Real Exchange Rate Volatility and Economic Growth: Evidence from Global Commodity Terms of Trade Shocks

Abstract

This paper revisits the long-standing question in international macroeconomics regarding the effect of real exchange rate volatility on economic growth. We advance the theoretical literature by showing that interaction of a fixed entry cost and real exchange rate uncertainty can decrease tradables production and GDP in a simple general equilibrium model without the financial frictions or nominal rigidities assumed in previous work. However, once we allow sticky prices, a monetary authority with sufficient reserves can stabilize the real exchange rate and increase GDP. We test the model empirically by showing that commodity terms of trade volatility and its interaction with the stock of reserves are a strong predictor of real exchange rate volatility, which in turn is negatively related to growth. The negative growth effect of real exchange rate volatility appears to be substantially larger in emerging markets The adverse growth effect of real exchange rate volatility also increases with trade openness.

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Keywords: Real Exchange Rate Volatility, Economic Growth

JEL: F31, F32, F33

1. Introduction

This paper revisits a long-standing question in international macroeconomics: how does real exchange rate volatility affect economic growth. The literature addressing the issue is large, but it has remained inconclusive due to conflicting results and the potential endogeneity of real exchange rate volatility to the business cycle. The recent survey by Eichengreen (2007), for instance, concludes that real exchange rate stability is likely to be a facilitating condition for growth, but that the evidence should be interpreted with caution. In the arguably most convincing study to date, Aghion et al. (2009) show that real exchange rate volatility is negatively associated with labor productivity growth if financial development is below a threshold and otherwise there is no clear relationship. However, since their estimation procedure relies on internal instruments for the effect of real exchange rate volatility on growth, it assumes that measures of past productivity growth, real exchange rate volatility and financial development are uncorrelated with contemporary productivity growth after controlling for contemporary real exchange rate volatility and financial development measures. Although their results appear to be robust, it is of course difficult to rule out all confounding factors. This assumption is untenable if, for example, domestic investment booms simultaneously increase real exchange rate volatility (via inflation, external capital flows or the monetary policy stance), expand domestic credit and therefore standard financial development measures like the private-credit-to-GDP ratio, and – by making domestic workers more productive – the future level of labor productivity.

In this paper, we estimate the effect of real exchange rate volatility on economic growth using commodity terms of trade volatility as an exogenous and external instrument for real exchange rate volatility. Although the paper is mainly empirical, we motivate the empirical analysis with a simple general equilibrium model of a small open economy where commodity

price fluctuations lead to real exchange rate fluctuations, discourage the production of tradable goods and decrease income per capita. The model advances the theoretical literature on real exchange rate volatility and growth by linking the two in a standard neoclassical two-sector model without the financial frictions or nominal rigidities assumed in the previous theoretical contributions we are aware of (see below). However, once we allow sticky prices a monetary authority with sufficient reserves can stabilize the real exchange rate and increase GDP.

Having developed the model, we turn to testing it in a new country panel dataset with commodity terms of trade, real exchange rate and growth information. Our key empirical findings can be summarized as follows. First, commodity terms of trade volatility and its interaction with the stock of reserves are a strong predictor of real exchange rate volatility, which in turn is negatively related to trade openness and growth. Second, the negative growth effect of real exchange rate volatility is main driven by, and substantially larger in emerging markets. Third, the adverse growth effects of real exchange rate volatility increase with trade openness.

In the remainder of the paper, Section 2 reviews the main theoretical arguments linking real exchange rate volatility to growth advanced in the literature. Section 3 presents a simple general equilibrium model showing how terms of trade volatility in global commodity markets can induce real exchange rate volatility, which can, in turn, decrease tradable goods production and output. Section 4 presents the data and Section 5 contains the estimation results. Section 6 contains some empirical robustness checks and Section 7 concludes the paper. Most data sources and variable definitions are contained in the appendix.

2. Real Exchange Rate Volatility and Output Growth

Given the large empirical literature, there is surprisingly little formal theory on the real exchange rate volatility-growth nexus. However, both theory and evidence suggest that overvalued real exchange rates can lead to foreign-financed spending booms when the exchange rate is high, followed by costly busts due to credit crunches and a rising real value of foreign-currency denominated debt when the real exchange rate adjusts (Calvo et al. 1996, Calvo 1998). If busts are costly, such a boom-bust dynamic should lower the country's average growth rate (Martin and Rogers 2000). Real exchange rate instability might induce durable goods consumers and firms to postpone irreversible investments (Dixit 1994), force producers and investors to pay adjustment costs to move across countries or between tradable and non-tradable sectors (Cottani et al. 1990). It could also exacerbate the losses linked to episodic Dutch Disease incidents (Benigno and Fornaro 2013) or nominal rigidities linked to inflexible debt obligations or wages (Mishkin 1996, Bianchi 2011, Aghion et al. 2009, Benigno et al. 2013).[1] Nonetheless, the only formal model linking real exchange rate volatility to output we are aware of is Aghion et al. (2009), where an exogenously induced real depreciation means that tradables producers must surrender more output to service wage contracts denominated in a mix of tradables and non-tradables. As a result the profit rate falls and the producer may run short of collateral need to finance productivity-increasing research. The likelihood of a binding credit constraint decreases

[1] Empirically, Cottani et al. (1990) link real exchange rate stability to increased investment and growth in developing countries. Dollar (1992) and Bosworth et al. (1995) link it to growth and Aghion et al. (2009) to productivity growth in financially underdeveloped economies. Ghura and Grennes (1993) and Bleaney and Greenaway (2001) link it positively to investment but find no evidence of a growth effect for sub-Saharan Africa.

with the level of financial development, so real exchange rate volatility should be most harmful in countries with low financial development.

