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ABSTRACT

The presence of purchasing power parity is often attributed to the exploitation of arbitrage opportunities in goods markets. We examine this presumption for a 1960-1996 monthly panel of bilateral exchange rates and trade for the G7 countries. The data exhibit strong mean reversion. However, despite allowing for substantial latitude in specification, we find very limited support for a simple arbitrage view. The deviations of real exchange rates and trade from trend are virtually uncorrelated. Large trade deviations neither trigger nor accelerate mean reversion. Large real exchange rate deviations do not lead to systematic changes in trade. Constricting the sample to eighteen-month episodes of notable mean reversion - large persistent depreciations starting from overvalued levels - does not reveal any systematic relation either. The timing of these episodes does point, however, to an alternative explanation of mean reversion: the majority of episodes occur during periods of *nominal* exchange rate regime instability, pointing towards exchange rate policy or speculation as the immediate cause of mean reversion. Both may, of course, reflect *expectations* of trade responses, opening an indirect role for *incipient arbitrage* in explaining mean reversion.

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1 Introduction

Purchasing power parity (PPP) provides a corner stone for much of international macroeconomics. Unsurprisingly, it's empirical validity has been the subject of extensive empirical research. While early studies mostly rejected PPP, the availability of longer time series and advances in econometric technique have turned the pendulum, with recent studies finding support at least for mean reversion if not for absolute PPP.[1] The expectation of (eventual) mean reversion often rests implicitly or explicitly on the constraining force of *goods* market arbitrage.[2] A recent literature explicitly focusing on the role of arbitrage, typically introducing costs of arbitrage —either directly or through the specification of the transaction technology— aiming to explain both delays in price adjustments and non-linear effects.[3] Correspondingly, findings supportive of mean reversion are generally also interpreted — at least implicitly — as evidence in favor of goods market arbitrage *causing* mean-reversion.

A priori, arbitrage based models of mean reversion in relative prices of tradables certainly have appeal. A sizable body of circumstantial evidence points to arbitrage being alive and well. To take just one anecdotal example, in the mid 1980s, well heeled US citizens were reported to arbitrage very significant price differentials between the DM and the $ prices of Mercedes cars by taking first class flights to Germany, buying a Mercedes for DM, shipping it back to the US and still coming out ahead. On a lesser scale, a stroll along the sidewalks of any large city reveals an abundance of international arbitrage activities ranging from batteries to stereos. Yet in the end this circumstantial evidence remains just that, to assess the aggregate importance of arbitrage, we need to know the size and, more importantly, the impact of these arbitrage activities on prices: Were flights to Germany so filled with eager car buyers to cause changes in the $ or the DM price of Mercedes cars?

This is the question we focus on in this paper. Our departure point is the simple obser-

[1] A very partial list of recent work includes Cumby (1996), Engel, Hendrickson and Rogers (1996), Frankel and Rose (1996), O'Connell (1997), Papell (1996), O'Connell and Wei (1997), Obstfeld and Taylor (1997), Parsley and Wei (1995,96). Froot and Rogoff (1995) and Rogoff (1996) provide an overview of the literature.

[2] See for instance Davutyan and Pippenger (1990), DeVries (1989), Fraser, Taylor and Webster (1991), Isard (1977), Michael, Nobay and Peel (1997), Prakash and Taylor (1996) and Webster (1987), *inter alia*.

[3] Benninga and Protopapadakis (1988), Coleman (1995), Dumas (1992), Obstfeld and Taylor (1997), O'Connell and Wei (1997), Williams and Wright (1991).

vation that effective arbitrage is a sufficient but not a necessary condition for mean reversion of relative prices. Alternative explanations for mean reversion, even with thresholds, are readily available. Two obvious candidates are deliberate policy actions by governments designed to maintain real exchange rates within (implicit or explicit) bands (Weber 1997) and the abandonment of overvalued pegs overwhelmed by financial flows — such as the EMS crisis. While these alternative explanations focus on events other than arbitrage as the immediate cause of the mean reversal, trade flows of course may nevertheless play an important role behind the scenes. The motivation for an exchange rate band is likely to be at least partly based on the expected negative consequences for trade of overvalued or excessively volatile real exchange rates, while the belief that an exchange rate is vulnerable to a run is likely to be influenced by actual or expected trade responses. Nevertheless, even if expected arbitrage plays a role in motivating government or financial market reactions, it is the latter, not the former, that in these scenarios brings about the mean reversion.

The empirical validity of alternative explanations of mean reversion cannot be disentangled by looking solely at the exchange rate behavior, the focus of most of the empirical literature. A complete validation of the arbitrage explanation requires evidence not only for mean reversion but also for a *causal* link between arbitrage and mean reversion, and hence requires a *joint* assessment of the behavior of relative prices and *quantities*. Specifically, if arbitrage is the cause for mean reversion, we should see a systematic link between trade flows and the deviation of the real exchange rate from trend.[4] Finding such responses would considerably strengthen the case for attributing mean-reversion to arbitrage, failure to find such linkages would instead suggest that other factors may be at the root of the mean reversion.

In this paper, we present some initial evidence on this point. Our empirical evidence is based on a sample of monthly bilateral trade flows and real exchange rates between the G7 countries since 1960, and proceeds in three steps. We first present unconditional correlations to characterize the relation between relative prices and trade flows in this sample. We then present a number of augmented mean reversion regressions, allowing the presence as well as the speed of mean reversion parameters to depend on current and lagged

[4]Likewise, if, as some recent papers suggest, mean-reversion exhibits a threshold non-linearity, we should be able to identify a systematic non-linear change of trade flows as the real exchange rate breaches the thresholds.

trade responses. Finally, we identify and examine, for each of our forty-two country-pairs, the eighteen month episode of the most pronounced mean reversion, specifically, a large depreciations starting from a substantially overvalued level. Focusing on these episodes has two advantages. First, the extreme episodes arguably reduce the ambiguity involved in identifying "overvaluation". Second, due to their highly over-/under-valued starting point, they effectively address the threshold problem (if the thresholds *exceed* the extreme real exchange rate values reached over a thirty-plus year sample they are arguably of low practical importance and, furthermore, cannot explain the mean reversion found by other authors for similar samples and time periods). A case study of these episodes, both in terms of examining the associated trade response and by checking whether alternative identifiable events coincided with the mean reversal, thus promises additional insight.

To preview the results, all of our tests point to the same conclusion: while we find strong support for mean reversion in the data — confirming prior results in the literature —, there is very little evidence for a link between mean reversion and changes in trade flows. Deviations of trade and of real exchange rates from trend are mutually virtually uncorrelated, large trade deviations do not seem to either cause or accelerate mean reversion, nor do large deviations of real exchange rates from trend seem to be systematically associated with deviation of trade from trend or even changes in trade relative to trend. Maybe most compelling, even within the subsample of the forty-two episodes of the most pronounced mean reversion, we find no systematic pattern between trade and relative prices. The subsample does, however, suggest alternative explanations: a majority of the clearest episodes of mean reversion occurred either during a collapse of a fixed exchange rate regime (Bretton Woods, 1971-73, ERM Crisis 1992) or during an episode of co-ordinated exchange rate policy (Plaza Agreement, 1985-86).

The results are open to a number of explanations. First, it might be that *incipient* rather than actual arbitrage drives pricing behavior. In models with costs of arbitrage, an incumbent firm knowing the entry costs of potential competitors will strive to keep relative prices below the threshold triggering entry, hence the mere *threat* of entry might lead the incumbent to alter prices in response to nominal exchange rate movements. Unobservable *potential* arbitrage might thus, by prompting price responses, prevent observable actual arbitrage. The possibility cannot be dismissed, and indeed our results suggest a strong connection between the speed of mean reversion and factors -such as proximity- that arguably facilitate arbitrage. However, it is unlikely that incipient arbitrage provides a complete explanation, for two reasons. First, as long as entry costs are constant, incipient arbitrage can only explain the presence of *bounds* on relative prices, it does not provide an explanation by itself for mean reversion *within* the bounds [O'Connell and Wei (1996)]. Second, it would appear prima facie unlikely that domestic firms had large enough margins to offset even the very large deviations from trend examined in the subsample of clear mean-reversion episodes.

