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Merging GSDEER and GSDEEMER: A Global Approach to Equilibrium Exchange Rate Modelling

- We have merged our GSDEER and GSDEEMER equilibrium exchange rate models for G10 and emerging markets within an unified global framework.
- We derive equilibrium exchange rate estimates for 35 currencies using a consistent structural model for the real-exchange rate.
- We model the Euro in a distinctive way, by using country-specific data from individual Euroland economies. This allows the equilibrium real exchange rate to vary across Euroland economies.
- Our new estimates show the US Dollar is fairly valued on a trade-weighted basis, but generally undervalued against other G10 currencies. We find the Euro to be overvalued against most other major currencies.
- In the emerging world, we now find most Asian and some Latin American currencies to be substantially undervalued against the US Dollar.
- New estimates for the Central and Eastern European currencies show them generally undervalued against both the Euro and US Dollar.

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Introduction

1. An Updated Global Approach to Equilibrium Exchange Rate Modelling

Our basic approach to currency forecasting has remained more or less unchanged since 1995. It has combined a sense of "value", obtained from models of long-term exchange rate equilibrium; an assessment of short-term fundamental pressures, derived from the views of our country economists (as well as auxiliary models); estimates of sentiment and flows, obtained from a detailed analysis of currency positioning and cross-border balance of payments anecdotes; and technical analysis.

Underlying our approach to modelling equilibrium exchange rates has been the use of our GSDEER and GSDEEMER long-term fair value models

Underlying our approach has been the use of our GSDEER and GSDEEMER long-term fair value models. The usefulness of such type of models in predicting exchange rates remains a matter of debate. In general, the results of econometric testing of equilibrium models have so far been mixed, showing better performance at longer time horizons, especially when focusing on the ability of such models to forecast the direction of change (*i.e.* the ability of models to forecast a rise or decline in the exchange rate, rather than a specific level).

These results are consistent with our own findings for the GSDEER and GSDEEMER models that we have been using for the past 10 years. We find that these models do outperform a random walk and PPP over a medium to long-term horizon, and have helped us to forecast longer-term currency moves with reasonable accuracy. In addition, we have found our models to be of significant value in understanding the drivers of exchange rates over the long run. Indeed, econometric estimates showing the marginal impact of fundamentals on real exchange rates can be very helpful in understanding and measuring the channels of transmission within the economy.

Our research on BRICs economies illustrates that the world has become more integrated. It is no longer appropriate to strictly distinguish between two separate worlds. A global approach is also needed in currency modelling

Since 1995, the area of currency research and modelling has seen tremendous growth. This was partly induced by the introduction of the Euro, partly by recurrent currency crises in the emerging world, and partly by theoretical innovations in time series econometrics. At the same time, the world has become significantly more integrated, both through merchandise trade and financial flows. In such a world, the barriers between developed and developing economies have become blurred.

For some months, we have been developing our underlying models to incorporate the more recent advances in econometric analysis as well as to bring the emerged and emerging worlds together. The introduction of the BRICs concept into our analysis reflects a belief that it is no longer appropriate to distinguish between two separate worlds. Here, we explain our new valuation model and present some of the results. This new equilibrium model forms only one part of our approach to currency modelling, and we will therefore continue to develop other exchange rate models.

2. New Equilibrium Exchange Rate Estimates: The Main Results

For most G10 crosses, our new equilibrium exchange rate estimates are only slightly different from our old estimates, but for a number of emerging markets, our estimate of equilibrium is now considerably stronger than before.

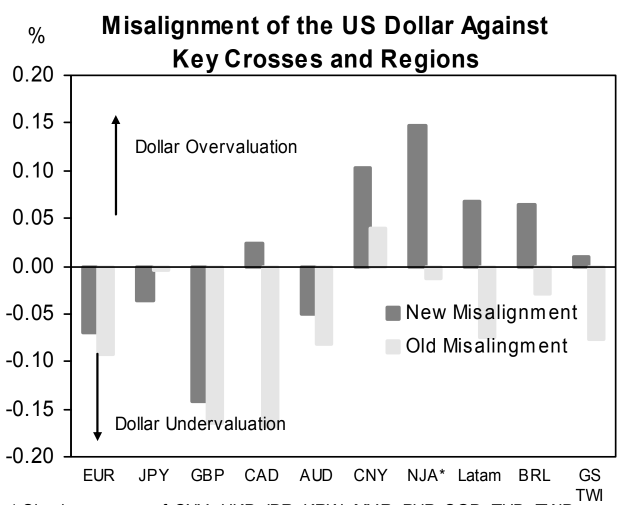
Our new estimates suggest that the US Dollar is undervalued against most G10 currencies. The degree of misalignment, defined as the percentage difference between the current spot rate and the estimated equilibrium, is generally very similar to our previous estimates. For example, our estimate for EUR/$ equilibrium is now 1.18. compared with 1.15 before, implying 9% undervaluation versus to 11% before. Similarly, our new equilibrium estimates for $/JPY, GBP/$ and AUD/$ are also very similar to the old estimates. The exception is Canada, where our new equilibrium estimate for the CAD is substantially stronger. This reflects the new model's ability to capture terms-of-trade improvements, which have been significant in Canada due to commodity price increases in recent years. The CAD is trading close to our new equilibrium estimate, whereas our old estimate suggested a significant overvaluation.

The US Dollar is undervalued against most G10 currencies. The degree of misalignment is very similar to our previous estimates

Outside the G10, our estimates have changed more substantially for many currencies , generally in the direction of a stronger equilibrium against the US Dollar. Our estimates for equilibrium in Asian currencies are now generally more appreciated, including for the Chinese Renminbi and the Korean Won. We now estimate the CNY and the KRW to be 10% and 22% undervalued against the US Dollar, respectively. For Non-Japan Asia as a region, our estimate of equilibrium against the US Dollar, is 18% stronger than before, reflecting a greater appreciation impact on the real exchange rate from labour productivity gains. The results also suggest that the world's most undervalued currencies are within this region. Specifically, we estimate that both the Malaysian Ringgit and the Indonesian Rupiah are undervalued by as much as 25%, which is the largest valuation gap in our sample of 35 currencies.

Outside the G10, our estimates have changed for many currencies. Our estimates for misalignment show potential appreciation in the emerging market currencies, particularly in Asia

In relation to the trade-weighted US Dollar, these results together mean that the trade-weighted equilibrium is weaker than our previous estimate. This reflects the combination of weaker (from the perspective of the US Dollar) equilibrium estimates against currencies in Non-Japan Asia and against the Canadian Dollar and relatively stable estimates for the rest of G10. We therefore now estimate that the US Dollar is trading close to equilibrium on a trade-weighted basis, whereas our previous estimates indicated that the US Dollar was 7% undervalued on such a broad index.



* Simple average of CNY, HKD, IDR, KRW, MYR, PHP, SGD, THB, TWD

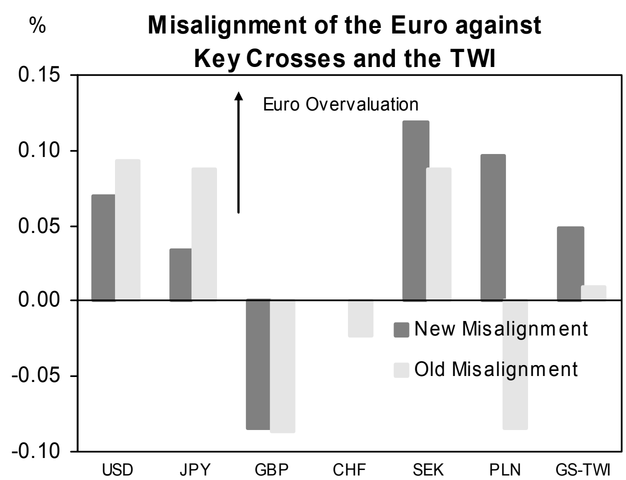


Table 1 – Equilibrium Estimates, Old and New

		New		Old	
	Spot rate*	GSDEER	Misalignment	GSDE(EM)ER	Misalignment
G3					
EUR/$	1.27	1.18	7.0%	1.15	9.3%
$/¥	106.9	110.8	-3.6%	107.5	-0.5%
Europe					
£/$	1.86	1.60	14.2%	1.55	16.5%
EUR/£	0.68	0.74	-8.4%	0.74	-8.7%
EUR/CZK	30.0	24.0	20.1%	31.6	-5.2%
EUR/HUF	251.05	252.28	-0.5%	301.51	-20.1%
EUR/NOK	8.10	7.60	6.1%	8.24	-1.8%
EUR/PLN	4.18	3.78	9.6%	4.53	-8.4%
EUR/SEK	9.21	8.11	11.9%	8.40	8.8%
EUR/CHF	1.54	1.54	0.1%	1.58	-2.3%
$/TRY	1.37	1.97	-44.2%	1.65	-20.3%
EUR/SKK	38.9	38.1	2.0%	-	-
$/RUB	27.9	22.9	18.1%	30.0	-7.5%
$/ZAR	6.30	6.46	-2.5%	6.34	-0.6%
Americas					
$/ARS	2.89	2.36	18.6%	2.91	-0.6%
$/BRL	2.47	2.31	6.4%	2.54	-2.9%
$/C$	1.25	1.22	2.4%	1.46	-16.8%
$/MXN	11.02	11.52	-4.5%	12.15	-10.3%
$/CLP	577	519	10.1%	629	-9.0%
$/PEN	3.25	3.07	5.7%	3.47	-6.6%
$/COP	2347	2376	-1.2%	2363	-0.7%
$/ECS	25250	27813	-10.2%	-	-
$/VEB	2147	1886	12.2%	2633	-22.6%
Asia					
A$/$	0.77	0.73	4.9%	0.72	5.9%
$/CNY	8.28	7.42	10.3%	7.95	3.9%
$/HKD	7.80	7.43	4.7%	6.77	13.2%
$/INR	43.4	39.1	9.8%	-	-
$/KRW	1000	795	20.5%	1191	-19.1%
$/MYR	3.80	2.82	25.8%	3.89	-2.4%
NZ$/$	0.72	0.57	20.2%	0.56	22.0%
$/SGD	1.65	1.64	1.0%	1.67	-0.9%
$/TWD	31.3	27.0	13.9%	28.2	10.0%
$/THB	39.5	35.1	11.3%	42.2	-6.8%
$/IDR	9478	6973	26.4%	11202	-18.2%
$/PHP	54.2	44.4	18.1%	49.7	8.4%

**Spot rate at 13th May 2005*

In this context, it is worth noting that our current global currency views are based on the idea that the US Dollar will have to trade on the weak side of long-term equilibrium for some time. This will be necessary to reduce current imbalances in the US economy to levels that are long-term sustainable. The fact that the trade-weighted Dollar is trading near long-term equilibrium and within undervalued territory against many G10 currencies is not sufficient to become bullish US Dollar in the near term. We have discussed this issue in detail in a number of recent research pieces. For a discussion of our shorter-term global currency views, please see the Global FX Monthly Analyst and the Global Markets Daily.

