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A New Study of De Facto Regime Classification
Moving to Multilateral Exchange Rate Arrangement_based on scheme

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Abstract: This approach adopts hierarchical K-means Clustering method as a basic classing tool to assign 97 countries' samples to different de facto exchange rate regime groups over the period of 1976 to 2008. Besides, we constructed a fisher discrimination functions based on the classification for the extensibility and inheritability of the regime classification, and deduced the classification for 2009. The classification cast new light that in past thirty years the effective exchange rate in all regimes has become more stable over time. The classification coding also proves that: 1) Nominal bilateral and effective exchange rates have increasing trend as well as inflation form pegging to floating; 2) Comparing to developing countries, the behavior of developed countries' effective exchange rate is more stable; 3) With the development of globalization, more and more developing countries choose to peg their major trade partners' currency, which was reflected in the behavior of effective exchange rate. The classification coding database of the study can support further quantity studies on exchange rate regime, specially form the multilateral perspective.

Keywords: de facto exchange rate regime, effective exchange rate, K-means clustering, Fisher discrimination

1. Introduction

Exchange rate regime, also called exchange rate system or exchange rate arrangement, is a series arrangement and regulars made by currency authority for setting, maintaining and managing its exchange rates. As an important part of open-macroeconomic decision, exchange rate regime decides the connection style of one country to other economics. On the one hand, choice of exchange rate regime is relative with country's level of economic development and macroeconomic goal. On the other hand, it is also affected by international monetary system, such as Bretton Woods, regional currency cooperation etc. Mussa(1986) noted that there are substantial and systematic differences in the behavior of real exchange rates under different nominal exchange rate regimes across a wide range of individual cases. Since then, exchange rate regime's choice, classification and its effects to economy have become a hot topic in international economics.

With further studies, more and more scholars found that the actual exchange rate regimes adopted by countries are not the same as their officially announced. Therefore, there is a discrepancy between de jure exchange rate regimes, which are officially claimed by government, and de facto exchange rate regimes, which are countries followed in practice. From 1980s, researchers have

discussed the classification method of de facto exchange rate regime. Although the de facto classification is often used as database in empirical study of exchange regimes, however there are still lots of difference in different classification schemes (IMF, various issues; Ghosh, Gulde, Ostry, and Wolf, 1997, 2002; Reinhart and Rogoff, 2004; Dubas, Lee and Mark, 2005; Levy-Yeyati and Sturzenegger, 2001, 2003, 2005; etc) because of different time frequency and study period, different coverage, different reference indicators, different methodology and so forth. It is easy to understand that the results of relative studies based on these different schemes are inconsistent. Genberg and Swoboda (2004) pointed that the de facto classification has rapidly become a new standard in research on exchange rate regimes.

The remainder of the paper is structured as follows. In section 2, we present some detail need to note. Section 3 contains the introduction about the K-means clustering method and data source. Section 4 describes the classification procedure. We analyze classification results and compared with other coding systems in section 5. Section 6 makes a conclusion.

2. Important issues

2.1 Study period, frequency and moving windows

In 1976, the Jamaica Accord has given more autonomy to countries in the choice of exchange rate system. Since then, countries not only can make use of monetary or fiscal policy to stabilize the exchange rate fluctuations, but also can adopt pegging or managed floating regime to do it. In considering about the consistency in international rules, we choose the data after 1976 to study.

It has been proved that the frequency will cause an obvious impact on classification in existing studies. Even adopting the same methodology to class, if the frequency is different the results of classification are different as well. For instance, although the methodology is the same, Bailliu and Murray (2003) adopted 5-year moving window from a medium-term perspective and found more flexible regime often accompanying with higher economic growth. Nevertheless, Ghosh et al. (2002) used yearly data and observed that the growth rate of country in intermediate exchange rate regime is often higher the others'.

High frequency data such as monthly and quarterly data can provide more information, but high frequency data also could contained more noise which will increase the likelihood of false classification. In our studies, we tried monthly, quarterly and yearly data to class. The classification result based on yearly data is more stable and reasonable. It is very easy to distinguish and explain the difference. In common sense, most of countries would not change their exchange rate policy frequently considering the high switching cost.

Exchange rate regime is not only reflected by current fluctuations of exchange rate, but also reflected in the past fluctuations. In another words, exchange rate regime is reflected by a dynamic process. Hence, the judgment of regime should be made by continuous observation or moving windows instead of only by calendar year. In this study, we adopt 3-year moving window to class.

2.2 Study period, frequency and moving windows

In de facto classification studies, lots of studies used the changes in official reserve as major evidence of official intervention, such as Coudert and Dubert (2004) and DUBas (2005). Levy-Yeyati and Sturzenegger (2001, 2003, and 2005) defined the change of central bank's net foreign assets

minus government deposits to measure the intervention in the foreign exchange market.

Tavlas et al. (2008) regarded that in the classification researchers should know the degree of monetary policy independence without relying exclusively on movements in exchange rates. Lots of literatures point out that changes in reserves are not a good proxy of exchange rate intervention.

First, foreign exchange reserves are not merely an important indicator of ability to repay foreign debt and for currency defense, but also an important tool to adjust domestic demand, imports and exports, prices of goods and services and so on. In practice, few monetary authorities only operate reserves to stabilize the foreign exchange rates.¹

Second, there are various ways to intervene foreign exchange rates. In Brazil and more than twenty other countries, foreign exchange market intervention is conducted through purchases or sales of debt denominated in local currency but indexed to dollar. In some economies, such as Thailand under Asia financial crisis and South Africa thereafter, intervention is carried-out in the forward market. Therefore, the extent of the intervention could not be reflected in official-reserve data (Rogoff et al., 2004, p. 27). Besides, domestic interest rates and other monetary policy would also affect the exchange rate.

