The Effects of Real Exchange Rate Volatility on Productivity Growth

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Abstract
This paper employs panel data instrumental variable regression and threshold effect estimation methods to study the link between real effective exchange rate volatility and total factor productivity growth. The results illustrate that real effective exchange rate volatility negatively affects total factor productivity growth. But this effect is not very high. This outcome is corroborated by estimations using an alternative measurement of real effective exchange rate volatility and on a subsample of developed countries. But for developing countries the negative effect of real effective exchange rate volatility is very large. We also found that real effective exchange rate volatility acts on total factor productivity according to the level of financial development. For very low and very high levels of financial development, real exchange rate volatility has no effect on productivity growth but for moderately financially developed countries, real exchange rate volatility reacts negatively on productivity.

Keywords: real effective exchange rate, volatility, total factor productivity growth, panel data instrumental variable regression, threshold effect estimation, stochastic frontier analysis

Introduction

The main goal of this paper is to study the empirical link between real effective exchange rate volatility and total factor productivity growth.

Pushing further the research program launched by the analysis of the relationship between volatility and growth in general and the real exchange rate instability-growth nexus in particular, recent works have focused on the study of the connection between real exchange rate volatility and productivity. In the literature, there are two papers that analyze the association between exchange rate volatility and productivity growth: (Aghion et al., 2006) and (Benhima, 2010). Two of the identified channels through which exchange rate volatility affects productivity are investment and exports. The instability of the real exchange rate changes market signals, disorients investors and leads to an inefficient allocation of investment which in turn acts negatively on total factor productivity. Real exchange volatility can shrink tradable goods exports and foreign direct investment by the uncertainty it creates. This fall in both exports and foreign direct investment may consequently hinder total factor productivity. (Aghion et al., 2006) use a panel of 83 countries from 1960 to 2000. They find that real exchange rate volatility can have a non-negligible effect on productivity growth, and the impact is function of the level of the financial development of the countries. Exchange rate volatility acts negatively on productivity growth in countries with low levels of financial development while it has no effect on countries with high levels of financial development. (Benhima, 2010) argues that the effect of exchange rate flexibility on productivity can also depend on liability dollarization. In a panel of 76 countries going from 1995 to 2004, she discovers that the negative impact of exchange rate flexibility on productivity is more pronounced in countries with high degree of dollarization.

This paper fits into the related literature by conducting a general study on the relationship between real effective exchange rate volatility and total factor productivity growth. As indicated above, there are not many works that analyze this particular and important connection. Hence we contribute to this literature in the following manner. Firstly, in the previous literature, productivity growth is measured as the ratio of real output per worker. Thus the variable used for productivity growth is a measurement of partial productivity. To solve this problem, we introduce a new measurement of total factor productivity growth derived from the stochastic production frontier literature (Kumbhakar and Lovell, 2000). Secondly, to take account the potential nonlinear effects of real exchange rate volatility on productivity growth, the previous works use an interaction of real exchange rate volatility and financial development. There is no problem with this econometric method but it only captures the nonlinearity in the variables. To solve this, we utilize the (Hansen, 1999) method of estimating thresholds effects in non-dynamic panel data. This method allows us to take account the potential existence of nonlinearity. Thirdly, we introduce two measurements of real exchange rate volatility that have not been used before. The first of these is the standard deviation of the residuals of the REER regressed on its lagged value and a trend. The second measure is based on the Fano Factor (ratio of the variance and the mean of a random process in some time window). The results show, first, that real exchange rate volatility affects negatively productivity growth. Robustness analysis demonstrates that this outcome is corroborated by estimations using an alternative measurement of real effective exchange rate volatility and on subsamples of developed and developing countries. Moreover, for developing countries the negative effect of real effective exchange rate volatility is very large. Second, the results illustrate that the effect of real exchange rate volatility on productivity depends on the level of financial development. For very low levels of financial development, real exchange rate volatility has no effect on productivity growth. For moderately financially developed countries, real exchange rate volatility reacts negatively on productivity and for highly financially developed countries, real exchange rate volatility has no effect on productivity. The intuition behind this result is that countries that are poorly financially developed do not have the infrastructure (high capital stock, high investment, large financial connections) to make them vulnerable to real effective exchange rate (REER) volatility. They need to become slightly larger for REER play a role. In contrast in countries that are moderately financially developed, the financial network is fairly large and many firms are connected financially. Hence any REER volatility can harm the system. Finally countries that are highly financially developed have many insurance and protection mechanisms that protect them against the detrimental effects of REER volatility.

