An Input-Output Sticky-price Model

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Abstract:

Input-output price model is able to calculate modifications of other prices or the whole price index in response to changes in some prices. Over the years, scholars tried to improve it and designed a lot of expansion models, which continues to be refined. However, the vast majority of the improved models are still trapped in the assumption that price block does not exist when they are applied to analyze the effects of changes in prices. According to this research, we find that the degree of smoothness of prices' transmission makes the result great different. Therefore, this paper, in line with sticky price theory, especially the characteristics of Fischer model (Fischer, 1977a; Phelps and Taylor, 1977), improves the classical model on price transmission to make it more fitting to the real situation. Besides, the IO sticky-price model is extended. In addition, the paper also adopts the improved model and takes advantage of China's actual data from 1992 to 2002 to examine the effects of sticky price on Chinese economy under the changes in one sector's product price.

Keywords**:** IO price model; sticky price; price transmission; IO analysis

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Catalogue

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1 Introduction

Price theory, which is at the core of Economics, shares long-term development with the price model. The input-output price model, one of price models, mainly calculates modifications of other prices or the whole price index in response to changes in some prices. Input-output analysis manifests the interdependent relationship during prices of different sectors (including residents and other sectors) in the national economy. IO price model has advantages in measuring prices' size, the price impact and ripple effect. Input-output price model is able to fully consider and reflect the effects of price transmission system, and the price impact coefficient calculated is a fully coefficient. Therefore, the use of input-output price model analysis shows the effect in response to price changes, not only reflect the direct impacts of price changes, but also reflect the indirect ones.

The first input-output price model was formulated by Leontief (1947, 1986 the second version), also known as the cost - pricing structure , which was used to study the interdependence during prices of the various sectors in the United States. From a cost perspective, the price model reflects formation and ripple effects in prices. The price change is limited to inter-industry framework under the assumption that the input

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coefficients remain unchanged. Besides, the model does not consider other factors except cost changing. Based on gap between the classical model and the actual situation, the input-output price model has since been developed by a lot of scholars.

Georgescu-Roegen (1951) first spelled out the definition of the dynamic Price theory; he also put forward a dynamic input-output price model, in which the price of each commodity must cover its current unit product cost and the "interest" of necessary capital, equipment, etc. Sollow (1959) considered such a dynamic price model was more reasonable than the model of Hawkins. Morishima (1958), Solow (1959), Duchin (1988) and others made the dynamic pricing model by the entrepreneur maximizing the sum of profits and capital gains, or minimizing expenditures; Johansen (1978), Duchin & Lange (1992) further proposed a kind of dynamic model with variable factor prices and technology. Fatemeh Bazzazan & Peter WJ Batey (2003) did a detailed overview of above models, and set up an extended input-output price model that is based on the partial-closed input-output price model, but also talking about the price model of resources. During expansion and improvement of the model, the approach of putting various theories into the IO price model is a very important aspect. In China, scholars have used many kinds of the theories, including the optimization theory (Liu Xiuli & Xi-Kang Chen, 2003; Guo Wei & Zhang Ping，2003), Avenue theory (He Jing & Xi-Kang Chen , 2005; Yuan-Tao Xie , 2006), as well as the idea of general equilibrium.

The researches above succeeded in obtaining some valuable conclusions. At the same time, various papers to extend IO price model provides referrible methods. Price transmission is hampered actually to some extent, but existing IO research involving this is virtually non-existent. Hong-Xia Zhang (2008) further developed and improved the input-output price model, by considering the relationship between supply and demand and by considering the impact of government price regulation. It is different from the price transmission. However, it is too important to be ignored. This resulted in our attention and thought. This paper will try to reflect the sticky character of the price based on IO analysis, as far as possible to ensure the model's operability too.

2 Relevant Theories

2.1 The details and analysis of the IO price modeling

Classical input-output price model has five basic assumptions as follows:

Assumption 1: Price modifications of affected commodities (sectors) in response to change in some prices are due to the changes of the cost of material consumption, without considering impact of changes in wages or profit and tax.

Assumption 2: Though raw materials, fuel and power prices were raised, the companies will not take various measures to reduce material consumption and other cost.

Assumption 3: At price formation the model does not consider the depreciation changes.

Assumption 4: Do not consider the supply and demand effects on prices.

Assumption 5: The model does not consider time-delay factor and block problem in price transmission. In other words, the impacts of the price change transmit through the industry chain instantaneously. There is no time-delay problem or other constraints. In this hypothetical premise, increased costs caused by price increase will be transmitted to further impact on prices; and such conduction type is full and smooth. Ultimately, the results measured are the maximum.

The assumptions above of classical IO price model determine scope of the application. The following text will introduce the detail calculation methods and formulas of the model based on the above assumptions.

Input-output price model can be set up on the basis of the price transmission mechanism. Firstly we assume that there are n sectors. Throughout this model description the following set of indices will be used:

Δp_i =the quantity changing of product price of sector i

$\Delta p_{(o)j\neq i} = (\Delta p_1 \Delta p_2 \cdots \Delta p_{i-1} \Delta p_{i+1} \cdots \Delta p_n)$

a_{ij}： The element in row i column j of technical input coefficient matrix A.

a_i： The vector in row i of the technical input coefficients matrix A, without a_{ii} ,

$a_i = (a_{i1} \ldots\ldots a_{i,i-1}, \; a_{i,\; i+1}, \ldots\ldots a_{in})$. a_i^{T} is its transpose, a column vector.

$\overline{A}$ is technical input coefficient matrix A without row i and column j. $\overline{A}^T$ is its transpose.