Although we refer to Eichengreen (2007) for a review of the large empirical literature, Cottani et al. (1990) show that real exchange rate stability is associated with increased investment and growth in developing countries. Dollar (1992) and Bosworth et al. (1995) also find a positive relationship with growth. Ghura and Grennes (1993) and Bleaney and Greenaway (2001) link real exchange rate stability to investment but not growth in sub-Saharan Africa. All of these studies may suffer from endogeneity problems, however. For example a decline in growth can potentially destabilize the real exchange rate as foreign capital flees the economy or the central bank either lowers interest rates to protect output or raises interest rates to protect the currency. Aghion et al. (2009) seek to address the potential endogeneity concern using system GMM estimation and find that real exchange rate instability decreases productivity growth in financially underdeveloped economies. However, the fact that their estimation procedure relies entirely on internal instruments requires them to assume that the lagged levels and differences of the variables of interest are only correlated with contemporary growth via contemporary real exchange rate volatility and financial development. As we discussed in the introduction, it is possible to think of scenarios where this assumption will fail to hold. In order to advance understanding further, we use commodity terms of trade volatility as an external instrument for real exchange rate volatility.

3. A Simple General Equilibrium Model

We study a simple general equilibrium model for a small open economy that is exposed to terms of trade shocks. Since our goal is to link terms of trade volatility to real exchange rate volatility

and GDP in the simplest possible framework we initially abstract from alternative shocks, such as productivity and monetary shocks. The model shows that uncertainty coupled with an irreversible investment cost to begin tradable goods production can deter entry to the tradable sector and decrease GDP. The model differs from the few previous models of real exchange rate uncertainty and output (Calvo et al. 1996, Aghion et al. 2009) because the results do not depend on the presence of labor market, nominal or financial frictions. The only distortion is the presence of an arbitrarily small entry cost into the tradable sector. It also differs from the literature on investment under uncertainty (Dixit 1994) in linking uncertainty to investment in a open-economy general-equilibrium framework rather than a firm or industry setting.

We assume that the economy has a unit mass of agents and consumes a composite import good (m) and a composite non-tradable good (n). Each agent's utility is

$$u = n^{\beta} m^{1-\beta} , \qquad (1)$$

where $\beta \in (0,1)$. A fraction of δ of the agents work in the tradable sector, where they produce an export good x, and a fraction $1-\delta$ work in the non-tradable sector. The prices of the export and non-tradable goods are measured in terms of import goods and denoted p_x and p_n. The international terms of trade are $p_x / p_m = p_x$. The small open economy assumption means that the export good is a negligible fraction of both the domestic and the foreign consumption bundles, so terms of trade shocks will only affect domestic prices and the real exchange rate via income. For the same reason we can assume that the price level of the average trading partner is constant and equal to unity.

The productivity level in both sectors is normalized to one, so each agent produces a single good. The sectors differ, however, in the fact that, in order to become a tradables producer, an agent must pay a fixed entry cost of f import goods. Assuming an entry cost to initiate tradables production seem plausible at least for emerging markets, where firms have limited previous exposure to the international marketplace and may have to upgrade quality. The assumption that there is a fixed cost of exporting also underpins the burgeoning volume of models of international trade with heterogeneous firms started by Marc Melitz and co-authors (Melitz 2003, Ghironi and Melitz 2005, Melitz and Ottaviano 2008). If we interpret the tradable sector as a manufacturing sector, the model can study an industrializing country that is opening up to trade, but whose structural transformation can be hindered by real exchange rate volatility.

The timing is that first agents choose a sector to produce in and tradable producers pay the fixed entry cost. Then the terms of trade p_x are determined by the world market. Then agents produce and then they consume. The terms of trade are distributed with cumulative density $F(p_x)$, mean μ_{p_x} and variance σ_{p_x}.

A. Equilibrium for a given labor allocation

We first characterize the equilibrium for any fixed share of the labor force allocated to tradable production δ and a fixed share allocated to non-tradable production $1-\delta$. Once the agents have produced they face the sector-specific budget constraints

$$p_n n + m \leq I_j, \tag{2}$$

where $I_j, j = x, n$ is the sector-specific income:

$$I_x = p_x \text{ and } I_n = p_n \quad . \tag{3}$$

Maximizing (1) subject to (2) implies constant expenditure shares on the non-tradable and the import good:

$$p_n n = \beta I_j \text{ and } p_m m = (1-\beta) I_j \, . \tag{4}$$

Since $p_m = 1$ the consumer price index is

$$P = p_n^{\beta} p_m^{1-\beta} = p_n^{\beta} \tag{5}$$

GDP measured in terms of the import good is

$$G = p_x^{\delta} p_n^{1-\delta} \tag{6}$$

The price of the non-tradable good must clear the non-tradable market. Solving the equilibrium condition $1-\delta = \beta X / p_n$ and using (6) implies the relative price

$$p_n = (\beta/(1-\delta))^{1/\delta} p_x . \tag{7}$$

Using (7) in (5)-(6) gives the equilibrium values of GDP, the consumer price index and the PPP-adjusted GDP level:

$$G = (\beta/(1-\delta))^{(1-\delta)/\delta} p_x \tag{8}$$

$$P = (\beta/(1-\delta))^{\beta/\delta} p_x^{\beta} \tag{9}$$

$$G^{ppp} \equiv X/P = (\beta/(1-\delta))^{(1-\delta-\beta)/\delta} p_x^{1-\beta} \ . \tag{10}$$