I am grateful to Patrick Guillaumont, Olivier Cadot, Mohamed Chaffai, Michael Goujon for helpful comments and suggestions. All remaining errors are mine.

The remainder of the paper is organized as follows. The second section presents the econometric models and estimations methods; the third section analyzes the data and variables. The fourth section gives the results and the last part concludes.

Econometric models and estimations methods

In this section, we give a brief review of the econometric methods used to estimate the relationship between real exchange rate volatility and productivity growth.

The panel data instrumental variable estimation method

We use the panel data instrumental variable method to estimate a model of the form:

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$$TFPG_{it} = \alpha REERVOL_{it} + X_{it}\beta + \mu_i + \varepsilon_{it} \quad (1)$$

Where $TFPG_{it}$ is total factor productivity growth; $REERVOL_{it}$ the logarithm of real effective exchange rate volatility; X_{it} indicates the control variables utilized in the study; μ_i are the individual specific effects; ε_{it} is the idiosyncratic error term; i specifies countries and t the time. The control variables used are: financial development, openness, human capital, government consumption, inflation, trend of terms of trade and a crisis variable. We use panel data instrumental variable to estimate the model in (1) because we suspect real exchange rate volatility to be endogenous. We use only lagged real exchange rate volatility as instrument.

The threshold effect estimation method

The fact that the threshold variable is dependent on financial development comes from the theoretical model developed by (Aghion et al., 2006). This is why we use the (Hansen, 1999) method of thresholds estimation in non-dynamic panels to test for the potential nonlinear effects of REER volatility on productivity.

We estimate an equation having the following form:

$$TFPG_{it} = \alpha_1 REERVOL_{it} I(FD_{it} \le \gamma) + \alpha_2 REERVOL_{it} I(FD_{it} > \gamma) + X_{it}\beta + \mu_i + \varepsilon_{it} \quad (2)$$

Where $I(\cdot)$ is the indicator function; FD_{it} is the financial development variable (ratio of domestic credit to private sector to GDP); γ is the threshold level; α_1 and α_2 are the marginal effects of real exchange rate volatility which can be different according to the threshold level; all other variables are defined the same way as in equation (1). In this study we use a triple threshold model. This means that we can rewrite equation (2) as:

$$\begin{aligned} TFPG_{it} = {} & \alpha_1 REERVOL_{it} I(FD_{it} \le \gamma_1) + \alpha_2 REERVOL_{it} I(\gamma_1 < FD_{it} \le \gamma_2) \\ & + \alpha_3 REERVOL_{it} I(\gamma_2 < FD_{it} \le \gamma_3) + \alpha_4 REERVOL_{it} I(\gamma_3 < FD_{it}) \\ & + X_{it}\beta + \mu_i + \varepsilon_{it} \end{aligned} \quad (3)$$

Where the thresholds are ordered, hence $\gamma_1 < \gamma_2 < \gamma_3$.

Data and variables

In this section, we present the data used in the study and show how the variables of interest are calculated.

Description of the data

The sample of study contains 74 countries: 24 developed and 50 developing countries over the period 1975-2004. The choice of the sample is based on the availability of data, the choice of the variables of the study and because we want to investigate both developed and developing countries. Our study focuses on medium and long term relations, thus the averages over five years were calculated. The data essentially come from the World Bank (World Development Indicators, 2006), Barro and Lee (2010), International Financial Statistics (IFS), April 2006, Centre d'Études et de Recherches sur le Développement International (CERDI) 2006, (Caprio and Klingebiel, 2003), and (Kaminski and Reinhart, 1999).