We now estimate that the US Dollar is trading close to equilibrium on a trade-weighted basis, but there are significant regional patterns of misalignment

Table 2 – Estimates for End of 2005 and 2006

	Estimates for End of 2005		Estimates for End of 2006	
	New GSDEER	Old GSDE(EM)ER	New GSDEER	Old GSDE(EM)ER
G3				
EUR/$	1.20	1.14	1.22	1.13
$/¥	108.0	106.4	106.0	104.5
Europe				
£/$	1.60	-	1.63	-
EUR/£	0.75	0.74	0.75	0.73
EUR/CZK	25.0	30.8	24.9	30.6
EUR/HUF	261	302	264	314
EUR/NOK	7.73	8.22	7.73	8.18
EUR/PLN	3.45	4.10	3.12	4.18
EUR/SEK	8.21	8.41	8.33	8.43
EUR/CHF	1.55	1.58	1.54	1.57
$/TRY	2.05	1.64	2.12	1.75
EUR/SKK	38.1	-	37.1	-
$/RUB	23.9	31.0	25.3	32.9
$/ZAR	6.51	6.47	6.39	6.51
Americas				
$/ARS	2.63	3.00	2.89	3.07
$/BRL	2.40	2.65	2.49	2.74
$/C$	1.22	1.46	1.18	1.46
$/MXN	11.7	12.3	11.7	12.7
$/CLP	516	642	523	654
$/PEN	3.10	3.43	3.10	3.45
$/COP	2466	2350	2526	2398
$/ECS	28234	-	28545	-
$/VEB	2220	2781	2571	33303
Asia				
A$/$	0.75	0.72	0.76	0.72
$/CNY	7.09	7.84	6.70	7.77
$/HKD	7.37	6.69	7.21	6.65
$/INR	39.4	-	39.0	-
$/KRW	738	1172	736	1189
$/MYR	2.86	3.80	2.79	3.75
NZ$/$	0.58	0.55	0.60	0.56
$/SGD	1.63	1.65	1.61	1.64
$/TWD	26.5	27.2	26.1	26.8
$/THB	34.6	42.5	33.7	42.2
$/IDR	7042	11903	7088	122332
$/PHP	41.8	49.3	42.9	50.5

Our trade weighted Euro is relatively more overvalued than in previous estimates

Turning to Europe, our new estimates suggest that the Euro is generally overvalued on the majority of the cross-rates, consistent with our previous conclusions. Both the NOK and the SEK are more undervalued than before relative to the Euro. Specifically, the SEK is now trading 12% weaker than the estimated equilibrium relative to the EUR, and the NOK is trading 6% weaker than equilibrium. In the case of the NOK, significant appreciation of the equilibrium exchange rate associated with the rise in the price of oil is reflected in the equilibrium fitted value. Our new estimates also show that the CHF is very close to fair value relative to the Euro, in line with our previous estimates.

In terms of the trade-weighted Euro, we find that the Euro is now 6% overvalued compared to our previous estimate of 2%. The increase in the overvaluation on the TWI basis reflects a greater valuation gap against a number of currencies in Non-Japan Asia and Eastern Europe, and particularly Russia.

Brazil much stronger than in previous estimates. The valuations of the EMEA currencies are mixed

Our new equilibrium estimates for the Japanese Yen are slightly weaker than before, with the $/JPY equilibrium at 111, compared with 108 before. We note, however, that the nominal $/JPY equilibrium is drifting steadily lower due to the impact of persistently lower inflation than in trading partners. This effect is illustrated in Table 2, which shows the forward looking equilibrium estimates. The equilibrium estimate for end-2006 stands at 106.

In Latin America, most currencies are significantly undervalued against the US Dollar, with the exception of Mexico, Colombia and Ecuador. Most noteworthy perhaps is the change in our estimate for equilibrium for the Brazilian Real to 2.31 from 2.54, suggesting still significant undervaluation.

New estimates for the New European Markets show that CZK, PLN, SKK and RUB are undervalued, while HUF and TRY are overvalued. This is broadly in line with the previous GSDEEMER values, save for $/RUB, where the new estimate for equilibrium points to a much stronger Rouble than before.

Tables 1 and 2 show the equilibrium estimates for all our crosses. We show the end-of-period spot rates for April 2005, the revised equilibrium estimates up to December 2006, and the corresponding misalignment. For comparison, we show the previous GSDEER and GSDEEMER misalignments too.

In the rest of this paper, we focus on the methodology behind our new equilibrium exchange rate estimates.

3. Models of Long-Term Equilibrium Exchange Rates: An Introduction

Before we turn to the specifics of our new global approach to equilibrium exchange rate modelling, we outline how our framework fits in among other equilibrium models and put it in the context of developments in currency research more broadly.

Any attempt to classify the numerous approaches to equilibrium exchange rate modelling under neat categories is open to some form of criticism. And yet, we believe that such a classification can be a great aid in understanding where our own models fit.

There are many approaches to modelling the equilibrium exchange rate

As a first step, it is useful to revisit the definition of the real exchange rate, which in most models is defined as the relative price of home to foreign goods, calculated as the product of the nominal exchange rate and a ratio of domestic to foreign CPIs or PPIs. According to this definition, the bilateral real exchange rate for the USD against the JPY would be defined as the product of two terms, the nominal exchange rate of Yen per Dollar, and the ratio of the US CPI to the Japanese CPI. According to this definition, a nominal appreciation of the USD relative to the JPY, or a rise of US relative to Japanese CPI, would lead to a strengthening of the bilateral real exchange rate of the USD against the Yen.

If the real exchange rate is defined as a function of the nominal exchange rate and relative CPIs, one can then think of the equilibrium nominal exchange rate, which is the variable we ultimately care about, as a function of the equilibrium real exchange rate and relative CPIs. Such a simple transformation allows a first classification of exchange rate models into two groups.

The are two types of models. One genre assumes constant equilibrium exchange rate, while the new generation of models allows the equilibrium exchange rate to evolve with economic fundamentals

One set of models assumes a constant equilibrium real exchange rate, and focuses on explaining the evolution of relative CPIs. A second group takes CPIs as given and focuses instead on explaining the evolution of the equilibrium real exchange rate. The simplest form of the first type of model is Purchasing Power Parity (PPP), where the equilibrium real exchange rate is assumed to be constant and relative CPI's evolve in order to equate the price of domestic and foreign goods through international trade arbitrage. The so-called "monetary model" is a more sophisticated extension of PPP, which fleshes out the determination of prices in each country by imposing continuous equilibrium in the domestic and foreign money markets.

A second set of models has centred its explanatory efforts on the evolution of the equilibrium real exchange rate. In this approach, the equilibrium real exchange rate is allowed to vary over time as a function of real economic fundamentals. In turn, there have been two methodological approaches within this strand of research. In one, the equilibrium real exchange rate is simulated, starting from normative assumptions. In the second, it is estimated using econometric techniques.

The FEER framework, which was introduced by John Williamson (1994), is an example of the first, simulated approach. The basic idea is that the medium run equilibrium real exchange rate is determined by simultaneous internal and external economic equilibrium, where internal equilibrium is defined as full employment (NAIRU) and external equilibrium is defined as the level of the current account balance that is sustainable from a financing perspective in the medium-run. In turn, the external balance is built upon normative assumptions about the sustainable capital account. Hence, the calculated FEER tends to be quite sensitive to the normative assumptions imposed and estimates of "fair value" for the major exchange rates based on this approach vary significantly (see Macdonald, 1999, Wren–Lewis 2004).

Our own GSDEER model, which we have been using for the major currencies since 1995, is an example of the second, econometric approach. Here, the equilibrium real exchange rate is modelled as a function of relative productivity. The theoretical approach for such a model was first developed by Balassa and Samuelson in the mid-1960s. These economists noted that real exchange rates based on broadly defined price indices, which include both traded and non-traded goods, show a productivity bias. Countries that exhibit relatively high productivity in the traded goods sectors have a tendency to exhibit real exchange rate appreciation. The theory states that the rise in productivity in the traded goods sector leads to a nominal appreciation that offsets this competitive advantage, leaving the traded goods real exchange rate constant. However, in terms of the overall price index, there would be real appreciation unless there was automatically triggered arbitrage between the traded and non-traded goods sectors. In our initial attempts to calculate GSDEER, we generally used estimates of trend productivity growth in the business sector (using OECD data) and assumed unity for the marginal impact, i.e., 1% per annum stronger performance of productivity would suggest a 1% per annum rise in the equilibrium real exchange rate. Over the years, we have modified this approach based on econometric findings suggesting that values other than unity might be more applicable.