The second explanation for mean reversion focuses on factors other than arbitrage, potential or actual. Specifically, mean reversion may be brought about either by financial speculation forcing an abandonment of a misalligned (primarily overvalued) pegged rate (implying an immediate associated mean reversion of the real rate) or by deliberate uni- or multi-lateral policy measures designed to keep the real exchange rate within some bounds. Indirect support for these explanations is provided by our sample of pronounced mean reversion episodes: thirty-five of the forty-two episodes occurred during three periods of exchange rate system instability, the collapse of the Bretton Woods system of 1971-73, the dollar overvaluation in 85-86 and the ERM crisis of 1992.

As discussed above, these alternative explanations of mean reversion are of course linked to the arbitrage view since real exchange rate targets and speculative attacks are partly based on beliefs about the trade consequences of misalignments. Thus, though we find little evidence of arbitrage induced mean reversal per se, our results are consistent with mean reversal caused by speculation or policy action motivated by the *expectation* of adverse trade consequences.

The rest of the paper is organized as follows. Following a brief description of the data, we present the core results in the third section. The results are in turn presented in five steps. We begin by presenting unconditional correlations to draw out some of the sturdy stylized facts. We then turn to simple and augmented mean reversion regressions to more formally examine the link between trade flows and the real exchange rate. In the next step, we restrict the sample to episodes of significant mean reversion — sustained depreciations starting from overvalued levels and sustained appreciations starting from undervalued levels. We then explore whether cross-sectional differences in the speed of mean reversion can be related to factors that arguably influence the feasibility of arbitrage before concluding by summarizing the results of a range of robustness tests.

2 Data

The empirical work is based on monthly time series for bilateral exports, exchange rates and prices for Canada, France, Germany, Italy, Japan, the United-Kingdom and the United States. All data are taken from the IMF International Financial Statistics and the IMF Direction of Trade databases. The sample comprises 42 bilateral relationships. To compute real exports from country A to country B, the nominal imports of country B from country A (again measured in US$) were converted into the local currency of the exporting country and deflated by the export price index of the exporting country.[5] Real imports are based on the import deflators. Thus while the same nominal magnitudes (in US$) underlie both the export and the import data, real exports from A to B numerically differ from real imports of B from A because of the different deflators. The two series of course nevertheless measure the same concept and would be identical if bilateral trade deflators were available. In the regressions reported below, we thus report one result for each of the twenty-one independent country pair series.

The real exchange rate used in the main part of the paper is based on the CPI, defined such that an increase denotes a depreciation of the home currency. All series are transformed into deviations from trend, computed as the residual of a regression of the log real exchange rate and log trade flows on a constant and on a time trend. Below, the terms "real exchange rate" and "exports" refer, if not otherwise noted, exclusively to these *deviations from trend* rather than to the actual values. As a robustness check, we have recomputed all results for a PPI based series — also constructed based on IFS data — for quarterly rather than monthly data, and for the residual of a quadratic trend. The results from these alternative specifications — which turn out to be very similar to the results for the monthly CPI based series — are summarized briefly at the end of the empirical section.

3 Results

The arbitrage explanation of mean reversion suggests a —possibly nonlinear— link between exports and imports and exchange rate movements. We search in three steps for such a link

[5]The use of bilateral import data from x to y to measure bilateral exports from y to x, in preference to the (also available) export data from y to x was based on the widely held perception of lower measurement errors for imports compared to exports.

in our dataset. We begin with simple scatterplots and unconditional correlations. We then turn to mean reversion regressions, first replicating the baseline specification to confirm that the real exchange rate data indeed exhibit mean reversion - which they do - before augmenting the specification to allow for trade flows to influence both the presence and the speed of mean reversion. In the final section, we separately consider, for each of the forty-two country pairs, the eighteen months period of the largest depreciation starting from a highly overvalued level.

3.1 Correlations

The simple correlation pattern of real exchange rates and trade flows, plotted in figure 1a for all monthly observations for all country pairs, provides a natural starting point for the exploration. The plot is indeed a scatter, suggesting no systematic contemporaneous link, the numerical correlation coefficient, at 0.0212**, is very close to (though significantly different from) zero.[6]

In the presence of threshold effects, a correlation would only be expected for the (relatively scarce) large exchange rate deviations which might be difficult to detect in the full dataset. To examine this possibility, we sort the data by the exchange rate deviation and compute the correlation by decile. If threshold effects are important, we should see a larger correlation for the deciles with the largest positive and the (in absolute terms) largest negative deviations compared to the middle decile.

Table 1 reports the results. On the export side, the intra-decile correlations are sharply higher for the largest positive and the largest (in absolute terms) negative real exchange rate deviations, and indeed, the correlation are only significant for these two deciles. However, in absolute size, the correlations remain quite small, below 0.15. On the import side, the two extreme deciles again exhibit the largest (absolute) correlations, and are both highly significant, however, for the decile of the largest depreciations, the correlation is positive rather than negative.

We next examine the weaker hypothesis that the *change* in the deviation of exports from trend (if not its level) is significantly correlated with the deviation of the exchange

[6] The correlation between import and real exchange rate deviations equals 0.0195***. Throughout the paper, *,** and *** denote correlation coefficients/parameter estimates significantly differing *from zero* at the 10, 5 and 1 percent level.

rate from trend. Figure 1b plots the two series. If a highly undervalued real exchange rate (as indicated by a positive deviation) triggers an increase in arbitrage boosting exports (from whatever level relative to trend they happen to occupy) we should expect to see a positive correlation pattern. No such pattern emerges, indeed, the correlation coefficient, at -0.007, is of the wrong sign although very close to (and insignificant from) zero.

One possible explanation for this absence of a significant *contemporaneous* link between the real exchange rate deviation from trend and either the deviation or the change in the deviation of exports from trend is a lagged response of arbitrage to price deviations, reflecting prior contract commitments, shipment delays etc that may prevent the link from appearing in our monthly data. Figures 1c and 1d shed some light on this possibility, plotting the real exchange rate deviation at time t against the *sum* of the *change* in the deviation of exports over the subsequent three months and the subsequent twelve months period. The figures again do not suggest a clear-cut link, and indeed the correlations between the exchange rate and the cumulative change in exports are significantly *negative*, though small, at -0.016** for the three month change and -0.058*** for the twelve month cumulative change.

In sum, our initial rough exploration of the dataset does not lend much credence to arbitrage based explanations of real exchange rate reversals. We fail to find a significant link between exchange rates and trade quantities: the deviation of the exchange rate from trend is largely uncorrelated with (i) the deviation of exports from trend (ii) the contemporaneous change in the deviation of exports from trend and (iii) the cumulative change in the deviation of exports from trend over the subsequent quarter and year.[7] The only suggestion of a more sizeable correlation occurs within the subset of the most undervalued real exchange rate observations, even here, the correlation increases to a quite small 0.15.[8]

Ocular inspection of course has its limits. We thus next turn to a more formal econometric examination of arbitrage effects in the context of mean reversion regressions.

[7]Though our econometric approach differs somewhat, the findings of course link both to the very large literature on the price elasticity of exports and imports.

[8]The findings are not specific to the CPI based real exchange rate, the correlations are similarly low for the monthly PPI based measure and for the quarterly CPI based measure.