The calculation of Total Factor Productivity Growth

The previous works use output per worker as a measure of productivity. This is a partial or incomplete measurement of productivity. A better indicator of a country's productivity is total factor productivity, which attempts to incorporate the efficacy with which both capital and labor inputs are employed. Additionally, this paper is the first to introduce a measure of total factor productivity exploiting the stochastic nature of the economy. We use the primal approach of decomposition of total factor productivity developed by (Kumbhakar and Lovell, 2000). We estimate the following flexible translog production function:

$$\ln y_{it} = \beta_0 + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \frac{1}{2}\beta_{KK}\left(\ln K_{it}\right)^2 + \frac{1}{2}\beta_{LL}\left(\ln L_{it}\right)^2 + \beta_{KL}\ln K_{it}\ln L_{it} + \beta_{tK} t\ln K_{it} + \beta_{tL} t\ln L_{it} - u_{it} + v_{it} \quad (4)$$

Where the variables are capital K_{it} and labor L_{it}; $\exp(-u_{it})$ is the technical efficiency; v_{it} is the stochastic error term; t indicates time and i indexes the countries. If technical inefficiency $u_{it} \geq 0$, then technical efficiency, $\exp(-u_{it})$, lies in the range $(0,1]$. Technical inefficiency is calculated

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according to the (Battese and Coelli, 1992) specification. After this we calculate the components of total factor productivity growth by using the information coming from the estimation of equation (4) (Kumbhakar and Lovell, 2000).

Table 1, in the appendices, presents the maximum likelihood estimates of the translog stochastic production function given in equation (4). The majority of the coefficients β are significant at conventional levels. The Wald test shows that the Cobb Douglas function is rejected as the suitable representation of the data. We conducted a Wald test instead of a likelihood ratio test for the Cobb Douglas specification because we could not obtain the estimates for this restriction in order to perform the likelihood ratio test. The coefficient of the interaction between capital and labor is negative indicating the existence of substitution effect between the two production factors. The coefficient of time squared is positive indicating that the second part of the neutral part of technological progress has a positive effect on output. The signs of the interaction of capital and time, on the one hand, and labor and time, on the other hand, illustrate that the non-neutral part of technological progress increases with capital and decreases with labor. The coefficient of capital is not significant but that of capital squared is positive and significant, meaning that very high levels of capital have a positive effect on output. The coefficient of labor and labor squared are respectively negative and positive. This suggests that at low levels, labor reduces output but very high levels of labor augment output. The inverse logit of γ is highly statistically significant and the value of γ is very close to 1. This means that a great part of the disturbance term is due to the existence of technical inefficiency. The estimated value of η is positive and significant, suggesting that the degree of inefficiency decreases over time toward the base level. The last period for each country i contains the base level of technical inefficiency. The estimated parameters in Table 1 allow us to carry out the decomposition of total factor productivity growth according to (Kumbhakar and Lovell, 2000) method.

The measurement of Real Effective Exchange Rate Volatility

We calculate two measurements of REER volatility. We employ two measures for robustness purposes. As indicated above these two variables have not been used before. The first measurement is calculated according to (Combes *et al.,* 1999). In the results this first measurement of real effective exchange rate volatility is referred to as REER volatility 1. The second measurement of real exchange rate instability is calculated as the Fano factor named after the physicist Ugo Fano, who invented it (Fano, 1947). In the results this second measurement of real effective exchange rate volatility is referred to as REER volatility 2. The use of the Fano factor is one of the contributions of this paper. Despite its simplicity, it is the first time that this variable is employed as a measure of volatility in all the field of Economics. I am not aware of any other work that has done it.

Results

In this section, we will respectively present the results of the panel data instrumental variable estimation and those of the threshold effect estimation.

Panel data instrumental variable estimation results

Table 2, in the appendices, gives the panel data instrumental variable estimation results for all countries with the variable real effective exchange rate volatility 1. The results of the Anderson LM statistic illustrate that all our equations are identified. This means that the excluded instrument is pertinent, implying that it is linked with the endogenous variable. The Weak identification test shows that the identification is strong as the Cragg-Donald Wald F statistic is above 15% of OLS bias. Hence our excluded instrument is not weakly correlated with the endogenous regressor. The Sargan-Hansen J statistic is not reported because it is always zero since our model is exactly identified. This is because we use only one instrument. The F-test for the joint significance of all the coefficients is fairly high and significant in all equations. The R-squared is not reported since it actually has no statistical meaning in the situation of 2SLS/IV. The number of observations largely decreases when we introduce the crises variable but remains in reasonable proportions in the other estimations.