We have merged our GS-DEER model for G10 currencies with our GS-DEEMER model for emerging currencies — We now use one consistent global framework

The BEER-type (Behavioural Equilibrium Exchange Rate) models constitute a second form of the econometric approach. Here, the set of variables driving the equilibrium real exchange rate is expanded beyond relative productivity to include other fundamental determinants. Our approach to modelling long-run equilibrium real exchange rates in the emerging economies has generally fallen within this category. Indeed, GSDEEMER relies on a simple theoretical model of a small open economy and posits that, in equilibrium, the real exchange rate will be affected by relative productivity, the terms of trade, long-term foreign financing, trade openness, and G3 real interest rates.

While our previous GSDEER and GSDEEMER models differ in terms of the set of variables used in estimating the equilibrium exchange rate, they share a common thrust regarding the dynamic nature of the equilibrium real exchange rate, the importance of relative productivity growth over the long run, and the methodological approach of estimating as opposed to simulating the equilibrium real exchange rate. Our efforts in the following sections are motivated by our desire to find an even tighter common theoretical and empirical framework applicable to both major and emerging currencies.

4. Re-Specification of GSDEER/GSDEEMER and Data Description

Our new model specification follows in the tradition of GSDEER and GSDEEMER, in the sense that the focus is on trying to explain the evolution of the equilibrium real exchange rate using econometric tools. Unlike GSDEER, our new model includes fundamental variables beyond relative productivity, and unlike GSDEEMER, the number of variables is limited to three, as we explain below, and these are common to all the countries.

We use three economic fundamentals to explain the equilibrium exchange rate: productivity, net international investment position and terms of trade

Our model is similar in structure to that of Clarke and Macdonald (1999), but, unlike these authors, we exclude cyclical variables as we only focus on the long-run "fair value" of the exchange rate and not on the short-run deviations from fair value. We therefore start with a simple structural model of the real exchange rate using three explanatory variables: relative productivity, the terms of trade and the net international investment position as a percent of GDP. The intuition behind the selection of these variables and a description of the data is provided in Box 1.

The real exchange rate is calculated as the bilateral real exchange rate against the US Dollar, and all variables are expressed in terms of differences against the US. To calculate the real exchange rate, we use the product of the nominal exchange rate (in terms of units of local currency per US Dollar) and the ratio of domestic to foreign CPIs.

The data we use for calculating the real exchange rates are end of period nominal exchange rates and CPI ratios. We favour CPI as opposed to PPI for one main reason: the PPI includes commodity prices and, given that the terms of trade variable already includes commodity prices, we want to avoid double counting. The International Investment Position (IIP) data are based on two sources – Lanes and Milesi-Ferretti's (2000) net foreign asset data and the IMF's net international investment position series. We construct indices of the terms of trade by calculating ratios of export prices to import prices.

We use quarterly data from 1973:4 to 2004:4 for the major economies. For many of the emerging economies, data availability forces the sample to start later (for details see table 7 in the appendix). Under most circumstances, short time series do not allow robust estimates of equilibrium particularly on a country by country basis (Husted and Macdonald, 1999; Nelson and Sul, 2003). Therefore, we

Box 1: Selection and Description of Explanatory Variables

Productivity: The impact of productivity on the real exchange rate is expected to follow the well-known Balassa-Samuelson doctrine, which states that relatively larger increases in productivity in the traded goods sector are associated with a real appreciation of the currency of given a country. We use a combination of quarterly data for labour productivity published by the OECD and data from country-specific sources.

Net International Investment Position (IIP): This can affect the real exchange rate through the portfolio-balance effect. For instance, a deficit in the current account generally creates an increase in the net foreign debt of a country, which has to be financed by internationally diversifying investors. The associated adjustment of their portfolio structure demands a higher expected return. At given interest rates, this can only be accomplished through a depreciation of the currency of the debtor country (Maeso-Fernandez, Osbat and Schnatz, 2001). We construct the series by using the IMF's estimates of IIP. This dataset does not start until 1988 for some countries, however. Therefore we use NFA growth rates, provided by Lane and Milesi-Ferretti (2000) to construct a historical dataset for IIP.

Terms of Trade: The real exchange rate should also be affected by commodity price shocks through their impact on the terms of trade. For instance, an increase in the price of oil improves the international competitiveness of a country that is relatively less dependent on oil. Overall, a lasting deterioration of the terms of trade of a country should result in a depreciation of the real exchange rate of that country. We use quarterly data for export and import prices provided by the IMF.

construct a panel by pooling all the countries together. This means that we estimate one cross-country equation rather than individual country regressions. Pooling the data yields more efficient estimates as we have more observational power in estimating the relationship, particularly when we impose the assumption of homogeneity for our bilateral currency crosses. Our assumption of homogeneity is important because it prevents variables from third countries from contaminating a bilateral cross. For example, Japanese productivity should not be a component of the $/ARS currency cross (see Box 2).

Pooling the countries yields efficiency and more accuracy in estimation

Box 2: Imposing Homogeneity - Example of Triangular Arbitrage

Consider two Dollar exchange rates, one with the Yen and the other with the Euro. If we want to estimate each of these Dollar cross rates with the following two regressions, we have:

¥/$ = alpha(Yj-Yus)*

EUR/$ = beta(Yeur-Yus)*

where *Yj* is the log of Japanese productivity, *Yus* is the log of US productivity, and *Yeur* is the log of Euroland productivity. Alpha and beta are the estimated coefficients, which are different for each equation. The exchange rates are also expressed in logs.

In the next step we may want to derive the ¥/EUR cross rate *¥//EUR = ¥/$ - EUR/$*.

I: *¥//EUR = alpha*(Yj-Yus) - beta*(Yeur-Yus)*

Alternatively one could also try to estimate the ¥/EUR cross directly:

II: *¥//EUR = gamma*(Yj-Yeur)*

Both ¥/EUR estimates could produce different fitted fair values and there may not be an obvious method to discriminate between both. In addition, estimator I also depends on the productivity of the third country, the US in this example.

However, if we use panel techniques and impose *alpha = beta* across the panel, I and II simplify to one equation:

¥//EUR = alpha(Yj-Yeur),*

So that the ¥//EUR rate is only affected by the Japan versus Euroland productivity.

5. Modelling the Euro-Dollar Exchange Rate

Modelling the Euro-Dollar equilibrium exchange rate involves complications which are absent in the case of the other currencies. This is because the intra-Euroland exchange rates were irrevocably fixed only in 1999. Creating a synthetic Euro using the 1999 weights, and using regional inflation measures to calculate a synthetic Euro real exchange rate for the 1970s and 1980s involves heroic assumptions about the behaviour of intra-regional real exchange rates throughout the whole sample being analysed. In particular, such a strategy forces the assumption that intra-regional real exchange rates have stayed constant throughout the whole sample. However, the process of intra-regional convergence involved significant real appreciation of the Spanish Peseta and Italian Lira, among others, so such an assumption is obviously not a good starting point to model the Euro.

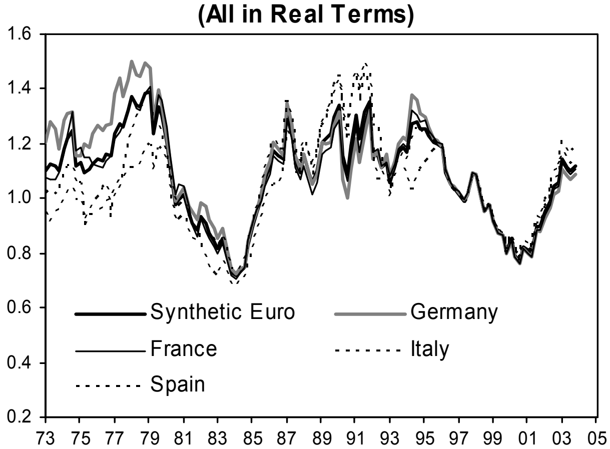
The real exchange rate in each Euroland economy varies with domestic inflation

Rather than constructing a synthetic Euro first, and using that in our estimations, we follow another approach. We construct Legacy Euro rates for the five Euro economies in our sample: Germany, France, Italy, the Netherlands and Spain. Therefore, we multiply the old national Dollar exchange rates with the fixed Euro conversion rates for these currencies. For example, we convert the $/FRF rate into a EUR/$ rate by using 1 Euro = 6.55957 French Francs. This generates a series of five Legacy Euro rates against the Dollar. Obviously, all these series are identical since the start of EMU. We then use these nominal legacy EUR/$ rates to calculate individual real EUR/$ rates for each individual economy. These real exchange rates are used to estimate our panel and calculate individual fitted Euro fair values for each country. Finally, and to construct our GS Synthetic Euro-Dollar rate, we average the five fitted Euro rates, using GDP chain weights.

We create legacy Euro rates for the five major Euroland economies. We estimate these economies individually — exploiting country specific fundamentals. Consequently, we have different real equilibrium exchange rates for each of the Euroland economies

The chart below shows the so-constructed legacy Euro rates against the Dollar (in real terms), with the synthetic Euro-Dollar (in real terms) plotted in black. As can be seen, real exchange rates have not been identical. In particular, there are significant differences in the earlier years. For that reason, the strategy of modelling them separately as bilateral real exchange rates against the US Dollar, and creating a synthetic Euro-Dollar exchange rate after the estimation is better suited to capture the additional information from the intra-regional variation, which would get lost if we followed the typical inverse strategy.

