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Exchange rate volatility and productivity growth: The role of financial development ☆

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ABSTRACT

The vast empirical exchange rate literature finds the effect of exchange rate volatility on real activity to be small or insignificant. In contrast, this paper offers empirical evidence that real exchange rate volatility can have a significant impact on productivity growth. However, the effect depends critically on a country's level of financial development. The results appear robust to time window, alternative measures of financial development and exchange rate volatility, and outliers. We also offer a simple monetary growth model in which real exchange rate uncertainty exacerbates the negative investment effects of domestic credit market constraints.

1. Introduction

Throughout the developing world, the choice of exchange rate regime stands as perhaps the most contentious aspect of macroeconomic policy. For example, China's relatively inflexible exchange rate system has been subject to intense international criticism meanwhile South African policymakers are chastised for not doing enough to stabilize their country's highly volatile currency. Despite the perceived centrality of the exchange rate regime to long-run growth and economic stability, the existing theoretical and empirical literatures on exchange rates or on growth offer little guidance on this subject. The theoretical exchange rate literature is mainly tailored to richer countries with highly developed institutions and markets (e.g., Garber and Svensson, 1995; Obstfeld and Rogoff, 1996), and it offers almost no discussion of

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long-run growth. The empirical literature on exchange rates is largely negative, suggesting to some that the degree of exchange rate flexibility simply does not matter for growth, or for anything except the real exchange rate.[1]

This paper tests whether 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. Significant and robust evidence is found that the more financially developed a country is, the faster it will grow with a more flexible exchange rate. The volatility of real shocks relative to financial shocks—which features so prominently in the literature on developed country exchange rate regimes—also matters for developing countries. But because financial shocks tend to be greatly amplified in financially underdeveloped economies, one has to adjust calibrations accordingly.

Fig. 1 shows the relationship between productivity growth and exchange rate flexibility for countries at different levels of financial development. The upper graphs consider the volatility of the effective real exchange rate and the lower graphs deal with the exchange rate regime classification proposed by Reinhart and Rogoff (2004). Each case provides a comparison between the residuals of a productivity growth regression on a set of variables and the residuals of an exchange rate flexibility regression on the same variables. This gives adjusted measures of volatility and flexibility that are purged from any collinearity with the standard growth determinants. Countries are ranked according to their level of financial development measured by private credit to GDP averaged over five-year periods. The left-hand side in both panels shows the lower quartile whereas the right-hand side shows the upper quartile of the distribution. There is clearly a negative relationship between productivity growth and exchange rate flexibility for less financially developed countries, whereas there is no such relationship for the most developed economies.

The results in Fig. 1 represent preliminary evidence that the growth effects of real exchange rate volatility and the flexibility of the exchange rate regime vary with the level of financial development. The main purpose of this paper is to explore the robustness of this finding and to rationalize it. The next section determines the extent to which the level of financial development affects the impact of exchange rate volatility on growth. A systematic panel data analysis is conducted, using a data set for 83 countries over the years 1960–2000. When a country's de facto degree of exchange rate flexibility is interacted with its level of financial development the results prove to be both robust and highly significant. Various measures of exchange rate flexibility are considered, including the volatility of the real effective exchange rate and the exchange rate regime. The classification of Reinhart and Rogoff (2004) is used in the main analysis, but the results are generally robust to other de facto classifications.[2] A high degree of exchange rate flexibility consistently leads to lower growth in countries with relatively thin financial markets. Moreover, these effects are not only statistically significant, they appear quantitatively significant as well. For example, the estimates indicate that a country which lies in the middle of the lower quartile (e.g., Zambia in 1980), with credit to GDP of 15%, would have gained 0.94% of annual growth had it switched from a flexible to a totally rigid exchange rate. Even a country in the middle of the second quartile (like Egypt in 1980), with credit to GDP of about 27%, would have gained 0.43% growth per year by adopting a uniform pegged exchange rate.

The core results appear to hold intact against a variety of standard robustness tests, including attempts to quarantine the results against outliers and regional effects and allowing for alternative control variables. Alternative measures of exchange rate volatility are considered and the country's distance to the technological frontier is introduced as both, an alternative, and a supplementary, interaction variable. To address the problem of exchange regime endogeneity, we use techniques within the GMM methodology and we also examine the broader historical evidence on the choice of exchange rate regime. Finally, we propose an alternative estimation strategy based on a difference-in-differences approach using an industry-level data set. All these tests contribute to making us confident that the empirical results are indeed robust and capture the causality from exchange rate volatility to growth.

Even though the focus on financial development as a key factor affecting the link between exchange rate volatility and growth is novel, we carefully examine the related exchange rate literature and show that it can be fully reconciled with our results.

In Section 3, a model that rationalizes the empirical evidence is presented. It is an open monetary economy model with wage stickiness, where exchange rate fluctuations affect the growth performance of credit-constrained firms. Exchange rate fluctuations in turn are caused by both real and financial aggregate shocks. The basic mechanism underlying the positive growth interaction between financial development and exchange rate volatility can be explained as follows. Suppose that

[1] The classic paper is Baxter and Stockman (1989). In their survey, Ghosh et al. (2003) state that "perhaps the best one can say is that the growth performance of pegged regimes is no worse than that of floating regimes". More recent studies include Levy-Yeyati and Sturzenegger (2003), Razin and Rubinstein (2006), Husain et al. (2005), De Grauwe and Schnabl (2008), and Dubas et al. (2005). We note that Baldwin (1989), in his analysis of European Monetary Union, argued that a single currency might have growth effects on Europe by reducing the exchange rate premium on capital within Europe. Husain et al. (2005) argue informally that fixed rates may be more important for countries with more fragile political and financial institutions, but they do not provide any direct evidence for this view. There is some evidence of an effect of exchange rate volatility on trade levels (e.g., Rose, 2000). The effect, however, does not appear to be large and it is even less clear that the resulting trade expansion has any great impact on welfare (see Krugman, 1987; Bacchetta and van Wincoop, 2000). Dubas et al. (written independently) conclude relatedly to our starting Fig. 1, that low income countries grow faster under fixed rates. Levy-Yeyati and Sturzenegger (2003), however, find the opposite. In the next section, we will show how our results can be reconciled with the literature.

[2] The classification of Reinhart and Rogoff is more appropriate in our context, since they focus mainly on exchange rate volatility, in particular including dual and multiple exchange rates. Other classifications, such as Levy-Yeyati and Sturzenegger (2003), capture better the constraints on monetary policy by including changes in reserves in defining their classification. However, the focus of this paper is on exchange rate volatility.