All eight equations in Table 2 show that real effective exchange rate volatility is statistically significant at conventional levels and have the expected sign. Except equation (1) and (4), we observe that the effect of REER volatility is not too high. Referring to regression (7), an increase in REER volatility by 100% reduces total factor productivity growth just

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by an amount equivalent to 0.362 percentage points. The absolute value of the REER volatility coefficient in equations (1) and (4) diminishes drastically when we control for both human capital and financial development in regressions (2) and (3), and from estimations (5) to (8). This suggests that the effect of REER volatility on total factor productivity growth may pass through these last two variables. We observe that the standard errors of the coefficients of REER volatility are very small. This implies that the corresponding confidence intervals, though not reported, are tinier meaning that the coefficients of REER volatility are estimated with great precision. The use of instrumental variables in the estimations makes it possible to say that the negative relation between REER volatility and total factor productivity growth seems to go from REER volatility towards productivity growth and not the reverse. This result of adverse impact was also found by (Aghion et al., 2006). They discovered that real exchange rate volatility have a negative and significant effect on productivity in the long-run. Hence our finding is similar to theirs. Thus our estimations corroborate those found in the literature by using different measurements of REER volatility and productivity, and also different regression techniques.

The results also highlight that total factor productivity growth is strongly positively influenced by human capital and financial development. But the effect of human capital is more marked than that of financial development. The other variables have the expected signs but are statistically insignificant.

Table 3, in the appendices, provides the panel data instrumental variable estimation results for the developed countries with the variable real effective exchange rate volatility 1. The results of the Anderson LM statistic illustrate that all our equations are identified. This means that the excluded instrument is pertinent, implying that it is linked with the endogenous variable. The Weak identification test shows that the identification is strong as the Cragg-Donald Wald F statistic is above 20% of OLS bias. Hence our excluded instrument is not weakly correlated with the endogenous regressor. The Sargan-Hansen J statistic is not reported because it is always zero since our model is exactly identified. This is because we use only one instrument. The F-test is statistically significant in all equations. The coefficient of determination is not reported since it actually has no statistical meaning in the situation of 2SLS/IV.

The results in Table 3 illustrates that REER volatility affects negatively total factor productivity growth in developed countries. As in the main estimations, we observe that the effect of REER volatility is very small. Also the standard errors of REER volatility are small. But, contrary to the main results, the coefficient of REER volatility remains stable after we introduce financial development, human capital and, more generally, the other control variables. As in the main estimations, the impact of human capital remains larger than that of financial development. It is important to notice here that inflation and the crises variable become significant in most equations and have the expected signs. The other remaining variables have the expected signs but are not significant.

Table 4, in the appendices, shows the panel data instrumental variable estimation results for the developing countries with the variable real effective exchange rate volatility 1. The results of the Anderson LM statistic illustrate that all our equations are identified. This means that the excluded instrument is pertinent, implying that it is linked with the endogenous variable. The Weak identification test shows that the identification is strong as the Cragg-Donald Wald F statistic is above 20% of OLS bias. Hence our excluded instrument is not weakly correlated with the endogenous regressor. The Sargan-Hansen J statistic is not reported because it is always zero since our model is exactly identified. This is because we use only one instrument. The F-test is statistically significant and the coefficient of determination is not reported since it actually has no statistical meaning in the situation of 2SLS/IV.

As stated above, Table 4 presents the results of the estimations for the developing countries. As in the previous regressions, REER volatility influences negatively total factor productivity growth. But conversely to the previous results, the effect of REER volatility is very high. Referring to regression (1), an increase in REER volatility by 100% reduces total factor productivity growth by an amount equivalent to 1.75 percentage points. This is approximately 5 times the effect of REER volatility we calculated for the overall sample. This suggests that REER volatility is more harmful to developing countries than to developed countries. Just as in the developed countries, the coefficient of REER volatility is stable and its standard error is small. Openness continues to influence positively TFPG.