The model is derived according to the cost structure. Only the price of sector i changes and that is Δp_i (%); prices of other n-1 sectors correspondingly change by cost driving, which can be set up for Δp_j (j≠k). Δp_j should be composed of two parts as follows:

Direct impact: $\Delta p_i a_{ij}$;

Indirect impact: $\sum_{\substack{l=1 \\ l\neq i}}^{n} \Delta p_{l\neq i} a_{lj}$;

Then

$$\Delta p_j = \Delta p_i a_{ij} + \sum_{\substack{l=1 \\ l \neq i}}^{n} \Delta p_{l \neq i} a_{lj} \tag{1}$$

If we describe it in matrix form, that is: $\Delta P_{(o)\, j \neq i} = \Delta p_i a_i^T + \Delta P_{(o)\, j \neq i} \overline{A}^T$

Thus,

$$\Delta P_{(o)\, j \neq i} = (I - \overline{A}^T)^{-1} a_i^T \Delta p_i \tag{2}$$

The derived method is similar to the idea of Leontief inverse matrix. The vector $(I - \overline{A}^T)^{-1} a_i^T$ can be called as price impact multiplier of sector i (Ren Zeping, Pan Wenqing & Liu Qiyun, 2007).

Similarly, if m sectors at the end change their prices as $\Delta P^m = (\Delta P_{n-m+1}, \Delta P_{n-m+2}, \cdots, \Delta P_n)^T$, the impact to (n-m) sectors before them can be calculated. The formula is:

$$\begin{pmatrix} \Delta p_1 \\ \Delta p_2 \\ \vdots \\ \Delta p_{n-m} \end{pmatrix} = \begin{pmatrix} \overline{b_{(n-m+1).1}} & \cdots & \cdots & \overline{b_{n1}} \\ \overline{b_{(n-m+1).2}} & \cdots & \cdots & \overline{b_{n2}} \\ \vdots & & & \vdots \\ \overline{b_{(n-m+1)(n-m)}} & \cdots & \cdots & \overline{b_{n(n-m)}} \end{pmatrix} \begin{pmatrix} \overline{b_{(n-m+1)(n-m+1)}} & \cdots & \cdots & \overline{b_{n(n-m+1)}} \\ \overline{b_{(n-m+1)(n-m+2)}} & \cdots & \cdots & \overline{b_{n(n-m+2)}} \\ \vdots & & & \vdots \\ \overline{b_{(n-m+1)n}} & \cdots & \cdots & \overline{b_{nn}} \end{pmatrix}^{-1} \begin{pmatrix} \Delta p_{(n-m+1)} \\ \Delta p_{(n-m+2)} \\ \vdots \\ \Delta p_n \end{pmatrix}$$

The first two matrix elements at the right side of the equation come from Leontief inverse matrix $\left(I - A\right)^{-1}$. Price changes are measured in relative numbers, which are the ratios that price changes compared with the original price level.

Let $K = \begin{pmatrix} \overline{b_{(n-m+1).1}} & \cdots & \cdots & \overline{b_{n1}} \\ \overline{b_{(n-m+1).2}} & \cdots & \cdots & \overline{b_{n2}} \\ \vdots & & & \vdots \\ \overline{b_{(n-m+1)(n-m)}} & \cdots & \cdots & \overline{b_{n(n-m)}} \end{pmatrix} \begin{pmatrix} \overline{b_{(n-m+1)(n-m+1)}} & \cdots & \cdots & \overline{b_{n(n-m+1)}} \\ \overline{b_{(n-m+1)(n-m+2)}} & \cdots & \cdots & \overline{b_{n(n-m+2)}} \\ \vdots & & & \vdots \\ \overline{b_{(n-m+1)n}} & \cdots & \cdots & \overline{b_{nn}} \end{pmatrix}^{-1}$

Then the model's reduced form can be gotten and K can be named as price impact matrix multiplier.

The extent to which model reflects the real situation depends on the degree that the assumptions of model according with economic reality. Therefore, when the model is used to measure the impact of price, it is necessary to combine with the supply and demand situation and government policies, etc., in order to obtain a more realistic fitting conclusion under the analysis of the actual economic system. The above model assumptions are strong, which have some large gaps with the economic realities. The following section 2.2 will concretely exposit one of the gaps at the theoretical and practical aspects.

2.2 Price stickiness theory

2.2.1 A price-stickiness example in China

Price stickiness is common in the economy. At the production flow, resource product price increasing will directly pull the purchase price of raw materials, fuels and power, eventually bring upward pressure on industry goods price and consumable prices under the mechanism of price transmission. According to the line graph (Fig.1) in "Zhejiang: price changes of resource product and their impact study", it is obvious that purchased prices of industrial products rose less than the price of raw materials, fuels and power. Similarly, price changes of consumer goods are less than those of purchased prices of industry goods, and the gap seems to become wider. Therefore, price transmission process is not as smooth as the description in the classical model. The situation can be called as price stickiness, which generally means the slowly adjusted trend in the nominal price in the actual economy.

