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# The "Impossible Trinity" Hypothesis in an Era of Global Imbalances: Measurement and Testing

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## Abstract

We outline new metrics for measuring the trilemma aspects: exchange rate flexibility, monetary independence, and capital account openness, taking into account substantial international reserve accumulation that has taken place since the 2000s. Since 1990, the trilemma variables in emerging markets have converged towards intermediate levels, characterizing by managed flexibility, using sizable international reserves as a buffer while retaining some degree of monetary autonomy. We test the linearity of the trilemma, and find that the weighted sum of the three trilemma variables adds up to a constant. Thus, a rise in one trilemma variable should be traded-off with a drop of the weighted sum of the other two.

## 1. Introduction

A fundamental contribution of the Mundell–Fleming framework is the "impossible trinity," or the "trilemma," which states that a country may simultaneously choose any two—but not all—of the following three goals: monetary independence, exchange rate stability and financial integration. In the famous triangle usually found in any international macroeconomics textbook, each of the three sides can represent the full extent of monetary independence, exchange rate stability, and financial integration, yet it is not possible to be simultaneously on all three sides of the triangle.[1]

A key message of the trilemma is that policy makers face a tradeoff; increasing one trilemma variable would induce a drop in the weighted average of the other two. A country opting for greater financial openness, for example, must choose whether to forgo exchange rate stability or monetary independence depending on its policy preferences. Yet, to our knowledge, the validity of this tradeoff among the three trilemma variables has not been empirically tested properly, possibly because the trilemma hypothesis does not impose an exact functional relationship between the three policy variables, and because it is simply quite difficult to create systematic metrics that measure the extent of achievement in the three policy goals.

To fill this gap, we first introduce the "trilemma indexes," that measure the extent of achievement in each of the three policy goals of the trilemma, namely monetary independence, exchange rate stability, and financial integration. These indexes allow us to trace the evolving configurations of the international financial architecture during the post Bretton–Woods period.

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Second, we test whether the three indexes are linearly related with each other. If this is found to be true, it indicates that the notion that countries can only pursue two out of the three policy goals is correct. For this purpose, we examine whether the weighted sum of the three trilemma policy variables adds up to a constant with all three positive weights so that we can confirm the notion that a rise in one trilemma variable should be traded-off with a drop of a linear weighted sum of the other two trilemma variables.

Section 2 outlines the methodology for the construction of our "trilemma indexes." This section also presents summary statistics of the indexes to show how the indexes have evolved over years through major global economic events. Section 3 tests the validity of a linear specification of the trilemma indexes. Section 4 concludes the paper.

## 2. Measures of the Trilemma Dimensions

*Construction of the Trilemma Measures*

*Monetary independence (MI)* The extent of monetary independence is measured as the reciprocal of the annual correlation of the monthly interest rates between the home country and the base country. Money market rates are used.[2]

The index for the extent of monetary independence is defined as:

$$MI = 1 - \frac{\text{corr}(i_i, i_j) + 1}{2}$$

where $i$ refers to home countries and $j$ to the base country. By construction, the maximum and minimum values are 1 and 0, respectively. Higher values of the index mean more monetary policy independence.[3]

Here, the base country is defined as the country that a home country's monetary policy is most closely linked with as in Shambaugh (2004). The base countries are Australia, Belgium, France, Germany, India, Malaysia, South Africa, the UK, and the USA. For the countries and years for which Shambaugh's data are available, the base countries from his work are used, and for the others, the base countries are assigned based on the International Monetary Fund's (IMF) *Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER)* and the Central Intelligence Angency's *CIA Factbook*.