3.2 Mean Reversion Regressions

If we denote the deviation from trend of the real exchange rate for the country pair (i, j) at time t by RER_t^{ij}, the standard mean reversion regression is given by:

$$\Delta RER_t^{ij} = \alpha_0 RER_{t-1}^{ij} + \epsilon_t^{ij} \qquad (1)$$

where Δ denotes the first difference operator, i and j denote the home and foreign country, α_0 is the mean reversion parameter and ϵ is assumed to be $N(0, \sigma^2)$.[9] Under mean reversion, $\alpha_0 < 0$. Figure 2 plots ΔRER_t^{ij} against RER_{t-1}^{ij} for the entire sample, suggesting the negative -if muted- correlation indicative of mean reversion. Table 2 report the coefficients, t-statistics and implied half-lives obtained by estimating equation 1 for the individual country pairs and for the panel, using the entire sample.[10]

The results are uniformly supportive of mean reversion and lie well within the range of previous findings, suggesting that the behavior of real exchange rates in the present sample matches those of previous studies. The implied half-lives differ quite significantly, ranging from a low of a few months between France, Germany and the United Kingdom — at the low end of previous non-threshold estimates — to a high of ten years for Canada-US and fifteen years for Canada-Japan. In terms of the arbitrage view the very long estimated half-life for the United States versus Canada perhaps deserves particular attention as these two economies are generally viewed as highly integrated.[11]

Under the hypothesis that arbitrage is the main factor leading to mean reversion in relative prices *and* that the deviation of trade flows from trend to an important extent reflects the deviation of the real exchange rate from trend, a close analogue to 1 is given by:

$$\Delta RER_t^{ij} = \beta_1 EX_{t-1}^{ij} + \beta_2 IM_{t-1}^{ij} + \epsilon_t^{ij} \qquad (2)$$

where EX^{ij} and IM^{ij} denote the deviation from trend of real bilateral exports and real bilateral imports. Under the null, a positive deviation of exports from trend indicates an

[9]As the real exchange rate is detrended, no constant term is required.

[10]All panel results incorporate the O'Connell (1997) adjustment, with six lags.

[11]Obstfeld and Taylor (1997) similarly find Canada to be something of an outlier in their AR , though less so in their threshold regressions.

undervalued real exchange rate forced back to trend by the export boom, yielding a negative β_1 coefficient. Analogously, imports above trend suggest an overvalued real exchange rate depreciating back to trend as a result of the import boom, yielding a positive β_2 coefficient. The results are reported in the left half of Table 3 and are uniformly much weaker compared to the standard regression. Indeed, there is not a single instance of a significant negative β_1 and a significant positive β_2 coefficient. Only for one country pair, United Kingdom-Italy, are both trade coefficients significant, however, the signs are the opposite of what arbitrage would suggest. In short, the regression results confirm our finding in the previous section: deviations of trade from trend do not systematically co-vary with the deviations of real exchange rates from trend.

A weaker hypothesis is that at least the *cumulative changes* in the trade deviations over longer periods reflect the working of arbitrage, pressuring relative prices to return to trend, suggesting the following regression:

$$\Delta RER_t^{ij} = \beta_1 \sum_{k=1}^{q} \Delta EX_{t-k}^{ij} + \beta_2 \sum_{k=1}^{q} \Delta IM_{t-k}^{ij} + \epsilon_t^{ij} \tag{3}$$

Under this interpretation, exports accelerating relative to trend indicate an undervalued real exchange rate. If arbitrage is a significant factor, we expect the exchange rate to be driven back to trend, yielding a negative β_1 coefficient. In like vain, accelerating imports (relative to trend) suggest an overvalued exchange rate. In the presence of arbitrage pressures, the real exchange rate should depreciate back to trend, yielding a positive β_2 coefficient. The second set of coefficients in Table 3 report the results for the twelve month cumulative change (i.e. q=12). The fit is again quite poor, only half the coefficients are signed in accordance with the priors, only six coefficients are significant (of which, again, only half are signed "correctly").[12]

The results presented so far do not lend much credence to the view that arbitrage induced trade flows are the main *origin* of mean reversals in relative prices: neither the deviation of trade from trend nor the change in the deviation of trade from trend seems to explain the presence of mean reversion very well. Possibly, however, trade flows at least *accelerate* mean reversal, even if other factors are the *cause* for the initial reversal. We

[12] For an alternative three month lag, results are even less in accordance with the null, with only a quarter of coefficients signed in accordance to priors.

examine this possibility by directly introducing the deviation of trade flows into the familiar mean reversion regression to examine whether the *speed* of mean reversion, *conditional* on controlling for the *level* of the real exchange rate deviation, depends upon whether the trade flow deviation from trend has changed in the previous few months. Specifically, we estimate:

$$\Delta RER_t^{ij} = [\alpha_1 + \beta_1 \sum_{i=1}^{k} \Delta EX_{t-i}^{ij} + \beta_2 \sum_{i=1}^{k} \Delta IM_{t-i}^{ij}] RER_{t-1}^{ij} + \epsilon_{ij,t} \tag{4}$$

Under the strict arbitrage view, the mean reversion occurs solely because the deviation of the real exchange rate from trend causes trade flows that trigger the adjustment of relative prices, we would hence expect $\alpha_1 = 0$, $\beta_1 < 0$ and $\beta_2 > 0$. A failure to find significant coefficients on the β coefficients can be interpreted as evidence against the arbitrage view, while a significant coefficient on α, independent of the coefficients on the trade variables, would suggest the presence of other factors beyond arbitrage driving relative prices back towards trend. A finding of a significant negative α_1 coupled with negative β_1 and positive β_2 occupies the middle ground, allowing a role for the level of the exchange rate deviation to trigger mean reversion through some non-trade mechanism (such as policy changes or speculative attacks) and permitting trade responses to influence the speed of mean reversion.

The results, for lag length 3 and 12 months, are reported in Table 4. The estimated α_1 coefficient is consistently negative and is significant in about half of the cases. In contrast, only seven of the forty-two interactive coefficients are significant at the three months lag, of those, only three are of the predicted sign and no case shows the expected predicted pattern of $\beta_1 < 0$ and $\beta_2 > 0$. Exactly the same picture merges when using the twelve month lag. Ten of the forty-two coefficients are significant, of which again only four have the predicted sign. The panel estimates are generally significant, however, in each case one of the coefficients has an incorrect sign. There is thus little compelling evidence that the presence of large cumulative deviations of trade from trend exert an influence on the speed of mean reversal of relative prices.

3.3 Extreme Cases

The results presented yield scant support for a significant role of arbitrage in either causing or accelerating mean reversion. While telling by themselves, our findings leave open the possibility that arbitrage plays a subsidiary role difficult to detect in noisy data. As a final test, we therefore restrict the sample to episodes of unambiguous mean reversion. For each bilateral real exchange rate, we identify the episode of the largest eighteen month depreciation, starting from at least a ten percent overvalued level. Table 5 lists the starting dates of these episodes.

Under the arbitrage view, we would expect the mean-reverting depreciation episodes starting from an overvalued level to be accompanied by — or at least preceded by — rising imports and declining exports: during the episodes the exchange rate approaches trend but remains overvalued, hence trade flows should continue to move away from trend, albeit at a decreasing *rate*. We should thus see the deviation of exports from trend to widen, and hence should observe negative changes in the deviation, and vice versa for the appreciation periods. Figures 3a and 3b plot the changes in the export deviation from six months prior to the mean reversion to eighteen months thereafter for depreciation and appreciation episodes. The figures leave little room for interpretation: even in these unambiguous episodes of mean reversion, the export deviation is not suggestive of large arbitrage activity taking place.

If not trade, what else caused these episodes of mean reversion? A closer look at the timing of the forty-two country cases is instructive: all but seven fall into three periods: the breakdown of the Bretton Woods system and the first oil shock, the Plaza accord marking the end of the extreme dollar overvaluation, and the ERM crisis. It might thus be supposed that large *real* exchange rate reversals are primarily caused by nominal exchange rate swings. That, somewhat curiously, is however not the case: a decomposition reveals that eighty percent of the real exchange rate change over the eighteen month period is attributable to changes in the relative local currency price rather than to changes in the nominal exchange rate.[13]

3.4 The Speed Of Mean Reversion

Our results leave little doubt that a simple arbitrage explanation — accelerating trade flows leading firms to adjust prices — does not provide a satisfactory explanatory of mean reversion. As discussed above, this is not to say that arbitrage does not matter at all, in particular, the mean reversion may be caused by policy actions and/or financial flows

[13] Wei and Parsley (1996), using a different methodology, report a similar result.

and/or firm pricing decisions which themselves are partly driven by the *expected* emergence of arbitrage if the current real exchange rate trend were to persist. If so, we would expect to find that the speed of mean reversion — in cross section — depends on the relative ease of arbitrage. To explore this issue further, figures 4a and 4b plot the mean reversion coefficients against two measures of potential and actual goods market integration, distance (between the respective national capitals) and trade shares.[14] To obtain the latter, we first divided bilateral trade (and likewise the sum of bilateral GDP) by the sum of all trade flows (the sum of all GDPs), rescaling the two series to add to unity. We then construct the trade share as the ratio of the bilateral trade share to the bilateral GDP share.

