesis 4

In order to determine whether the type of price conduction during the study period is demand-driven or supply-driven, we use the $transmission_{ij}$ (model 1, 2), which represents the existence of price conduction. The $pcor_{ij}$ (model 3, 4) and the lag_{ij} (model 5, 6) which represent the price conduction lag are used as dependent variables, and the regression results are shown in Table 5 using forward and backward association coefficients as independent variables.

Table 4 Regression Test of the Type of Price Transmission relation

	(1)	(2)	(3)	(4)	(5)	(6)
supply07	7.1945* (1.89)		0.2864*** (2.82)		-3.4444* (-1.93)	
supply12		7.1421* (1.92)		0.2490*** (2.79)		-2.7462* (-1.74)
demand07	2.0024 (0.55)		0.1039 (0.58)		-0.9568 (-0.30)	
demand12		1.8007 (0.50)		0.1818 (0.99)		-1.5758 (-0.49)
constant	1.0960*** (7.62)	1.1285*** (8.11)	0.6566*** (64.42)	0.6559*** (66.29)	3.4469*** (19.23)	3.4318*** (19.68)
LR chi2	13.56*** (0.001)	13.53*** (0.001)				

(the value in the regression argument parentheses is the value of the z or t test statistic, and the value in the parentheses below the chi-square statistic is the p value)

The test results show that all the forward correlation coefficients remain statistically significant in the previous regression test when the forward correlation coefficient and the backward correlation coefficient are regressed at the same time. At the same time, all backward correlation coefficients are no longer statistically significant. The reason for this regression result is that the forward correlation and the backward correlation are not independent. As discussed earlier, as a result of the high-end production technology and the refinement of the division of labor, the industrial

relationship has become more complex, and there is a certain correlation between the forward and backward links. Therefore, the backward correlation also showed a better statistical significance in the single regression. But two. The results of the merger regression show that the leading relationship of price transmission is still the forward relationship, that is, the price transmission relationship is supply-driven, which indicates that hypothesis 4 holds.

5. Conclusions

The empirical test of the above four hypotheses shows that the price transmission relationship is inextricably related to the industry relationship, and it is reasonable to use the industry association to explain and even predict the price transmission relationship. Hypothesis 1 shows that the formation of the price conduction relationship between manufacturing products is closely related to the forward and backward industrial relations between the product sectors, that is, the consumption and distribution of the products in production are inextricably related to each other. The detailed division of labor and the extension of the industrial chain promote the forward and backward links between the departments. The industrial chain interweaves with each other to form a complex and related industrial network. With the continuous expansion of the industrial network, the industry chain has become more and more intertwined with each other. The price transmission relationship is long among the various sectors of the industry. Stable existence, any product price change will have an impact on the price of each product in the economy.

Furthermore, the establishment of hypothesis 2 and hypothesis 3 shows that the two characteristics of price transmission-the intensity of transmission and the time-delay of transmission-can be explained in accordance with economic logic. With the enhancement of the forward and backward correlation, the intensity of the price conduction relationship also increases, and the specific performance is the increase of the correlation degree of the two price series. At the same time, the time lag of the price conduction relationship decreases, that is, the time required to reach the maximum

degree of correlation between the two price series becomes shorter. This further proves that it is reasonable and credible to use industrial association to explain the price transmission relationship, and the industrial correlation relationship can be very good. Describe the characteristics of the price transmission relationship.

On this basis, hypothesis 4 shows that in the manufacturing industry, the leading role in price transmission is forward rather than backward, that is, the current price transmission in China is a supply-driven relationship. In other words, the supply-side factor is the main force that affects the price transmission relationship.

In addition, the empirical results also show that there is no significant difference between the statistical significance and the economic significance when using the input-output coefficient of 2007 or 2012. This indicates from a side that the industrial structure of China's manufacturing industry has not changed significantly during the period analyzed in this paper. In 2007, just before the outbreak of the world financial crisis, China is still in a period of rapid economic development, but in 2012, it is still in the period of rapid economic development. China's economy has been growing at a "shift period" and is stepping into the "new normal". With this in mind, the structure of the economy has not changed significantly. This conclusion clearly shows that deepening economic reform is urgent. Combined with the conclusion that the supply-side factors dominate the price transmission relationship at present, it is a reasonable direction to look for the "new driving force" of economic growth by focusing on the optimization and upgrading of the industrial structure from the supply-side.

Reference

- Caporale G M, Pittis N. Causality Links between Consumer and Producer Prices: Some Empirical Evidence[J]. *Southern Economic Journal*, 2002, 68(3):703-711.
- Chen L H, Finney M, Lai K S. A threshold cointegration analysis of asymmetric price transmission from crude oil to gasoline prices[J]. *Economics Letters*, 2005, 89(2):233-239.
- ChiWei Su. An empirical study of Taiwan's bond market based on the nonlinear dynamic model[J]. *Applied Financial Economics*, 2009, 19(19):563-574.
- Clark T E. Do producer prices lead consumer prices?[J]. *Economic Review - Federal Reserve Bank of Kansas City*, 1995, 80(Third Quarter):25-39.
- He Liping, Fan Gang, Hu Jiani. CPI vs. PPI: Which Drives Which? [J]. *Economic Research*, 2008(11): 16-26.
- Holzman F D. Inflation: Cost-Push and Demand-Pull[J]. *Econometrica*, 1960, 50(2):20-42.
- Kinnucan H W, Forker O D. Asymmetry in Farm-Retail Price Transmission for Major Dairy Products[J]. *American Journal of Agricultural Economics*, 1987, 69(2):307-328.
- Mclaren A. Asymmetry in Price Transmission in Agricultural Markets[J]. *Review of Development Economics*, 2015, 19(2):415-433.
- Rui M, Dionisio A, Mendes D A. Asymmetric price transmission within the Portuguese stock market[J]. *Physica A Statistical Mechanics & Its Applications*, 2004, 344(1-2):312-316.
- Serra T, Goodwin B K, Gil J M, et al. Non-parametric Modelling of Spatial Price Relationships[J]. *Journal of Agricultural Economics*, 2006, 57(3):501-522.
- Shrinivas A, Gómez M I. Price transmission, asymmetric adjustment and threshold effects in the cotton supply chain: a case study for Vidarbha, India[J]. *Agricultural Economics*, 2016, 47(4):435-444.
- Silver J L, Wallace T D. The lag relationship between wholesale and consumer prices: An application of the Hatanaka-Wallace procedure[J]. *Journal of Econometrics*, 1980, 12(3):375-387.
- Yang Zihui, Zhao Yongliang, Liu Jianhua. A Nonlinear Research on the Transmission Mechanism between CPI and PPI: Positive Price Transmission or Reversed Price Transmission?[J]. *Economic Research*, 2013(3): 83-95.
- Zerihun Gudeta Alemu. Causality links between consumer and producer price inflation in South Africa[J]. *Applied Economics Letters*, 2012, 19(1):13-18.
- Zhang Chengsi. Long-run Equilibrium, Reversed Price Transmission, and Monetary Driving--Price Transmission Mechanism of Different Stages in China [J]. *Economic Research*, 2010(6): 42-52.
- Zlatcu I, Kubinschi M, Barnea D. Fuel Price Volatility and Asymmetric Transmission of Crude Oil Price Changes to Fuel Prices[J]. *Theoretical & Applied Economics*, 2015, xxii.