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Liquidity and Exchange rate volatility: The role of financial development

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Abstract:

Using a large panel dataset covering both advanced and developing countries over the period 1980-2015, this paper does two things. First, it explores the impacts of liquidity on the dynamics of exchange rate. We find evidence of a significant relationship between liquidity and real exchange rate volatility, which is, however, diverse and strongly depends on the way to measure liquidity level. Second, it investigates whether the nature of the linkage between liquidity and real exchange rate depends on the level of financial development of a country. This hypothesis is empirically validated in our study.

Keywords: Exchange rate volatility; Liquidity: Financial development

JEL classification: E51; F31; F33

1. Introduction

Exchange rate is an important macroeconomic variable used as parameter for determining international competitiveness and also considered as an indicator of competitiveness of domestic currency. Since the breakdown of the Bretton-Woods system in 1973, the exchange rates in many countries, either developing countries or developed countries, have been considerably fluctuating. On the one hand, the impacts of exchange rate volatility on macroeconomic variables have received considerable attention in the literature. For instance, Aghion et al. (2009) argue that real exchange rate volatility can have a significant impact on long-term rate of productivity growth, but the effect depends critically on a country's financial development level. On the other hand, assessing the determinants of exchange rate volatility remains one of the most challenging empirical problems in macroeconomics (Williamson, 1994) and is still in debate among researchers. This is due to using different approaches based on different theoretical models of exchange rate determination. Some studies focus on the sources of exchange rate volatility by applying a specific exchange rate model while others are based on a synthesis of theoretical models. The existing literature lists a set of macroeconomic factors contributing to exchange rate movement, notably trade and financial openness, domestic and foreign money supplies, interest rates, productivity differentials, inflation level and so on.

Since the 2007 subprime crisis, among various potential determinants, policy-makers have taken particular interest in the impact of liquidity on the fluctuation of exchange rate. On the one side, developed countries consider that a sharp increase in liquidity in emerging economies is an important factor driving exchange rate volatility. On the other side, emerging countries shift the blame on recent unconventional monetary policies in advanced economies. Despite an intense political debate about liquidity's impacts on the dynamics of exchange rates, the existing literature offers little guidance on this issue. To fill this acknowledge gap, this paper aims at shedding light on the role of liquidity in stabilizing exchange rate volatility. In other words, we address the question of whether the extent of liquidity would foster or slower the real exchange rate volatility in an economy.

Furthermore, Aghion et al. (2009) reveal that a country's level of financial development matters in choosing how flexible an exchange rate system should be if the objective is to maximize long-run productivity growth. Therefore, another goal of this paper is to test whether RER volatility declines if the country is more financially developed. On the other hand, financial shocks seem to be greatly amplified in financially underdeveloped economies. We, thus, also examine whether financial development helps smooth or amplify liquidity shocks to the real exchange rate. Resolving these questions will guide us to formulate better economic policies to lower RER volatility.

<Insert Figure 1 – 2>

Figures 1 – 2 shows the relationship between liquidity and exchange rate flexibility and volatility for countries at different level of financial development, which is measured by two proxies: (i) the ratio of domestic credit to private sector to GDP (financial institution development); and (ii) the ratio of total stock market capitalization to GDP (financial market development). The upper graphs consider the exchange rate regime classification proposed by Ilzetzki et al. (2017) and the lower graphs deal with the effective real exchange rate volatility. As displayed in Figures 1 – 2, we find preliminary evidence that the nature of the linkage between liquidity and the RER volatility as well as the flexibility of exchange rate regimes vary with the level of financial development. In the next sections, we try to investigate the robustness of this finding and to rationalize it for an un-balanced panel dataset covering 118 countries over the period 1980 – 2015.

The rest of this paper is organized as follows. Section 2 discusses the theoretical and empirical literature on the linkage between liquidity and RER volatility. Section 3 describes the data setting. Section 4 presents the methodology of estimation and the regression analysis of the RER volatility. Section 5 explores the nature of the link between liquidity and RER volatility. Conclusion and policy implications are in Section 6.

2. Literature review

In the literature, the studies concerning exchange rate volatility can be divided into two strands: (*i*) the impacts of exchange rate volatility and (*ii*) macroeconomic factors contributing to the exchange rate fluctuation. The present paper builds on and relates to the role of liquidity in determining the exchange rate volatility. Therefore, this section only provides a brief literature review on the relationship between liquidity and exchange rate volatility.

In the concerned literature, Dornbusch's (1976) well known exchange rate overshooting hypothesis has become a central building block. The central focus of Dornbusch's model is on the impact of monetary shock on the exchange rate and output (and thus indirectly on unemployment). Given sticky prices in the short run, an increase in the money supply leads to an immediate real depreciation, which is the results of a nominal depreciation needed to sustain money market equilibrium. An increase in money supply also rises real balances but reduces interest rates. Thus, the nominal exchange rate is expected to appreciate in order to equalize domestic and foreign assets' return. In other words, the initial nominal depreciation followed by a further appreciation implies that the nominal exchange overshoots its new equilibrium. The original level of the real exchange rate is therefore expected to be restored due to a rising price and the nominal appreciation. During this adjustment process, the real depreciation and low interest rates' level lead to an increase in demand and a decrease in unemployment, which in turn cause inflationary pressures. The important influence of Dornbusch's model is evident in the rapidly growing "New Open Economy

Macroeconomics" literature (Obstfeld and Rogoff, 1995; 2000). Rogoff (2002) also argues that Dornbusch's exchange rate overshooting hypothesis has become one of the most influenced researches in international economics over the entire twentieth century. However, few empirical studies find support for Dornbusch overshooting hypothesis. For instance, Eichenbaum and Evans (1995) investigates the effects of shocks to U. S. monetary policy on exchange rates. The author find that a contractionary shock to U. S. monetary policy leads to (i) persistent, significant appreciations in U. S. nominal and real exchange rates and (ii) significant, persistent deviations from uncovered interest rate parity in favor of U. S. interest rates. Regarding non-US G7 countries, Kim and Roubini (2000) show that in response to a monetary contraction exchange rate initially appreciates but after a few months, the exchange rate depreciates over time in accordance with the uncovered interest parity condition. According to Bjørnland (2009), many of empirical studies, in particular those using vector autoregressive (VARs) approaches, disregards the strong contemporaneous interaction between monetary policy and exchange rate movements by placing zero restrictions on them. In contrast, by imposing a long-run neutrality restriction on the real exchange rate, Bjørnland (2009) allows contemporaneous interaction between the interest rate and the exchange rate. The author suggests that a contractionary monetary policy shock has a strong effect on the exchange rate, which appreciates on impact. Precisely, the maximum effect occurs within 1–2 quarters, and the exchange rate thereafter gradually depreciates to baseline. This finding is consistent with the Dornbusch overshooting hypothesis.

The interaction between liquidity and exchange rate is also addressed in Grilli and Roubini (1992), who present a two-country extension of Lucas's (1988a) work on cash-in-advance constraints in asset markets. In Grilli and Roubini's model, the goods and asset markets are temporally separated and money is used for transactions in both. The authors first find that the exchange rate level depends on the share of money used for asset transactions: a greater share appreciates the currency. Second, an increase in domestic bonds' supply appreciates the domestic currency. Lastly, the liquidity effects of bond supply shocks result in an excess volatility of nominal exchange rates. In another theoretical work, to analyze the effects of money injections on interest rates and exchange rates, Alvarez et al. (2000) build a model in which agents must pay a Baumol (1952) - Tobin (1956) style fixed cost to exchange bonds and money. Due to this fixed cost, asset markets are endogenously segmented because agents trade bonds and money only infrequently. Government's money injections via an open market operation only influence the consumption of agents, who currently trade in asset markets, and then affect real interest rates and real exchange rates. The author shows that with moderate amounts of segmentation, persistent liquidity effects interest rates and volatile and persistent exchange rates. In the same vein, Caballero and Krishnamurthy (2005) develop a model of market segmentation that draw a distinction between domestic and international liquidity to study the consequences of monetary policy in the segmented financial market in the case of emerging countries. The authors find evidence of the oversensitivity of the exchange rate to monetary policy and the role of the exchange rate in endogenously aligning the extent of domestic credit squeeze with the limited international liquidity.

More recently, Brunnermeier and Pedersen (2009) provide a model about the causal link between asset's market liquidity and traders' funding liquidity: traders' ability depends on their availability of funding, while traders' funding depends on the assets' market liquidity. According to the authors, the interaction between funding and market liquidity lead to illiquidity spirals. Through the theoretical model, they also argue that the dynamics of market liquidity is related to market volatility. In the same year, Adrian et al. (2009) build a theoretical foundation for a funding liquidity channel in an intertemporal equilibrium pricing model in which the fluctuation of dollar-funded intermediaries' risk appetite is associated with the tightness of their balance sheet constraints. The main finding is that funding liquidity aggregates of U.S. financial intermediaries can forecast exchange rate growth at short-term horizons, both in-sample and out-of-sample, and for a large set of currencies.

Over the last few years, some empirical works provide systemic study of liquidity in the foreign exchange market. Lustig et al. (2011) consider a "slope" factor in exchange rates as a factor on which high interest rate currencies load more than low interest rate currencies. The authors show that this slope factor is a global risk factor, which can account for most of the cross-sectional variation in average excess returns between high and low interest rate currencies. As a result, US investors load up on global risk, particularly during bad times by investing in high interest rate currencies and borrowing in low interest rate currencies. Investigating the relation between global foreign exchange volatility and the excess returns to carry trade portfolios, Menkhoff et al. (2012) find evidence of a significantly negative return co-movement of high interest rate currencies with global volatility, whereas low interest rate currencies provide a hedge against volatility shocks. Moreover, they show that liquidity risk also matters for excess returns, which are more strongly related to unexpected components of volatility than to expected components.

