Information Technology and Quantitative Management (ITQM 2015)

On Pass-through of RMB Exchange Rate to Prices of Different Industries

Benlan He\textsuperscript{a,b,d}, Hanxu Zhu\textsuperscript{c*}, Daobin Chen\textsuperscript{d}, Yong Shi\textsuperscript{e}

\textsuperscript{a}Post-Doctoral Research Station of University of Chinese Academy of Science, Zhongguancun East Road 80, Haidian District, Beijing, 100190, China
\textsuperscript{b}Post-Doctoral Research Center of Industrial and Commercial Bank of China, No. 55 Fuxingmen Street, Xicheng District, Beijing, 100140, China
\textsuperscript{c}Central University of Finance and Economics, Beijing 100081, China
\textsuperscript{d}Industrial and Commercial Bank of China, No. 55 Fuxingmen Street, Xicheng District, Beijing, 100140, China
\textsuperscript{e}Research Center on Fictitious Economy & Data Science, University of Chinese Academy of Science, Zhongguancun East Road 80, Haidian District, Beijing, 100190, China

Abstract

This paper employs time series method and Dynamic Bayesian Network method to measure the pass through of RMB exchange rate to prices of different industries. The result shows that the direct transfer effect of RMB exchange rate on RMPI, CGPI and CPI is remarkable. At the same time, the RMB exchange rate can also have indirect influence on PPI, CGPI and CPI of different industries. This study indicates that wood, chemistry, textile and other labor-intensive industry prices are sensitive to the fluctuation of RMB exchange rate, while the exchange rate pass-through effects of energy, black metal, non-ferrous metals and other mineral industries prices are not significant.

Keywords: RMB Exchange Rate; Prices; Pass Through Effect; Dynamic Bayesian Network

1. Introduction

Exchange rate is crucial to the economic growth and price stability for a country. With the development of the globalization of the world economy and the deepening of China’s foreign trade, the role of RMB exchange rate on China’s economy and inflation is further enhanced and the RMB exchange rate pass through effect also increasingly plays an important part in the formulation of the exchange rate regime and the monetary policy. Since China adopted the rate of exchange rate regime in July 2005, the exchange rate of RMB against the U.S.
dollar fell from 8.27 to 6.16 in June 2014, resulting in the cumulative appreciation of about 25.51%. At the same time, the expectation of RMB appreciation will stimulate the influx of “hot money”, and exert an significant influence on China’s monetary policy and the development of its economy and industry. Therefore, exploring the exchange rate transmission effect to prices of China has important meaning both in theory and practice.

The earliest studies on the exchange rate transmission mechanism to prices were carried out from the micro level and focused on the incomplete transfer effect of the exchange rate on the import price and its causes, such as [1-4] in the text. Some scholars have shifted from micro to macro since 1990s and studied the transfer effect of exchange rate based on the macroeconomic framework, such as [5-8]. The empirical researches mainly focus on calculating the exchange rate pass through effect, such as [9-15].

The research has made great contributions for the interpretation of the transmission mechanism of RMB exchange rate to the prices and provides an important reference to this paper, but there are still shortcomings. First, although the majority of scholars have conducted research on the pass-through effect of RMB exchange rate on PPI, CPI, they did not study the pass-through effect of the exchange rate on RMPI, PPI, CGPI and CPI in domestic price chain from upstream prices to lower reaches simultaneously; Second, the existing literature did not explore more deeply to the pass-through of the RMB exchange rate to subdivision industry prices of the micro level, resulting in insufficient evidence for the pass-through effects. Then, how does the RMB exchange rate transfer its impact on subdivided sectors? What is the degree of transfer effect? There is no comprehensive study.

Therefore, this paper attempts to explore the RMB exchange rate pass through effects on domestic prices since January1999 based on the existing research and study the pass-through effects of the RMB exchange rate on prices of different stages in the price chain and on domestic prices of subdivided sectors based on data from different industries. Time-series analysis and the Dynamic Bayesian Network model will used in the study to straighten out the effect of RMB exchange rate on industrial structure and inflation and provide policy basis and empirical support for the Bureau of China to make reasonable exchange rate policy and the differentiated industrial policy.