Since the price of foreign output is unity, the consumer price index P equals the price of domestic output in terms of foreign output, i.e. the real exchange rate. An increase in P is a real appreciation. For any given labor allocation δ, the real exchange rate is increasing in the terms of trade, $\partial P/\partial p_x = \beta(\beta/(1-\delta))^{\beta/\delta} p_x^{\beta-1} > 0$. In this simple model terms of trade shocks are actually the *only* cause of real exchange rate fluctuations. For any given labor allocation δ, from (8) we have $\partial \ln G^{ppp}/\partial \ln p_x = 1$, the elasticity of GDP in international prices with respect to the terms of trade is unity and independent of the trade share in GDP. The reason is that terms of trade gains increase the demand and the price of the non-tradable good in (7) proportionally to the tradable price. Thus the whole economy benefits equally from terms of trade fluctuations. In contrast, $\partial \ln G^{ppp}/\partial \ln p_x = 1-\beta$: the elasticity of the PPP-adjusted GDP level with respect to terms of trade shocks equals the import share in GDP. The PPP-adjusted GDP level is less sensitive to terms of trade gains because it accounts for the welfare loss as the price of non-

tradables is bid up during a terms of trade boom. Conversely, it corrects for the welfare gain from cheaper non-tradables caused by a terms of trade decline.

B. Labor allocation

We now consider the optimal labor allocation. When deciding which sector to enter workers compare the expected utilities from entering the tradable and non-tradable sectors. Using (1) and (4) the utility level for a sector j worker facing a realized terms of trade level p_x is

$$uj = (\beta I_j / p_n)^{\beta}((1-\beta)I_j)^{1-\beta} = KI_j / P, \tag{11}$$

.

where $K = \beta^{\beta}(1-\beta)^{1-\beta}$ and the general price level P is substituted from (5). Substituting (3) and (9) for the equilibrium income and price levels, and taking expectations over p_x, gives

$$E_{p_x}(u_x) = K(\beta/(1-\delta))^{-\beta/\delta} E_{p_x}\left(p_x^{1-\beta}\right) \tag{12}$$

$$E_{p_x}(u_n) = K(\beta/(1-\delta))^{(1-\beta)/\delta} E_{p_x}(p_x^{1-\beta}) = (\beta/(1-\delta))^{1/\delta} E_{p_x}(u_x), \tag{13}$$

Workers move until expected utility is equated across the two sectors:

$$E_{p_x}(u_n) = E_{p_x}(u_x) - f \tag{14}$$

Substituting (12) and (13) gives

$$KE_{p_x}\left(p_x^{1-\beta}\right)(\beta/(1-\delta))^{(1-\beta)/\delta} = KE_{p_x}\left(p_x^{1-\beta}\right)(\beta/(1-\delta))^{-\beta/\delta} - f \quad (15)$$

The labor allocation (15) has two important implications. First, without a fixed entry cost to the tradable sector, terms of trade and real exchange rate uncertainty will not affect the labor allocation. To see this note that for $f = 0$, (15) simply implies $1-\delta = \beta$ - the labor force share of non-tradables equals their constant expenditure share - and therefore $\partial(1-\delta)/\partial\sigma_{p_x}^2 = 0$. From (7) and (12)-(13) we have $p_n = p_x$ and $E_{p_x}(u_x) = E_{p_n}(u_n) = KE_{p_x}(p_x^{1-\beta})$, so terms of trade changes have identical welfare effects across sectors. Intuitively, while terms of trade gains only increase the income from tradable production directly, the rising income of tradable producers increases the demand for the non-tradable and its price in (7) increases proportionally to the tradable price. Because the aggregate risk due to terms of terms fluctuations is perfectly shared between the two sectors, it does not affect the relative return to producing the tradable or the labor allocation. Given the neutral effect on labor allocation, terms of trade fluctuations also do not affect GDP measured in international (non-PPP) prices, i.e., in (8) $\partial E_{p_x}(G)/\partial\sigma_{p_x} = 0$. Terms of trade volatility nonetheless decrease the *PPP-adjusted* GDP level in (10), which is a concave function of the terms of trade: $\partial^2 G^{PPP}/\partial p_x^2 < 0$, so $\partial E_{p_x}(G^{ppp})/\partial\sigma_{p_x}^2 < 0$. Intuitively, during terms of trade booms non-tradables become scarce relative to import goods and during terms of trade declines they become relatively abundant. The fluctuations in the marginal rate of substitution across imports and non-tradables due to the supply constraint on the latter decreases the expected utility level $E_{p_x}(u_x^{\delta}u_n^{1-\delta}) = KE_{p_x}(G^{PPP})$.