Banti et al. (2012) construct a measure of global liquidity risk in the foreign exchange market by using a broad data set of 20 US dollar exchange rates and order flow of institutional investors over 14 years. The authors first show that there is a strong common component in liquidity across currencies. Second, the liquidity risk is priced in the cross-section of currency returns. Similarly, Mancini et al. (2013) support significant variation in liquidity across exchange rates, substantial illiquidity costs, and strong commonality in liquidity across currencies and with equity and bond markets. They also argue that liquidity risk has a strong impact on carry trade returns and is priced.

In the most recent work, Banti and Phylaktis (2015) investigate the determinants of the time variation of the common component of exchange rate market liquidity across developed and emerging market currencies. On the other hand, they analyze the impact of funding liquidity constraints and capital flows. A set of important findings are drawn from the work of Banti and Phylaktis: (i) funding liquidity constraints reduce FX market liquidity; (ii) increasing global capital flows increase liquidity; (iii) these two effects were stronger during the recent financial crisis, when liquidity dry-ups were severe; and (iv) a shock to speculator capital would lead to a reduction in market liquidity through a spiral effect.

Overall, despite an intense debate on the macroeconomic determinants of exchange rate volatility, the empirical analyses on the links between liquidity and exchange rate fluctuation have been scarce and failed to provide a general consensus on this topic. Furthermore, the existing empirical literature offers almost no discussion of the possible influence of financial development on the relationship between liquidity and exchange rate. The next sections, thus, tend to investigate the question of whether the effect of liquidity on exchange rate depends on a country's level of financial development.

3. Data setting

As mentioned above, this paper aims to explore the reaction of exchange rate to the changes in liquidity across countries under the financial development effect. Given this aim, the main explanatory variable in our empirical models is liquidity. Regarding liquidity measures, Chen et al. (2012) distinguish core liquidity and noncore liquidity. The authors define core liquidity as total resident deposits in commercial banks and other depositary corporations, which do not include inter-bank deposits. By contrast, noncore liquidity is defined as the total nonresident deposits in commercial banks and other deposit corporations as well as loans and securities (other than shares) of commercial banks, nonbanks and other financial intermediaries. Due to the data unavailability, this paper only partially follows the work of Chen et al. (2012). To measure liquidity of a country, we use two alternative indicators. This first one is liquid liabilities, which are also known as broad money, or M3. The second one is bank deposits, which comprise commercial banks and other financial institutions that accept transferable deposits, such as demand deposits.

Together with the main explanatory variable, liquidity indicators, the conditioning variable is a country's financial development level. Following Svirydzenka (2016), we distinguish financial institution development and financial market development. Financial institution depth is measured by domestic credit to private sector, which refers to financial resources provided to the private sector. To capture financial market depth, we use the value of stock market capitalization that is defined as total value of all listed shares in a stock market. These two indicators are collected Global Financial Development Database (GFDD).

In addition, according to the so-called "New Open Economy Macroeconomics", non-monetary factors (real shocks) also have gained importance in explaining exchange rate volatility (Calderon 2004). Therefore, together with the liquidity variable, a set of potential macroeconomic determinants will be also introduced in our empirical models.

The first one is interest rate differentials, which are frequently used as an auxiliary determinant of the real exchange rate. The role of interest rate in determining the exchange rate volatility is addressed in many theories. For instance, Dornbusch's overshooting model (1976) confirms a negative relationship between interest rate and exchange rate. Frankel (1979) develops a model of exchange rate so-called "real interest rate differential" model, which incorporates the role of inflationary expectations of the flexible price monetary model and the sticky prices of the Dornbusch's model of exchange rate determination. Similarly, the Mundell-Flemming model also supports the role of interest rate on the exchange rate determination: higher interest differential would attract capital inflows and result in exchange rate appreciation.

The second one is the productivity differentials. The impact of productivity differentials on real exchange rate equilibrium is analyzed on the Balassa-Samuelson hypothesis (Balassa (1964) and Samuelson (1964)) against which other equilibrium exchange rate theories should be compared. The Balassa-Samuelson hypothesis assumes that developing countries with low levels of GDP per capital experience persistent real income convergence to the level of real income in the frontier country and a concurrent appreciation in the real value of their domestic currency. By the same logic, advanced countries grow rich by advancing productivity in traded modern sectors. As productivity in the modern sector rises, wage levels rise, so prices of nontraded goods (in traditional sectors) will have to rise (as there has been no rise in productivity in that sector). If the overall price index is measured as a weighted average of traded and nontraded goods prices, relatively rich countries will tend to have "overvalued" currencies (Taylor and Taylor, 2004). In this paper, we consider GDP per capita as proxy for the Balassa-Samuelson productivity effect. Moreover, the quadratic term for GDP per capita is also included in order to allow for the possible nonlinear effect of economic growth on the exchange rate volatility.

The third one is the trade openness level (*OPEN*) which impacts on the real exchange rate movement is deeply studied in Hau (2002). The author presents an intertemporal monetary model of a small open economy with both tradable and non-tradable sectors. He claims that both monetary and aggregate supply shocks are shown to produce smaller real exchange rate volatility if the country is more open to foreign trade. The author further supports his claim via an empirical research covering forty-eight countries: Differences in trade openness explain a large part of the cross-country variation in the effective real exchange rate's volatility. In the concerned literature, the most well-known trade openness indicator is the Sachs et al. (1995) index.[1] Although this index serves as a proxy for a wide range of policy and institutional differences and not only of trade policy (Rodriguez and Rodrik, 1999), it can only suggest that a country is either open or closed. This index is also difficultly constructed due to the unavailability of many data components. Besides, the statistical correlation between the Sachs–Warner (SW) index and other variables of interest is not always obvious and difficult to set an econometric model and to interpret the empirical results. For these reasons, we employ the simplest standard trade openness indicator measured by the sum of exports and imports to GDP.

The fourth one is the terms of trade (*TOT*), which is defined by the ratio of export prices to import prices. Edward (1989) and Elbadawi (1994) distinguish two contrary effects of terms of trade on exchange rate volatility. An improvement in terms of trade leads to a positive income effect, which represents as an increase in both domestic purchasing power and domestic demand for non-traded goods. Consequently, the real exchange rate will be appreciated. By contrast, an improvement in terms of trade causes a negative substitution effect that makes the imported goods' consumption relatively more expensive. In general, the total effect of terms of trade on the volatility of real exchange rate depends on the strength of income and substitution effects. The present paper measures the TOT by the net barter terms of trade index, which is calculated as the percentage ratio of the export unit value indexes to the import unit value indexes, measured relative to the base year 2000.

The firth one is the level of government expenditures. In fact, the government expenditures are mostly used for non-tradable sectors. Therefore, an increase in government expenditures can cause a pressure on the relative price of non-tradable products. In other words, the rising government spending in response to an increase in domestic demand can lead to an appreciation of the real exchange rate (Edward, 1989). Frenkel and Mussa (1985) also evidence the link between government expenditures and equilibrium real exchange rate in the long-run. To measure government spending, we use general government final consumption expenditures that include all government current expenditures for purchases of goods and services (including compensation of employees). This indicator also includes the expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation.

The last added macroeconomic explanatory variable in our empirical model is capital flows. As suggested in Corden (1994), capital inflows, which generate higher demand for both tradable and

[1] The SW index, which is constructed by Sachs et al. (1995), is a dummy variable for openness based on five individual dummies for specific trade-related policies. Relying on this index, a country is classified as closed if it displays at least one of the following characteristics: average tariff rates of 40% or more; nontariff barriers covering 40% or more of trade; a black market exchange rate that is depreciated by 20% or more relative to the official exchange rate, on average, during the 1970s or 1980s; a state monopoly on major exports; a socialist economic system.

non-tradable goods, lead to a higher relative price of non-tradable goods and to the real exchange rate appreciation. The impacts of capital flows on the exchange rate volatility is also widely investigated in a large number of empirical studies. For instance, Ricci et al. (2013) show that an increase in net foreign assets tends to be associated with appreciating real exchange rates for a sample of 48 industrial countries and emerging markets. A similar result is also pointed out for a sample of 42 emerging and developing countries over the period 1980–2006 in Combes et al. (2012). According to the authors, both public and private inflows are associated with an appreciation of the real effective exchange rate. Precisely, among private inflows, portfolio investments display the biggest impact on the appreciation, while private transfers have the smallest effect. The possible impacts of capital flows on the exchange rate volatility will be investigated through the introduction of two indicators in our empirical model: net foreign assets and foreign direct investment.

Exchange rate volatility measures

We now turn our attention to the possible measures of exchange rate volatility. In the voluminous literature on exchange rate volatility, there is no general consensus on the appropriate method for measuring such volatility. On the one hand, a large set of studies utilize new empirical statistical and econometrical methods to capture the exchange rate volatility. According to McKenzie (1999), the autoregressive conditional heteroscedastic (ARCH) model advanced by Engle (1982) and the generalized autoregressive conditional heteroscedastic (GARCH) model developed independently by Bollerslev (1986) and Taylor (1986) can be used to generate predicted values of exchange rate volatility. In this vein, Baum et al. (2004) and Choudhry (2005) apply the GARCH model for measuring volatility to investigate the impacts of exchange rate volatility on the volume of bilateral exports.