Third, reserves and foreign assets would be affected by valuation effects. Even the scale of assets and liability are changeless, but the change in exchange rate, assets price and the yield, will still lead to the change of international reserve in foreign currency, which is completely unrelated with foreign exchange intervention. Gourichas and Rey (2005) estimated that from 1976 to 2005, the stabilizing valuation effects contribute 31% of the changes in US's gross foreign position. IMF (2005) held a symposium about global imbalance and value effect, and found that 8 industrial countries and 4 emerging and developing countries in 49 countries have existed significant valuation effects.

Habermeier (2009) noted that intervention practices in characterizing exchange rate arrangements have become increasingly complex, while adequate data on intervention are unavailable sometimes. Since there is not a perfect proxy of official intervention, in our study we do not adopt reserves or similar variables to measure intervention to avoid the erroneous judgment. Actually, if a monetary authority manipulated exchange rates, the performance of exchange rate itself can reveal the information in a medium or long term.

2.3 Freely falling

Some studies have shown the relationship existing between inflation and exchange rate regime: high-inflation countries have to often adjust exchange rate tending to adopt a more flexible exchange rate arrangement. (Ghosh et al., 2002; Rogoff et al. 2004)

Drastic volatility in exchange rate (an utter lack of monetary control) with very high inflation should be included in a special category. Under this situation, monetary authority often have no ability to control or manage the exchange rate, but it does not mean the authority do not want to control. Very high inflation or hyperinflation is often companied with continuing depreciation in exchange rate. Although the classification method is different, we adopt the similar conception given by Reinhart and Rogoff (2004), and use "freely falling" to present the special exchange regime.

2.4 Effective exchange rate

With the advance of economic globalization, few countries only have sole trade partner.

¹ In Jan. 2004, People's Bank of China injected \$45 billion from reserves to Bank of China and China Construction Bank for their recapitalization.

Multilateral trade becomes more and more popular. Respectively, more countries and regions tend to adopt basket of currencies as a reference to arrange exchange rate. In IMF's de jure classification, since 1980s there are some countries pegging to composite currency, which was constituted by major trade partner's currencies. Since July 2005, China has been moving to exchange rate regime with reference to a basket of currencies as well.

Although most of the countries' currency basket is opaque, the more reasonable assumption is to set basket according to the trade situation. Frankel and Wei (1994) studied Southeast Asian countries, and found that international trade has a very role in construction of currency-basket exchange rate. Ogawa and Ito (2002) built an international trade model for US, Japan and Asian emerging-market countries. They proposed that the optimality of the exchange rate regime for emerging-market countries should minimize the fluctuation of the trade balances. The effective exchange rate, which has the similar idea as currency basket, is calculated by trade-weighted bilateral exchange rate. To reflect the importance of multilateral issues in exchange rates, we include effective exchange rate as one of class variables.

2.5 Calibration for classification results

Obstfeld and Rogoff (1995) regard that fixed exchange rate are not always fixed. Actually, only few limited countries can hold fixed exchange rate level in five years or longer. Calvo and Reinhart (2002) point out that floating exchange rate is probably not real fully float. Governments let market to determine the exchange rate, only because they want to minimize the volatility of exchange rate. It does not mean they give up the supervision on exchange rate. Klein and Shambaugh (2008) propose that we should treat exchange rate regime in dynamic respective in their study on exchange rate duration. They found that although almost half of fixed exchange rate regime cannot last more than 3 years, if fixed regime is still unchanged, a fixed level is very likely changed to another fixed level. The similar situation could happen in floating regime: Few countries' exchange rate behavior is freely floating in a long term. Sometimes, lack of shock could also lead to the exchange rates become stable even they are under floating regime.

The above analysis demonstrates that, though we can use machine algorithm to classify, we still need to study regime case by case and distinguish the special samples by manual review, especially to the edge samples of two different categories.

3. Methodologies and data source

Based on Hierarchical K-means Clustering Method and Fisher Discriminant Analysis, the paper classifies exchange rate regime for countries by using four variables: the annual change of nominal effective exchange rates (3-year average change in percent, noted as Q_{neer}), the annual change of nominal exchange rates (3-year average change in percent, noted as Q_{ner}), the volatility of nominal exchange rates (3-year standard deviation of the percentage change, noted as $Q_{\Delta ner}$), and the annual change of Consumer Price Index (3-year average change in percent, noted as Q_{cpi}).

3.1 Hierarchical K-MEANS clustering method

Clustering is to assign observations into different subsets or clusters, based on specific criteria. The method can group objects of similar kind into respective categories. In generally, clustering

methods can be divided into four kinds: Partitioning algorithms, Hierarchical algorithms, Self-Organizing Map, and Balanced Iterative Reducing and clustering.

Hierarchical k-means clustering: The k-means algorithm is used by setting k to several subsets. Then, the subsets are divided again into sub-subsets. It could be thought that we adopt K-means algorithm under hierarchical algorithm frame. (Böcker et al., 2004) K-MEANS clustering method, proposed by MacQueen, does not need to set the number of groups in advance. Besides, for a large dataset, it is the fastest clustering method.

K-MEANS Clustering: Firstly, choose K data points randomly as initial cluster centers. For remained observations, assign each of them to the nearest cluster centers. And then, re-calculate the new cluster centers. Repeat the previous steps until the convergence criterion is met. K-MEANS clustering has following characters: observations in each cluster are very close with each other, and different clusters are distinguishable.

Given there is a dataset with n sample points, the algorithm proceeds by following steps: Build up two recursion sets: Set $L=(A_1, A_2, \dots, A_k)$ and set $P=(P_1, P_2, \dots, P_k)$. Randomly generate k points as cluster centers, $L^0=(A_1^0, A_2^0, \dots, A_k^0)$. Calculate the first round classification and get $P^0=f(L^0)=(P_1^0, P_2^0, \dots, P_k^0)$, in which:

$$P_i^0 = \{x \in \Omega \mid d(A_i^0, x) \leq d(A_j^0, x), j=1, 2, \dots, K, j \neq i\} \quad (1)$$

1. Calculate the new cluster centers $L^1=g(P^0)=(A_1^1, A_2^1, \dots, A_k^1)$, in which cluster center A has q points. $D(A, P_i^0)$ is the distance measurement for dataset A.

$$A_i^1 = \{A=(x_1, x_2, \dots, x_q) \mid \text{Min}[D(A, P_i^0)]\} \quad (2)$$

2. Repeat the above iterative calculation, $L^n=g(P^{n-1})$, $P^n=f(L^n)$. Then we can get the classification result series $V^n=(L^n, P^n)$.