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Table 5, in the appendices, displays the panel data instrumental variable estimation results for all countries with the variable real effective exchange rate volatility 2. The results of the Anderson LM statistic illustrate that all our equations are identified. This means that the excluded instrument is pertinent, implying that it is linked with the endogenous variable. The Weak identification test shows that the identification is strong as the Cragg-Donald Wald F statistic is above 25% of OLS bias. Hence our excluded instrument is not weakly correlated with the endogenous regressor. The Sargan-Hansen J statistic is not reported because it is always zero since our model is exactly identified. This is because we use only one instrument. The F-test is significant in all equations. The R-squared is not reported since it actually has no statistical meaning in the situation of 2SLS/IV.

As indicated above, in Table 5, we present the estimation results using the second measurement of REER volatility. We see that REER volatility continues to affect negatively TFPG. As in the main results, the effect of REER volatility is not very high. The standard error of the coefficient of REER volatility is also very low, suggesting a high degree of precision in the estimation of this coefficient. Contrarily to the main estimations, the coefficient of REER volatility remains stable when we introduce financial development and human capital. Like in the main regressions, the impact of human capital and openness are greater than that of financial development. The other control variables have the expected signs but are not significant.

Threshold effect estimation results

Table 6, in the appendices, gives the results of the regressions using the threshold effect estimation method (Hansen, 1999). Before examining the results, it is important to note that the (Hansen, 1999) method is designed for balanced panel data. Hence, we had to eliminate the missing values from our sample of study. Consequently, we had only 54 countries with a total of 270 observations left out of 74 countries and from sub-periods 1980-1984 to 2000-2004. This drastically reduces the number of observations, but we have a sufficient number of observations on which we can conduct statistical inference. Also for these estimations we use the second measurement of REER volatility. The upper part of Table 6 provides the test for the existence of threshold effects in the estimated equations while the lower part gives the coefficient estimates. The results illustrate that there does not exist a first or a second threshold but there is a third threshold in all equations. This, because the bootstrapped p-values show that the triple threshold is statistically significant at 10% level. Moreover referring to regression 4 in Table 6, Figure 1, in the appendices, depicts that the likelihood ratio curve touches the x-axis between (-1.5) and (-1.0). Hence there exists a triple threshold value $\hat{\gamma}$ between these two values. The estimate of this threshold is very precise since the confidence interval for this parameter is very narrow. The confidence interval for the threshold parameter corresponds to the values where the likelihood ratio is below the dashed horizontal line. The coefficient of REER volatility below the second threshold is highly statistically significant but since the corresponding threshold is not significant, we conclude that REER volatility has no impact on total factor productivity growth at this threshold level. Thus for very low levels of financial development, REER volatility has no effect on total factor productivity growth. On the other hand, the coefficient of REER volatility below the third threshold is negative, highly significant and its corresponding threshold is also statistically significant. Consequently, for moderately financially developed countries, REER volatility reacts negatively on productivity. Although this negative effect is not economically very high, it remains robust to the introduction of control variables. It is also very precise since its standard errors are very small. The coefficient of REER volatility above the third threshold is positive but is not statistically significant. Hence for highly financially developed countries, REER volatility has no impact on productivity. Referring to equation (4), we see that the estimated triple threshold is equal to (-1.216962) and keeps the same value across all equations. The corresponding level of financial development is 0.2961. This value is slightly below the median of financial development. This illustrates that there are a lot of countries above this threshold level and that it is not out of sample. As in the main estimations in Table 2, openness has a larger effect than financial development. But contrarily to the main results, government consumption and inflation are significant and have the expected signs.

In short, the intuition behind the conditioning on the level of financial development is that countries that are less financially developed do not have the substructure (large investment, good capital stock, high financial interlinks) to make them defenseless against REER volatility. They have to become slightly bigger for REER volatility to play. In contrast in countries that are moderately financially developed, the

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financial interconnections are fairly large and many firms are linked financially. Hence any REER volatility can damage the system. Finally countries that are highly financially developed have many insurance and protection mechanisms that protect them against the damaging effects of REER volatility.

(Aghion et al., 2006) also found that the effect of REER volatility on productivity depends on the level financial development. Contrarily to them we find that for very low levels of financial development, real exchange rate volatility has no effect on productivity growth. It has a negative impact only for moderately financially developed countries. Last but not least, we discover, in line with their findings, that for highly financially developed countries, real exchange rate volatility has no effect on productivity.