Further modification of the ARCH models is also used in Orlowski (2003) to study the role of monetary policy regimes on lowering inflation and the exchange rate risk premium. The exchange rate volatility has been also captured by various modifications of standard deviation. For instance, in a set of early works (e.g. Kenen and Rodrik, 1986; Koray and Lastrapes, 1989; and Chowdhury, 1993), the exchange rate volatility is modeled as the moving sample standard deviation of the growth rate of the real exchange rate. Differing from the works listed above, to measure the exchange rate volatility, Dell'Ariccia (1999) employs the standard deviation of the first difference of the logarithmic exchange rate as well as two alternative measures, notably the sum of the squares of the forward errors and the percentage difference between the maximum and minimum nominal spot rate. In another study, Belke and Setzer (2003) consider the exchange rate volatility as the standard deviation of the 12 month-to-month changes in the logarithm of the spot rate. Overall, there has been a lack of agreement about the measure of exchange rate volatility. According to Clark et al. (2004), there is no generally accepted model of firm behavior subject to risk arising from fluctuations in exchange rates and other variables. Consequently theory cannot provide a definitive guidance as to which measure of exchange rate volatility is most suitable. Moreover, regarding the studies measuring the exchange rate volatility by ARCH/GARCH approach, Meese and Rogoff (1983) suggest that there are inherent difficulties in predicting exchange rates. We, therefore, adopt two alternative measures of observed exchange rate volatility, which are also used in Aghion et al. (2009).

We first consider the volatility of exchange rate as the flexibility of the exchange rate regime based on the exchange rate classification of Ilzetzki et al. (2017). The IMF annual classification orders regimes from the most rigid to the most flexible:

$$\begin{cases} 1 = De\ facto\ peg \\ 2 = De\ facto\ crawling\ peg \\ 3 = Managed\ floating \\ 4 = Freely\ floating \\ 5 = Freely\ falling \\ 6 = Dual\ market\ in\ which\ parallel\ market\ data\ is\ missing \end{cases}$$

The second volatility measure is the five-year standard deviation of the effective real exchange rate, which is collected from International Financial Statistics (IFS, IMF).[2]

Empirical model setting

Our empirical strategy tries to make maximum use of both time and cross-country dimensions of available annual data set. Given this aim, the empirical model is formulated as follows:

$$ER_{it} = \beta_0 + \beta_1 LID_{it} + \beta_2 LID_{it} \times FD_{it} + \beta_3 FD_{it} + \beta_4 RIR_{it} + \beta_5 PRO_{it} + \beta_6 GE_{it} + \beta_7 TOT_{it} + \beta_8 OPEN_{it} + \beta_9 CF_{it} + u_{it} \qquad \textbf{(1)}$$

where *ER* is a measure of exchange rate volatility, *LID* represents different liquidity indicators, *FD* represents two indicators of financial development, *RIR* is real interest rate, *PROD* includes two indicator of productivity, *GE* is the government expenditure, *TOT* is the terms of trade, *OPEN* represents the openness level, *CF* includes two indicators of capital flows, *DUM* is income level dummy and u is an error term that contains country- and time-specific fixed effects. We provide an outline of all variables of interest in Appendix A.

Data setting

On the one hand, we exclude the countries with unavailable data, the transition economies and small economies with a population of less than 500 000 in 2000 from our analysis. The information on the transition economies and population size are from the World Bank Global Development Network Database (GDN) and the WDI, respectively. On the other hand, in order to avoid the potential problem of heterogeneity in cross-country economic development level, there are two data samples

[2] Real effective exchange rate is the nominal effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs. An increase in the real effective exchange rate represents an appreciation of the local currency.

on which the estimation is based: (i) the high-income sample; and (ii) the low and middle – income countries (see Appendix B).

<*Insert Table 1*>

We summarize our datasets and provide means and standard errors of both dependent and independent variables in Table 1. Table 1 also reports the correlation coefficients between exchange rate volatility variables and all independent variables. On the one hand, it can be seen that the values of dependent and independent variables display a considerable variation, justifying the use of panel estimation techniques as well as two separate datasets, notably high-income versus low-income countries. On the other hand, the sign and significance of correlation coefficients also display a considerable variation, ranging from negative to positive, from small to important, from insignificant to significant. Thus, we should not be surprised to see different empirical results for different data samples.

4. Empirical specification

Our empirical specification is performed in three steps. First, we test for the order of integration or the presence of unit root of our panel. Second, having established the order of integration, we use the heterogeneous panel co-integration technique developed by Pedroni (1999) to test for the long run co-integrated relationships among the variables of interest. In the last step, the Fully Modified OLS (FMOLS) will be applied.

4.1. Panel unit root tests

Unit root tests are traditionally used to test for the order of integration of the variables or to verify the stationarity of each variable. To test for the panel unit root, a number of empirical tests have developed in the literature, notably Levin, Lin and Chu (2002, hereafter, LLC) (2002), Im, Pesaran and Shin (2003, hereafter, IPS) (2003), Maddala and Wu (1999, hereafter, MW); Choi (2001); and Hadri (2000). From among these different panel unit root tests, the LLC test and the IPS test are the most popular. Both of these tests are based on the Augmented Dickey-Fuller (ADF) principle. Here, due to our unbalanced data, we apply the W_{tbar} test proposed by Im et al. (2003) and the Fisher test initialled by Maddala and Wu (1999), which consider the non-stationarity (presence of a unit root) as the null hypothesis.

Im et al. (2003) allow for residual correlation, heterogeneity of the autoregressive root and error variances across individual members of the panel. IPS suggests an average of the Augmented Dickey-Fuller (ADF) test to each individual series. Considering a panel of *N* cross sections observed over *T* periods, the ADF regression estimation for each individual is given as follows:

$$\Delta y_{i,t} = \gamma z_{i,t} + \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \theta_{i,j} \Delta y_{i,t-j} + \epsilon_{i,t} \qquad (2)$$

where $z_{i,t}$is the deterministic component, p_i is the lag length that is permitted to vary across panel individual members, $\epsilon_{i,t}$ are identically, independently distributed (*i.d.d.)* across *i* and *t* with:

$$\begin{cases} E(\epsilon_{i,t}) = 0 \\ E(\varepsilon_{i,t}^2) = \sigma_i^2 < \infty \\ E(\epsilon_{i,t}, \epsilon_{j,t}) = 0 \; for \; all \; i \neq j \end{cases} \quad (3)$$

The null hypothesis is that each series in the panel includes a unit root, i.e. $H_0 \; : \; \rho_i = 0$ for all *i* and the alternative hypothesis is defined as:

$$H_1 : \begin{cases} \rho_i < 0 \; for \; i = 1,2, \dots, N_1 \\ \rho_i = 0 \; for \; i = N_1 + 1, \dots, N \end{cases} \quad (4)$$

IPS requires the fraction of the individual time series that are stationary to be nonzero: $\lim_{N\to\infty} (N_1/N) = \delta$ where $0 < \delta \leq 1$. The IPS *t*-bar statistic is defined as the average of the individual ADF statistics as:

$$\bar{t} = \frac{1}{N} \sum_{t=1}^{N} t_{\rho_i} \quad (5)$$

Where t_{ρ_i} is the individual *t*-statistic for testing the null hypothesis H_0 for all *i*. Im et al. (2003) propose the standardized statistic as follows:

$$W_{tbar} = \frac{\sqrt{N}\left(\bar{t} - \frac{1}{N}\sum_{i=1}^{N} E[t_{iT}|\rho_i = 0]\right)}{\sqrt{\frac{1}{N}\sum_{i=1}^{N} Var[t_{iT}|\rho_i = 0]}} \to N(0,1) \quad (6)$$

where $E[t_{iT}|\rho_i = 0]$ and $Var[t_{iT}|\rho_i = 0]$ are the mean and the variance of t_{iT}, respectively.

Maddala and Wu (1999) propose a Fisher-type test:

$$P = -2 \sum_{t=1}^{N} ln(p_i) \quad (7)$$

Which combines the *p*-values from unit root tests for each cross-section *i* to test for unit root in panel data. Under the assumption of cross sectional independence, *P* has a χ^2 distribution with 2 degrees of freedom. According to Maddala and Wu (1999), both the IPS and Fisher tests relax the restrictive assumption of the LLC test that ρ_i is the same under the alternative hypothesis. Moreover, these two tests combine information based on individual unit root tests.

4.2. Panel cointegration test

Like the panel unit root tests, panel cointegration tests can be motivated by the search for more powerful tests than those obtained by applying individual time-series, which have low power for short *T* and short span of the data. In the concerned literature, several alternative techniques for testing cointegration in a panel data have recently developed. Kao (1999) proposes the ADF type tests similar to the classical approach adopted by Engle and Granger (1987). In all Kao's tests, the cointegration vector and short run dynamics to be homogeneous across the individual panel members. In this paper, we apply the cointegration test developed by Pedroni (1999, 2004), who relaxes the assumption of homogeneity of Kao (1999) and allows for considerable heterogeneity across individuals. The Pedroni panel co-integration technique makes use of a residual-based ADF test. The Pedroni test for the long-run co-integrated relationship is based on the estimated residuals from following model:

$$y_{i,t} = \gamma z_{i,t} + \beta_{1,i}x_{1,i,t} + \beta_{2,i}x_{2,i,t} \ldots + \beta_{k,i}x_{k,i,t} + e_{i,t} \tag{8}$$

where $z_{i,t}$ is the deterministic component (fixed effects α_i and/or individual time effect $\delta_{i,t}$, and k is the number of regressors $x_{i,t}$, which are assumed to be *I(1)* (i.e. $x_{i,t} = x_{i,t-1} + u_{i,t}$ and not cointegrated with each other. The term $e_{i,t} = \rho_i e_{i,t-1} + u_{i,t}$ is the deviations from the modelled long-run relationship. If the series are co-integrated, $e_{i,t}$ should be a stationary variable. *Equation 4* differs from *Equations 2-3* in which we introduce the RER control variable in considering that the real exchange rate directly influences financial openness and trade openness.