The second implication of (15) is that with any positive entry cost to the tradables sector, terms of trade volatility discourages entry into the tradable sector and decreases GDP both in international price and PPP terms. The reason is that with $f > 0$ (15) implies that $(1-\delta) > \beta$. The price of non-tradables in (7) is less than the price of tradables and therefore GDP increases with the labor force share of the tradable sector δ. The higher income offered by tradables production after entrepreneurs pay the fixed entry cost, $E_{p_x}(u_n) < E_{p_x}(u_x)$ in (12)-(13), means that the absolute income from tradables is more volatile: $\sigma^2_{u_n} = [(\beta/(1-\delta))^{1/\delta}]^2 \sigma^2_{u_x} < \sigma^2_{u_x}$. As terms of trade volatility increases, tradable production becomes less attractive and the sector's labor force share and GDP decrease. Formally, the employment falls in (15):

$$\partial E_{p_x}(p_x^{1-\beta}) / \partial \sigma^2_{p_x} < 0 \Leftrightarrow \partial \delta / \partial \sigma^2_{p_x} < 0. \tag{16}$$

The fall in the tradables sector employment share in turn decreases GDP in (8) and (10):

$$\partial G / \partial \sigma^2_{p_x} = p_x \underbrace{[\partial(\beta/(1-\delta))^{(1-\delta)/\delta} / \partial \delta]}_{>0} \underbrace{[\partial \delta / \partial \sigma^2_{p_x}]}_{<0} < 0 \tag{17}$$

$$\partial G^{ppp} / \partial \sigma^2_{p_x} = (\beta/(1-\delta))^{(1-\delta-\beta)/\delta} \underbrace{[\partial E(p_x^{1-\beta}) / \partial \sigma^2_{p_x}]}_{<0} + p_x^{1-\beta} \underbrace{[\partial(\beta/(1-\delta))^{(1-\delta-\beta)/\delta} / \partial \delta]}_{>0} \underbrace{[\partial \delta / \partial \sigma^2_{p_x}]}_{<0} < 0. \tag{18}$$

Lastly, note that (15) can be written

$$KE_{p_x}(p_n^{1-\beta}) = KE_{p_x}\left(p_n^{-\beta}\right) - f, \tag{19}$$

and therefore the labor allocation to the tradables sector δ and GDP in (8) and (10) only depend on the price of non-tradables p_n and the real exchange rate p_n^{β} rather than directly on the terms of trade p_x. In other words, terms of trade shocks only affect GDP via the real exchange rate. We summarize these results in the following proposition, which we prove in the appendix.

Proposition 1

Suppose there is a positive entry cost to the tradable sector $f > 0$. *Then*

(a) Terms of trade volatility increases real exchange rate volatility.

(b) Real exchange rate volatility decreases the labor force share of the tradable sector.

(c) Real exchange rate volatility decreases GDP in international as well as PPP prices.

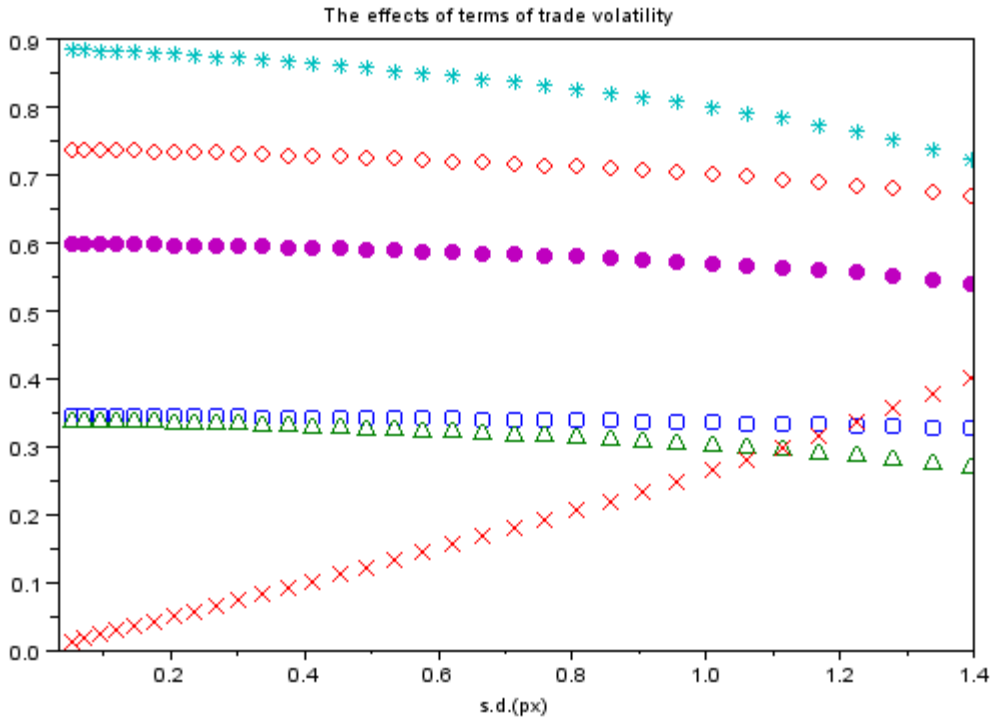
C. Numerical Simulation

Although the model does not allow for a closed for solution we simulate the outcomes numerically. Thus Figure 1 assumes that the terms of trade p_x are uniformly distributed on $[1-\varepsilon, 1+\varepsilon]$ with $\varepsilon \in [0.1, 0.9]$ and mean unity. We set the fixed entry cost to the tradable sector to $f = 0.4$ or 40% of the profit and the expenditure shares on non-tradables to $\beta = 0.5$. Given the distribution of p_x we compute the distributions for $p_x^{1-\beta}$ and p_x^{β}. We then compute real exchange rate variance using from (9) $\sigma_P^2 = \left[(\beta/(1-\delta))^{\beta/\delta}\right]^2 \sigma^2_{p_x^{\beta}}$, and solve (8), (10), (12), (13), (15) for expected real GDP in international and PPP prices, expected utility in the two sectors, the labor force share of the tradable sector and the standard deviation of the real exchange $\sqrt[2]{\sigma_P^2}$.