Legacy Euro Rates Against Current Euro (All in Real Terms)



6. Econometric Methodology and Results

The econometric methodology that we employ is a single-equation VAR, namely, Dynamic OLS (i.e., DOLS as developed by Stock and Watson in 1993) applied to pooled data (Nelson and Sul, 2004) for the countries in our panel.[1] The model assumes homogeneity in the coefficients, which is equivalent to saying that the long-run coefficients in the co-integrating vector are restricted to be the same for all the countries. In addition to increasing the efficiency of our estimated parameters, this also helps with the consistency of estimated cross rates (see Box 2 above). When we calculate the fitted equilibrium exchange rates, we use the country-specific data multiplied by the homogenous coefficients.

Productivity and terms of trade explain most of the variation in the real exchange

We realised that it may be problematic to include some of the EMEA markets in the panel because they have a history of severe market controls or central planning. The Czech Republic, Hungary, Poland, Slovakia and Russia were particularly affected. Therefore, we estimate these countries individually using exactly the same methodology and variables as in the panel.[2]

More specifically, using the pooled dataset described above (or in the case of the former command economies, un-pooled country-specific data) we estimate the following equation.[3]

$$\mathrm{REER}_{it} = \alpha_i + \beta_1 \mathrm{Proddif}_{it} + \beta_2 \mathrm{IIPdif}_{it} + \beta_3 \mathrm{TOTdif}_{it} + error_{it}$$

where REER_{it} is the real exchange rate at time t for country i, and all the explanatory variables are calculated as ratios relative to the United States. Notice that because we assume homogeneity, the impact of fundamentals on the long-run equilibrium real exchange rate (captured by the β coefficients) is the same for all countries. Because all of the explanatory variables, save net IIP,[4] are transformed into natural logarithms, we can interpret β as the long-run elasticities associated with the levels of the variables. In other words, they show the percentage change in the long-run equilibrium real exchange rate for a 1% change in the fundamentals.

Table 3 - Regression Results

Variable	Coefficient
PRODDIF	0.231**
IIPDIF	0.001*
TOTDIF	0.348**

Where ** denotes significant at the 5% level and * at the 10% level

Table 3 above shows the estimated coefficients from the revised GSDEER model. Consistent with our priors, all coefficients are positive and statistically significant. The results indicate that a 1 percent increase in relative productivity is associated with a 0.23% real appreciation over the long run, while a 1 percent rise in the terms of trade leads to a 0.35% appreciation of the real exchange rate. For IIP the interpretation is slightly different: a 1 percentage point rise in IIP relative to GDP leads to a 0.001% appreciation of the real exchange rate.

Using the estimated coefficients, we can calculate the equilibrium nominal exchange rates from the fitted values of our model (displayed in Tables 1 and 2). This calculation provides our best estimates for the long-run equilibrium bilateral exchange rates.

1. The DOLS estimation requires leads and lags of all the explanatory variables in differences. These are simply designed to correct for possible endogeneity. We therefore do not report them as we do not use them to derive fitted values or to generate forecasts.
2. Without the homogeneity restriction.
3. Estimation start date differs for each country. See Table 7 in Appendix.
4. We cannot transform the IIP variable into logs as the variable is negative for most countries. We therefore expressed IIP as a percentage of GDP.

7. How Well Do Our Revised GSDEER Estimates Perform?

Estimating the coefficients in levels is the first stage of co-integration analysis. But to test the predictive ability of the model, it is necessary to estimate the model in changes, which is conventionally referred to as an error correction model (ECM). Unlike the first stage co-integrating model, we estimate this second stage by allowing the ECM to be country-specific (or heterogeneous). This allows each country to adjust to equilibrium at a different speed, while sharing a common long-run co-integrating relationship (from the homogenous panel). This implies that the ECM regressions are in the form of:

Out of sample tests, suggest that our model is stable and robust

$$\Delta \mathrm{E}_{\mathrm{it}} = \alpha_{\mathrm{i}}(\mathrm{REER}_{\mathrm{i,t\text{-}1}} - \mathrm{LRFIT}_{\mathrm{i,t\text{-}1}}) + \gamma_i^1(\Delta \mathrm{E}_{\mathrm{it\text{-}1}}) + \gamma_i^2(\Delta \mathrm{p}_{\mathrm{it\text{-}1}} - \Delta \mathrm{pstar}_{\mathrm{it\text{-}1}}) + \gamma_i^3(\Delta \mathrm{proddif}_{\mathrm{it\text{-}1}})$$
$$+ \gamma_i^4(\Delta \mathrm{iipdif}_{\mathrm{it\text{-}1}}) + \gamma_i^5(\Delta \mathrm{totdif}_{\mathrm{it\text{-}1}}) + error_{it}$$

Where the Δ prefix denotes change. The change in the nominal exchange rate for each country *i* at time *t* is a function of the adjustment parameter α_i for each *i*. The γ_is capture the lagged changes from each of the fundamentals, for each country *i.*

Formally, out-of-sample tests are used to gauge the performance and stability of our model. For each country, we calculate recursive residuals, which are the one-period ahead forecasting errors associated with each period. These are then used to calculate the cumulative sum of residuals test (CUSUM test) and the variance of the cumulative sum of residuals (CUSUM square test). These tests have a null hypothesis of parameter stability and error variance stability, respectively.

At the 95% confidence interval, we find that the proportion of periods in which our model violates parameter stability is fairly low. Table 4 shows that only two countries out of 38 countries fall outside the 95% confidence interval over 5% of the time. Interestingly, the rare violation of parameter stability usually occurs in the beginning of the sample period: for the UK in 1980 to 1981 and for the Netherlands in 1980 to 1983. The CUSUM-square test displayed in Table 5 shows that the variance in the forecast errors from our model is also small. Only two countries, the Netherlands and South Africa have variance instability falling outside the 95% interval, more than 5% of the time.

The CUSUM tests suggest that our model is fairly stable and reliable. However and paradoxically, they could also mean that the model is performing continually badly in each and every period. In other words, the model could be wrong but in a stable fashion. To rule out this possibility, we test the explanatory power of the ECM by examining the adjusted R squares of the model. Conventionally, the explanatory power from an ECM for the nominal exchange rate is notoriously poor (Cheung et al, 2002, Mark, 2001, Rogoff and Meese 1983). Seminal work by Ronald MacDonald reports R squares that are lower than our model.[5] This is a rough indication that our model is not only stable but that its forecasting ability is quite good when compared with the standards in the literature.

One additional potential criticism of the DOLS approach is that it assumes that all of the drivers of the long-run fitted value are exogenous – that all the adjustment in the cointegrating vectors comes through the nominal exchange rate. Therefore, we also assess the degree to which our revised GSDEER model may overlook the contributions to the adjustment process from relative prices, relative productivity, the terms of trade and the net international investment position. We do this by comparing our equilibrium values (which implicitly assume the nominal exchange rate does all the adjustment) with the multivariate Beveridge-Nelson trend (see Wright et al, 2004) implied by the

5. Macdonald, 1999 reports R squares for his VECM model. We report adjusted R squares as this corrects for degrees of freedom. However, when comparing like with like, our ECMs have a larger R square than does Macdonald's ECM model.

VECM, which allows for the adjustment to operate through all the variables in the system. Reassuringly for most countries, the REER from both our single equation DOLS and Beveridge-Nelson model look very similar, implying that the nominal exchange rate does most of the adjustment, and that the long-run assumptions underlying our model are quite robust.

Table 4 - Parameter Stability Test - CUSUM* Test

Country	Percentage of Period Instability
Argentina	0.00%
Australia	0.00%
Brazil	1.47%
Canada	1.03%
Chile	0.00%
China	0.00%
Colombia	1.89%
Ecuador	0.00%
France	0.00%
Germany	0.00%
Hong Kong	0.00%
India	0.00%
Indonesia	0.00%
Italy	0.00%
Japan	0.00%
Korea	0.00%
Malaysia	0.00%
Mexico	0.00%
Netherlands	0.00%
New Zealand	0.00%
Norway	2.13%
Peru	0.00%
Philippines	0.00%
Singapore	0.00%
South Africa	5.00%
Spain	12.64%
Sweden	0.00%
Switzerland	1.03%
Taiwan	0.00%
Thailand	0.00%
Turkey	0.00%
UK	6.52%
Venezuela	0.00%
Panel Average	**0.96%**
Czech Republic	4.00%
Hungary	4.00%
Poland	0.00%
Russia	4.50%
Slovaka	4.00%

note: a figure above 5% shows instability

* Cumulative sum of residuals test

Table 5 - Variance Stability - CUSUM* Square Test

Country	Percentage of Period Instability
Argentina	3.39%
Australia	0.00%
Brazil	1.28%
Canada	0.00%
Chile	0.00%
China	0.00%
Colombia	1.89%
Ecuador	0.00%
France	0.00%
Germany	0.00%
Hong Kong	0.00%
India	0.00%
Indonesia	0.00%
Italy	0.00%
Japan	0.00%
Korea	0.00%
Malaysia	0.00%
Mexico	0.00%
Netherlands	22.50%
New Zealand	0.00%
Norway	2.13%
Peru	0.00%
Philippines	0.00%
Singapore	0.00%
South Africa	13.51%
Spain	0.00%
Sweden	0.00%
Switzerland	1.03%
Taiwan	0.00%
Thailand	0.00%
Turkey	0.00%
UK	3.16%
Venezuela	0.00%
Panel Average	**1.48%**
Czech Republic	0.00%
Hungary	0.00%
Poland	0.00%
Russia	4.00%
Slovakia	4.00%

note: a figure above 5% shows instability

* Variance of the cumulative sum of residuals

8. Directions for Further Research

Our revised GSDEER model will remain one of our core building blocks of exchange rate forecasting. We plan to supplement our new model with further new research related to that described here. One avenue high on the agenda is to model the trade-weighted value of all the exchange rates discussed in this paper.