The null hypothesis in the Pedroni test is whether ρ_i is unity. On the one hand, the Pedroni technique allows testing for the possible co-integrated relationship: Model without heterogeneous trend and ignoring common time effect (**M1**); Model without common time effect and allowing heterogeneous trend (**M2**); Model with heterogeneous trend and allowing common time effect (**M3**); Model with common time effect and ignoring heterogeneous trend (**M4**). On the other hand, the Pedroni test considers seven statistics for the test of the null hypothesis of no co-integration in a heterogeneous panel. The first group based on pooling data along the within dimension includes: the "panel v-stat" and the "panel rho-stat" are similar to the Phillips and Perron (1988) test; the panel pp-stat (panel non-parametric) and the "panel adf-stat" (panel parametric) are analogous to the single-equation ADF-test. The second group of tests calling "between dimensions" is comparable to the group mean panel tests of Im et al. (2003). The "between dimensions" tests include three tests: group rho-stat; group pp-stat; and group adf-stat.

4.3. Estimation of Panel Cointegration Models

According to Pedroni (2000), in a panel cointegrated system, the Ordinary Least Square (OLS) estimator is biased and its asymptotic distribution depends on nuisance parameters associated with the dynamics of the underlying system. Therefore, several techniques are developed to provide efficient cointegrating vector estimators and to infer the panel cointegration models. Pedroni (2000) proposes a Fully Modified OLS estimator (FMOLS), which can be seen as a generalization of Phillips and Hensen (1990), while Kao and Chiang (2000) develop an alternative approach based on a Panel Dynamic Least Squares (DOLS) estimator.

Pedroni (2000) considers the following cointegrated system for a panel of $i = 1, \ldots, N$ members:

$$y_{it} = \alpha_i + \beta x_{it} + \mu_{it}$$
$$x_{it} = x_{i,t-1} + \varepsilon_{it} \quad (9)$$

where the term α_i allows the cointegrating relationship to include member specific fixed effects. The variables y_{it} and x_{it} are cointegrated for each member of the panel, with cointegrating vector β if y_{it} is integrated of order one. The vector error process $\xi_{it} = (u_{it}, \varepsilon_{it})'$ is stationary with asymptotic covariance matrix Ω_i that is decomposed as:

$$\Omega_i = \begin{bmatrix} \Omega_{u_i} & \Omega_{u\varepsilon_i} \\ \Omega_{\varepsilon u_i} & \Omega_{\varepsilon_i} \end{bmatrix} = \Omega_i^0 + \Gamma_i + \Gamma_i' = \begin{bmatrix} \Omega_{u_i} & \Omega_{u\varepsilon_i} \\ \Omega_{\varepsilon u_i} & \Omega_{\varepsilon_i} \end{bmatrix} + \begin{bmatrix} \Gamma_{u_i} & \Gamma_{u\varepsilon_i} \\ \Gamma_{\varepsilon u_i} & \Gamma_{\varepsilon_i} \end{bmatrix} + \begin{bmatrix} \Gamma'_{u_i} & \Gamma_{u\varepsilon_i} \\ \Gamma_{\varepsilon u_i} & \Gamma'_{\varepsilon_i} \end{bmatrix} \quad (10)$$

Where $\Omega_{u_i}$is the long run variance of the residual u_{it}, Ω_{ε_i} refers the $(k \times k)$ long run covariance among the ε_{it} and $\Omega_{\varepsilon u_i}$ is the $(k \times 1)$ long run covariance between u_{it} and ε_{it} that captures the endogenous feedback effect between y_{it} and x_{it}. Considering this feedback effect, the FMOLS estimator, which eliminates the bias due to the endogeneity, is given as:

$$\hat{\beta} = N^{-1} \sum_{i=1}^{N} \left(\sum_{i=1}^{T} (x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)' \right)^{-1} \left(\sum_{i=1}^{T} (x_{it} - \bar{x}_i) y_{it}^* - T\hat{\gamma}_i \right) \quad (11)$$

where

$$\begin{cases} y_{it}^* = (y_{it} - \bar{y}_i) - \dfrac{\widehat{\Omega_{\varepsilon u_i}}}{\widehat{\Omega_{\varepsilon_i}}} \Delta x_{it} \\ \hat{\gamma}_i = \widehat{\Gamma_{\varepsilon u_i}} + \widehat{\Omega_{\varepsilon u_i}^0} - \dfrac{\widehat{\Omega_{\varepsilon u_i}}}{\Omega_{\varepsilon_i}} \left(\widehat{\Gamma_{\varepsilon_i}} - \widehat{\Omega_{\varepsilon_i}^0} \right) \end{cases} \quad (12)$$

and $\bar{x}_i$ and $\bar{y}_i$ refer to the individual specific means. According to Pedroni (2000), under the assumption of cross sectional independence, the FMOLS is asymptotically unbiased and its t-statictic is standard normal:

$$T\sqrt{N}(\hat{\beta} - \beta) \rightarrow N(0, \vartheta)$$
$$t_{\hat{\beta}} \rightarrow N(0,1) \quad (13)$$

where ϑ depends on $\bar{x}_i$ and $\bar{y}_i$ and the dimension of x_{it}. The t-statistic can also be computed as:

$$t_{\hat{\beta}} = \sqrt{N} \sum_{i=1}^{N} t_{\widehat{\beta_i}} \quad (14)$$

where $t_{\widehat{\beta_i}}$ is the t-statistic of the individual FMOLS estimator.

Comparing to the FMOLS estimator, the DOLS estimator accounts for possible serial correlation and endogeneity of the regressors by augmenting the cointegrating regression (Equation 9) with lead, lag, and current values of the first differences of the I(1) regressors (Kao and Chiang, 2000). Kao and Chiang (2000) also suggest the superiority of the DOLS over the FMOLS. However, the DOLS estimator seems to be very sensitive to the number of leads and lags added in the regression. Despite this drawback, to our knowledge, there is no statistical method allowing us to determine an optimal number of leads and lags used in the DOLS estimator. Moreover, regarding our limited time span, even for a DOLS estimator with only one lead/lag, the number of degrees of freedom is quite short. Lastly, given our strongly unbalanced panel data, introducing leads and lags of Δx_{it} as additional regressors in the regression of interest can lead to the biased empirical results. For these reasons, the present paper only applies the FMOLS estimator to address the question of whether the effect of liquidity on exchange rate volatility depends on a country's level of financial development.

5. Empirical results

We start this section with the results of panel unit root tests reported in Tables 2-3. The IPS and MW tests indicate that the null hypothesis of non-stationarity cannot be rejected in favor of the alternative hypothesis of stationarity for all variables in both HI and LI countries samples. Thus, we apply the panel unit roots to series in first differences. This step also allows us to determine the order of integration of our series. As shown in Tables 2-3, the IPS and MW results strongly reject the null hypothesis of non-stationarity for all variables at the 1% significance level. Accordingly, we run the Pedroni test with the variables, which are integrated of order one.

<Insert Tables 2-3>

Heterogenous cointegration analysis

We first apply Pedroni's (2003) cointegration test to find evidence of the possible linkage between the exchange rate volatility and dependent variables of interest. Second, we employ the FMOLS estimator to investigate the nature and the sign of the relationship detected in the first step. Due to the variety of measures of exchange rate volatility and liquidity, we consider four different empirical models as follows:

Model 1.1: $$FLE_{it} = \alpha_i + \beta\begin{pmatrix} LL_{it};\ FID_{it};\ FMD_{it};\ LL_{it} \times FID_{it};\ LL_{it} \times FMD_{it}; GDP_{it}; \\ GDP^2{}_{it};\ GE_{it};\ TOT_{it}; OPEN_{it};\ NFA_{it}; FDI_{it}; RIR_{it}; \end{pmatrix} + \varepsilon_{it}$$

Model 1.2: $$FLE_{it} = \alpha_i + \beta\begin{pmatrix} BD_{it};\ FID_{it};\ FMD_{it};\ BD_{it} \times FID_{it};\ BD_{it} \times FMD_{it}; GDP_{it}; \\ GDP^2{}_{it};\ GE_{it};\ TOT_{it}; OPEN_{it};\ NFA_{it}; FDI_{it}; RIR_{it}; \end{pmatrix} + \varepsilon_{it}$$

Model 2.1: $$VOL_{it} = \alpha_i + \beta\begin{pmatrix} LL_{it};\ FID_{it};\ FMD_{it};\ LL_{it} \times FID_{it};\ LL_{it} \times FMD_{it}; GDP_{it}; \\ GDP^2{}_{it};\ GE_{it};\ TOT_{it}; OPEN_{it};\ NFA_{it}; FDI_{it}; RIR_{it}; \end{pmatrix} + \varepsilon_{it}$$

Model 2.2: $$VOL_{it} = \alpha_i + \beta\begin{pmatrix} BD_{it};\ FID_{it};\ FMD_{it};\ BD_{it} \times FID_{it};\ BD_{it} \times FMD_{it}; GDP_{it}; \\ GDP^2{}_{it};\ GE_{it};\ TOT_{it}; OPEN_{it};\ NFA_{it}; FDI_{it}; RIR_{it}; \end{pmatrix} + \varepsilon_{it}$$

where the term α_i allows the cointegrating relationship to include member specific fixed effects, β refers to the vector of coefficients and ε_{it} is the residual. In Models 1.1 – 1.2, we consider the exchange rate volatility as the flexibility of exchange rate regime (FLE), while Models 2.1 – 2.2 measure the exchange rate volatility by the five-year standard deviation of the effective real exchange rate (VOL).

<Insert Tables 4>

We report the Pedroni statistics under the different model specifications for all data samples in Table 4. Significant values for most deferent statistics, in particular in the model with heterogeneous trend and allowing common time effect, allow us to reject the null hypothesis of no co-integrated relationship among the variables in question at least 10% significance level. We can, therefore, conclude the long-run co-integrated relationship among the variables of interest. We now turn our attention to the nature of the relationship between exchange rate volatility and its potential determinants in both HI and LI countries.