*Exchange rate stability (ERS)* To measure exchange rate stability, annual standard deviations of the monthly exchange rate between the home country and the base country are calculated and included in the following formula to normalize the index between zero and one:

$$\text{ERS} = \frac{0.01}{0.01 + \text{stdev}(\Delta(\log(exch\_rate))}.$$

Merely applying this formula can easily create a downward bias in the index, that is, it would exaggerate the "flexibility" of the exchange rate especially when the rate usually follows a narrow band, but is de- or revalued infrequently. To avoid such

downward bias, we also apply a threshold to the exchange rate movement as has been done in the literature. That is, if the rate of monthly change in the exchange rate stayed within ±0.33% bands, we consider the exchange rate is "fixed" and assign the value of one for the ERS index. Furthermore, single year pegs are dropped because they are quite possibly not intentional ones.[4] Higher values of this index indicate more stable movement of the exchange rate against the currency of the base country.

*Financial openness/integration (KAOPEN)* Without question, it is extremely difficult to measure the extent of capital account controls.[5] Although many measures exist to describe the extent and intensity of capital account controls, it is generally agreed that such measures fail to capture fully the complexity of real-world capital controls. Nonetheless, for the measure of financial openness, we use the index of capital account openness, or *KAOPEN*, by Chinn and Ito (2006, 2008). *KAOPEN* is based on information regarding restrictions in the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions* (*AREAER*). Specifically, *KAOPEN* is the first standardized principal component of the variables that indicate the presence of multiple exchange rates, restrictions on current account transactions, on capital account transactions, and the requirement of the surrender of export proceeds (see Chinn and Ito, 2008). Since *KAOPEN* is based upon reported restrictions, it is necessarily a *de jure* index of capital account openness (in contrast to *de facto* measures such as those in Lane and Milesi-Ferretti (2006)). The choice of a *de jure* measure of capital account openness is driven by the motivation to look into policy intentions of the countries; *de facto* measures are more susceptible to other macroeconomic effects than solely policy decisions with respect to capital controls.[6]

The Chinn–Ito index is normalized between zero and one. Higher values of this index indicate that a country is more open to cross-border capital transactions.

The dataset covers 184 countries for the period 1970–2010. The data set we examine does not include the USA, since we believe the USA is the "*N*th country" which is not subject to the constraints of the trilemma.

### *Tracking the Indexes*

*Variations across country groupings* Comparing these indexes provides some interesting insights into how the international financial architecture has evolved over time. However, just looking at the evolution of open macro policies through the lens of the three trilemma policies may not be sufficient; it is increasingly important to shed light on the role of international reserve (IR) holding.

Since the early 2000s, while a growing number of developing countries have opted for greater flexibility in exchange rate, IR/GDP (gross domestic product) ratios increased dramatically, especially in the wake of the East Asian crises, and most evidently among emerging market countries (see Figure 1). Between 1990 and 2011, global reserves increased from about US$1 trillion to more than US$10 trillion. While the IR/GDP ratio of industrial countries has been relatively stable at approximately 6–8%, the IR/GDP ratio of developing countries increased from about 10% to about 25%. Today, about three quarters of the global IR are held by developing countries, geographically concentrating in Asia, where reserves increased from about 10% in 1980 to about 34% in 2010 (or 33% even after excluding China). The most dramatic changes occurred in China, increasing its IR/GDP ratio from about 1% in 1980, to about 48% in 2010.