Conclusion

For a long time, economists were not interested in the relation between business cycle and economic growth but since (Ramey and Ramey, 1995), the number of works studying this link has exploded. In line with these studies, the connection between real exchange rate volatility and productivity growth has also recently been examined. The theory suggests that real exchange rate volatility acts on productivity according to some threshold variable: financial development or liability dollarization. We studied the effects of REER volatility on total factor productivity growth using a panel of 74 countries from 1975 to 2004. Using panel data instrumental variables and threshold effects estimation methods, we first found that REER volatility affects negativity total factor productivity growth and second, we discovered that this impact of REER volatility depends on the level of financial development of the countries.

Although the results were illuminating, some warnings deserve to be underlined. Firstly, while the threshold effect estimation method takes into account the unobservable heterogeneity of the countries, it does not control for the endogeneity of REER volatility. Secondly, we did not isolate, empirically, the precise channels through which REER volatility affects total factor productivity growth nor have we studied the impact of REER volatility on the components of productivity growth.

From a policy perspective, the results found in this paper indicate that the negative effects of REER volatility in the long term are not negligible. Hence efforts made in reducing REER volatility will be translated, in the long-run, into huge productivity gains.

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Appendices

Table 1. Estimation of the translog stochastic production function

Dependent variable: $\ln y$		
Regressors	Coefficients	Std. Err.
t	-0.0121	0.0723
$(1/2)t^2$	0.0069*	0.0041
$\ln K$	0.2323	0.1754
$\ln L$	-0.7615***	0.2695
$(1/2)(\ln K)^2$	0.0327***	0.0098
$(1/2)(\ln L)^2$	0.1240***	0.0255
$\ln K \ln L$	-0.0304*	0.0160
$t \ln K$	0.0102***	0.0028
$t \ln L$	-0.0173***	0.0046
Constant	17.5921***	2.9582
μ	0.0682	0.2992
η	0.0852***	0.0097
$\ln \sigma_s^2$	-1.4390***	0.5071
Inverse logit of γ	3.0663***	0.5359
σ_s^2	0.2372	0.1203
γ	0.9555	0.0228
σ_u^2	0.2266	0.1203
σ_v^2	0.0106	0.0008

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 2. Panel data instrumental variable estimation results for all countries with the variable real effective exchange rate volatility 1

Dependent Variable: Total factor productivity growth								
Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
REER volatility 1+	-0.0143***	-0.00407**	-0.00413**	-0.0141**	-0.00343**	-0.00412**	-0.00362*	-0.00339*
	(0.00550)	(0.00205)	(0.00202)	(0.00545)	(0.00172)	(0.00202)	(0.00187)	(0.00172)
Openness+	0.0166*			0.0169*				
	(0.00869)			(0.00867)				
Human capital+		0.0399***	0.0387***		0.0382***	0.0386***	0.0377***	0.0381***
		(0.00299)	(0.00296)		(0.00310)	(0.00298)	(0.00318)	(0.00310)
Financial development+			0.00511***		0.00522***	0.00522***	0.00518***	0.00535***
			(0.00174)		(0.00171)	(0.00177)	(0.00175)	(0.00174)
Inflation+				-0.000573				
				(0.00597)				
Government consumption+				-0.00726		-0.00148		-0.00181
				(0.0101)		(0.00469)		(0.00474)
Crises					-0.000423		-0.000166	-0.000476
					(0.00286)		(0.00295)	(0.00286)
Trend of terms of trade							4.51e-05	
							(0.0220)	
Observations	303	293	291	303	231	291	226	231
Number of countries	66	64	64	66	51	64	50	51
P-value Under-identification test	0.00216	0.000545	0.000567	0.00202	9.58e-05	0.000564	0.000190	9.98e-05
Weak identification test	9.713	12.50	12.37	9.763	16.25	12.33	14.69	16.07
F test	6.976	95.16	67.50	3.754	49.29	50.46	36.55	39.49
P-value F	0.00114	0	0	0.00557	0	0	0	0

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. + These variables are measured in logarithms.

Sargan-Hansen J statistic not reported because it is always zero since our model is exactly identified (we use one instrument).

