FOREIGN EXCHANGE RESERVE DEMAND: AN INFORMATION VALUE APPROACH

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ABSTRACT We perform a statistical analysis to examine the international reserve accumulation of four selected emerging market countries: Argentina, Brazil, Korea and Turkey. We perform Granger causality tests to investigate the information value of key macroeconomic variables on foreign exchange reserves. We use a simple unrestricted vector autoregression analysis to capture a reduced form analysis of the demand for international reserves. Our results suggest that interest rate differentials with the US contain potentially useful information for foreign exchange reserve accumulation for Argentina and Turkey. Similarly, consumption differential with the US and net exports contain information for foreign exchange reserve movements in Korea.
JEL F32
Keywords Foreign exchange reserves, Vector Autoregression

öz Çalışmada Arjantin, Brezilya, Kore ve Türkiye gibi dört yükselen ekonominin uluslararası rezerv biriktirme davranışları istatiksel bir analiz çerçevesinde incelenmektedir. Seçilmiş makroekonomik değişkenlerin uluslararası rezervleri açıklama gücü Granger nedensellik testleri ile sınanmaktadır. Kısıtlanmamış vektör özgecikme analizi yardımıyla ulusrararası rezerv talebinin indirgenmiş form analizine bakılmaktadır. Bulgularımız, rezerv artışlarının Arjantin ve Türkiye'de ülke faizlerinin ABD faizleri ile olan farkı ile; Kore de ise ülke tüketiminin ABD tüketimi ile farkı ve net ihracat değişkenleri ile ilişkili olduğunu göstermektedir.
JEL F32
Anahtar Kelimeler Uluslararası rezervler, Vektör Özgecikme Analizi

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1. Introduction

This study presents a statistical analysis that examines the foreign exchange reserve demand of four selected emerging market countries: Argentina, Brazil, Korea and Turkey. We perform Granger causality tests to explore the information value of key macroeconomic variables on foreign exchange reserves, employing a simple unrestricted vector autoregression framework. Our findings indicate that interest rate differentials with the US contain potentially useful information for foreign exchange reserve accumulation for Argentina and Turkey. This suggests portfolio adjustments as a main motivation behind foreign exchange reserve movements, in addition to the precautionary saving one. Similarly, consumption differential with the US and net exports contain information for foreign exchange reserve movements in Korea indicating the relative dominance of prudential motives for reserve management practices of the central bank.

The following two decades after the collapse of Bretton Woods display a shift towards more flexible exchange rate regimes which is accompanied by acceleration in capital account liberalization efforts in many emerging market economies. In theory, absence of a fixed exchange rate eliminates the demand for foreign exchange reserves since the exchange rate adjusts to clear the market and handle necessary balance of payment adjustments. However, the level of reserves has increased substantially in many emerging market countries along with increased flexibility in exchange rate regimes after 1980s.

Capital account liberalization has complicated effects on foreign exchange reserve accumulation in emerging market countries. On the one hand, increased capital inflows resulted in a surge in foreign exchange reserve levels of these countries.[1] On the other hand, volatile and short-term nature of these flows destabilized exchange rate markets, where foreign exchange reserve accumulation was accompanied by current account deficits. These imbalances caused emerging market economies to be more prone to currency crises and sudden reversals of capital. The epidemic financial crises of 1990s interrupted the accumulation of reserves sharply in many emerging market economies. These experiences provoke the self-insurance

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[1] Durdu et al. (2008) suggest that financial globalization is one of the determinants of the surge in foreign exchange reserve demand of countries that experienced sudden stops in last two decades.

motive which resulted in a substantial increase in reserves in the aftermath of the crises. Central banks mounted up reserves as precautionary savings to cushion the blow in case of a sudden-stop.[2]

A part of the literature employs buffer stock models to examine the foreign exchange reserve demand in this era.[3] However, the stochastic nature of these models combined with complicated explanations of crises carries the reserve issue to a more complicated framework than assessing an optimal level of reserves. In a world where crises are more associated with expectations of agents rather than a mechanical balance of payments adjustment, the role assigned to international reserves and their optimal level remains vague. The absence of any convincing theoretical argument for an optimal level urged central banks to adopt some ad-hoc rules where a sufficient level of reserves is depicted as a key to self-insurance in a world of rapid reversals of capital flows. Reserves scaled with short-term or gross level of debt is the novel benchmark of this prudential framework. A popular one is the Greenspan-Guidotti rule which suggests reserves be equal to the short-term debt of a country.[4] However, reserve accumulation is a costly policy. Rodrik (2006) calculates the cost of this kind of an ad-hoc reserve accumulation as 1 percent of the GDP and recommends more emphasis on debt reducing policies for these countries.