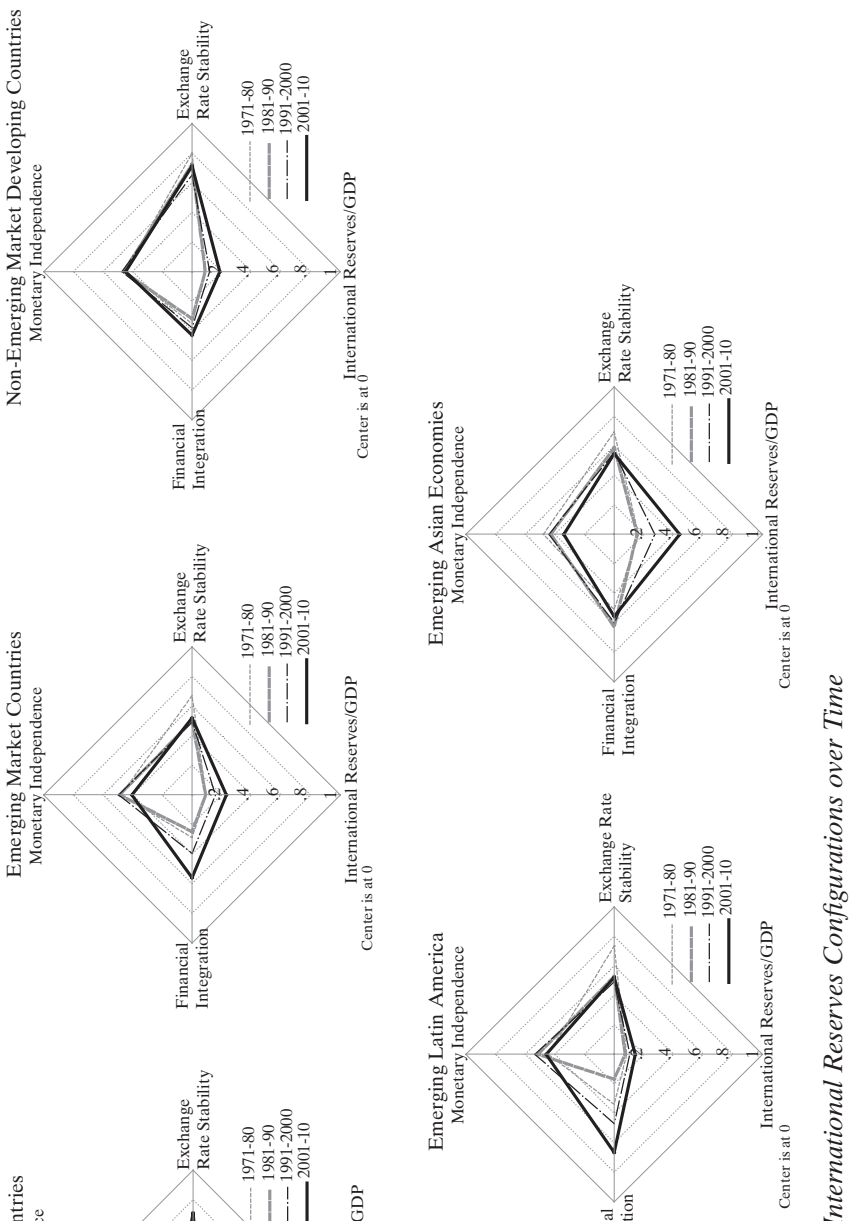


*Figure 1. The Trilemma and International Reserves Configurations over Time*

Many researchers have pointed out the increasing importance of financial integration as a determinant for IR hoarding (Aizenman and Lee, 2007; Cheung and Ito, 2009; Delatte and Fouquau, 2012; Obstfeld et al., 2008), suggesting a link between the changing configurations of the trilemma and the level of international reserves.

In fact, holding an adequate amount of IR may indeed allow an economy to achieve a certain target combination of the three trilemma policies. For example, a country pursuing a stable exchange rate and monetary autonomy may try to liberalize cross-border financial transactions while determined not to give up the current levels of exchange rate stability and monetary autonomy. In such a case, the monetary authorities may try to hold a sizeable amount of IR so that they can stabilize the exchange rate movement while retaining monetary autonomy. Or, an economy with open financial markets and fixed exchange rate could independently relax monetary policy, though temporarily, as long as it holds a massive amount of IR.

The "diamond charts" suffice this purpose and intuitively summarize the development of trilemma policy combinations while incorporating IR holding. Figure 1 illustrates the trends for different income-based or geographical groups of countries.[7] Each country's configuration at a given instant is summarized by a "generalized diamond," whose four vertices measure monetary independence, exchange rate stability, IR/GDP ratio, and financial integration. The origin has been normalized so as to represent zero monetary independence, pure float, zero international reserves, and financial autarky.