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Table 3. Panel data instrumental variable estimation results for developed countries with the variable real effective exchange rate volatility 1

Dependent Variable: Total factor productivity growth								
Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
REER volatility 1+	-0.00688**	-0.00630**	-0.00475**	-0.00311*	-0.00327*	-0.00313*	-0.00758**	-0.00332*
	(0.00293)	(0.00283)	(0.00199)	(0.00184)	(0.00176)	(0.00185)	(0.00362)	(0.00179)
Financial development+	0.00828**	0.00669*					0.00803**	
	(0.00351)	(0.00348)					(0.00368)	
Crises		-0.0120*	-0.00863*		-0.00601			-0.00593
		(0.00709)	(0.00497)		(0.00406)			(0.00413)
Inflation+			-0.173***	-0.131***	-0.121***	-0.132***		-0.125***
			(0.0271)	(0.0288)	(0.0271)	(0.0310)		(0.0291)
Human capital+				0.0305***	0.0324***	0.0306***		0.0328***
				(0.0101)	(0.0105)	(0.0102)		(0.0107)
Government consumption+						-0.00148		-0.00640
						(0.0156)		(0.0166)
Trend of terms of trade							0.0377	
							(0.0960)	
Observations	102	72	74	104	74	104	97	74
Number of countries	24	17	17	24	17	24	23	17
P-value Under-identification test	0.00196	0.00455	0.00380	0.00325	0.00800	0.00315	0.00670	0.00817
Weak identification test	10.65	8.915	9.302	9.346	7.460	9.298	7.831	7.276
F test	5.821	3.681	18.07	31.42	25.29	23.20	3.233	19.69
P-value F	0.00445	0.0177	3.03e-08	0	0	0	0.0273	5.89e-11

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.+ These variables are measured in logarithms.

Sargan-Hansen J statistic not reported because it is always zero since our model is exactly identified (we use one instrument).

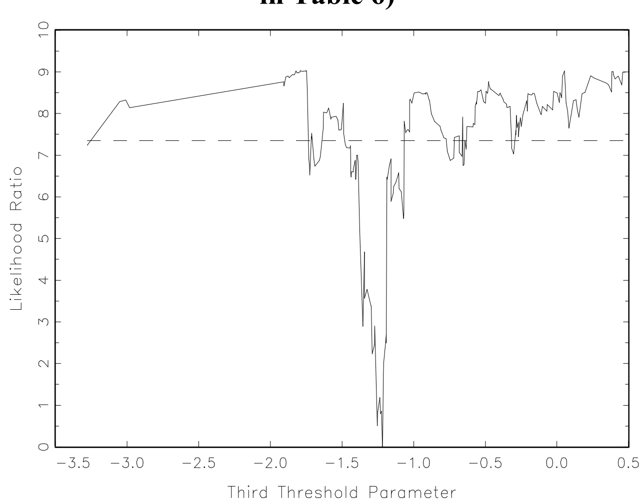
Diallo I. 2015. The Effects of Real Exchange Rate Volatility on Productivity Growth. *Eastern European Business and Economics Journal* **1**(2): 66-84.

Table 4. Panel data instrumental variable estimation results for developing countries with the variable real effective exchange rate volatility 1

Dependent Variable: Total factor productivity growth		
Regressors	(1)	(2)
REER volatility 1+	-0.0175**	-0.0158**
	(0.00760)	(0.00699)
Openness+		0.0214**
		(0.0106)
Government consumption+		-0.00480
		(0.0112)
Crises	0.0119	0.0139
	(0.0111)	(0.0105)
Observations	169	169
Number of countries	36	36
P-value Under-identification test	0.00575	0.00536
Weak identification test	7.970	7.986
F test	2.840	2.329
P-value F	0.0620	0.0595

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.+ These variables are measured in logarithms.
Sargan-Hansen J statistic not reported because it is always zero since our model is exactly identified (we use one instrument).

Figure 1. Confidence interval for the triple threshold effect (regression 4 in Table 6)



Diallo I. 2015. The Effects of Real Exchange Rate Volatility on Productivity Growth.
Eastern European Business and Economics Journal **1**(2): 66-84.