We have a rich agenda for future currency modelling

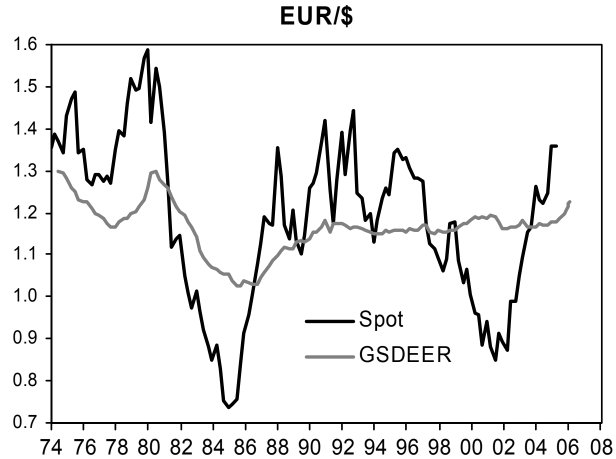
We will also explore ways of re-analysing our so-called Adjusted GSDEER model, which attempts to 'adjust' our equilibrium exchange rates for the shorter term, mainly cyclical, dynamics existent in the markets. As we have done before, we will attempt to analyse different frequencies of such a dynamic model.

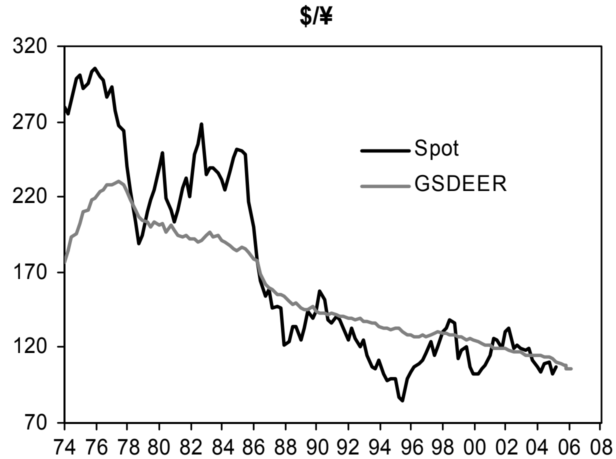
Another possible avenue for future research will be to estimate 'probability' models[6] around our central GSDEER equilibrium estimates, allowing us to state degrees of confidence about both our estimates of equilibrium and such estimates coinciding with market prices.

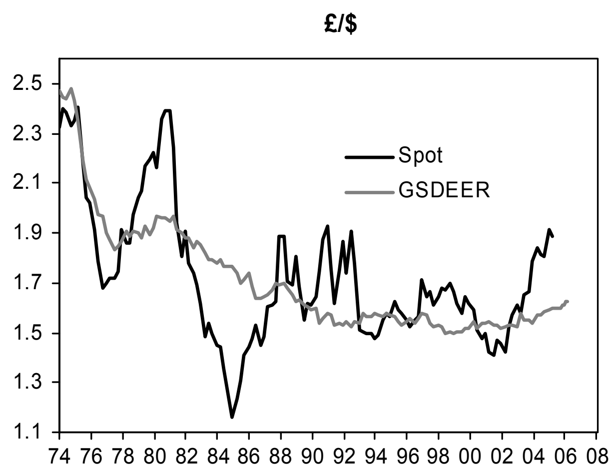
Of course, we will supplement all of these model-based attempts with our ongoing regular FX research, including the broad balance of payments (BBoP) analysis that we pioneered our regular and detailed analysis of M&A and cross border portfolio flow dynamics, and of course technical analysis.

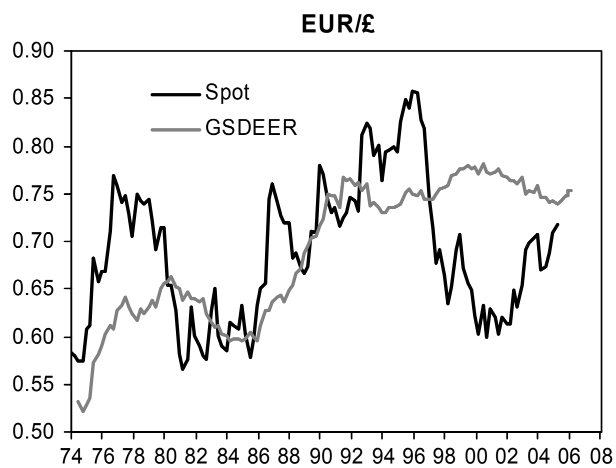
6. Based on a forthcoming paper by Wright and Robertson.

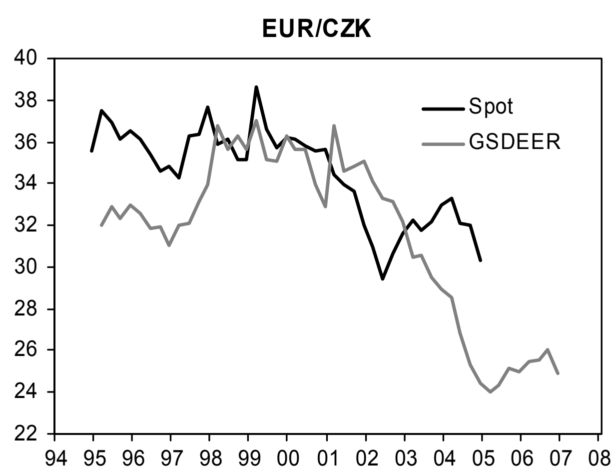
Graphs of Actual Exchange Rates and Fitted Values From Our New GSDEER Model

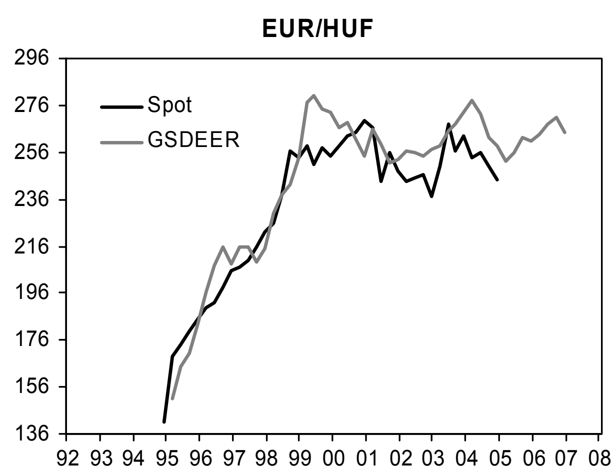


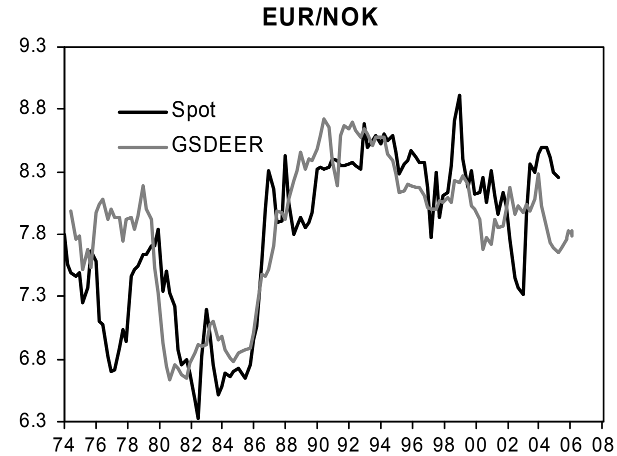


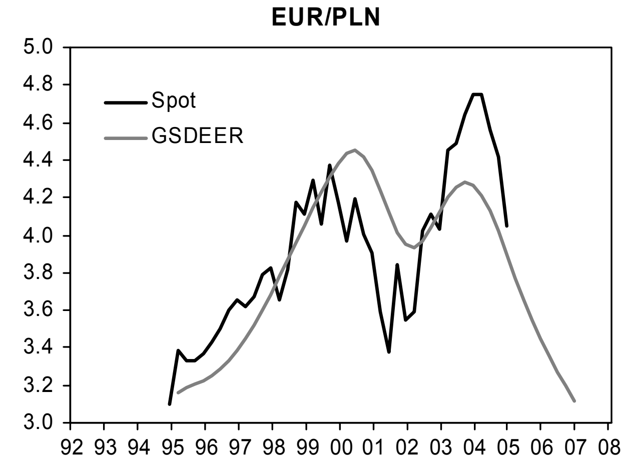


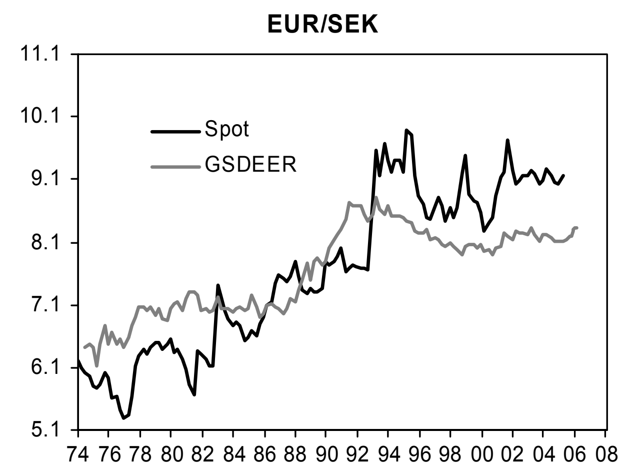







EUR/NOK
Spot
GSDEER
9.3
8.8
8.3
7.8
7.3
6.8
6.3
74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04 06 08