Figure 4a reveals a clear negative relation between the speed of mean reversal and bilateral distance. As both transportation and information costs are likely to increase with distance, the finding is consistent with a trade view of mean reversion. The Canada-United States pair is seen to be an outlier, with much slower mean reversion compared to both similarly distant countries and countries with similar trade share. As Canada and the US are widely viewed as being among the most integrated trading partners (which is confirmed by their high trade share), this finding presents a significant puzzle for any arbitrage based explanation of mean reversion. Abstracting from the outliers, Figure 4a reveals three clusters. Real exchange rate deviations between France, Germany and the United Kingdom — located close to each other and trading primarily with each other — are rapidly undone. The second cluster consists of Italy vis a vis these three countries, while the third cluster is dominated by inter-continental country pairs. The pattern clearly suggests that relative location plays a significant role in determining the persistence of real exchange rate "misalignments", confirming prior results by Parsley and Wei (1996), Obstfeld and Taylor (1996) and Engle et al. (1997).

One of the channels through which distance might influence the speed of mean reversion is trade, based on the well known gravity relation. Figure 4b examines this possibility and indeed a similar, though considerably more noisy — pattern of clusters emerges, with France, Germany and the United Kingdom combining high trade weights with fast mean reversion. Italy, at least vis a vis France and Germany, provides the second cluster, combining similar trade weights with slower mean reversion. The third cluster — again abstracting

[14]The data were taken from, or constructed based upon, Shang-Jin Wei's NBER web-page, www.nber.org wei.

from the Canada-US outlier, is provided by the inter-continental pairs with relatively low trade weights and persistent real exchange rate deviations. It is noteworthy, though, that the simple correlation between distance and the speed reversion is more pronounced than the correlation between trade and mean reversion, suggesting that distance exerts additional influences through other channels. Exchange rate policy is an obvious candidate here, it is noticeable that the cluster of countries displaying fast mean reversion — with the partial exception of the United Kingdom — have been linked within a formal exchange rate system for most of the sample period.

We explore the cross-sectional differences in mean reversion more formally by regressing the estimated mean-reversion coefficients of the standard regression (Table 2) on the log of the bilateral distance (between the capitals), the output share and the trade share, obtaining:

$$\underset{}{\text{Mean-Rev.Coef}} = \underset{(6.09)}{-0.735} \; \underset{(5.77)}{+0.082}\ \text{Distance} \; \underset{(2.04)}{-0.809}\ \text{GDP} \; \underset{(2.79)}{+0.043}\ \text{Trade}$$

with an R^2 of 0.76 (t-statistics in brackets). The finding is surprising: controlling for distance and for relative market size, a greater bilateral trade share will lead to slower mean reversion. Greater proximity accelerates mean reversion, as does market size. The latter finding is consistent both with an arbitrage view — in the presence of fixed arbitrage cost, arbitrage will commence at a smaller price deviation the larger the market — and with the alternative views — significant real exchange rate "misalignments" between large countries are arguably more likely to induce policy responses and/or speculative attacks. A glance back at the data reveals a major reason for the curious positive coefficient of trade: given the close connection between trade and distance, the trade variable picks out the Canada-United States outlier, which remains as a major challenge to the arbitrage view.

3.5 Robustness Tests

To examine whether our results depend upon the particular price series, frequency and detrending method we replicated results for four alternative specifications. First, using a PPI rather than a CPI based real exchange rate. Second, using quarterly rather than monthly data. Third, using the residual of a quadratic trend rather than the residual of an AR(1) as our measure of the deviation. Fourth, restricting the sample to the post-1973 period. The results of the robustness tests casts little doubt on the findings reported below. We find strong evidence for mean reversion for the alternative specifications, furthermore, the European trio of France, Germany and the United Kingdom exhibit the smallest half-lives. Turning to the trade-real exchange rate nexus, the key finding of no significant link is confirmed: replicating the regressions reported in Tables 3 and 4, we typically find one, and never more than three out of the twenty-one coefficients, to have a significantly different sign from the CPI specification. These differences are within the range of what should be expected given our confidence levels. This "robustness" of results confirms the basic message depicted in the previous sections: the real exchange rate, however measured, reverts to trend, however, the mean reversion is not linked directly to trade flows.

4 Conclusion

The consensus in the empirical literature has swung back to the view that real exchange rates are stationary over longer periods, more specifically, that deviations of the real exchange from trend are undone over time, possibly in a non-linear fashion with fast(er) reversion occurring once the real exchange rate deviation from trend exceeds some threshold. The presence of mean reversion has been attributed to goods market arbitrage pressures constraining relative price divergences.

The starting point of our paper has been the simple observation that arbitrage is a sufficient but not a necessary condition for mean reversion in relative prices. Alternative explanations are readily available: on the pro-active side, governments may have implicit or explicit exchange rate band targets, on the passive side, the collapse of overvalued pegged rate regimes may lead to a sudden return of the nominal and, in the presence of sticky prices, real exchange rates to sustainable levels. A look at cases of evident mean reversals in our sample —- large depreciations starting from overvalued levels — proved instructive in this respect: the collapse of the Bretton Woods system, the unraveling of the dollar bubble in the wake of the Plaza agreement and the ERM crisis of 1992 accounted for the vast majority of clear-cut cases of mean reversion.

This strong association between nominal exchange rate regime crisis and episodes of sharp mean reversal (episodes which arguably play a not inconsiderable econometric role in the literature on mean reversion, in particular mean reversion with threshold effects) is quite instructive in itself, but of course does not rule out a case for arbitrage induced trade flows in either triggering these crisis or in accelerating mean reversion once under way. To examine the role of trade flows in undoing real exchange rate misalignments, we explored data on bilateral real exchange rates and trade among the G7 economies. Despite allowing for substantial latitude in terms of specification and data, we failed to unearth much support for the presence of a sturdy *direct* link. The deviation of the real exchange rate from trend is not significantly correlated either with the deviation of trade from trend, or even the *change* in the deviation, suggesting that misalignments do not trigger arbitrage motivated sudden changes in trade flows. Furthermore, neither the deviation of trade flows from trend nor the change in the deviation appears to be association with either the presence or the speed of mean reversion. The absence of a clear link between exchange and trade deviations — in either direction — holds both for the entire sample, and perhaps more telling, even for the set of clear mean reversion episodes. As the starting points for the latter are close to the extreme points for the entire sample, "threshold" effects cannot be adduced to explain these results.

In short, and quite unambiguously, we do not find convincing (or even suggestive) evidence in favor of arbitrage either *directly* causing or at least accelerating mean reversion, casting some doubt on the mechanisms implicitly assumed in some of the recent work. The results are open to three interpretations. First, we might have failed to detect a link that is, in fact, present. While we have undertaken a deliberately unconstrained search for the link — in terms of both specification and data — it is, of course, not possible to rule out this possibility. Second, arbitrage may — anecdotes notwithstanding — in fact not be of sufficient quantitative importance to trigger mean reversion. Third, somewhat perversely, we may not find the arbitrage-mean reversion link precisely because it is important, or at least considered to be important by financial markets and governments. As trade considerations arguably motivate government exchange rate policy, as asset market expectations on appropriate exchange rates are at least partly based on expected future trade flows, and as firms base their pricing decisions at least partly on the behavior of foreign competitors, the *expectation* of arbitrage (or, more neutrally, of significant trade responses to misalligned rates) may trigger policy adjustments, speculative flows or firm pricing adjustments which prevent the expected arbitrage from actually occurring.

Our finding that the *speed* of mean reversion tends to be faster between countries located close to each other, between countries with sizeable bilateral trade (with the notable exception of Canada and the United States) and between large countries — factors arguably facilitating arbitrage — lends some credence to this view.