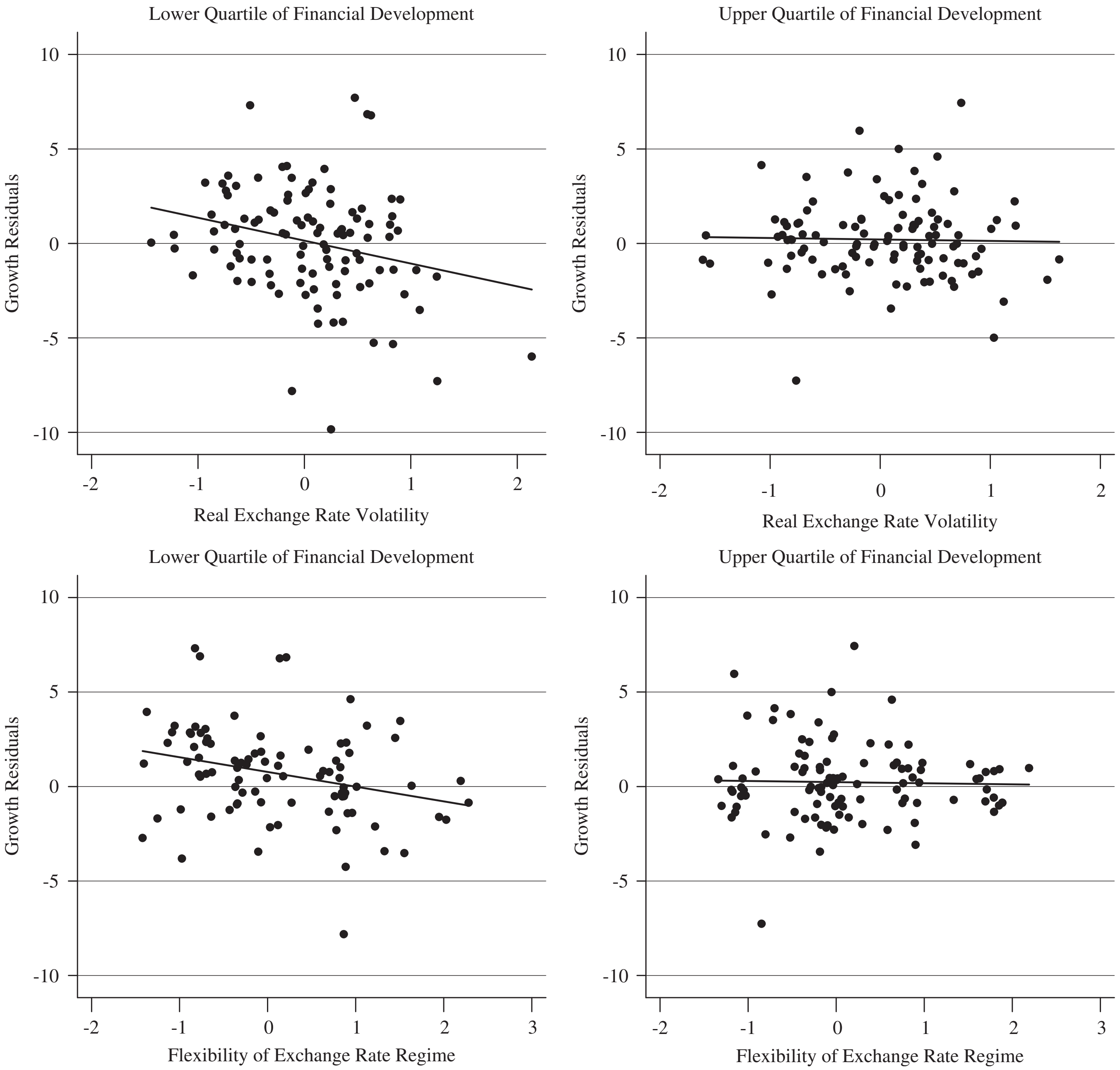

Fig. 1. Real exchange rate volatility, exchange rate flexibility and productivity growth. *Notes*: The growth residuals are derived from a pooled regression using five-year average data for 83 countries over 1970–2000. The controls include initial productivity, secondary schooling, financial depth, government expenditure, trade openness, term-of-trade growth and an indicator of banking and currency crises. The variables are defined in Section 2 and in the Appendix. For each quartile, growth residuals are regressed on the adjusted measures of real exchange rate volatility and the flexibility of the exchange rate regime.

the borrowing capacity of firms is proportional to their current earnings, with a higher multiplier reflecting a higher degree of financial development in the economy. Suppose in addition that the nominal wage is preset and cannot be adjusted to variations in the nominal exchange rate. Then, following an exchange rate appreciation, firms' current earnings are reduced, and so is their ability to borrow in order to survive idiosyncratic liquidity shocks and thereby innovate in the longer term. Depreciations have the opposite effect. However, the existence of a credit constraint implies that in general the positive effects of a depreciation on innovation will not fully compensate the negative effect of an appreciation. This, in turn, may help explain why in Fig. 1 growth in countries with lower financial development benefits more from a fixed exchange rate regime, and more generally from a stabilized exchange rate.[3] Section 2 also shows that the superior growth performance of

[3] A related explanation, which can be easily formalized in the context of our model, is that the lower financial development, the more the anticipation of exchange rate fluctuations should discourage R&D investments. This would lower growth if these investments were to be decided before firms know the realization of the aggregate shock.

a more stable exchange rate holds as long as the volatility of financial market shocks is large compared to the volatility of real shocks (and that, in principle, the optimal monetary regime allows the exchange rate to move to offset real shocks without introducing excess noise in the exchange rate). In any case, the source of shocks (real versus financial) only matters at lower levels of financial development.

The remaining part of the paper is organized as follows. Section 2 develops the empirical analysis and the results, with the corresponding data being detailed in the Appendix. Section 3 presents an illustrative model to think about exchange rate policy and growth, and rationalizes the main empirical results of this paper. It also presents further empirical evidence using industry-level data consistent with the proposed mechanism. The Appendix provides additional empirical results.

2. Empirical analysis

Previous studies have shown that financial development fosters growth and convergence, conditions macroeconomic volatility, or may play a crucial role in financial crises. An interesting question is whether the level of financial development also conditions the impact of monetary arrangements, such as the exchange rate regime. Our basic hypothesis is that the exchange rate regime, or more generally exchange rate volatility, has a negative impact on (long-run) growth when countries are less developed financially.

To test these predictions, we consider standard growth regressions to which we add a measure of exchange rate flexibility, as well as an interaction term with exchange rate flexibility and financial development or some other measures of development. In this section, three measures related to exchange rate flexibility are considered: (i) the exchange rate regime based on the natural classification of Reinhart and Rogoff (2004), henceforth RR; (ii) the standard deviation of the real effective exchange rate; (iii) the degree of real “overvaluation”, as a deviation of the real exchange rate from its long-term value. We also examine the interaction between terms-of-trade shocks, the exchange rate regime, and growth. We first present the methodology and the variables used and then the results based on a dynamic panel of 83 countries over the 1960–2000 period.

2.1. Data and methodology

As is now standard in the literature, a panel data set is constructed by transforming the time series data into five-year averages. This filters out business cycle fluctuations, so we can focus on long-run growth effects. The dependent variable is productivity growth, rather than total growth. We use the GMM dynamic panel data estimator developed in Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998) and we compute robust two-step standard errors by following the methodology proposed by Windmeijer (2004).[4] This approach addresses the issues of joint endogeneity of all explanatory variables in a dynamic formulation and of potential biases induced by country-specific effects. The panel of country and time-period observations is unbalanced. Appendix B presents the list of countries included in the sample.

The benchmark specification follows Levine et al. (2000) who provide evidence of a growth enhancing effect of financial development; they were the first to use the system GMM estimation we are using. We consider productivity growth instead of total growth, but our regressions are estimated with the same set of control variables.[5] Starting from this benchmark, we examine the direct effect on growth of our exchange rate flexibility measures. Then, we look at the interaction between these measures and the level of financial development. More specifically, the following equation is estimated:

$$y_{i,t} - y_{i,t-1} = (\alpha - 1)y_{i,t-1} + \gamma_1 ER_{i,t} + \gamma_2 ER_{i,t} * FD_{i,t} + \delta FD_{i,t} + \beta' Z_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t}, \quad (1)$$

where $y_{i,t}$ is the logarithm of output per worker; $ER_{i,t}$ is either the degree of flexibility of the exchange rate regime, real exchange rate volatility, or a measure of overvaluation; $FD_{i,t}$ is a measure of financial development; Z_{it} is a set of other control variables; μ_t is the time-specific effect; η_i is the country-specific effect; and $\varepsilon_{i,t}$ is the error term.

Our hypothesis is that $\gamma_1 < 0$ and $\gamma_2 > 0$ so that the impact of exchange rate flexibility $\gamma_1 + \gamma_2 * FD_{i,t}$ is more negative at low levels of financial development. Moreover, when γ_1 and γ_2 have opposite signs, a threshold effect arises:

$$\frac{\delta(y_{i,t} - y_{i,t-1})}{\delta ER_{i,t}} = \gamma_1 + \gamma_2 FD_{i,t} > 0 \;\Leftrightarrow\; FD_{i,t} > \widetilde{FD} := -\frac{\gamma_1}{\gamma_2}.$$

Tables 1–3 report threshold levels of financial development above which a more flexible exchange rate becomes growth enhancing. The standard errors of the respective threshold levels are computed using a delta method, that is by taking a first-order Taylor approximation around the mean. Notice that in small samples, the delta method is known to result in excessively large standard errors.

[4] It has been recognized that the two-step standard errors are downward biased in a small sample and the Windmeijer (2004) method corrects for that. Notice that, as the two-step estimator is asymptotically efficient, this approach is superior to just relying on first step estimates and standard errors as is common in the empirical growth literature that uses small samples. See Bond (2002) for a simple description of the methodology we follow.

[5] See their Table 5, p. 55. The other differences with Levine et al. (2000) are that we use a larger data set, we use the Windmejer standard errors, and we include a financial crisis dummy. Loayza and Ranciere (2006) show that their results stay unchanged when the original panel is extended to 83 countries over 1960–2000 and when a crisis dummy is introduced. Levine et al. (2000) show similar results when the same equation is estimated in cross-section with legal origin as external instrument.

Three measures for the variable $ER_{i,t}$ are used. First, we compute an index of flexibility of the exchange rate regime in each five-year period based on the RR exchange rate classification. Ignoring the free falling category, the RR annual natural broad classification orders regimes from the most rigid to the most flexible: $ERR_t \in \{1,2,3,4\} = \{fix, peg, managed\ float, float\}$. Hence, the index of exchange rate flexibility is constructed in each five-year interval as[6]

$$Flex_{t,t+5} = \frac{1}{5}\sum_{i=1}^{5} ERR_{t+i}.$$

The second measure is the five-year standard deviation of annual log differences in the effective real exchange rate. The effective rate is constructed as a trade-weighted index of multilateral real rates as explained in Appendix A. The third measure is the five-year average deviation from a predicted level of the real effective exchange rate.[7]

Financial development is measured as in Levine et al. (2000) by the aggregate private credit provided by banks and other financial institutions as a share of GDP. The dependent variable is growth in real GDP per worker. The set of control variables includes average years of secondary schooling as a proxy for human capital, inflation and the size of the government (government expenditure as proportion of GDP) to control for macroeconomic stability, and an adjusted measure of trade openness.[8] A dummy indicating the frequency of a banking or a currency crisis within each five-year interval is introduced in the robustness checks. This indicator controls for rare but severe episodes of aggregate instability likely to be associated with large changes in the variables of interest.[9] Definition and sources for all variables are given in Appendix C.

2.2. Exchange rate flexibility and financial development

Tables 1, 2 and 3 present the estimations of the impact of the exchange rate regime, exchange rate volatility and real overvaluation on productivity growth. Each table displays the results of four regressions. The first regression estimates the effects of the exchange rate measure along with financial development and a set of control variables, without interaction term. The second regression adds a variable interacting the exchange rate measure and the measure of financial development in order to test our main prediction: the presence of a *non-linear effect* of exchange rate volatility on growth depending on the level of financial development. The third and fourth regressions replicate the same regressions with the addition of a dummy variable indicating the frequency of a currency or banking crisis in the five-year interval.