An alternative critical explanation for the acceleration in international reserve accumulation in recent years is based on the f*ear of floating* argument provided by Calvo and Reinhart (2002). They argue that, while many emerging market economies have officially adopted floating exchange rate regimes after the financial crises of late 1990s, they hold a certain amount of reserves to conduct discretionary interventions to the foreign exchange market. If these interventions are undertaken to gain comparative advantage by depreciation of domestic currency, central bank might end up with an excess accumulation of foreign exchange reserves. Dooley et al (2004) argue that this mercantalist view provides an explanation to high foreign exchange reserve holdings of China that pursues an an export-led growth strategy. Aizenman and Lee (2007) conduct an empirical study and suggest that the mercantalist motive accounts for a limited part of the foreign exchange reserve pile up of emerging market countries, while precautionary motive is still the prevailing factor.

Another appealing basis for reserve management practices after 1990s is the portfolio approach to balance of payments and exchange rate, which

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[2] See Feldstein (1999), Aizenmann and Marion (2005).
[3] See Frenkel and Jovanovic (1981) and Flood and Marion (2002).
[4] See Guidotti (1999), Greenspan (1999). Recently, Jeanne and Ranciere (2006) develop a model that suggests an optimal level close to the one provided by this *ad hoc* rule.

takes account of other financial assets besides money. According to this view, demand for domestic and foreign assets is determined by portfolio adjustments of profit maximizing investors. Similarly, central bank reserves are part of the asset portfolio of a country. Therefore, the evolution of reserve management was clearly changing from a " residual item" perspective of 1970's towards a " portfolio and risk management" framework of date. Prudential policies go hand in hand with cost-effective management of reserves. Value-at-risk models and stress tests are widely applied by many central bankers today in addition to simple benchmark rules.[5]

Next section presents our data and some stylized facts. Third section displays the model and results of the corresponding Granger causality analysis. The fourth and the last section concludes.

2. Data and Stylized Facts

We examine movements of foreign exchange reserves and its correlations with other main economic variables, namely, GDP, consumption, exports, imports, interest rates and inflation, for the emerging market countries in our sample. The quarterly data used in the study is taken from the IMF / IFS database. For Turkish data, we use the recently revised data provided by the Turkish Statistical Institute.[6] The series are in log difference form.

The common characteristics of all these countries is that they suffered major financial crises in the last two decade: Argentina (2001), Brazil (1999), Turkey (1994 and 2001) and Korea (1997). Thus, we perform Chow structural break test to detect if there are structural changes in policies of these countries in their post-crisis periods. Accordingly we have divided series of Argentina, Brazil, Turkey and Korea in sub-periods as before and after the crisis.

Table 1 suggests that reserve accumulation processes of these countries since 1960 are not correlated. Figure 1 suggests that reserve accumulation is low in all countries until 1990s. All countries except Korea have periods of instability and external debt problems at the end of 1970s, and adopt stabilization and structural adjustment programs in 1980s. Moreover, increasing financial liberalization is another common policy of all these countries during 1980s. The next decade, 1990s, displays further financial liberalization in the first half, followed by sudden stop crises in the second half. Accordingly, reserve accumulation is slightly stronger in the first half of 1990s, compared to 1980s, but this surge is interrupted with financial
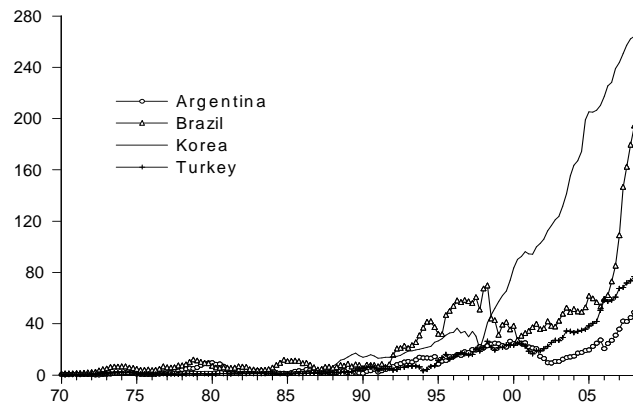
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[5] See Nugee (2000) and Putnam (2004).
[6] Data for the national accounts go back to 1960 for Korea, 1987 for Turkey, 1991 for Brazil, and 1993 for Argentina Reserve data go back further past where available.

crises. We can see a significant acceleration in reserve levels of all countries after 2000.