EUR/PLN
Spot
GSDEER
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08


EUR/SEK
Spot
GSDEER
11.1
10.1
9.1
8.1
7.1
6.1
5.1
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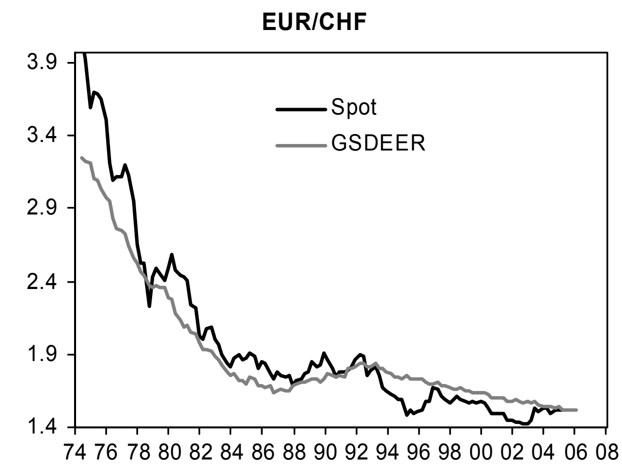
EUR/CHF
Spot
GSDEER
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3.4
2.9
2.4
1.9
1.4
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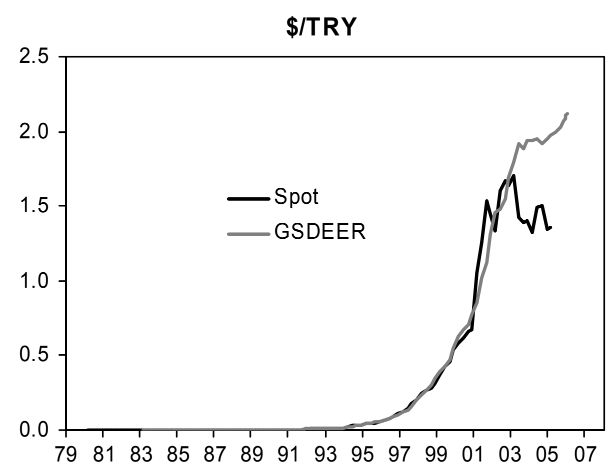
$/TRY
Spot
GSDEER
2.5
2.0
1.5
1.0
0.5
0.0
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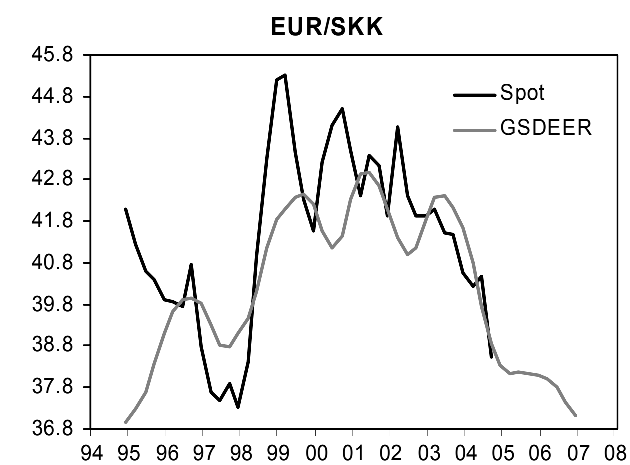
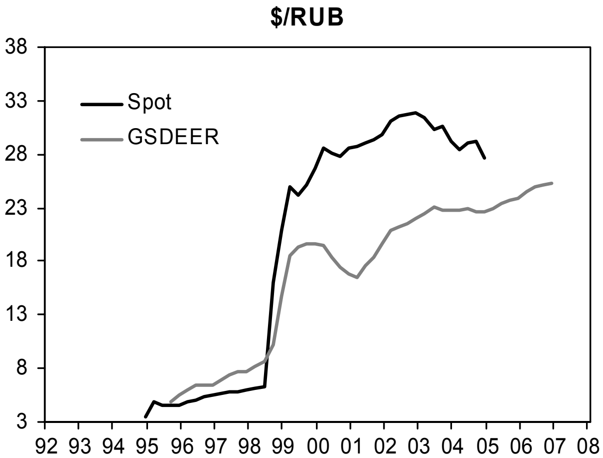
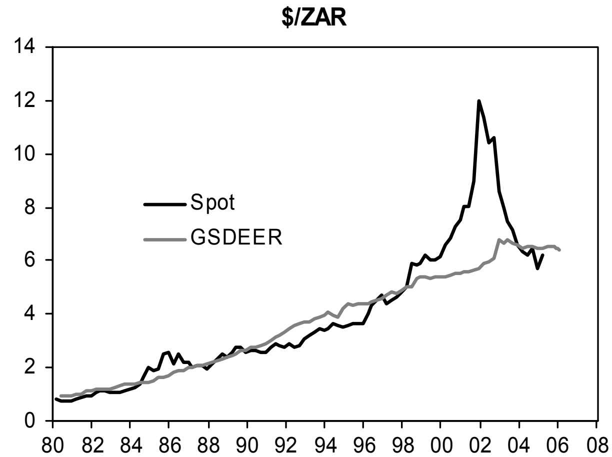

EUR/SKK
Spot
GSDEER
45.8
44.8
43.8
42.8
41.8
40.8
39.8
38.8
37.8
36.8
94 95 96 97 98 99 00 01 02 03 04 05 06 07 08


$/RUB
Spot
GSDEER
38
33
28
23
18
13
8
3
92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08


$/ZAR
Spot
GSDEER
14
12
10
8
6
4
2
0
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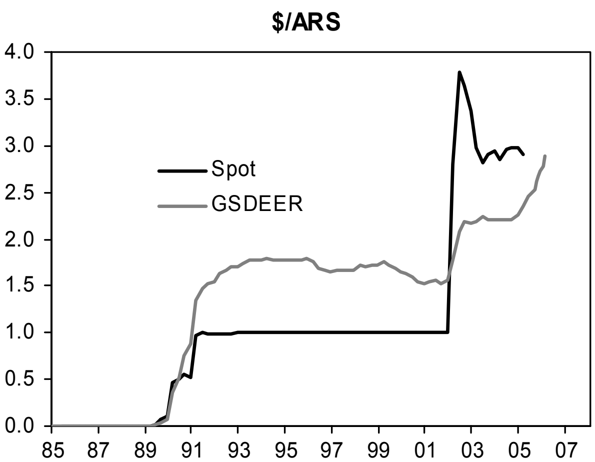
$/ARS
Spot
GSDEER
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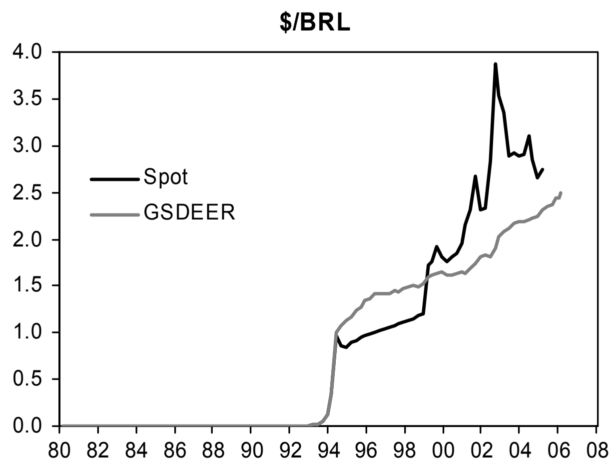
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
85 87 89 91 93 95 97 99 01 03 05 07


$/BRL
Spot
GSDEER
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3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
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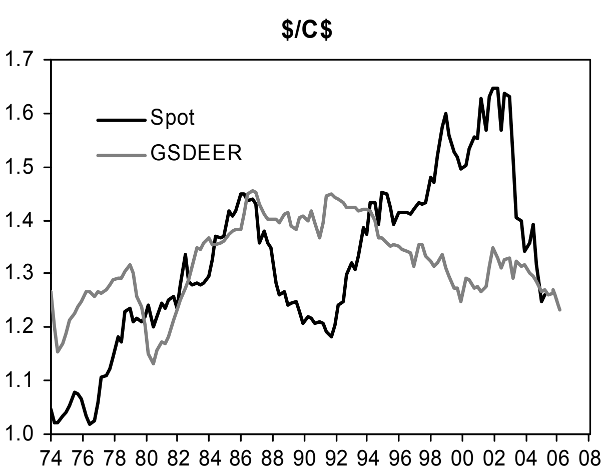
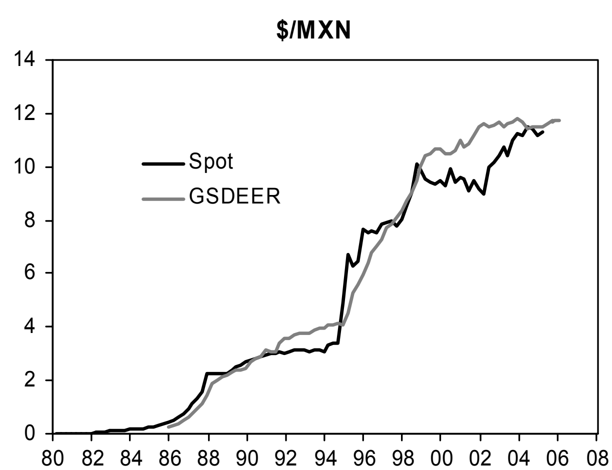