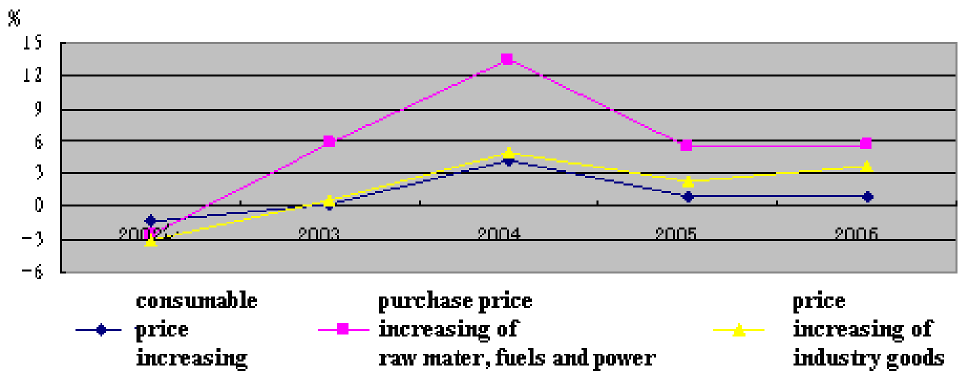

Fig. 1 The price change trend of consumable, raw material and industry goods in 2002-2006

Source: The National Bureau of Statistics of China

2.2.2 Conception of price stickiness

Where is the price stickiness theory from? Keynesian economic theory explains monetary non-neutral character through the assumption of the price stickiness. In the classical models, when economic agents have no illusion, adjusting wages and prices quickly to make money in the economy are neutral. If so, the money supply increasing or decreasing will not affect the actual adjustment in economic variables, but merely a corresponding change in the price level and nominal wage levels. However, much experience shows that currency in the real economy is not neutral. Keynesian insists on using price stickiness to explain monetary non-neutral. When prices are sticky, the price level can not be adjusted quickly.

The section investigates the staggered price adjustment theory that broached by some Keynesian. Based on the theory, some interesting models can be found.

There are three different models of such staggered price adjustment: the Fischer, or Fischer-Phelps-Taylor, model (Fischer, 1977a; Phelps and Taylor, 1977); the Taylor model (Taylor, 1979, 1980), and the Caplin-Spulber model (Caplin and Spulber, 1987).

The first two, the Fischer and Taylor models, should be paid more attention to. They posit that wages or prices are set by multiperiod contracts or commitments. In each period, the contracts governing some fraction of wages or prices expire and must be renewed. The central result of the models is that multiperiod contracts lead to gradual adjustment of the price level to nominal disturbances. As a result, aggregate demand disturbances have persistent real effects.

It is not realistic that all prices must be reset before each period. Therefore, the Fischer model assumes that prices (or wages) are determined but not fixed. That is, when a multiperiod contract set prices for several periods, it can specify a different price for each period. In the Taylor model, in contrast, prices are fixed: a contract must specify the same price each period it is in effect. This model therefore examines what happens when not all prices are adjusted every period. Thus price adjustment is time-dependent. (Because the concrete models are unusable to the following content, they are ignored.)

The prices in current period are determined by the previous ones. For simplicity, we assume that prices in each sector are adjusted through a staggered approach in a certain length of time. According to the Fischer model, we set that:

$$P_i^{(t)} = (1-\beta_i)P_i^{(t-2)} + \beta_i P_i^{(t-1)} \tag{3}$$

Where $P_i^{(t)}$ = the price of section i in period t. It is partially determined by the prices in period t-1 and t-2.

β_i = weight of the price of section i in period t-1 and can be called as sticky weight.

3 Methodology

3.1 The simple Input-output sticky-price Model to reflect direct impact

3.1.1 Deduction of the classical IO price model

Assuming that the price in sector one changes, so $p_1^{(1)} = p_1^{(0)} + \Delta p_1$

（1） $p_2^{(1)} = p_1^{(1)}\alpha_{12} + p_2^{(0)}\alpha_{22} + p_3^{(0)}\alpha_{32} + u_2 = p_2^{(0)} + \Delta p_1\alpha_{12}$

$p_3^{(1)} = p_1^{(1)}\alpha_{13} + p_2^{(0)}\alpha_{23} + p_3^{(0)}\alpha_{33} + u_3 = p_3^{(0)} + \Delta p_1\alpha_{13}$

（2） $p_2^{(2)} = p_1^{(1)}\alpha_{12} + p_2^{(1)}\alpha_{22} + p_3^{(1)}\alpha_{32} + u_2$

$p_3^{(2)} = p_1^{(1)}\alpha_{13} + p_2^{(1)}\alpha_{23} + p_3^{(1)}\alpha_{33} + u_3$

（3） $p_2^{(3)} = p_1^{(1)}\alpha_{12} + p_2^{(2)}\alpha_{22} + p_3^{(2)}\alpha_{32} + u_2$

$p_3^{(3)} = p_1^{(1)}\alpha_{13} + p_2^{(2)}\alpha_{23} + p_3^{(2)}\alpha_{33} + u_3$ ……

Thus, the price change in each step can be measured by reduction:

（1） $\Delta p_2^{(1)} = \Delta p_1\alpha_{12}$； $\Delta p_3^{(1)} = \Delta p_1\alpha_{13}$

（2） $\Delta p_2^{(2)} = \Delta p_2^{(1)}\alpha_{22} + \Delta p_3^{(1)}\alpha_{32}$； $\Delta p_3^{(2)} = \Delta p_2^{(1)}\alpha_{23} + \Delta p_3^{(1)}\alpha_{33}$

（3） $\Delta p_2^{(3)} = \Delta p_2^{(2)}\alpha_{22} + \Delta p_3^{(2)}\alpha_{32}$； $\Delta p_3^{(3)} = \Delta p_2^{(2)}\alpha_{23} + \Delta p_3^{(2)}\alpha_{33}$ ……

The prices of sector 2 and sector 3 can be formed by adding price changes of every step together:

$$\Delta p_2 = \Delta p_1\alpha_{12} + \Delta p_2\alpha_{22} + \Delta p_3\alpha_{32}$$

$$\Delta p_3 = \Delta p_1\alpha_{13} + \Delta p_2\alpha_{23} + \Delta p_3\alpha_{33}$$

