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Monetary Policy, Exchange Rate and Capital Flow

—— From "Equilateral Triangle" to "Scalene Triangle"

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Abstract: The traditional "Impossible Trinity" is an equilateral triangle. But since 2008, importance of capital flow has been greatly elevated, and equilateral triangle has transformed into scalene triangle. We first in the literature propose the "Scalene Impossible Trinity", which is a more general analytical framework about "Impossible Trinity". We also establish a theoretical model, and with the premise of "Scalene Impossible Trinity", calculate the optimal level of macro-prudential management regarding cross-border capital flow and optimal level of international monetary policy coordination within different foreign exchange rate regimes. Our proof shows that even if foreign exchange rate could float freely, the central bank should conduct a certain level of macro-prudential management of cross-border capital flow. Based on this model and recent practices of The People's Bank of China, we also present the New Macro-Financial Policy Framework (New MFPF), which is "Macro-prudential management + Exchange rate flexibility + International monetary policy coordination." Only by adopting this three-pronged strategy, the central bank could attain macroeconomic equilibrium.

Keywords: Impossible Trinity; Capital Flow; Macro-prudential Management; Policy Framework.

JEL Codes: E52; F38; F41.

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The views expressed in this paper are those of the authors and do not represent the PBC.

1. Introduction

Impossible Trinity (also known as Inconsistent Trinity or Trilemma), is an important analytical framework of policy choice in open macroeconomics. According to this framework, monetary authority[3] of a certain economy should choose among free capital flow, fixed exchange rate, and independent monetary policy. Actually, it could only choose two at the same time at most, and give up the remaining one. The expanded impossible trinity based on this framework (Yi and Tang, 2001) deems it possible that the monetary authority could choose among the three proportionately. The traditional "Impossible Trinity", even in the expanded fashion, gives equal weight to capital flow, exchange rate regime, and monetary policyindependence, and is an equilateral triangle. So, if capital flows freely, a floating exchange rate could isolate the domestic economy from external shock, and guarantees independent monetary policy. For example, when capital inflow increases, the local currency will appreciate and restrain demand for the local currency, deterring further inflow, in which case the local monetary authority could maintain a different interest rate policy from other economies, which shows its monetary policy independence.

But since 2008 global financial crisis (GFC), through quantitative easing, central banks of advanced economies injected excessive liquidity, which didn't fully support the real economy. Instead significant part of these liquidity supported arbitrage transactions in the global financial market. This made global capital flow much more substantial than before, and its direction susceptible to acute changes. The new development increases the relative importance of capital flow to exchange rate regime and monetary policy independence, which means that the equilateral triangle has transformed into scalene triangle. In other words, with increasing international capital flow, freely-floating exchange rate is not enough to contain capital flow, not to mention to help maintain independent monetary policy. In the most extreme scene, exchange rate regime could disappear from the triangle. The impossible trinity and trilemma degenerates into dilemma. Taking this into consideration, Sun (2010) first in

[3]Monetary authority and central bank are interchangeable in this paper.

the literature presents "*Impossible trinity becomes dilemma. It's only possible to maintain independent monetary policy with the help of capital control. If capital flows freely or near freely, it will be more difficult to maintain independent monetary policy.*" Rey (2013) also presents "Dilemma" at the Jackson Hole conference held by U.S. Federal Reserve, which means the monetary policy could only choose one between free capital flow and independent monetary policy.

To contain more and more influential global cross-border capital flow, international organizations including International Monetary Fund (IMF) and monetary authorities around the globe did many theoretical and practical experiments. Some even adjusted previous policy standing. For example, IMF changed its opposing attitude towards capital control, and deemed it appropriate when the economy runs near potential output, local currency is not undervalued, foreign exchange reserve is sufficient, and capital flow fluctuates only temporarily. In this case, capital control could become one of the policy choices together with macroeconomic adjustment, macro-prudential policy, etc. (The Economist (2011), Ostry et al. (2011), and others). Some emerging market economies (EMEs) strengthened capital control, while other EMEs experimented macro-prudential management regarding cross-border capital flow. China has experimented and established systematic macro-prudential management regarding cross-border capital flow. This includesmacro-prudential management about cyclical leveraging of market entities, and about excessive speculations, both of which generate satisfactory results. The logic of these policy measures is that if capital flow becomes more important, we must conduct macro-prudential management regarding capital flow, in order to maintain the optimal equilibrium.

This paper first in the literature proposes the "Scalene Impossible Trinity". Among the three of capital flow, exchange rate regime, and monetary policy independence, capital flow is more important. "Scalene Impossible Trinity" refers to the triangle whose three vertices are free capital flow (2 vertices) and full capital control (1 vertex). If monetary authority chooses full capital control, it could achieve fixed exchange rate and independent monetary policy. If it chooses free capital flow, it could only achieve relatively stable exchange rate and relatively independent

monetary policy, which means that freely-floating exchange rate could not guarantee independent monetary policy, and that even dependent monetary policy could not guarantee fixed exchange rate. “Equilateral Impossible Trinity” and the so-called “Dilemma” are both special cases of “Scalene Impossible Trinity”. We also establish a theoretical model, and with the premise of “Scalene Impossible Trinity”, calculate the optimal level of macro-prudential management regarding cross-border capital flow and optimal level of international monetary policy coordinationwithin different foreign exchange rate regimes. This model could be the theoretical foundation for macro-prudential management regarding cross-border capital flow and international monetary policy coordination.Based on this model and recent practices of The People’s Bank of China, we also present the New Macro-Financial Policy Framework (New MFPF), which is “Macro-prudential management + Exchange rate flexibility + International monetary policy coordination.”The remaining sections are as follows. Section 2 is literature review, which systematically combs through the thoughts trail relevant to “Impossible Trinity”. Section 3 presents “Scalene Impossible Trinity”. Section 4 presents several recent representative cases of losing monetary policy independence even with freely-floating exchange rate. Section 5 is the theoretical model. Section 6 summarizes the practices of The People’s Bank of China in macro-prudential management regarding cross-border capital flow, increasing exchange rate flexibility and strengthening international monetary policy coordination. Section 7 concludes.

2. Literature Review

It’s generally perceived that the theory of “Impossible Trinity” was presented by Mundell (1963) and Fleming (1962), but Mundell and Fleming didn’t call it “Impossible Trinity” or “Trilemma” explicitly. Actually, Friedman had already stated in his monograph “Essays in Positive Economics” (Friedman 1953), that if a nation chooses to fix its exchange rate, its inflation will be influenced by other economies, resulting it losing monetary policy independence, which is the de facto “Impossible Trinity”. In their 1963 book “A Monetary History of the United States, 1867-1960”

(Friedman and Schwartz 1963), Friedman and Schwartz also stated several times that within a gold standard monetary regime, how the de facto fixed exchange rate system influences inflation of economies. Major western economies abandoned the gold standard exactly because they couldn't cope with economic crisis effectively, while being influenced by monetary policy of major economies.

Calvo, Leiderman, and Reinhart (1993)look into cross-border capital flow of Latin America in 1990s and argues that capital flow of this time was affected by local fundamentals, such as economic and political reforms, and also by external factors, such as U.S. recession and long-lasting international environment of low interest rate. Calvo, Leiderman, and Reinhart (1996) further emphasize that global capital market integration and globalization of investment are behind the external factors. Even freely-floating exchange rate couldn't isolate external shock. Highly fluctuating capital flow could push real exchange rate to appreciate in short time and hurt competitivity of strategical sectors, further influencing the steady state of the economy. Based on previous two papers, Fernandez-Arias (1996) further categorizes influencing factors of capital flow into push factors and pull factors, which establishes research framework about capital flow.

Obstfeld and Taylor (1997)formally transform the theory from Mundell (1963)and (Fleming 1962)into Macroeconomic policy trilemmaand Inconsistent trinity. Policy makers could only choose two among free capital flow, fixed exchange rate and independent monetary policy oriented to domestic economy. This term became widely accepted.Obstfeld, Shambaugh, and Taylor (2005) conduct econometric analysis to data after 1870 and find that in these 130 plus years, "Impossible Trinity" generally holds. Interest rates of those countries adopting fixed exchange rate regime are more correlated with that of base economy, which means less monetary independence.