$/C$
Spot
GSDEER
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04 06 08


$/MXN
Spot
GSDEER
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12
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8
6
4
2
0
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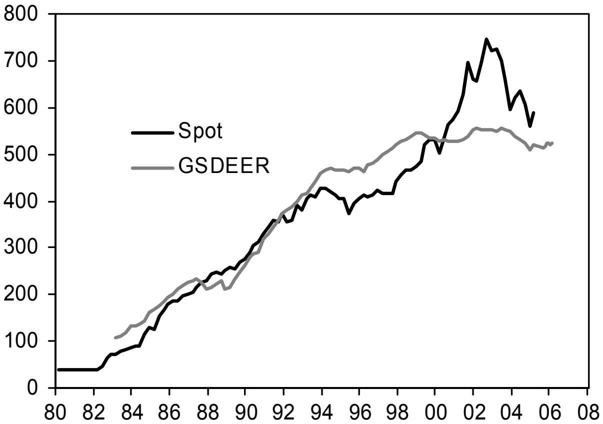
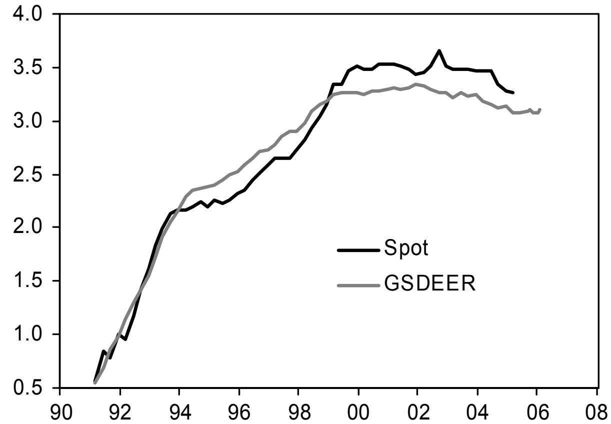
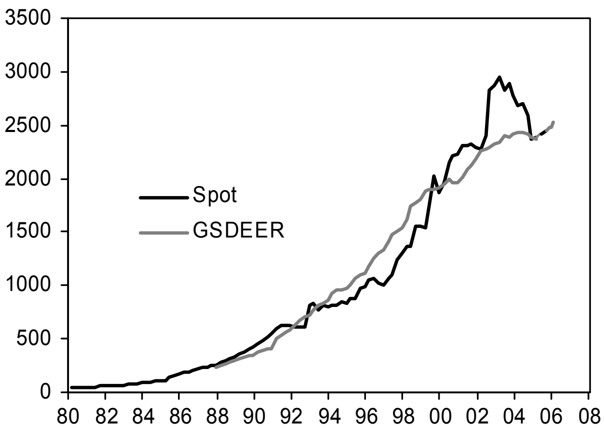
$/CLP



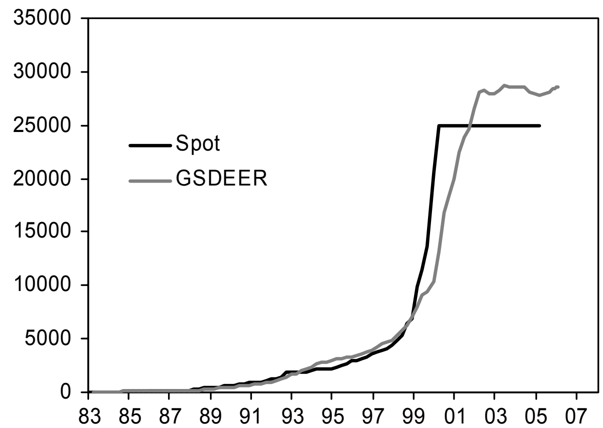
$/PEN



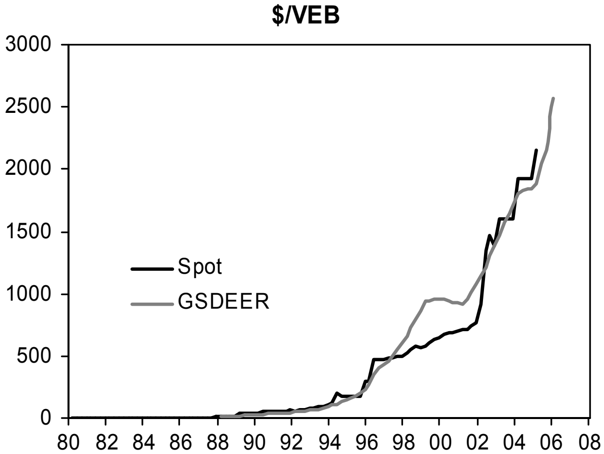
$/COP



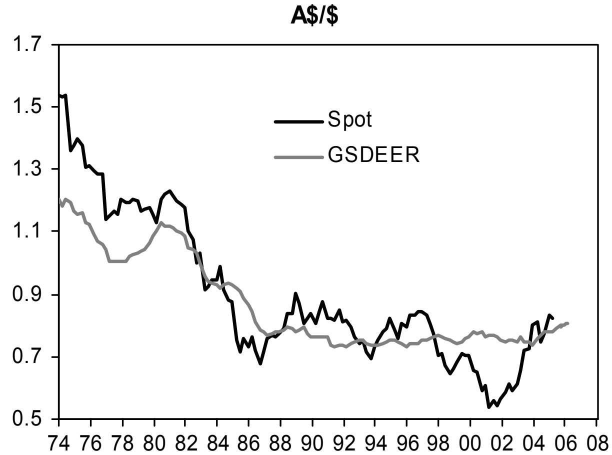
$/ECS

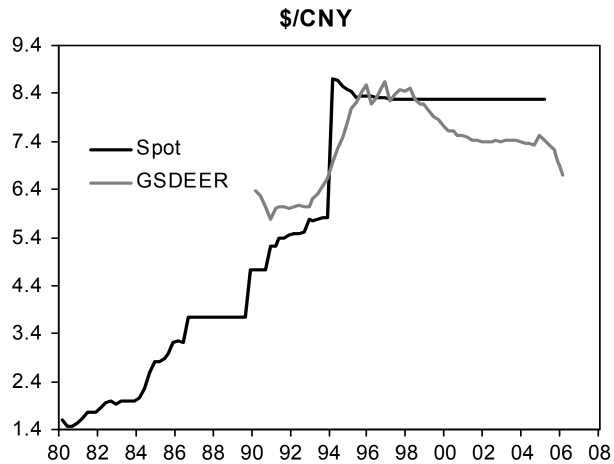


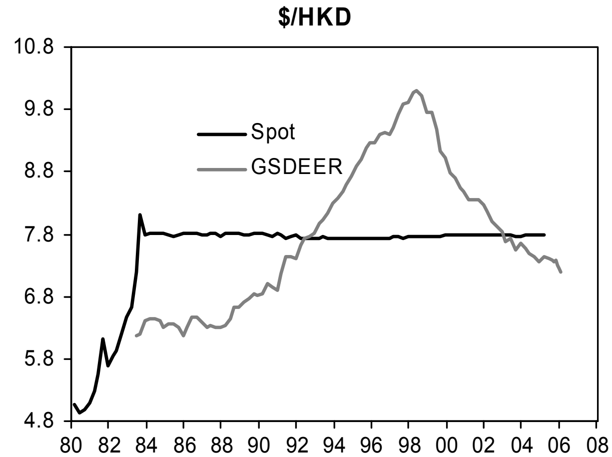
$/VEB



A$/$




$/CNY
9.4
8.4
7.4
6.4
5.4
4.4
3.4
2.4
1.4
Spot
GSDEER
80 82 84 86 88 90 92 94 96 98 00 02 04 06 08


$/HKD
10.8
9.8
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7.8
6.8
5.8
4.8
Spot
GSDEER
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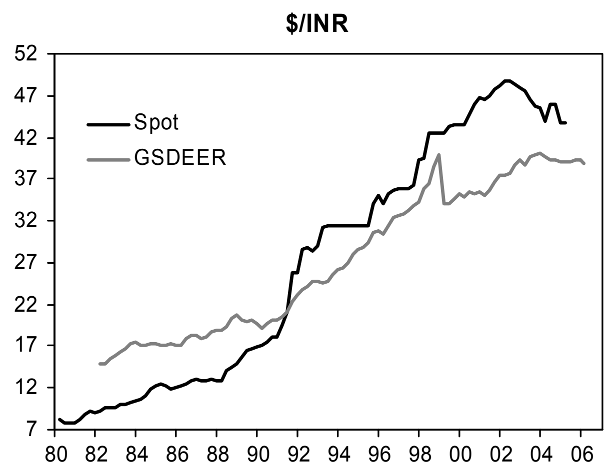
$/INR
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42
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27
22
17
12
7
Spot
GSDEER
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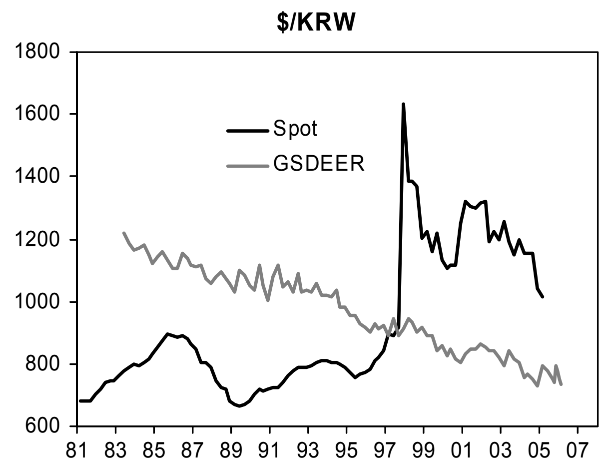
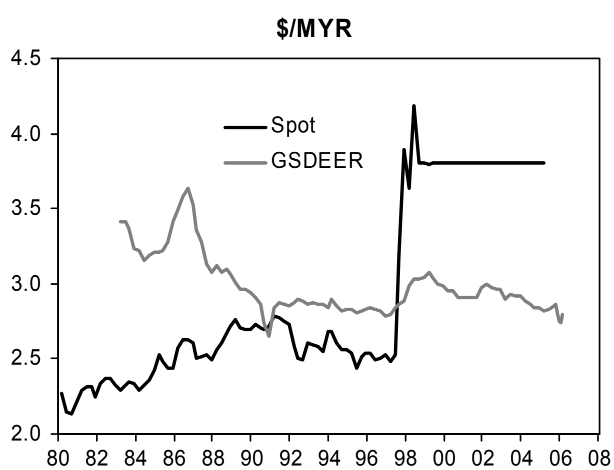