In matrix form:

$$\begin{pmatrix}\Delta p_2\\ \Delta p_3\end{pmatrix} = \begin{pmatrix}1-\alpha_{22} & -\alpha_{32}\\ -\alpha_{23} & 1-\alpha_{33}\end{pmatrix}^{-1}\begin{pmatrix}\alpha_{12}\\ \alpha_{13}\end{pmatrix}\Delta p_1$$

Therefore, the general situation can be formed as:

$$\Delta p_{(o)j\neq i} = (I - \overline{A}^T)^{-1} a_i^T \Delta p_i$$

3.1.2 Simple IO sticky-price model

For simplicity, we assume that prices in each sector are adjusted through a staggered approach in a certain length of time. According to the formulation (3) and the above deduction, the staggered adjustment can be shown as following equations:

（1） $p_2^{(1)} = ((1-\beta_1)p_1^{(0)} + \beta_1 p_1^{(1)})\alpha_{12} + p_2^{(0)}\alpha_{22} + p_3^{(0)}\alpha_{32} + u_2 = p_2^{(0)} + \beta_1 \Delta p_1 \alpha_{12}$

$p_3^{(1)} = ((1-\beta_1)p_1^{(0)} + \beta_1 p_1^{(1)})\alpha_{13} + p_2^{(0)}\alpha_{23} + p_3^{(0)}\alpha_{33} + u_3 = p_3^{(0)} + \beta_1 \Delta p_1 \alpha_{13}$

（2） $p_2^{(2)} = ((1-\beta_1)p_1^{(0)} + \beta_1 p_1^{(1)})\alpha_{12} + ((1-\beta_2)p_2^{(0)} + \beta_2 p_2^{(1)})\alpha_{22} + ((1-\beta_3)p_3^{(0)} + \beta_3 p_3^{(1)})\alpha_{32} + u_2$

$p_3^{(2)} = ((1-\beta_1)p_1^{(0)} + \beta_1 p_1^{(1)})\alpha_{13} + ((1-\beta_2)p_2^{(0)} + \beta_2 p_2^{(1)})\alpha_{23} + ((1-\beta_3)p_3^{(0)} + \beta_3 p_3^{(1)})\alpha_{33} + u_3$

（3） $p_2^{(3)} = ((1-\beta_1)p_1^{(0)} + \beta_1 p_1^{(1)})\alpha_{12} + ((1-\beta_2)p_2^{(1)} + \beta_2 p_2^{(2)})\alpha_{22} + ((1-\beta_3)p_3^{(1)} + \beta_3 p_3^{(2)})\alpha_{32} + u_2$

$p_3^{(3)} = ((1-\beta_1)p_1^{(0)} + \beta_1 p_1^{(1)})\alpha_{13} + ((1-\beta_2)p_2^{(1)} + \beta_2 p_2^{(2)})\alpha_{23} + ((1-\beta_3)p_3^{(1)} + \beta_3 p_3^{(2)})\alpha_{33} + u_3$

……

Similarly, the price change in each step can be gotten as follows:

（1） $\Delta p_2^{(1)} = \beta_1 \Delta p_1 \alpha_{12}$; $\Delta p_3^{(1)} = \beta_1 \Delta p_1 \alpha_{13}$

（2） $\Delta p_2^{(2)} = \beta_2 \Delta p_2^{(1)} \alpha_{22} + \beta_3 \Delta p_3^{(1)} \alpha_{32}$; $\Delta p_3^{(2)} = \beta_2 \Delta p_2^{(1)} \alpha_{23} + \beta_3 \Delta p_3^{(1)} \alpha_{33}$

（3） $\Delta p_2^{(3)} = ((1-\beta_2)\Delta p_2^{(1)} + \beta_2 \Delta p_2^{(2)})\alpha_{22} + ((1-\beta_3)\Delta p_3^{(1)} + \beta_3 \Delta p_3^{(2)})\alpha_{32}$

$\Delta p_3^{(3)} = ((1-\beta_2)\Delta p_2^{(1)} + \beta_2 \Delta p_2^{(2)})\alpha_{23} + ((1-\beta_3)\Delta p_3^{(1)} + \beta_3 \Delta p_3^{(2)})\alpha_{33}$

……

For gaining the fully price effects, price changes of each step should be added together. Just for the reason, the result showed no sticky character except step 1 when the number of steps is infinite. In other words, the model just shows direct impact of the price change.

$\Delta p_2 = \beta_1 \Delta p_1 \alpha_{12} + \Delta p_2 \alpha_{22} + \Delta p_3 \alpha_{32}$; $\Delta p_3 = \beta_1 \Delta p_1 \alpha_{13} + \Delta p_2 \alpha_{23} + \Delta p_3 \alpha_{33}$

In form of matrix: $\begin{pmatrix} \Delta p_2 \\ \Delta p_3 \end{pmatrix} = \begin{pmatrix} 1-\alpha_{22} & -\alpha_{32} \\ -\alpha_{23} & 1-\alpha_{33} \end{pmatrix}^{-1} \begin{pmatrix} \alpha_{12} \\ \alpha_{13} \end{pmatrix} \beta_1 \Delta p_1$

Thus $\Delta p_{j \neq i} = (I - \overline{A}^T)^{-1} a_i^T \beta_i \Delta p_i$ (4)

3.2 Further expansion of IO sticky-price model to reflect indirect impact

Because the above model does not fully reflect the price stickiness in the process of price transmission, theoretical models need to be further improved. This subsection will focus on the research, making that the indirect impact can also reflect the price stickiness. The above set of indices can be similarly used throughout this model.