2. Modeling

2.1. Dynamic Bayesian Network

Bayesian network describes the relationship between the probabilities using a directed acyclic graph. Each node in networks has a direction, and no loop node. The connections between nodes are described by conditional probability. Any node probability in Bayesian network should take the collection between the parents’ nodes before and child’s node after into account, but it does not consider the time information on the price indexes, which shows a relatively static graphics mode. The Dynamic Bayesian Network (DBN) in this paper is an expansion in processing time series in Bayesian network, which is based upon the spread of the probability of each price. Such new stochastic model in which the spread of probability combines time information has better performance in terms of describing the timing and uncertainty and so on.

A Bayesian network \( N \) is a representation of a joint distribution of price index \( \mathcal{X} = \{X_1, \ldots, X_n\} \), which consists of two components:

1. a directed acyclic graph \( \mathcal{G} = (\mathcal{X}, E) \) encoding conditional (in-)dependencies
2. a family \( \theta \) of conditional distributions \( P(X_i | Pa_i) \), where

\[
Pa_i = \{Y \in X \mid (Y, X_i) \in E\}
\]
The joint distribution of $X$ is given by
\[
P(X) = \prod_{i=1}^{n} p(X_i | Pa_i)
\]

The problem of constructing such a price network is understood as follows: given a multiset of $X$-instances $D = \{X_1, \ldots, X_n\}$; we should find a network graph $\mathcal{G}$ that best matches $D$. The notion of a good match is formalized by a scoring function $S(\mathcal{G}, D)$ having positive values and minimized for the best matching network. Thus the point is to find a directed acyclic graph $\mathcal{G}$ with the set of vertices $X$ minimizing $S(\mathcal{G}, D)$.

2.2. BNFinder Algorithm

BNFinder algorithm [16] can divide the set of prices into an ordered set of disjoint subsets of prices, and then choose the best overall score network according to different sorting to quickly find the optimal structure of price networks based on the observed values. Compared to other algorithms of DBN, BNFinder algorithm has significant advantages [17] in dealing with a large sample and the probability of network. Therefore, this article will use BNFinder algorithm to study the relationship between the exchange rate and the price indexes.

We consider some assumptions first on the form of a scoring function. The first one states that $S(\mathcal{G}, D)$ is decomposed into a sum over the set of random indexes of local scores, which depend on the values of each price and its parents in the graph only.

Assumption 1 (additivity) $\sum_{i=1}^{n} S(X_i, Pa_i : D_{\mid\{X_i\}, Pa_i})$, where $D_{\mid Y}$ denotes the restriction of $D$ to the values of the members of $Y \subseteq X$.

When there is no need to examine the acyclicity of the graph, this assumption allows to compute the parents set of each variable independently. Thus the point is to find $Pa_i$ minimizing $S(X_i, Pa_i : D_{\mid\{X_i\}, Pa_i})$ for each $i$.

Assumption 2 (splitting) $S(Pa) = g(Pa) + d(Pa)$ for some functions $g$, $d : P(X) \rightarrow R^+$ satisfying $Pa \subseteq Pa' \Rightarrow g(Pa) \leq g(Pa')$.

The above assumption expresses the fact that scoring functions can be decomposed into two components: $g$ penalizing the complexity of a network and $d$ evaluating the possibility of explaining data by a network. This assumption is used in the following algorithm to avoid networks inadequate component $g$.

Algorithm 1

1. $Pa := \emptyset$ ;

2. for each $P \subseteq X$ chosen according to $g(P)$ ;
   (a) If $s(P) < s(Pa)$ then $Pa := P$ ;
   (b) If $g(P) \geq s(Pa)$ then return $Pa$ ; stop.

In the above algorithm how we choose $Pa$ according to $g(P)$ depends on the value of the component $g$ of the local score. Suppose that the scoring function satisfies Assumptions 1-2, and then if we apply Algorithm 1 to each price index we can find an optimal network. A disadvantage of the above algorithm is that finding a proper subset $P \subseteq X$ involves computing $g(P)$ for all successors $P$ of previously chosen subsets. It may be avoided when a further assumption is imposed.
Assumption 3 (uniformity) $|Pa| = |Pa| \Rightarrow g(Pa) = g(Pa')$.