3. The condition to terminate iteration is $|u_{n+1}-u_n|/u_{n-1} \leq \epsilon$, in which $u_n = \sum_{i=1}^k D(A_i^n, P_i^n)$.

In this paper, we use the K-means clustering algorithm provided by SPSS12.0, which adopts squared Euclidean to measure distance, $D(A_i^n, P_i^n) = \sum (A_i^n - P_i^n)^2$.

Because K-means needs to identify the number of clustering in advance, therefore before the formal clustering, we need to identify the number of clusters based on the comparison of different clustering results from economic meaning. When the subset centers cannot display obvious difference, we end the clustering process.

Generally, we should use the variables in same attribute to do analysis. Once the variables have huge difference, we need to standardize the data first. But the standardization process will introduce some negative impacts as well. First, the standardization will lose some important information in valuable variables. Second, after the standardization, the economic meaning of valuables will become vague. The four variables used in this paper do not have obvious difference in data attribute, so it need not to standardize.

3.2 Fisher Discriminant Analysis

Discriminant analysis is a discriminant method based on the characters of points in cluster and the characters of cluster categories. As a linear discriminant method Fisher discriminant analysis uses coordinate transformation to find out the appropriate coordinate separating data points. The different groups can be separated as far as possible under such coordinate.

Get K groups of p-dimensions observations in :

when they arrange the exchange rate. For China, although the internal settlement exchange rate was abolished by Jan 1st 1985, during 1985 to 1993 China still used Dual Exchange Rate: Official Rate and foreign exchange swap market rate. According to statistical literature, the 80% foreign exchange trade was through foreign exchange swap market at that period. Therefore, we only study China's regime after 1994.

The special process for members of euro area: EURO is the only currency identified by Europe Monetary Union (EMU) and the Unified legal currency used in EMU members. Since Jan 1st 1999, it started to be officially used in 11 countries -- Austria, Belgium, France, Germany, Finland, Netherland, Luxemburg, Ireland, Italy, Portugal, and Spain. They are so called Eurozone countries. And by Jan 1st 2002, their original currencies were totally stopped in market. After 1999, the research of Exchange Rate Regime for above countries refers to the overall exchange rate of Euro.

3. Customer Price Indexing (CPI).

The CPI data of each country is from the CPI based on Laspeyres price index in International Finance Statistics published by IMF. After 1999, for Euro area countries, the overall CPI of euro area is used as the indicator. Since East Germany and West Germany was merged on Oct. 3rd 1990, the CPI series of Germany used in this paper starts from 1992.

4. Classification procedure and discriminant analysis

In our study, we regard that the movement of exchange rates themselves reveal the fact of authorities' purpose in a relatively long term, such as three years. High volatility case has a more flexible exchange rate regime, while stable case often means a more fixed one. This presumption could be wrong in a short term study, because it is very hard to distinguish the lack of shock's stabilization (de facto floating regime) and the drastic fluctuation by pegging switch. By the contrast and analysis of the classification results, our hypothesis is confirmed.

4.1 Reference currency

As a major world trading currencies, dollar became the target currency pegging by lots of countries. However, we also should notice that because of history, trade and some other factors, there are some countries choose other currencies or denominated units (SDR) as their reference currency, such as Euro (after 1999), Deutsche Mark (before 1999), French Franc (before 1999), British Pounds, Japanese Yen and SDR (Special Drawing Right). In order to reflect the actual situation as far as possible, we list the reference currency for each country under different time in Appendix 1.

4.2 Data preparation

In the study, the classification is based on three basic variables: nominal bilateral exchange rate, nominal effective exchange rate and CPI. These variables have different data attributes. First variable is a ratio series, while latter two variables are index. Besides, the variation in exchange rate and price act decisive role in defining exchange rate regime. Hence, we calculate the 3 year-moving average of the percentage changes in nominal exchange rate, nominal effective exchange rate and CPI, and the 3-year standard deviation of the percentage changes in nominal exchange rate, denoted respectively as Q_{ner} , Q_{neer} , Q_{cpi} and $Q_{\Delta ner}$.

4.3 Classification procedure

After removing the 586 samples with missing data, there are 2518 classifiable data points for 97 countries in 32 moving windows. The study adopts five-way classification according to the volatility patterns: pegging, limited flexibility, managed floating, freely floating and freely falling. The final naming is according to the comparison and analysis among the performance of every variables in each group. The features of these five categories are described in Section 5. Appendix 2 displays the clustering flowchart.

Step 1: Sieving hard peg and peg

Firstly, we sieve 422 hard peg samples (when Q_{ner} and $Q_{\Delta ner}$ equal to 0) and 220 peg samples (when Q_{ner} and $Q_{\Delta ner}$ are less than 0.15²), and leave 1876 data points.

Step 2: Sieving part of freely falling³

If percentage change in CPI is more than 80%, we defined the sample in freely falling. Hyperinflation means domestic monetary condition deterioration. Under this situation, monetary authorities often have no ability to maintain exchange rate rules any more. After removal 78 freely falling samples, 1798 samples are waiting for clustering.

Step 3: The first round cluster

After several trials, we use algorithm to classify the data into the 4 clusters. We called the first pass of the data the first round cluster. The final cluster centers of first round clustering are displayed in table 1. Category 1 has 1346 samples waiting for further classification.