Based on the figures, industrialized countries and emerging market countries have moved towards deeper financial integration while non-emerging market developing countries have only inched toward financial integration.[8] While pursuing greater financial openness, industrialized countries have lost monetary independence, as have emerging market countries but to a much smaller extent. Emerging market countries, after giving up some exchange rate stability during the 1970s, have not changed their stance on the exchange rate stability at an intermediate level whereas non-emerging market developing countries seem to be remaining at, or slightly oscillating around, a relatively high level of exchange rate stability. Interestingly, emerging market countries stand out from other groups by achieving a relatively balanced, mid-level combination of the three macroeconomic goals along with a substantially increased amount of IR holding by the 2000s.

Emerging market countries in Latin America (LATAM) and Asia have moved somewhat toward exchange rate flexibility in the 1970s, a contrast from the group of non-emerging market developing countries. LATAM countries have rapidly increased financial openness although Asian emerging market economies have retained a stable level of financial openness through the sample period. One distinctive characteristic of the group of Asian emerging market economies is that it holds much more international reserves than any other group while having achieved a balanced combination of the three policy goals.[9]

These changes in the policy configurations can be abrupt and radical, caused by major economic events such as currency crisis and changes in the international monetary system. We statistically test whether significant economic events such as the collapse of the Bretton Woods system, the debt crisis of 1982, and the Asian crisis of 1997–98 are associated with structural changes in the three indexes. We find that for both industrialized and developing countries, major international economic events have impacted the policy arrangements significantly. The statistical results and discussions are omitted to conserve space, but they can be found in the working paper version of this paper (Aizenman et al., 2012).

## 3. Verifying the Empirical Validity of the Trilemma

*Linearity among the Trilemma Indexes*

While the preceding analyses are quite informative on the evolution of international macroeconomic policy orientation, we have not shown whether these three macroeconomic policy goals are "binding" in the context of the impossible trinity. That is, it is important for us to confirm that countries have faced the tradeoffs based on the trilemma. A challenge facing a full test of the trilemma tradeoff is that the trilemma framework does not impose any obvious functional form on the nature of the tradeoffs between the three trilemma variables.

Despite the lack of any specific functional form to express the relationships between the three policy goals, we can conceptualize the linear hypothesis of the trilemma by placing a simplex on a plane in a third-dimensional domain constructed by the three indexes (as the axes). A combination of the three policy goals may be expressed as a point within or on (one of the three vertexes or sides of) the simplex whose coordinates are determined by the three indexes.

That means a trilemma linear version implies that the weighted sum of the three trilemma policy variables adds up to a constant. In which case, a rise in one of the three trilemma variables leads to a drop in the weighted sum of the other two—corresponding to a move from one point to another within or on the generalized triangle. Hence, we can test the validity of the trilemma hypothesis using a simple linear functional form such as equation (1):

$$1 = a_j MI_{i,t} + b_j ERS_{i,t} + c_j KAOPEN_{i,t} + \varepsilon_t \tag{1}$$

where $j$ can be either IDC, ERM, or LDC, each representing the subsamples of industrialized countries, European Exchange Rate Mechanism, and developing countries.

Because we have shown that different subsample groups of countries have experienced different development paths, we allow the coefficients on all the variables to vary across different groups of countries—industrialized countries, the countries that have been in the European Exchange Rate Mechanism (ERM), and developing countries—allowing for interactions between the explanatory variables and the dummies for these subsamples.[10] The regression is run for the full sample period as well as the subsample periods partitioned by major economic events.

The rationale behind this exercise is that policy makers of an economy must choose a weighted average of the three policies in order to achieve a best combination of the two. Hence, if we can find the goodness of fit for the above regression model is high, it would suggest a linear specification is rich enough to explain the tradeoff among the three policy dimensions. In other words, the lower the goodness of fit, the weaker the support for the existence of the tradeoff, suggesting either that the theory of the trilemma is wrong, or that the relationship is nonlinear.