In Table 1, regression [1.1] illustrates the absence of a linear effect of the exchange rate regime on productivity growth. This result is consistent with previous studies. In contrast, regression [1.2] shows that the interaction term of exchange rate flexibility and financial development is positive and significant. The more financially developed an economy is, the higher is the point estimate of the impact of exchange rate flexibility on productivity growth. Furthermore, the combined interacted and non-interacted coefficient of flexibility becomes significant at the 5% level (as indicated by the Wald test in Table 1). Combining these two terms enables us to identify a threshold level of financial development below (above) which a more rigid (flexible) regime fosters productivity growth. The point estimate of the threshold is close to the sample mean of the financial development measure. In regressions [1.3] and [1.4], we introduce the crisis dummy described above. While the frequency of crisis indeed has a negative impact on productivity growth, the non-linear effect of exchange rate regime on growth remains robust and its point estimate stays almost unchanged.

The main result of Table 1 is that letting the degree of exchange rate flexibility vary with the level of financial development allows us to identify significant growth effects of the exchange rate regime. The implication is that less financially developed economies may derive growth benefits from maintaining a rigid exchange rate regime. As illustrated by the examples given in the Introduction, these benefits can be economically large. This result provides a novel rational interpretation for the "fear of floating" behavior based on long run productivity growth.

Table 2 presents similar results with exchange rate volatility measured by the five-year volatility of the change in multilateral real exchange rates. Regression [2.1] indicates that exchange rate volatility has a significant negative impact on productivity growth. This effect is economically important: an increase of 50% in exchange rate volatility—which corresponds to the mean difference in volatility between a fixed and a flexible exchange rate (see the Appendix)—leads to a 0.33% reduction in annual productivity growth. This effect is only marginally reduced when we control for the impact of a crisis, as in regression [2.3]. Regression [2.2] shows that the interaction between exchange rate volatility and financial development is positive and significant: the more financially developed an economy is, the less adversely it is affected by exchange rate volatility. Here again, the economic impact is important. For instance, consider Chile, whose level of financial depth ranges from 10% in 1975 to 70% in 2000. This drastic change decreases the negative impact of exchange rate volatility

[6] The information on the flexibility of exchange rate is reported for each country-five years interval during which the RR classification indicates a non-free falling regime for at least three out of five years.

[7] This deviation is computed as the average log difference between the actual exchange rate and the exchange rate predicted by country and time-specific characteristics (income per capita, population density, regional and time dummies) as in Dollar (1992). We also considered average log differences from a HP detrended multilateral exchange rate series as in Goldfajn and Valdes (1999), and found similar results.

[8] More precisely we use the residuals of a pooled regression of (imports + exports)/GDP against structural determinants of trades such as landlock situation, an oil producers dummy, and population.

[9] For instance, Hnatkovska and Loayza (2005) present evidence that crisis volatility can explain an important part of the negative relationship between volatility and growth observed in middle-income economies.

Table 1
Growth effects of exchange rate regime flexibility.

Period: Unit of observation:	1960–2000 Non-overlapping five-year averages			
	[1.1]	[1.2]	[1.3]	[1.4]
Degree of exchange rate flexibility (Reinhart and Rogoff classification)	−0.191 0.349	−1.135* 0.579	−0.144 0.288	−1.227** 0.563
Financial development (private domestic credit/GDP, in logs)	0.684** 0.347	0.185 0.160	0.655** 0.326	0.258 0.941
Initial output per worker (log(initial output per worker))	−0.150 0.418	−0.117 0.447	−0.152 0.447	−0.126 0.461
Flexibility ∗ financial development		0.303** 0.146		0.336** 0.159
Control variables				
Education (secondary enrollment, in logs)	1.493** 0.630	1.518** 0.676	1.481** 0.574	1.509** 0.605
Trade openness (structure-adjusted trade volume/GDP, in logs)	1.632* 0.914	1.626* 0.858	1.719** 0.869	1.407* 0.799
Government burden (government consumption/GDP, in logs)	−1.842* 1.088	−1.950* 1.136	−1.917* 1.114	−1.989* 1.150
Lack of price stability (inflation rate, in log[100 + inf . rate])	−2.731 1.757	−2.767 1.761	−1.660 2.088	−2.470 1.850
Crisis (banking or currency crisis dummy)			−1.826* 1.054	−1.741* 1.075
Intercept	15.711** 7.5131	17.418** 8.509	10.940 9.4513	15.731* 9.2799
No. countries/no. observations	79/562	79/562	79/562	79/562
Specification tests (*p-values*)				
(a) Sargan test	0.252	0.227	0.291	0.367
(b) Serial correlation				
First-order	0.000	0.000	0.000	0.000
Second-order	0.348	0.361	0.441	0.388
Wald tests (*p-values*)				
Ho: exchange rate flexibility total effect = 0		0.009		0.000
Ho: financial development total effect = 0		0.035		0.044
Threshold analysis				
Growth enhancing effect ofexchange rate flexibility				
Private credit/GDP greater than		0.424		0.385
s.e.		0.190		0.170

Notes: The estimation method is two-step system GMM with Windmeijer (2004) small sample robust correction. Time and fixed effects are included in all the regressions.
Standard errors are presented below the corresponding coefficients. Symbols ** and * means significant at 5% and at 10%.
Dependent variable: growth rate of output per worker.
Source: Authors' estimations.

on growth by a factor of five. Moreover, our estimate indicates that exchange rate volatility exhibits no significant impact on productivity growth for the set of the financially most developed economies.[10]

[10] These are countries with a private credit to GDP ratio in the range of [90%,120%]. This includes the euro aera, the UK, Switzerland, Finland, Sweden, the US, and Australia.

Table 2
Growth effects of real effective exchange rate volatility.

Period:	1960–2000			
Unit of observation:	Non-overlapping five-year averages			
	[2.1]	[2.2]	[2.3]	[2.4]
Real exchange rate volatility	−0.637**	−3.124**	−0.554**	−3.319**
	0.273	1.204	0.262	1.208
Financial development	1.111**	−0.650	0.987**	−0.729
(private domestic credit/GDP, in logs)	0.455	0.808	0.402	0.821
Initial output per worker	−1.112**	−0.530	−1.025**	−0.828**
(log(initial output per worker))	0.391	0.474	0.360	0.404
Exchange rate volatility * financial development		0.677**		0.706**
		0.262		0.277
Control variables				
Education	1.807**	1.778**	1.976**	2.378**
(secondary enrollment, in logs)	0.532	0.694	0.465	0.585
Trade openness				
(structure-adjusted trade volume/GDP, in logs)	1.053*	1.115**	1.420**	1.579*
	0.572	0.769	0.569	0.975
Government burden	−0.416	−0.928	−1.068	0.871
(government consumption/GDP, in logs)	1.153	1.070	1.104	1.372
Lack of price stability	−2.569*	−1.961	−1.872*	−1.172
(inflation rate, in log[100 + inf . rate])	1.487	1.237	1.117	1.379
Crisis			−2.250**	−2.857**
(banking or currency crisis dummy)			0.878	1.374
Intercept	18.325**	13.346**	15.689**	14.556**
	7.043	5.072	5.848	6.971
No. countries/no. observations	83/615	83/615	83/615	83/615
Specification tests (*p-values*)				
(a) Sargan test	0.461	0.241	0.663	0.187
(b) Serial correlation				
First-order	0.000	0.000	0.000	0.000
Second-order	0.462	0.383	0.572	0.516
Wald tests (*p-values*)				
Ho: exchange rate flexibility total effect = 0		0.000		0.000
Ho: financial development total effect = 0		0.032		0.012
Threshold analysis				
Growth enhancing effect of exchange rate flexibility if				
Private credit/GDP greater than		1.01		1.10
s.e.		0.34		0.39

Notes: The estimation method is two-step system GMM with Windmeijer (2004) small sample robust correction. Time and fixed effects are included in all the regressions.
Standard errors are presented below the corresponding coefficients. Symbols ** and * means significant at 5% and at 10%.
Dependent variable: growth rate of output per worker.
Source: Authors' estimations.

Table 3
Growth effects of effective exchange rate real overvaluation.

Period:	1960–2000			
Unit of observation:	Non-overlapping five-year averages			
	[3.1]	[3.2]	[3.3]	[3.4]
Degree of real exchange rate overvaluation	−0.995**	−1.162*	−1.176**	−1.179**
(log deviation from equilibrium exchange rate)	0.504	0.711	0.534	0.659
Financial development	0.636*	−0.101	0.595*	−0.040
(private domestic credit/GDP, in logs)	0.345	2.509	0.330	2.163
Initial output per worker	−0.038	−0.360	−0.057	−0.355
(log(initial output per worker))	0.382	0.531	0.369	0.518
Real overvaluation ∗ financial development		0.205**		0.163**
		0.077		0.082
Control variables				
Education	1.185*	1.532**	1.245**	1.645**
(secondary enrollment, in logs)	0.613	0.772	0.595	0.800
Trade openness	1.328**	1.619**	1.462*	1.630**
(structure-adjusted trade volume/GDP, in logs)	0.626	0.688	0.812	0.777
Government burden	−1.457*	−2.184	−1.329	−1.931
(government consumption/GDP, in logs)	0.827	1.358	0.875	1.483
Lack of price stability	−4.505**	−3.819**	−3.857**	−3.708**
(inflation rate, in log[100 + inf .rate])	1.009	1.160	0.935	0.881
Crisis			−1.281	−2.082
(banking or currency crisis dummy)			1.326	1.284
Intercept	27.612**	27.551**	25.148**	26.882**
	5.720	8.751	5.556	7.626
No. countries/no. observations	83/615	83/615	83/615	83/615
Specification tests (*p-values*)				
(a) Sargan test	0.413	0.224	0.279	0.220
(b) Serial correlation				
First-order	0.000	0.000	0.000	0.000
Second-order	0.268	0.278	0.359	0.271
Wald tests (*p-values*)				
Ho: exchange rate flexibility total effect = 0		0.000		0.000
Ho: financial development totaleffect = 0		0.037		0.028
Threshold analysis				
Growth enhancing effect overvaluation				
Private credit/GDP greater than		1.63		1.28
s.e.		0.65		0.48

Notes: The estimation method is two-step system GMM with Windmeijer (2004) small sample robust correction. Time and fixed effects are included in all the regressions.
Standard errors are presented below the corresponding coefficients. Symbols ** and * mean significant at 5% and at 10%.
Dependent variable: growth rate of output per worker.
Source: Authors' estimations.