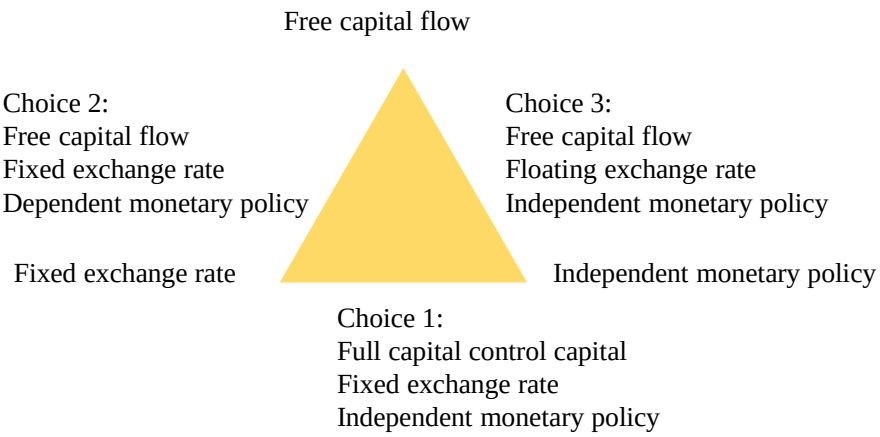

Figure 1 "Impossible Trinity" (Equilateral Triangle)

Yi and Tang (2001) introduce the triangle coordinate, and embody "Impossible Trinity" into an equilateral triangle with coordinates. Exchange rate regime, monetary policy independence, and capital flow have value in [0,1]. With the help of coordinates reading, "Impossible Trinity" is introduced into the model as the constraint of government objective function. Yi and Tang (2001) further elaborate the "Impossible Trinity" into an expanded impossible trinity, and argue that in-between exchange rate regime could trigger financial crisis, and financial system will evolve into freely-floating, or fully fixed exchange regime, which are called corner solution.

"Impossible Trinity" faces challengers, including Obstfeld himself. Model of Obstfeld and Rogoff (1995) tells the mechanism that when a nation lowers its interest rate, global money supply increases and consumption demand is also elevated. Obstfeld, Shambaugh, and Taylor (2005) also point out that without capital control, the current correlation between interests of countries with floating exchange rate and that of base country is higher than previous. Other research has similar conclusion. Kim (2001) explores empirical relations between economic variable without a pre-specified theory, and finds that even within the floating G7, expansive monetary policy of U.S. will generate positive spillover effect, which amounts to 1/4 to 1/2 of the effects of U.S. policy on U.S. economy. At the same time, monetary policy of other economies has no significant counter-effect on U.S. monetary policy.Ciccarelli and Mojon (2010) also find that in mostly floating 22 OECD economies, inflation becomes a global phenomenon. There exists a common factor to explain 70% of the

global inflation. This common factor reflects both global inflation trend, and business cycles, and connects global inflation with domestic inflation through stable error correction mechanism. Floating exchange rate fails to isolate external shocks. Gourinchas and Obstfeld (2012) utilize event study and panel regression to analyze financial crisis during 1973-2010. They report that domestic credit expansion and real exchange rate appreciation are the most important and significant indicators of financial crisis. For EMEs, more FX reserve helps lower the probability of financial crisis much. According to their model, if the monetary authority keeps capital flow free in booming times, on the one hand, domestic credit could expand due to capital inflow, on the other hand, capital inflow could push real exchange rate to appreciate, both of which greatly increase the probability of financial crisis. Obviously, "Impossible Trinity" shows shortcoming in practices. Only floating exchange rate can't keep domestic economy isolate to global capital tide, and other tools are needed to help. Edwards (2015) analyzes monetary policy of Chile, Columbia and Mexica during 2000-2008, whose results show that floating exchange rate failed to bring monetary policy independence. U.S. interest rate policy was imported into these 3 economies, to the extent of 50%, 74%, and 33%.

Sun (2010) innovatively presents the theory of "Dilemma". He argues that interest rate markets and FX markets of both countries need to be in equilibrium. But the location of equilibrium depends on relevant market strength of the two countries. If money market of one country is substantially deeper, it will exert decisive influence on capital flow direction, which will break the constraint of exchange rate regime. Sun (2010) further elaborates that "*Impossible trinity becomes dilemma. It's only possible to maintain independent monetary policy with the help of capital control. If capital flows freely or near freely, it will be more difficult to maintain independent monetary policy.*" If "Impossible Trinity" of every economy is effecting, then only one economy could maintain independent monetary policy, of which U.S. is the only possible economy at current stage. Once U.S. cuts interest rates, capital will flow to other economies, unrestricted by exchange rate. It's only possible to maintain independent monetary policy with help of some capital control.

Rey (2013)also argues for “Dilemma”, and against the traditional “Impossible Trinity”. Exchange rate regime disappears from “Impossible Trinity”, and monetary policy authority could only choose one from free capital flow and independent monetary policy. Her research finds highly positive correlation among capital flows around the globe, which further correlate with VIX. Recursive VAR further finds that monetary policy of the core economy (U.S.) is important determinant of global financial cycles, which further impacts leverage of global banking system, credit flow and growth, and establishes the events chain of “U.S. monetary policy→VIX→Global capital flow→Global credit expansion”. The prescription includes capital control, international monetary policy coordination, macro-prudential policy, etc.McKinnon said in 2014, “*there’s only one country that’s truly independent and can set its monetary policy. That’s the United States*” (Edwards, 2015).

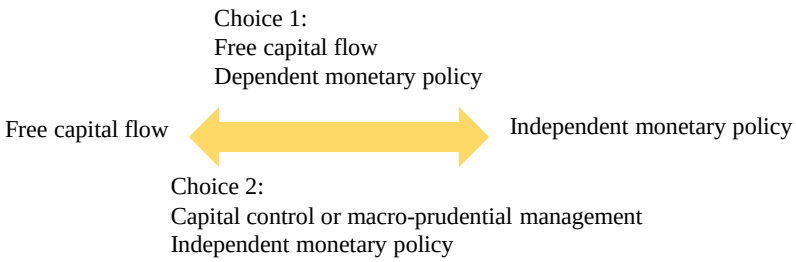

Figure 2 “Dilemma”

Academic research about prescriptions in Rey (2013) is also conducted. Obstfeld, Shambaugh, and Taylor (2010) find that FX reserve exists for both external drain and internal drain, which refers to deposits changing into cash. This validates necessity of developing countries to hold substantial FX reserve to contain capital flow. Because that external drain and internal drain could coincide with each other, we need to pay more attention to capital flow, especially for more monetarizedeconomies. Taylor (2013) argues that central banks need to go back to rule-based policy system in 1980s and 1990s, which renders international coordination possible. Qureshi et al. (2011) conducts empirical tests regarding capital control and macro-prudential measures of EMEs during 1998-2005. The results show that more capital flow and macro-prudential measures regarding FX correlate with lower FX loans. Experiences

since 2008 GFC also shows that capital control and macro-prudential measures in booming era could increase economic strength during crisis era. Forbes et al. (2016) finds that capital flow tax in Brazil reduces foreign capital inflow into Brazilian equity and bond markets. The crucial factor is not the tax cost, but the signaling effect. Pasricha et al. (2015)argues that when EMEs' economy expands, their capital flow and capital control measure have spillover effect on other EMEs, which is more evident in Latin America. This again validates the necessity of international policy coordination. EMEs need to consider policy spillover effect when planning capital control.

Follow-up research on "Dilemma" emerges frequently. As a proof of "Dilemma", Ahmed and Zlate (2014) find that after 2008 GFC, global capital flow becomes more sensitive to interest rate difference, which means that post-crisis pressure on capital flow brought by non-synchronized monetary policy is substantially higher that pre-crisis, and lowers monetary policy independence significantly. There is also no exchange rate regime in this research. Rose (2014) shows that countries with floating exchange rate and inflation target and those with fixed exchange rate have no evident difference on business cycles and capital flows. Aizenman, Chinn, and Ito (2016) also argues that after 2008 GFC, the policy interest rates of EMEs become more sensitive to global financial cycles. Wu and Lu (2016) build a model of ineffective monetary policy within a floating exchange rate regime, core of which is the influence of global risk aversion. With global risk aversion increasing, even with a loosening monetary policy, its effects could be counterbalanced completely

Some scholars conduct research on channels of monetary policy transmission bypassing exchange rate regime. Mohanty (2014) quotes discussion in Bank for International Settlements (BIS) that after GFC, global interest rates and asset prices become more synchronized, which can't be explained by business cycle. Both short-term and long-term interest rates of EMEs are influenced by advanced economies, especially U.S. Transmission channels include policy rate reaction, bond market, cross-border bank lending, etc. Although EMEs could reduce capital inflow pressure by currency appreciation, they still couldn't reduce speculative demand from

investors based on risk-taking. Mohanty (2014) also cites research from Brazilian central bank, which states that its advanced derivative markets, highly open capital market, floating exchange rate all amplify the shock to Brazilian economy by global crisis. Benigno, Converse, and Fornaro (2015) finds that capital inflow in low interest rate environment will promote labor to migrate from tradable sectors, such as manufacture, to non-tradable sectors. This migration is correlated with severity of ensuing crisis.

