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Abstract

We analyze and quantify the interdependence of real effective exchange rates while considering the regional location of countries. More specifically, using the dynamic hierarchical factor model (Moench et al 2011), we decompose exchange rate movements into worldwide and two regional factors as well as country-specific elements. Then we provide evidence that a substantial proportion of variation in the exchange rates is country-specific.

JEL classification: F31

Keywords: Real effective exchange rates, dynamic hierarchical factor model, variance decomposition

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1 Introduction

In the past, some studies have been carried out on the interdependence of exchange rates. This interdependence, which can be measured by the sensitivity of one currency to another in regression analysis, is important since changes in one currency likely affect the currency of other countries (e.g., McKinnon and Schnabl 2003). Furthermore, currency interdependence has been examined in the context of inferring actual exchange rate regimes which may be deviating from official ones (e.g., Frankel and Wei 2008). However, a bilateral nominal exchange rate, often vis-à-vis the US dollar, dominates the literature (e.g., MacDonald and Taylor 1992), rather than a real effective exchange rate which is also important, e.g., as an indicator of the international competitiveness of a country.

Against this background, this paper analyzes and quantifies the interdependence of a real effective exchange rate, mainly for advanced countries, while making use of information on the regional location of countries. Distinguishing features of this paper are: 1) application of the recently developed statistical method, the dynamic hierarchical factor model (Moench et al. 2011) which allows us to decompose exchange rate changes into four hierarchies while keeping them economically interpretable, and 2) quantification of the contribution of each hierarchy to the total variation in exchange rates.

2 Econometric method

Correlation between economic variables has been of interest to economists since economic events are often highly correlated with one another. Classic studies used the principle component approach and/or the factor model to extract commonality among a panel of stationary variables. One recent extension is to decompose data into common and idiosyncratic factors (i.e., a two-level decomposition) in a nonstationary environment (Bai and Ng 2004). Another extension is Moench et al. (2011) that has proposed the 4-level hierarchical factor model for a panel of stationary variables. The latter is also attractive in the presence of multiple common factors. By imposing extra information when grouping countries to hierarchies, this model facilitates researchers in identifying each factor. Here we make use of geographical information since adjacent countries tend to possess similar cultures and economic structures, to be very important trade partners, and to share common trading hours through which investors receive information simultaneously.

Following closely the notation used in Moench et al (2011), this 4-level decomposition of a vector Z_{bsnt} can be written, from the low to high levels, as:

$$
\begin{aligned}
Z_{bsnt} &= \lambda^{n}_{Hbsn} H_{bst} + e_{Zbsnt} && (1)\\
H_{bst} &= \Lambda_{Gbs} G_{bt} + e_{Hbst} && (2)\\
G_{bt} &= \Lambda_{Fb} F_t + e_{Gbt} && (3)\\
X_{bnt} &= \lambda^{n}_{Gb} G_{bt} + e_{Xbnt} && (4)
\end{aligned}
$$

where the Greek letters are loadings, and t is time ($t = 1, \ldots, T$). Components which cannot be explained by the factors (F, G and H) are treated as residuals (e).

More specifically, the lowest (i.e., individual) level classification is characterized as Z_{bsnt} containing individually the exchange rates of all countries (Eq. 1). Each exchange rate movement is decomposed to a regional level common factor H_{bst} and country-specific elements e_{Zbsnt}. Since the latter does not have a common factor, country-specific elements are assumed to be independent across countries.

In our analysis, there are two levels of regional classification (Levels 2 and 3, Table 1). Level 2 consists of 4 regional factors; namely H_{11t} for the Euro area, H_{12t} for the non-Euro European area, H_{21t} for the Asia-Pacific area, and H_{22t} for the American area, (i.e., $b = 1, 2$ and $s = 1, 2$). This classification is based largely on geographical information. But a distinction is made between Euro members and non-members since within the single currency area nominal exchange rates are identical among member countries, and thus a high level of correlation is expected among them.

Level 3 is based on whether or not countries are in Europe; European factors are shown as G_{1t}, and non-Europeans as G_{2t} ($b = 1, 2$). These factors affect the second level regional factors. In turn, former regional factors (G_{1t} and G_{2t}) are influenced by a worldwide commonality (F) (Eq. 3). Here, one common factor is assumed to exist in each group (i.e., $G_1, G_2, H_{11}, H_{12}, H_{21}, H_{22}$ and F) in our model.[1] Finally, a vector of exchange rates, X_{nt}, is the highest level of country classification covering European countries (X_{1t}) and non-European countries (X_{2t}) (i.e., $n = 1, 2$).

For the estimation, each factor is assumed to be stationary and is in the form of the first-order autoregression.