Second, the estimated coefficients in the above regression model should give us some approximate estimates of the weights countries put on the three policy goals. However, the estimated coefficients alone will not provide sufficient information about "how much of" the policy choice countries have actually implemented. Hence, looking into the predictions using the estimated coefficients and the actual values for the variables (such as $\hat{a}MI$, $\hat{b}ERS$, and $\hat{c}KAOPEN$) will be more informative.

Third, by comparing the predicted values based on the above regression, i.e. $\hat{a}MI + \hat{b}ERS + \hat{c}KAOPEN$, over a time horizon, we can get some inferences about how "binding" the trilemma is. If the trilemma is found to be linear, the predicted values

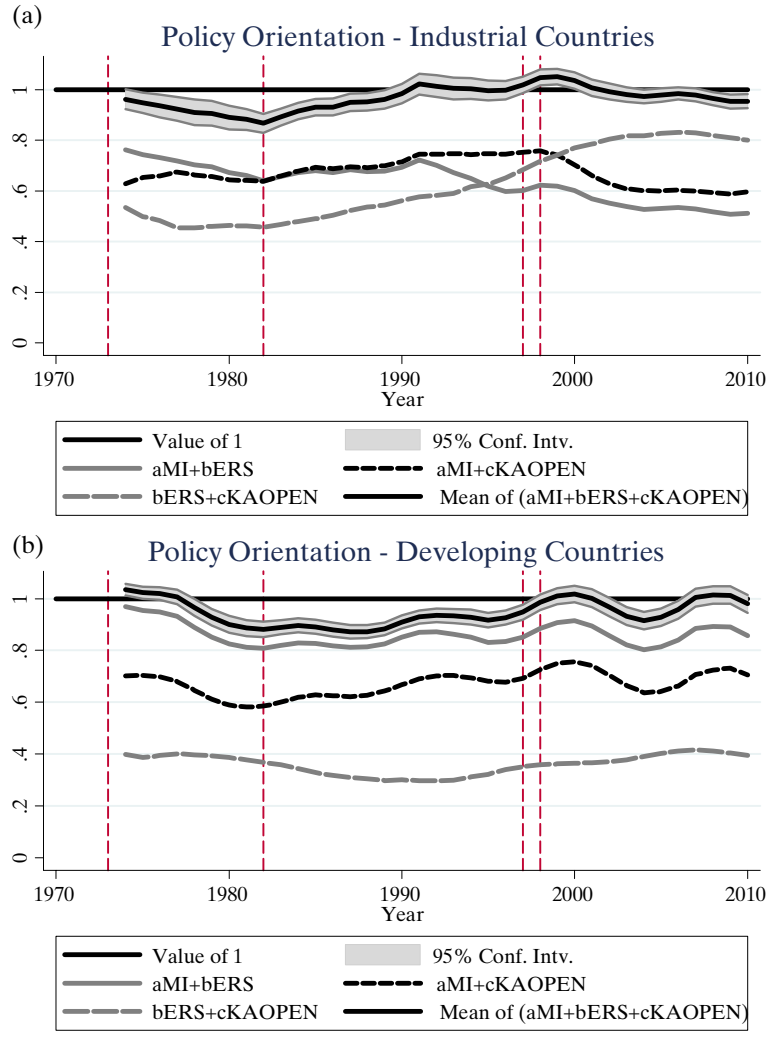


*Figure 2. Policy Orientation of Industrial and Developing Countries (a) Industrial Countries (b) Developing Countries*

*Notes*: The vertical lines correspond to the candidate break years.
The shaded areas indicate the 95% confidence interval for aMI + bERS + cKAOPEN.

should hover around the value of 1, and the prediction errors should indicate how much of the three policy choices have been "not fully used" or to what extent the trilemma is "not binding."[11]

The results from the estimation based on equation (1) yield the adjusted $R^2$ for the full sample model to be above 95%, which indicates that the three policy goals are linearly related to each other and add up to a constant.[12] Hence, we have evidence that countries face the tradeoff among the three policy options.

