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ARE EXCHANGE RATES DRIVEN BY GLOBAL OR LOCAL FACTORS?

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This Working Paper should not be reported as representing the views of the French Ministry of Finance, but as author views.

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Abstract

This paper uses factor analysis to present an original explanation of floating exchange rate movements. I estimate the shares of domestic and external drivers of these evolutions and find that external common factors are the main drivers of exchange rates and that there is a common pattern for both advanced and emerging countries. These results are robust in time and across countries according to multiple robustness checks. I also provide economic interpretations of the underlying factors. If traditional drivers are found (US relative economic situation, commodity prices), I also find a selective perception of risk aversion between advanced and emerging economies. This work falls within the literature on monetary conditions (more precisely Mundell's trilemma). The study covers 26 countries, and I detail how results vary between emerging and advanced economies.

Résumé

Cet article propose, en utilisant une analyse factorielle, une explication originale des évolutions des taux de change. Les parts relatives des déterminants internes et externes de ces mouvements sont estimées, ce qui permet de montrer que les facteurs communs externes constituent les principaux déterminants des évolutions de taux de change et qu'il existe un schéma commun aux économies avancées et émergentes. De multiples tests de robustesse assurent que ces résultats sont robustes dans le temps et d'un pays à l'autre. De plus, des interprétations économiques des facteurs sous-jacents estimés sont présentées. Des déterminants usuels sont trouvés (situation économique relative des États-Unis, prix des matières premières), mais la perception relative du risque dans les économies avancées par rapport aux économies émergentes est également mise en valeur. Ce travail est à relier à la littérature sur les conditions monétaires (plus précisément le trilemme de Mundell). L'étude porte sur 26 pays, et je détaille comment les résultats varient entre les économies émergentes et avancées.

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1. Introduction and Main Findings

Exchange rate fluctuations are traditionally considered as shock absorbers mitigating the effect of shocks on economies. For example, a recession in a country can trigger capital outflows from this country and lead to exchange rate depreciation, which boosts competitiveness and supports an economic recovery. This stabilizing role of the exchange rate can function only if the exchange rate reflects the economic situation of a country relative to its partners. In the current environment of global financial integration, the stabilizing capacity of the exchange rate has come into question (Coeuré, 2015). Indeed, recent academic evidence suggests that financial conditions are increasingly determined by global rather than domestic factors (Rey (2015), Edwards (2015), or Obstfeld (2015)). This could imply that exchange rates do not sufficiently reflect domestic circumstances, which would lead to suboptimal economic outcomes. This would complicate policy setting, by hampering the exchange rate channel of monetary policy. It would mean that domestic targets would have to be achieved through channels other than exchange rates, including through internal and socially costly adjustments or macro-prudential tools.

This study assesses the respective importance of domestic and global factors in exchange rate movements. It also investigates whether some countries (e.g. emerging economies) are more influenced by global factors than other countries. In a second step, it provides an economic interpretation to the global factors identified, notably to assess the weight of foreign developments and policy orientations.

The empirical strategy relies on a simple statistical analysis to extract the main common factors to exchange rate fluctuations. The focus is on bilateral exchange rates of all currencies with the USD, while robustness tests based on effective exchange rates confirm the results. Bilateral exchange rate evolutions exhibit a high correlation (Table 1). They are expected to reflect economic conditions in the issuing country and in the United States, but they may also reflect other global forces. The conclusions are based on analyses over different geographical samples and time samples and on a detailed analysis of the global factors to support their economic interpretation. Finally, the relative weight of domestic and global factors is estimated in a regression analysis using as inputs the global factors determined in the factor analysis.

The main results can be summarized as follows:

- **Exchange rate movements are primarily driven by global factors**. Country-specific factors explain only a quarter of exchange rate movements on average across the advanced and emerging economies in the sample.
- **This conclusion is robust over time and across countries, and the common factors are the same for emerging and advanced economies**. Still, the relative importance and direction of each factor in exchange rate dynamics vary across countries.
- **Bilateral exchange rates with the dollar are found to be mainly driven by:** *(i)* variation of the US real effective exchange rate (REER), which is itself strongly related to US GDP growth, *(ii)* commodity prices, *(iii)* changes in the RMB/USD parity, and *(iv)* relative financial stress in advanced economies compared to emerging economies. The identification of this last driver is one main contribution of this paper.

Table 1 – Correlation between (real) bilateral exchange rates against the dollar (Quarterly data over 1999-2014)

	aus	can	nzl	nor	ukd	che	swe	jpn	zoe	isl	cze	hun	rom	pol	isr	chl	col	mex	bra	ind	phl	sgp	kor	tha	tur	zaf
aus	1.00																									
can	0.95	1.00																								
nzl	0.96	0.91	1.00																							
nor	0.87	0.92	0.88	1.00																						
ukd	0.24	0.35	0.41	0.49	1.00																					
che	0.95	0.87	0.93	0.88	0.23	1.00																				
swe	0.79	0.80	0.83	0.90	0.69	0.80	1.00																			
jpn	0.06	-0.04	-0.12	-0.09	-0.32	0.09	0.01	1.00																		
zoe	0.80	0.87	0.84	0.94	0.54	0.85	0.89	-0.12	1.00																	
isl	0.06	0.21	0.24	0.33	0.90	0.03	0.51	-0.37	0.37	1.00																
cze	0.88	0.93	0.85	0.93	0.28	0.89	0.77	-0.09	0.93	0.11	1.00															
hun	0.83	0.90	0.85	0.95	0.45	0.84	0.82	-0.17	0.96	0.29	0.97	1.00														
rom	0.82	0.92	0.84	0.90	0.45	0.79	0.77	-0.26	0.92	0.32	0.95	0.95	1.00													
pol	0.77	0.87	0.77	0.89	0.42	0.75	0.76	-0.24	0.89	0.27	0.94	0.95	0.95	1.00												
isr	0.65	0.52	0.54	0.43	-0.16	0.66	0.42	0.29	0.41	-0.40	0.55	0.41	0.43	0.48	1.00											
chl	0.83	0.82	0.74	0.67	0.19	0.73	0.67	0.24	0.63	0.03	0.71	0.61	0.68	0.66	0.73	1.00										
col	0.90	0.85	0.82	0.72	0.05	0.83	0.61	0.11	0.67	-0.15	0.81	0.71	0.75	0.73	0.80	0.91	1.00									
mex	-0.36	-0.32	-0.36	-0.33	0.00	-0.47	-0.30	-0.31	-0.46	0.11	-0.38	-0.33	-0.28	-0.14	-0.21	-0.28	-0.32	1.00								
bra	0.89	0.90	0.79	0.75	0.09	0.82	0.63	0.15	0.72	-0.08	0.85	0.75	0.81	0.78	0.76	0.92	0.95	-0.30	1.00							
ind	0.95	0.90	0.89	0.79	0.09	0.90	0.67	0.09	0.73	-0.09	0.86	0.77	0.79	0.74	0.75	0.83	0.94	-0.35	0.94	1.00						
phl	0.79	0.68	0.70	0.55	-0.04	0.73	0.50	0.18	0.51	-0.25	0.65	0.50	0.57	0.53	0.86	0.87	0.93	-0.34	0.85	0.85	1.00					
sgp	0.86	0.71	0.79	0.58	-0.08	0.82	0.52	0.16	0.51	-0.29	0.67	0.54	0.56	0.53	0.86	0.80	0.91	-0.33	0.82	0.89	0.94	1.00				
kor	0.62	0.71	0.73	0.68	0.74	0.52	0.71	-0.38	0.63	0.69	0.55	0.62	0.73	0.63	0.12	0.52	0.46	0.01	0.51	0.52	0.33	0.34	1.00			
tha	0.92	0.86	0.85	0.75	0.09	0.87	0.67	0.13	0.71	-0.12	0.82	0.71	0.75	0.70	0.81	0.90	0.96	-0.40	0.93	0.95	0.94	0.93	0.48	1.00		
tur	0.86	0.94	0.85	0.90	0.39	0.80	0.79	-0.10	0.92	0.27	0.94	0.93	0.95	0.91	0.47	0.76	0.79	-0.37	0.85	0.83	0.61	0.60	0.66	0.80	1.00	
zaf	0.73	0.76	0.70	0.72	0.38	0.71	0.75	0.38	0.69	0.29	0.63	0.65	0.60	0.54	0.34	0.67	0.57	-0.44	0.68	0.67	0.42	0.44	0.54	0.59	0.70	1.00

Correlations between 0.8 and 1 appear in dark green; between 0.6 and 0.8 in light green; between 0.4 and 0.6 in yellow; between 0.2 and 0.4 in orange; between 0 and 0.2 in red and in grey for negative values. A correlation of one indicates that the series have exactly the same evolutions.

Source: IMF, IHS Economics.

2. Literature review

2.1 Determinants of exchange rate evolutions

In the second half of the twentieth century, economists developed several models to explain what determines exchange rate. They were encouraged among other things by the development of floating exchange rate regimes after the collapse of the Bretton Woods system and the end of the gold standard in 1971. A very large literature emerged, with static as well as dynamic models, mostly based on macroeconomic variables. From Mundell-Fleming's idea (1962) on balance of payments flows to various monetarist models (including Dornbusch (1976) or Frenkel (1978) on the stock of money or Branson and Henderson (1985), for portfolio models), economic fundamentals were at the heart of models explaining exchange rates. More recently, carry-trade positions, risk aversion or central bank interventions in the foreign exchange market are also frequently used to describe exchange rate movements. Moreover, other fundamental variables are also used: productivity variations (Balassa and Samuelson (1964)), commodity prices (Golub (1983)), or the fiscal budget balance (Sachs and Wyplosz, (1984)). More micro-founded models have also been developed, introducing rational expectations (Blanchard and Watson (1984)) or asymmetric information (Kyle (1985)).

However, empirical analyses have not fully validated these theoretical models, partly due to restrictive assumptions on which these models are based. For example, Flood and Rose (1995) showed that the exchange rate was much more volatile than macroeconomic variables. If a lot of progress on modeling has been made, there are still some unsolved issues around exchange rate evolutions, and this study aims at providing complementary elements of analysis.

2.2 Exchange rate movements and monetary policy independence

In theory, exchange rate flexibility promotes monetary independence. Financial integration has intensified significantly for decades, along with the liberalization of capital mobility. Obstfeld (2012) emphasizes in this regard the increasing levels of gross foreign assets and liabilities resulting from these capital flows, and how they may induce vulnerability. This financial flows dynamism applies to both advanced and emerging economies. In addition, pegging currencies to an anchor currency is generally not an explicit objective of monetary policy. Mundell's trilemma states that choosing a fixed exchange rate regime cannot go along with monetary policy independence when capital moves freely (Mundell, 1960). This theory has sometimes been abusively interpreted as stating that floating exchange rates allow monetary policy independence even with free capital flows. An unresolved question is to know to which extent this stronger statement holds.

Despite the classic argument that flexible exchange rates make it possible (or at least easier) for monetary policies to accommodate domestic shocks, it is well known that global factors – beyond policy decisions taken by other countries – can play significantly on exchange rate developments. For instance, one can expect changes in oil prices or changes in the global risk aversion to have an impact on exchange rates for all economies. The effect of oil price fluctuations on exchange rates has been particularly well documented since the foundational work of Golub (1983), Krugman (1983) and Corden (1984).

Even when it is not explicitly targeted, the exchange rate is a variable that is considered by the monetary authorities. Because, for some economies, exchange rate variations can disrupt financial stability, for instance through balance sheet effects in the case of currency mismatch, or make it harder for the central bank to reach its inflation target, exchange rate movements are widely followed by policy makers even if the exchange rate is not an explicit target. In an empirical study on three Latin American countries with floating exchange rate regime, Edwards (2015) shows that the US monetary policy impacts the decisions taken by the studied central banks, partly because central banks may want to avoid "excessive" exchange rate volatility. Obstfeld (2015) explains that in the case of floating exchange rate, central banks can have their decisions affected by those of others, especially if these impact domestic macroeconomic conditions[1].

In the end, no matter how monetary independence is defined, central banks are forced to take into account certain developments beyond their domestic economy to build their monetary policy. This is the case as long as these changes influence their domestic targets, and it is true even for countries with flexible exchange rates.

Measuring the share of the evolutions of floating exchange rates reflecting global exogenous shocks would shed light on what kinds of shocks exchange rates respond to and on the constraints on monetary policy. If exchange rates respond mainly to exogenous external shocks, monetary authorities would see pressure on their independence, as they must react to these developments (sometimes to the detriment of other internal conditions). The constraint is all the more important if the exchange rate absorbs multiple external shocks.

This work is related to recent work challenging the idea that floating exchange rates would entirely insulate monetary policy from external evolutions, and in particular other central banks' policies. In particular, Rey (2015) argues that there is a global financial cycle, partly driven by US monetary policy: this implies that some countries import financial conditions that are not *a priori* desirable for their economies. Indeed, a tightening of monetary conditions

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[1] According to his definition of independence, as long as central banks aim at *domestic* objectives, which are not explicitly linked to the parity of the currency, they are independent: it remains their choice to tradeoff between several domestic objectives (inflation, unemployment, macro-financial stability) without calling into question their independence. (The need to tradeoff between several domestic objectives may require moving away from the macroeconomic optimum if they have fewer instruments than goals.)

in the United States induces capital outflows elsewhere. In order to contain potentially destabilizing effects from these sudden outflows, central banks from other countries may be forced to raise their interest rates – regardless of their exchange rate regime.

2.3 Factor analysis

Factor models summarize the common information contained in a set of observed series into a smaller number of factors. In the context of long and rich data samples, factor analysis is particularly interesting. The literature dealing with this kind of models focuses most of the time on large samples (following the approach of Stock and Watson (2002)). Nevertheless, some authors work on samples with a limited number of variables (e.g. Doz and Lenglart, 1999). Since the early 2000s, dynamic approaches have boomed, with a wide variety of models (see Barhoumi et al. (2012) for a literature review).