The simulation results in Figure 1 show that increasing terms of trade volatility increases real exchange rate volatility and decreases the labor force share of the tradable sector and GDP

measured in international as well as PPP prices. As the standard deviation of the terms of trade increases from zero to the maximum of 1.4 the employment share of the tradable sector decreases from about 34.5% to 32.6% of the total labor force. The standard deviation of the real exchange rate increases monotonically and expected GDP in international price and PPP terms decrease by about 11% and 19%. These findings show that real exchange rate volatility can be associated with large output drops even when the only distortion is a fixed cost of entering the tradable sector and we abstract from nominal rigidities, credit market failures, increasing returns and pecuniary externalities (Calvo et al. 1996, Mishkin 1996, Bianchi 2011, Benigno et al. 2013, Mishkin 1996, Aghion et al. 2009, Calvo 1998, Benigno and Fornaro 2013).

Figure 1 The effects of terms of trade variability on economic outcomes. The labor force share of the tradable sector (o), standard deviation of the real exchange (x), utility from non-tradable and tradable production (Δ and ◊) and international-price and PPP-adjusted GDP (• and*) against the standard deviation of the terms of trade. β=0.5, f=0.4, μ_{px}=1, p_x~U[1-ε,1+ε], ε∈[0.1,0.9].



D. The effect of sticky prices, a monetary authority and reserves access

[to be completed]

4. Data and methodology

We use an annual country panel dataset spanning 1970 to 2009. We study separately a full sample of countries, OECD countries as distinct from emerging markets, a sample of commodity exporters which includes both OECD and non-OECD countries, and Latin America, which is considered particularly vulnerable to external shocks. The dependent variable in the estimations is the annual growth rate of PPP-adjusted per-capita GDP. [note: run with real GDP as a robustness check?] Real exchange rate volatility is measured as the standard deviation of country $i's$ real effective exchange rate (REER) over the twelve months of each calendar year. The computation of the REER is described in the appendix. The instrument for REER volatility is the volatility of the commodity terms of trade (CTOT) index used in Aizenman et al. (2012). We describe this index in the appendix and refer to Aizenman et al. (2012) for further discussion. The volatility of the index is constructed the same way we construct the volatility of the REER, i.e., it is the standard deviation over the twelve months of the calendar year. The empirical specification is

$$g_{it} = \alpha_0 + \alpha_1 REERVol_{i(t-1)} + \phi_i + \rho_t + \eta t + \varepsilon_{it}, \qquad (1)$$

where g_{it} is the growth rate of real PPP-adjusted GDP per capita in country i in year t. On the right hand side, $REERVol_{i(t-1)}$ is the lagged value of REER volatility, φ_i and ρ_t are country

fixed effects, t is a time trend, and ε_{it} is an i.i.d. error term. The lagged measure of real exchange rate volatility, $REERVol_{i(t-1)}$, is estimated in the first stage of the IV procedure using the lagged volatility of the country's commodity terms of trade, $CTOTVol_{i(t-1)}$, as instrument and including the other regressors. Tables 1-2 display the summary statistics and sample countries.

5. Results

Table 3 presents results for the relationship between commodity terms of trade volatility, real exchange rate volatility and reserves management. In OECD countries terms of trade volatility is significantly related to real exchange rate volatility, while in emerging markets – as previously documented by Aizenman et al. (2012) – reserves management seems to play a crucial role: countries with larger reserves are better able to buffer the real exchange rate against commodity price fluctuations, most likely by intervening in the foreign exchange market. In Table 4 we show the simple OLS results from regressing economic growth on real exchange rate volatility in a fixed effects panel. We find that growth and real exchange rate volatility are strongly related in both the full sample and all subsamples. In Table 5 we proceed to use the real exchange rate determinants identified in Table 3 to correct for the potential endogeneity of real exchange rate volatility to growth in Table 4. Comparing the coefficients on real exchange rate volatility across Tables 4 and 5 informally or contrasting them formally via a Hausman test (see the bottom of Table 5) suggests that real exchange rate volatility is endogenous to growth at least at the OECD sample, which might be expected. However, we cannot reject that real exchange rate volatility as exogenous in the emerging market samples. Nonetheless, to proceed cautiously we continue to estimate the growth-real exchange rate volatility relationship using IV estimation for all country

groups. We also note that the first stage estimates show that commodity terms of trade volatility and, in some specifications, its interaction with reserves are good predictors of real exchange rate volatility: the Kleibergen-Paap Rk Wald F statistics consistently reject that the model is under-identified and that the true size of the five percent significance test exceeds ten percent due to weak instruments (Stock and Yogo 2002).