Figure 2 illustrates the goodness of fit from a different angle. In the panels of figures, the solid lines show the means of the predicted values (i.e. $\hat{a}MI + \hat{b}ERS + \hat{c}KAOPEN$) based on the regression result for the groups of industrial countries (top) and developing countries (bottom). To incorporate the time variation

of the predictions, the subsample mean of the prediction values as well as their 95% confidence intervals (that are shown as the shaded areas) are calculated using five-year rolling windows. The panels also display the rolling means of the predictions using the coefficients and actual values of only two of the three trilemma terms—$\hat{a}MI + \hat{b}ERS$, $\hat{a}MI + \hat{c}KAOPEN$, $\hat{b}ERS + \hat{c}KAOPEN$ so as to show the changing ranking of policy combinations (of the two out of the three trilemma policy goals) overtime.

From these figures, we can first see that the predicted values based on the model hover around the value of one closely for both subsamples. For the group of industrial countries, the prediction average is statistically below the value of one in the late 1970s through the beginning of the 1990s. However, since then, one cannot reject the null hypothesis that the mean of the prediction values is one, indicating that the trilemma is "binding" for industrialized countries. For developing countries, the model is under-predicting from the end of the 1970s through the late 1990s. However, unlike the IDC group, the mean of the predictions becomes statistically smaller than one in the early 2000s and goes back to around the value of one in the last few years of the sample period. More importantly, for both subsamples, the mean of the predictions never rises above the value of one in statistical sense, implying not only that the three macroeconomic policies are linearly related with each other, but also that countries have never implemented an infeasible combination of policies.

### *Development of Policy Preferences*

The figures also show that, among industrialized countries, the policy combination of increasing exchange rate stability and more financial openness rapidly became prevalent after the beginning of the 2000s. Among developing countries, the policy combinations of monetary independence and exchange rate stability has been quite dominant throughout the sample period while the policy combination of exchange rate stability and financial openness has been the least prevalent over, most probably reflecting the bitter experiences of currency crises.

### *Robustness Checks*

*Different estimation specifications* One may question the uniqueness of this regression exercise since our estimation model has an identity scalar as the dependent variable. As a robustness check, we ran a regression of $MI_{i,t}$ on $ERS_{i,t}$ and $KAOPEN_{i,t}$. Using the estimated coefficients for *ERS* and *KAOPEN*, we recover the estimates for $a_j$, $b_j$, and $c_j$ in equation (1), and recreate the panels of figures shown in Figure 2. These alternative figures appear to be very much comparable with Figure 2 (not reported) and therefore confirm our conclusions about the linearity of the trilemma indexes as well as the development of the subsample mean of prediction values based on equation (1).

Showing the linearity of the three trilemma indexes using a pooled panel estimation method may be misleading. A rise in one index for one country can involve a fall in the weighted sum of the other two for *another* country, which can still be captured as a linear relationship among the three indexes in a panel context. Hence, we test the linearity of the three indexes for each of our sample countries. The results confirm our prior findings. Among the countries tested, the smallest adjusted $R^2$ is 89%, followed by the second smallest adjusted $R^2$ of 92%. The mean adjusted $R^2$ is 97%, and more than 90% of the sample countries have the adjusted $R^2$ over 95%. These findings reconfirm the linearity of the three indexes.

Although all three indexes range between zero and one, these indexes may not be stationary, in which case estimation results could be spurious. However, even if the indexes are nonstationary, if one could show that they are cointegrated, the linearity of the indexes still holds. Hence, we conduct cointegration tests for each of the sample countries to show the linearity of the three indexes. Following Johansen's (1991) method, we conduct multiple trace tests to find the rank of the cointegration relationship, i.e. the number of cointegration equations, among *MI*, *ERS*, and *KAOPEN* in a vector error correction (VECM) specification.[13] Here, the rank of three would mean that all three indexes for that particular country are stationary. The rank of either one or two would mean the indexes are linearly related while the rank of zero means there is no linear relationship among the three indexes.