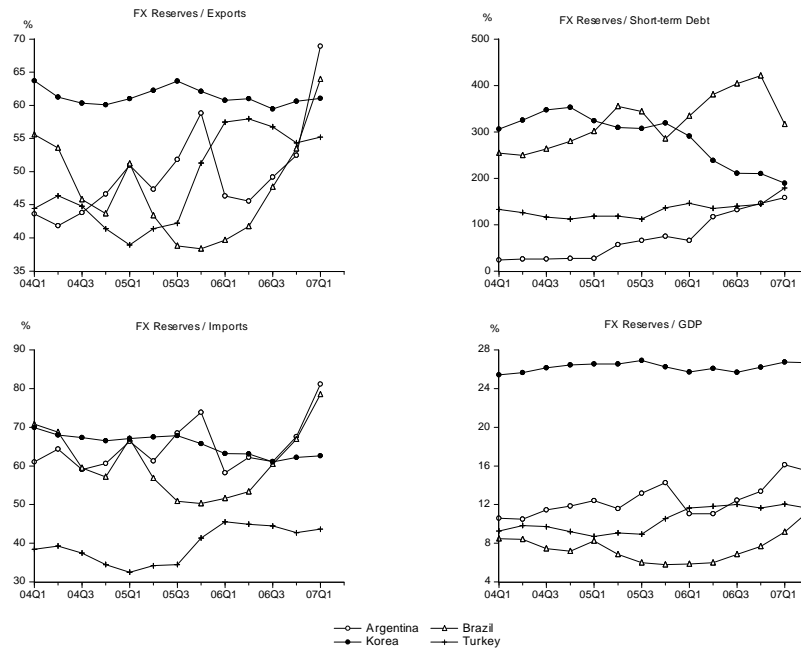**Table 1. Correlations between FX Reserves of Selected Countries (1960-2007, log difference)**

	Argentina	Brazil	Korea	Turkey
Argentina	1,00	0,05	0,04	0,07
Brazil	0,05	1,00	0,08	0,08
Korea	0,04	0,08	1,00	0,10
Turkey	0,07	0,08	0,10	1,00

Figure 1. Foreign Exchange Reserves (Billions of US dollars)

The reserves ratios to other variables after 1996 are depicted in Figure 2. Reserves to GDP ratio is very high in Korea compared to other countries. Korea's reserves are as large as a quarter of its GDP. Turkey has relatively higher reserves to GDP ratio compared with Argentina and Brazil, but lower reserves to imports ratio which is consistent with the fact that Turkey is the only country with a high current account deficit in the group.

Table 2 presents a comparison of standard deviations of the foreign exchange reserves and main variables in pre-crisis and post-crisis periods for countries in our sample. Reserve volatility persists at Argentina and Brazil after the crises, while it is relatively lower compared to the volatility of other variables in the former one. In Korea, post crisis period reveals higher volatility of all other variables except reserves. Turkish data suggest that all variables including reserves are lower relative to pre-crisis period.

Figure 2. FX Reserves Ratios

Table 2. Standard Deviations of FX Reserves and Main Variables (log difference)

	GDP	Con	Exp	Imp	Reserves	r	Inf
Argentina: pre-crisis (93q1-01q3)	0,06	0,04	0,11	0,07	0,14	0,23	1,17
Argentina: post-crisis (01q4-07q1)	0,28	0,27	0,18	0,22	0,13	0,51	0,67
Brazil: pre-crisis (91q3-98q4)	0,22	0,20	0,19	0,13	0,20	1,01	0,46
Brazil: post-crisis (99q1-07q1)	0,11	0,12	0,12	0,12	0,13	0,13	0,23
Korea: pre-crisis (60q1-97q3)	0,09	0,08	0,09	0,09	0,15	0,10	0,35
Korea: post-crisis (97q4-07q1)	0,12	0,12	0,12	0,12	0,11	0,22	0,61
Turkey: pre-1994 crisis (87q4-94q2)	0,16	0,17	0,17	0,18	0,19	0,28	0,14
Turkey: (middle period) (94q3-00q4)	0,06	0,06	0,08	0,07	0,17	0,33	0,11
Turkey: post-crisis (01q1-07q1)	0,06	0,06	0,05	0,05	0,06	0,22	0,18
Average of pre-crisis periods	0,13	0,12	0,14	0,12	0,17	0,41	0,53
Average of post-crisis periods	0,14	0,14	0,12	0,13	0,11	0,27	0,42