The IV estimates in Table 5 suggest that the adverse effects of real exchange rate volatility may be mainly an emerging market phenomenon. The point estimate for the OECD sample is insignificant and actually positive, while the estimates are significantly negative for emerging markets. In the emerging market sample, one standard deviation increase in real exchange rate volatility decreases growth by about 2.2 percentage points.[2] Comparing the means for real exchange rate volatility across the OECD and emerging economy samples in Table 1 further reveals that emerging markets are exposed to much greater real exchange rate volatility. They therefore seem to experience larger growth losses due to both, the greater marginal effect of real exchange rate volatility and the greater absolute volatility levels they are exposed to.

In Table 6 we study the potential mediating effect of trade openness in the relationship between real exchange rate volatility and growth. More open economies should be more vulnerable to real exchange rate shocks all else constant (Rodrik 1998, 1999).[3] In order to control for the potential endogeneity of trade openness we use five-year average trade openness (the sum of imports and exports relative to GDP) preceding the first sample year as an instrument for trade openness. The results show, as expected, that more open economies are more vulnerable to real exchange rate volatility than closed economies.

[2] Including all controls in the same regression yields a very similar estimate of -0.018 (significant at the 10% level).
[3] Another reason to control for trade openness is if some economies, such as middle income economies, tend to be trade more, be more exposed to real exchange rate volatility and have high growth rates.

6. Empirical Robustness

Although in principle IV estimation makes it unnecessary to consider other growth determinants, in Table 7 we control for the lagged growth rate of TFP in the non-tradables sector relative to the tradables sector, the lagged value of GDP per capita and its square, inflation and squared inflation. The first control intends to capture the Harrod-Balassa-Samuelson effect, i.e., the hypothesis that productivity tends to grow faster in the tradables than the non-tradables sector and therefore GDP growth may be correlated with REER appreciation (Rogoff 1996). Income per capita, openness and inflation could also be correlated with REER volatility if high-income countries have a larger non-tradables share in GDP, more open economies are more likely to sustain purchasing power parity due to lack of trade barriers, or inflation destabilizes the nominal exchange rate (Dornbusch 1985, De Gregorio et al. 1994, Rogoff 1996).

7. Conclusion

This paper has studied the link between real effective exchange rate volatility on economic growth. After presenting a simple open-economy general equilibrium model, we tested its key predictions and documented a number of stylized facts. Commodity terms of trade volatility and its interaction with the stock of reserves are a strong predictor of real exchange rate volatility, which in turn is negatively related to trade openness and growth. The negative growth effect of real exchange rate volatility is mainly a problem for emerging markets, which are more vulnerable to a given real exchange rate shock as well as more exposed to such shocks. Lastly, as expected we find that the adverse effect of real exchange rate volatility increases with the exogenous component of trade openness.

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Appendix

Variable Definitions

Real GDP Growth: The yearly (quarter-to-quarter) percentage change of real $US GDP ($Y_i$) for each country i, ln(Y(t))-lnY(t-4)). The main source is the IMF International Financial Statistics (IFS) dataset, where we use the deflator provided by the IMF to deflate the nominal value of domestic currency GDP for each country. Then, we transform that value into US$ using the nominal exchange rate provided in IFS. Other sources used in the paper for real GDP are OECD Source, Economic Intelligence Unit (EIU), DataStream (DS) and the CEIC Data Company Ltd. (CEIC).

Commodity Terms of Trade: We use the commodity terms-of-trade (CTOT) dataset from Aizenman et al. (2012). The CTOT index is the ratio of a weighted average price of a country's main commodity exports to a weighted average price of its main commodity imports. Specifically, CTOT for country j in period t is

$$CTOT_{jt} = \prod_i (P_{it} / MUV_t)^{X_j^i} / \prod_i (P_{it} / MUV_t)^{M_j^i},$$

where P_{it} is a common price index for six commodity categories (food, fuels, agricultural raw materials, metals, gold, and beverages) in year t; X_j^i is country $j's$ average share of exports of commodity i as a percent of GDP from 1970 to 2009; M_j^i is the corresponding average share of imports. The commodity prices are deflated by a manufacturing unit value index (*MUV*). Since X_j^i and M_j^i are averaged over time, the movements in $CTOT_{jt}$ are invariant to changes in

export and import volumes in response to price fluctuations. They, therefore, isolate the impact of commodity prices on the country's commodity terms of trade. By excluding industrial goods, and concentrating on commodity prices, the CTOT focuses on the most volatile component of import and export prices. We refer to Aizenman et al. (2012) for more details and data sources.

Real Effective Exchange Rates (REER): The real effective exchange rate index represents a trade-weighted nominal effective exchange rate index adjusted for relative movements in national prices, $REER = \Pi_i [(e/e_i)(P/P_i)]^{w_i}$, where e: Exchange rate of the subject currency against the US dollar (US dollars per currency in index form); ei: Exchange rates of currency i against the US dollar (US dollars per currency i in index form); wi: bilateral trade based weights attached to the country/ currency i in the index. The weights are calculated based on total (exports + imports) bilateral trade; P: Consumer Price Index (CPI) of Subject country and Pi is the Consumer price index of country i. An Increase in REER implies a Real Domestic Appreciation. Data belongs to the IFS dataset, OECD and JP Morgan.

Stock of Reserves: Defined as the total stock of international reserves minus gold. Sources are IFS, DS and EIU.