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Table 1: **Correlations By Decile**

	1	2	3	4	5	6	7	8	9	10
Exports	0.039 *	0.011	-0.024	-0.008	0.007	0.019	0.025	-0.010	-0.011	0.149 ***
Imports	-0.146 ***	-0.014	-0.035	0.002	0.052 **	-0.008	-0.007	-0.012	-0.004	0.270 ***

The table reports the correlation between the deviation from trend of the bilateral real exchange rate and the deviation from trend of bilateral exports and bilateral imports. The sample period is 1960:01 to 1996:12. The sample is sorted by the real exchange rate deviation (in increasing order). Column 1 reports the correlation for the decile of the smallest (i.e. most negative) real exchange rate deviations, column 10 reports the correlation for the decile of the largest (i.e. most positive) real exchange rate deviations. $*$, $**$, and $***$ indicate significance at the 10, 5 and 1 percent level.

Table 2: **Univariate Mean Reversal Regressions**

Exporter-Importer	*RER* Full Sample	t	Half Life (M)
U.K. -Germany	-0.2113	4.59	3
France-U.K.	-0.2309	6.04	3
France-Germany	-0.1709	4.86	4
France-Italy	-0.0848	6.28	8
Italy-U.S.	-0.0740	4.45	9
Germany-Italy	-0.0709	4.95	9
U.K. -Italy	-0.0609	4.62	11
France-U.S.	-0.0401	4.39	17
U.K. -U.S.	-0.0393	4.52	17
Italy-Japan	-0.0387	5.08	17
Japan-U.S.	-0.0356	3.33	19
Germany-U.S.	-0.0269	3.58	25
France-Japan	-0.0203	5.02	34
Canada-U.K.	-0.0168	5.69	40
U.K. -Japan	-0.0150	4.37	46
Canada-France	-0.0139	5.58	49
Canada-Italy	-0.0107	5.70	64
Canada-Germany	-0.0099	4.87	69
Germany-Japan	-0.0096	3.31	72
Canada-U.S.	-0.0057	4.14	119
Canada-Japan	-0.0036	3.81	189
Panel	-0.0221	9.37	31

Regression: $\Delta RER_t^{ij} = \alpha_0 RER_{t-1}^{ij} + \epsilon_t^{ij}$

where RER_t^{ij} is the monthly real bilateral exchange rate between countries i and j. The three columns report, respectively, the estimate and t-statistic for α_0 and the implied half-life, in months, of a deviation in RER^{ij}. The sample period is 1960:1 to 1996:12. The last row reports the results from a GLS panel regression that includes all 21 bilateral exchange rates. The regressions allow for six-lag serial correlation in ϵ. Critical values for the coefficients at the 10, 5 and 1 percent level are 2.52, 2.83 and 3.18 for the bilateral, and 2.13, 2.62 and 3.19 for the panel specifications (See Dickey and Fuller (1981) and Quah (1994)).

Table 3: **Exchange Rate Mean Reversal And Trade Flows**

Exporter-Importer	EX_t	t	IM_t	t	Cumu. 12 Months ΔEX	t	Cumu. 12 Months ΔIM	t
Can-Fra	0.0091	1.18	-0.0057	0.89	0.0081	1.14	- 0.0083	1.48
Can-Ger	0.0052	1.27	-0.0046	0.83	0.0136	3.20	0.0108	1.89
Can-Ita	0.0006	0.14	-0.0047	0.82	0.0068	1.52	-0.0042	0.63
Can-Jap	-0.0014	0.25	-0.0112	2.01	0.0066	1.59	-0.0168	3.50
Can-UK.	-0.0071	1.30	-0.0014	0.28	0.0042	0.82	-0.0027	0.53
Can-USA	0.0002	0.01	-0.0045	0.41	-0.0351	3.73	0.0345	3.97
Fra-Ger	-0.0059	0.82	0.0100	1.20	-0.0088	1.26	0.0067	0.87
Fra-Ita	0.0009	0.14	-0.0170	1.78	-0.0001	0.02	0.0133	1.41
Fra-Jap	-0.0071	1.33	0.0018	0.33	-0.0042	0.94	0.0004	0.08
Fra-UK.	0.0174	1.83	-0.0155	1.63	0.0051	0.58	0.0012	0.13
Fra-USA	-0.0049	0.41	-0.0026	0.21	0.0000	0.00	0.0044	0.47
Ger-Ita	-0.0096	1.66	0.0034	0.45	0.0018	0.25	-0.0105	1.11
Ger-Jap	-0.0068	0.98	-0.0061	1.08	-0.0108	1.94	-0.0170	2.69
Ger-USA	-0.0008	0.09	-0.0051	0.57	-0.0075	0.96	-0.0029	0.34
Ita-Jap	0.0020	0.49	0.0009	0.26	-0.0019	0.57	-0.0010	0.31
Ita-USA	-0.0126	1.30	-0.0020	0.27	-0.0042	0.55	-0.0043	0.57
Jap-USA	-0.0052	0.60	0.0005	0.04	-0.0006	0.10	-0.0109	1.80
UK.-Ger	-0.0091	1.36	-0.0019	0.28	-0.0001	0.02	-0.0088	0.79
UK.-Ita	0.0191	2.53	-0.0292	3.80	0.0104	1.47	-0.0118	1.14
UK.-Jap	0.0063	1.27	-0.0023	0.41	0.0052	1.23	-0.0089	1.73
UK.-USA	0.0061	0.64	0.0016	0.45	0.0004	0.06	0.0010	0.21
Panel	0.0041	2.59	0.0038	2.29	0.0027	1.79	-0.0032	1.92

Regression 1 (first four columns): $\Delta RER_t^{ij} = \beta_1 EX_{t-1}^{ij} + \beta_2 IM_{t-1}^{ij} + \epsilon_t^{ij}$

Regression 2 (last four columns): $\Delta RER_t^{ij} = \beta_1 \sum_{k=1}^{q} \Delta EX_{t-k}^{ij} + \beta_2 \sum_{k=1}^{q} \Delta IM_{t-k}^{ij} + \epsilon_t^{ij}$

where RER_t^{ij} is the monthly real bilateral exchange rate between countries i and j and EX_{t-1}^{ij} (IM_{t-1}^{ij}) are real exports (imports) of country i to (from) country j. The sample period is 1960:1 to 1996:12. The last row reports the results from a GLS panel regression that includes all 21 bilateral exchange rates. The regressions allow for six-lag serial correlation in ϵ. Critical values for the coefficients at the 10, 5 and 1 percent level are 2.52, 2.83 and 3.18 for the bilateral, and 2.13, 2.62 and 3.19 for the panel specifications (See Dickey and Fuller (1981) and Quah (1994)). Abbreviations: Can: Canada, Fra: France, Ger: Germany, Ita:Italy, Jap: Japan.