Table 1 The centers' performance of the first round clustering

Final Cluster Centers				
Cluster	1	2	3	4
Q_{neer}	4.913	27.040	64.078	16.976
Q_{ner}	5.317	31.621	21.915	15.781
$Q_{\Delta ner}$	3.357	16.288	15.407	11.092
Q_{cpi}	6.470	53.995	20.412	19.539
Num. of Cases	1346	103	16	333
Category	Waiting for further clustering	Freely falling	Freely float	Freely float

Category 2 has 103 data points, which are named finally as freely falling category because of the center of CPI change percent above 50% and larger fluctuation existing in Q_{ner} and Q_{neer} . Category 3 and 4 should be included in freely float according to the centers' performance of variables. The average changes of nominal and effective exchange rates are more than 15%, and amplitude of nominal exchange rates is more than 10%. However, there are some slight difference in category 3 and 4. In category 3, changes of effective exchange rates are very obvious, and the center of Q_{neer} is more

² The choice of threshold 0.15 is based on empirical judgment. When Q_{ner} is bigger than 0.15, the $Q_{\Delta ner}$ increases rapidly and has no obvious patterns.

³ Although we use the same name "freely falling" to a special category, the judgment standard is different with Reinhart and Rogoff (2004), who set the criteria as annual change in CPI equal or bigger than 40%.

than 50%. The abnormal in effective exchange rate is stem from exchange rate regime reform (Costa Rica, Ghana and Nigeria) or the major trade partner encountering currency crisis (Bolivia and Paraguay⁴).

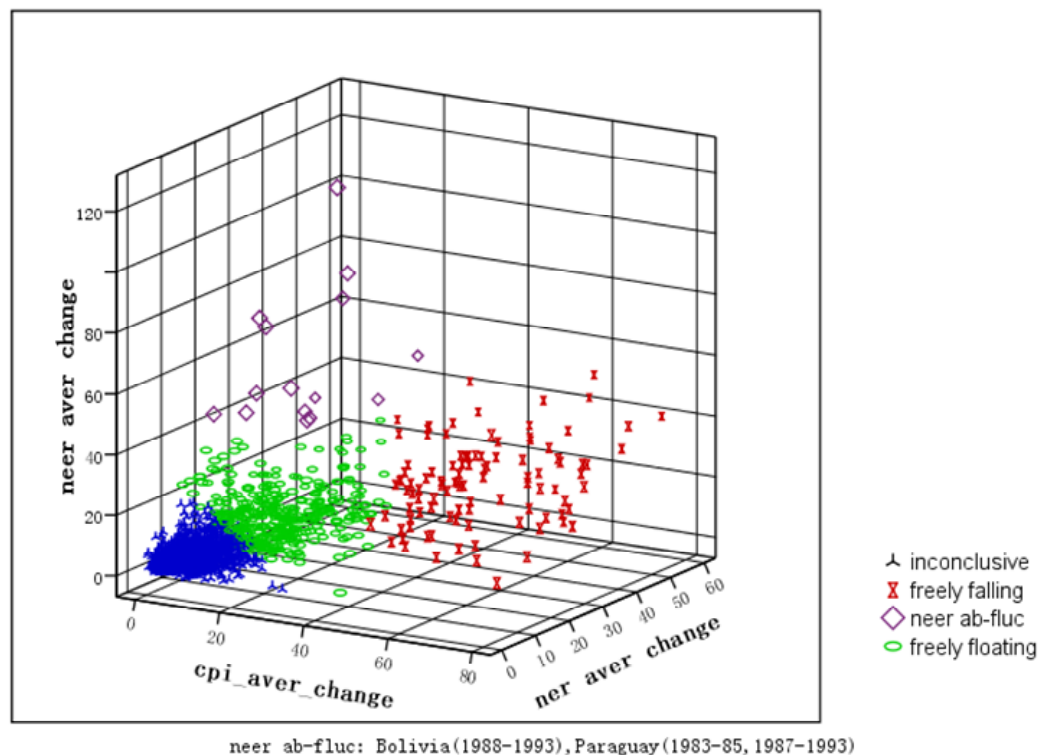


Figure 1 The space distribution of 1st round clustering

Step 4: The second round cluster

We classify the 1346 data points into 3 sub-categories in second round clustering. The changes in CPI are back to normal range (below 10%), therefore we do not need Q_{cpi} to assist. The final cluster centers of second round clustering are displayed in table 2.

Table 2 The centers' performance of the second round clustering

Final Cluster Centers			
Cluster	1-1	1-2	1-3
Q_{neer}	3.075	6.101	11.262
Q_{ner}	3.013	8.939	3.928
$Q_{\Delta ner}$	1.939	5.650	2.176
Num. of Cases	744	500	102
Category	Waiting for clustering	Waiting for classifying	Limited flexible

744 data points of category 1-1 and 500 data points of category 1-2 do not display an explicit

⁴ Bolivia's main trade partners are US 23.3%, Brazil 13.3% and Argentina 7.3%. Paraguay's main trade partners are Brazil 22.8%, US 15.5% and Argentina 9.2%. The weights come from Bayoumi et al. (2006). Brazil (1983-1995) and Argentina (1982-1994) experienced currency crisis.

spatial distribution, so we will reclassify them respectively. In category 1-3, the center of Q_{ner} is around 4, while the center of $Q_{\Delta ner}$ is around 2 - half of Q_{ner} 's. It means that the movement of exchange rates has some regular pattern, or the exchange rate is under control. We name category 1-3 as limited flexible by the performance of final centers of variables. The data points' space distribution is displayed by figure 2.