Bruno and Shin (2015a) and Bruno and Shin (2015b) are two papers published in the same year about cross-border capital flow, which look into bank leverage channel of easy monetary policy of advanced economies influencing EMEs, from perspective of dynamic model, and econometric test respectively. They also construct the events chain of "U.S. monetary easing→Global banks increase leverage and provide low-cost fund to EMEs banks→Credit expansion in EMEs". They find that appreciation of EMEs currency could not stop the previous chain. This is because appreciation makes balance sheets of local firms more healthy and more capable to borrow, which results in credit expansion too.Koepke (2015) continues with the push/pull factors framework. Results show that push factors influence more on portfolio investment, less on bank lending and FDI, but pull factors exert strong influence on all three, especially bank lending. Data from McCauley, McGuire, and Sushko (2015) shows that after 2008 GFC, U.S.D. credit from banks and institutional investors to non-bank institutions outside of U.S. increases from 6 trillion dollars to 9 trillion dollars. Several rounds of QE of U.S. Federal Reserve changed capital flow mechanism. Before GFC, capital flowed mainly in the form of bank lending, but after GFC, bond investment became more important. Banks increased bond holding, and non-bank institutions lent more dollar credit. Interestingly, influence of global capital market on capital flow is not new. Accominotti and Eichengreen (2016) observe that European capital flow during 1919-1932 was broadly influenced by global capital market.

Passari and Rey (2015) further develops on Rey (2013) and find that correlation of equity price, bank lending of a certain economy with global business cycles is not

much related with exchange rate regime choice, which means that it may not be the case that freely-floating exchange rate regime isolates external shocks.

"Dilemma" is still not widely accepted by academia. For example, Klein and Shambaugh (2015) find that limited capital control won't increase monetary policy independence significantly, compared with free capital flow. At the same time, partly-floating exchange rate regime could significantly increase monetary policy independence. Obstfeld (2015) also defends "Impossible Trinity" on the ground that more flexible exchange rate regime brings more flexibility in containing external shocks, compared with fixed exchange rate regime. But this paper admits that it's still not enough to isolate external shock only with exchange rate regime.

3. Scalene Impossible Trinity

3.1 Scalene Impossible Trinity

We believe the equilateral form of "Impossible Trinity" doesn't depict the reality accurately, and the "Dilemma" is not enough to explain what is happening in the real economy. In the traditional equilateral form, capital flow, exchange rate regime and monetary policy independence are equally important. With free capital flow, floating exchange rate could effectively isolate external shock, to maintain monetary policy independence. But since 2008 GFC, through quantitative easing, central banks of advanced economies injected excessive liquidity. This made capital flow much more substantial than before, and its direction susceptible to acute changes. The new development increases the relative importance of capital flow to exchange rate regime and monetary policy independence. The equilateral triangle isn't fit for reality. But in "Dilemma", exchange rate regime completely disappears from "Impossible Trinity", in which case monetary policy independence completely relies on capital flow management. This emphasizes capital flow, butunduly ignores what exchange rate could do in adjusting money supply and demand both in domestic market and abroad.

Asa matter of fact, the equilateral form and dilemma are both extreme cases of triangle theory. The underlining case should be "Scalene Impossible Trinity", which is

the scalene form of “Impossible Trinity”. We introduce 3-dimensional Cartesian coordinate system in this paper to accurately illustrate “Impossible Trinity”, which is shown in Figure 3.

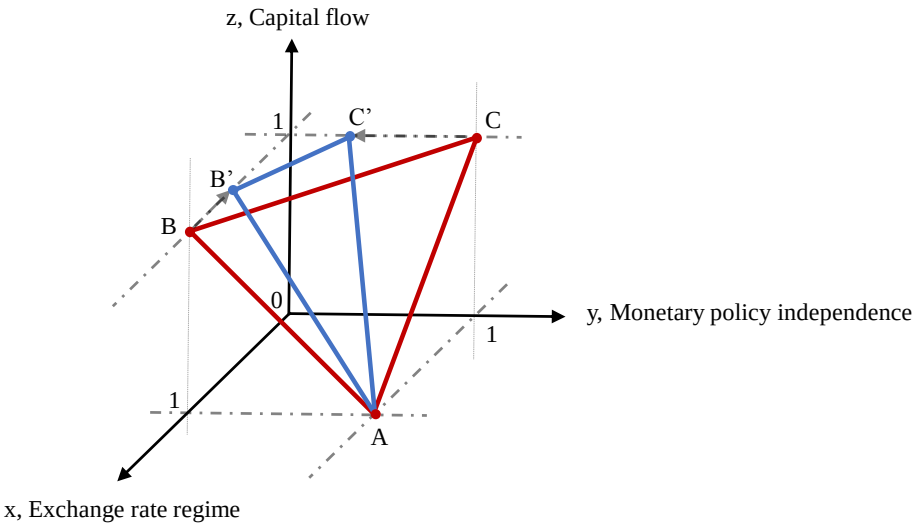

Figure 3 “Impossible Trinity” (Scalene Triangle)

In the 3-dimensional Cartesian coordinate system of Figure 3, axes x, y, z represent exchange rate regime, monetary policy independence, and capital flow. x=0 means freely floating exchange rate regime, x=1 means fixed exchange rate regime; y=0 means completely dependent monetary policy,in which case monetary policy decisions are made fully in accordance with international coordination, y=1 means independent monetary policy, in which case there is no international monetary policy coordination. It should be noted that the international monetary policy coordination in this paper doesn’t specifically refer to active or passive coordination, and is only an objective illustration of monetary policy dependence. The coordination mainly takes the form of interest rate policy coordination. z=0 means full capital control, z=1 means free capital flow. Choices 1, 2, 3 correspond to vertices A, B, C. ΔABC is the traditional equilateral form of “Impossible Trinity”.

ΔAB’C’ in Figure 3 is the scalene form of “Impossible Trinity”. Compared with the equilateral form ΔABC, vertex A, the combination of full capital control, fixed exchange rate, and independent monetary policy, doesn’t changed. This is because capital flow is more important than the other two, if there is full capital control, the

elevated importance of capital flow becomes ineffective. Vertex B, the combination of free capital flow, fixed exchange rate, dependent monetary policy, moves to B'. If capital flows freely, even if monetary policy becomes completely dependent, i.e. interest rate follows other central banks, fixed exchange rate couldn't be guaranteed. Because the capability of central bank to maintain fixed exchange rate is not unlimited, which depends on its FX reserve balance, and issuance ability of domestic currency. As well, vertex C, the combination of free capital flow, floating exchange rate, and independent monetary policy, moves to C'. This is because if capital flows freely, floating exchange rate is unable to guarantee independent monetary policy. The movement of points B and C both shows the importance elevation of capital flow in "Impossible Trinity", which results in equilateral triangle ABC transforming into scalene triangle AB'C'. It's worth to mention that BB'doesn't necessarily equal to CC'. "Dilemma" is the extreme case of axis x collapse, in which case points B' and C' in Figure 3 merge into point (0,0,1), and point A maps into point (0,1,0)on plane (x=0).

Thus, we have the following definition and proposition.

Definition: Among the three of capital flow, exchange rate regime, and monetary policy independence, capital flow is more important. "Scalene Impossible Trinity" refers to the triangle whose three vertices are free capital flow (B' and C') and full capital control (A). If monetary authority chooses full capital control, then fixed exchange rate and independent monetary policy could be achieved at the same time. If it chooses free capital flow, it could only achieve relatively stable exchange rate and relatively independent monetary policy.

Proposition: "Equilateral Impossible Trinity" is a special case of "Scalene Impossible Trinity", which means that capital flow, exchange rate regime and monetary policy independence are equally important. In this case, scalene triangle transforms into equilateral triangle. "Dilemma" is also a special case of "Scalene Impossible Trinity", which means capital flow renders exchange rate completely unable to adjust money supply and demand both in domestic market and abroad. In this case, scalene triangle collapses into a line segment on the plane of monetary

policy independence and capital flow.

3.2 Further Extension of "Scalene Triangle"

Further analysis shows that after importance of capital flow is elevated, policy choice set of the monetary authority becomes the pentagon ADC'B'E, which is the intersection of plane AB'C' and cube $(0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1)$, as shown in Figure 4. Monetary authority will make the optimal choice within this pentagon.

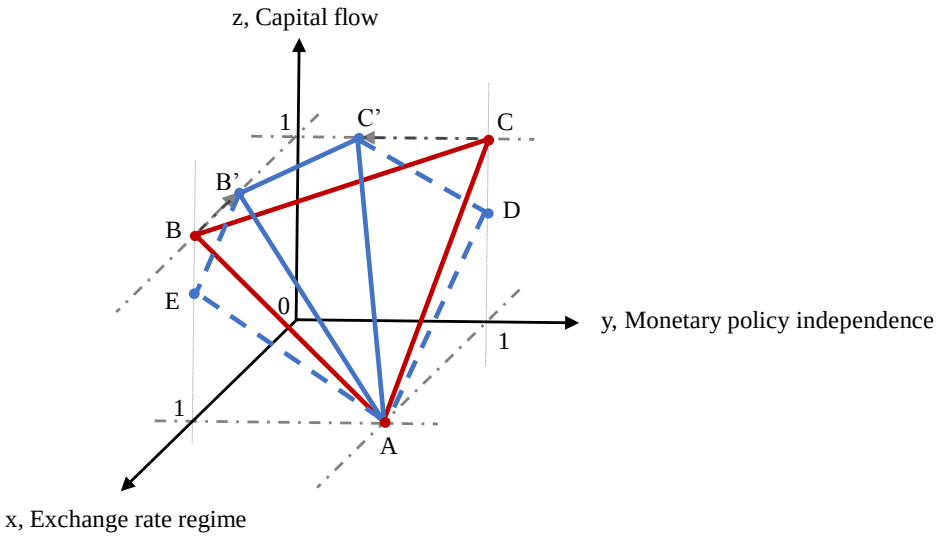

Figure 4 "Impossible Trinity" (Pentagon)

Next, we'll analyze the attributes of this pentagon.