Δp_j should be composed of two parts as follows:

Direct impact: $\beta_i \Delta p_i a_{ij}$;

Indirect impact: $\sum_{\substack{l=1 \\ l \neq i}}^{n} \beta_l \Delta p_{l \neq i} a_{lj}$;

Then $\Delta p_j = \beta_i \Delta p_i a_{ij} + \sum_{\substack{l=1 \\ l \neq i}}^{n} \beta_l \Delta p_{l \neq i} a_{lj}$ (5)

If we describe it in matrix form, that is: $\Delta P_{j \neq i} = \beta_i \Delta p_i a_i^T + \Delta P_{j \neq i} C \overline{A}^T$

Thus, $\Delta P_{j \neq i} = (I - C\overline{A}^T)^{-1} a_i^T \beta_i \Delta p_i$ (6)

Where $\Delta p_{j \neq i} = (\Delta p_1 \Delta p_2 \cdots \Delta p_{i-1} \Delta p_{i+1} \cdots \Delta p_n)$; $C = \begin{pmatrix} \beta_1 & & & & & \\ & \ddots & & & & \\ & & \beta_{i-1} & & & \\ & & & \beta_{i+1} & & \\ & & & & \ddots & \\ & & & & & \beta_n \end{pmatrix}_{(n-1)\times(n-1)}$

The derived method is also similar to the idea of Leontief inverse matrix. The vector $(I - \overline{A}^T)^{-1} a_i^T$ can be called as sticky price impact multiplier of sector i.

Similarly, if m sectors finally change their prices as $\Delta P^m = (\Delta P_{n-m+1}, \Delta P_{n-m+2}, \cdots, \Delta P_n)^T$, the impact to (n-m) sectors before them can be calculated. The formula is:

$$\begin{pmatrix}\Delta p_1\\ \Delta p_2\\ \vdots\\ \Delta p_{n-m}\end{pmatrix}=\left(I-C_{n-m}\begin{pmatrix}\overline{a_{(n-m+1)(n-m+1)}} & \cdots & \cdots & \overline{a_{n(n-m+1)}}\\ \overline{a_{(n-m+1)(n-m+2)}} & \cdots & \cdots & \overline{a_{n(n-m+2)}}\\ \vdots & & & \vdots\\ \overline{a_{(n-m+1)n}} & \cdots & \cdots & \overline{a_{nn}}\end{pmatrix}\right)^{-1}\begin{pmatrix}\overline{a_{(n-m+1).1}} & \cdots & \cdots & \overline{a_{n1}}\\ \overline{a_{(n-m+1).2}} & \cdots & \cdots & \overline{a_{n2}}\\ \vdots & & & \vdots\\ \overline{a_{(n-m+1)(n-m)}} & \cdots & \cdots & \overline{a_{n(n-m)}}\end{pmatrix}C_m\begin{pmatrix}\Delta p_{(n-m+1)}\\ \Delta p_{(n-m+2)}\\ \vdots\\ \Delta p_n\end{pmatrix}$$

Where $C_{n-m}=\begin{pmatrix}\beta_1 & & & \\ & \beta_2 & & \\ & & \ddots & \\ & & & \beta_{n-m}\end{pmatrix}$; $C_m=\begin{pmatrix}\beta_{n-m+1} & & & \\ & \beta_{n-m+2} & & \\ & & \ddots & \\ & & & \beta_n\end{pmatrix}$

The deduction of the model is similar to that of the classical model. According to this model, both of the direct impact and the indirect impact can be measured to a certain extent. Therefore, the model will be used to further study and be called as the new model in what come next.

3.3 Concrete explanations of parameters in IO sticky-price model

First and foremost, this section will show the method to measure the sticky weight β_i that is one of the most important parameters in the model.

Keynesian considers the price stickiness is mainly generated from the menu costs and coordination failures; in theory, the relevant values should be obtained from the perspective of micro-surveys. However, taking the difficulty of the actual operation into account, this paper will use the terms of life cycle in each department instead of that. Specifically, the average of the GDP elasticity coefficient should be firstly calculated, and then compare it with 1. If the coefficient equals to or is greater than 1, the sticky weight of the sector will be set to equal to 1; contrarily, if the coefficient is less than 1,

$$E_i=\frac{MC_i}{AC_i}\times 100\% \tag{7}$$

Where E_i means the average of the GDP elasticity coefficient in sector i;

$$MC_i = \frac{GDP_{it} - GDP_{i0}}{GDP_t - GDP_0} \times 100\% \; ; \quad AC_i = \frac{(GDP_{it} + GDP_{i0})/2}{(GDP_t + GDP_0)/2} \times 100\%$$

GDP_{i0} , GDP_{it} are separately the GDP of sector i at the beginning and in term t.

GDP_0 , GDP_t separately mean the GDP in term 0 and term t.

Then $\begin{cases} \beta_i = 1 & \text{if} \quad E_i \geq 1 \\ \beta_i = E_i & \text{if} \quad E_i < 1 \end{cases}$

The other parameters are similar to the classical mode, so the paper omits the relevant explanations.

3.4 Application and relevant problems

There is substantial empirical analysis literature using IO Price Model regarding the impact of the price changes in the national economy. Most of these papers use IO price model for one department or some departments to solve the price problems, involving both of the regional scope and the global scope; both of provinces and cities across the country; and as well as a majority of the nationwide analysis. For example: Yu, Chi and Su (2002) analysis oil price and its effects to other sectors in the national economy, as well as Ren, Pan and Liu (2007); Zhong Qifu studied the impacts of the sectors in response to the price change in agriculture, and the correlation analysis by Wang Wei (2008); Liu Xiuli and Chen Xikang (2003) have researched the water resource price and its impacts. There are also a lot of analysis in provinces and cities price system, such as Zhen and Cai (2006), Ge Xiongcan (1996), Ren Zeping and Liu Qiyun (2007), etc.