The above assumption suggests the notation $g([Pa]) = g(Pa)$. The following algorithm uses the uniformity of $g$ to reduce the number of computations of the component $g$.

Algorithm 2

1. $Pa := \emptyset$;

2. for $p = 1$ to $n$
   (a) If $g(p) \geq s(Pa)$ then return $Pa$; stop
   (b) $P = \arg \min_{|\mathcal{Y} = \mathcal{X} : |P| = p} s(Y)$
   (c) If $s(P) < s(Pa)$ then $Pa := P$

Suppose that the scoring function satisfies Assumptions 1-3. Then apply Algorithm 2 to each price index, we can find an optimal network.

2.3. Mutual Information Test

There are three criteria in BNFinder algorithm: MDL, BDE and MIT. Mutual information test(MIT) can measure not only two linear correlation between the price indexes, but also their non-linear correlation, which does not depend on the theoretical probability distribution of the overall time series or specific models. The overall distribution of financial time series is usually unknown, so the application has outstanding advantages [18] in processing the financial time series. Therefore, we choose MIT as a scoring function criterion.

Consider two vectors of price indexes $(\hat{X}, \hat{Y})$, let $p_{\hat{X}}$, $p_{\hat{Y}}$ and $p_{\hat{X}, \hat{Y}}$ be the probability density function of $(\hat{X}, \hat{Y})$. Denote by $H(\hat{X})$, $H(\hat{X}, \hat{Y})$ and $H(\hat{Y} | \hat{X})$ the entropy of $\hat{X}$, the joint entropy of the two arguments $(\hat{X}, \hat{Y})$ and the conditional entropy of $\hat{Y}$ given $\hat{X}$. Then the mutual information can be defined by the following expression:

$$I(\hat{X}, \hat{Y}) = H(\hat{Y}) - H(\hat{Y} | \hat{X}) = H(\hat{X}) + H(\hat{Y}) - H(\hat{X}, \hat{Y})$$

$$= \int \int p_{\hat{X}, \hat{Y}}(x, y) \log \frac{p_{\hat{X}, \hat{Y}}(x, y)}{p_{\hat{X}}(x)p_{\hat{Y}}(y)} dx dy$$

Since $H(\hat{Y}) \geq H(\hat{Y} | \hat{X})$, we have $I(\hat{X}, \hat{Y}) \geq 0$, assuming equality iff $\hat{X}$ and $\hat{Y}$ are statistically independent. So the mutual information between the vectors of price indexes $\hat{X}$ and $\hat{Y}$ can be considered as a measure of dependence between these indexes, or better yet, the statistical correlation of $\hat{X}$ and $\hat{Y}$.

[19-20] use a standard measure for the mutual information, the global correlation coefficient, defined
by \( \hat{\lambda}(\tilde{X}, \tilde{Y}) = \sqrt{1 - e^{2I(\tilde{X}, \tilde{Y})}} \). This measure varies between 0 and 1. The function \( \hat{\lambda} \) captures the overall dependence both linear and nonlinear between \( \tilde{X} \) and \( \tilde{Y} \). According to the properties of the mutual information, we can construct an independence test based on the following hypothesis: \( H_0 : I(X, Y) = 0 \) and \( H_1 : I(X, Y) > 0 \). If \( p_{X,Y}(x, y) = p_X(x)p_Y(y) \), then the independence between the price indexes is found. If \( p_{X,Y}(x, y) \neq p_X(x)p_Y(y) \), then we reject the null hypothesis of independence.

3. Empirical Analysis

3.1. Selection and Pretreatment of Variables

There are three categories of indicator data in this paper. Among them, the nominal effective exchange rate data NEER is obtained from Bank for International Settlements (BIS) statistic database; the Purchasing Price Index Of Raw Material (RMPI), the industrial producer price index (PPI), the corporate goods price index (CGPI), the consumer price index (CPI) and their various sub-industry index data are all from Chinese National Bureau of Statistics; CGPI and its sub-sectors of data are from the official website of People's Bank of China. The time interval of the sample is between January 1999 and June 2014. The selected data frequency is monthly.