[1]While not reported here, assumption of the presence of common factors is consistent with evidence from the statistical tests (e.g., Bai and Ng 2007).

$$
\begin{aligned}
F_t &= \rho_F F_{t-1} + \varepsilon_{Ft} & \varepsilon_{Ft} \sim N(0, \sigma_F^2) \\
e_{Gbt} &= \rho_{Gb} e_{Gbt-1} + \varepsilon_{Gbt} & \varepsilon_{Gbt} \sim N(0, \sigma_{Gb}^2) \\
e_{Hbst} &= \rho_{Hbs} e_{Hbst-1} + \varepsilon_{Hbst} & \varepsilon_{Hbst} \sim N(0, \sigma_{Hbs}^2) \\
e_{Xbnt} &= \rho_{Xbn} e_{Xbnt-1} + \varepsilon_{Xbnt} & \varepsilon_{Xbnt} \sim N(0, \sigma_{Xbn}^2) \\
e_{Zbsnt} &= \rho_{Zbsn} e_{Zbsnt-1} + \varepsilon_{Zbsnt} & \varepsilon_{Znbst} \sim N(0, \sigma_{Zbsn}^2)
\end{aligned}
$$

The abovementioned model is estimated using the Markov Chain Monte Carlo (MCMC) method. We follow the assumption about the prior distribution used in Moench et al (2011). For example, the prior distribution of factor loadings and ρ are assumed the standard normal, and that of variance parameters an inverse of χ^2 distribution.[2] In order to obtain reliable estimates, the first 50,000 out of our 100,000 draws are discarded, and every 50th observation from the remaining 50,000 draws is used for the analysis. Furthermore, convergence diagnostics are calculated based on the Geweke test, but are not reported here for the sake of brevity.

3 Empirical results

Real effective exchange rate data are obtained from the International Financial Statistics of the International Monetary Fund. They (IFS code..REUZF, 2005=100) are constructed using the consumer price index and weights determined by the size of trade (unit values) to each trading partner, and cover the sample period from 1980Q1 to 2012Q2 for 30 countries, most of which are advanced ones (see Table 1).[3] These countries are classified as Group 1 (12 Euro countries), Group 2 (10 non-Euro European countries), Group 3 (4 Asia-Pacific countries) and Group 4 (4 American countries). In the subsequent analysis, we analyze exchange rate growth, i.e., the first difference of log exchange rates ($Log(S_t/S_{t-1}) \times 100$), in order to take account of their nonstationarity in levels.

[2] Our estimation is based on the Matlab codes of Professor Ng which are disseminated on her homepage. The details of assumptions about the prior distributions are stated there.

[3] Mexico and Costa Rica are not categorized as advanced countries according to the IMF classification (as of this writing). They are included for analysis because Mexico is part of the North American Free Trade Agreement (NAFTA). Inclusion of Costa Rica is for computational reasons. We failed to obtain results from the dynamic hierarchical factor model using only NAFTA countries.

The basic statistics are summarized in Table 2, and the conventional correlations (the highest- and lowest-40) of exchange rate pairs are listed in Table 3. The sign of the average exchange rate suggests that the direction of exchange rate movements is quite diversified; half of the countries have experienced an exchange rate increase (Table 2). Furthermore, among them, the Polish Zloty rate experienced high volatility. The volatility can be measured by the standard deviation and is closely associated with acceleration in domestic inflation from the late 1980s to the early 1990s. Otherwise, other exchange rates appear quite comparable.

In addition, as expected, high correlation is obtained from a pair of Euro member countries, particularly Germany and the Netherlands (Table 3). In contrast, the lowest correlation is obtained between Greece and Singapore, countries from different geographical groups. As in the classic principle component approach, all the data are standardized to have zero mean and variance equal to one before we implement the dynamic hierarchical factor model.

The variance decomposition for each country is obtained by:

$$Var(Z_{bsn}) = \gamma_F(Var(F)) + \gamma_G(Var(e_{Gb})) + \gamma_H(Var(e_{Hbs})) + \gamma_G(Var(e_{Zbsn})) \quad (5)$$

where γ is a composite of parameters, λ and Λ in Eq. (1) to (4), and results are presented in Table 4 from which several findings can be drawn. First, there is a clear difference between countries about the contribution of each factor to the total variation of exchange rates, but a country-specific element is generally most significant (71% on average, Table 4). This element is more important for a group which contains countries with a heterogeneous background. In this regard, the country-specific variation is least important among the Euro members (Group 1) but still accounts for nearly 60% of the total variation. Given that their nominal rates are identical, heterogeneity in prices and trading partners seem to be significantly different among member countries. This also suggests a diversified external competitiveness within the Euro area. The non-Euro European and Asia-Pacific groups have exhibited a similar proportion of country-specific effects (over 80%). This outcome for non-Euro European countries may be due to their heterogeneities among countries; this group consists of member and non-member states of the European Union (EU) as well as countries which have recently joined the Euro zone (Table 1).