The input-output sticky price model can be used in the fields as long as the classical model can be applied to. It can be applied to measure the impact of the price changes ripple effect in sectors of IO table, with finding the degree of price impact between sectors because of the price changes, and making sure their sequencing. Besides, by comparing the result of the original model and that of the new one, the sticky price impact can be found after analysis, and then getting the affected extent. We can say this is a unique feature of the new model.

4 Empirical Analysis

4.1 Data collected and data processing

It is difficult to achieve fully compliant data for the model, so the article chooses some data instead, which should be acceptable. The data collected for empirical analysis include Data (1) GDP and added value of 54 sectors in 1998-2003, Data (2) the constant price input-output table with 62 sectors in 2002.

Data in (1) for quantitative analysis used in the second and tertiary industry are from "China Statistical Yearbook" in 1999-2004, and added value of the industrial sectors are calculated according to main economic indicators of each sectors comparing with GDP. In the light of absence of the added value of the primary industry in the “China Statistical Yearbook”, the sector added value is calculated from the output of the sector in the same year, according to the ratio of output and added value in the same year. The choice of 6-year data is because the average elasticity ratio of sector added value to GDP in a certain period of time will be more accurate than one year. By using these data, E_i and β_i can be measured. Specific calculating process can be found in Reference [24], and Table 1 in the appendix can show detail data.

Data (2) comes from the 1987-2005 constant price input-output tables released by the National Bureau of Statistics of China in 2008, which is discrete including 1987, 1992, 1997, 2002 and 2005. All of these five tables do not have the same sectors. Here only selected the data in 2002, first, because it is accomplished by the actual measurement, containing the smaller error; on the other hand, because it can couple with Data (1) throughout the model.

However, the sector classification in data (1) and that in data (2) are different. In order to enable the couple process between them, some methods should be used. This article carries out the necessary deletion and merger, and then gets the relevant data with 29 sectors. Table 2 shows the specific methods.

4.2 Application of the IO sticky-price model in Chinese national economy

This section assumes that price of agricultural products increases, and through the model measures the increasing degree of product prices in other sectors to identify the sensitivity of the various industries to price changes of agricultural products. The models used here contain both of the classical model and the new model in order to facilitate the comparison next; about specific formulas, please see Formula (2) and Formula (6) above. In Table 3 based on two kinds of input-output price models, it is separately shown that the price impact of 28 sectors in response to the 100% price increasing of agricultural products, where the data are arranged in accordance with the result of the classical model in descending order. Data in Table 4 are arranged on the basis of the result of the new model in descending order. In line with Table 4, a histogram can be illustrated, i.e. Fig. 2.

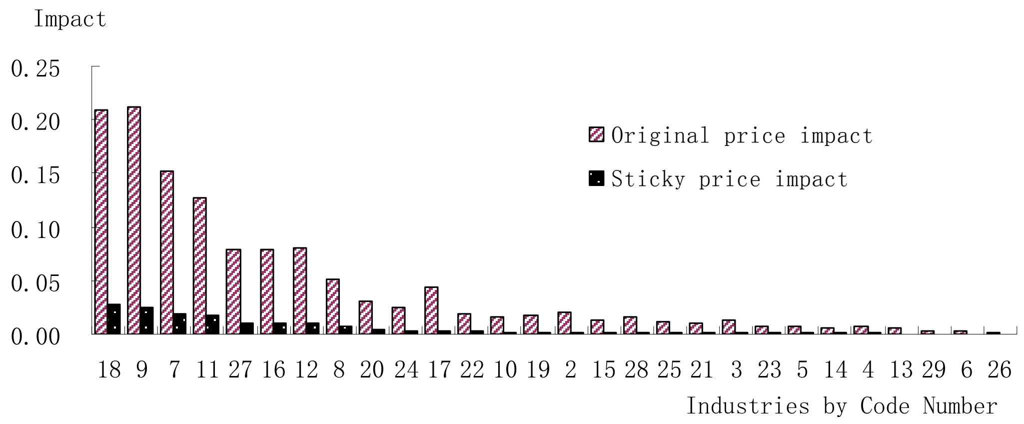

Fig. 2 The results of the classical model and the new one

Under considering the price stickiness, the order that is dependent on the increase degree of prices in various sectors hardly changes. In both of them, the top four sectors affected most largely are Rubber Products, Textile Industry, Beverage Manufacturing, Leather, Furs, Down and Related Products. Similarly, the last four sectors in the queue separately are Printing and Record Medium Reproduction, Real Estate, Construction Material and Other Nonmetal Minerals Mining and Dressing, Water Production and Supply Industry. However, the new results should be evidently less than the original model results in line with Fig. 2.

5 Conclusion and Prospect

We analyzed and summarized the IO price model systemically, and described the certain block in the price transmission process by using the tools of input-output analysis in this paper. Those conclusions enrich the theory researches of the price model, and break a new path for the quantitative analysis of it.

In section 2, the study summed up the IO price model assumptions and the specific structural characteristics, pointed out that the objectivity of existence of the price stickiness in the real economy (2.2 section of Figure 1), and introduced the theory of price stickiness, and to clarify the classical IO Price Model having room for the improvement in price transmission. In Section 3 the input-output sticky price model was constructed (3.1 and 3.2), right following which we designed a cohesive method of calculating the weights (3.3); also elaborate on the scope of application of the old and the new models. Section 4 contains an empirical analysis, an analysis of the impact of price changes of agricultural products; besides, it compared the similarities and differences between two kinds of models.