Because the aim of this study is to find common (external) drivers of exchange rate dynamics, factor analysis appears to be particularly relevant. The hypothesis is that the high correlation between exchange rate series (Table 1) makes it possible to identify common factors that drive all countries' exchange rates. More specifically, factor analyses provide tools to identify and assess the part of exchange rate movements that comes from common factors.

In the literature, factor analysis is used to address various macroeconomic policy issues. To cite only a few examples, Bernanke, Boivin and Eliasz (2005) developed a FAVAR model (factor-augmented vector autoregression) to study the effects of US monetary policy. Stock and Watson, in 1999 and 2002 respectively, studied cyclical variables (Chicago Fed National Activity Index, CFNAI) and inflation forecasts.

This paper builds on the few existing factor analysis of exchange rate movements in the literature. Cayen and al. (2010) conduct a factorial analysis on bilateral exchange rates for six advanced economies between 1981 and 2007 and provide an economic interpretation of the estimated factors. Engel and al. (2012) test the predictive power of models to explain the currency changes of 17 advanced economies thanks to factors estimated with these exchange rate series. McGrevy-Greenaway and al. (2012) also work on a large sample of countries (including emerging economies) with out-of-sample analyses. The authors highlight the significant role of key currencies (euro, yen and Swiss franc) in explaining exchange rate developments against the dollar. This would be a way to improve the usual bilateral models.

3. Methodology – A Two-Step Approach

3.1 Step 1: Factor analysis

3.1.1 General approach

The first step (section 4) consists in running factor analysis on several samples to measure to what extent exchange rate movements are driven by common factors. Two samples are considered, reflecting data constraints: one over a long period (1981-2014) but with only 8 advanced economies and one over a shorter period (1999-2014) with 26 advanced and emerging economies. Complementary analysis is also provided in the appendix to test the robustness of the results on various sub-samples. This section gives innovative results on exchange rate mechanisms. Its goals can be summarized by the following issues:

- Relevance of the Factor Analysis: Can a factor analysis explain satisfactorily the variation in exchange rates, including for all countries?
- Robustness over time and according to the selected sample: Between the different samples, are there differences in the results of the factor analysis? Are the results over the recent period in line with the estimates over a long period from the previous section?

3.1.2 Specification: static analysis on first differences

Consider a sample consisting of N variables and length T. It is assumed that these variables present a high correlation so that they contain redundant information. The idea is to express each of the N variables as a linear combination of *(i)* P (with P < N) unobservable latent variables, called *common factors,* which are common to the N variables and that synthesize the joint information of the sample and *(ii)* an idiosyncratic component, specific to each variable. Each idiosyncratic country-specific component has variance ψ_i over the period and is uncorrelated with both the common factors and the idiosyncratic component of other countries. The mean of the factors is normalized to zero, their variance to one and they are orthogonal to each other over the study period.

More specifically, a static factor analysis of a sample of centered reduced variables $(x_{i,t})_{i=1..N;t=1..T}$ can be written:

$$x_{i,t} = \sum_{p=1}^{P} \lambda_p^i \times f_{p,t} + \varepsilon_{i,t}$$

Where λ_p^i, called *weight of the factor p for i*, measures the correlation between the observable i and factor p. We call *communality* the sum $\sum_{p=1}^{P}(\lambda_p^i)^2$: it represents the share of the variance of x_i explained by the P factors. $\varepsilon_{i,t}$ is the idiosyncratic component, of variance ψ_i.

Despite the existence of temporal correlation, using a static analysis remains relevant in practice. Indeed, static analysis is interesting for its simplicity (calculation times for dynamic analysis can quickly explode when a significant number of series is involved). This can explain that several articles performing factor analysis, particularly on exchange rates (see for example Greenaway-MacGrevy et al. (2012)), work in a static framework. Moreover, static analyses generally lead to very similar results to those produced by dynamic analyses (Lenglart Doz (1999), or Cayen and al. (2010)). Some of the results of this paper can be compared to the estimates of Cayen and al. (2010) and further confirm this point.

Exchange rates are not stationary variables[2]: working in first differences is a solution that has the advantage of simplicity in the case of bilateral exchange rates, which are series integrated of order 1 (Dickey-Fuller tests are presented in the appendix). Bai and Ng (2004) show that the cumulated series from factors estimated on first differences are consistent estimates of the true factors in level for large N and T. The variable used in this study is the first difference of the logarithm of the bilateral real exchange rate of country i against the dollar (the real bilateral exchange rate is the value of a consumption basket in country i in terms of an American consumption basket). In other words, the variable of interest is approximately the growth rate of the bilateral exchange rate against the dollar and its rise corresponds to the appreciation of the currency of country i against the dollar. From now on, f denote factors estimated on first differences and F their cumulated value.

The choice to work in first differences induces an identification problem because the model cannot uniquely determine common deterministic trend factors. This comes from the fact that variables are centered before running the analysis, which leads, when cumulating the estimated factor analysis in first differences, to the existence of a trend in the specification

[2] Factor analyses on non-stationary variables require some arbitrary trade-offs. One promising method is to exploit the recent literature seeking to develop factors models for non-stationary series. However, Combes and Doz (2014) point out that the answers found at this stage in the literature on this subject leave unresolved issues. In particular, they show the challenges associated with the normalization of the data that is done before conducting the factor analysis. In particular, the authors highlight a problem of robustness of the results to changes in scale.

in level[3]. The evolution of the exchange rate in level of country i (from its initial value) is the sum of the contribution of common factors, with country-specific weights and of an idiosyncratic component. But this latter part can in fact be divided into two components: *(i)* the random idiosyncratic contribution, which comes directly from the estimated idiosyncratic component in the factor analysis and *(ii)* an idiosyncratic deterministic trend over the period, which appears exclusively in the country-specific part, reflecting the fact that the factor analysis was done on centered first differences. The smaller the gap between the first and last point of the sample, the flatter this trend. The estimated factors must as a consequence be seen as corrected from their own trend (if they had one).

Several criteria are used to determine the number P of factors retained. From N variables, it is possible to estimate up to N factors that would fully explain the common variance of these variables. In practice, the goal is that factors explain most of the correlations between variables, and the correlation between the idiosyncratic terms is not zero but represents a negligible part of the correlation between the observed variables. The challenge is how to retain a limited P among N existing factors, in order to "optimize" the synthesis of the information contained in the variables. In practice, the following criteria were compared to make this choice: *(i)* the Kaiser-Guttman criteria, which selects the factors that are associated with a greater than unity eigenvalue of the matrix of correlation of the series (meaning that they explain a greater share of the total variance than 1/N), *(ii)* the proportion of the total variance explained by the factors (the threshold is set at 70%) and *(iii)* Bai and Ng criteria (Bai et Ng, 2002) for the sample with large N.

3.2 Step 2: Interpretation of the factor

The second step of this study (section 5) aims at giving an economic interpretation to the estimated factors. The analysis is based on the shape of the factors and of the associated country-specific weights. It is complemented by ad hoc correlation and cointegration tests to confirm the proposed interpretations.

3.3 Data

The factor analysis is performed on quarterly data of real bilateral exchange rate against the dollar[4]. The consumer price index comes from quarterly series of the IMF and the nominal exchange quarterly data is provided by IHS Economics (average value over the quarter of daily data). The real effective exchange rate data are sourced from the BIS.

There is a practical justification for the choice of the dollar as reference. In theory, any one of the selected currencies could have been used as reference for the factor analyses in this study. In theory, the total share of exchange rates fluctuations that can be explained by common factors does not depend on the choice of the reference. However, the shape of the estimated factors depend on the reference currency, and their interpretation is easier and more meaningful when the dollar is chosen.

The sample covers the euro area at the aggregate level and 25 countries:

- <u>10 advanced economies/area:</u> Australia, Canada, Japan, New Zealand, Norway, United Kingdom, Switzerland, Sweden, Euro Area, Iceland,

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[3] The estimated model $y_{i,t} = \frac{\Delta e_{i,t} - \mu_i}{\sigma_i} = \sum_{p=1}^{P} \lambda_p^i \times f_{p,t} + \varepsilon_{i,t}$, when cumulated, becomes (with F and E the cumulated values of f and ε) : $e_{i,t} = e_{i,1} + \sigma_i \times \left(\sum_{p=1}^{P} \lambda_p^i \times F_{p,t} + E_{i,t} + \frac{\mu_i}{\sigma_i} \times t \right)$.

[4] The choice to study bilateral exchange rates around a single pivot automatically leads to lose a series which would not be the case if effective exchange rates were used. But this choice seems justified given the current use of bilateral exchange rates and the fact that the real effective exchange rate can be easily deduced.

- 16 emerging economies: Brazil, Chile, Colombia, Mexico, Czech Republic, Hungary, Poland, Romania, Israel, Turkey, India, Philippines, Korea, Singapore, Thailand, South Africa.

The selection of the countries and the choice of the period were based on two requirements: the availability of the data and a floating exchange rate regime or equivalent (as classified by the IMF) over the whole period. Depending on the country and on data availability, the data is used on the interval 1981q1-2014q3 or 1999q1-2014q3.

The Kaiser-Meyer-Olkin test (KMO) (Kaiser, 1974) is used to assess whether it is relevant to conduct a factor analysis on the sample, by measuring whether the correlation between the series of interest is strong enough. The KMO statistical test involves a comparison between the observed correlation of variables and their partial correlations. The higher this ratio (between 0 and 1), reflecting the weakness of partial correlations, the stronger the common correlations (hence with a common factor), which justifies a factor analysis (see Appendix).

4. The exchange rates of advanced and emerging economies are mainly driven by common factors

4.1 Factor analysis on different samples

4.1.1 Analysis on eight advanced economies over 1981-2014

The analysis starts by focusing on advanced economies, for which it would seem most likely to extract common developments. One advantage of this first step is that a relatively long time sample is covered, which implies longer series of factors and therefore facilitates interpretation. For eight advanced economies, available data and the exchange rate regime allow to work on a relatively long time period (1981q1 to 2014q3). Thereafter, this sample will be denoted S-AE-LONG. It includes the following eight advanced economies: Australia, Canada, Japan, New Zealand, Norway, United Kingdom, Switzerland and Sweden. The euro area is not included in this sample because the euro was introduced in the middle of the period, which could bias the estimate.

A static factor analysis is performed on centered and standardized growth rates of bilateral real exchange rates. The Kaiser-Meyer-Olkin index of simplicity (KMO) is estimated at 0.83, reflecting the high level of correlation between variables, which suggests that running a factor analysis is relevant.

The factor analysis points to retaining two common factors. Indeed, only two factors are associated with eigenvalues greater than unity (4.6 and 1.4). The third is worth 0.7. These two factors would explain 75% of the common variance of the data. This level is higher than the 70% threshold previously set (see Table 2).

Table 2 – Choice of the number of factors – S-AE-LONG

Factor	Eigenvalue	Cumulated share of common variance explained
1	4.60	0.58
2	1.36	0.75
3	0.72	0.83
4	0.44	0.89
5	0.34	0.93
6	0.26	0.96
7	0.16	0.98
8	0.13	1.00

Source: Author's calculations.

In addition, for each of the selected countries, the communality, defined as the variance explained by the chosen factors (here two), appears important: its value is estimated at 60% for Japan and over 70% for the other considered countries (see Table 3).

Table 3 – Communality associated with the two factors (share of the variance explained by the two factors)

Country	Communality
Australia	0.79
Canada	0.73
New Zealand	0.70
Norway	0.83
United Kingdom	0.70
Switzerland	0.85
Sweden	0.77
Japan	0.60

Source: Author's calculations.

This means that individual specific components play a fairly limited role in the evolution of the exchange rate against the dollar as they explain only 25% of the variance of exchange rate movements. This result shows the importance of global factors in the exchange rate movements in comparison to domestic factors. These results are consistent with the study by Cayen and al. (2010), which conduct a comparable analysis albeit with significant differences (including the length of the studied sample and the list of countries considered).

4.1.2 Analysis of a broader sample of countries and a shorter period

The previous approach is now developed starting from 1999 with a larger sample of countries. By reducing the time period studied, it is possible to broaden the sample of countries, and in particular to include emerging economies in the estimation. In this section, a new factor analysis is run with a sample of 26 countries (that will be denoted S-ALL or sample ALL in the rest of the paper). The KMO index is 0.87, which is clearly sufficient to perform a factor analysis (see Appendix for detailed complements).

For this sample ALL, the choice of the number of factors is more difficult: the previously used criterias select four factors, but the fifth eigenvalue is 0.99, which raises the question of including an additional factor (see Table 4). In this case, the sample counts 26 countries; we can then consider that we are in the situation of large samples described by Bai and Ng and calculate IC criteria (Bai and Ng, 2002). This additional test suggests that a number of four factors should be retained for the sample ALL.