If we assume "Scalene Impossible Trinity", then policy choice of the monetary authority must be limited in the cube $(0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1)$. In addition, policy choice also needs to satisfy:

$$\rho x + \sigma y + \varphi z \leq 2 - d \qquad (1)$$

In equation(1), ρ is the importance factor of exchange rate regime, σ is the importance factor of monetarypolicy independence, and φ is the importance factor of capital flow. Because the three are not equally important anymore, we don't necessarily have $\rho = \sigma = \varphi = 1$. $2 - d$ is the freedom of choice for the impossible trinity.

The border of space represented by equation (1)is the plane:$\rho x + \sigma y + \varphi z = 2 - d$.Vertex B' of "Scalene Impossible Trinity" ΔAB'C' is the crossing point of this plane with line $(y = 0, z = 1)$, vertex C' is the crossing point of this plane with line

($x = 0, z = 1$). Except for the scalene triangle, some parts of this planes are still in the cube ($0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1$).The intersection of this plane and the cube is the border of policy choice set, which is the pentagon ADC'B'E.

If $\rho = \sigma = \varphi = 1$, $d = 0$, then scalene triangle goes back to equilateral triangle. If$\rho = 0, \sigma = \varphi = d = 1$, then scalene triangle collapse into dilemma. In the following discussions, we assume scalene triangle doesn't collapse into dilemma, i.e. $d = 0$, and the freedom of choice for impossible trinity is 2. Then we have:

$$\rho x + \sigma y + \varphi z = 2 \quad (2)$$

Now, we'll discuss value of ρ, σ, φ.

a. Importance of capital flow should be higher that exchange rate and monetary policy independence, which means$\varphi > \rho$ and $\varphi > \sigma$.

b. Importance of capital flow couldn't go unlimited. This is because if it goes unlimited, it becomes possible that the distance between crossing point of the pentagon and axis z, and the origin is less than 1. Then we have $\varphi < 2$.

c. Importance factor of the three should all be positive, which means: $\rho > 0, \sigma > 0, \varphi > 0$.

d. This plane should contain point A(1,1,0) in Figure 4, then we have$\rho + \sigma = 2$, i.e.$\sigma = 2 - \rho$.

e. The distance between point B' and axis z should be less than 1, then we have $2 - \varphi < \rho$.

f. The distance between point C' and axis z should be less than 1, then we have $2 - \varphi < \sigma$. Remember that$\sigma = 2 - \rho$, so $\varphi > \rho$, which repeated condition a.

From condition a and d, we have$\varphi > 1$.

From condition c and d, we have $0 < \rho < 2$.

Then equation (2) becomes:

$$\rho x + (2 - \rho) y + \varphi z = 2 \quad (3)$$

Coefficients in the above equation should satisfy: $\max(1, \rho, 2 - \rho) < \varphi < 2$ and $0 < \rho < 2$.

3.3 A Numerical Example of "Scalene Impossible Trinity" Framework

To better illustrate the analytical framework of "Scalene Impossible Trinity", we

provide here a numerical example. Following previous discussion, coefficients in "Scalene Impossible Trinity" equation (3) should satisfy:

$$\max(1, \rho, 2-\rho) < \varphi < 2, \quad 0 < \rho < 2$$

Let's assume $\varphi = 1.5$, $\rho = \sigma = 1$. Equation (3) becomes:

$$x + y + 1.5z = 2$$

In above equation, the sum of capital flow, exchange rate regime, monetary policy independence is still 2, which means the freedom of choice for the monetary authority is still 2, and the same as traditional "Impossible Trinity". Because importance of capital flow is elevated and its importance factor is now 1.5 instead of 1, value ranges of exchange rate flexibility x and monetary policy independence y are both decreased. The geometric expression of "Impossible Trinity" is now similar to Δ AB'C' in Figure 3.

When capital flows freely, z=1, and equation (3) becomes x+y=0.5, which means freedom of choice about exchange rate flexibility and monetary policy is only 0.5. Whatever policy combination the monetary authority chooses, it's unable to achieve fixed exchange rate or independent monetary policy. If monetary authority chooses to abandon monetary policy independence (y=0), it could only achieve relatively stable exchange rate (x=0.5). The choice limit is then point B' in Figure 3. Point B (x=1, y=0) of "Fixed exchange rate + Dependent monetary policy" is out of choice set for monetary authority. If monetary policy chooses floating exchange rate (x=0), it could only achieve relevantly independent monetary policy (y=0.5). The choice limit is then point C' in figure 3. Point C (x=0, y=1) of "Floating exchange rate + Monetary policy independence" is out of choice set for monetary authority.

When full capital control is enforced, z=0 and equation (3) becomes x+y=2. In this case, monetary authority could accomplish point A in figure 3, "Fixed exchange rate + Independent monetary policy". This is because capital flow has more weight, once it's fully controlled, the scalene triangle and equilateral triangle coincide with each other, and there's no difference between the two. This is why point A could be a vertex of both equilateral triangle Δ ABC and scalene triangle Δ AB'C'. This case is illustrated by Theorem 1 in section 5 of this paper. When capital flow is not fully

controlled, differences emerge between the two triangles.

After policy choice set of the monetary authority expands to the pentagon ADC'B'E from equilateral triangle Δ ABC, one possible optimal choice of monetary authority on the 3 aspects at the same time is (x=0.4, y=0.4, z=0.8)[4], which is an example of "Partial exchange rate flexibility + Partial international monetary policy coordination + Partial capital flow management". This is illustrated by Theorem 3 in section 5 of this paper.

4. Several Cases

In recent years, there are two typical occasions to observe the "Scalene Impossible Trinity". One is in June 2013, in which U.S. Federal Reserve announced its intention to conditionally quit QE when appropriate. Another one is in 2015, during which the expectation of interest rate hiking of U.S. Federal Reserve was elevated and realized in December that year. The common factor of these two occasions is the issuing country of reserve currency (U.S.) tightened its monetary policy, resulting in capital outflow from EMEs and depreciation of EMEs currencies. It should be noted that the 3 economies we choose, Brazil (in 2013 and 2015), Russia (in 2015), and Indonesia (in 2013) all adopted floating exchange rate regime. The currencies of the 3 economies couldn't depreciate enough to cope with the change of monetary policy of U.S. Federal Reserve. Interest rate increase of local currency ensued. It's only when the interest rates were elevated higher enough, the currency depreciation finally stopped. During these times, growth of the 3 economies were quite tepid, especially Brazil and Russia, which experiences negative economic growth. The higher interest rates add flare to flame on domestic economy. The combination of "free capital flow + freely-floating exchange rate" didn't isolated external shocks. Monetary policy independence suffered and the 3 economies followed policy direction of U.S. Federal Reserve.

[4] This is only a numerical example, not the actual solution.