Empirical results

Table 5 and 6 present the estimations of the impact of liquidity and a set of control macroeconomic variables on exchange rate volatility. Each table displays the empirical results of two kinds of regressions. The first one estimates the effects of liquidity along with financial development and a set of control variables, without interaction term. The second one adds a variable interacting the liquidity measure and the measure of financial development in order to test the predication: the presence of a non-linear effect of liquidity on exchange rate volatility depending on the level of financial development.

Impacts of liquidity on exchange rate under the influence of financial development

Table 5 reports the empirical results in the case of HI countries. Among others, regressions [1.1[a]] and [1.2[a]] illustrate the absence of a linear effect of liquid liability and banking deposit on the flexibility of exchange rate regime. These two regressions also show that the flexibility of exchange rate regime does not depend on the level of financial development. However, the introduction of the interaction term of liquid liabilities and financial development level (regression [1.1[b]]) makes the estimated coefficient of liquid liabilities become positive and significant. The more financial developed an economy is, the higher is the point estimate of the impact of liquid liabilities on the flexibility exchange rate regime. In contrast, this finding is not confirmed in regression [1.2[b]], in which the liquidity is measured by banking deposit.

The empirical results reported in the four last columns in Table 5 only partially support the above results. First, all regressions [2.] indicate that only financial market development level has a significant negative impact on exchange rate volatility in HI countries. This effect is economically important: an increase in financial market development level leads to a reduction in exchange rate volatility. In other words, financial market plays an important role in stabilizing exchange rate in HI countries. Second, regarding regressions [2.1[b]] and [2.2[b]] with the presence of interaction terms, we reveal that the reaction of exchange rate volatility to the changes in liquidity varies in function of financial development level. For instance, regression [2.1[a]] without the interaction term indicates a significant positive effect of liquid liabilities on exchange rate volatility. However it becomes significant negative under the influence of financial institution development. It means that the nature of the relationship between exchange rate volatility and liquidity strongly depends on the level of financial institution development of an economy. In other words, a high level of financial institution development with a rational control of liquid liabilities may allow an economy to better manage its exchange rate variation. Third, when the liquidity is captured by banking deposit value, we do not obtain the same finding. For instance, the impact of banking deposit on exchange rate volatility is negative but insignificant in regression [2.2[a]]. However the non-interacted and interacted coefficients of banking deposit become significant when we integrate the influence of financial development level in regression [2.2[b]]. This finding once again confirm the role of financial development on modifying the nature of the linkage between liquidity and exchange rate volatility. An increase in banking deposit can lower the volatility of real exchange rates. However, this impact can be reinforced in an economy with a high level of financial institution development.

We now turn our attention to the empirical results for LI countries panel reported in Table 6, which are mostly different from those reported in Table 7. *First*, both measures of liquidity, notably liquid liabilities and banking deposit, contribute to an increase in the flexibility of exchange rate regime and then a rise in exchange rate volatility in regressions without the interaction term. *Second*, both financial institution development and financial market development seem to orient a LI country towards a more flexible exchange rate regime. In contrast, the impact of financial institution development on exchange rate volatility is different from that of financial market development. In detail, together with the strength of banking domestic system, a LI country tends to relax its exchange rates to pay more heed to market demand and supply. This trend can make exchange rates of a LI country become more volatile. This result provides a rational interpretation for the developed countries' consideration that a sharp increase in liquidity in emerging economies is an important factor driving exchange rate volatility.. Oppositely, the more developed financial market is, the less volatile exchange rate is. In other words, the development of financial market requires a LI economy to make more effort in controlling for the volatility of exchanger rate. Nevertheless, regarding the value of concerned estimated coefficients, we reveal that the negative impact of financial market development on exchange rate volatility is dominated by the positive impact of financial institution development. Due to this issue, LI economies cannot benefit from the development of financial system in terms of controlling for exchange rate volatility. *Third*, regressions with the interaction term show a set of contradictory results. On the one hand, the significant interaction terms of liquid liabilities and financial market development suggest that the development of financial market can reinforce the impact of liquid liabilities on the flexibility as well as on the volatility of exchange rate. On the other hand, the interaction term of banking deposit and financial institution development is significant positive in both VOL and FLE regressions. The more developed financial institution is, the higher is the point estimate of the impact of banking deposit on exchange rate volatility. Regarding the influence of financial market development on the reaction of exchange rate to liquidity, we reveal that a more developed financial market can reduce the positive effect of liquidity on exchange rate volatility.

By and large, the main results support the effect of liquidity on exchange rate volatility. This finding is consistent with Dornbusch's (1976) exchange rate overshooting hypothesis, which indicates that after an increase in money supply, exchange rate depreciates more than its long-run depreciation. Exchange rate is, thus, said to be overshooting when its immediate response to a shock is greater than its long-run response. We also reveal that the nature of the linkage between liquidity and exchange rate (positive or negative; significant or insignificant) depends on the way to measure liquidity level and exchange rate volatility. Furthermore, letting the degree of liquidity vary with the level of financial development allows us to confirm that the impact of liquidity on exchange rate volatility depends on the level of financial development. A high-income economy can benefit from financial institution development in terms of controlling for exchange rate volatility. In contrast, in a low-income country, financial market development seems to reduce the positive effect of liquidity on exchange rate flexibility and volatility.

Productivity's effect

As mentioned above, the productivity effect refers to the Balassa-Samuelson hypothesis (rapid economic growth is accompanied by real exchange rate appreciation because of differential productivity growth between tradable and non-tradable sectors). The present paper finds evidence of a non-linear effect of productivity on real exchange rate on both high-income and low-income countries. However, the non-linear effect in low-income countries is opposite to that observed in high-income countries. A low-income country tend to maintain a fixed exchange rate regime during the first stage of economic growth. At a threshold level of productivity, a low-income country prefers a floating regime to a rigid regime due the stabilizing role of flexible exchange rates. This finding is consistent with that of Ghosh and Ostry (2009) who argue that pegged exchange rates provide little benefit to developing countries in terms of either inflation or growth performance. Because such regimes are associated with greater likelihood of currency or financial crises. So that, developing countries as they became more financially integrated—should adopt freely floating exchange rates. This result does not provide a rational interpretation for the "fear of floating" behavior. In contrast, developed countries begin with a flexible exchange rate regime. When the productivity reaches a given threshold, advanced countries tend to reduce the flexibility level of their exchange rate regimes. Among others, to avoid a sharp currency volatility euro area maintains irrevocably fixed exchange rates (through the monetary union) with the countries with which they have the deepest economic ties, such as trade.

Impact of government expenditure

Different from the Balassa-Samuelson model in which the real exchange rate is fully determined by the supply side of the economy, demand factors do not matter, Aguirre and Calderon (2005) add monopolistic competition in the non-traded sector in Lane and Milesi-Ferretti's (2004) model and then allow for demand factors to influence the real exchange in the long run. Accordingly, an increase in government expenditure, which mostly falls on non-traded goods, leads to a rise in non-traded goods' relative price and thus appreciates the real exchange rate. However, the present paper only confirms this theoretical link in the case of developing countries. Moreover, an appreciation of the domestic currency by government spending shocks seems to allow developing countries to reduce the volatility level of exchange rates.

Impact of terms of trade

As suggested above, the terms of trade disturbances have been considered as a potential source of real exchange rate fluctuations in a large number of theoretical models. In our paper, the impact of terms of trade worsening on the exchange rate is empirically verified in both developed and developing countries. First, an improvement of terms of trade reduces the flexibility of exchange rate regime in both developing and developed countries. In the concerned literature, the terms of trade shocks induce an income effect (decline or increase in the domestic purchasing power) and a substitution effect (the consumption of imported goods more expensive or cheaper). So that, the final impact of terms of trade disturbances depends on the strength of the income and substitution effects. Our empirical results evidence that the income effect is predominant, hence, terms of trade improvements are associated with real appreciation in the long-run. However, domestic exports do not benefit from this currency appreciation. To mitigate the possible negative impact of currency appreciation, the related country might decrease the flexibility level of its exchange rate regime. It is explained by the significant negative values of TOT estimated coefficients in our regressions. A less flexible exchange rate regime, hence, leads to a decline in exchange rate volatility. However, this impact is only empirically confirmed in the case of developed countries.

Impact of openness

Regarding the impact of openness on exchange rate volatility, our empirical result is consistent with that of Obstfeld and Rogoff (2000) and Hau (2002) who emphasize that exchange rate volatility is negatively related to economic openness. Accordingly, trade openness can reduce the real exchange rate volatility due to a shock through higher import penetration by allowing a faster adjustment of the domestic aggregate price. Consequently, this mitigates the short-run impact of any shock (real or nominal) on real household balances and; hence, reduces the scope of such shocks to generate real effects on the real exchange rate (Calderón and Kubota, 2018).

Impact of capital flows and net foreign assets

In the present paper, we consider capital flows and net foreign assets as two indicators of the financial integration level. As reported in Tables 5 – 6, the interaction between financial integration and exchange rate is only concluded in the case of developing countries: financial openness amplifies the real exchange rate volatility. This finding is theoretically supported by the general equilibrium models in which imperfect capital mobility across international borders (financial frictions) and multi-period nominal contracts lead to varying degrees of nominal inertia (Sutherland, 1996). In these models, due to a money supply shocks, domestic and foreign bonds would pay different returns with imperfect capital mobility. Asset accumulation leads to a decline in domestic interest that in turn allows domestic consumers to raise their present consumption. However, as the consumption differential becomes more positive and interest rate differentials become negative, with imperfect capital mobility, the exchange rate does not depreciate as much as in the case of perfect capital mobility. Hence, rising financial integration can reduce interest rate volatility but foster exchange rate volatility.