According to the above-mentioned studies, we believe that the integration of price stickiness and the classical IO price model is beneficial to the improvement of the model, which makes the models better fitting to reality and actual economic conditions. Apart from above study, how to find a more ideal model expression and how to more accurately measure the parameters and the effect of price stickiness, need our required in-depth research and long-term efforts.

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Appendix

Table 1 Average Elasticity Coefficients and Sticky Weights in 1998-2003

Code Number	Sectors	AC_i	MC_i	E_i	β_i
1	Agriculture	9.408	1.289	0.137	0.137
2	Forestry	0.608	0.391	0.643	0.643
3	Animal Husbandry	4.991	3.057	0.613	0.613
4	Fishery	1.739	1.177	0.677	0.677
5	Coal Mining and Dressing	1.308	0.875	0.669	0.669
6	Petroleum and Natural Gas Extraction	2.674	2.385	0.892	0.892
7	Ferrous Metals Mining and Dressing	0.120	0.093	0.775	0.775
8	Nonferrous Metals Mining and Dressing	0.227	0.067	0.295	0.295
9	Construction Material and Other Nonmetal Minerals Mining and Dressing	0.219	0.013	0.059	0.059
10	Logging and Transport of Timber and Bamboo	0.124	−0.252	−2.032	−2.032
11	Food Processing	1.536	1.366	0.889	0.889
12	Food Manufacturing	0.750	0.786	1.048	1.000
13	Beverage Manufacturing	1.087	0.132	0.121	0.121
14	Tobacco Products	1.929	1.315	0.682	0.682
15	Textile Industry	2.223	1.557	0.700	0.700
16	Garments, Shoes and Hats Manufacturing	1.054	0.750	0.712	0.712
17	Leather, Furs, Down and Related Products	0.626	0.613	0.979	0.979
18	Wood-processing Industry	0.278	0.391	1.406	1.000
19	Furniture Manufacturing	0.182	0.233	1.280	1.000
20	Papermaking and Paper Products	0.757	0.915	1.209	1.000
21	Printing and Record Medium Reproduction	0.398	0.272	0.683	0.683
22	Cultural, Educational and Sports Goods	0.299	0.140	0.468	0.468
23	Petroleum Processing and Coking	1.300	1.821	1.401	1.000
24	Raw Chemical Materials and Chemical Products	2.535	2.561	1.010	1.000
25	Manufacture of Medicines	1.076	1.560	1.450	1.000
26	Chemical Fiber Manufacturing	0.374	0.081	0.217	0.217
27	Rubber Products	0.429	0.198	0.462	0.462
28	Manufacture of Plastic	0.851	1.087	1.277	1.000
29	Nonmetal Mineral Products	1.957	1.193	0.610	0.610

Code Number	Sectors	AC_i	MC_i	E_i	β_i
30	Smelting and Pressing of Ferrous Metals	2.366	3.023	1.278	1.000
31	Smelting and Pressing of Nonferrous Metals	0.814	1.125	1.382	1.000
32	Metal Products Manufacturing	1.151	1.108	0.963	0.963
33	Ordinary Machinery Manufacturing	1.582	1.474	0.932	0.932
34	Special Purpose Equipment Manufacturing	1.086	0.919	0.846	0.846
35	Transport Equipment	2.174	8.447	3.885	1.000
36	Electric Equipment and Machinery	2.098	2.565	1.223	1.000
37	Electronic and Telecommunications Equipment	3.064	5.983	1.953	1.000
38	Instruments, Meters, Cultural and Office Machinery	0.374	0.294	0.786	0.786
39	Production and Supply of Electric power and heat	4.307	4.321	1.003	1.000
40	Gas Production and Supply	0.054	0.192	3.556	1.000
41	Water Production and Supply Industry	0.256	0.081	0.316	0.316
42	Construction Business	6.681	6.702	1.003	1.000
43	The Primary Industry Services	0.265	0.322	1.215	1.000
44	Geological and Water Conservancy	0.359	0.204	0.568	0.568
45	Transport, Postal and Telecommunication Services	5.658	8.010	1.416	1.000
46	Commerce	8.078	6.183	0.765	0.765
47	Finance and Insurance	5.818	4.954	0.851	0.851
48	Real Estate	1.902	2.182	1.147	1.000
49	Social Services	3.702	5.601	1.513	1.000
50	Health Care, Sports and Social Welfare	0.959	1.441	1.503	1.000
51	radio, film and television industries	2.629	4.413	1.679	1.000
52	Scientific Research and Polytechnical Services	0.665	1.047	1.574	1.000
53	Government Agencies, Parties and Social Organizations	2.592	3.057	1.179	1.000
54	Other Tertiary Industry	0.309	0.282	0.913	0.913