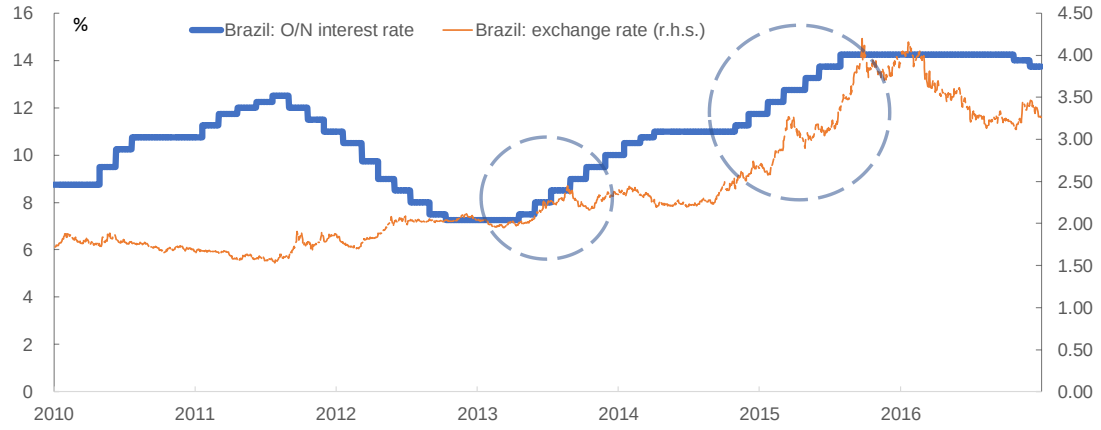

Figure 5 Interest rate and exchange rate of Brazil

Source: Wind

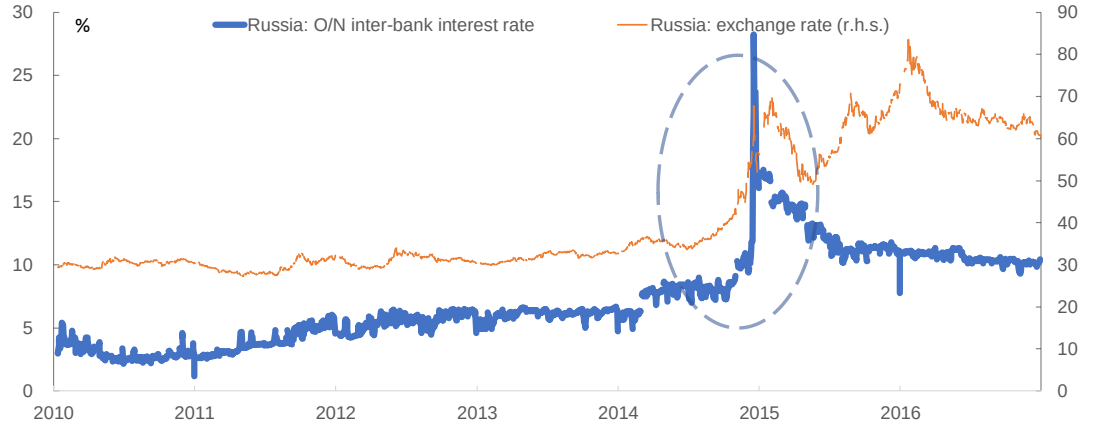

Figure 6 Interest rate and exchange rate of Russia

Source: Wind

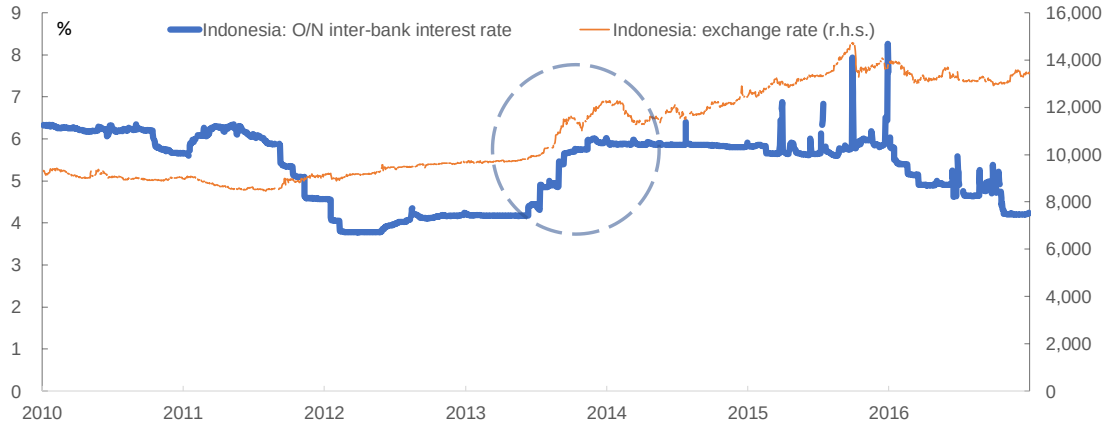

Figure 7 Interest rate and exchange rate of Indonesia

Source: Wind

5. Model

This paper adopts the 3-dimensional Cartesian coordinate systemof section 3 when building the model. x, y, and z have the same value and meaning as in section 3. Referenced to Yi and Tang (2001), we assume and improve the utility function of the central bank. With the premise of "Scalene Impossible Trinity", we calculate the optimal level of macro-prudential management regarding cross-border capital flow and optimal level of international monetary policy coordinationwithin different foreign exchange rate regimes.

5.1 Model Setting

5.1.1 Utility Function of the Central Bank

We assume the utility function of the central bank to be:

$$U = \theta x^{\alpha} + y^{\beta} + \lambda(1-x)\cdot z^{\gamma} \tag{4}$$

The first item illustrates central bank's preference to exchange rate risk. Given other conditions, central bank prefers lower exchange rate risk, i.e. fixed exchange rate. Marginal preference is decreasing, so $0 < \alpha < 1$. $\theta$is the importance factor of exchange rate in utility function of the central bank, $\theta > 0$.

The second item illustrates central bank's preference to monetary policy independence. Given other conditions, central bank prefers more independent monetary policy. Marginal preference is decreasing, so $0 < \beta < 1$. The importance factor of independent monetary policy in utility function of the central bank is standardized to be 1. International monetary policy coordination is an objective illustration of monetary policy dependence. Once central bank chooses the optimal level of monetary policy independence, it also chooses the optimal level of international monetary policy coordination.

The third item illustrates central bank's preference to capital flow. When capital flow level, z, has the value between 0 to 1, central bank conduct some management of capital flow, either in the form of partial capital control, or in the form of marco-prudential management. Cross-border capital flow could improve the global resource allocation, so given other conditions, central bank prefers freer capital flow.

Marginal preference is decreasing, so $0 < \gamma < 1$. The resource allocation function of capital flow correlates positively with flexibility of exchange rate. If exchange rate freely floats, the price signal is the strongest, and so is the resource allocation function. Taking this into consideration, we multiply $(1-x)$ to the third item. λ is the importance factor of capital flow in utility function of the central bank, $\lambda > 0$.

5.1.2 Budget Constraint in Accordance with "Scalene Impossible Trinity"

We borrow deductions from section 3. Because central bank always prefers more stable exchange rate, more monetary policy independence, and freer capital flow, the solution of the optimization problem should be located on the border of inequality constraint (1), which means the inequality constraint could be replaced by equality constraint (3):

$$\rho x + (2-\rho)y + \varphi z = 2$$

In equation (3), $\max(1, \rho, 2-\rho) < \varphi < 2$ and $0 < \rho < 2$.

We should distinguish between the two sets of importance factors, namely $\rho, 2-\rho, \varphi$ and $\theta, 1, \lambda$. The former one is the objective importance of capital flow, exchange rate regime, and monetary policy independence formed in financial market operations, while the latter one is the subjective preference of central bank regarding the three. These two sets of factors are not necessarily the same.

5.1.3 Utility Maximization of Central Bank

Central bank needs to solve:

$$\max_{x,y,z\in[0,1]} U = \theta x^{\alpha} + y^{\beta} + \lambda(1-x)\cdot z^{\gamma}$$

$$\text{s.t. } \rho x + (2-\rho)y + \varphi z = 2$$

$$x \le 1$$

$$-x \le 0$$

$$y \le 1$$

$$-y \le 0$$

$$z \le 1$$

$$-z \le 0$$

Because capital flow has the highest weight among "Impossible Trinity", we should

first ascertain optimal level of capital flow when solving the above optimization problem, and then ascertain optimal level of international monetary policy coordination. From $\rho x + (2-\rho)y + \varphi z = 2$, we get $y = \frac{2-\rho x-\varphi z}{2-\rho}$, and eliminate y by substituting this into objective function. Once we have optimal level of capital flow z, we could reach optimal level of international monetary policy coordination by $y = \frac{2-\rho x-\varphi z}{2-\rho}$, and realize the above optimization sequence. Now the optimization problem becomes:

$$\max U = \theta x^{\alpha} + \left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta} + \lambda(1-x)\cdot z^{\gamma}$$

$$\text{s.t. } x \le 1$$

$$-x \le 0$$

$$z \le 1$$

$$-z \le 0$$

5.2 Optimization without Pre-specified Exchange Rate Regime

x and z are to be determined without pre-specified Exchange Rate Regime.

We have Lagrangian:

$$\mathcal{L} = \theta x^{\alpha} + \left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta} + \lambda(1-x)\cdot z^{\gamma} - \mu(x-1) + \nu x - \omega(z-1) + \pi z$$

First order condition (F.O.C.):

$$\frac{\partial \mathcal{L}}{\partial x} = 0: \theta\alpha x^{\alpha-1} - \frac{\rho\beta}{2-\rho}\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta-1} - \lambda z^{\gamma} - \mu + \nu = 0$$

$$\frac{\partial \mathcal{L}}{\partial z} = 0: -\frac{\varphi\beta}{2-\rho}\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta-1} + \gamma\lambda(1-x)z^{\gamma-1} - \omega + \pi = 0$$

$$\mu(x-1) = 0$$

$$\nu x = 0$$

$$\omega(z-1) = 0$$

$$\pi z = 0$$

Then we need to discuss x and z at the same time. The solution depends on two

exponential equations. This paper won't discuss this case.