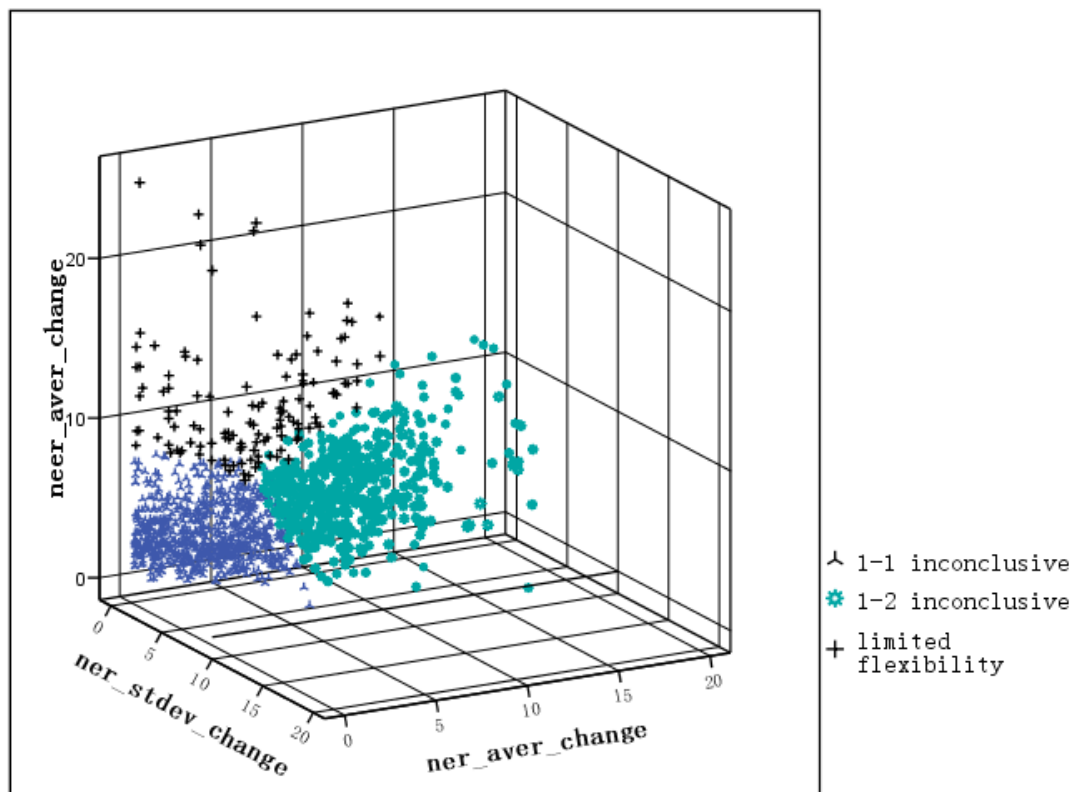


Figure 2 The space distribution of 2st round clustering

Step 5: The third round cluster

In the third round, we run the k-means algorithm twice for category 1-1 and category 1-2 respectively. We tried several times and found that the two groups are suitable for three-way classification scheme.

1) The clustering for category 1-1

As displayed in table 3, in category 1-1-2 the centroids of Q_{ner} and $Q_{\Delta ner}$ are bigger than other two groups. Therefore, the data points in category 1-1-2 should be more flexible than the one in category 1-1-1 and 1-1-3.

Table 3 The centers' performance of the clustering for category 1-1

Final Cluster Centers			
Cluster	1-1-1	1-1-2	1-1-3
Q_{neer}	2.535	2.243	5.294
Q_{ner}	1.396	4.546	3.642
$Q_{\Delta ner}$	0.988	3.083	1.946
Num. of Cases	313	259	172

2) The clustering for category 1-2

In table 4, the fluctuation of effective exchange rate (represented by Q_{neer}) in category 1-2-2 is smaller than other two groups. The $Q_{\Delta ner}$ in category 1-2-1 and the Q_{ner} in category 1-2-3 are very high. We conclude them into freely floating regime.

Table 4 The centers' performance of the clustering for category 1-2

Final Cluster Centers			
Cluster	1-2-1	1-2-2	1-2-3
Q_{neer}	7.447	4.794	8.341
Q_{ner}	8.989	7.649	11.535
$Q_{\Delta ner}$	8.860	3.680	4.307
Num. of Cases	125	262	113
Category	Freely floating	Managed floating	Freely floating

Step 6: The calibration

Machine algorithm clusters points by using the Euclidean distance metric in space. The objective and consistent metric standard can avoid the disturbance of subjective factors. However, just like we mentioned in the beginning of this section, it also could make some pseudo-classification. Therefore, we need to analyze and calibrate the clustering results, especially the data points at the edge of two or more groups. Through calibration, we can decrease the erroneous judgment as far as possible. Actually, most erroneous judgments can be identified. For instance, a country adopting freely floating regime is very hard to maintain a stable exchange rate in long term, because it should be suffered by external shocks more or less. Similarly, a country under limited flexible regime should be found some clues in the fluctuation of exchange rates. In the study, the calibration can be concluded in four situations. The final classification scheme (noted as H-R classification) after calibration is pegging (663 cases), limited flexible (513 cases), managed floating (683 cases), freely floating (477 cases) and freely falling (182 cases).

1. When a country switches the pegging target exchange rate into another pegging target, we still name the cases as pegging regime.
2. When a country switches the crawling pegging band to another one, we still name the cases as limited flexible regime.
3. If a country has obvious freely floating features, we still regard the country is under freely floating regime even sometimes the machine classes the points into other regimes.
4. To the data points at the edge of two or more groups, we name them by concrete analysis in the movement of exchange rates and the country's monetary policies.