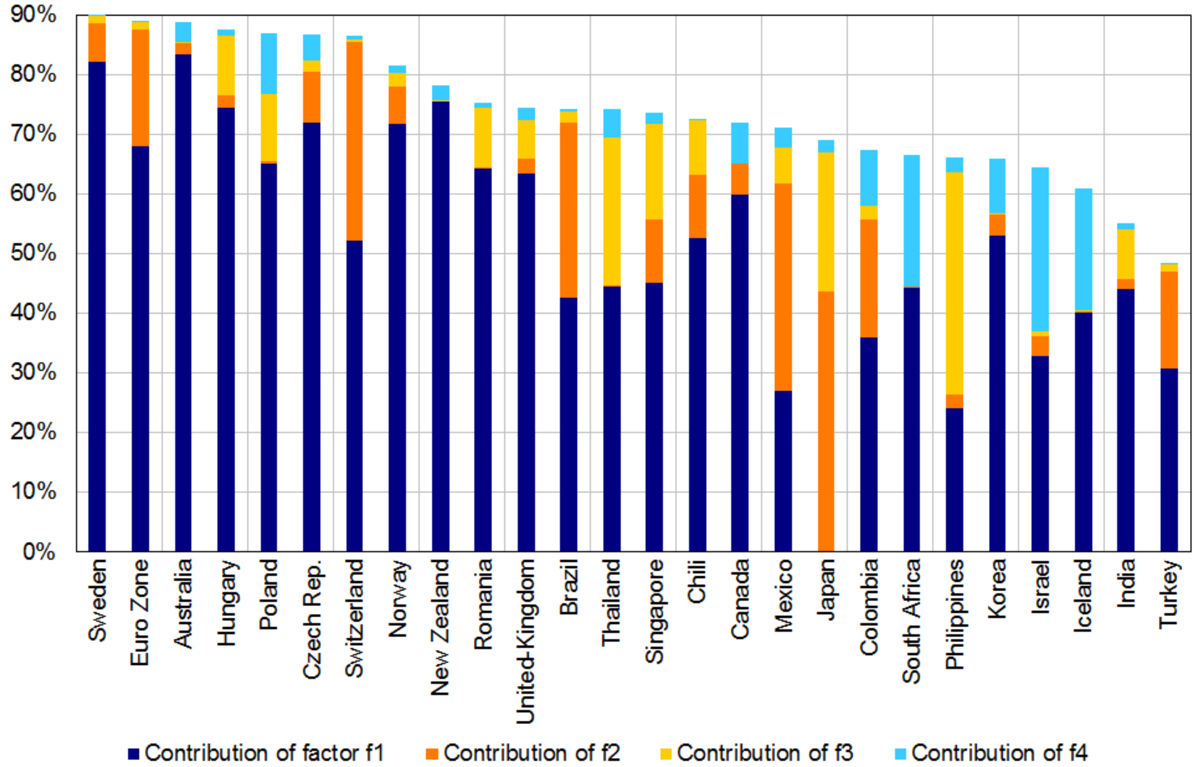
Table 4 – Choice of the number of factors for S - ALL

Factor	Eigenvalue	Cumulated share of common variance explained
1	13.48	0.52
2	2.62	0.62
3	1.77	0.69
4	1.38	0.74
5	0.99	0.78
6	0.77	0.81
7	0.67	0.83
8	0.56	0.86
9	0.51	0.88
10	0.48	0.89

Source: Author's calculations.

The four factors retained explain a major part of the variance in exchange rates (74% on average, more than 60% for all countries except for India and Turkey) (see Figure 1). This confirms the findings of the previous section that changes in exchange rates mainly reflect global forces, idiosyncratic parts being less important (even very small for some economies). And among these factors, the first one has a particular influence.

Figure 1 – Communality associated with the four factors



Source: Author's calculations.

4.2 Robustness of the factors (in time and according to the sample considered)

One interesting feature of the estimated factors is that they are very similar in the two samples. The correlation table shows a high and highly significant correlation between the two factors estimated with S-AE-LONG and the first two factors estimated with S-ALL (Table 4). Clear similarities between the relative weights associated with the two factors further confirm this conclusion (Figure 2).

Table 5 – Correlations between factors estimated with S-AE-LONG and S -ALL[5]

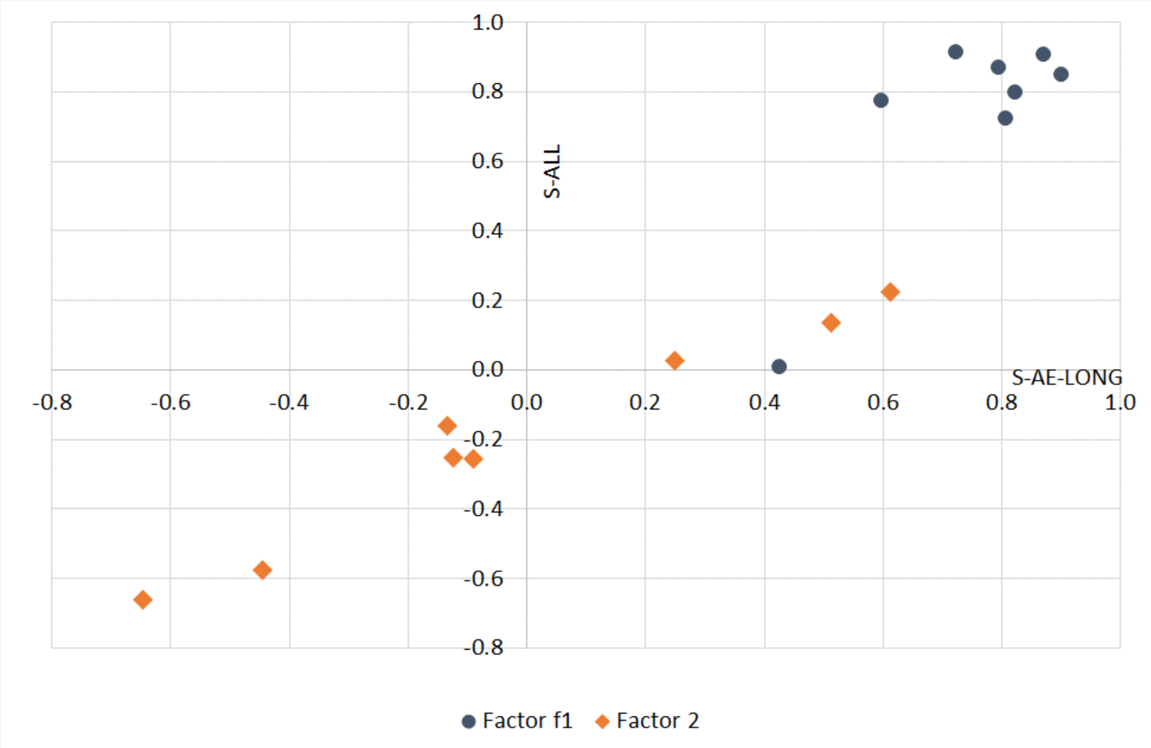
	f1-AE-LONG	f1 - ALL	f2-AE-LONG	f2 - ALL	f3 - ALL	f4 - ALL
f1-AE-LONG	1					
f1 - ALL	**0.9594***	1				
f2-AE-LONG	-0.5284*	-0.6099*	1			
f2 - ALL	0.1775	0	**0.6598***	1		
f3 - ALL	-0.0296	0	0.1586	0	1	
f4 - ALL	-0.1472	0	0.1996	0	0	1

* = significant at the 1% level

Source: Author's calculations.

[5] The existence of a nonzero correlation between f1-LONG-AE and f2 -LONG-AE comes from the fact that the correlation between these two variables is zero on the period over which they were estimated (1981-2014), but it has no reason to be zero over the 1999-2014 period considered here.

Figure 2 – Country-specific weights associated to the factors estimated with S-AE-LONG and S -ALL



Source: Author's calculations.

Complementary analyses developed in the appendix focus on sub-samples of S-ALL dividing this sample into a sub-sample of 10 advanced economies (including the Eurozone) and a sub-sample of 16 emerging markets. The conclusion is that the factors estimated are robust over time and across samples. The only difference is that the relative explanatory power of factors 2 and 3 is inverted when looking only at emerging economies. **In the end, the results provide robust evidence that exchange rates from all countries can be mainly explained by the same common factors.**

5. Economic interpretation of the factors

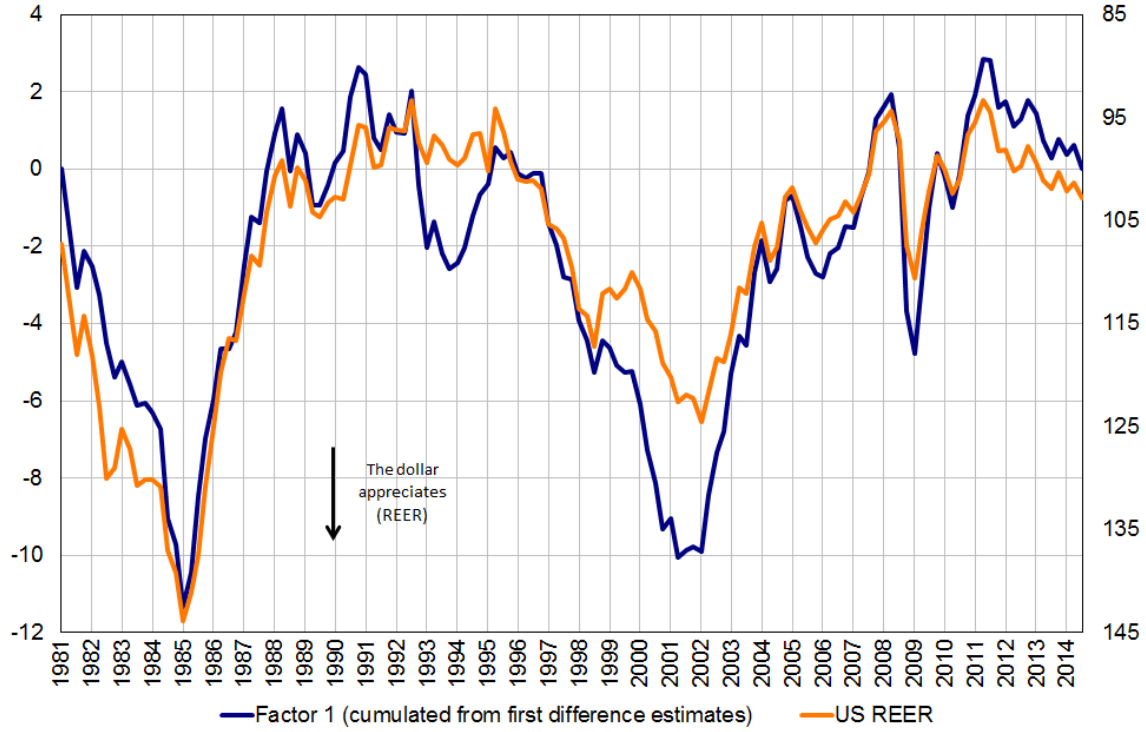
5.1 The US real effective exchange rate is the first factor behind bilateral exchange rate dynamics

5.1.1 Preliminary elements

The first factor is very close to the real effective exchange rate (REER[6]) of the United States (Figure 3). This is not surprising, as one would expect the relative situation of the United States with respect to the rest of the world to have a strong effect on bilateral exchange rates. Such a strong "US factor" does not come exclusively from the large size of the US economy in world GDP, but also from the fact that the exchange rates are studied relatively to the dollar.

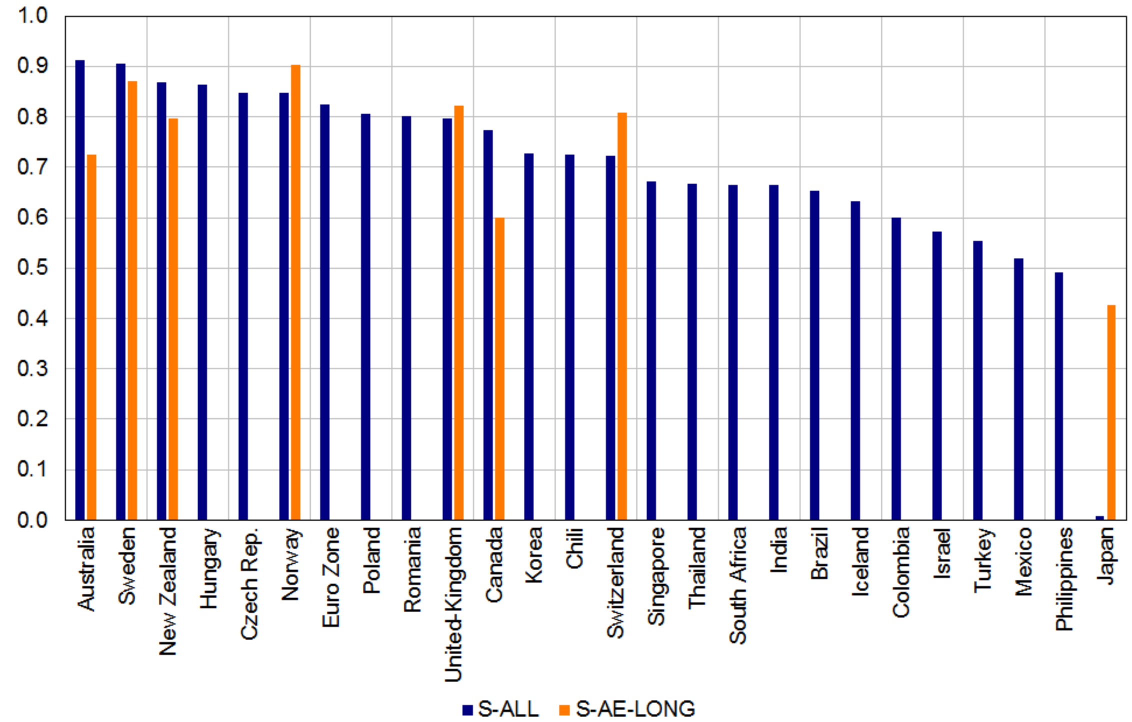
[6] Defined as the weighted average of bilateral real exchange rates with trading partners of a country.

Figure 3 – Factor 1 and US REER



Source: Author's calculations, BIS.