Trade Openness: Trade openness is the sum of merchandise exports and imports divided by twice the value of nominal GDP, all in current U.S. dollars. Data for Imports and Exports was extracted from IFS, DS, EIU and CEIC

Financial Development: Primary financial development measure is the ratio of private domestic credit to GDP from x. Alternatively, we use the M2/GDP ratio, where we retrieve M2 data from the IFS

Total Gross Capital Flows: Total gross capital flows are the sum of the absolute value of all liability increases and decreases plus total asset increases and decreases from the capital and

financial balance of each country as reported in the IMF's Balance of Payments Statistics (BOPS).

Current Account: From BOPS.

Inflation: Domestic CPI Inflation. Main sources are IFS, DS, EIU and CEIC.

Relative non-tradables TFP growth The measure of relative non-tradables TFP growth is constructed as weighted average TFP growth in non-tradables industries relative to weighted average TFP growth in tradeables industries. The industry TFP growth data is from the OECD Source dataset, where we define agriculture, mining, manufacturing and energy as tradables sectors and construction, wholesale and retail trade, finance and business sector services as non-tradables sectors. The weights used to aggregate the industries in a sector were calculated using industry value added from UNdata.

Tables and Figures

Table1: Summary Statistics

ALL COUNTRIES

Variable	Obs	Mean	Std. Dev.	Min	Max
Growth	1704	0.026377	0.034688	-0.18754	0.182689
REER volatility	1704	2.80949	2.377383	0.353443	27.47543
CTOT volatility	1704	0.00747	0.007753	0.000232	0.079333
Reserves	1673	0.105101	0.112658	0.000968	1.067249
Trade openness	1696	0.621281	0.524312	0.085116	3.56117
Financial Dev.	1717	0.70201	0.465582	0.07979	2.762488

OECD COUNTRIES

Variable	Obs	Mean	Std. Dev.	Min	Max
Growth	886	0.024124	0.023384	-0.0575	0.097408
REER volatility	886	1.942508	1.155011	0.353443	6.877339
CTOT volatility	886	0.006505	0.006549	0.000806	0.071981
Reserves	878	0.063677	0.052266	0.001745	0.325713
Trade openness	878	0.514236	0.268193	0.085116	1.826058
Financial Dev.	904	0.876274	0.48443	0.128154	2.762488

EMERGING MARKETS

Variable	Obs	Mean	Std. Dev.	Min	Max
Growth	818	0.028816	0.043639	-0.18754	0.182689
REER volatility	818	3.748544	2.939067	0.479028	27.47543
CTOT volatility	818	0.008517	0.008759	0.000232	0.079333
Reserves	795	0.150851	0.140413	0.000968	1.067249
Trade openness	818	0.736177	0.683806	0.102045	3.56117
Financial Dev.	813	0.50824	0.35457	0.07979	1.642509

COMMODITY EXPORTERS

Variable	Obs	Mean	Std. Dev.	Min	Max
Growth	244	0.020466	0.039792	-0.17293	0.182689
REER volatility	244	3.763892	2.975286	0.544709	15.81214
CTOT volatility	244	0.01385	0.014333	0.001294	0.079333
Reserves	244	0.087605	0.063534	0.007676	0.315937
Trade openness	244	0.432974	0.12338	0.102045	0.698151
Financial Dev.	238	0.557303	0.385246	0.094687	1.807956

LATIN AMERICA

Variable	Obs	Mean	Std. Dev.	Min	Max
Growth	234	0.019649	0.047453	-0.08035	0.182689
REER volatility	234	4.833511	3.111635	0.544709	15.81214
CTOT volatility	234	0.013155	0.011079	0.001675	0.079333
Reserves	234	0.099447	0.055795	0.012107	0.250137
Trade openness	234	0.324099	0.132861	0.102045	0.667818
Financial Dev.	261	0.350921	0.196994	0.099108	1.1305

Table 2: Countries Included

OECD		EMERGING		COMEX	LATAM
Australia	Spain	Argentina	Peru	Australia	Argentina
Austria	Sweden	Brazil	Philippines	Canada	Brazil
Belgium	Switzerland	Bulgaria	Poland	Chile	Chile
Canada	United Kingdom	Chile	Romania	Mexico	Colombia
Cyprus	United States	China	Russian Federation	Norway	Mexico
Denmark		Colombia	Saudi Arabia	Russian Federation	Peru
Finland		Croatia	Singapore	Saudi Arabia	Uruguay
France		Czech Republic	Slovak Republic	South Africa	Venezuela, RB
Germany		Hong Kong, China	Slovenia	Venezuela, RB	
Greece		Hungary	South Africa		
Iceland		India	Thailand		
Ireland		Indonesia	Turkey		
Italy		Israel	Uruguay		
Japan		Korea, Rep.	Venezuela, RB		
Netherlands		Malaysia	Latvia		
New Zealand		Mexico	Estonia		
Norway		Morocco	Lithuania		
Portugal		Pakistan			

Table 3: Commodity Terms of Trade Shocks, Reserves Management and REER Volatility