$/KRW
1800
1600
1400
1200
1000
800
600
Spot
GSDEER
81 83 85 87 89 91 93 95 97 99 01 03 05 07


$/MYR
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4.0
3.5
3.0
2.5
2.0
Spot
GSDEER
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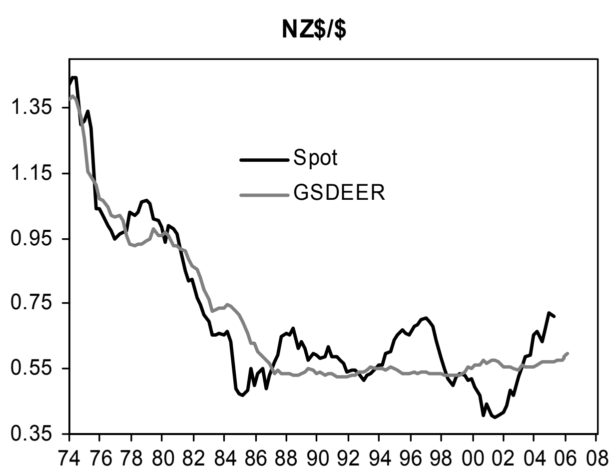
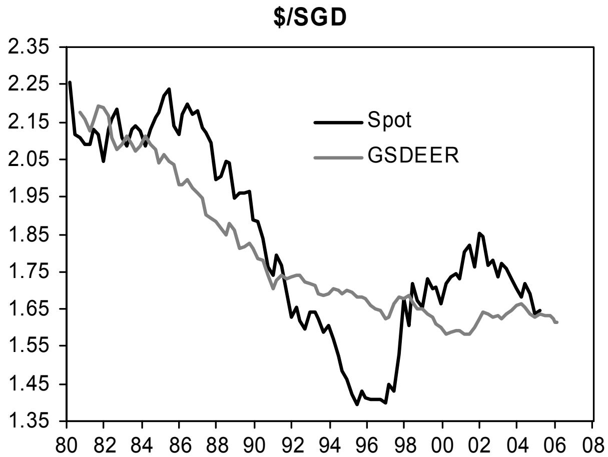
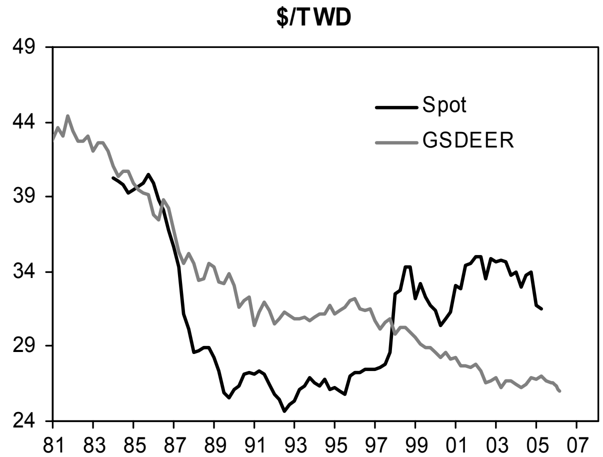
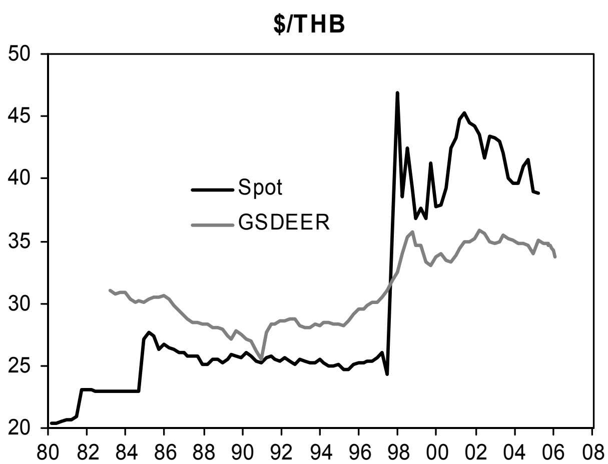
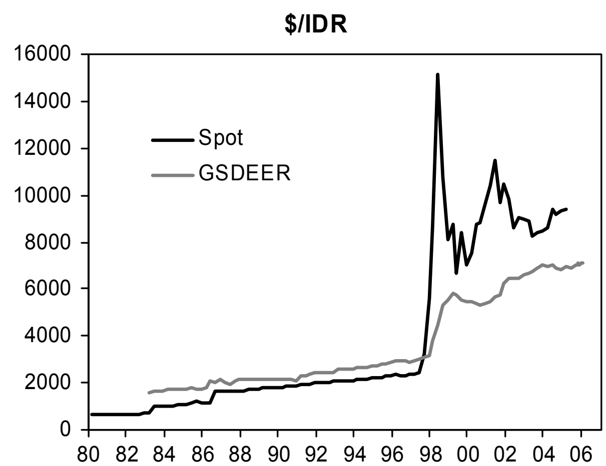
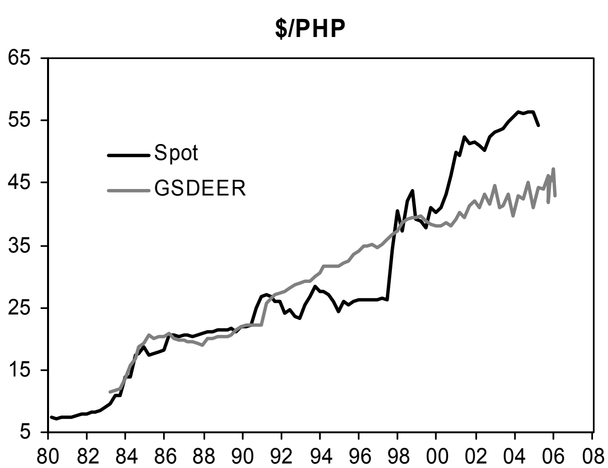

NZ$/$
1.35
1.15
0.95
0.75
0.55
0.35
Spot
GSDEER
74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04 06 08


$/SGD
Spot
GSDEER
2.35
2.25
2.15
2.05
1.95
1.85
1.75
1.65
1.55
1.45
1.35
80 82 84 86 88 90 92 94 96 98 00 02 04 06 08


$/TWD
Spot
GSDEER
49
44
39
34
29
24
81 83 85 87 89 91 93 95 97 99 01 03 05 07


$/THB
Spot
GSDEER
50
45
40
35
30
25
20
80 82 84 86 88 90 92 94 96 98 00 02 04 06 08


$/IDR
Spot
GSDEER
16000
14000
12000
10000
8000
6000
4000
2000
0
80 82 84 86 88 90 92 94 96 98 00 02 04 06


$/PHP
Spot
GSDEER
65
55
45
35
25
15
5
80 82 84 86 88 90 92 94 96 98 00 02 04 06 08

Appendix

1. Estimation of Hungary, Czech Republic, Poland, Slovakia and Russia

We estimate individual regressions for the Czech Republic, Poland, Slovakia and Russia. The cointegrating coefficients for the above countries are relatively large and significant. This is not unsurprising; typically, these countries have experienced major economic and social transition since 1995 and are playing "catch up". For instance, our regression results, displayed in Table 6, suggests that in Poland a 1% increase in productivity leads to a 2.4% appreciation in the real exchange rate; a 1% increase in terms of trade leads to a 0.93% appreciation, and finally a rise in 1% in net IIP (as a percentage of GDP) leads to a 2.91% appreciation in the real exchange rate.

2. Unit Root and Cointegration Tests for Panels

Our panel unit root tests are based on tests by Levin, Lin and Chu (2002); Harris Tsvalis (1996); Im, Pesaran and Shin (2002). These tests confirm that all of the variables used in our model are non-stationary.

Cointegration tests are based on Larsson et al (2002); and Binder, Hsiao & Pesaran (1999). These confirm that the real exchange rate is cointegrated with our three explanatory variables at the 5% level of significance.

3. Estimation Procedure

We use GLS not OLS to estimate our panel estimation. The DGLS estimator achieves asymptotic efficiency gains over DOLS, by incorporating cross-sectional weights in the equilibrium errors (Nelson and Sul 2003).

4. Start Dates Vary for Each Country, see Table 7.

Table 6 - Regression Results

Variable	Coefficient
Hungary	
PRODDIF	1.700**
TOTDIF	2.105**
IIPDIF	0.254**
Czech Republic	
PRODDIF	1.060*
TOTDIF	2.800*
IIPDIF	0.563*
Poland	
PRODDIF	1.968**
TOTDIF	0.748*
IIPDIF	2.422**
Slovakia	
PRODDIF	1.518**
TOTDIF	1.636**
IIPDIF	0.339*
Russia	
PRODDIF	0.088**
TOTDIF	0.827*
IIPDIF	0.299*

Where ** denotes significant at the 5% level and * at the 10% level

Table 7: Estimation Start Dates

Country	Estimation Start Date
Argentina	1985
Australia	1974
Brazil	1980
Canada	1974
Chile	1983
China	1993
Colombia	1994
Czech Republic	1995
Ecuador	1982
Euro Countries	1974
Hong Kong	1983
Hungary	1995
India	1982
Indonesia	1983
Japan	1974
Korea	1983
Malaysia	1983
Mexico	1985
New Zealand	1974
Norway	1974
Peru	1990
Philippines	1983
Poland	1995
Russia	1995
Singapore	1980
Slovakia	1995
South Africa	1980
Sweden	1974
Switzerland	1974
Taiwan	1983
Thailand	1982
Turkey	1983
UK	1974
Venezuela	1987

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