Impact of real interest rate

The results on the impact of interest rate on exchange rate volatility are mixed. On the one hand, we reveal that raising real interest rates leads to higher exchange rate volatility in advanced countries. On the other hand, in the case of developing countries, raising the interest rate is useful for stabilizing the exchange rate. In general, the empirical results indicate that the nature of the interaction between interest rate and exchange rate volatility depends on the level of economic development. This nuanced relationship has been also evidenced in a large set of empirical studies. Using a large panel data set of 80 countries, Goldfajn and Gupta (2003) find that high interest rates support the currency, but only when the banking system is strong. However, according to Kraay (2003), there is little evidence for or against the use of tight monetary policy to defend currencies. The mixed results are also produced in some time series analysis. For instance, Dekle et al. (2002), and Baig and Goldfajn (2002) argue that higher interest rates are associated with stronger exchange rates though the impact is small. In contrast, Gould and Kamin (2001) find no evidence of a significant relationship between interest rates and exchange rates in a set of emerging countries.

6. Conclusion

The focus of this paper is on exploring the impact of liquidity on the dynamics of exchange rate. To this end, we provide an empirical analysis for a panel dataset of 118 countries at different levels of economic development. Applying the FMOLS technique, we are able to deliver a set of interesting results. First, our empirical results, by and large, support the impact of liquidity on the real exchange rate volatility and the flexibility of exchange rate regime. However, these impacts are diverse and relatively depend on the way to measure the liquidity level and on the economic development level of a country. For instance, the exchange rate regimes in developing countries seems to be sensible to liquidity shocks, while advanced economies do not experience this evidence.

Second, our paper contributes to the literature by considering the impacts of liquidity on the dynamics of exchange rate under the influence of the financial development level instead of looking at this issue in isolation. Our main hypothesis is that the nature of the linkage between liquidity and exchange rate depends on the level of financial development of a country. This hypothesis is shown to be largely validated in developing countries, which provides fairly robust evidence suggesting the importance of financial development for the relationship between liquidity and exchange rate. This result is useful for policymakers in terms of choosing a rational development for the domestic financial system in developing countries. Precisely, if the objective is to stabilize exchange rates, developing countries should begin to favor the development of their financial markets. In contrast, the strength of financial institution allows an advanced country to mitigate the real exchange rate volatility due to a monetary shock.

To conclude, this empirical study serves as a complement to the existing literature on the interaction between the exchange rate movement and liquidity. However, to rationalize the empirical results listed above, an articulated structural model should be called for, which in turn remains an important challenge for our future researches.

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Appendix A: Data description

Variables	Indicators	Definition	Sources
Exchange rate volatility (ER)	Flexibility of exchange rate regime (FLE)	IFM exchange rate regime classification	Ilzetzki et al. (2017)
	Exchange rate volatility (VOL)	Five-year standard deviation of annual log differences in the effective real exchange rate	Author's calculation from International Financial Statistics (IFS) database
Liquidity (LID)	Liquid liabilities (LL)	Ratio of liquid liabilities to GDP	Global Financial Development Database (GFDD)
	Bank deposits (BD)	Demand, time and saving deposits in deposit money banks and other financial institutions as a share of GDP	GFDD
Financial development (FD)	Financial institution development (FID)	Domestic credit to private sector (% of GDP)	World Development Indicators (WDI)
	Financial market development (FMD)	Stock market capitalization to GDP (%)	GFDD
Interest rate	Real interest rate (RIR)	Real interest rate is the lending interest rate adjusted for inflation as measured by the GDP deflator (%)	IFS
Productivity effect (PRO)	GDP per capita (GDP)	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2010 U.S. dollars.	WDI
	Quadratic term of GDP per capita (GDP^2)	idem	WDI

Government expenditures	General government final consumption expenditure (GE)	All government current expenditures for purchases of goods and services (including compensation of employees) (%GDP)	WDI
Terms of trade	Net barter terms of trade index (TOT)	The ratio of the export price index to the import price index	United Nations Conference on Trade and Development (UNCTAD)
Openness (OPEN)	Trade openness	Sum of exports and imports to GDP (%)	WDI
Capital flows (CF)	Net foreign assets (NFA)	The sum of foreign assets held by monetary authorities and deposit money banks, less their foreign liabilities (% GDP).	IFS
	Foreign direct investment (FDI)	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. (% GDP)	WDI

Table 1: Summary statistics and correlations matrix

Variables	HI countries panel						LI countries panel					
	Mean	Std. Dev.	Min	Max	Correlation coefficient		Mean	Std. Dev.	Min	Max	Correlation coefficient	
					FLE	VOL					FLE	VOL
FLE	2.28	1.11	1.00	6.00	1.00	-	2.47	1.42	1.00	6.00	1.00	-
VOL	7.76	20.76	0.02	270.77	0.12*	1.00	176.09	1247.01	0.00	17847.93	0.10*	1.00
LL	81.30	55.78	6.87	399.11	-0.17*	-0.11*	36.86	30.48	0.00	353.02	-0.14*	-0.00
BD	75.71	59.11	11.31	479.67	-0.14*	-0.09*	28.31	27.00	0.00	312.33	-0.12*	-0.01
FID	107.37	58.30	0.23	357.32	0.08*	-0.04	42.81	54.10	-114.69	2066.19	0.10*	-0.02
FMD	70.33	102.20	0.00	1086.48	-0.06*	-0.06*	12.27	41.53	0.00	996.94	0.01	-0.02
LL*FID	10660.82	13062.35	12.15	81613.11	0.02	-0.07*	2289.64	4488.71	-13705.76	49256.45	-0.08*	-0.00
LL*FMD	9406.26	30808.43	0.00	375095.10	-0.11*	-0.06*	923.76	2889.26	0.00	32520.21	-0.05*	-0.02
BD*FID	10078.83	13110.77	11.44	92232.11	0.03	-0.06*	1827.45	3948.60	-10377.92	47835.31	-0.07*	-0.01
BD*FMD	8982.10	29564.04	0.00	359679.00	-0.12*	-0.06*	797.07	2587.48	0.00	27917.18	-0.03*	-0.02
RIR	5.62	6.23	-7.69	93.92	0.09*	-0.01	8.13	30.07	-97.81	789.80	0.02	-0.03
GDP	10.21	0.64	8.27	11.62	-0.15*	-0.20*	7.36	1.03	4.75	9.59	0.09*	-0.03*
GDP^2	104.75	12.86	68.42	134.98	-0.15*	-0.20*	55.26	15.27	22.55	92.06	0.10*	-0.03*
GE	18.35	4.80	5.62	41.48	-0.09*	-0.17*	13.92	5.53	0.00	63.94	-0.00	-0.11*
TOT	4.63	0.19	3.79	5.49	0.19*	-0.14*	4.94	2.29	3.06	27.36	-0.04*	-0.01
OPEN	4.32	0.64	2.77	6.12	-0.40*	-0.05*	4.10	0.51	1.84	5.77	-0.13*	0.05*
NFA	25.81	90.50	-53.17	810.73	-0.22*	-0.06*	3.74	86.31	-3638.18	329.94	-0.14*	0.01
FDI	4.42	11.23	-58.98	253.50	-0.15*	-0.06*	3.02	6.33	-82.89	89.48	-0.04*	-0.02

Notes: (*) indicates statistical significance at least 10% level.

Table 2: Unit root tests – HI countries panel

Variables	IPS test				MW test			
	Level		1st difference		Level		1st difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend
FLE	-6.60***	-5.50***	-16.19***	-13.49***	393.37***	114.72***	332.83***	286.61***
VOL	-10.72***	-8.51***	-20.31***	-17.12***	257.36***	206.22***	514.89***	405.02***
LL	2.41	-2.40**	-14.27***	-11.67***	49.81	107.64***	346.96***	283.47***
BD	1.42	-3.27**	-15.37***	-12.97***	60.16	113.01***	378.74***	301.28***
FID	3.35	-5.83***	-12.51***	-8.983***	41.69	54.23	310.12***	227.75***
FMD	-5.83***	-6.60***	-19.97***	-17.11***	367.95***	136.81***	501.47***	391.18***
LL*FID	4.66	0.07	-9.20***	-6.23***	45.74	74.66	232.06***	178.91***
LL*FMD	-1.80**	-8.09***	-18.00***	-13.75***	155.47***	165.71***	446.76***	332.64***
BD*FID	5.77	0.80	-10.26***	-7.217***	36.16	63.04	250.69***	181.86***
BD*FMD	5.77	-6.71***	-18.15***	-14.97***	144.75***	149.69***	441.66***	338.01***
RIR	-3.15***	-3.72***	-20.18***	-17.61***	118.46***	123.82***	488.86	408.08***
GDP	-0.14	2.02	-12.64***	-12.04***	70.28	50.79	303.30***	281.40***
GDP^2	0.35	1.84	-12.86***	-11.96***	63.43	52.82	308.70***	279.79***
GE	-4.17***	-3.11**	-17.97***	-16.23***	128.95***	105.22***	436.85***	439.23***
TOT	-0.19	0.92	-8.00***	-5.49***	62.66	71.54	194.91***	149.40***
OPEN	2.36	-3.84**	-19.25***	-16.11***	46.80	114.55***	472.01***	364.77***
NFA	2.83	0.32	-12.24***	-8.67***	41.46	83.11	294.58***	210.00***
FDI	-5.66***	-5.44***	-23.35***	-20.11***	154.17***	157.75	588.78***	475.83***

Notes: *** (**) means significant at 1% (5%)