Table 3 reports correlations of reserves with other main variables in the economy. One-lag correlations of reserves with GDP, exports and imports are high in both pre-crisis and post-crisis periods in Argentina. In Korea, the correlation of reserves with GDP, consumption, exports and imports are

much higher in post-crisis period relative to pre-crisis period. Turkish reserves are moderately correlated with interest rates. This correlation is contemporaneous before 2001 crisis and with one lag after the crisis.

Table 3. Correlations of Reserves with Other Variables

	GDP	GDP-1	GDP-2	Con	Con-1	Con-2	Exp	Exp-1	Exp-2	Imp
Argentina (93q1-01q4)	0,46	0,75	0,74	0,51	0,81	0,78	0,09	0,72	0,74	0,16
Argentina(01q4-07q1)	0,35	0,82	0,56	0,39	0,77	0,47	0,08	0,92	0,90	0,27
Brazil (91q3-98q4)	-0,22	-0,24	-0,11	-0,22	-0,23	-0,10	-0,16	-0,27	-0,19	-0,10
Brazil (99q1-07q1)	0,24	0,06	-0,05	0,23	0,07	-0,05	0,15	0,11	-0,07	0,22
Korea (60q1-97q3)	0,11	0,04	-0,08	0,07	0,04	-0,09	0,13	0,07	-0,07	0,02
Korea (97q3-07q1)	0,78	-0,25	-0,34	0,75	-0,29	-0,35	0,85	-0,11	-0,25	0,78
Turkey (87q4-94q2)	0,02	-0,18	0,27	0,01	-0,17	0,28	0,00	-0,20	0,38	0,01
Turkey (94q3-00q4)	0,33	-0,47	-0,07	0,36	-0,45	-0,08	0,44	-0,22	0,10	0,30
Turkey (01q1-07q1)	0,50	0,05	-0,01	0,51	0,05	-0,03	0,43	0,04	-0,01	0,48
	Imp-1	**Imp-2**	**r**	**r-1**	**r-2**	**inf**	**inf-1**	**inf-2**	**Res-1**	**Res-2**
Argentina (93q1-01q4)	0,80	0,74	-0,30	-0,23	-0,14	-0,13	-0,07	0,22	0,89	0,86
Argentina(01q4-07q1)	0,96	0,90	-0,31	-0,27	-0,24	-0,38	-0,61	0,18	0,95	0,83
Brazil (91q3-98q4)	-0,15	-0,06	-0,01	0,45	0,35	0,24	0,15	0,05	0,07	-0,17
Brazil (99q1-07q1)	0,10	-0,06	-0,11	-0,17	0,14	-0,02	0,18	-0,14	-0,12	0,26
Korea (60q1-97q3)	0,02	-0,10	0,09	0,15	0,07	-0,07	-0,19	-0,20	0,31	0,04
Korea (97q3-07q1)	-0,22	-0,34	-0,26	0,15	0,09	-0,04	0,15	0,09	0,14	-0,36
Turkey (87q4-94q2)	-0,20	0,33	-0,51	0,13	0,13	-0,01	-0,08	-0,02	-0,04	-0,07
Turkey (94q3-00q4)	-0,37	-0,11	-0,52	0,11	0,10	0,18	0,37	0,29	0,09	-0,20
Turkey (01q1-07q1)	0,03	-0,03	-0,05	-0,63	-0,09	-0,07	0,38	0,20	0,35	-0,02

3. Model and Results

In this section, we present a reduced form analysis of demand for international reserves using an unrestricted vector-autoregression (VAR) model. We undertake an information-value approach that is first introduced by Sims (1972, 1980). Friedman and Kuttner (1992) applies this framework to explore whether movements in monetary aggregates do contain potentially useful information for movements in income, disregarding the problem of causality. Similarly, our interest lies in whether our selected variables contain potentially useful information for predicting movements in foreign exchange reserves rather than looking for a direction of causation.