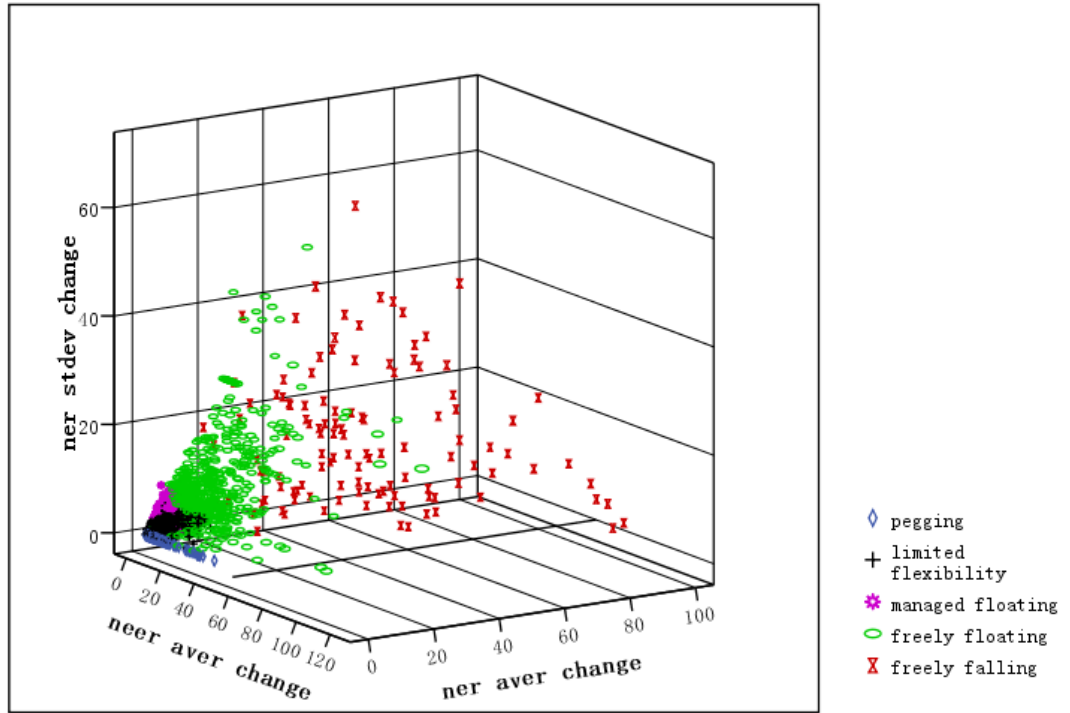


Figure 3 The space distribution of H-R classification scheme

Step 7: Discriminant analysis

After the clustering, we make use of linear discriminant analysis to estimate the discriminant functions. Therefore the extension or update of the classification database will become easier. The result of classification can be more succession and robustness under a relative consistent judgment standard. The study adopts Fisher linear discriminant and the sample set from 1977 to 2008. Table 5 lists the statistical test of discriminant functions. All the discriminant functions are statistical significance.

Table 5 The statistical test of discriminant functions

Test of Function(s)	Wilks' Lambda λ	Chi-square	df	Sig.
1 through 3	0.150	1842.249	12	0.000
2 through 3	0.790	228.348	6	0.000
3	0.986	13.875	2	0.001

The accuracy rate in-sample of the discriminant function is 83.8%. Considering about the manual calibration, the result of discriminant is acceptable. The discriminant functions are listed below:

$$D1 = 0.337 \times Q_{\text{neer}} - 0.273 \times Q_{\text{ner}} - 0.033 \times Q_{\Delta\text{ner}} - 2.095 \quad (8)$$

$$D2 = 0.214 \times Q_{\text{neer}} - 0.014 \times Q_{\text{ner}} + 0.046 \times Q_{\Delta\text{ner}} - 2.002 \quad (9)$$

$$D3 = -0.073 \times Q_{\text{neer}} + 0.548 \times Q_{\text{ner}} + 0.083 \times Q_{\Delta\text{ner}} - 3.507 \quad (10)$$

$$D4 = 0.142 \times Q_{\text{neer}} + 0.926 \times Q_{\text{ner}} + 0.300 \times Q_{\Delta\text{ner}} - 11.1197 \quad (11)$$

$$D5 = 0.615 \times Q_{\text{neer}} + 2.604 \times Q_{\text{ner}} + 0.524 \times Q_{\Delta\text{ner}} - 76.026 \quad (12)$$

The contrast of groups discriminated by functions 8 to 12 and H-R classification is exhibited in table 6. Due to the significant feature of variables in pegging group, this group gets the best discriminating result: the accuracy rate is more than 98%. The worse performance of discrimination is

freely floating, because the points (under de facto limited flexible or managed floating regime) are easier be included into freely floating when the country suffers drastic and temporary external shocks, and vice versa. Nevertheless, these false could be easy found in the context of past regime and authority's behavior. We adopt discriminant functions to classify the samples in 2009, and adjust 11 countries' classification results (among 97 countries).

Table 6 Comparison between discriminant results and H-R classification %

group %	Predicted Group Membership					Total
	Pegging	Limited flexibility	Managed floating	Freely floating	Freely falling	
Pegging	98.5	1.5	.0	.0	.0	100
Limited flexibility	21.6	75.4	3.0	.0	.0	100
Managed floating	.3	11.7	86.9	1.0	.0	100
Freely floating	1.2	2.9	25.1	67.8	2.9	100
Freely falling	.0	.0	.0	16.7	83.3	100

* 83.8% of original grouped cases correctly classified.

5. Comparison and analysis

There are several features in H-R classification⁵: 1) Most countries' exchange rate regime exhibits stability and coherence with time. The regime often gradually changes from pegging to floating, or vice versa. The classification provided by Levy-Yeayati and Sturzenegger (2005) does not show the similar feature, as displayed in table 7. It is very hard to understand many countries would adjust their exchange rate regime so frequently considering the switching cost. 2) When a country experienced freely falling regime, it is possible to keep in freely falling or follow a freely floating exchange rate regime.

Table 7 The segment comparison between coding system of LYS⁶ and our study

	LYS				H-R			
	Pakistan	Paraguay	Philippine	Singapore	Pakistan	Paraguay	Philippine	Singapore
1982	4	1	3	n.a.	3	1	4	2
1983	2	1	n.a.	1	3	4	4	2
1984	4	3	n.a.	n.a.	3	4	4	2
1985	4	2	n.a.	1	3	4	4	2
1986	4	3	n.a.	n.a.	2	4	2	2
1987	1	1	1	2	2	4	2	2
1988	2	1	2	3	3	4	2	2
1989	4	3	2	2	3	4	3	2
1990	2	4	4	1	3	4	3	2
1991	4	3	2	3	3	4	3	3
1992	2	4	3	3	3	4	3	3

⁵ The classification results can be get by contacting with authors.