	OECD	OECD	Emerging	Emerging	ComEX	ComEX	Latam	Latam
	REERvol	REERvol	REERvol	REERvol	REERvol	REERvol	REERvol	REERvol
CTOTvol (t)	26.3***	-3.91	-32.04	29.58	-33.07	36.93	-51.83	57.84*
	[8.74]	[24.27]	[35.93]	[39.42]	[36.67]	[35.47]	[39.70]	[29.69]
CTOTvol * RES (t)		259.15		-428.17***		-449.57***		-1,090.1***
		[161.75]		[145.81]		[69.0]		[206.2]
Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Euro Dummy	Yes	Yes	Yes	Yes	No	No	No	No
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	886	878	818	795	244	244	234	234
# of Countries	23	23	31	31	8	8	8	8

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. RES refers to International Reserves in US dollars as a fraction of GDP. All variables are calculated as a 3 year moving averages

Table 4: Growth and REER Volatility (Panel OLS Estimation)

	All	OECD	Emerging	ComEX	Latam
	Growth	**Growth**	**Growth**	**Growth**	**Growth**
REERvol (t-1)	-0.0044***	-0.0024**	-0.0046***	-0.0048**	-0.0042***
	[0.0010]	[0.0009]	[0.0010]	[0.0017]	[0.0011]
Time Trend	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1773	886	887	302	234
# of Countries	55	23	32	9	8
R-squared	0.1982	0.4763	0.2425	0.4117	0.4987

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Growth refers to real GDP per capita per cent annual change. All variables are calculated as a 3 year moving averages

Table 5: Growth and REER Volatility (Panel IV Estimation based on Table 4)

	All	OECD	Emerging	ComEX	Latam
	Growth	**Growth**	**Growth**	**Growth**	**Growth**
REERvol (t-1)	-0.0158***	0.0021	-0.0075*	-0.0088**	-0.0041*
	[0.0045]	[0.0044]	[0.0040]	[0.0037]	[0.0023]
Time Trend	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1673	922	795	244	234
# of Countries	54	24	31	8	8
Instruments (t-1)	CTOTvol CTOTvol*RES RES	CTOTvol	CTOTvol CTOTvol*RES RES	CTOTvol CTOTvol*RES RES	CTOTvol CTOTvol*RES RES
Kleibergen-Paap rk LM statistic	30.9558	17.5525	38.1034	26.2572	26.6156
Chi-sq P-val	0.000	0.000	0.000	0.000	0.000
Kleibergen-Paap rk Wald F statistic	9.4397	32.0735	14.7669	15.5258	12.8163
Stock-Yogo weak ID test critical values: 5%					
10% maximal IV rel bias	9.08		9.08	9.08	9.08
20% maximal IV rel bias	6.46		6.46	6.46	6.46
30% maximal IV rel bias	5.39		5.39	5.39	5.39
10% maximal IV size	22.3	16.38	22.3	22.3	22.3
15% maximal IV size	12.83	8.96	12.83	12.83	12.83
20% maximal IV size	9.54	6.66	9.54	9.54	9.54
25% maximal IV size	7.8	5.53	7.8	7.8	7.8
Hansen J Statistic	0.4289		0.6677		
Hansen J P-Value	0.807		0.7161		
Hauman Endog. Test					

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. RES refers to International Reserves in US dollars as a fraction of GDP. All variables are calculated as a 3 year moving averages. Regional Dummies are included in the full sample specification

Table 6: The Mediating Effect of Trade Openness

	All	OECD	Emerging	ComEX	Latam
	Growth	**Growth**	**Growth**	**Growth**	**Growth**
REERvol (t-1)	-0.0122***	-0.0079	-0.0070*	-0.0071	0.0211**
	[0.0037]	[0.0075]	[0.0042]	[0.0076]	[0.0097]
REERvol *TO (t-1)	-0.0018	0.0186	-0.0145**	-0.0076	-0.0893**
	[0.0047]	[0.0140]	[0.0067]	[0.0282]	[0.0369]
Time Trend	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Observations	1673	886	795	244	234
# of Countries	54	23	31	8	8
Instruments (t-1)	CTOTvol CTOTvol*RES CTOTvol*TO CTOTvol*RES*TO RES	CTOTvol CTOTvol*TO	CTOTvol CTOTvol*RES CTOTvol*TO CTOTvol*RES*TO RES	CTOTvol CTOTvol*RES CTOTvol*TO CTOTvol*RES*TO	CTOTvol CTOTvol*RES CTOTvol*TO CTOTvol*RES*TO RES
Kleibergen-Paap rk LM statistic	56.53	16.96	47.74	19.42	26.71
Chi-sq P-val	0.000	0.000	0.000	0.001	0.000
Kleibergen-Paap rk Wald F statistic	12.24	11.60	12.36	4.16	6.34
Stock-Yogo weak ID test critical values: 5%					
10% maximal IV rel bias	8.78		8.78	7.56	8.78
20% maximal IV rel bias	5.91		5.91	5.57	5.91
30% maximal IV rel bias	4.79		4.79	4.73	4.79
10% maximal IV size	19.45	7.03	19.45	16.87	19.45
15% maximal IV size	11.22	4.58	11.22	9.93	11.22
20% maximal IV size	8.38	3.95	8.38	7.54	8.38
25% maximal IV size	6.89	3.63	6.89	6.28	6.89
Hansen J Statistic	11.09		7.07	8.51	
Hansen J P-Value	0.01		0.07	0.04	

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. RES refers to International Reserves in US dollars as a fraction of GDP. All variables are calculated as a 3 year moving averages. TO refers to Initial (5 year average) of Total Trade over GDP