Each price index follows the basic structure and number: R MPI has 9 sub-sectors, the price index numbers are from R MPI1 to R MPI9. PPI has 39 sub-sectors, but there are only two values including 0 and 100, in other mining industrial producer price index data, so we regard them as outliers and remove the other mining industry, the numbers of remaining 38 industries are from PPI1 to PPI38. CGPI has 4 sub-sectors, the price index numbers are from CGPI1 to CGPI4. CPI has 8 sub-sectors, the price index numbers are from CPI1 to CPI8.

It should be noted that these four composite price indexes and their sub-sectors price indexes are based on the ones in the same period of last year, which are equal to 100; therefore these four price indexes are the growth rates in terms of the price indexes, rather than the indexes in the strict sense. In the process discussed below, for convenience of illustration, we use R MPI, PPI, CGPI and CPI representing the above four year growth rates of the price indexes over the same period of last year.

---

† The corresponding industries from R MPI1 to R MPI9 are fuel power industry, ferrous metals, non-ferrous metal materials and wires, chemicals, lumber and pulp, construction materials and non-metallic minerals, other industrial raw materials and semi-finished products, agricultural products, textiles and raw materials, respectively.

‡ The corresponding industries from PPI1 to PPI38 are coal mining and washing industry, oil and gas exploration industry, ferrous metal mining industry, non-ferrous metal mining industry, non-metallic mining industry, agro-food processing industry, food Copy the manufacturing, beverage manufacturing, tobacco, textiles, textile and garments manufacturing, leather and fur plush feather, wood processing and bamboo brown grass, furniture manufacturing, paper and paper products, printing and recording media, Sporting supplies, petroleum processing, coking and nuclear fuel processing industry, chemical materials and chemical products manufacturing, pharmaceutical manufacturing, chemical fiber, rubber products, plastic products, non-metallic mineral products, ferrous metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry, metal products, general equipment manufacturing, special equipment manufacturing, transportation equipment manufacturing, electrical machinery and equipment manufacturing, communications equipment, computers and other electronic equipment manufacturing, instrumentation and cultural office machinery manufacturing, handicrafts and other manufacturing industries, waste resources and recycling of waste materials, electricity and heat production and supply, gas production and supply, water production and supply, respectively.

§ The corresponding industries from CGPI1 to CGPI4 are agricultural products, minerals, kerosene and electricity, respectively.

** The industries from CPI1 to CPI4 are food, tobacco and liquor, clothing, household equipment and maintenance services, health care and personal products, transportation and communications, entertainment and educational products and services, housing, respectively.
Before discussing the price pass-through effect, we first observe the dynamic path of the RMB exchange rate and time series of four price indexes, as shown in Fig.1.

![Fig.1. NEER and Four Price Indexes](image)

We have ADF tests on these five time series, and the unit root test results show that the corresponding statistical probability p values of NEER, RMPI, PPI, CGPI, CPI are respectively 0.7621, 0.6353, 0.6743, 0.6533, 0.1505, which are greater than 0.05. In other words, at the 5% significance level, the null hypothesis that the RMB exchange rate and the four price indexes contain unit roots should not be denied, and all these time series are non-stationary. Therefore, in order to measure the relationship among the variables more accurately, we need to eliminate non-stationary features of these time series. According to the different characteristics of NEER and four price indexes, we take different approaches to smooth the data.

Since all price indexes are based on the ones in the same period of last year, which are equal to 100, hence they will not be seasonally adjusted in the data preprocessing stage. And the unit root test results of all-time series after the first-order differential show that the p-value are less than 0.05. This means that the first-order differential terms of these four time series are free from unit roots, which have already been smooth sequences.

However, this paper will smooth the NEER data, which is the original time series, using the local polynomial regression algorithm (LOESS). Fig.1a shows the results of the RMB exchange rate NEER decomposed. Seasonal ingredients from the decomposition of NEER sequence indicate significant seasonal fluctuations. Meanwhile, we have an ADF test on the long-term trend decomposed and the result demonstrates the effectiveness of LOESS method.

### 3.2. Analysis of the Results

Here we use dynamic Bayesian network model to make an in-depth study of the pass-through effect of the RMB exchange rate on RMPI, PPI, CGPI, CPI and prices by sectors.