Table 4: **Trade Flows And The Speed Of Mean Reversion**

	α_1	t	β_1	t	β_2	t	α_1	t	β_1	t	β_2	t
	3 Months						12 Months					
Can-Fra	-0.0134	1.64	-0.0154	0.34	-0.0264	0.65	-0.0132	1.54	-0.0078	0.17	0.0160	0.43
Can-Ger	-0.0095	1.40	0.0318	1.13	-0.0323	1.06	-0.0109	1.51	0.0516	2.11	-0.0119	0.36
Can-Ita	-0.0104	1.45	0.0314	1.51	-0.0090	0.24	-0.0118	1.55	0.0328	1.37	-0.0274	0.83
Can-Jap	-0.0038	0.83	-0.0152	0.63	-0.0023	0.10	-0.0023	0.48	0.0225	0.92	-0.0288	1.42
Can-UK.	-0.0158	1.76	0.0539	1.41	0.0110	0.27	-0.0142	1.51	0.0368	0.88	0.0306	0.84
Can-US.	-0.0059	1.25	0.0239	0.39	-0.0237	0.49	-0.0064	1.31	-0.1400	2.71	0.0675	1.59
Fra-Ger	-0.1680	6.14	-0.1290	0.77	-0.4800	2.43	-0.1870	6.47	0.2470	1.42	-0.5990	3.22
Fra-Ita	-0.0803	4.02	0.0602	0.70	0.1979	1.53	-0.0876	4.24	0.0896	0.82	-0.0388	0.30
Fra-Jap	-0.0197	1.90	0.0559	1.37	-0.1000	2.10	-0.0207	1.96	0.0228	0.78	-0.0856	1.59
Fra-UK.	-0.2370	7.38	0.0735	0.35	0.2120	0.98	-0.2320	7.07	0.1060	0.53	0.0951	0.54
Fra-US.	-0.0382	2.35	0.1170	1.09	-0.1410	1.64	-0.0485	2.93	0.2260	2.48	-0.0040	0.04
Ger-Ita	-0.0652	3.51	0.1650	1.90	0.1460	1.18	-0.0658	3.41	0.0402	0.35	0.1890	1.19
Ger-Jap	-0.0093	1.25	0.0233	0.39	-0.0024	0.04	-0.0116	1.47	-0.0225	0.42	0.1270	2.39
Ger-US.	-0.0276	2.04	0.0582	0.71	0.0017	0.01	-0.0308	2.13	0.0827	1.16	-0.1100	1.00
Ita-Jap	-0.0363	2.77	-0.1950	3.41	-0.0274	0.68	-0.0411	3.00	-0.1120	1.96	0.0211	0.46
Ita-US.	-0.0691	3.15	0.1270	1.14	0.0290	0.30	-0.0699	3.12	0.1530	1.72	-0.0833	0.75
Jap-US.	-0.0356	2.43	0.0071	0.06	0.0280	0.25	-0.0368	2.52	0.0436	0.47	0.0636	0.82
UK.-Ger	-0.2110	6.88	0.0577	0.35	0.4260	2.20	-0.2000	6.15	-0.0997	0.49	-0.1620	0.63
UK.-Ita	-0.0587	3.28	-0.0467	0.40	0.1560	1.29	-0.0601	3.34	-0.0939	0.85	0.0510	0.32
UK.-Jap	-0.0148	1.61	-0.0626	1.84	0.0420	0.93	-0.0139	1.48	-0.0224	0.64	0.0577	1.07
UK.-US.	-0.0401	2.55	0.0802	1.17	-0.0135	0.42	-0.0465	2.88	0.1070	1.60	-0.0398	1.05
Panel	-0.0192	1.75	0.0296	2.41	0.0189	7.52	0.0234	2.33	-0.0117	1.03	-0.0214	9.11

Regression 1: $\Delta RER_t^{ij} = [\alpha_1 + \beta_1 \sum_{i=1}^{3} \Delta EX_{t-i}^{ij} + \beta_2 \sum_{i=1}^{3} \Delta IM_{t-i}^{ij}] RER_{t-1}^{ij} + \epsilon_{ij,t}$

Regression 2: $\Delta RER_t^{ij} = [\alpha_1 + \beta_1 \sum_{i=1}^{12} \Delta EX_{t-i}^{ij} + \beta_2 \sum_{i=1}^{12} \Delta IM_{t-i}^{ij}] RER_{t-1}^{ij} + \epsilon_{ij,t}$

where RER_t^{ij} is the monthly real bilateral exchange rate between countries i and j and EX_{t-1}^{ij} (IM_{t-1}^{ij}) are real exports (imports) of country i to (from) country j. The sample period is 1960:1 to 1996:12. The last row reports the results from a GLS panel regression that includes all 21 bilateral exchange rates. The regressions allow for six-lag serial correlation in ϵ. Critical values for the coefficients at the 10, 5 and 1 percent level are 2.52, 2.83 and 3.18 for the bilateral, and 2.13, 2.62 and 3.19 for the panel specifications (See Dickey and Fuller (1981) and Quah (1994)). Abbreviations: Can: Canada, Fra: France, Ger: Germany, Ita:Italy, Jap: Japan.

Table 5: **Start Of Largest Epsiode Of Home Depreciation**

Starting date (month/year) of the largest currency depreciation of the exporting country over an 18 month period, starting from an initial value of the real exchange rate at least ten percent appreciated relative to trend.

Exporter	Importer	Month	Year
Bretton Woods Collapse/Oil Shock			
Germany	France	January	1972
Italy	France	February	1972
France	Canada	August	1972
Germany	Canada	August	1972
Japan	United States	September	1972
United Kingdom	Canada	December	1972
Italy	Canada	May	1973
Japan	Canada	May	1973
Italy	United Kingdom	July	1973
United Kingdom	Germany	August	1973
Japan	Germany	August	1973
Italy	Germany	September	1973
United States	Germany	October	1973
United States	Canada	October	1973
France	United Kingdom	February	1974
France	Germany	February	1974
France	Italy	July	1974
Plaza Agreement			
Italy	United States	March	1985
United Kingdom	United States	April	1985
France	United States	April	1985
Germany	United States	April	1985
United Kingdom	Italy	July	1985
United Kingdom	Japan	July	1985
Germany	Japan	October	1985
Italy	Japan	October	1985
France	Japan	November	1985
Canada	Japan	January	1986
United States	Japan	March	1986
ERM Crisis			
United States	France	August	1992
Japan	France	August	1992
Japan	Italy	September	1992
Germany	United Kingdom	September	1992
Japan	United Kingdom	September	1992
United States	United Kingdom	September	1992
United States	Italy	Sepptember	1992
Other			
Germany	Italy	November	1967
Canada	Italy	April	1975
Canada	Germany	August	1980
Canada	France	September	1980
Canada	United Kingdom	February	1981
Canada	United States	August	1982
United Kingdom	France	April	1990

Figure 1a: Exchange Rates and Exports

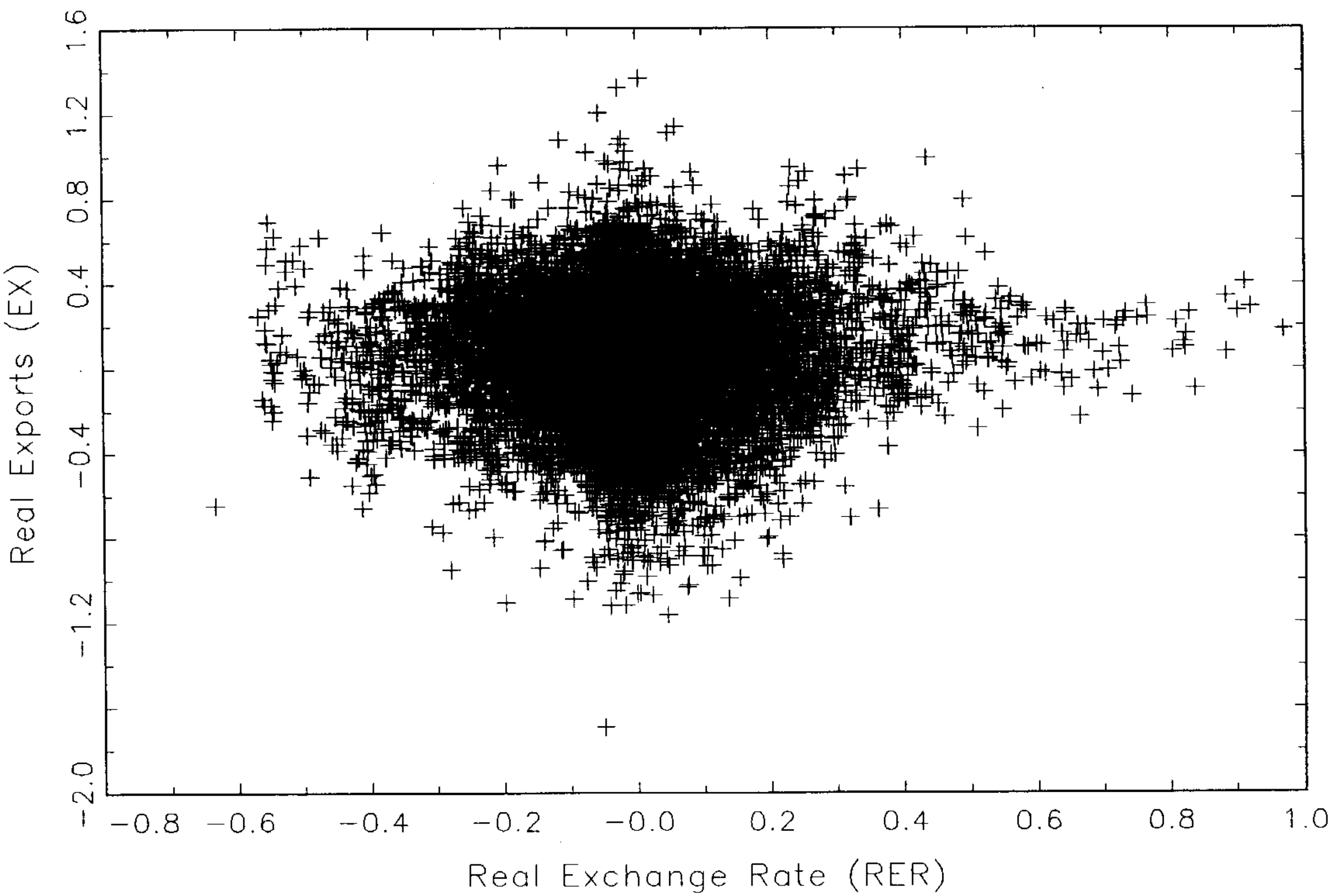


Figure 1b: Changes in Exports (1 month)