Before explaining each of these variables in detail, we should emphasize that the source of an increase in foreign exchange reserves can be many different sub-items like demand for domestic currency from the central bank by banks (e.g. because of high export revenues), demand for domestic currency from treasury (e.g. because of a foreign currency denominated loan) as well as a central bank intervention to boost liquidity or to keep the currency depreciated. While some of these can be predicted in advance,

some of them are beyond the control of the central bank. Therefore, it is not easy to differentiate whether the central bank has a precautionary savings policy or reserves are the residual items of the balance of payments. To this end, rather than forming a structural model, we examine the relation between possible variables using an unrestricted VAR framework.

Our first variable, net exports, is included in the model to account for the balance of payment approach. This variable tests if the movement of the volume of international transactions helps predict movements in foreign exchange reserves. An increase in net exports might affect the level of reserves positively depending on liquidity preferences of exporters and commercial banks.[7]

The consumption differential with the US serves two purposes. In a standard money demand equation, income (real GDP) has a positive relationship with demand for liquidity for transaction motive. According to portfolio balance approach, an increase in income raises the transaction demand and, keeping wealth constant, an individual investor has to give up domestic or foreign bonds to acquire liquidity. Yet, in our case, central bank keeps reserves as liquid assets. Therefore, we can expect reserve level to go up as a result of rising transaction demand of public, denominated in foreign currency. Since we have net exports in our model, we exclude GDP to avoid multicollinearity and used consumption, which moves in tandem with GDP. We take the difference with the US consumption because most reserves are held in US dollars.[8]

One can also argue that if the central bank has a precautionary policy, then foreign exchange reserves might go up to a point reinforcing the transaction demand. The increase can be " up to a point" because a very high GDP (or consumption) level might mean that the country is less subject to sudden capital reversals and therefore needs less precautionary savings for self-insurance.

Inflation and interest rate differentials have a complicated effect including the transaction, precautionary demands and quasi-fiscal costs. If US dollars were the only reserve currency available, then an increase in the US inflation

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[7] Yet, as discussed above, it is hard to find a one to one relationship between reserve increase and net exports. The relationship depends on a three-stage decision process. First, the exporter might prefer to keep the foreign exchange earnings abroad. If he decides to bring it to the country, then he might still keep it in a safe rather then depositing to a bank. This causes an increase in the Net Errors and Omissions account in balance of payments (An interesting fact is that the Net Errors and Omissions item is very big in many emerging market countries. This is also an indication of high foreign exchange holdings of the individuals in hard currency terms). Provided that the exporter deposits it to a bank, the bank might keep it as its own reserves (then reserves of the banking system goes up) or bring it to the central bank to exchange with domestic currency (reserves of the central bank goes up).

[8] According to the International Monetary Fund (2008) COFER database, 64 percent of the world's foreign exchange reserves are held in US dollars.

would result in a higher reserve demand provided that the domestic country would like to keep a certain level of reserves (either for intervention or precautionary purposes). On the other hand, in a portfolio management framework since alternative reserve currencies are available, there can be a shift from US dollars to another currencies. Similarly, a high domestic inflation would cause a shift to foreign assets.

Interest rate differentials capture two counteracting elements in the reserve demand equation. First, similar to a simple money demand equation, those represent the opportunity cost of holding reserves. The difference between holding non-liquid and liquid assets serves as a liquidity premium. An increase in the interest rate differential raises the opportunity cost of holding reserves, therefore we expect the level of reserves to go down. On the other hand, an opposing factor stems from the credibility-enhancing role assigned to reserves. A popular conjecture nowadays is that higher reserves might lower the risk premium as a result of increasing credibility. As the argument goes, the borrowing rate includes the risk premium paid by the country. If interest rates increase due to higher risk premium, the country may attempt to restore credibility by an increase in reserves.[9] This depends on the elasticity of risk premium to the credibility ensured by higher precautionary savings.

We specify the VAR model as:

$$\Delta X_{i,t} = \gamma + a_1 \Delta X_{i,t-1} + a_2 \Delta X_{i,t-2} + ... + a_p \Delta X_{i,t-p} + \varepsilon_t \qquad (1)$$

where, γ is a constant, Δ denotes difference, $i = 1, 2, ..., 4$ denote four countries in our sample, t denotes time and ε_t is a white noise error term and:

$$X_{i,t} = [res_{i,t} \quad nx_{i,t} \quad condif_{i,t} \quad rdif_{i,t} \quad \pi dif_{i,t}]' \qquad (2)$$

where *res* denotes foreign exchange reserves, *nx* denotes real net exports, *condif* denotes real consumption differential with the US, *rdif* denotes interest rate differential with the US, and *πdif* denotes inflation differential with the US where:[10,11]

$$condif_{i,t} = con_{i,t} - con_{us,t} \qquad (3)$$

$$rdif_{i,t} = r_{i,t} - r_{us,t} \qquad (4)$$

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[9] Levy-Yeyati (2008) provides an empirical study and suggests that one percent increase in international reserves helps to reduce the borrowing spread of an emerging market country around 0.5 percent.
[10] Net real exports and consumption are deflated by the US GDP deflator.
[11] We use Akaike Information Criteria and Schwartz Information Criteria to determine the appropriate lag length p.