Second, among Group 1, Austria, Germany and Netherlands have a relatively high weight for the worldwide common factor. Given the economic size, this common factor can be viewed as being closely associated with economic developments in Germany, and furthermore one could argue that the other 2 countries are influenced by Germany. Interestingly, Denmark possesses a very similar pattern of weights to those of these 3 countries although Denmark is not a member of the Euro. This implies a close economic link between Denmark and Germany.

Finally, country-specific effects are relatively low in American countries (Group 4) although it is slightly higher than the level of Group 1. This results largely from Canada where contributions from regional factors (particularly Regional factor II, Table 4) are substantial. Also note that 3 countries (the USA, Canada and Mexico) in this group form NAFTA, leading their markets to become more homogeneous.

4 Conclusion

Given that exchange rates are believed to be highly correlated among countries, we calculate the interdependence of real effective exchange rates using the recently developed data decomposition method (Moench et al 2011). Then, our results suggest that the evolution of real effective exchange rates is rather country-specific. The country-specific elements are less significant within the Euro area, but still account for more than 60% of the total variation, implying heterogeneous competitiveness. This underlines the importance of both idiosyncratic and 3^{rd} country effects when understanding exchange rate dynamics.

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Table 1. List Of Countries and Hierarchical Classification

Level 4 [X]	All countries (F)			
Level 3	Europe (G_1)		Non-Europe (G_2)	
Level 2	Group 1 (H_{11}) Euro	Group 2 (H_{12}) Non-Euro Europe	Group 3 (H_{21}) Asia-Pacific	Group 4 (H_{22}) America
Level 1 [Z]	Austria	UK	Japan	US
	Belgium	Denmark	Australia	Canada
	France	Sweden	NZ	Costa Rica
	Germany	Hungary	Singapore	Mexico
	Italy	Poland		
	Luxembourg	Malta		
	Netherlands	Cyprus		
	Finland	Norway		
	Greece	Switzerland		
	Ireland	Iceland		
	Portugal			
	Spain			

Note: Malta and Cyprus are Euro member countries, but are treated here as Non-Euro European countries since their entry date is very recent (2008). Factors are denoted as F, G, and H, and X and Z are country vectors.

Table 2. Basic Statistics for Changes in Exchange Rates

Country	Mean	Std Dev	Min	Max
Austria (AUS)	0.011	0.968	-2.468	2.239
Belgium (BEL)	-0.113	1.383	-5.284	2.346
France (FRA)	-0.142	1.410	-6.667	2.742
Germany (GER)	-0.158	1.584	-4.580	3.392
Italy (ITA)	0.031	2.044	-11.460	6.390
Luxembourg (LUX)	-0.070	0.864	-4.012	1.399
Netherlands (NET)	-0.082	1.413	-3.727	4.274
Finland (FIN)	-0.101	2.136	-9.539	5.635
Greece (GRE)	0.130	2.274	-13.343	5.811
Ireland (IRE)	0.120	2.136	-5.890	6.286
Portugal (POR)	0.217	1.688	-8.933	4.924
Spain (SPA)	0.015	1.868	-7.960	4.238
UK	-0.025	3.244	-13.232	9.723
Denmark (DEN)	0.042	1.413	-4.740	3.320
Sweden (SWE)	-0.255	2.875	-13.828	7.354
Hungary (HUN)	0.437	3.226	-10.961	9.379
Poland (POL)	-1.484	22.652	-245.141	24.027
Malta (MAL)	-0.070	1.493	-4.150	4.465
Cyprus (CYP)	-0.086	1.449	-4.299	6.025
Norway (NOR)	0.058	2.029	-10.624	5.062
Switzerland (SWI)	0.172	2.244	-7.592	8.085
Iceland (ICE)	-0.313	4.268	-24.550	11.286
Japan (JAP)	0.308	4.507	-10.541	19.259
Australia (AUST)	0.126	4.192	-20.560	10.403
NZ	0.174	3.768	-15.554	10.787
Singapore (SIN)	0.084	1.692	-7.160	4.489
US	-0.059	2.778	-5.879	8.731
Canada (CAN)	0.072	2.629	-11.283	6.583
Costa Rica (COS)	-0.170	6.976	-48.710	17.013
Mexico (MEX)	-0.143	6.826	-43.974	14.401

Note: Full sample (1980Q1-2012Q2).