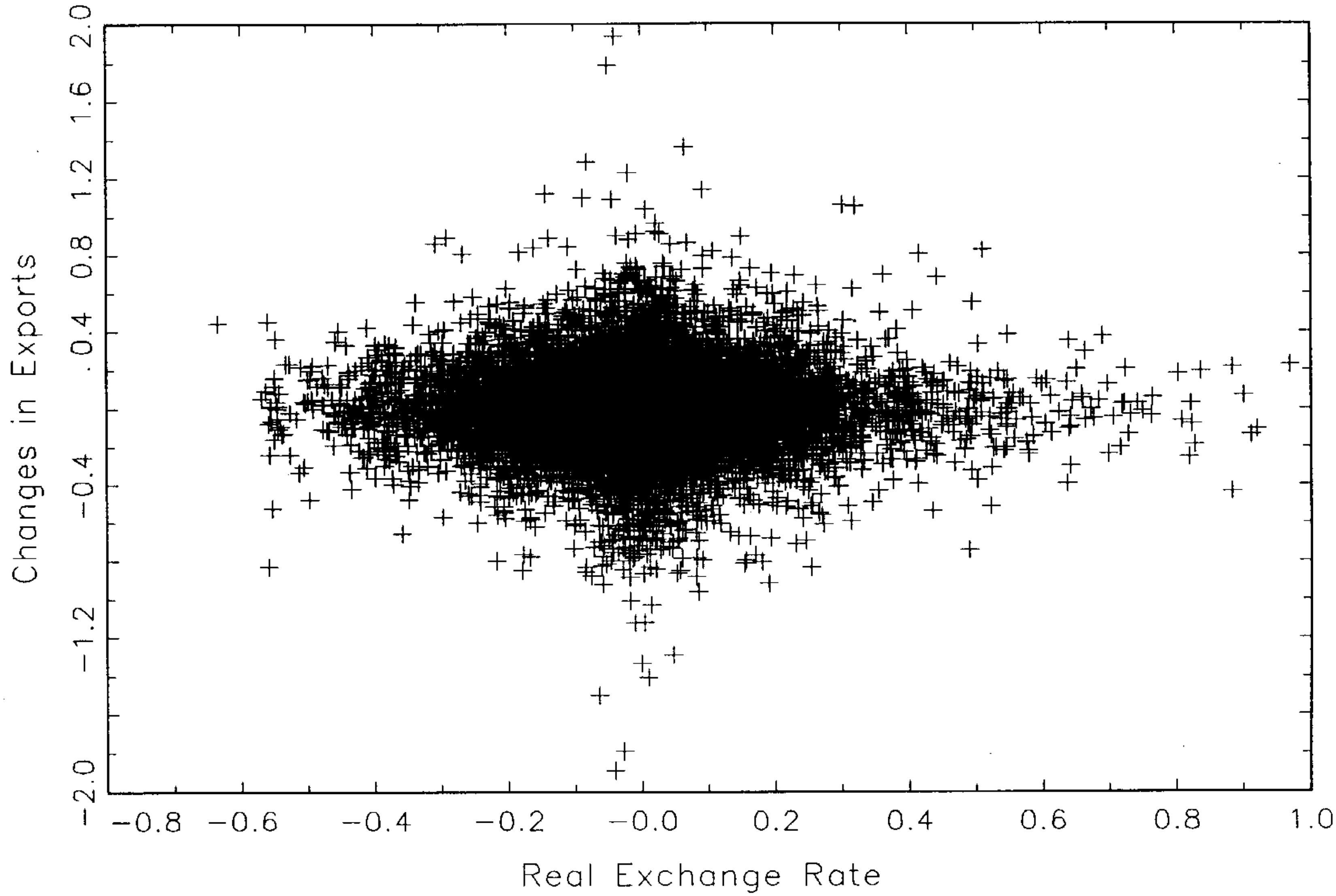


Figure 1c: Changes in Exports (Cumulative 3 months)

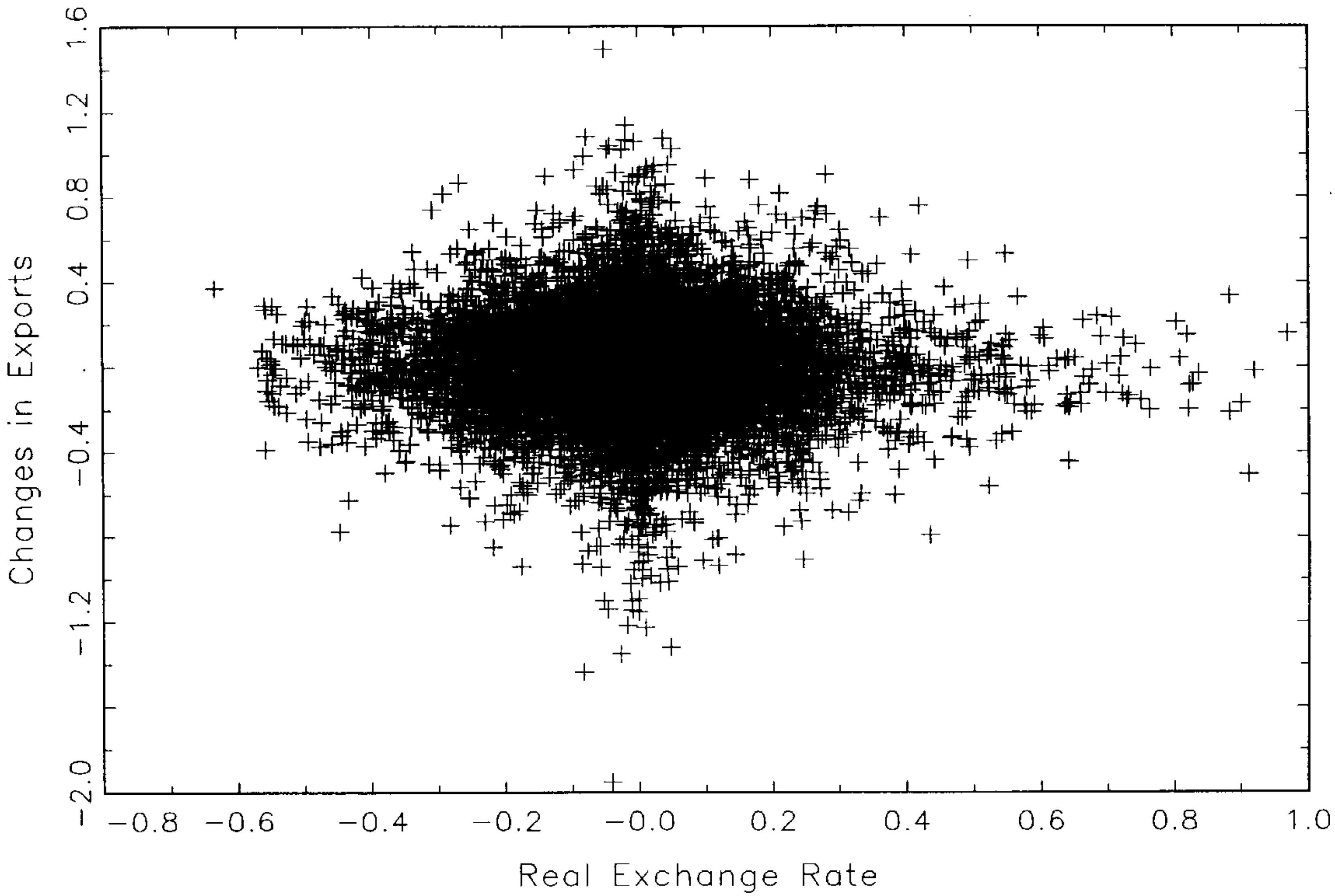


Figure 1d: Changes in Exports (Cumulative 12 months)