$$\pi dif_{i,t} = \pi_{i,t} - \pi_{us,t} \qquad\qquad (5)$$

where consumption is denoted with con, interest rate with r and inflation with π.

We apply Perron (1989) unit root test to allow for structural breaks in series due to financial crises experienced by the countries in our sample. In almost all of the series the null hypothesis of unit root cannot be rejected. Hence, we concluded that series are integrated of order one.[12]

The Granger causality test applies the standard F-test with the null hypothesis that coefficients of the independent variable and its lags are jointly zero:

$$H_0 : a_1 = a_2 = ... = a_p = 0 \qquad\qquad (6)$$

Table 4 reports the p-values of the test.[13] The relationship between reserves and interest rate differential is significant at 5 percent for Turkey and Argentina. The relationship between reserves and consumption is significant at 1 percent for Korea. The relationship between reserves and net exports is also significant at 10 percent for Korea. The results suggest no significant relationship between reserves and key macroeconomic variables in Brazil.

Table 4. VAR Coefficient Tests

	Argentina	Brazil	Korea	Turkey
Reserves	0,63	0,69	0,04	0,82
Net exports	0,65	0,97	0,06	0,82
condif	0,25	0,80	0,00	0,11
rdif	0,03	0,99	0,52	0,02
infdif	0,63	0,99	0,30	0,84

p-values for Wald test (null hypothesis is "the coefficients of the independent variable and its lags are jointly zero")
Dependent Variable: FX Reserves (Two lags for Argentina and four lags for the rest)

Our results first suggest that interest rate differentials with the US contain potentially useful information for foreign exchange reserve accumulation in Argentina and Turkey. In the model section we explained that the relationship between foreign exchange reserves and interest rate differentials with US depend on two offsetting affects. On the one hand, a higher interest rate differential with US means a higher opportunity cost of holding reserves which has a negative effect on reserve demand. On the other hand, a country which is subject to a higher borrowing rate due to higher risk premium might accumulate more reserves to restore credibility in the eyes of foreign investors. Therefore, while the former effect suggests a hint of a dominance

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[12] We performed vector autoregression analysis with dummy variables to take into account the crises, instead of a sub-sample analysis due to low number of observations.
[13] White heteroskedasticity test results do not reject the null assumption of homoscedasticity for any country specification.

of the portfolio balance approach on reserve management practices of Argentina and Turkey, a more robust inference requires an estimation of elasticity of the risk premium to the credibility provided by higher reserves for these countries.

The second result emerging from Table 4 is that net exports and the consumption differential with the US contain useful information in explaining foreign exchange reserve movements in Korea. The finding that net export contains information for reserve movement corroborates with Aizenman et al. (2005) study which points out trade openness as an explanatory factor in the pre-crisis period, as discussed in country surveys section. The information value of consumption differential with US on foreign exchange reserves might cover both transaction and precautionary demands, reinforcing each other. As argued before, enhanced capital flows due to capital account liberalization and the following financial crises episodes intensified the prudential motive for emerging market countries. In this respect, the information value of consumption differential with US explaining the movements in foreign exchange reserves might hint a stronger precautionary savings motive for Korea relative to the portfolio balance approach.

4. Conclusion

We explore whether potentially useful information could be extracted out of GDP, consumption, exports, imports, interest rates and inflation variables for predicting movements of foreign exchange reserves in four selected emerging market countries: Argentina, Brazil, Korea and Turkey. Our empirical (Granger causality) tests indicate two important results: (1) For Argentina and Turkey, interest rate diferentials with the US contain potentially useful information for foreign exchange reserve accumulation. This points to the portfolio adjustment motive as a main determinant of the volatility in reserves as well as the prudential motive. (2) For Korea, consumption differential with the US and net exports contain information for foreign exchange reserve movements suggesting the precautionary savings motive as a relatively stronger motivation than the portfolio adjustments for explaining the reserve accumulation.

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