5.3 Optimization with Pre-specified Exchange Rate Regime

With pre-specified exchange rate regime, x is fixed. The objective function

$$U = \theta x^{\alpha} + \left(\frac{2 - \rho x - \varphi z}{2 - \rho}\right)^{\beta} + \lambda(1 - x) \cdot z^{\gamma}$$

transforms into a function only of capital flow level z $U = U(z)$。

5.3.1 x=1, i.e. fixed exchange rate

From $y = \frac{2-\rho x-\varphi z}{2-\rho} = \frac{2-\rho-\varphi z}{2-\rho} \in [0,1]$, we have$z \in \left[0, \frac{2-\rho}{\varphi}\right]$.Coefficients in equation (3) must satisfy, $\max(1, \rho, 2 - \rho) < \varphi < 2$, plus $0 < \rho < 2$, we have: $\frac{2-\rho}{\varphi} < 1$.

$$U = \theta + \left(\frac{2 - \rho - \varphi z}{2 - \rho}\right)^{\beta}$$

$$\frac{\partial U}{\partial z} = -\frac{\varphi\beta}{2 - \rho}\left(\frac{2 - \rho - \varphi z}{2 - \rho}\right)^{\beta-1}$$

From $0 < \beta < 1$, and$\varphi > 1$, $\rho < 2$, we have $-\frac{\varphi\beta}{2-\rho} < 0$. $y = \frac{2-\rho-\varphi z}{2-\rho} \geq 0$, then $\frac{\partial U}{\partial z}$is negative whenever $y \neq 0$. By simple calculus, we know that the objective function has the maximum $\theta + 1$ when $z = 0$. We also get y=1.

Theorem 1: The optimal capital flow is 0 when exchange rate is completely fixed, i.e. full capital control. At the same time, central bank reaches full monetary policy independence.

The policy implication of this theorem is that when exchange rate is fixed, central bank should implement complete and extensive cross-border capital flow. The more, the better. Full capital control is not only necessity for monetary policy independence, but also the optimal choice of utility maximization of central bank. Less capital control brings more utility in the aspect of capital flow and resource allocation, but the loss of monetary policy independence weighs more important. Of course, within the background that current accounts of most countries are widely open, the effects of full capital control will be quite limited, and the cost of control will be relatively high. This is the exact reason why major advanced economies abandoned fixed exchange

rate and opened capital accounts during 1960s-1970s.

5.3.2 x=0, i.e. freely-floating exchange rate regime

From $y = \frac{2-\rho x-\varphi z}{2-\rho} = \frac{2-\varphi z}{2-\rho} \in [0,1]$, we have $z \in \left[\frac{\rho}{\varphi}, \frac{2}{\varphi}\right]$. Also by $\max(1, \rho, 2-\rho) < \varphi < 2$, and $0 < \rho < 2$ we have $\frac{\rho}{\varphi} > 0, \frac{2}{\varphi} < 1$. We can see that when x=0, value of z corresponding to the optimum must lie in (0,1), not 0 or 1.

$$U = \left(\frac{2-\varphi z}{2-\rho}\right)^{\beta} + \lambda z^{\gamma}$$

$$\frac{\partial U}{\partial z} = -\frac{\varphi\beta}{2-\rho}\left(\frac{2-\varphi z}{2-\rho}\right)^{\beta-1} + \gamma\lambda z^{\gamma-1}$$

Let $\frac{\partial U}{\partial z} = 0$, we have:

$$\gamma\lambda z^{\gamma-1} = \frac{\varphi\beta}{2-\rho}\left(\frac{2-\varphi z}{2-\rho}\right)^{\beta-1} \tag{5}$$

$$\text{i.e. } \gamma\lambda\left(\frac{2-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho} z^{1-\gamma}$$

Let $s_1 = \lambda\left(\frac{2-\varphi z}{2-\rho}\right)^{1-\beta}$, $s_2 = \frac{\varphi\beta}{2-\rho} z^{1-\gamma}$

When $z = 0$, $s_1 = \lambda\left(\frac{2}{2-\rho}\right)^{1-\beta} > 0 = s_2$;

When $z = \frac{2}{\varphi}$, $s_1 = 0 < \frac{\varphi\beta}{2-\rho}\left(\frac{2}{\varphi}\right)^{1-\gamma} = s_2$.

When $z \in \left(0, \frac{2}{\varphi}\right)$,

$$\frac{\partial s_1}{\partial z} = -\frac{\lambda\varphi(1-\beta)}{2-\rho}\left(\frac{2-\varphi z}{2-\rho}\right)^{-\beta} < 0$$

$$\frac{\partial s_2}{\partial z} = \frac{\varphi\beta(1-\gamma)}{2-\rho} z^{-\gamma} > 0$$

By continuous function theorem, there is only one z_1 in $\left[0, \frac{2}{\varphi}\right]$ such that $s_1 = s_2$.

The second order derivative of objective function at z_1 is:

$$\frac{\partial^2 U}{\partial z^2} = -\frac{\varphi^2\beta(1-\beta)}{(2-\rho)^2}\left(\frac{2-\varphi z}{2-\rho}\right)^{\beta-2} - (1-\gamma)\gamma\lambda z^{\gamma-2}$$

By $0 < \beta, \gamma < 1, 0 < \rho < 2, \lambda > 0, \varphi > 0, y \geq 0, z > 0$,

$$\frac{\partial^2 U}{\partial z^2} < 0$$

So, when $z = z_1$, the objective function has the local optimum.

When $z_1 \leq \frac{\rho}{\varphi}$, the global optimum is at $z = \frac{\rho}{\varphi}$. When $z_1 > \frac{\rho}{\varphi}$, the global optimum is at $z = z_1$. Once we have z, by $y = \frac{2-\varphi z}{2-\rho}$we could get optimal level of monetary policy independence. We should note that when objective function reaches maximum at $z = \frac{\rho}{\varphi}$, y is 1. Then we have Theorem 2.

Theorem 2: With exchange rate floats freely, central bank should conduct some capital control or macro-prudential management, and the control or management level should be the solution of equation $\gamma\lambda\left(\frac{2-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$ or $\frac{\rho}{\varphi}$. If the optimal management level of capital flow is solution of equation $\gamma\lambda\left(\frac{2-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$, the central bank should participate in international monetary policy coordination, participation level should correspond to $y = \frac{2-\varphi z}{2-\rho}$. If optimal management level of capital flow is $\frac{\rho}{\varphi}$, then central bank could reach full monetary policy independence.

The policy implication of this theorem is that because capital flow is the most important in "Impossible Trinity", central bank must conduct macro-prudential management regarding capital flow. If not, equilibrium might not be achieved. Central bank must choose between capital flow and monetary policy independence, and maintain relative independence or full independence of monetary policy by partial capital control or macro-prudential management. For most cases in which the optimal management level of capital flow is solution of equation $\gamma\lambda\left(\frac{2-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$, The combination of "macro-prudential management + international monetary policy coordination" is better than the two choices of free capital flow or full capital control. This theorem covers "Dilemma" to some extent.

5.3.3 0<x<1, i.e. exchange rate lies between fixed and freely-floating

From $y = \frac{2-\rho x-\varphi z}{2-\rho} \in [0,1]$, we have$z \in \left[\frac{\rho(1-x)}{\varphi}, \frac{2-\rho x}{\varphi}\right]$. Again by $\max(1, \rho, 2 -$

ρ) < φ < 2, and $0 < \rho < 2$, we have $\frac{\rho(1-x)}{\varphi} > 0, \frac{2-\rho x}{\varphi} < 1$.

$$U = \theta x^{\alpha} + \left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta} + \lambda(1-x)\cdot z^{\gamma}$$

$$\frac{\partial U}{\partial z} = -\frac{\varphi\beta}{2-\rho}\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta-1} + \gamma\lambda(1-x)z^{\gamma-1}$$

Let $\frac{\partial U}{\partial z} = 0$, we have:

$$\gamma\lambda(1-x)z^{\gamma-1} = \frac{\varphi\beta}{2-\rho}\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta-1} \quad (6)$$

$$\text{i.e. } \gamma\lambda(1-x)\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$$

Let $t_1 = \gamma\lambda(1-x)\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{1-\beta}$, $t_2 = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$

When $z = 0$, $t_1 = \gamma\lambda(1-x)\left(\frac{2-\rho x}{2-\rho}\right)^{1-\beta} > 0 = t_2$;

When $z = \frac{2-\rho x}{\varphi}$, $t_1 = 0 < \frac{\varphi\beta}{2-\rho}\left(\frac{2-\rho x}{\varphi}\right)^{1-\gamma} = t_1$.

When $z \in \left(0, \frac{2-\rho x}{\varphi}\right)$,

$$\frac{\partial t_1}{\partial z} = -\frac{\varphi}{(2-\rho)}(1-\beta)\gamma\lambda(1-x)\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{-\beta} < 0$$

$$\frac{\partial t_2}{\partial z} = (1-\gamma)\frac{\varphi\beta}{2-\rho}z^{-\gamma} > 0$$

By continuous function theorem, there is only one z_2 in $\left[0, \frac{2-\rho x}{\varphi}\right]$ such that $t_1 = t_2$.