Figure 4 – Share of the variance of each currency explained by factor 1[7]



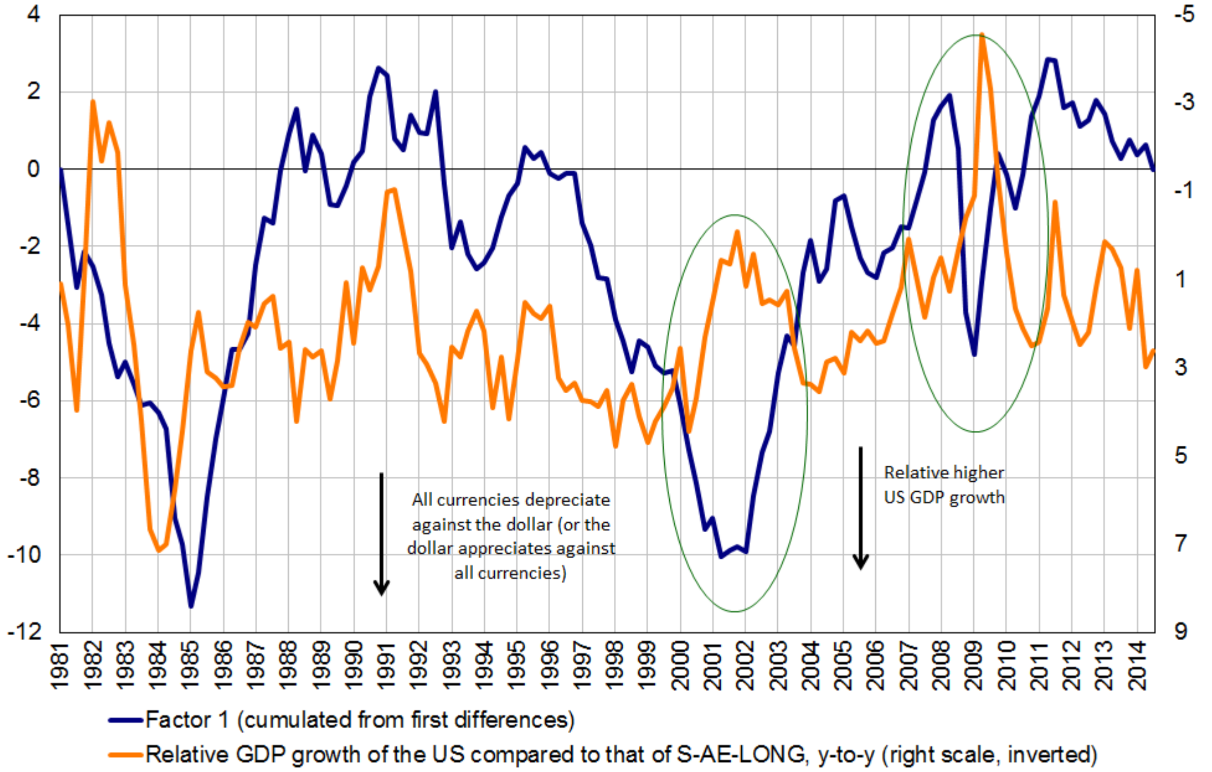
Source: Author's calculations.

[7] The low weights obtained in the case of Japan may come from the particularly active monetary policy of the Bank of Japan to deal with domestic issues or, for long term evolutions, from the fact that Japan was at the technological frontier.

The positive sign of all country-specific weights associated with the first factor confirms the role played by this factor. This (positive) sign (see Figure 4) means that all the bilateral exchange rates against the dollar move in the same direction when this factor evolves. This reinforces the interpretation of the factor F1 as an index reflecting the real exchange rate of the dollar.

The strong negative correlation between F1 and relative US GDP growth[8] also supports this analysis. Indeed, a boom in the US economy is expected to be correlated with a stronger dollar[9] (decrease of factor F1), while a phase of slowdown to a depreciation (increase of factor F1). Figure 5 shows the joint evolution of the factor F1 and relative US GDP growth compared to GDP growth in the other countries of the sample[10]: they appear negatively correlated.

Figure 5 – Factor 1 and relative US GDP growth[11]



Source: Author's calculations, OECD, IMF.

Two episodes show a counter-intuitive positive correlation, which can be explained by exceptional circumstances. In the figure above, there are two phases (surrounded by a green circle) during which significant decreases in factor F1, which thus correspond to periods of dollar appreciation, coincide with major slowdown in US growth. This temporary inversion of the expected link between growth and dollar level reflects the atypical nature of the associated events: burst of the Internet bubble, the September 11th attacks and the beginning of the war in Iraq for the first phase, and Lehman Brothers' fall for the second. The positive correlation observed between factor F1 and US relative growth during these episodes can be explained by the unusual role of the dollar in the international monetary system (*safe haven* phenomenon).

[8] The estimated correlation is -0.38, when removing from the sample the following years: 2000 to 2003 and 2008-2009.

[9] The correlation between F1 and the Fed's rate is much less marked.

[10] Difference between US quarterly y-to-y GDP growth and GDP weighted quarterly y-to-y GDP growth of S-AE-LONG countries.

[11] Growth is drawn with an inverted scale.

Box 1 – Key trends in the US REER since 1981

Between 1981 and 1985, the dollar tended to appreciate against other currencies, mainly due to the set up by the Fed Chairman Paul Volcker of a very restrictive monetary policy to control inflation through high real interest rates. The tensions associated with the Cold War were then quite important, which called for further pressure towards appreciation of the dollar as a safe haven currency.

The year 1985 was characterized by two important events: Gorbachev's coming to power in the USSR, which partially released the pressure of the conflict and the Plaza agreements, signed by the G7 but Canada and Italy. Given the excessive appreciation of the dollar, the G7 reached an agreement to publicly intervene in the foreign exchange market (USD 10 billion intervention spread over the year 1985 by the major central banks, including an important contribution of the German authorities in February and March) to lower the dollar. Thus a long period of depreciation of the dollar was observed until the end of the 80s, and continued after 1987 despite the Louvre Accord, planed this time to limit the fall of the dollar.

Until the early 1990s, the uncertainty around the collapse of the Soviet bloc and the Gulf War might be the reason for the small magnitude of the dollar movements. The late 90s were a period of solid growth thanks to a productivity boom induced by ICT. This dynamism has led to upward pressure on the dollar.

The early 2000s saw a reverse in the trend, with the explosion of the Internet bubble, the September 11th attacks and rising tensions with Iraq. Widening "twin deficits" (fiscal and current deficits, with the Fed's monetary policy staying accommodative) pulled the dollar down.

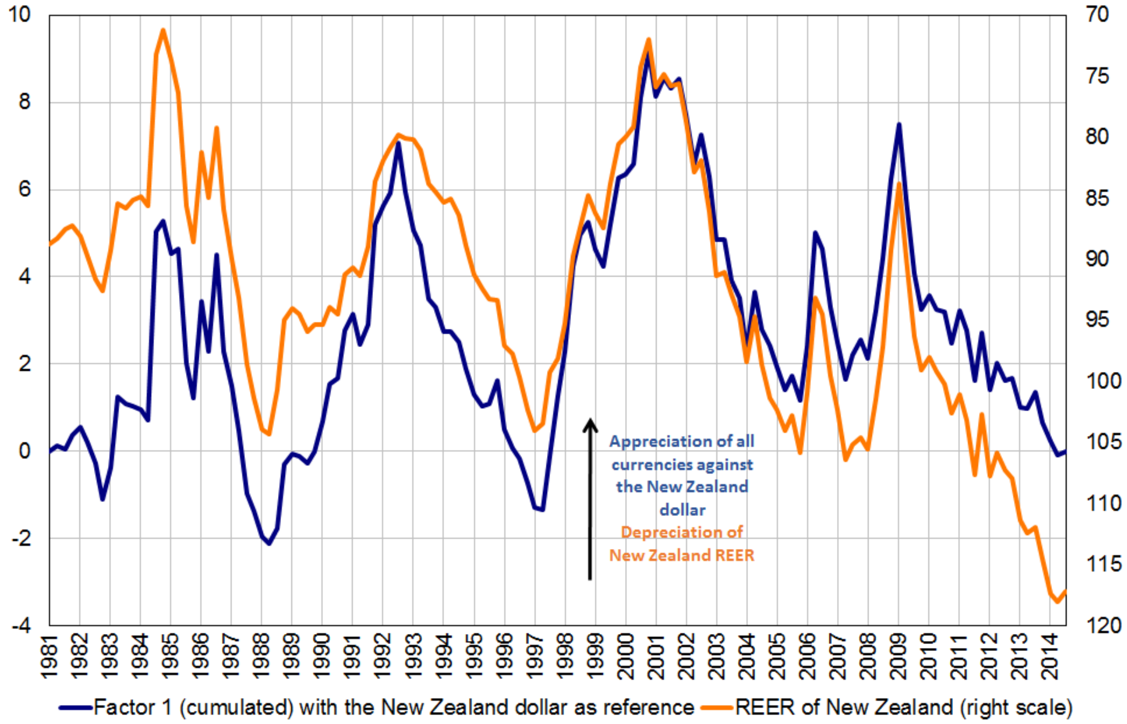
The collapse of Lehman Brothers in September 2008 generated a liquidity crisis and led to a massive, brutal and relatively punctual appreciation of the dollar. Subsequently, the monetary policy of the Fed was very accommodative, reaching the zero lower bound and introducing long-term purchase of securities programs.

The improved economic outlook in the United States and the end of securities purchase programs explain the appreciation trend of the dollar since the early 2010s.

5.1.2 Interpretation of the factor 1 as the REER of the currency of reference

A factor analysis empirically shows that the first factor represents the "aggregate relative strength" of the currency of reference. This thesis is confirmed by an analysis conducted with other currencies of reference (by taking as an illustrative example the New Zealand dollar instead of the US dollar). In this case, all the weights assigned to the first factor have the same positive sign and the first factor shows very important similarities with the REER from New-Zealand (see Figure 6).

Figure 6 –Factor 1 and REER of New Zealand – currency of reference: New Zealand dollar



Source: Author's calculations, BIS.

A factor analysis using series of REER rather than series of bilateral exchange rates presents the advantage of not choosing any reference currency. Such an analysis is presented in the appendix: it appears that the choice of the US dollar as the reference when working with bilateral exchange rates is justified because of its important weight in the REER (coming from both US GDP size and the fact that many countries are pegged to the US dollar) and of its international status. The first factor when we use REER series is strongly correlated to f1-ALL (estimated with the bilateral exchange rates against the US dollar). Working with the US dollar as the reference implies that the first factor captures the international role of the dollar, in addition to the mechanical effect of the choice of the reference.

Moreover, back to bilateral exchange rates, the correlation between the three other factors depending on the selected currency of reference (US dollar or New Zealand dollar) (and using the sample ALL) is significant as shown in the table below. It also the case when the factors are coming from an analysis on REER data. This confirms the robustness of the estimation and of the analysis of these factors as global factors.

Table 6 – Correlation between factors estimated from different samples

	USA-f2-ALL	NZL-f2-ALL	USA-f3-ALL	NZL-f3-ALL	USA-f4-ALL	NZL-f4-ALL
USA-f2-ALL	1.0000					
NZL-f2-ALL	**0.8350***	1.0000				
USA-f3-ALL	-0.0000	-0.4533*	1.0000			
NZL-f3-ALL	0.4215*	0.0000	**0.4212***	1.0000		
USA-f4-ALL	0.0000	0.0723	0.0000	-0.1227	1.0000	
NZL-f4-ALL	-0.1027	-0.0000	-0.0914	-0.0000	**0.8746***	1.0000

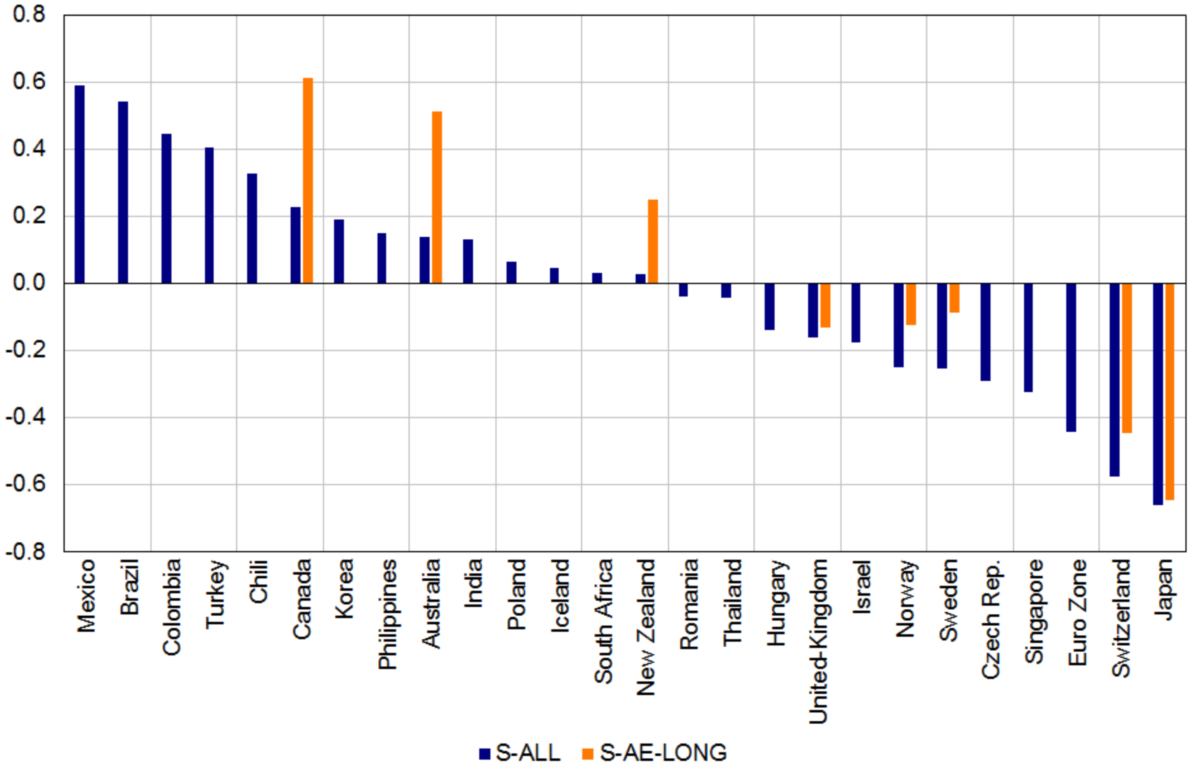
* = significant at the 1% level

Source: Author's calculations.

5.2 Commodity prices are the second factor behind the dynamics of exchange rates

The country-specific weights on F2 (see Figure 7) discriminate two groups of countries according to the presence or absence of commodities resources. For some countries, the weight is positive, meaning that the exchange rate of the currencies of these countries appreciates when the factor F2 rises, while for others, the currency depreciates against the dollar when the factor F2 rises.