(1) The Pass-Through of NEER on RMPI

As shown in Fig.2 (a), the direct driving effects of RMB exchange rate on RMPI are quite large and the pass-through probability is 0.9998. As the RMPI is the upstream price index, this paper only analyzes the direct effect of the RMB exchange rate path-through on RMPI and its sub-sectors price. From Fig. 2 (b) we can see that RMPI of 6 industries except ferrous materials, nonferrous metal material and wire, chemical raw materials industry are directly affected by the fluctuation of RMB exchange rate and all of the pass-through probabilities are 1.
(2) The Pass-Through of NEER on PPI

As shown in Fig. 2(a), the direct pass-through effects of NEER on PPI are very small and the pass-through probability is only 0.1144. As for PPI of subdivided industries, all the pass-through probabilities are less than 0.7. But in the Bayesian network we constructed, we find that RMPI has a strong effect on PPI, leading to an indirect effect of the RMB exchange rate on PPI. Fig. 3 shows that, the fluctuations of RMPI in fuel, wood and paper pulp, building materials and non-metallic mineral, other industrial raw materials and semi-finished products sectors can effectively drive the variation of PPI, and the number of industries affected is as many as 26. Among them, RMPI of the building materials and non-metallic mineral industry can influence as many as 18 industries in PPI. These findings are consistent with our expectations. First, China’s imports are largely of industrial equipment and raw materials and the international price changes have a significant impact on PPI. Second wood and paper pulp, raw materials, fuel and power industry are all raw materials for the industrial production industry and their prices fluctuations can exert an influence on the industrial production industry directly. Third, the time range selected is from 1999 to 2014 years. During these years real estate market in China has been in the stage of rapid development. Building materials and non-metallic mineral raw materials are important material bases of the construction, decoration, real estate industry and the rise in their prices can be passed on directly to producer price. Therefore, the effects of the RMB exchange rate fluctuations are mainly passed through the four upstream industries indirectly to PPI in the subdivision industries.

Fig.2. (a) NEER - Prices (The Direct Pass-Through); (b) NEER – Prices of different Industries
(3) The Pass-Through of NEER on CGPI
The pass-through effects of RMB exchange rate on CGPI are very significant. Fig.2 indicates that there are three of the CGPI’s four industries directly affected by the RMB exchange rate, including the agricultural products, kerosene and processing industry. In contrast, the direct pass-through effects of RMB exchange rate of the mineral products industry are smaller than those of the three industries and the transfer probability is less than 0.7. As is known to all, although China has abundant natural resources, there is still a serious shortage of storage capacity of some metallic ores resources. For these resources, China depends heavily on foreign markets and lacks international influence in pricing. The need of metallic ores resources makes the exchange rate pass through effects much smaller.

(4) The Pass-Through of NEER on CPI
As shown in Fig.2, the direct pass-through effects of RMB exchange rate on CPI are much significant and the main affected industries are food industry, household appliances and repair service industry with the probability of about 0.8.

4. Conclusion

This paper uses monthly data during January 1999 and June 2014 and applies time series method and dynamic Bayesian network algorithm to discuss the pass-through effects of RMB exchange rate on prices in different stages and in subdivided sectors. Firstly the paper adopts stationary test for the RMB exchange rate
and the four price index time series and uses local polynomial regression algorithm to eliminate the non-stationary process. Then, it calculates the pass-through effects of RMB exchange rate on the four price indexes. Finally we study the relationship between the RMB exchange rate and price indexes of different segments of the industry.

The results show that the direct pass-through effects of the RMB exchange rate on RMPI, CGPI and CPI are significant, while the effects on PPI are not remarkable. Besides, the RMB exchange rate can also have an indirect influence effect on PPI, CGPI and CPI by the pass-through effects of the prices by sectors. In addition, the RMB exchange rate has a notable impact on inflation and commodity prices. From the existing literatures, the application of dynamic Bayesian network to the pass-through effects on prices in this paper is an innovation in the field, and has high practical value.

Acknowledgements

We would like to thank Kun Guo, Wen Long and Qian Wan for their help with this study.

References