⁶ Levy-Yeayati and Sturzenegger, 2001, 2003, 2005

1993	4	3	1	1	3	4	3	3
1994	6	2	4	3	3	4	3	3
1995	4	2	4	3	3	3	3	3
1996	4	2	1	2	3	3	3	3
1997	4	3	4	4	3	3	4	3

说明：1-钉住，2-爬行（有限弹性），3-肮脏浮动（管理浮动），4-自由浮动，6-无法分类

5.1 Features in the de facto regime type

In the paper, the flexibility of exchange rates is gradually increasing from pegging, limited flexible, managed floating, freely floating to freely falling, as displayed in table 8.

Pegging exchange rate regime means the fluctuation in nominal exchange rates or in effective exchange rates should be very small (below 0.3%). The change of $Q_{\Delta ner}$ is far less than that of Q_{ner} in limited flexible regime. In managed floating, the standard deviation of nominal exchange rates is half of their average change, or the movements of effective exchange rates are stable. In freely floating exchange rate regime, nominal exchange rates no matter bilateral or multilateral have no obvious pattern. The exchange rates substantially fluctuate and company with drastic change in CPI (more than 35%) under freely falling exchange rate regime.

Table 8 Mean performance of groups

Mean	Q_{ner}	Q_{ner}	$Q_{\Delta ner}$	Q_{cpi}
Pegging	5.567	0.079	0.071	5.004
Limited flexible	4.416	2.456	1.595	5.99
Managed floating	4.903	6.929	4.139	7.02
Freely floating	15.626	14.884	10.567	16.503
Freely falling	36.687	40.77	17.923	355.646

5.2 Mean analysis

Table 9 lists the mean of exchange rates and CPI in different periods, different regime types and different stages of development.

1. Exchange rates have the same tendency in fluctuation with CPI. Pegging regime is often accompanying with low inflation, while country with high inflation would tend to choose floating exchange rate regime to decrease the domestic price pressure. Ghosh et al. (2002) and Rogoff et al. (2004) have the same discovery.

2. Although the movement pattern of nominal bilateral exchange rates in each regime type does have obvious difference across different time period, but there is a the decreasing trend in effective exchange rates, as marked in table 9. In the period of 1977 to 1986, global trade flows are smaller than 1990s and 2000s. The monetary authorities especially in developing countries paid less attention on multilateral issues. With the globalization, the share of trade in economy has increased. Effective

exchange rates become more and more important, because few countries have only one trade partner.

3. Almost in all type of exchange rate regimes, the fluctuation in effective exchange rates of developing countries is bigger than that of developed countries, though the difference is decreasing. Developed countries have longer and richer experience in trade and international finance, while developing countries have gradually caught up in recent twenty years.

4. The minimum of mean in effective exchange rates' average change moves from 1977-1986's managed floating regime to 1987-1996's limited flexible regime, and finally to 1997-2008's pegging regime. This is probably because of more developing countries choose effective exchange rates or synthetic exchange rates of basket currencies as their pegging target.

Table 9 Mean performance for different exchange rate regime type under different period⁷

Period	Type	Developed countries' mean performance				Developing countries' mean performance			
		Q_{neer}	Q_{ner}	$Q_{\Delta ner}$	Q_{cpi}	Q_{neer}	Q_{ner}	$Q_{\Delta ner}$	Q_{cpi}
1997~ 2008	Pegging	2.64	0.1	0.09	1.88	2.62	0.01	0.01	3.07
	Limited flexible	2.53	1.74	1.21	1.85	4.24	2.58	1.36	7.44
	Managed floating	4.05	6.43	4.46	2.51	4.52	7.14	4.11	6.11
	Freely floating	7.66	10.75	8.21	3.12	13.02	15.75	10.46	13.46
	Freely falling					28.28	35.11	24.62	106.6
1987~ 1996	Pegging	2.67	0.06	0.04	3.23	5.75	0.01	0.01	3.33
	Limited flexible	3.28	2.21	1.54	3.93	4.84	3.13	2.21	6.82
	Managed floating	3.56	5.7	3.86	4.58	5.53	7.19	3.88	10.62
	Freely floating	10.16	10.7	6.22	9.15	20.75	15.19	11.54	21.22
	Freely falling					34.17	36.3	17.69	111.78
1977~ 1986	Pegging	2.94	0.04	0.05	6.24	9.62	0.18	0.15	8.94
	Limited flexible	4.26	2.32	1.46	6.45	8.73	2.87	2.12	10.74
	Managed floating	4.39	7.01	4.14	8.61	6.97	7.55	4.05	10.08
	Freely floating	13.59	12.62	7.41	14.81	16.66	15.72	11.87	18.66
	Freely falling	39.32	40.34	13.28	103.11	35.07	41.25	17.86	318.82

5.3 China's de facto exchange rate regime

In 1994's reform, foreign exchange swap markets were replaced by a national inter-bank foreign exchange market. Since then, china unified the parallel exchange rates by the sole official rates. Therefore, we only study China's de facto regime after 1994, as listed in table 10.

From 1995 to 1997, China is classified into limited flexible regime in H-R's and IMF's classification, while in RR's and LYS's coding system China always adopted pegging regime. China's nominal exchange rate against 1 US\$ was change from the 1995's 8.4 to 8.28.

⁷ The definition of developed countries and developing countries is come from IMF's World Economic Outlook Report.

Table 10 China's de facto exchange rate regimes under different classification

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
H-R	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2
RR ⁸	1	1	1	1	1	1	1	1	1	1	1	1	1	n.a.	n.a.
IMF ⁹	2	2	2	1	1	1	1	1	1	1	1	1	1	n.a.	n.a.
LYS	n.a.	1	1	1	1	1	1	1	1	1	n.a.	n.a.	n.a.	n.a.	n.a.