Figure 7 – Share of the variance of each currency explained by factor 2

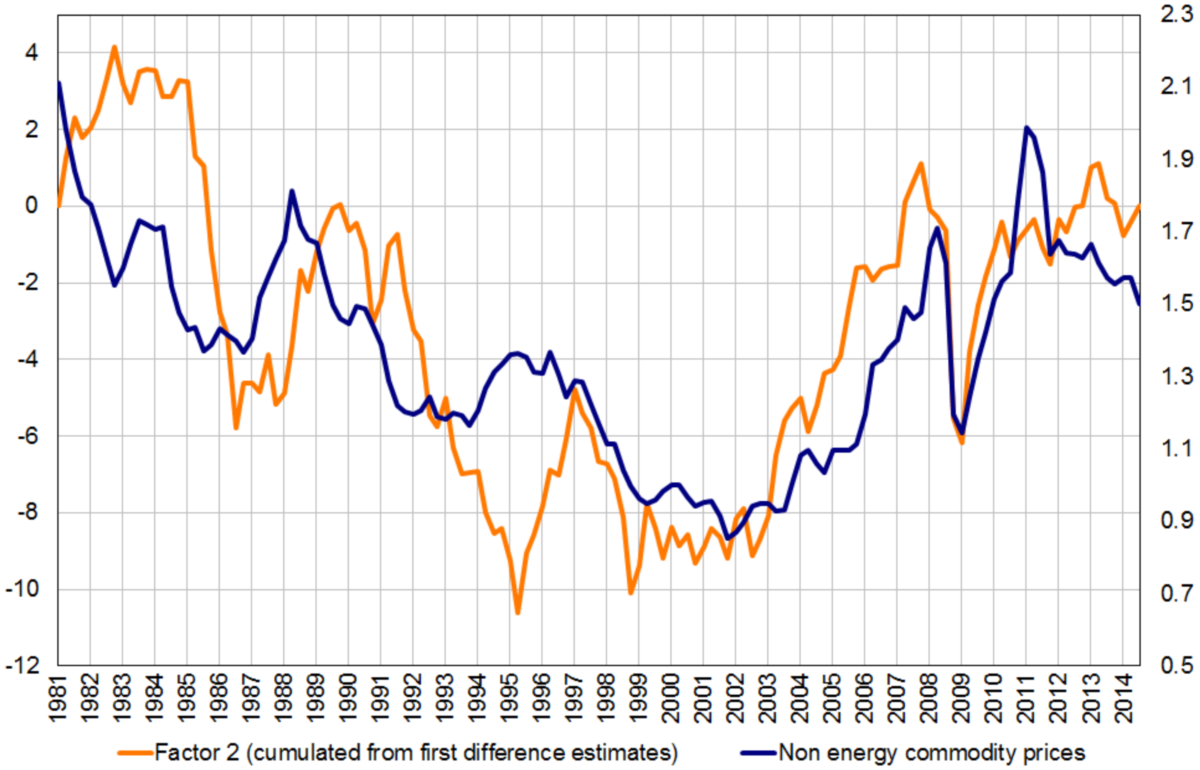


Source: Author's calculations.

On the one hand, Latin-American countries, Australia, Canada, New Zealand, Turkey or Philippines appear with a positive sign, consistently with the fact that they are exporting countries (of oil or other commodities). On the other hand, Norway, the United Kingdom, the Euro Zone, Switzerland, Sweden, Japan, and Singapore are characterized by a negative weight. For the latter group, all countries (except Norway and to a lesser extent the UK) are commodity importers. Finding a negative weight for Norway may seem surprising given economic theory but seems consistent with the conclusion of several empirical studies. Indeed, Akram (2000) mentions two Norwegian studies (Bjorvik, Mork and Uppstad, 1998 and Akram and Holter, 1996) that find little or no significant relationship between oil prices and value of the Norwegian krona. Akram (2000) even obtains a positive covariance (instead of the expected negative sign) between oil prices and the exchange rate krona / ECU. He then shows that this result does not reflect the absence of the theoretically expected link between oil and exchange rates but that linear empirical approaches fail to capture the actual non-linear relation[12].

[12] Akram (2000) shows that the relationship depend on the value of the oil barrel and on the sign of the trend of the price (downward or upward).

Figure 8 – Factor F2 and non-energy commodity prices



Source: Author's calculations, IMF, Daily Press.

It is possible to find a long-term relationship between the factor F2 and commodity prices. The estimated factor F2 (cumulated from first differences) presents in the long run similarities with the non-energy commodities and oil prices[13] (see Figures 8 and 9).

If a classic cointegration Engel and Granger test is not significant over the period, a cointegration test supports the thesis of a long-term relationship between the factor 2 and the price of commodities (oil and non-energy), as long as a break date in the cointegration relationship (specifically a level change) is allowed. Such a break (ie a break in the intercept) introduces a limited change in the relationship between commodity prices and factor F2 over time. This kind of change can be explained by the gradual emergence of new factors determining commodity prices. The chosen break date is calculated through a test defined by Gregory and Hansen and is the 4th quarter of 1992, a year after the end of the war in Iraq. With this break date, the long-term relationship is true at the 10% threshold (see Table 7 and Figure 10).

This interpretation is in line with the multiple economic analyses (Golub (1983), Krugman (1983) and Corden (1984)) showing that a decrease (respectively increase) of the real price of oil is associated[14] with a depreciation (appreciation) of real exchange rate for exporting countries and a real appreciation (depreciation) for importing countries. The results obtained above in this study lead to interpret the second factor as a "commodity" factor, which is besides coherent with the conclusions in Cayen et al. (2010).

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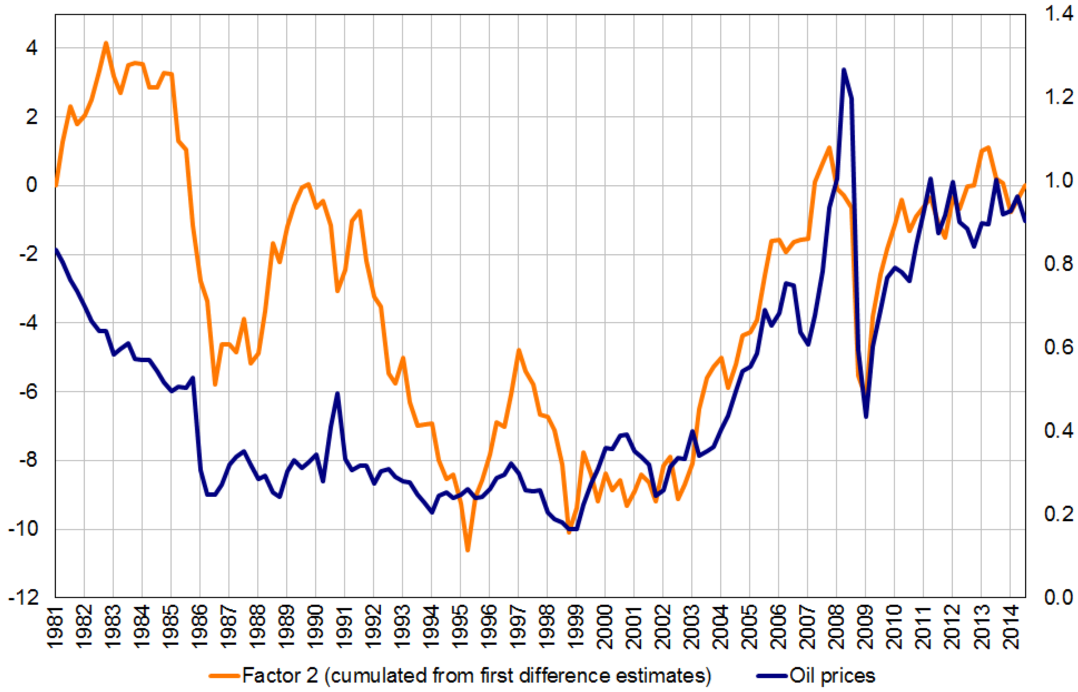
[13] Both expressed in real terms (deflated by the US GDP deflator).

[14] Debates on endogeneity issues between commodity prices and exchange rates are not really solved in the literature.

Figure 9 – Factor F2 and oil prices



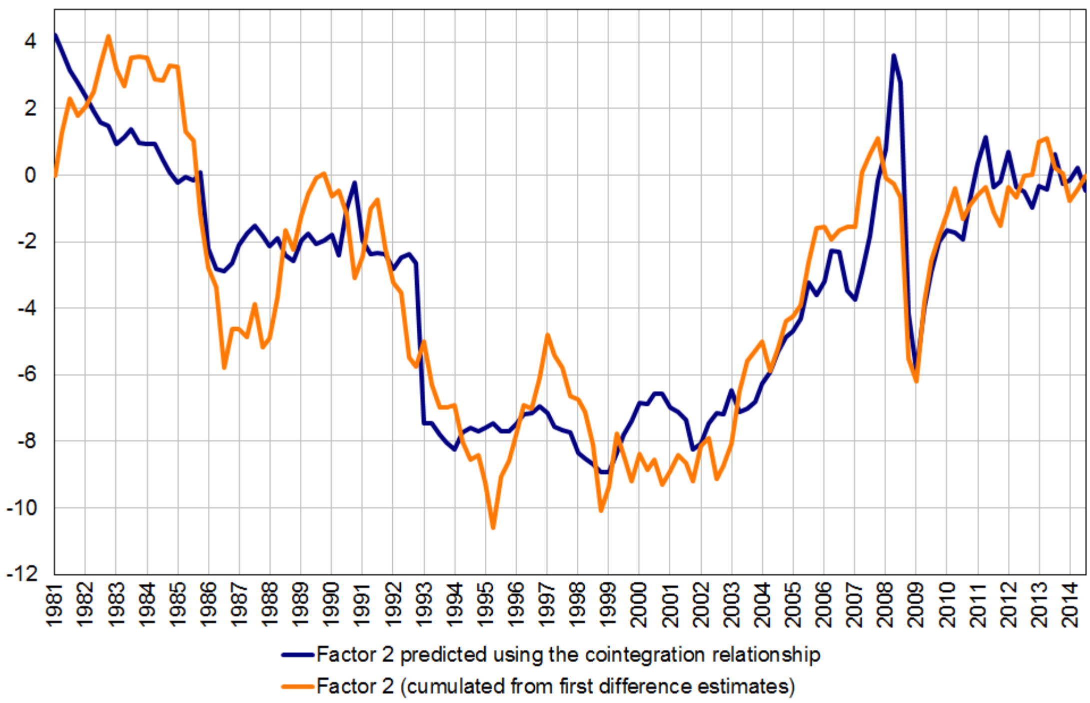
Source: Author's calculations, IMF.

Table 7 – Cointegration tests of a long-term relationship between the factor 2 and the price of commodities (oil and non energy)

Break date	Test	Stat.	Critical values		
			1%	5%	10%
None	Engel-Granger	-3.0	-4.4	-3.8	-3.5
1992q4 (break in level)	Gregory-Hansen	-4.7	-5.4	-4.9	-4.7

Source: Author's calculations.

Figure 10 – Factor F2 estimated by factor analysis and predicted using the cointegration relationship

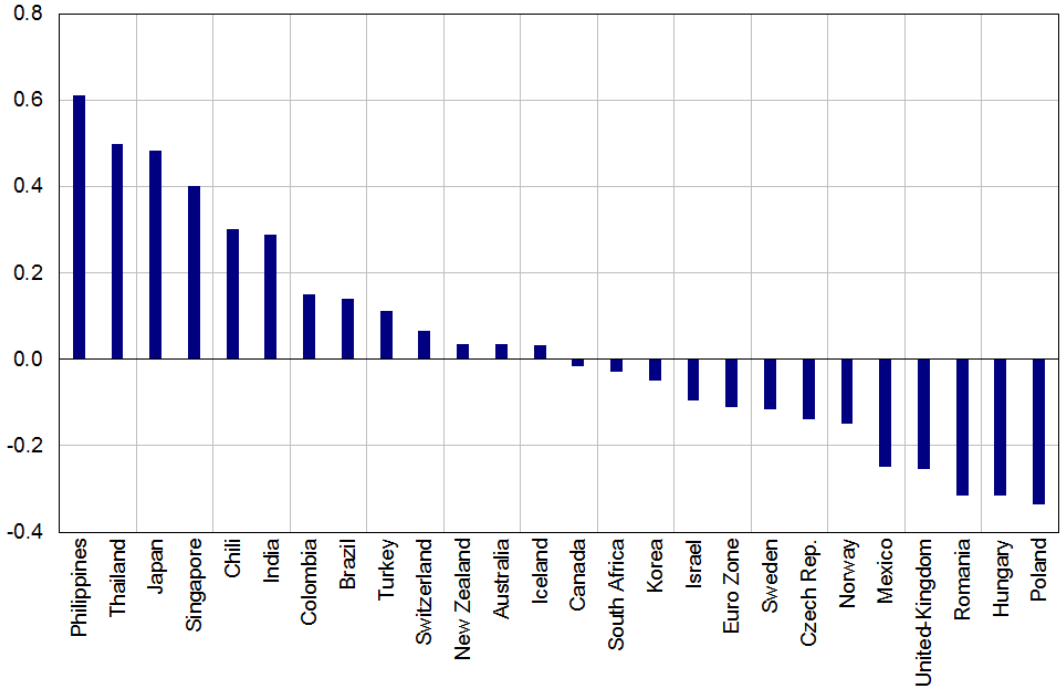


Source: Author's calculations.