The second order derivative of objective function at z_2 is:

$$\frac{\partial^2 U}{\partial z^2} = -\frac{\varphi^2\beta(1-\beta)}{(2-\rho)^2}\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{\beta-2} - (1-\gamma)\gamma\lambda(1-x)z^{\gamma-2}$$

From $0 < \beta, \gamma < 1, 0 < \rho < 2, \lambda > 0, \varphi > 0, y \geq 0, z > 0$,

$$\frac{\partial^2 U}{\partial z^2} < 0$$

So, when $z = z_2$, the objective function has the local optimum.

When $z_2 \leq \frac{\rho(1-x)}{\varphi}$, global optimum is at $z = \frac{\rho(1-x)}{\varphi}$. When $z_2 > \frac{\rho(1-x)}{\varphi}$, global optimum is at $z = z_2$. Once we have z, by $y = \frac{2-\rho x-\varphi z}{2-\rho}$ we could get optimal level of

monetary policy independence. We should note that when objective function reaches maximum at $z = \frac{\rho(1-x)}{\varphi}$, y is 1. Then we have theorem 3.

Theorem 3: When exchange rate lies between fixed and freely-floating, central bank should conduct some capital control or macro-prudential management, and the control or management level should be the solution of equation $\gamma\lambda(1-x)\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$ or $\frac{\rho(1-x)}{\varphi}$. If the optimal management level of capital flow is solution of equation $\gamma\lambda(1-x)\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$, the central bank should participate in international monetary policy coordination, participation level should correspond to $y = \frac{2-\rho x-\varphi z}{2-\rho}$. If optimal management level of capital flow is $\frac{\rho(1-x)}{\varphi}$, then central bank could reach full monetary policy independence.

The policy implicationof this theorem is that if exchange rate is in between, central bankalso shouldn't choose free capital flow or full capital control. It must choose between capital flow and monetary policy independence, and maintain relative independence or full independence of monetary policy by partial capital control or macro-prudential management. Because the exchange rate is less flexible, the freedom of central bank police choice is also less than that in theorem 2. For most cases in which the optimal management level of capital flow is solution of equation $\gamma\lambda(1-x)\left(\frac{2-\rho x-\varphi z}{2-\rho}\right)^{1-\beta} = \frac{\varphi\beta}{2-\rho}z^{1-\gamma}$, The combination of "macro-prudential management + international monetary policy coordination" is the optimal choice for the central bank.

We should note that the above 3 theorems don't conflict with each other. With the change of economic development phase and international economic environment, monetary authority might choose different exchange rate regimes, and correspondingly, the optimal management level of capital flow and optimal level of international monetary policy coordination might also change. Different theorem could fit for different times when optimal policy combination is chosen. Specifically, theorem 1 needs fixed exchange rate + full capital control, which could hardly be exactly achieved. Most economies fit for theorem 2 or 3. Theorem 2 applies to those

economies with clean floating exchange rate regime, but from above deduction, we could see that for most cases, these economies should conduct macro-prudential management regarding cross-border capital flow, and should participate in international monetary policy coordination. Theorem 3 applies to those economies with a managed floating exchange rate regime, and not a clean floating regime. Again, from the above deduction, we could see that these economies should also conduct macro-prudential management regarding cross-border capital flow, and should participate in international monetary policy coordination. The levels of macro-prudential management and international monetary policy needs to be higher in theorem 3 than theorem 2 to compensate for lower exchange rate flexibility. It should be noted that, with increasing exchange rate flexibility, these economies which fit for theorem 3 previously could now fit for theorem 2, and should choose new optimal levels of macro-prudential management and international monetary policy coordination.

6. China Practice

From previous analysis, if exchange rate is freely-floating, or lies between fixed and freely-floating, as a result of elevated importance of capital flow, central bank still needs to conduct partial management of capital flow, or it will not achieve optimal equilibrium. At the same time, it's also necessary to increase exchange rate flexibility and conduct international monetary policy coordination. ANew Macro-Financial Policy Framework (New MFPF) needs to be applied, i.e. "Macro-prudential management + Exchange rate flexibility + International monetary policy coordination." Only by adopting this three-pronged strategy, the central bank could attain macroeconomic equilibrium. In recent years, China has several good practices.

6.1 Improving Macro-prudentialManagement regarding Capital Flow

The previous model doesn't tell whether the optimal capital flow should be achieved by capital control or macro-prudential management. But it should be noted that capital control is unable to effectively contain risk from capital flow. First, the

effectiveness of capital flow suffers, especially in more open economies. Even if it could work in short term, it couldn't contain capital flow as a result of economic imbalance. With further development of financial markets and financial products innovation, there are more and more channels to circumvent capital control. Jin and Li (2005) finds that China's capital control effectively maintains the interest difference of U.S.D. between domestic market and abroad, but fails to effectively contain capital outflow and hot money inflow. Pasricha et al. (2015) use panel data and find that even if capital control benefits capital flow, monetary policy independence, and exchange rate, these benefits are still small, while capital control brings spillover effects to other EMEs. Second, capital control is unable to contain systematic and global risk. Capital control restricts certain operations of micro-entities, and isn't enough to cope with shock to market confidence and expectation, and contagion of financial risk from cross-border capital flow. Third, capital control costs high. It will twist market operation, split domestic and global money market, lower utilization efficiency of money, and raise cost of capital. China's economy is both open and gigantic, and relies heavily on global trade. Inappropriate control could impact confidence and balance of payments.

As contrary, macro-prudential measures could effectively cope with cross-border capital flow risk. Different with capital control measures and from a global perspective, macro-prudential management contains cross-border capital flow risk counter-cyclically, by price based and market-oriented measures. To some extent, it restrains excessive shock from capital flow, reduces capital flow's inference on monetary policy and renders monetary policy more independent. In the mode of macro-prudential management, macro-financial authorities adopt measures from macro and counter-cyclic perspective, to prevent systematic risk from cyclical fluctuation of financial system and cross-sector risk contagion, to maintain the stability of the whole financial system. IMF also published series of papers to rank the policy tools monetary authorities should use to cope with capital flow. They proposed to mainly utilize macro-prudential tools, and treat capital control as the last resort.

The People's Bank of China (PBOC) researched into macro-prudential

management measures in mid-2009, introduced the dynamic adjustment mechanism of differentiated reserve requirement in 2011, upgraded this mechanism into Macroprudential Assessment (MPA) in 2016, and established the macro-prudential policy framework. In 2015, based on market status and international experiences, PBOC added foreign exchange (FX) liquidity and cross-border capital flow into macro-prudential management, and further improved this framework.

Generally speaking, PBOC improves management mode of micro-entities from the elevated perspective of macro-prudential, adopts more mid- and post-macro-prudential management measures, which is more market-oriented and dynamically adjustable, in place of pre-approval and quota management. The following two kinds of capital flow are policy focus. One is substantial leverage financing, including hedge funds from China and abroad, domestic financial institutions and enterprises. The other is market speculation with retained funds, which is conducted by some enterprises. The macro-prudential management starts with counter-cyclic adjustment of leveraging and containing short-term speculations.

Macro-prudential policy tools regarding cross-border capital flow also are two-folds. The first are quantitative tools about FX exposure and external debt of banking system, which are introduced to contain external debt growth in the time of capital inflow, accumulation of FX assets of banks in the time of capital outflow, and external leverage ratio of banks. The second are price based macro-prudential tools, such as non-interest-bearing reserve requirement to contain leverage growth.

6.1.1 Macro-prudential Management regarding Cyclical Leveraging Behavior

The first practice is macro-prudential management regarding leveraging in domestic FX market.In August2015. Selling pressure of FX futures were beyond normal level, which showed speculative and cyclic behaviors. To counter-cyclically adjust FX liquidity, and contain irrational expectations, PBOC announced macro-prudential measures about FX futures and RMB trading by the end of August 2015. The new price-based measures required all financial institutions to deposit FX risk reserve calculated as 20% of their respective FX short exposure (including future and swap), and contained FX speculative behavior of some enterprises and

international entities.Monetary authority restrained speculative demand, and made FX future price more relevant to real demand.

The second practice is macro-prudential management regardingleveraging of domestic entities through external debt. In 2015, PBOC established macro-prudential managementmode about cross-border financing in Shanghai Pilot Free Trade Zone (FTZ). On January 25th, 2016, PBOC expanded the marco-prudential management pilot program of holistic cross-border financing to 27 banking financial institutions and enterprises registered in the 4 FTZs of Shanghai, Guangdong, Tianjin and Fujian. This program was further expanded to nation-wide financial institutions and enterprises on April 29th, 2016.Within this mode, PBOC could adjust relevant parameters based on macroeconomic adjustment needs and results of MPA, adjust cross-border financing of financial institutions and enterprises counter-cyclically, make cross-border financing more relevant with broad economy, solvency and balance of payments, contain leverage and currency mismatch, and prevent systematic financial risk.