Table 5. Panel data instrumental variable estimation results for all countries with the variable real effective exchange rate volatility 2

Dependent Variable: Total factor productivity growth

Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
REER volatility 2+	-0.00355*	-0.00857**	-0.00627**	-0.00768**	-0.00744**	-0.00299*	-0.00355*	-0.00626**
	(0.00195)	(0.00345)	(0.00300)	(0.00381)	(0.00369)	(0.00170)	(0.00191)	(0.00308)
Inflation+		-0.00252			-0.000487			
		(0.00533)			(0.00478)			
Government consumption+		-0.00549		-0.00472			-7.67e-05	
		(0.00950)		(0.00845)			(0.00505)	
Financial development+	0.00609***	0.00748**	0.00522*	0.00589*	0.00550*	0.00599***	0.00608***	0.00523*
	(0.00189)	(0.00359)	(0.00302)	(0.00335)	(0.00326)	(0.00183)	(0.00193)	(0.00302)
Human capital+	0.0372***					0.0366***	0.0372***	
	(0.00335)					(0.00357)	(0.00337)	
Openness+			0.0137*	0.0169**	0.0167**			0.0136*
			(0.00738)	(0.00709)	(0.00691)			(0.00737)
Crises			-0.000302			-0.000748		-0.000304
			(0.00483)			(0.00297)		(0.00484)
Trend of terms of trade								0.00181
								(0.0378)
Observations	294	307	238	302	303	234	293	238
Number of countries	65	68	53	67	67	52	65	53
P-value Under-identification test	0.00520	0.00222	0.00365	0.0106	0.00943	0.00226	0.00425	0.00448
Weak identification test	7.980	9.573	8.664	6.596	6.820	9.612	8.328	8.218
F test	58.82	2.900	4.160	4.007	4.342	44.39	43.57	3.422
P-value F	0	0.0227	0.00301	0.00367	0.00210	0	0	0.00560

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.+ These variables are measured in logarithms.

Sargan-Hansen J statistic not reported because it is always zero since our model is exactly identified (we use one instrument).

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Table 6. Threshold effect estimation method for all countries with the variable real effective exchange rate volatility 2

Dependent Variable: Total factor productivity growth				
Regressors	(1)	(2)	(3)	(4)
Estimated single threshold	-2.180058	-2.180058	-2.180058	-2.180058
F1 single threshold	9.384393	9.278434	9.015172	8.793222
Bootstrap p-value single threshold	[0.216667]	[0.290000]	[0.246667]	[0.303333]
Estimated double threshold	-2.110279	-2.110279	-2.110279	-2.110279
F1 double threshold	9.698860	10.228568	9.388542	9.877381
Bootstrap p-value double threshold	[0.163333]	[0.166667]	[0.236667]	[0.196667]
Estimated triple threshold	-1.216962	-1.216962	-1.216962	-1.216962
F1 triple threshold	9.543235*	9.435386*	9.243788*	9.025115*
Bootstrap p-value triple threshold	[0.060000]	[0.090000]	[0.086667]	[0.086667]
REER volatility 2 threshold 1+	0.000244	0.000369	0.000285	0.000434
	(0.001406)	(0.001358)	(0.001399)	(0.001345)
REER volatility 2 threshold 2+	0.008188***	0.008205***	0.008103***	0.008089***
	(0.001729)	(0.001699)	(0.001766)	(0.001747)
REER volatility 2 threshold 3+	-0.002226***	-0.002194***	-0.002164***	-0.002106***
	(0.000725)	(0.000728)	(0.000733)	(0.000739)
REER volatility 2 threshold 4+	0.000174	0.000173	0.000200	0.000208
	(0.000364)	(0.000367)	(0.000366)	(0.000366)
Openness+	0.013826***	0.013617***	0.013489***	0.013137***
	(0.004273)	(0.004217)	(0.004290)	(0.004221)
Financial development+	0.006615***	0.007448***	0.006409***	0.007220***
	(0.001915)	(0.002179)	(0.001902)	(0.002154)
Government consumption+		-0.010631**		-0.011353**
		(0.005249)		(0.005263)
Inflation			-0.002083	-0.002871*
			(0.001572)	(0.001711)
Observations	270	270	270	270
Number of countries	54	54	54	54

Note: P-values in square brackets; robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Number of Bootstrap replications 300
+ These variables are measured in logarithms