Table 3. Correlations Between Exchange Rate Changes

Lowest 40 Pairs		Corr	Highest 40 Pairs		Corr
GRE	SIN	0.001	GER	SWE	0.470
POR	POL	0.001	FRA	SIN	-0.473
SWE	CYP	0.002	GRE	SWE	0.473
UK	COS	-0.002	BEL	SWE	0.476
IRE	SPA	-0.003	FRA	SWE	0.478
HUN	NZ	-0.003	FRA	LUX	0.481
FIN	USA	-0.003	FRA	POR	0.483
IRE	UK	-0.004	BEL	SIN	-0.494
UK	SWE	0.005	NET	POL	0.500
BEL	AUST	-0.006	GRE	SIN	-0.501
FIN	GRE	-0.006	NET	SWE	0.509
ITA	USA	-0.007	NET	SIN	-0.531
ITA	GRE	-0.007	GER	SIN	-0.544
POR	UK	-0.007	AUS	LUX	0.574
IRE	USA	-0.008	GER	LUX	0.594
LUX	JAP	0.008	JAP	USA	0.599
FRA	POR	0.008	LUX	NET	0.600
UK	USA	-0.009	FRA	IRE	0.626
FRA	CYP	0.009	BEL	FRA	0.630
ITA	DEN	-0.010	GER	IRE	0.650
FIN	CYP	-0.011	IRE	GRE	0.654
AUS	AUST	0.012	FRA	GER	0.654
POL	NZ	-0.014	FRA	NET	0.658
SPA	CAN	-0.014	BEL	IRE	0.661
BEL	JAP	-0.015	LUX	GRE	0.662
SPA	SWE	-0.015	AUS	IRE	0.664
ITA	UK	0.016	NET	IRE	0.672
FIN	UK	-0.016	FRA	GRE	0.692
GRE	UK	-0.016	AUS	FRA	0.703
UK	POL	-0.016	AUS	BEL	0.742
UK	HUN	-0.016	BEL	NET	0.756
HUN	COS	0.018	GER	GRE	0.762
GER	AUST	-0.019	NET	GRE	0.764
POR	USA	-0.019	BEL	GER	0.766
LUX	USA	-0.019	AUS	GRE	0.771
ITA	UK	-0.019	BEL	GRE	0.806
GER	UK	-0.020	BEL	LUX	0.856
SWE	JAP	0.020	AUS	NET	0.887
FRA	SPA	-0.020	AUS	GER	0.898
GRE	IRE	0.023	GER	NET	0.916

Note: See Table 2 for abbreviation of country names. Full sample.

Table 4. Variance Decomposition

Country	Worldwide Factor:	Regional factor I:	Regional factor II:	Country specific factor:
	$Var(F)$	$Var(e_{Gb})$	$Var(e_{Hbs})$	$Var(e_{Zbsn})$
Austria	0.404	0.178	0.177	0.241
Belgium	0.278	0.123	0.122	0.477
France	0.251	0.111	0.110	0.528
Germany	0.431	0.190	0.190	0.189
Italy	0.009	0.004	0.004	0.983
Luxembourg	0.208	0.092	0.091	0.609
Netherlands	0.440	0.194	0.193	0.173
Finland	0.023	0.010	0.010	0.956
Greece	0.004	0.002	0.002	0.993
Ireland	0.250	0.110	0.110	0.529
Portugal	0.036	0.016	0.016	0.933
Spain	0.029	0.013	0.013	0.945
Regional Ave	0.197	0.087	0.087	0.630
UK	0.121	0.053	0.093	0.734
Denmark	0.452	0.199	0.347	0.002
Sweden	0.004	0.002	0.003	0.992
Hungary	0.004	0.002	0.003	0.992
Poland	0.021	0.009	0.016	0.953
Malta	0.014	0.006	0.011	0.969
Cyprus	0.112	0.049	0.086	0.753
Norway	0.007	0.003	0.005	0.985
Switzerland	0.033	0.015	0.026	0.926
Iceland	0.009	0.004	0.007	0.979
Regional Ave	0.084	0.037	0.058	0.822
Japan	0.009	0.097	0.095	0.799
Australia	0.044	0.482	0.472	0.002
NZ	0.005	0.052	0.051	0.893
Singapore	0.000	0.000	0.000	0.999
Regional Ave	0.028	0.063	0.069	0.839
US	0.003	0.037	0.072	0.887
Canada	0.030	0.329	0.637	0.005
Costa Rica	0.000	0.000	0.000	1.000
Mexico	0.007	0.082	0.158	0.753
Regional Ave	0.010	0.112	0.217	0.661
Ave of All	0.108	0.082	0.104	0.706

Note: The table shows the proportion of each factor to the total variation in the real effective exchange rate using the dynamic hierarchical factor model.