When we apply this cointegration test to each of the sample countries in the balanced dataset, 13 out of 60 countries (or 22%) are found to have the rank of three, meaning that all the indexes are stationary for these countries, for which the previous simple linear analysis is sufficient. Twenty-nine countries, or 48%, of the sample are found to have either one linear relationship (23 countries) or two linear relationships (six countries).[14] For 18 countries, or 30% of the sample, the three indexes are not cointegrated. If we use information criteria to determine the number of cointegration equations, the proportion of no cointegration drops. When the Schwarz Bayesian information criterion is used, 45 countries out of 60 yield one or two cointegration ranks (i.e. 25% of the sample countries have no cointegration), whereas the Hannan and Quinn information criterion yields eight countries (13%) having no cointegration relationship.

*Revisit of the role of international reserves holding* Given the rapid increase in the importance of IR holding in the financial globalized world, we may need to think about the relationship among the three trilemma policy goals in terms of not just the trilemma, but the quadrilemma (Aizenman, 2011).[15]

That said, we re-estimate the modified version of equation (1) that includes a variable for IR holding (as a share of GDP) along with its interactions with the LDC and ERM dummies (results not reported). Several findings must be noted. First, including the variable for IR holding barely improves the goodness of fit of the estimations, only by one or two percentage points. Second, the coefficient on the IR holding variable is significant for the subsample periods that start in 1983 or later, suggesting that the role of IR holding is important in the context of the trilemma, but after the 1980s. Third, the role of IR holding in the trilemma seems to be more limited among developing countries—when the LDC subgroup has a significantly different coefficient on IR holding than industrialized countries, the magnitude of the coefficient is usually smaller than that of industrialized countries.

These findings indicate that the linearity does exist primarily for the original three policy variables under the trilemma, i.e. monetary independence, exchange rate stability, and financial openness. Despite the increasing importance of IR holding, the role of IR holding in the linear relationship among the trilemma policy goals is limited. It may be possible that the role of IR holding in the context of the trilemma is increasing since the beginning of the 2000s of financial globalization, but scrutinizing the changing role of IR holding is outside the scope of this paper.

## 4. Concluding Remarks

In this paper, we have described a methodology to trace the changing patterns in the configurations of the trilemma that have taken shape. Our methodology reveals the

striking differences in the choices that industrialized and developing countries have made over the 1970–2010 period. The trend suggests that among emerging market countries, the three dimensions of the trilemma configurations: monetary independence, exchange rate stability, and financial openness, are converging towards a "middle ground" with managed exchange rate flexibility, which they attempted to buffer by holding sizable international reserves, while maintaining medium levels of monetary independence and financial integration. In contrast, industrialized countries have been experiencing divergence of the three dimensions of the trilemma and moved toward the configuration of high exchange rate stability and financial openness and low monetary independence as most distinctively exemplified by the euro countries' experience.

We also tested the linearity of the three macroeconomic policy goals to examine whether countries do face the tradeoffs based on the trilemma. Our results confirmed that countries do face the binding trilemma. That is, a change in one of the trilemma variables would induce a change with the opposite sign in the weighted average of the other two. In that sense, we have provided substantial empirical contextto the hypothesis of the "impossible trinity."