Table 3 presents regressions that focus on the effect of real exchange rate overvaluation. We present the results using the deviation between the actual effective real exchange rate and its predicted value.[11] In the baseline regression [3.1], real

[11] We obtain similar results when we consider HP deviation from trend when—as in Goldfajn and Valdes (1999)—the HP filter parameter is set high enough (lamba = 10^8).

overvaluation has a significant and economically important negative effect on growth: a 20% overvaluation translates into a reduction of 0.2% in annual productivity growth (computed from regression [3.1] as $0.99 * \ln(120/100)$). Regression [3.2] studies the effect of interacting real overvaluation and financial development and shows that the more financially developed an economy is, the less vulnerable it becomes to real overvaluation. Using the previous example, a change in financial depth comparable to the one experienced by Chile over 1975–2000 results in a reduction by two of the negative effect of real overvaluation on productivity growth.

2.3. Terms-of-trade growth and exchange rate flexibility

It is often argued that a flexible exchange rate regime is desirable since it can stabilize the effects of real shocks. Recent empirical evidence actually shows that flexible exchange rate regimes tend to absorb the effects of terms-of-trade shocks (see Broda, 2004; Edwards and Levy-Yeyati, 2005). We examine this issue by including terms-of-trade growth and terms-of-trade volatility in our previous regressions and present the results in Table 4.

In regression [4.1], a 10% deterioration in the terms of trade leads to a reduction of 0.9% in productivity growth.[12] In regression [4.2], we find that the impact on productivity growth of a terms-of-trade shock crucially depends on the nature of the exchange rate regime. It is larger under a fixed exchange rate regime and close to zero under a floating regime. This result confirms the stabilizing role of flexible exchange rates. However, in regression [4.3], we show that this stabilization effect fully coexists with the growth enhancing effect of a more fixed regime at low level of financial development. Thus, the empirical evidence shows that even though exchange rate flexibility dampens the impact of terms-of-trade shocks, it has a negative overall impact on growth for financially less developed countries since on average, terms-of-trade growth is close to zero.

Regression [4.4] shows that terms-of-trade volatility has a negative effect on productivity growth: a one standard deviation increase in terms-of-trade volatility reduces growth by 0.4 percentage point. In regression [4.5], we find that a more flexible exchange rate regime dampens the negative impact of terms-of-trade volatility. In fact, the total effect of terms-of-trade volatility on productivity growth becomes close to zero under a fully flexible regime. In regression [4.6], we find that the interaction of exchange flexibility with financial development and with terms-of-trade volatility are both positive and significant suggesting that both variables condition the impact of exchange rate flexibility on productivity growth. However, even under the assumption of large terms-of-trade volatility—set at the 75th percentile of the variable sample distribution—a more fixed exchange regime is growth enhancing for countries in the lowest quartile of financial development.[13]

2.4. Alternative exchange rate regime classifications

Very similar results are obtained with three substantially different measures of exchange rate flexibility. However, given the recent interest for exchange rate classifications schemes, it is useful to focus on exchange rate regimes and examine the results with other schemes. The previous literature has not examined the interaction between exchange rate flexibility and financial development, but has looked at the impact of exchange rate regimes for subgroups of countries. In particular, Levy-Yeyati and Sturzenegger (2003) (LYS) find that exchange rate flexibility is growth-enhancing for less developed countries.[14] We examine the extent to which our results are consistent with theirs.

Table 5 presents the robustness test to four alternative de facto exchange rate classifications. For the sake of comparison, we consider the shorter sample of 1970–2000. In three out of four cases, our main result holds. First, our result is confirmed when the degree of exchange rate flexibility is measured on a more detailed scale using RR fine classification (i.e., using 13 categories instead of the 4 used in the other tables). We notice that the implicit threshold above which a flexible exchange rate regime is growth enhancing is almost identical for the fine and coarse RR classifications.[15] Second, the alternative de facto "consensus" classification of Ghosh et al. (2003) yields similar results.

In contrast, when the LYS classification is used, the interaction with the level of financial development becomes negative but insignificant. In order to understand the differences between the results obtained with the RR and LYS classifications, we modify the latter in the following way: first, we eliminate the observations classified as free-falling by RR; second, we reclassify the observations with a dual exchange rate according to the RR classification.

This procedure generates a classification that combines the LYS clustering approach with the main innovations of RR. Interestingly, when this modified classification is used in the baseline regression, our main finding is confirmed. In that case, the point estimate of the interaction term is slightly higher than the point estimate of the interaction term in the regression using the RR classification on the same sample period (0.68 versus 0.43).

[12] Our findings confirms the results of Mendoza (1997) who show that both negative terms-of-trade change and terms-of-trade uncertainty lower economic growth.

[13] The 75th percentile of the sample distribution of terms-of-trade volatility in log is 2.38 and the 25th percentile of the sample distribution of financial development in log is 2.65. The total growth effect of exchange rate flexibility, moving up one step in the RR classification, for a country with such levels of terms-of-trade volatility and financial development is therefore $-2.748 + 0.476 * 2.38 + 0.525 * 2.6 = -0.25$.

[14] Bleaney and Francisco (2007), however, conclude that LYS results lack robustness.

[15] 55% versus 59% when the fine classification over 1970–2000 is considered.

Table 4
Growth effects of exchange rate regime flexibility, terms-of-trade growth and volatility.

Period:	1960–2000					
Unit of observation:	Non-overlapping five-year averages					
	[4.1]	[4.2]	[4.3]	[4.4]	[4.5]	[4.6]
Terms-of-trade growth	0.092*	0.327*	0.385**			
	0.054	0.169	0.173			
Terms-of-trade volatility				−0.205*	−0.987**	−1.189**
				0.113	0.421	0.410
Degree of exchange rate flexibility		−0.068	−0.826		−0.853**	−2.748**
(Reinhart and Rogoff classification)		1.226	0.658		0.392	1.179
Financial development	1.039**	0.783*	0.285	0.681*	0.722**	−1.178
(private domestic credit/GDP, in logs)	0.463	0.395	0.192	0.378	0.411	0.755
Initial output per worker	−0.526	−0.644*	−0.702	−0.396	−0.173	−0.061
(log(initial output per worker))	0.460	0.381	0.465	0.404	0.455	0.514
Flexibility * terms-of-trade growth		−0.107**	−0.136**			
		0.044	0.062			
Flexibility * terms-of-trade volatility					0.394**	0.476**
					0.197	0.191
Flexibility * financial development			0.357**			0.525*
			0.159			0.283
Control variables						
Education	1.740**	2.301**	2.301**	1.541**	1.457**	1.166*
(secondary enrollment, in logs)	0.517	0.467	0.571	0.529	0.642	0.687
Trade openness	0.652	1.493	1.385*	1.339	1.734**	1.832**
(structure-adjusted trade volume/GDP, in logs)	0.746	1.074	0.706	0.962	0.878	0.931
Government burden	−0.770	−0.762	−0.707	−0.136	−0.977	−0.810
(government consumption/GDP, in logs)	1.248	1.191	0.982	[1.049]	0.930	0.930
Lack of price stability	−2.620**	−4.354**	−3.560**	−2.805*	−1.997*	−1.900*
(inflation rate, in log[100 + inf . rate])	1.260	1.784	1.432	1.567	0.989	1.020
Intercept	13.700**	20.450**	20.000**	13.886	13.388	17.756
	6.31	12.850	9.815	7.358	14.469	15.327
No. countries/no. observations	83/615	79/562	79/562	83/615	79/494	79/494
Specification tests (*p-values*)						
(a) Sargan test	0.335	0.420	0.680	0.670	0.840	0.830
(b) Serial correlation						
First-order	0.000	0.000	0.000	0.000	0.000	0.000
Second-order	0.499	0.450	0.450	0.610	0.510	0.480

Notes: The estimation method is two-step system GMM with Windmeijer (2004) small sample robust correction. Time and fixed effects are included in all the regressions.
Standard errors are presented below the corresponding coefficients. Symbols ** and * mean significant at 5% and at 10%.
Dependent variable: growth rate of output per worker.
Source: Authors' estimations.