Note: 1 represents pegging regime (including no separate legal tender, peg, currency board arrangement, horizontal band that is narrower than or equal to +/-2%, de facto peg). 2 represents limited flexible regime (including crawling peg, crawling band that is narrower than or equal to +/-2%, de facto crawling peg, de facto crawling band that is narrower than or equal to +/-2%).

After 2005's exchange reform, Chinese authorities had allowed about 15.5% nominal appreciation against US\$ from July 2005 to the end of 2008. Even effective exchange rate index had appreciated more than 10%. China has taken an important step towards more flexible exchange rate regime. Obviously pegging regime, as named by RR's and IMF's classification, is not an appropriate description for China's exchange rate arrangement after 2005.

5.4 Comparison with other classifications

Although our clustering methodology is totally different with the method used by Reinhart and Rogoff (2005), the final coding systems of these two studies are closer than other classification schemes. We present the Canada's de facto regime as an example. (See table 11) Because the classification provided by Reinhart and Rogoff's is highly depended on authors' judgment, the results are susceptible to subjective impact. We make use of machine to classify and we give the discriminant functions, therefore our study is more objective and extensible.

Table 11 Canada's de facto exchange rate regimes under different classification

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
H-R	2	2	2	2	2	2	2	2	2	2	2	2	2	2
RR	2	2	2	2	2	2	2	2	2	2	2	2	2	2
IMF	4	4	4	4	4	4	4	4	4	4	4	4	4	4
LYS	4	2	4	4	2	4	4	2	4	2	4	4	4	4
	1982	1983	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
H-R	2	2	2	2	2	2	3	3	3	3	3	3	3	3
RR	2	2	2	2	2	2	3	3	3	3	3	3	n.a.	n.a.
IMF	4	4	4	4	4	4	4	4	4	4	4	4	4	n.a.
LYS	4	4	4	4	4	4	4	4	4	n.a.	n.a.	n.a.	n.a.	n.a.

Note: 2 has the same meaning as table 10. 3 represents managed floating (including crawling band that is wider than or equal to +/-2%, de facto crawling band that is narrower than or equal to +/-5%, Moving band that is narrower than or equal to +/-2%, and managed floating). 4 represent freely floating.

6. Conclusion

Although every country provides its de jure exchange rate regime, the practical arrangement is

⁸ Reinhart and Rogoff (2004). <http://terpconnect.umd.edu/~creinhar/Data/ERA-Annual%20coarse%20class.xls>

⁹ IMF (various issues)

often not as the de jure regime. Measuring the de facto exchange rate regime is helpful to analyze the determinant in regime, the regime's choice and other related issues. The paper adopted hierarchical K-means clustering algorithm and discriminant analysis method to classify on the movement of bilateral and multilateral exchange rates themselves.

The results of the study exhibit the stability and transition in a country's regimes. This feature is displayed in IMF's de facto classification and Reinhart and Rogoff (2004)'s classification. Therefore, reform on exchange rate regime should be gradual. If the reform exceeds the adjustment demand in exchange rate or lack the necessary institution support, market force will reversely affect regime. Besides, there is a relationship between the fluctuations in exchange rates and CPI. When we prepare to change the exchange regime, we also need to realize the possible inflation pressure and take some precautionary measures.

In late thirty years, the fluctuation of effective exchange rate decreases sharply, except freely falling. It is proved that more and more countries pay attention on multilateral perspective, not only on bilateral one. Since global economic crisis broke up, international situation become more complicated. The trend of diversification and multilateralism has been strengthened because of security issues. In 1990s, the multilateral exchange rates could not very important in the study of exchange regime's classification, but in 21st century it is not enough only depending on bilateral exchange rates' movement to judge the regime.

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Appendix 1: The reference currencies

1) US dollar

Algeria, Antigua and Barbuda, Armenia, Australia, Bahamas, Bahrain, Belize, Bolivia, Burundi, Canada, Chile, China, P.R. : Mainland, China, P.R. : Hong Kong, Colombia, Costa Rica, Czech Republic, Dominican Republic, Fiji, Georgia, Ghana, Grenada, Guyana, Hungary, Iran, Iraq, Israel, Japan, Lebanon, Lesotho, Malaysia, Netherlands Antilles, New Zealand, Nicaragua, Nigeria, Oman, Pakistan, Papua New Guinea, Paraguay, Philippines, Qatar, Romania, Samoa, Saudi Arabia, Singapore, Solomon Islands, South Africa, St. Kitts and Nevis, St. Lucia, St. Vincent & Grens., Trinidad and Tobago, Uganda, United Kingdom, Uruguay, Venezuela, Rep. Bol., Zambia (1975–2008); Dominica (1979–2008); Malawi, Sierra Leone (1984–2008); Gambia (1986–2008); Russia, Ukraine (1995–2008); Bulgaria, Germany (1975–1998); Euro area (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain (1999–2008))

2) British Pound

Ireland (1975–1978); Gambia (1975–1985)

3) Deutsche Mark

Austria, Belgium, Croatia, Cyprus, Denmark, Finland, France, Greece, Iceland, Italy, Macedonia, FYR, Moldova, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United States (1975–1998); Ireland (1979–1998)

4) French Franc

Cameroon, Central African Rep., Côte d' Ivoire, Equatorial Guinea, Gabon, Morocco, Togo, Tunisia (1975–1998)

5) Belgian Franc

Luxembourg (1975–1998)

6) Italian Lira

Malta (1975–1998)

7) Euro

Bulgaria, Cameroon, Central African Rep., Côte d' Ivoire, Croatia, Cyprus, Denmark, Equatorial Guinea, Gabon, Iceland, Macedonia, FYR, Malta, Moldova, Morocco, Norway, Poland, Slovak Republic, Sweden, Switzerland, United States, Togo, Tunisia (1999–2008)

8) SDR

Malawi, Sierra Leone (1975–1983); Congo, Dem. Rep. of (1975–2008)

Appendix 2: Clustering Process