The third practice is macro-prudential management regardingleveraging on offshore RMB market. After exchange rate reform of August 11th, 2015, some speculative forces expressed pessimistic expectation about China's economy, and shorted RMB with leverage. Speculators needed to borrow RMB first before they could short, which rendered the RMB financing cost the key. To increase the cost of speculative shorting of RMB, and to contain RMB outflow, since January 25th, 2016, PBOC enlarged the scale of deposits for which financial institutions have normal reserve requirement, to include deposits of foreign financial institutions in domestic financial institutions. This measure established the long-term counter-cyclical adjustment mechanism regarding cross-border RMB funds. It helped contain cyclical behavior of cross-border RMB funds flow, guide foreign financial institutions to improve liquidity management, promote healthy operation, prevent macro-financial risk, and maintain financial stability.

6.1.2 Macro-prudential Management regarding excessive speculation

In August 2015, RMB trading business grew really fast and far beyond normal level,

and possibly showed some arbitrage behavior. PBOC adopted macro-prudential measures to RMB trading business in mid-September 2015, increased RMB trading fee of several banks with abnormal trading behavior, and restrained arbitrage behavior by price based measures.The new measures were quite effective that RMB trading volume of financial institutions went back to normal level, short-term arbitrage was effectively suppressed, and the previous elevated RMB trading fee has been lowered to normal level.

From previous analysis, we can see that macro-prudential management of PBOC regarding capital flow focuses on leveraging and speculation, from two perspectives of foreign exchange market and external debt, adjusts counter-cyclically by open, transparent, and market-oriented measures, which improves operations of financial institutions and maintains financial stability. These measures work well in practices. Offshore RMB liquidity tightened periodically, and speculation decreased. RMB future and trading business went back to normal level, and FX demand of banks and enterprises based on normal business activity has been satisfied.

6.2Increasing Exchange Rate Flexibility

Although floating exchange rate isn't enough to contain capital flow, and so not the sufficient condition to guarantee independent monetary policy, without enough exchange rate flexibility, monetary authority will be even more incapable to contain capital flow. As a result, we still need to increase exchange rate flexibility. Since exchange rate reform in 2005, PBOC endeavored to improve exchange rate flexibility, and the reform direction has never changed. Current regime of RMB exchange rate is manageable floating regime which is based on market demand, and referenced to a currency basket, but the market hasn't fully understood the operating mode of this regime, which resulted contradiction between increasing exchange rate flexibility and stabilizing exchange rate expectation. So, in August 2015, PBOC clarified the RMB mid-price quoting mechanism to be "closing price of last trading day + value change of currency basket". This mechanism is truly transparent, and takes into consideration "based on market demand", "referenced to currency basket" and "stabilize market expectation". The increased exchange rate flexibility greatly enhanced monetary

policy independence.

6.3Strengthening International Monetary Policy Coordination

Within“Scalene Impossible Trinity”, capital flow is more important, even with flexible exchange rate and macro-prudential management, it still may not be enough to maintain ideal independent monetary policy. With economic and financial globalization further deepening, the positive welfare effect of monetary policy coordination becomes stronger, which makes coordination the new trend (Sun, Yin and Chai, 2016). In the past, the relation of monetary policy authorities forms an unequal game, like Stackelberg game from game theory. The unequal status of monetary authorities make the decision sequence also unequal. U.S. Federal Reserve is the decisive leader, while other monetary authorities could only choose to follow suits or not. Recently, from the global practices, monetary authorities show new trend of improving coordination. This new trend corresponds to deepening economic globalization and evolution of monetary policy objectives. Economic structure of countries becomes more similar, utility function of output and inflation becomes more similar, while elevating economic openness increases spillover effect of output and inflation fluctuation of other economies to domestic economy. All these factors increase the benefits from monetary policy coordination, and further promote the international coordination. Current coordination is embodied in that when monetary authority of certain economy is contemplating its monetary policy, it not only considers domestic output gap and inflation rate, but also considers output gaps and inflation rates of other economies. Each authority wants to maximize domestic welfare, but to do this, it must also consider economic and financial conditions of other economies. To maximize domestic welfare is the utmost objective of economic and financial policies. From this perspective, international monetary policy coordination means partial independent monetary policy. If coordination is good for domestic welfare and macroeconomic equilibrium, it should be one pragmatic option of monetary policy.

From methodological perspective, the current pattern of international monetary policy coordination is flexible. The coordination exists in that monetary authorities

takes economic and financial status of other economies into consideration of monetary policy, instead of bilateral agreement. The important part is that both parties strengthen communication, and understand corresponding party's judgement on economic and financial cycle, monetary policy decision rules, and other specific factors in decision making. The coordination should promote other monetary authorities to consider domestic factors when making monetary policy decisions.

At current stage, the difficulty in international monetary policy coordinationdecreases, while maneuverabilityincreases. In the process, financial markets help promoteinternational monetary policy coordination. Global monetary authorities sufficiently consider market expectations in making monetary policy decisions. Within the background of financial globalization, global financial market expectations impact each other to some extent, which forms the link of monetary policy of global central banks. For example, after U.S. presidential election in November 2016, global market expected expansionary fiscal policy of the U.S. to push output and inflation higher, which resulted in higher U.S.D. interest rate. Especially when U.S. Federal Reserve increased interest rates twice in December 2016 and March 2017, U.S. treasury yield brought global yield curves to an upward track. As such, transmission effects of domestic fundamentals and foreign factors added to each other, and interest rates of China's monetary market and bond market also increased. Market supply and demand pushed upwards interest rates of Medium-term Lending Facility(MLF), StandingLendingFacility (SLF) and Open Market Operations (OMO) of PBOC, i.e. central bank interest rates, which to some extent embodied international monetary policy coordination.

In a nutshell, with the "Scalene Impossible Trinity" in mind, China works from 3 aspects: improving macro-prudential management regarding cross-border capital flow, increasing RMB exchange rate flexibility, and strengthening international monetary policycoordination, and maintains macroeconomic equilibrium.

7. Conclusion

This paper combs through the thought trail from "Equilateral Impossible Trinity" to

“Dilemma”, and presents first in the literature “Scalene Impossible Trinity”.Compared with traditional “Equilateral Impossible Trinity” and “Dilemma” presented by Sun (2010) and others, the “Scalene Impossible Trinity” is a more general analytical framework. “Equilateral Impossible Trinity” and the so-called dilemma are both special cases of “Scalene Impossible Trinity”. “Equilateral Impossible Trinity” is a special case, which means that capital flow, exchange rate and monetary policy independence are equally important. “Dilemma” is also a special case, which means capital flow renders exchange rate completely unable to adjust money supply and demand both in domestic market and abroad. Based on this, and referenced to Yi and Tang (2001), we assume and improve the utility function of the central bank. With the premise of “Scalene Impossible Trinity”, we calculate the optimal level of macro-prudential management regarding cross-border capital flow and optimal level of international monetary policy coordinationwithin different foreign exchange rate regimes.

The theoretical model of this paper makes several innovations:

First, we build 3-dimensional Cartesian coordinate system of “Impossible Trinity”.This coordinate system express exchange rate regime, monetary policy independence, and capital flow with 3 axes, which could intuitively, accurately, and quantitatively illustrate “Equilateral Impossible Trinity”, “Scalene Impossible Trinity”, “Dilemma”, and could form the theoretical foundation for further discussion about “Impossible Trinity”.

Second, we solve optimization problem from utility function of central bank. The current main-stream macroeconomic models all assume that central bank cares about output and inflation, and so decide policy direction, but they don’t include the utility function of central bank in mechanism design. This makes them incomplete and unsuitable to solve mechanism design problems. The model of this paper complements current macroeconomic models.

Third, model in this paper is practical and could be easily extended. If we connect parameters in this model with actual data of financial system, we could get the exact location of optimum. The settings of the model also provide flexibility in designing

and calculating optimum.

Model in this paper could be the theoretical foundation for macro-prudential management regarding cross-border capital flow, and international monetary policy coordination. PBOC's practices summarized in this paper, such as macro-prudential management, improving exchange rate flexibility, and strengthening international monetary policy coordination, could also be a helpful mapping from this model into the real world.

Based on this model and recent practices of The People's Bank of China, we present the New Macro-Financial Policy Framework (New MFPF), which is "Macro-prudential management + Exchange rate flexibility + International monetary policy coordination." First, it's necessary to conduct macro-prudential management regarding capital flow, even if there are clean floating exchange rate and complete international monetary policy coordination. Second, although floating exchange rate isn't enough to contain capital flow, and so not the sufficient condition to guarantee independent monetary policy, without enough exchange rate flexibility, monetary authority will be even more incapable to contain capital flow. As a result, the central bank still needs to increase exchange rate flexibility. Third, within the background of further deepening economic and financial globalization, the difficulty in international monetary policy coordinationdecreases, while maneuverability increases, and the positive welfare effect becomes stronger. International monetary policy coordinationcould help maximize domestic welfare, which is the utmost policy objective of central banks, and becomes the new trend.Within the new policy framework, only by adopting this three-pronged strategy, the central bank could attain macroeconomic equilibrium.

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