The treatment of dual exchange rate regimes and high inflation episodes are two key differences between the RR and the LYS classifications. In particular, where there are parallel and shadow exchange rate markets impacting a significant amount of economic activity, RR use these rates to construct a de facto exchange rate regime which can sometimes exhibit much more flexibility than the underlying official rate. As RR show, when there are sharp sustained departures between the official and parallel rate, it is very often the official rate that (periodically) adjusts. RR also create a separate category (freely falling) for countries with inflation rates over 40% on the grounds that such countries have dysfunctional monetary regimes

Table 5
Growth effects of exchange rate regime flexibility alternative exchange rate regime classifications.

Period:	1970–2000	1970–2000	1970–2000	1970–2000	1970–2000
Unit of observation:	Non-overlapping five-year averages				
Exchange rate classification	De facto (RR coarse)	De facto (RR fine)	De facto (Gosh et al.)	De facto (initial LYS)	De facto (modified LYS)
Degree of exchange rate flexibility	−1.742**	−0.863**	−2.280**	1.628	−2.795**
	0.745	0.390	0.954	1.660	1.207
Financial development	−0.800	−1.270	−0.740	−0.462	−1.017
	0.666	0.963	0.990	0.500	1.100
Initial output per worker	0.132	−0.085	−0.180	−0.391	−1.076
(log(initial output per worker))	0.378	0.430	0.489	0.630	0.639
Flexibility * financial development	0.428**	0.215**	0.830**	−0.462	0.688**
	0.229	0.080	0.435	0.501	0.335
No. countries/no. observations	79/421	79/421	79/401	79/418	79/388
Specification tests (p-values)					
(a) Sargan test	0.596	0.24	0.585	0.31	0.35
(b) Second-order serial correlation	0.125	0.565	0.114	0.59	0.41

Notes: The specification of the regression is identical to regression 2, Tables 1 and 2. The coefficients for the other control variables—secondary schooling, inflation, openness to trade and government size—are not reported.
Exchange rate flexibility annual coding: de facto (RR coarse): four ways Reinhart and Rogoff fine classification (1: fix to 4: float). De facto (RR fine): 13 ways Reinhart and Rogoff fine classification (1: fix to 13: float). De facto (Gosh et al.): three ways consensus classification 1 = fix and peg regime, 2 = intermediated regime, 3 = floating regime. De facto (Levy-Yeyati et al.): four ways classification coded as (1: fix; 2: peg; 3 managed float; 4 float).
Dependent variable: growth rate of output per worker.
Source: Authors' estimations.

and cannot be put in the same bucket as countries with flexible exchange rates and low inflation rates.[16] These differences in categorization appear to drive the differences between the LS and RR results.

2.5. Endogeneity issues

At this point, the main qualification to our results would seem to be the standard question of endogeneity. To examine whether this is a serious issue in our context, we can (i) make various test within the GMM methodology and (ii) examine the broader existing empirical evidence on the determinants of exchange rate regimes or exchange rate volatility. Both perspectives indicate that endogeneity is not a major factor behind our results. First, the dynamic panel procedure using the GMM system estimator controls for the potential endogeneity of all the explanatory variables and accounts explicitly for the biases induced by including the initial level of productivity in the growth regressors. It is true that the estimation procedure is valid only under the assumption of *weak exogeneity* of the explanatory variables. That is, they are assumed to be uncorrelated with future realizations of the error term. This assumption can be tested using a Sargan test of overidentification which evaluates the entire set of moment conditions in order to assess the overall validity of the instruments. The results of the Sargan test in Tables 1–4 show that the validity of the instruments cannot be rejected.[17] As a robustness check, we re-estimate regression [1.2] in Table 1 by substituting in the instrument matrix the third lag level of the explanatory variables for the second lag level.[18,19] Regression [6.2] in Table 6 presents the results of the estimation. Lagging the set of internal instruments yieldsvery similar estimates and insures that our results are not biased by the presence of some omitted variables that could be correlated with exchange rate flexibility and might have an independent effect on the next period's innovation in productivity growth.

Furthermore, our empirical approach has several features that makes it less vulnerable to a potential endogeneity bias. First, we focus on identifying *contrasting growth effects* of exchange rate flexibility and volatility at different levels of

[16] Note also that freely falling regimes tend to grow out of failed fixed exchange rate systems.

[17] A second test examines whether the differenced error term is second-order serially correlated, a necessary condition for the consistency of the estimation. In all regressions, we can safely reject second-order serial correlation.

[18] For predetermined variables, such as initial income or initial secondary schooling, the first lag level is replaced by the second lag level. In order to make the estimations comparable with alternative sets of instruments, regression [1.2] (Table 1) is re-estimated over 1970–2000 and over 1975–2000.

[19] The results reported in the main tables are obtained using an instrument matrix that includes only the closest appropriate lags of the explanatory variables. The choice to restrict the instrument matrix is dictated by two considerations: (i) the Sargan test loses power when the set of instruments becomes large; (ii) if we used more instruments, we would run into a classical overfitting problem.

Table 6
Growth effects of exchange rate regime flexibility endogeneity issues and alternative set of instruments.

Period:	1970–2000	1970–2000	1970–2000	1975–2000	1975–2000	1975–2000
Unit of observation:	Non-overlapping five-year averages					
	[6.1]	[6.2]	[6.3]	[6.4]	[6.5]	[6.6]
Degree of exchange rate flexibility	−1.742**	−2.527**	−2.357**	−3.090**	−3.124**	−3.090**
(Reinhart and Rogoff classification)	0.745	1.197	1.179	1.453	1.500	1.453
Financial development	−0.800	−0.725	−0.819	−2.055	−1.962	−2.055
(private domestic credit/GDP, in logs)	0.666	0.907	0.918	1.455	1.359	1.455
Initial output per worker	0.132	−0.150	−0.076	0.102	0.147	0.178
(log(initial output per worker))	0.378	0.564	0.572	0.540	0.824	0.917
Flexibility ∗ financial development	0.428**	0.553**	0.513**	0.751**	0.766**	0.642**
	0.229	0.246	0.261	0.321	0.376	0.339
No. countries/no. observations	79/421	79/421	79/416	79/352	76/343	76/342
Specification tests (*p-values*)						
(a) Sargan test	0.596	0.285	0.26	0.269	0.298	0.245
(b) Second-order serial correlation	0.125	0.319	0.89	0.619	0.543	0.487

Notes: The specification of the regressions is identical to regression 2, Table 1. The coefficients for the other control variables—secondary schooling, inflation, openness to trade and government size—are not reported.
Regression [6.1] is the same as regression [1.2], Table 1, estimated over 1970–2000.
Regression [6.2] is the same as regression [6.1] with all internal instrument lagged by one time-unit.
Regression [6.3] is the same as regression [6.1] with VetoPoint introduced as external instrument.
Regression [6.4] is the same as regression [1.2], Table 1, estimated over 1975–2000.
Regression [6.5] is the same as regression [6.4] with Creditor Rights introduced as external instrument.
Regression [6.6] is the same as Regression [6.4] Creditor Rights and VetoPoints introduced as external instruments.
Dependent variable: growth rate of output per worker.
Source: Authors' estimations.

financial development. Endogeneity will be less of an issue with an interaction term than with single variables.[20] Second, similar results are obtained for various measures of exchange rate volatility, as well as for other measures of financial development (see below). Finally, by excluding high inflation "freely falling" exchange rate regimes in our baseline regressions, we are hopefully eliminating the most egregious cases where weak institutions would simultaneously explain low productivity growth and the choice of exchange rate regime (generally flexible because high inflation makes a sustained fix impossible).

A second way to address the potential endogeneity problem is to rely on the existing literature that tries to explain exchange rate volatility or exchange rate regimes. The literature on exchange rate volatility is small, but it finds some robust determinants for the degree of volatility. For instance, Hau (2002) finds a negative correlation between real exchange rate volatility and trade openness.[21] However, this does not affect our estimation as our specification includes both real exchange rate volatility and trade openness as regressors and treat them as jointly endogenous. Hausmann et al. (2006) investigate the determinants of real exchange rate volatility and find that GDP growth has a positive and statistically significant effect. This finding suggests that if a reverse causality link stems for growth to volatility, this link should be positive thus reinforcing our results.

The literature on the endogeneity of exchange rate regimes is more extensive, but it has been largely inconclusive. For instance, Juhn and Mauro (2002) apply the extreme bound method of Levine and Renelt (1992) on the effect of a large set of variables on the exchange rate regime and do not find any robust determinant.[22] However, in a recent paper, Levy-Yeyati et

[20] Assume for instance that the choice of exchange rate regime coincides with the choice of other policies associated with higher future growth opportunities unaccounted for by the set of explanatory variables. This could directly bias the estimation of the effect of exchange flexibility in a linear regression. In contrast, this could bias the estimation of the interaction coefficient in our set up only to the extent that the correlation between such policies and exchange rate flexibility or volatility varies significantly with the level of financial development.

[21] Bravo-Ortega and Di Giovanni (2006) have complemented this finding by showing that real exchange volatility is correlated with an index of remoteness defined as weighed geographical distance from main trade centers. This correlation suggests that remoteness can be a valid external instrument for real exchange volatility. However, remoteness exhibits almost no time variation and thus is a weak instrument in our dynamic panel context. When we use remoteness as an external instrument in a pure cross-sectional estimation, our results broadly hold but with less significance.