5.3 The factor 3 could capture the influence of the renminbi in exchange rates, especially from a regional perspective

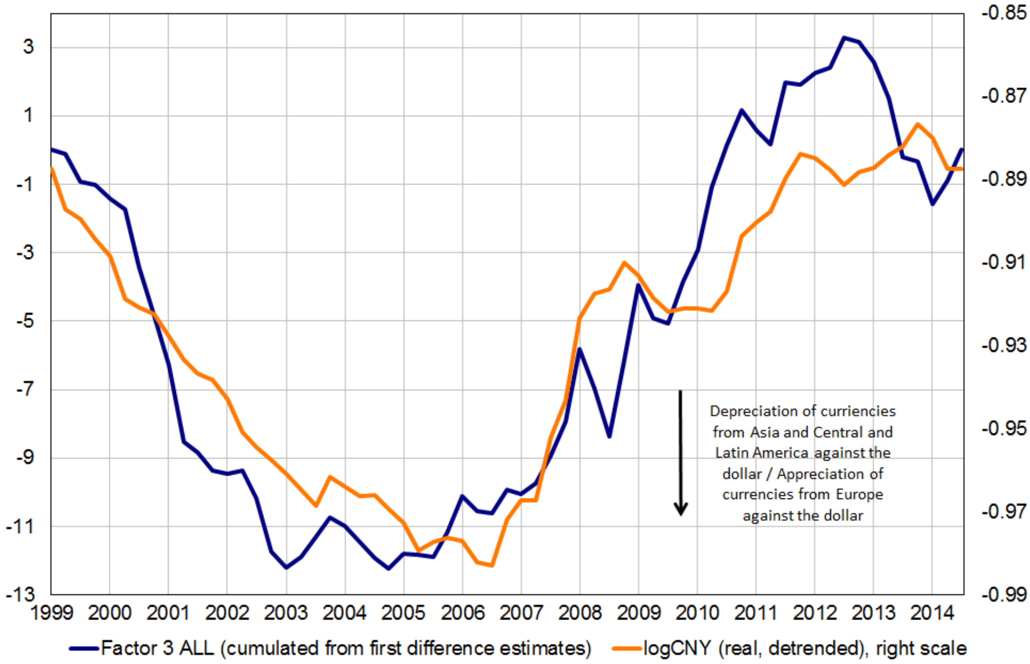
The estimated country-specific weights show that this factor affects differently the currencies from European countries on the one hand, and on the other hand from Latin American and Asian countries (see Figure 11). Therefore, this factor may reflect specific regional dynamics.

Figure 11 – Share of the variance of each currency explained by factor 3



Source: Author's calculations.

Figure 12 – Factors F3-ALL (cumulated from first difference estimates)



Source: Author's calculations, IMF, OECD.

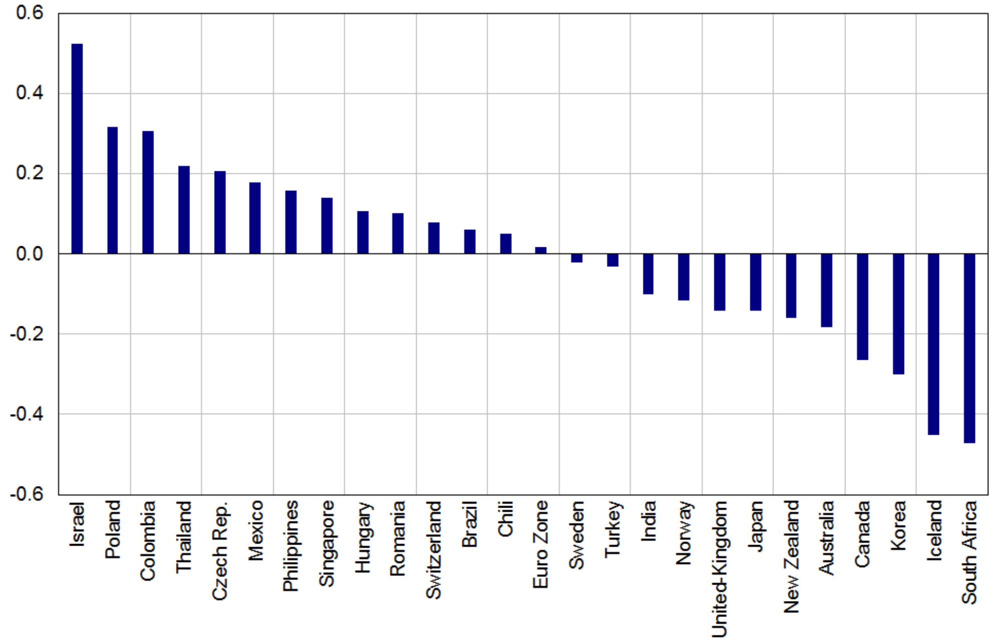
One interpretation of the factor is that it presents links with the evolution of the renminbi. As shown in Figure 12, the factors F3 has a long rising phase from the mid-2000. This factor shows a significant correlation with the evolution of the renminbi against the dollar on the period[15] (0.93). One way to interpret it is to consider it as a "renminbi" factor, the exchange rate regime of the Chinese currency allowing to consider the developments of the renminbi against the dollar relatively exogenous (in large part discretionary, at least until the late 2000s). An appreciation of the renminbi would limit China's exports, which is positive for exports of countries that use to sell consumer goods to China or compete in third markets (implying a pressure for the appreciation of their own currency). On the contrary, countries that provide intermediary goods also see their exports limited, which can lead to a downward pressure on their currency.

5.4 The fourth factor may capture a measure of financial stress in advanced economies relative to emerging financial markets

Factor 4, which appears in last position for S-ALL, discriminates emerging economies from advanced economies. Indeed, the signs of the weights associated to factor 4 (see Figure 13) allow to distinguish two groups: first the advanced economies (with the notable exception of South Africa) having a negative weight and then all the emerging economies, with a positive weight. An increase of this factor is therefore associated with a depreciation of advanced currencies and appreciation of emerging currencies.

Factor F4 is shaped by the episodes of high volatility in financial markets of advanced economies. The shape of factor F4, visible in the figure 14, presents two peaks, in 2001-2002 and 2008-2009. These two phases correspond to episodes already mentioned in the section 5.1 as the burst of the Internet bubble and the September 11 attacks for the first and the great financial crisis for the second. These large fluctuations show similarities with the VIX index that synthesizes the level of risk aversion in the markets and is built from the volatility on the stock index Standard and Poor's (see Figure 14). The correlation between this index[16] and factor F4 is 0.60.

Figure 13 – Share of the variance of each currency explained by factor 3

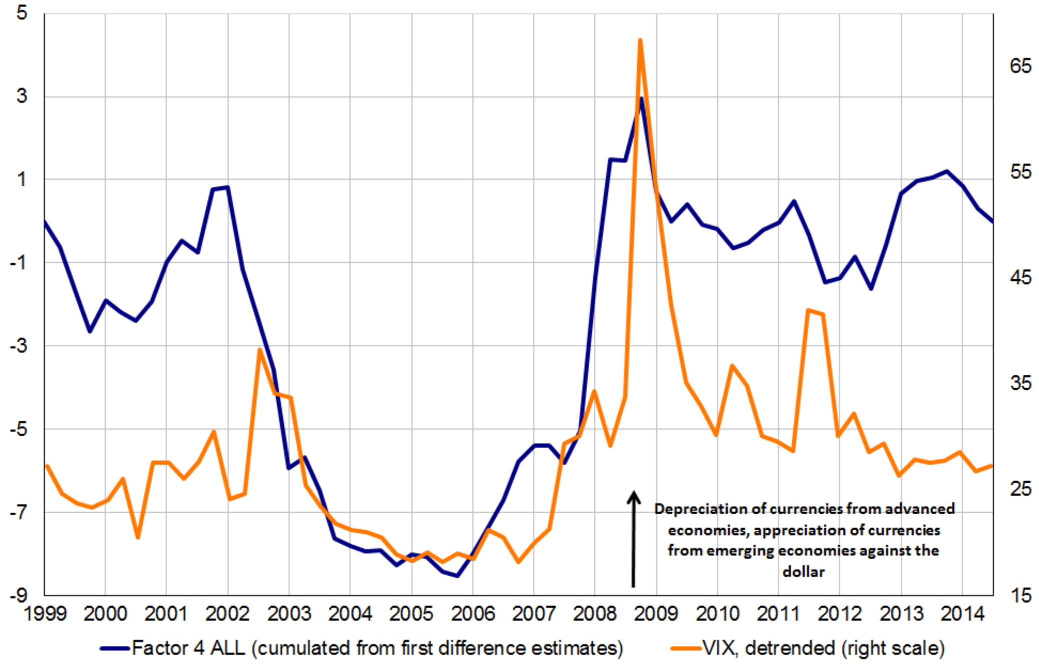


Source: Author's calculations.

[15] Detrended to make them more comparable.

[16] Detrended to make them more comparable variables.

Figure 14 – Factor F4-ALL and the VIX

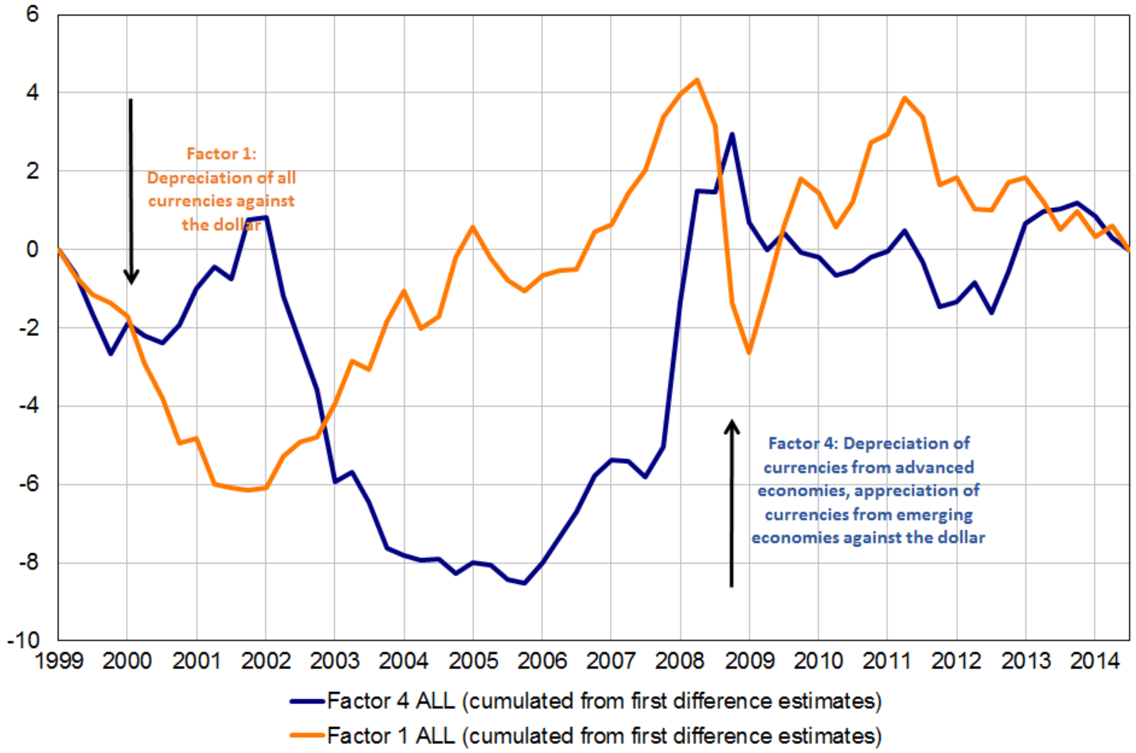


Source: Author's calculations, CBOE.

The factor F4 can then be interpreted as a description of the "financial stress in advanced economies relatively to emerging markets", corrected from global flight to quality effects that are captured by the factor 1 (see Figure 15). Factor F4 reflects an attenuated pressure on the exchange rates of emerging economies in the global crises during the decade 2000. Indeed, at the time of extreme crises in 2001 and 2008, two separate forces played on the exchange rates:

- Flight to quality: the volatility in financial markets strongly increased, which is reflected by an increase in the VIX. These phases, because of the international currency status of the dollar, were associated with the appreciation of the dollar against all other currencies of developed and emerging economies. This effect is conveyed by the factor F1.
- A second effect, less pronounced, of targeted aversion in the advanced economies, epicenter of both crises, with respect to emerging economies, which tends to soften the shock on emerging currencies. This effect is captured by F4.

Figure 15 – Factors F1-ALL and 4-ALL



Source: Author's calculations.

These findings provide a more precise explanation than the interpretation by Rey (2015) of the VIX, which she described as a synthesis of global risk aversion: if there exists a favorable global movement in favor of the dollar due its safe haven status, the fact that past crises had their epicenter in advanced economies was also taken into account by investors which helped mitigate the downward pressure on emerging currencies. The specific situation of South Africa might result from its status of regional financial center, with close connections to London.

The increase of factor F4 over end 2011 - mid 2013 and the widening gaps with the VIX can be read as a reflection of *(i)* a rise in risk aversion on the euro area during the euro area debt crisis, which does not appear in the VIX which is based on US markets and *(ii)* a perception of a lower risk in emerging economies, in the context of the Fed's quantitative easing policy and capital flows toward emerging markets. The fall of factor 4 in 2013 can be interpreted by a stress relief at the European level coupled with an increase in risk aversion towards emerging economies with the beginning of the anticipated Fed tightening.

6. Conclusion

This study shows that the dynamics of exchange rates against the US dollar are mainly due to external factors and that the individual characteristics of economies play a secondary role. Global factors explain on average three quarter of the variance of currency changes.

Exchange rate dynamics can be largely explained by four factors: *(i)* a "United States" factor, which captures the evolution of the dollar against all currencies, *(ii)* a "commodities" factor which implies that a rise in commodity prices induces an appreciation (resp. depreciation) of the exchange rate of exporters (resp. importers), *(iii)* a "renminbi" factor that presents a high correlation with the Chinese currency, whose appreciation vis-à-vis the dollar goes along with the appreciation of currencies from Asia and Latin America and, finally, *(iv)* an "advanced-emerging economies financial stress" factor that reflects the different situation of advanced and emerging economies during recent major crises, whose epicenter was in the advanced economies. If the factors *(ii)* and *(iv)* correspond to common *international* shocks, it is interesting to note that the factors *(i)* and *(iii)* show the international impact of *national* developments (US and China).