Table 3: Unit root tests – LI country panel

Variables	**IPS test**				MW test			
	Level		1st difference		Level		1st difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend
FLE	-4.65***	-3.20***	-21.57***	-14.83***	207.33***	187.86***	725.00***	551.27***
VOL	-8.19***	-4.85***	-17.60***	-10.89***	370.92***	310.40***	684.24***	500.22***
LL	4.12	-0.55	-20.40***	-16.51***	138.14	229.49***	955.79***	655.93***
BD	7.16	1.33	-18.65***	-15.22***	94.89	188.46	884.56***	713.73***
FID	0.56	1.38	-23.55***	-21.02***	172.61	159.43	890.53***	759.18***
FMD	0.73	-3.56***	-21.30***	-17.38***	91.56	152.20	635.46***	491.87***
LL*FID	5.29	3.69	-19.43***	-17.50***	137.96	156.28	752.36***	742.17***
LL*FMD	1.97	-2.36***	-18.26***	-12.95***	84.59	143.54***	549.06***	419.68***
BD*FID	7.34	4.90	-17.50***	-15.52***	119.49	162.56	685.40***	636.81***
BD*FMD	2.87	-1.55*	-17.43***	-12.32***	80.19	131.63**	521.42***	399.14***
RIR	-14.19***	-10.24***	-32.47***	-20.45***	587.80***	511.81***	1379.86***	1082.18***
GDP	9.59	-1.52*	-19.14***	-16.86***	99.14	248.01***	731.42***	638.28***
GDP^2	10.42	-0.57	-18.48***	-16.65***	96.48	228.02***	706.80***	638.28***
GE	-6.34***	-4.11***	-29.44***	-24.98***	301.01	247.36***	1084.13***	874.47***
TOT	-2.75***	1.55	-21.11***	-17.94***	203.28**	150.53	867.63***	694.34***
OPEN	-3.89	-3.97***	-30.12***	-26.49***	238.64***	263.33***	1149.15***	943.91***
NFA	-0.26	-2.68***	-25.41***	-21.49***	197.07**	242.57***	961.69***	774.39***
FDI	-6.19***	-7.35***	-34.18***	-29.50***	289.66***	339.11	1327.51***	1099.42***

Notes: *** (**) means significant at 1% (5%)

Table 4: Pedroni cointegration test's results

	HI countries							
Statistic value	FLE model				VOL model			
	M1	M2	M3	M4	M1	M2	M3	M4
panel v-stat	2.750	4.687	2.402	3.841	7.157	9.327	2.387	4.659
panel rho-stat	-1.573	-3.676	-4.623	-6.606	-5.703	-5.940	-2.979	-3.996
panel pp-stat	-4.044	-6.918	-6.876	-8.764	-5.239	-5.129	-4.091	-4.277
panel adf-stat	-0.261	-3.254	-4.391	-5.935	-5.112	-7.291	-5.270	-7.892
group rho-stat	-2.845	-3.206	-4.768	-4.168	-3.184	-2.811	-2.337	-3.016
group pp-stat	-5.523	-7.285	-9.074	-8.641	-4.657	-4.070	-2.716	-2.850
group adf-stat	2.549	-3.473	-5.886	-6.138	-5.942	-7.053	-5.892	-7.257
	LI countries							
Statistic value	FLE Model				VOL model			
	M1	M2	M3	M4	M1	M2	M3	M4
panel v-stat	6.136	6.539	2.174	-4.000	-5.059	10.343	-10.185	2.097
panel rho-stat	-3.462	-5.863	-2.216	-4.168	-81.742	-4.341	-93.376	4.014
panel pp-stat	-4.865	-9.394	-3.670	-8.916	2.234	-2.725	8.496	4.317
panel adf-stat	-3.053	-3.602	-4.130	-4.771	16.593	11.034	25.774	4.356
group rho-stat	2.550	3.168	-3.800	-2.075	-341.996	-11.559	-276.158	12.311
group pp-stat	2.042	3.424	-4.733	-8.704	-6.792	-2.907	-4.299	3.613
group adf-stat	5.967	3.357	3.293	-4.196	-3.120	-2.352	-2.051	4.828

Notes: M1: Model without heterogeneous trend and ignoring common time effect. M2: Model without common time effect and allowing heterogeneous trend. M3: Model with heterogeneous trend and allowing common time effect. M4: Model with common time effect and ignoring heterogeneous trend.

Table 5: FMOLS results for HI countries panel

Independent variables	FLE model				VOL model			
	Model 1.1[a]	Model 1.1[b]	Model 1.2[a]	Model 1.2[b]	Model 2.1[a]	Model 2.1[b]	Model 2.2[a]	Model 2.2[b]
LL	0.004	0.005*	-	-	0.133***	0.216***	-	-
	(1.457)	(1.964)			(2.960)	(2.745)		
BD	-	-	0.002	0.003	-	-	-0.057	-0.137**
			(0.802)	(1.235)			(-1.162)	(-2.250)
FID	-0.002	-0.002	-0.002	-0.002	-0.095	-0.035	-0.028	0.038
	(-1.640)	(-1.449)	(-1.505)	(-1.429)	(-1.257)	(-0.744)	(-0.894)	(1.119)
FMD	0.000	0.000	0.000	0.000	-0.021***	-0.082***	-0.021**	-0.133***
	(-1.575)	(0.340)	(-1.381)	(0.043)	(-2.727)	(-2.657)	(-2.409)	(-5.568)
LL_FID	-	0.000	-	-	-	-0.001**	-	-
		(0.090)				(-2.401)		
LL_FMD	-	0.000	-	-	-	0.000**	-	-
		(-0.985)				(2.076)		
BD_FID	-	-	-	0.000	-	-	-	-0.001***
				(0.137)				(-3.513)
BD_FMD	-	-	-	0.000	-	-	-	0.000***
				(-0.627)				(5.295)
GDP	8.151***	8.570***	8.077***	8.429***	326.695***	326.627***	277.428***	218.302***
	(7.717)	(10.425)	(7.589)	(10.717)	(10.279)	(8.669)	(7.756)	(7.029)
GDP2	-0.414***	-0.437***	-0.411***	-0.430***	-16.280***	-16.317***	-13.847***	-10.419***
	(-7.365)	(-9.857)	(-7.230)	(-10.074)	(-9.755)	(-8.092	(-7.361)	(-6.286)
GE	0.010	0.010	0.012	0.011	0.908	0.533	0.770	1.022
	0.492	(0.643)	(0.595)	(0.757)	(1.433)	(0.892)	(1.383)	(1.107)
TOT	-0.250**	-0.248***	-0.271**	-0.278***	-16.588***	-19.191***	-8.829***	-8.867***
	(-2.393)	(-3.173)	(-2.629)	(-3.822)	(-6.033)	(-5.965)	(-2.890)	(-3.547)
OPEN	-1.065***	-1.024***	-1.046***	-1.004***	-30.741***	-37.781***	-24.519*	-30.517***
	(6.604)	(8.438)	(6.545)	(8.887)	(7.786)	(7.896)	(5.535)	(7.902)
NFA	-0.003	-0.003*	-0.001	-0.002	-0.079	-0.093	0.097	0.114
	(-1.254)	(-1.896)	(-0.696)	(-1.257)	(-1.452)	(-1.405)	(0.892)	(1.590)
FDI	-0.001	-0.002	-0.001	-0.002	-0.019	-0.016	0.007	0.065
	(-0.264)	(-0.639)	(-0.277)	(-0.685)	(-0.332)	(-0.180)	(0.112)	(0.915)
RIR	-0.002	-0.002	-0.002	-0.001	0.465***	0.457***	0.457***	0.514***
	(-1.038)	(-1.122)	(-0.867)	(-0.877)	(6.763)	(5.494)	(5.851)	(7.556)

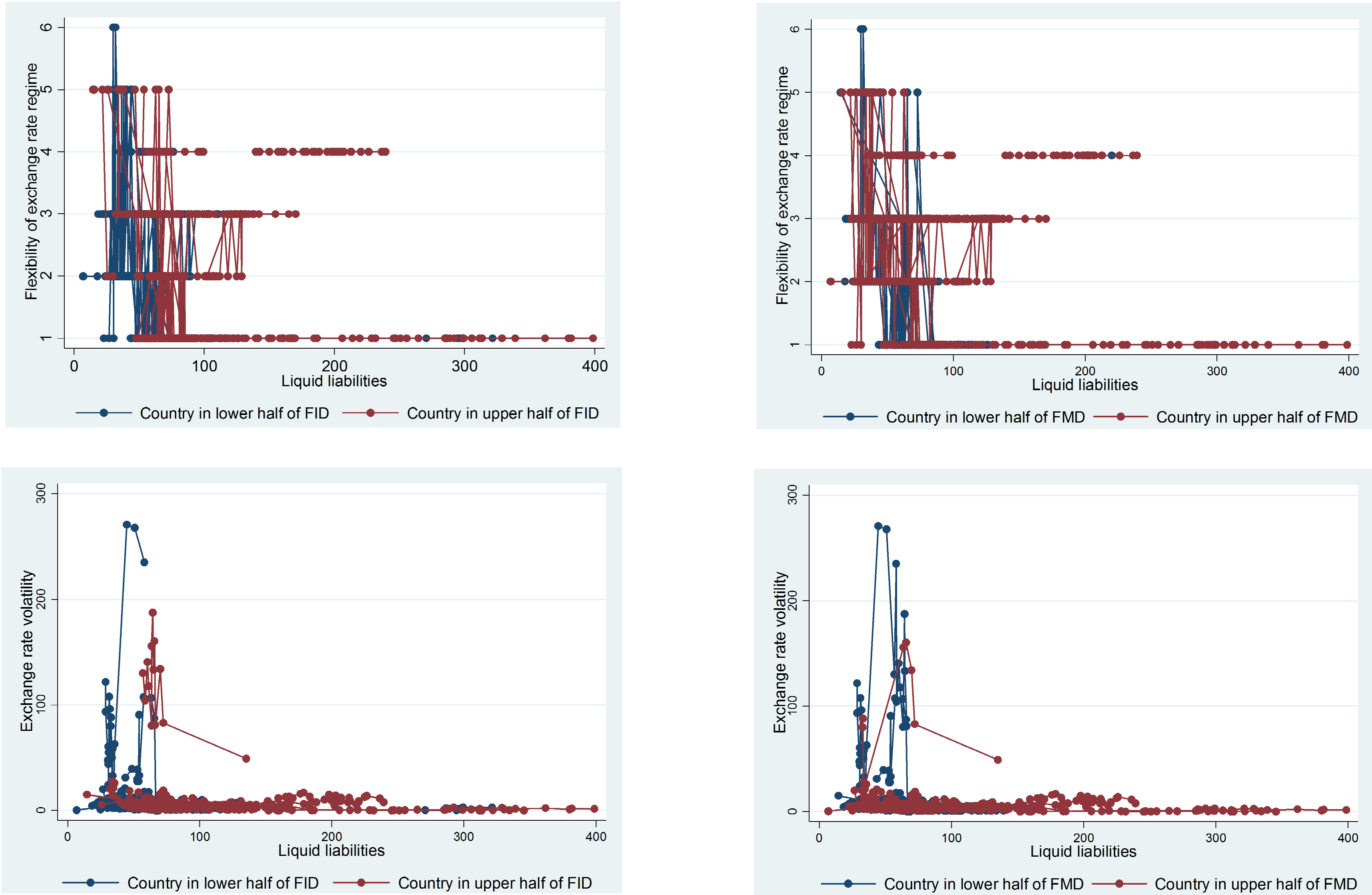
Notes: Value in parentheses is t-statistic. *** (**; *) means significant at 1% (5%; 10%). [a]: Model in which liquidity is measured by liquid liabilities.
[b]: Model in which liquidity is measured by banking deposit.