[22] The findings of Juhn and Mauro (2002) have been obtained using Levy-Yeyati and Sturzenegger (2003) de facto classification and the IMF de jure classification. We applied the same methodology to the RR classification and found the same result. We would like to thank Paulo Mauro for sharing his methodology.

al. (2004), using a logit analysis, find that some political variables can explain the likelihood of adopting a given exchange rate regime. We find that one of their political variables, VetoPoints, is a good instrument for exchange rate regimes.[23] We re-estimate our baseline specification with the variable VetoPoints as an external instrument. The estimates are presented in regression [6.3] in Table 6 and show results similar to the ones obtained using internal instruments. We also introduce a time-varying index of creditor protection constructed by Djankov et al. (2007) as an external instrument for the level of financial development and, again, find very similar results (see regressions [6.5] and [6.6]).

Beyond econometric tests, one can use the broad historical evidence to form a judgement on the endogeneity of exchange rate choices to future growth prospects. This is the approach followed by Eichengreen (1992) in his classical treatise. He shows that countries' choice to exit the inter-war gold standard had a huge impact on their subsequent growth trajectories. At the same time, the undisputed dogma in that period was that staying within the gold standard system was a necessary condition for economic recovery. A detailed discussion of the history of post-war exchange rate regimes falls outside the scope of this paper. However, our reading of the evidence compiled by De Vries (1985) and Boughton (2001), in their massive sequential histories of the International Monetary Fund, is certainly consistent with politics, history and ideology playing a dominant role in most countries' choice of exchange rate or monetary policy regime.[24] Indeed, although it is hard to deny that growth was always an objective of monetary policy, history clearly points at the existence of a large exogenous (for our purposes) component to exchange regime choice as well.[25]

2.6. Other robustness tests

The set of regressions presented in Tables 1–6 offers solid evidence that the level of financial development plays an important role in mitigating the negative effects of exchange rate volatility on productivity growth. It is also reassuring that control variables in the regressions have the expected effects: education and trade openness have a positive and often significant impact on growth while the effect of inflation and government burden is negative although not always statistically significant. Moreover, the results stay unchanged when the effects of crises are accounted for.

To further test the robustness of the main results, we conducted a large number of additional test and found that the results are indeed robust. The Appendix available in the supplementary material gives the details of these tests and we just summarize them in this subsection.

Different time windows: When shorter sample periods are considered, the main results basically hold. However, they become more significant in the post Bretton-Woods era, e.g., if we drop the first decade in the data, 1960–1970. On the other hand, when we restrict to the 1960–1980 period, the results are no longer significant.

Alternative measures of exchange rate volatility: We consider two alternative measures of exchange rate volatility: first, a measure of *real* effective exchange rate volatility computed with CPI indices and nominal exchange rates; second, a measure of *nominal* effective exchange rate volatility. The results are very similar to our baseline estimation when we use CPI-based real exchange volatility. The results are also similar with nominal effective exchange rate volatility when the estimation is restricted to the post Bretton-Woods era. However, this result is not robust to the inclusion of the pre Bretton-Woods era: in that case, the interaction coefficient becomes small and insignificant. This result may not be surprising since nominal volatility was much lower under Bretton Woods.

Alternative measures of financial development: Our initial and preferred measure is private credit to GDP from banks and other financial institutions. Our main result still holds when we consider the other side of the financial sector balance sheet (liquid liabilities over GDP) or when we restrict ourselves to a measure of the degree of financial intermediation provided by deposit money banks (deposit money banks assets over GDP).

Alternative measure of economic development: Instead of financial development we consider the distance to the technology frontier as measured as the difference in labor productivity with respect to the US. The results show that the interaction between labor productivity and exchange rate flexibility has a positive and significant impact on growth. The interpretation is that the higher the level of productivity is, the better (or the less detrimental) is the impact of a more flexible exchange rate on productivity growth.

Omission of continents: Our main result remains stable and significant when sub-groups of countries are omitted in a systematic way.

Crises and regime switching: A typical scenario of a currency crisis is a period of a fixed exchange rate with growth followed, after a large devaluation, by a more flexible exchange rate and a depressed economy (e.g., the Asian, Mexican and

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[23] We would like to thank Eduardo Levy-Yeyati for providing us with the data. VetoPoints is an index measuring the extent of institutionalized constraints on the decision-making powers of chief executives. Notice that the non-political variables used in Levy-Yeyati et al. (2004) are already included in our set of control variables.

[24] The dominant view of the IMF on exchange rate arrangement changed several time the last 30 years of the past century. In the early seventies, the IMF proposed to substitute to the failing Bretton Woods system a system of fixed but adjustable exchange rate. Later in the decade, the conventional wisdom in the Fund became that the floating-rate regimes were working reasonably well. In the eighties, the Fund became gradually more favorable to fixed exchange rates regimes and their associated stabilizing and trade-promoting virtues. This position was later reversed in the nineties and the IMF started promoting exit strategies for countries seeking exchange rate flexibility (Eichengreen et al., 1998).

[25] Mussa (1986), especially, presents compelling evidence that the different behavior of real exchange rates under fixed versus floating regimes cannot possibly be attributed to exchange rate regime endogeneity (in part because the change typically occurs exactly on the day a country switches regimes even when the decision is announced long in advance).

Southern Cone crises). To determine whether this might be the driving force behind our results in Table 1 we conduct various tests. First, we introduce a crisis dummy in Table 1 and show that this does not significantly affect our results. A second and more stringent test consists of assigning the growth costs associated with a currency collapse to the pre-collapse regime. When we do this, the results yield estimates that are very similar to our baseline specification. Two reasons explain the stability of our results: first, the number of re-classified observations only represent a small share of our data set; second and more importantly, with the exception of the notorious "twin" banking and currency crises of the 1990s that were associated with large output contractions, currency crises, in contrast to banking crises, are not generally associated with large output losses.

Robustness against alternative non linear hypotheses: Our strategy has been to use an interaction term to test the hypothesis of a non-linear growth effect of exchange rate flexibility or exchange rate volatility in the level of financial development. To test the validity of our specification, we consider alternative non-linear hypotheses. We find that the interaction effect between exchange rate flexibility and financial development remains strongly significant.

3. A simple model

In this section, we propose a stylized model to rationalize the empirical findings and in particular illustrate how the interaction of exchange rate flexibility and financial development may affect productivity growth. We focus on the basic mechanism through which a flexible exchange rate can have a negative impact on growth and leave out other mechanisms described in the literature.[26] The model shows how excess volatility in the exchange rate can, in principle, produce excess volatility in profits and thereby lower the economy wide average level of investment. An example of this idea can be drawn, for example, from the exchange rate pass-through literature (à la Dornbusch, 1987). Suppose a Korean exporter to the United States faces relatively fixed wage costs in local currency. However, when the dollar/won exchange rate fluctuates, the exporter is not able to completely pass through the cost change to US importers (perhaps because of competitive pressures in the US market). Then, exchange rate volatility leads to fluctuations in profits. These, in turn, can lower investment in an environment where the costs of external finance exceed those of internal finance (as documented by the large empirical literature on the effects of cash flow on investment, see, for example Gertler and Gilchrist, 1994).

The model combines two main elements. First, productivity grows as a result of innovation by those entrepreneurs with sufficient funds to meet short-run liquidity shocks. This feature is similar to Aghion, Angeletos, Banerjee, and Manova (2005) (AABM). Second, macroeconomic volatility is driven by nominal exchange rate movements in presence of wage stickiness. This monetary feature borrows from the recent New Open Economy Macroeconomics literature. Critically, we make the realistic assumption that unless exchange rates are pegged, risk premium shocks lead to exchange rate volatility in excess of any movement required to offset real shocks (an assumption that is strongly supported by the vast literature on the empirical determinants of exchange rates).

The basic mechanism is presented in the next three subsections. We first focus on the case where firms only face shocks to the nominal exchange rate and introduce productivity shocks in Section 3.4. Section 3.5 provides empirical evidence supporting the main mechanism. Using industry-level data, we find that the negative impact of exchange rate volatility in less financially developed economies is larger for industries with higher liquidity needs.

3.1. A small open economy with sticky wages

Consider a small open economy populated by overlapping generations of two-period lived entrepreneurs and workers. The economy produces a single good identical to the world good. One half of the individuals are selected to become entrepreneurs, while the other half become workers. Individuals are risk neutral and consume their accumulated income at the end of their life. Growth will be determined by the proportion of entrepreneurs who innovate.

Since firms in the small domestic economy are price-takers, they take the foreign price of the good at any date t, P_t^*, as given. Assuming purchasing power parity (PPP), converted back in units of the domestic currency, the value of one unit of sold output at date t is equal to

$$P_t = S_t P_t^*, \tag{2}$$

where P_t is the domestic price level and S_t is the nominal exchange rate (number of units of the domestic currency per unit of the foreign currency). P_t^* is assumed constant and normalized to 1. Thus, $P_t = S_t$. We begin with the case where exchange rates are driven entirely by risk premium (or noise) shocks, so that under floating S is exogenous. Later, we will introduce productivity shocks and illustrate how only excess exchange rate volatility is an issue.