Despite the heterogeneity between emerging and advanced economies, the same common factors were found, which gives them a global dimension. Economic conditions in emerging economies differ greatly from those in advanced economies, which could have led to a divergence on the determinants of exchange rates for these two categories. This study shows that the estimated factors are *global* given that currency fluctuations for the two groups are explained by very similar factors.

The global nature of these factors is consistent with recent studies that highlight the importance of global forces in monetary and financial conditions. In line with Bernanke (2015), one can assume that "the existence of global common shocks, or country-specific shocks that are transmitted internationally through trade and commodity markets, naturally implies the existence of" global factors in exchange rates. The important common share of the evolution of exchange rates supports the idea of spillovers of financial conditions across countries and potential significant constraints on monetary policies[17] in face of large external exogenous shocks.

7. Appendix

7.1 Abbreviation of countries' name

aus	Australia
bra	Brazil
can	Canada
che	Switzerland
chl	Chili
col	Colombia
cze	Czech Republic
hun	Hungary
ind	India
isl	Iceland
isr	Israel
jpn	Japan
kor	Korea

mex	Mexico
nor	Norway
nzl	New-Zealand
phl	Philippines
pol	Poland
rom	Romania
sgp	Singapore
swe	Sweden
tha	Thailand
tur	Turkey
ukd	United-Kingdom
zaf	South Africa
zoe	Euro Area

[17] An interesting complementary work to confirm this point could be to measure the country-specific share of economic cycles and to compare it with country-specific share of exchange rates' evolutions.

7.2 Methodology

Table 8 –Unit root test on bilateral exchange rates for 26 countries over the period 1999-2014 in level and in first differences

In level	Statistic	Critical values			In first differences	Statistic	Critical values		
		1%	5%	10%			1%	5%	10%
aus	-0.901	-3.563	-2.92	-2.595	aus	-5.805	-3.565	-2.921	-2.596
can	-1.32	-3.563	-2.92	-2.595	can	-5.665	-3.565	-2.921	-2.596
nzl	-0.69	-3.563	-2.92	-2.595	nzl	-5.396	-3.565	-2.921	-2.596
nor	-1.416	-3.563	-2.92	-2.595	nor	-5.756	-3.565	-2.921	-2.596
swe	-1.632	-3.563	-2.92	-2.595	swe	-4.863	-3.565	-2.921	-2.596
ukd	-1.849	-3.563	-2.92	-2.595	ukd	-5.259	-3.565	-2.921	-2.596
che	-0.886	-3.563	-2.92	-2.595	che	-6.304	-3.565	-2.921	-2.596
jpn	-1.591	-3.563	-2.92	-2.595	jpn	-6.44	-3.565	-2.921	-2.596
zoe	-1.071	-3.563	-2.92	-2.595	zoe	-5.804	-3.565	-2.921	-2.596
isl	-1.615	-3.563	-2.92	-2.595	isl	-7.096	-3.565	-2.921	-2.596
cze	-1.124	-3.563	-2.92	-2.595	cze	-5.802	-3.565	-2.921	-2.596
hun	-1.362	-3.563	-2.92	-2.595	hun	-5.616	-3.565	-2.921	-2.596
rom	-1.2	-3.563	-2.92	-2.595	rom	-5.657	-3.565	-2.921	-2.596
pol	-1.576	-3.563	-2.92	-2.595	pol	-5.771	-3.565	-2.921	-2.596
tur	-1.28	-3.563	-2.92	-2.595	tur	-6.642	-3.565	-2.921	-2.596
isr	-1.007	-3.563	-2.92	-2.595	isr	-5.661	-3.565	-2.921	-2.596
chl	-1.381	-3.563	-2.92	-2.595	chl	-6.035	-3.565	-2.921	-2.596
col	-0.606	-3.563	-2.92	-2.595	col	-5.846	-3.565	-2.921	-2.596
mex	-3.162	-3.563	-2.92	-2.595	mex	-7.688	-3.565	-2.921	-2.596
bra	-0.902	-3.563	-2.92	-2.595	bra	-5.704	-3.565	-2.921	-2.596
ind	-0.451	-3.563	-2.92	-2.595	ind	-5.924	-3.565	-2.921	-2.596
phl	-0.162	-3.563	-2.92	-2.595	phl	-5.089	-3.565	-2.921	-2.596
sgp	0.393	-3.563	-2.92	-2.595	sgp	-5.914	-3.565	-2.921	-2.596
kor	-1.529	-3.563	-2.92	-2.595	kor	-5.668	-3.565	-2.921	-2.596
tha	-0.348	-3.563	-2.92	-2.595	tha	-5.474	-3.565	-2.921	-2.596
zaf	-1.499	-3.563	-2.92	-2.595	zaf	-5.893	-3.565	-2.921	-2.596

Source: Author's calculations, IMF, IHS Economics.

Table 9 –Interpretation of the KMO ratio according to Kaiser (1974)

in the .90s, marvelous
in the .80s, meritorious
in the .70s, middling
in the .60s, mediocre
in the .50s, miserable
below .50, unacceptable

Source: Kaiser (1974).

7.3 Robustness checks using sub-samples

This section aims at providing additional proof of robustness of the conclusions of the paper. I consider the following three samples, over the period 1999-2014:

- S-ALL - the sample is mentioned in the core of the article and gathers all countries (26 in number).
- S-AE - advanced economies (10 countries including Euro Zone).
- S3-EM - emerging economies (16 countries).

The three correlation thresholds are high enough to ensure a “meritorious” factor analysis as shown in the following table.

Table 10 – Degree of correlation for the different samples

Sample	S1 - ALL	S2 - AE	S3 - EM
KMO	0.87	0.87	0.86

Source: Author’s calculations

The number of selected factors varies across samples: 4 for the samples ALL (as explained in the main text) **and EM, and 2 for the AE case (see Table 11).** For both samples EM and AE, the two classical criteria (larger than unity eigenvalues and share of the explained variance greater than 70%) lead quite naturally to respectively four and two factors.

Table 11 – Choice of the number of factors for S-AE and S-EM

Factor	S-AE		S-EM	
	Eigenvalue	common variance	Eigenvalue	common variance
1	6.46	0.65	7.94	0.50
2	1.27	0.77	1.56	0.59
3	0.63	0.84	1.35	0.68
4	0.54	0.89	1.02	0.74
5	0.36	0.93	0.77	0.79
6	0.30	0.96	0.57	0.83
7	0.15	0.97	0.52	0.86
8	0.13	0.98	0.47	0.89
9	0.09	0.99	0.42	0.91
10	0.06	1.00	0.35	0.94

Source: Author’s calculations.

The factors estimated using different samples (S-ALL, S-AE, S-EM and the AE-LONG sample) are very similar, highlighting their global relevance and the robustness of the econometric analysis carried out. Indeed, the correlation between the various factors estimated on different samples, as well as with those estimated on the reduced sample of developed countries (but over a longer period) suggests a close proximity between these factors (see Table 12).

Table 12 – Correlation between factors estimated from different samples

	f1 - ALL	f1 - AE	f1 - EM	f1-AE-LONG	f2 - ALL	f2 - AE	f2 - EM	f2-AE-LONG	f3 - ALL	f3 - EM	f4 - ALL	f4 - EM
f1 - ALL	1.0000											
f1 - AE	**0.9588***	1.0000										
f1 - EM	**0.9711***	**0.8635***	1.0000									
f1-AE-LONG	**0.9594***	**0.9923***	**0.8707***	1.0000								
f2 - ALL	0.0000	0.1813	-0.1525	0.1775	1.0000							
f2 - AE	-0.0962	0.0000	-0.1657	0.0255	**0.8523***	1.0000						
f2 - EM	-0.1015	-0.2009	-0.0000	-0.1899	-0.5428*	-0.2363	1.0000					
f2-AE-LONG	-0.6099*	-0.5245*	-0.6384*	-0.5284*	**0.6598***	**0.7717***	-0.1889	1.0000				
f3 - ALL	0.0000	-0.0600	0.0627	-0.0296	-0.0000	0.3306*	**0.7877***	0.1586	1.0000			
f3 - EM	0.0584	0.1290	-0.0000	0.1365	**0.7354***	**0.7103***	0.0000	**0.5171***	0.5418*	1.0000		
f4 - ALL	0.0000	-0.1541	0.1318	-0.1472	-0.0000	0.1301	-0.0996	0.1996	-0.0000	0.1906	1.0000	
f4 - EM	-0.0781	-0.1575	-0.0000	-0.1766	-0.0818	0.0032	0.0000	0.1343	-0.0651	-0.0000	**0.8372***	1.0000

* = significant at the 1% level

Source: Author’s calculations.

The correlation table highlights levels of large and highly significant correlations, which leads us to the following observations:

- The factors 1 estimated with all samples of countries are very close ;
- The factors 2 estimated in samples including developed economies (ALL, AE and AE-LONG) seem very close. The third factor estimated on the sample of emerging countries is also close to factors 2 ALL, AE and AE-LONG.

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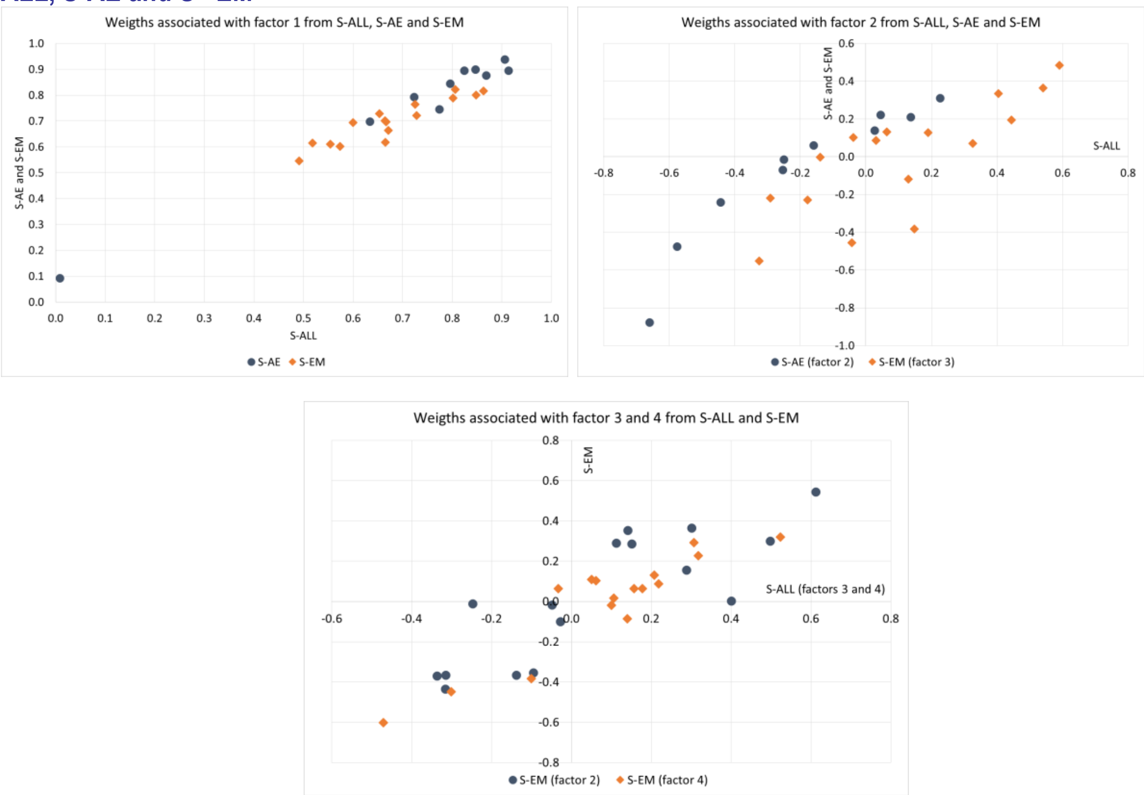
- The factor 3 of the sample ALL is strongly correlated to the factor 2 from the panel of emerging economies (noted "Factor 3" thereafter);
- The factors 4 of the samples with all economies and with only the emerging economies are strongly correlated.

The signs of the weights provide consistent evidence confirming the robustness of the conclusions previously found. Indeed, the following charts show that the weights (and to some extent their relative proportion) support the similarities assumed based on the correlations (Figures 10-13).

Figure 16 – Comparison of the country-specific weights associated to the factors estimated with S-ALL, S-AE and S –EM



Source: Author's calculations.

7.4 Justification for the choice of the currency of reference – REER analysis

A factor analysis on REER justifies the choice of the dollar as the currency of reference in this study. The use of bilateral exchange rates against the dollar gives results easier to interpret than when REER are used. However, having a currency of reference also means giving up the direct analysis of the exchange rate of the currency of reference, which by design cannot enter the field of the studied exchange rates. Moreover, changes in the REER provide information on the overall evolution of the level of the currency. By running a factor analysis on the REER over the sample ALL + US, the following observations appeared:

- The KMO statistic is 0.69, close to the threshold limit reducing the relevance of a factor analysis.
- The analysis of eigenvalues also leads to keep four factors[18]. The correlation between these four factors and that estimated in the main text with the ALL sample (and bilateral

[18] The 5th eigenvalue being significantly lower than the fourth.

exchange rates against the US dollar) is remarkably important as shown table 13, which means that similar factors are found.

- The weights associated with the first factor strongly highlights the United States (as well as Japan and Switzerland[19]), as shown in the figure 17.