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## Notes

1. See Obstfeld et al. (2005) for further discussion and references dealing with the trilemma.
2. The data are extracted from the IMF's *International Financial Statistics*, supplemented by the Bloomberg database.
3. The index is smoothed out by applying the three-year moving averages encompassing the preceding, concurrent, and following years $(t-1, t, t+1)$ of observations. For some countries and some years, especially early in the sample, the interest rate used for the calculation of the index is constant throughout a year, thereby making corr$(i_i, i_j)$ undefined. In such a case, we assign the value of 0.5 to the index. Constant policy interest rates could represent a high degree of monetary independence while they could also reflect the possibility that the home country uses other noninterest rate policy tools to implement monetary policy (e.g. manipulation of required reserve ratios and providing window guidance; or financial repression) which may or may not reflect the home country's monetary independence. Given that it is impossible to fully account for these issues in the calculation of MI, assigning an MI value of 0.5 for such a case appears to be a reasonable compromise.
4. The choice of the ±0.33% bands is based on the ±2% band based on the annual rate, that is often used in the literature. Also, to prevent breaks in the peg status owing to one-time realignments, any exchange rate that had a percentage change of zero in 11 out of 12 months is considered fixed. When there are two re/devaluations in 3 months, then they are considered to be one re/devaluation event, and if the remaining 10 months experience no exchange rate movement, then that year is considered to be the year of fixed exchange rate. This way of defining the threshold for the exchange rate is in line with the one adopted by Shambaugh (2004).
5. See Chinn and Ito (2008), Kose et al. (2006), and references for discussions and comparisons of various measures on capital restrictions.
6. *De jure* measures of financial openness also face their own limitations. The private sector often circumvents capital account restrictions, nullifying the expected effect of regulatory capital controls (Edwards 1999). Also, IMF-based variables are too aggregated to capture the subtleties of actual capital controls, that is, the direction of capital flows (i.e. inflows or outflows) as well as the type of financial transactions targeted.
7. The emerging market countries (EMG) are defined as the countries classified as either emerging or frontier during the period of 1980–1997 by the International Finance Corporation, plus Hong Kong and Singapore.
8. The diamond chart for the group of industrialized countries excluding the Euro member countries appears similar to the one for the group of industrialized countries shown in Figure 1, except for their lower levels of exchange rate stability and slightly higher levels of monetary independence (not shown, but available in Aizenman et al. (2012)).
9. Further observations and analysis on the indexes can be found in the working paper version of this paper (Aizenman et al., 2012).
10. The dummy for ERM countries is assigned for the countries and years that correspond to participation in the ERM (i.e. Belgium, Germany, France, Ireland, Italy, and Luxembourg from 1979 on; Spain from 1989; UK only for 1990–91; Portugal from 1992; Austria from 1995; Finland from 1996; and Denmark and Greece from 1999) or ERM II (Estonia, Lithuania, and Slovenia from 2004; and Cyprus, Latvia, Malta, and Slovak Republic from 2005).
11. If the trilemma is not binding, i.e. the predicted value based on equation (1) is below the value of one, such a policy combination can be shown as a point within the space between the

origin and the triangle plain in the three dimensional domain. A policy combination that yields the prediction above the value of 1 would be located somewhere "outside" the triangle (from the origin), so that it would be an "infeasible" policy combination.

12. When the estimation is conducted for the subsample periods, the goodness of fit is found to be high as well. Refer to the working paper version of this article for the table with complete regression results.

13. Since our primary focus is not an intensive time series analysis, we systematically implement this analysis for each of our sample countries while assuming the lag length to be 2.

14. Given the nature of the indexes, it is possible that one or some of the three indexes do not change values at all for some time period, which creates the issue of (perfect) multicollearity among the indexes and which therefore makes it impossible for the cointegration test to be executed using all the three indexes. In such a case, we would remove the variable that is apparently causing the multicollearity and apply the cointegration test to the remaining two variables. Or, we would apply the cointegration test (while using all three indexes) only to the period when there appears to be no multicollearity if multicollearity is an issue in a short period.

15. Aizenman et al. (2010) empirically show that pursuing greater exchange stability can be increasing output volatility for developing economies, but that that can be mitigated by holding a greater amount of IR than the threshold of about 20% of GDP. Aizenman et al. (2011) find that Asian emerging market economies seem to have adopted a policy combination of the three trilemma policies and IR that allow these economies to lessen output volatility through reduced real exchange volatility. Aizenman and Ito (2012) show that high levels of IR holding may allow countries to choose a policy combination from a wider range of spectrum of policy combinations without affecting the levels of output volatility. On the issue of foreign exchange interventions in the context of the trilemma, refer to Aizenman and Glick (2009).