In a fixed exchange rate regime, S_t is constant, whereas under a flexible exchange rate regime S_t is random and fluctuates around its mean value $E(S_t) \equiv \overline{S}$. The reason why fluctuations in the nominal exchange rate S_t will lead to fluctuations in firms' real wealth, with consequences for innovation and growth, is that nominal wages are rigid for one period and preset

[26] Notice, however, that the theoretical literature has not examined the link between exchange regimes and growth, but has focused on the level of output or of welfare.

before the realization of S_t. This in turn exposes firms' short-run profits to an exchange rate risk as the value of sales will vary according to S_t whereas the wage bill will not.[27,28]

For simplicity, the real wage at the beginning of period t is assumed equal to some reservation value, kA_t. The parameter $k<1$ refers to the workers' productivity-adjusted reservation utility, say from working on a home activity, and A_t is current aggregate productivity which is first assumed to be non-random. Thus

$$\frac{W_t}{E(P_t)} = kA_t,$$

where W_t is the nominal wage rate preset at the beginning of period t and $E(P_t)$ is the expected price level. Using the fact that $E(P_t) = E(S_t) = \bar{S}$, we immediately get

$$W_t = k\bar{S}A_t. \tag{3}$$

3.2. The behavior of firms

Individuals who become entrepreneurs take two types of decisions.[29] First, at the beginning of their first period, they need to decide how much labor to hire at the given nominal wage; this decision occurs after the aggregate shocks are realized. Second, at the end of their first period entrepreneurs face a liquidity shock and must decide whether or not to cover it (if they can) in order to survive and thereby innovate in the second period. The proportion ρ_t of entrepreneurs who innovate determines the growth rate of this economy. We first describe production and profits and then consider these two decisions in turn.

3.2.1. Production and profits

The production of an entrepreneur born at date t in her first period, is given by

$$y_t = A_t\sqrt{l_t}, \tag{4}$$

where l_t denotes the firm's labor input at date t.[30]

Given current nominal wages, nominal profits at the end of her first period are given by

$$\Pi_t = P_t y_t - W_t l_t = A_t S_t\sqrt{l_t} - kA_t\bar{S}l_t. \tag{5}$$

In her second period, the entrepreneur innovates and thereby realizes the value of innovation v_{t+1}, with probability ρ_t which depends upon whether the entrepreneur can cover her liquidity cost at the end of her first period. As we shall see, in an economy with credit constraints, the latter depends upon the short-term profit realization and therefore upon both employment and the aggregate shocks in the first period.

Employment in the first period is then chosen by the entrepreneur in order to maximize her net present value:

$$\max_{l_t}\{A_t P_t\sqrt{l_t} - kA_t\bar{S}l_t + \beta\rho_t E_t v_{t+1}\}, \tag{6}$$

where β denotes the entrepreneur's discount rate.

3.2.2. Innovation, liquidity shocks and credit constraints

Innovation upgrades the entrepreneur's technology up by some factor $\gamma>1$, so that a successful innovator has productivity $A_{t+1} = \gamma A_t$. It is natural to assume that the value of innovation v_{t+1} is proportional to the productivity level achieved by a successful innovator, that is

$$v_{t+1} = vP_{t+1}A_{t+1},$$

with $v>0$.

Next, we assume that innovation occurs in any firm i only if the entrepreneur in that firm survives the liquidity shock C_t^i that occurs at the end of her first period. Absent credit constraints, the probability of overcoming the liquidity shock would be equal to one, if the value of innovation is larger than the cost, and to zero otherwise. In either case, this probability would be independent of current profits. However, once we introduce credit constraints, the probability of the entrepreneur being able to innovate will depend upon her current cash-flow and therefore upon the choice of l_t.

[27] The crucial feature in the model is that the input price is rigid. On the other hand, the degree of price flexibility is not crucial. It would not be difficult to generate other examples of how excess exchange rate volatility raises the volatility of profits and thereby lowers investment under a broad variety of assumptions and models.

[28] In this benchmark model, the interesting measure of the real exchange rate is based on labor costs. The real rate based on price levels becomes of interest once we introduce non-traded goods or distribution services. That real exchange rates are more volatile under a flexible exchange rate regime is documented in the Appendix.

[29] One can easily extend the model so as to allow firms to increase the probability of innovation by investing more in R&D ex ante.

[30] Our choice of production technology is made for analytical simplicity and our results extend to more general settings.

The liquidity cost of innovation is assumed proportional to productivity A_t, according to the following linear form (multiplied by P_t as it is expressed in nominal terms):

$$C_t^i = c^i P_t A_t,$$

where c^i is independently and identically distributed across firms in the domestic economy, with uniform distribution over the interval between 0 and c. While all firms face the same probability distribution over c^i ex ante, ex post the realization of c^i differs across firms. We assume that the net productivity gain from innovating (e.g., as measured by $\nu\gamma$) is sufficiently high that it is always profitable for an entrepreneur to try and overcome her liquidity shock.

In order to pay for her liquidity cost, the entrepreneur can borrow on the local credit market. However, credit constraints will prevent her from borrowing more than a multiple $\mu - 1$ of current cash flow Π_t. We take μ as being the measure of financial development and we assume that is it constant.[31] The borrowing constraint is no longer binding if μ becomes large.

Thus, the funds available for innovative investment at the end of the first period are at most equal to

$$\mu\Pi_t,$$

and therefore the entrepreneur will innovate whenever

$$\mu\Pi_t \geqslant C_t^i. \tag{7}$$

Thus, the probability of innovation ρ_t is equal to[32]

$$\rho_t = \min\left(\frac{\mu\Pi_t}{cS_tA_t}, 1\right). \tag{8}$$

3.2.3. Equilibrium profits

The probability of innovation ρ_t can be substituted in the entrepreneur's maximization problem. The entrepreneur will choose l_t to maximize (6) which yields

$$l_t = \left(\frac{S_t}{2k\bar{S}}\right)^2$$

and therefore

$$\Pi_t = \psi A_t S_t^2, \tag{9}$$

where $\psi \equiv 1/(4k\bar{S})$. Therefore, equilibrium profits are increasing in the nominal exchange rate S_t.

Next, from (8), the probability of innovation can be expressed as

$$\rho_t = \min\left(\frac{\mu\psi}{c}S_t, 1\right). \tag{10}$$

3.3. Productivity growth and the main theoretical prediction

Expected productivity at date $t+1$ is equal to

$$E(A_{t+1}) = E(\rho_t)\gamma A_t + (1 - E(\rho_t))A_t.$$

The expected rate of productivity growth between date t and date $(t+1)$ is correspondingly given by

$$g_t = \frac{E(A_{t+1}) - A_t}{A_t} = (\gamma - 1)E(\rho_t). \tag{11}$$

We consider distributions of S_t such that for some values of S_t we have $\rho_t = 1$.[33] The following can then established:

Proposition 1. *Moving from a fixed to a flexible exchange rate reduces average growth. Moreover when μ is not too small, the growth gap decreases with financial development.*

Proof. From (11), the average growth rate g_t is proportional to the expected proportion of innovating firms. Thus, to compare a fixed exchange rate (i.e., no exchange rate volatility) with a flexible rate, we just need to look at the difference between the corresponding expected innovation probabilities[34]:

$$\Delta_t = \overline{\rho} - E(\rho_t),$$

[31] If μ was endogenous, it would decrease with more volatile profits, thus reinforcing the negative impact of exchange rate volatility.

[32] We always have $\rho_t > 0$ since $\Pi_t > 0$ in equilibrium and $S_t > 0$.

[33] A standard assumption would be that $\ln S_t \sim N(0, \sigma_s^2)$.

[34] The model can be turned into a convergence model, for example by assuming that innovating firms catch up with a world technology frontier growing at some rate $\overline{g}$, at a cost which is proportional to the world frontier productivity. Based upon the convergence analysis in Aghion et al. (2005), we conjecture that the lower the degree of financial development in a country, the more likely it is that higher exchange rate volatility will prevent the country from converging to the world technological frontier in growth rates and/or in per capita GDP levels.

where

$$\overline{\rho} = \min\left(\frac{\mu}{4kc}, 1\right)$$

and

$$E(\rho_t) = E\left(\min\left(\frac{\mu S}{4kc\overline{S}}, 1\right)\right).$$

To demonstrate the first part of the proposition, consider first the case where $\overline{\rho} < 1$. Then $E(\rho_t) = E(\min(\overline{\rho}S/\overline{S}, 1))$. If we had $\rho_t < 1$ for all S_t, then ρ_t would be linear in S_t and therefore we would have $E(\rho_t) = E(\overline{\rho}S/\overline{S}) = \overline{\rho}$. But, since we assume that there are some values of S_t for which $\rho_t = 1$, then ρ_t is a concave function of S_t and therefore by Jensen's inequality we have that $E(\rho_t) < \overline{\rho}$. When $\overline{\rho} = 1$, it is also obvious that $E(\rho_t) \leqslant \overline{\rho}$ since $\rho_t \leqslant 1$.

The second part of the proposition follows from the fact that $\overline{\rho} = 1$ when $\mu \geqslant 4kc$, so that for such levels of μ, the growth gap decreases with μ since $E(\rho_t)$ increases with μ (while $\overline{\rho}$ is constant). □

The superior performance of fixed exchange rates is driven by the asymmetry implied by the liquidity constraint and the resulting concavity of the ρ function.[35] These in turn imply that large depreciations do not compensate the impact of large appreciations: once $\rho_t = 1$ is reached any further depreciation cannot have any impact on growth.[36]

3.4. On the stabilizing role of flexible exchange rates

In the previous section, the only aggregate shocks were exchange rate risk premium (noise) shocks to the exchange rate. In this section, we allow for real shocks. Assume that domestic productivity is random and can be expressed as

$$A_t = \overline{A}_t e^{u_t}, \tag{12}$$

where (i) $\overline{A}_t$ is the country's level of knowledge at date t, which in turn results from innovations in period $t-1$, according to

$$\overline{A}_t = (\rho_{t-1}(\gamma - 1) + 1)A_{t-1};$$

(ii) u_t is a productivity shock with mean $E(u_t) = 0$ and variance σ_u^2.