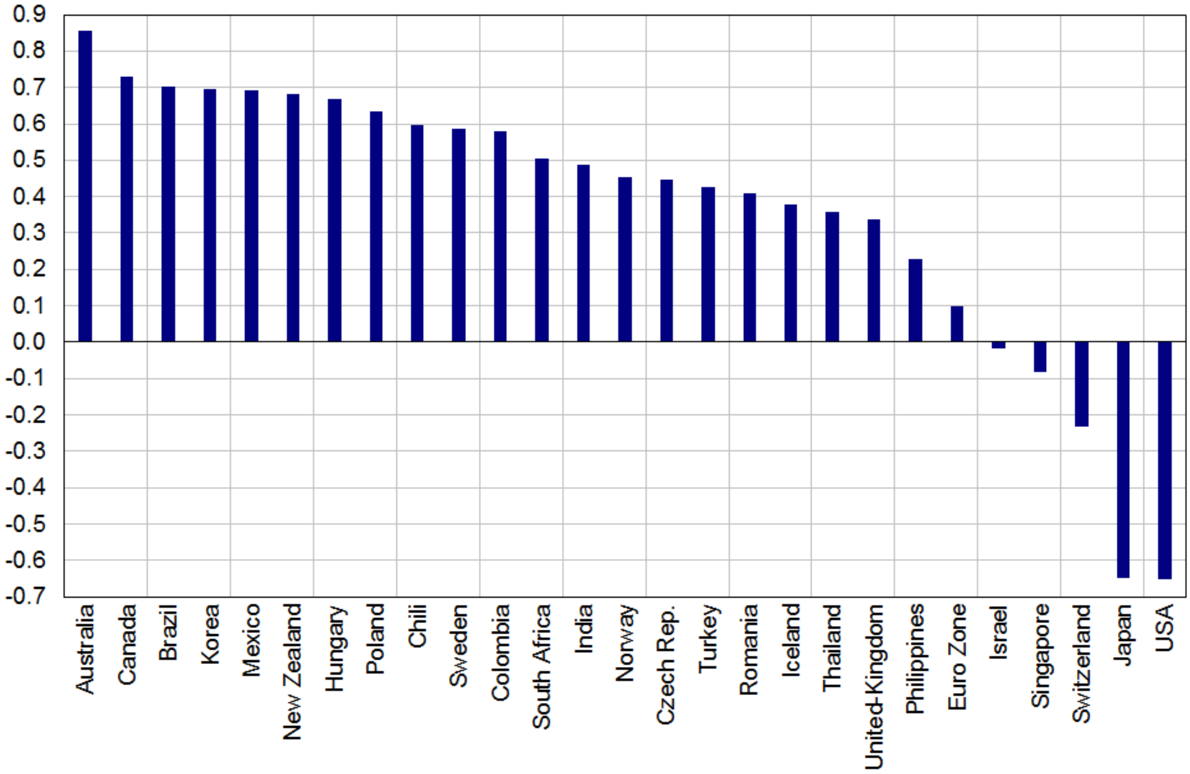
Table 13 – Correlation between factors estimated from different samples

	f1 - ALL	f1 - ALL+USA	f2 - ALL	f2 - ALL+USA	f3 - ALL	f3 - ALL+USA	f4 - ALL	f4 - ALL+USA
f1 - ALL	1.0000							
f1 - ALL+USA	**0.7982***	1.0000						
f2 - ALL	0.0000	-0.5522*	1.0000					
f2 - ALL+USA	0.4754*	-0.0000	**0.7524***	1.0000				
f3 - ALL	-0.0000	-0.1376	-0.0000	-0.1591	1.0000			
f3 - ALL+USA	0.0263	0.0000	-0.1225	0.0000	**0.6115***	1.0000		
f4 - ALL	0.0000	-0.0551	0.0000	-0.2837	0.0000	-0.4726*	1.0000	
f4 - ALL+USA	0.1698	-0.0000	0.1264	-0.0000	0.3729*	-0.0000	**0.7645***	1.0000

* = significant at the 1% level

Source: Author's calculations.

Figure 17 – Share of the variance of each currency explained by factor 1



Source: Author's calculations.

These observations justify the choice to work with bilateral currency against the dollar: the correlation between series is greater, and the special role of the dollar appears in the analysis on REER, reflecting both the heavy weight of the United States (or of countries pegged to the dollar) in the calculation of REER and the major international role of the dollar in the international monetary system.

[19] This may come from the strong role of *safe heaven* of the currencies of these two countries.

7.5 Going further on the analysis of the estimated factors

Methodology

Once the factors are estimated, it is possible to clarify the significance and to measure the extent of the identification problems mentioned in the methodology section. By regressing normalized (but not centered) variables on the estimated factors, we have:

$$\frac{\Delta e_{i,t}}{\sigma_i} = \sum_{p=1}^{P} a_{p,i} \times f_{p,t,T} + b_i + \xi_{i,t}.$$

This regression is expected to provide close results to the factor analysis run in the main text. However, it brings two additional elements. First, the estimates of the $a_{p,i}$ give some information on the previously estimated weights λ_p^i: one should expect that the $a_{p,i}$ will have the same signs as the weights[20], and hope that they are statistically significant for most countries. Secondly, it is possible to interpret the presence of a non-significant coefficient b_i as a sign that the identification issue is negligible (because the slope of the deterministic trend is very low over the period).

Results

The results confirm and supplement the various conclusions of the paper.

- **First, the drivers of exchange rates are the same for advanced and emerging economies.** One proof of this thesis is that the factors estimated with S-AE are not specific to advanced economies but are global factors. Real bilateral exchange rate evolutions for countries outside the sample are regressed with the two factors estimated from S-AE-LONG. The constraints of data availability and exchange rate regime constrain to run the following regression for the period 1999-2014 and over 26 countries:

$$\frac{\Delta e_{i,t}}{\sigma_i} = a_i \times f_{1,t} + b_i \times f_{2,t} + c_i + \xi_{i,t}$$

  The results of this OLS regression are given in the table 14.

- **First, the important levels of statistical significance indicate that both estimated factors have global relevance: they significantly explain exchange rate fluctuations of several countries including among those that have not been used to estimate them.** Indeed, for the first factor (related to the US economy), all the coefficients, except for Mexico, are highly significant. It is the case for 17 out of the 26 considered countries for the 2nd factor (commodity prices). The adjusted R^2 presented in the table shed additional light. These R^2 unsurprisingly reach high levels for advanced economies (including the euro area, which was not in the sample S-AE-LONG used to estimate the factors). But the R^2 is lower for emerging economies. This is coherent with the fact that other factors may be useful to capture other drivers that are important for emerging economies.

- **The signs obtained for the coefficients confirm the interpretation of the factors developed in the preceding paragraphs.** The coefficient before the first factor is positive for all countries. The one associated to the 2nd factor is significantly negative for commodity importers: Switzerland, Sweden, Japan, Eurozone, Czech Republic, and Singapore. It is significantly positive for exporters of various commodities: oil, but also agriculture and minerals. The case of Korea seems atypical with a positive coefficient instead of the expected negative sign.

[20] In this regression, the magnitude of the estimated coefficients no longer corresponds to the proportion of variance of the currency explained by factors.

- **Finally, the non-significance of the constant moderates the concerns with identification mentioned above for the time period of the estimation.** Apart from the case of Singapore[21], the constant is not significantly different from zero for the entire sample. This finding supports the idea that the average growth $\mu_{i,T}$ is small enough during the estimation period (1981 to 2014) to consider that the model identification issues are negligible.

Table 14 – Regression of the exchange rates on the estimated factors

	f1—AE-LONG		f2—AE-LONG		Constant		adj-R²	T
Australia	**0.705*****	(0.0444)	**0.339*****	(0.0461)	0.0296	(0.0391)	0,91	62
Canada	**0.464*****	(0.0627)	**0.555*****	(0.0651)	0.0113	(0.0552)	0,82	62
New Zealand	**0.758*****	(0.0671)	**0.178****	(0.0696)	0.0467	(0.0590)	0,79	62
Norway	**0.900*****	(0.0654)	-0.0673	(0.0679)	-0.00828	(0.0575)	0,80	62
United-Kingdom	**0.830*****	(0.0809)	-0.0413	(0.0840)	-0.0607	(0.0712)	0,69	62
Switzerland	**1.049*****	(0.0583)	**-0.564*****	(0.0606)	0.0783	(0.0513)	0,84	62
Sweden	**0.958*****	(0.0514)	**-0.110****	(0.0534)	-0.0641	(0.0452)	0,88	62
Japan	**0.573*****	(0.101)	**-0.853*****	(0.105)	-0.00582	(0.0887)	0,52	62
Euro Zone	**0.995*****	(0.0635)	**-0.311*****	(0.0659)	0.0124	(0.0558)	0,81	62
Iceland	**0.542*****	(0.113)	0.139	(0.118)	-0.0717	(0.0998)	0,40	62
Czech Rep.	**0.899*****	(0.0798)	**-0.194****	(0.0828)	0.107	(0.0701)	0,70	62
Hungary	**0.806*****	(0.0806)	0.0104	(0.0836)	0.0397	(0.0709)	0,70	62
Romania	**0.686*****	(0.101)	0.0437	(0.105)	0.116	(0.0886)	0,52	62
Poland	**0.601*****	(0.0999)	**0.190***	(0.104)	0.00734	(0.0878)	0,53	62
Israel	**0.551*****	(0.127)	-0.127	(0.132)	0.0202	(0.112)	0,24	62
Chili	**0.422*****	(0.103)	**0.388*****	(0.107)	-0.109	(0.0903)	0,51	62
Colombia	**0.228***	(0.121)	**0.418*****	(0.126)	-0.0175	(0.107)	0,31	62
Mexico	0.00672	(0.106)	**0.696*****	(0.110)	-0.0706	(0.0936)	0,47	62
Brazil	**0.194***	(0.101)	**0.610*****	(0.105)	-0.0268	(0.0886)	0,52	62
India	**0.487*****	(0.117)	0.171	(0.122)	0.0975	(0.103)	0,35	62
Philippines	**0.333****	(0.136)	0.0929	(0.141)	0.0261	(0.120)	0,13	62
Singapore	**0.819*****	(0.102)	**-0.355*****	(0.106)	**0.176***	(0.0901)	0,51	62
Korea	**0.510*****	(0.102)	**0.293*****	(0.106)	-0.00281	(0.0897)	0,51	62
Thailand	**0.592*****	(0.119)	-0.0384	(0.124)	0.0506	(0.105)	0,33	62
Turkey	**0.228***	(0.126)	**0.371*****	(0.130)	0.0121	(0.110)	0,26	62
South Africa	**0.519*****	(0.103)	**0.275****	(0.107)	-0.0970	(0.0904)	0,51	62

*** p<0.01, ** p<0.05, * p<0.1

Standard errors in brackets

Source: Author's calculations.

- **In the end, the two additional factors estimated with S-ALL supplement the analysis**. The four estimated factors offer a greatly improved modeling of changes in the exchange rates of emerging economies and Japan. A similar regression to that mentioned above was carried out with the four factors estimated in the scenario ALL. The following graph shows the substantial progress made on the R^2 with the inclusion of these four factors (instead of only two factors in the first regression).

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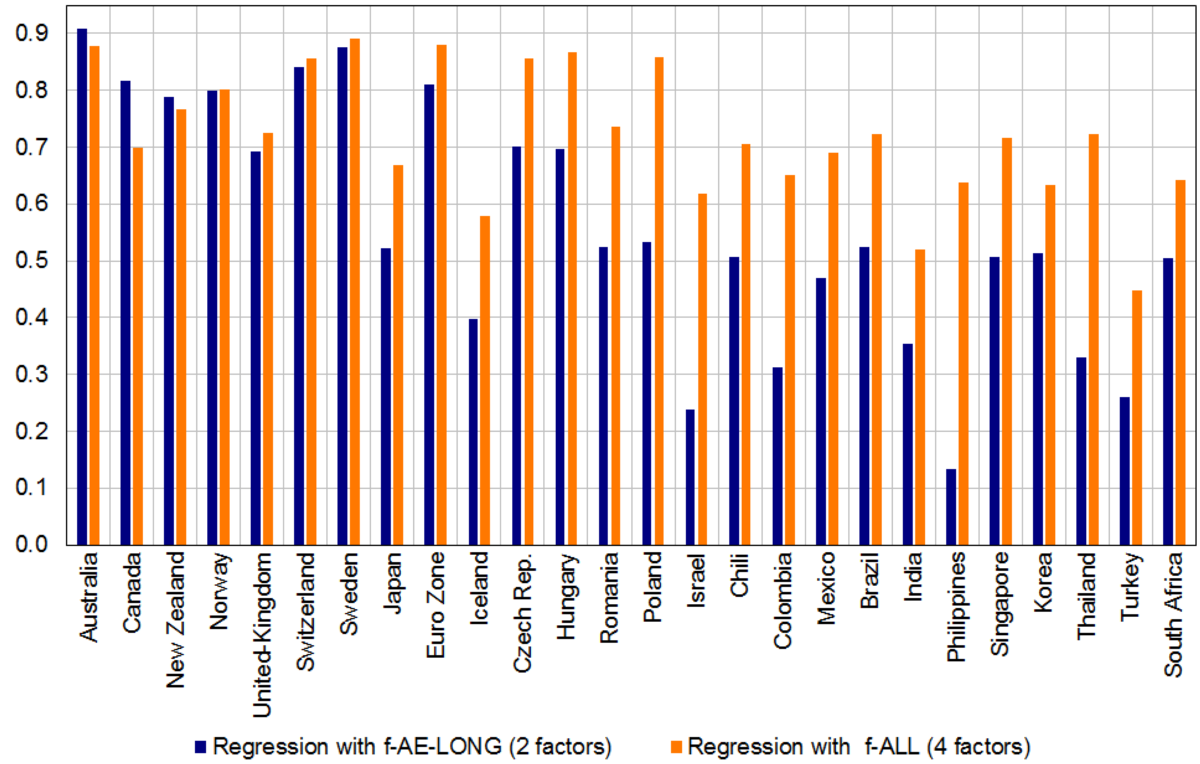
[21] Singapore's case presents the specificity of having changed exchange rate regime classification by the IMF in 2013 and 2014 and being considered now in "stabilized arrangement", which separates it from strictly floating exchange rate economies.

Figure 18 – R^2 from the regression of exchange rates on estimated factors



Source: Author's calculations.

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