Table 6: FMOLS results for LI countries panel

Independent variables	FLE model				VOL model			
	Model 1.1[a]	Model 1.1[b]	Model 1.2[a]	Model 1.2[b]	Model 2.1[a]	Model 2.1[b]	Model 2.2[a]	Model 2.2[b]
LL	0.009***	0.009***	-	-	9.950***	24.335***	-	-
	(5.200)	(3.835)			(10.895)	(18.31)		
BD	-	-	0.007***	0.002	-	-	11.175***	30.517***
			(3.348)	(0.869)			(9.858)	(19.690)
FID	0.003**	0.003*	0.004***	0.000	4.693***	10.328***	4.851***	12.686***
	(2.613)	(1.771)	(3.676)	(-0.109)	(7.494)	(13.29)	(7.534)	(15.061)
FMD	0.001***	0.000	0.001**	0.001*	-0.319*	-1.883***	-0.528***	-1.907***
	(3.324)	(-0.651)	(2.784)	(1.757)	(-1.826)	(-5.42)	(-3.008)	(-5.937)
LL_FID	-	0.000	-	-	-	0.120***	-	-
		(0.299)				(12.022)		
LL_FMD	-	0.000***	-	-	-	-0.036***	-	-
		(2.877)				(-5.148)		
BD_FID	-	-	-	0.000***	-	-	-	0.187***
				(3.443)				(4.966)
BD_FMD	-	-	-	0.000	-	-	-	-0.041***
				(-0.074)				(-7.084)
GDP	-7.677***	-7.212***	-6.596***	-5.689***	-1323.430***	-2823.018***	-375.084	-2719.986***
	(-9.961)	(-10.05)	(-8.803)	(-7.824)	(-3.646)	(-7.830)	(-1.007)	(5.757)
GDP2	0.471***	0.429***	0.414	0.346***	47.893***	145.414***	-3.905	146.140***
	(9.195)	(8.928)	(8.293)	(7.103)	(2.019)	(6.101)	(-0.160)	(-17.933)
GE	-0.011	-0.010	-0.009	-0.006	-47.963***	-67.005***	-46.859***	-64.137***
	(-1.584)	(-1.544)	(-1.416)	(-0.949)	(-13.290)	(-18.800)	(-12.784)	(-1.751)
TOT	-0.359***	-0.338***	-0.368***	-0.370***	-18.704*	-33.993**	-38.176**	-51.166***
	(-6.063)	(-6.162)	(-6.537)	(-6.957)	(-1.720)	(-2.180)	(-2.245)	(14.635)
OPEN	-0.718***	-0.758***	-0.706***	-0.706***	-469.561***	-621.719***	-437.775***	-578.266***
	(9.329)	(10.491)	(9.616)	(10.045)	(11.829)	(15.910)	(10.757)	(-4.069)
NFA	0.033***	0.033***	0.034***	0.033***	-0.133	2.901***	0.839	3.645***
	(19.428)	(20.352)	(20.145)	(20.54)	(0.152)	(3.330)	(1.929)	(19.690)
FDI	0.030***	0.036***	0.031***	0.032***	51.707***	85.510***	52.705***	87.644***
	(4.312)	(5.239)	(4.543)	(4.761)	(15.632)	(22.100)	(15.681)	(22.234)
RIR	-0.007***	-0.006***	-0.006***	-0.006***	-2.689***	-2.439***	-2.724***	-2.954***
	(-7.278)	(-6.882)	(-7.263)	(-7.018)	(-5.447)	(-5.180)	(-5.422)	(-6.162)

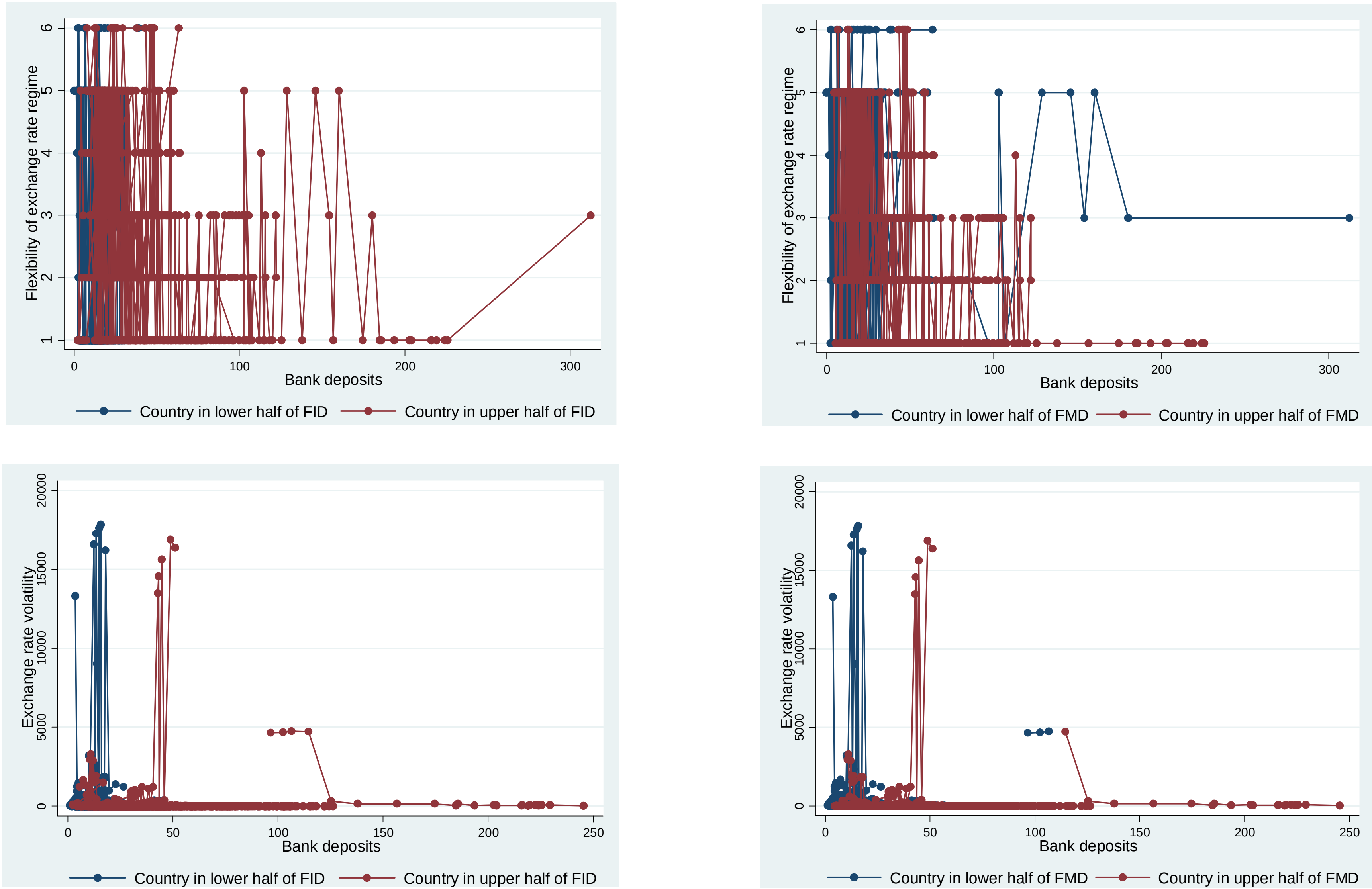
Notes: Value in parentheses is t-statistic. *** (**; *) means significant at 1% (5%; 10%). [a]: Model in which liquidity is measured by liquid liabilities. [b]: Model in which liquidity is measured by banking deposit.

Figure 1: Exchange rate, liquidity and financial development – HI country panel



Notes: Financial institution development (FID); Financial market development (FMD)

Figure 2: Exchange rate, liquidity and financial development – LI country panel



Notes: Financial institution development (FID); Financial market development (FMD