The nominal wage is set before the productivity shock is known. Thus, analogously to Eq. (3) we have $W_t = k\overline{SA}_t$. It is easy to show that Eq. (9) is replaced by

$$\Pi_t = \overline{\psi}_t A_t^2 S_t^2, \tag{13}$$

where $\overline{\psi}_t \equiv 1/(4k\overline{SA}_t)$. Thus, the probability of innovation is given by

$$\rho_t = \min\left(\frac{\mu\overline{\psi}_t}{c} A_t S_t, 1\right). \tag{14}$$

This probability is determined by the volatility of the product $A_t S_t$. Following the same logic as in the previous analysis, the optimal policy now is for the monetary authorities to stabilize AS as opposed to simply S. This is a completely standard result (e.g., Obstfeld and Rogoff, 1996). Any policy conclusions from our empirical results must be tempered by this observation: an ideal central bank policy would stabilize AS. In a world where the central bank has perfect information on the shocks and can exactly control the exchange rate, the growth-maximizing regime does not literally involve a fixed exchange rate. However, as long as exchange rate risk premium shocks remain when the productivity shock is introduced, and as long as the central bank is not entirely successful in offsetting them, there remains the possibility that fixed rate regime is still preferable to an imperfect managed float. This is particularly likely to be the case when the effective size of the real shocks are small relative to the risk premium shocks and when the country has a low level of financial development. The fact that we later find the consistent result that relatively fixed exchange rate regimes produce higher growth rates in financially less developed countries perhaps suggests that, in practice, countries have difficulties offsetting A shocks without introducing other significant volatility in S.

Notice that the model's insight can be applied to other types of shocks and can thus be consistent with the negative relationship between volatility and growth documented by Ramey and Ramey (1995), as long as this negative correlation is exacerbated by financial underdevelopment.

[35] Such concavity would not hold, for example if the distribution of liquidity costs c had mass points on (the upper part of) its support. In that case, an increase in the volatility of exchange rates might foster growth by making it possible for firms to pay a high liquidity cost at least under exceptionally high realizations of S_t. Note, however, that in a world where such a "gambling for resurrection" effect were to dominate, one would observe a positive correlation between exchange rate (or, more generally, macroeconomic) volatility and growth. However, this is not what we observe if we look at cross-country panel data (see AABM and the empirical analysis in the next section).

[36] Notice that a crucial aspect in our analysis is that nominal profits are more sensitive to the nominal exchange rate than the liquidity cost. Given the production function (4), this property holds in the model. With a different production function, we may need to introduce some nominal rigidity in the liquidity cost in order to get the same result.

3.5. Empirical evidence

This subsection provides empirical evidence consistent with the theoretical mechanism outlined above. This mechanism implies that exchange rate volatility will be specially harmful to firms that have high liquidity needs in countries with a low degree of financial development. This hypothesis is tested using industry-level data and measures of industry-specific liquidity needs from Raddatz (2006).[37]

The industry-level production and employment data come from the 2006 UNIDO Industrial Statistics Database and cover the period 1970–2000.[38] There are 28 manufacturing sectors. The resulting data set is an unbalanced panel of 47 countries, but we ensure that for each country-year we have a minimum of 10 sectors, and that for each country, there are at least 10 years of data. As for the cross-country regression, we construct a five-year average panel. We use the measure of sector-specific *liquidity needs* constructed by Raddatz (2006), which is computed as the ratio of inventories to sale using balance-sheet data of US public manufacturing firms. The Appendix reports the measure of liquidity needs for each industry.

To see whether the differential impact of exchange rate volatility across industries with different liquidity needs varies with the level of financial development, the following equation is estimated:

$$y_{i,j,t} - y_{i,j,t-1} = \alpha_1 LN_j * ER_{i,t} + \alpha_2 LN_j * ER_{i,t} * FD_{i,t} + \gamma Z_{i,j,t} + \eta_j + c_{i,t} + \varepsilon_{i,j,t}, \quad (15)$$

where $y_{i,j,t}$ is the logarithm of output per worker in sector j in country i in period t; LN_j is the industry-specific measure of liquidity needs; $FD_{i,t}$ is private credit to GDP and $Z_{i,j,t}$ is a vector of controls. All the specifications include a country-time effect $c_{i,t}$ and an industry-specific fixed effect η_j. Notice that the three dimension panel (country, industry, time) reduces considerably potential endogeneity biases. Country-time fixed effects allow to control for any time-varying country-specific factor that could be correlated with the productivity growth performance and exchange rate volatility or the exchange rate regime. The effect identified by the regression is the difference in productivity growth between industries with different liquidity need across countries with a different level of exchange rate volatility and financial development.

The results are presented in Table 7. From columns 1 and 3, we find that both the flexibility of exchange rate regime and exchange rate volatility reduce that the productivity growth of sectors with high liquidity need relatively to the ones with low liquidity needs. The differential impact is economically significant.[39] Columns 2 and 4 show that α_1 and α_2 in Eq. (15) are both significant and with the expected sign. By combining these estimates with the level on financial development, one finds that the differential effect of exchange rate volatility across industries is maximal at low level of financial development and fully vanishes at the highest level of financial development.[40] In sum, the results for the industry-level regression provide supporting evidence in favor of the mechanism of the model.

4. Conclusion

The vast empirical literature following Baxter and Stockman (1989) and Flood and Rose (1995) generally finds no detectable difference in macroeconomic performance between fixed and floating exchange rate regimes. In this paper, we argue that instead of looking at exchange rate volatility in isolation, it is important to look at the interaction between exchange rate volatility and both the level of financial development and the nature of macroeconomic shocks. Our main hypothesis is that higher levels of excess exchange rate volatility can stunt growth, especially in countries with thin capital markets and where financial shocks are the main source of macroeconomic volatility. This hypothesis is shown to be largely validated by cross-country panel data, which thus provide fairly robust evidence suggesting the importance of financial development for the relationship between the choice of exchange rate regime and long-run growth.[41] We also provide an explanation that rationalizes these results.

Are our result at odds with the prescriptions of the standard exchange rate models? Not necessarily. The classical literature holds that the greater the volatility of real shocks relative to financial shocks in a country, the more flexible the exchange rate in that country should be. Our analysis shows that this prescription has to be modified to allow for the fact that financial market shocks are amplified in developing countries with thin and poorly developed credit markets. Clearly, more fully articulated structural models are needed to properly measure the trade-offs, which in turn remains an important challenge for future research.

[37] Using an approach in the spirit of Rajan and Zingales (1998), Raddatz finds that low financial development implies a higher output volatility especially in the sectors with high liquidity needs.

[38] We use the version that reports data according to the 3-digit ISIC Revision 2 classification. We convert data reported in current US dollars into constant international dollars using the Penn World Tables (Heston et al., 2002).

[39] The measure of liquidity need ranges between 0.06 and 0.26. Column 1 reports a point estimate for α_1 equal to -4.13. Hence a one unit increase in exchange rate flexibility reduces productivity growth by -0.3 percentage points for an industry with lowest liquidity needs (Petroleum Refineries) but by -1.3 percentage point for an industry with the highest liquidity needs (Leathers). See Appendix D for the measure of liquidity needs reported for each industry.

[40] The level of financial development measured by the log of the percentage ratio of private credit to GDP varies in the sample between 1.5 and 4.8.

[41] Rogoff et al. (2004) and Husain et al. (2005) do find differences in exchange rate regime performance across developing countries, emerging markets and advanced economies. However, perhaps because they do not incorporate any structural variables in their regressions such as private credit to GDP, or distance to frontier, they only found significant and robust effects of exchange rate regime choice on growth in advanced economies.

Table 7
Industry-level evidence on growth effects of exchange rate regime flexibility and real effective exchange rate volatility: The role of liquidity needs.

Period:	1970–2000			
Unit of observation:	Non-overlapping five-year averages			
	[7.1]	[7.2]	[7.3]	[7.4]
Liquidity needs ∗ exchange rate flexibility	−5.078**	−17.35**		
	2.217	5.51		
Liquidity needs ∗ exchange rate flexibility ∗ financial development		3.813**		
		1.386		
Liquidity needs ∗ exchange rate volatility			−4.418**	−11.8**
			2.126	5.39
Liquidity needs ∗ exchange rate votality ∗ financial development				2.773**
				1.349
Control variables				
Initial output per worker	−0.03	−0.046	−0.047	−0.025
(in logs)	0.16	0.158	0.16	0.16
Industry share in manufacturing output	−0.043**	−0.037**	−0.028	−0.03*
	0.017	0.017	0.017	0.017
Liquidity needs ∗ financial development	0.512	−0.692	0.36	−1.516
	1.47	1.45	1.62	1.89
Intercept	6.415**	6.703**	6.69**	6.299**
	1.914	1.919	1.957	1.958
No. observations	5740	5740	5740	5740
No. countries/no. industries	47/28	47/28	47/28	47/28

Notes: The estimation uses a three-dimensional panel: time, country, industry. Country-time fixed effects and industry fixed effects are included in each regression.
Financial development is measured by the log of the percentage ratio of private credit to GDP. Table A.11 in the Empirical Appendix report the measure of liquidity needs in each industry.
Standard errors are presented below the corresponding coefficients. Symbols ** and * mean significant at 5% and at 10%.
Dependent variable: industry growth rate of output per worker.
Source: Authors' estimations.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jmoneco.2009.03.015.

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