Table 2 Check List between Sectors in 2002 IO Table and Table 1

New Code Number	Original Code Number	Sectors in 2002 IO Table	Original Code Number	Sectors in Table 1
1	1	Agriculture	1	Agriculture
2	2	Coal Mining and Dressing	5	Coal Mining and Dressing
3	3	Petroleum and Natural Gas Extraction	6	Petroleum and Natural Gas Extraction
4	4	Ferrous Metals Mining and Dressing	7	Ferrous Metals Mining and Dressing
5	5	Nonferrous Metals Mining and Dressing	8	Nonferrous Metals Mining and Dressing
6	6	Construction Material and Other Nonmetal Minerals Mining and Dressing	9	Construction Material and Other Nonmetal Minerals Mining and Dressing
7	8	Alcoholic and its Beverage	13	Beverage Manufacturing
	9	Other Beverage		
8	10	Tobacco Products	14	Tobacco Products
9	11	Textile Industry	15	Textile Industry
10	12	Garments, Shoes and Hats Manufacturing	16	Garments, Shoes and Hats Manufacturing
11	13	Leather, Furs, Down and Related Products	17	Leather, Furs, Down and Related Products
12	15	Papermaking and Paper Products	20	Papermaking and Paper Products
13	16	Printing and Record Medium Reproduction	21	Printing and Record Medium Reproduction
14	17	Cultural, Educational and Sports Goods	22	Cultural, Educational and Sports Goods
15	18	Petroleum Processing, Coking and Nuclear Fuel Processing	23	Petroleum Processing and Coking
	19	Petroleum Refining and Coking		
16	22	Manufacture of Medicines	25	Manufacture of Medicines
17	23	Chemical Fiber Manufacturing	26	Chemical Fiber Manufacturing
18	24	Rubber Products	27	Rubber Products
19	25	Manufacture of Plastic	28	Manufacture of Plastic
20	30	Smelting and Pressing of Ferrous Metals	30	Smelting and Pressing of Ferrous Metals
21	31	Smelting and Pressing of Nonferrous Metals	31	Smelting and Pressing of Nonferrous Metals
22	32	Metal Products Manufacturing	32	Metal Products Manufacturing
23	38	Railway Transit Equipment	35	Transport Equipment
	39	Motor Industry		
	40	Ship mechanical and spare parts		
	41	Other Transit Equipment		
24	52	Production and Supply of Electric power and heat	39	Production and Supply of Electric power and heat
25	53	Gas Production and Supply	40	Gas Production and Supply
26	54	Water Production and Supply Industry	41	Water Production and Supply Industry
27	55	Construction Business	42	Construction Business
28	60	Finance and Insurance	47	Finance and Insurance
29	61	Real Estate	48	Real Estate

Table 3 Results of classical model and the new model in descending order of the former

Order	Code Number	Sectors	classical Model Results	New Model Results
1	9	Textile Industry	0.2125	0.0242
2	18	Rubber Products	0.2098	0.0273
3	7	Beverage Manufacturing	0.1519	0.0197
4	11	Leather, Furs, Down and Related Products	0.1269	0.0172
5	12	Papermaking and Paper Products	0.0805	0.0108
6	27	Construction Business	0.0794	0.0109
7	16	Manufacture of Medicines	0.0792	0.0109
8	8	Tobacco Products	0.0517	0.0069
9	17	Chemical Fiber Manufacturing	0.0437	0.0028
10	20	Smelting and Pressing of Ferrous Metals	0.0310	0.0040
11	24	Production and Supply of Electric power and heat	0.0253	0.0030
12	2	Coal Mining and Dressing	0.0202	0.0021
13	22	Metal Products Manufacturing	0.0190	0.0024
14	19	Manufacture of Plastic	0.0171	0.0021
15	10	Garments, Shoes and Hats Manufacturing	0.0168	0.0021
16	28	Finance and Insurance	0.0159	0.0017
17	15	Petroleum Processing and Coking	0.0135	0.0017
18	3	Petroleum and Natural Gas Extraction	0.0129	0.0012
19	25	Gas Production and Supply	0.0115	0.0016
20	21	Smelting and Pressing of Nonferrous Metals	0.0096	0.0012
21	5	Nonferrous Metals Mining and Dressing	0.0079	0.0009
22	23	Transport Equipment	0.0074	0.0009
23	4	Ferrous Metals Mining and Dressing	0.0069	0.0008
24	14	Cultural, Educational and Sports Goods	0.0065	0.0009
25	13	Printing and Record Medium Reproduction	0.0056	0.0005
26	6	Construction Material and Other Nonmetal Minerals Mining and Dressing	0.0036	0.0002
27	29	Real Estate	0.0024	0.0003
28	26	Water Production and Supply Industry	0.0017	0.0001

Table 4 Results of classical model and the new model in descending order of the latter

Order	Code Number	Sectors	classical Model Results	New Model Results
1	18	Rubber Products	0.2098	0.0273
2	9	Textile Industry	0.2125	0.0242
3	7	Beverage Manufacturing	0.1519	0.0197
4	11	Leather, Furs, Down and Related Products	0.1269	0.0172
5	27	Construction Business	0.0794	0.0109
6	16	Manufacture of Medicines	0.0792	0.0109
7	12	Papermaking and Paper Products	0.0805	0.0108
8	8	Tobacco Products	0.0517	0.0069
9	20	Smelting and Pressing of Ferrous Metals	0.0310	0.0040
10	24	Production and Supply of Electric power and heat	0.0253	0.0030
11	17	Chemical Fiber Manufacturing	0.0437	0.0028
12	22	Metal Products Manufacturing	0.0190	0.0024
13	10	Garments, Shoes and Hats Manufacturing	0.0168	0.0021
14	19	Manufacture of Plastic	0.0171	0.0021
15	2	Coal Mining and Dressing	0.0202	0.0021
16	15	Petroleum Processing and Coking	0.0135	0.0017
17	28	Finance and Insurance	0.0159	0.0017
18	25	Gas Production and Supply	0.0115	0.0016
19	21	Smelting and Pressing of Nonferrous Metals	0.0096	0.0012
20	3	Petroleum and Natural Gas Extraction	0.0129	0.0012
21	23	Transport Equipment	0.0074	0.0009
22	5	Nonferrous Metals Mining and Dressing	0.0079	0.0009
23	14	Cultural, Educational and Sports Goods	0.0065	0.0009
24	4	Ferrous Metals Mining and Dressing	0.0069	0.0008
25	13	Printing and Record Medium Reproduction	0.0056	0.0005
26	29	Real Estate	0.0024	0.0003
27	6	Construction Material and Other Nonmetal Minerals Mining and Dressing	0.0036	0.0002
28	26	Water Production and Supply Industry	0.0017	0.0001