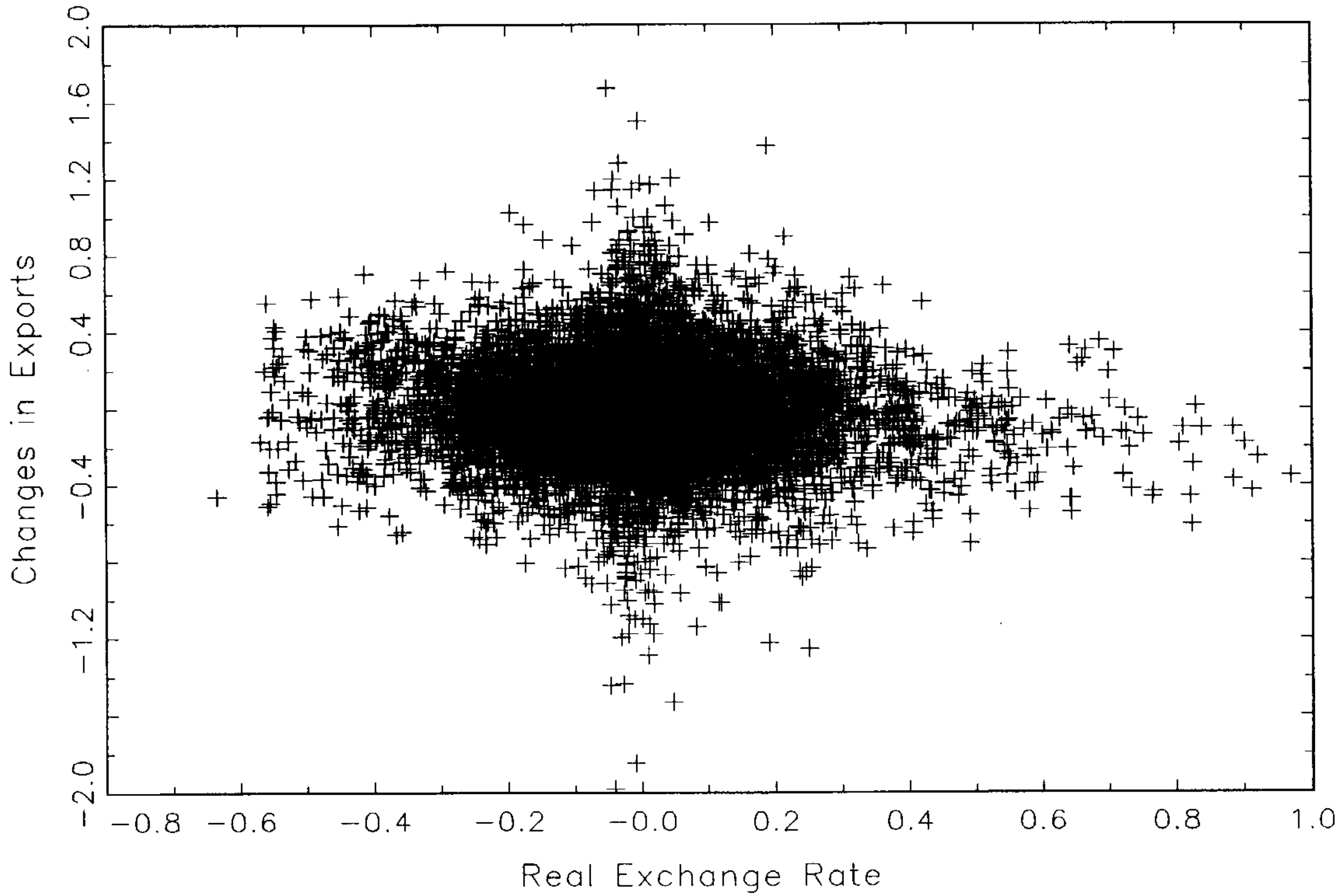


Figure 2: Exchange Rate – Level vs. Differences

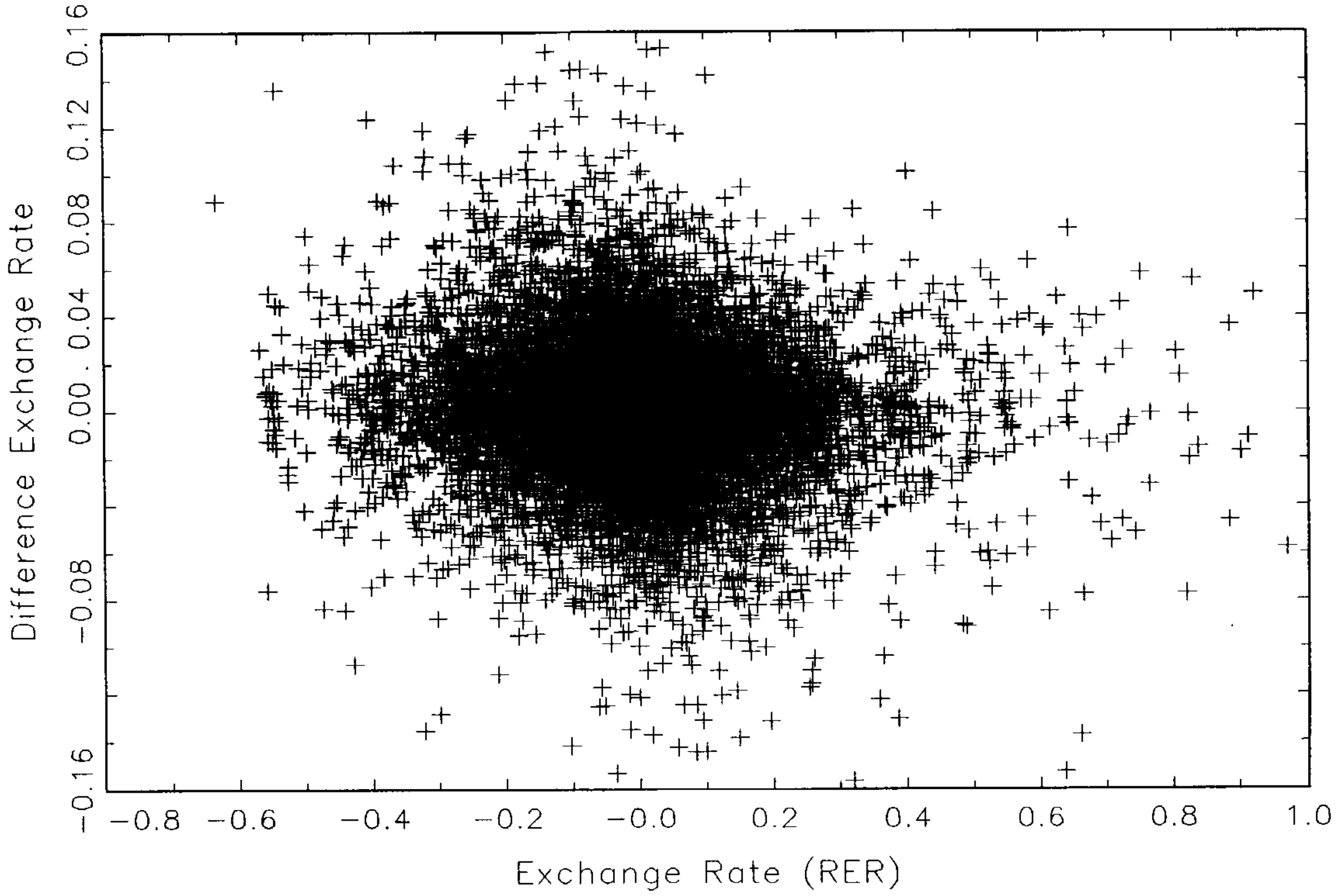
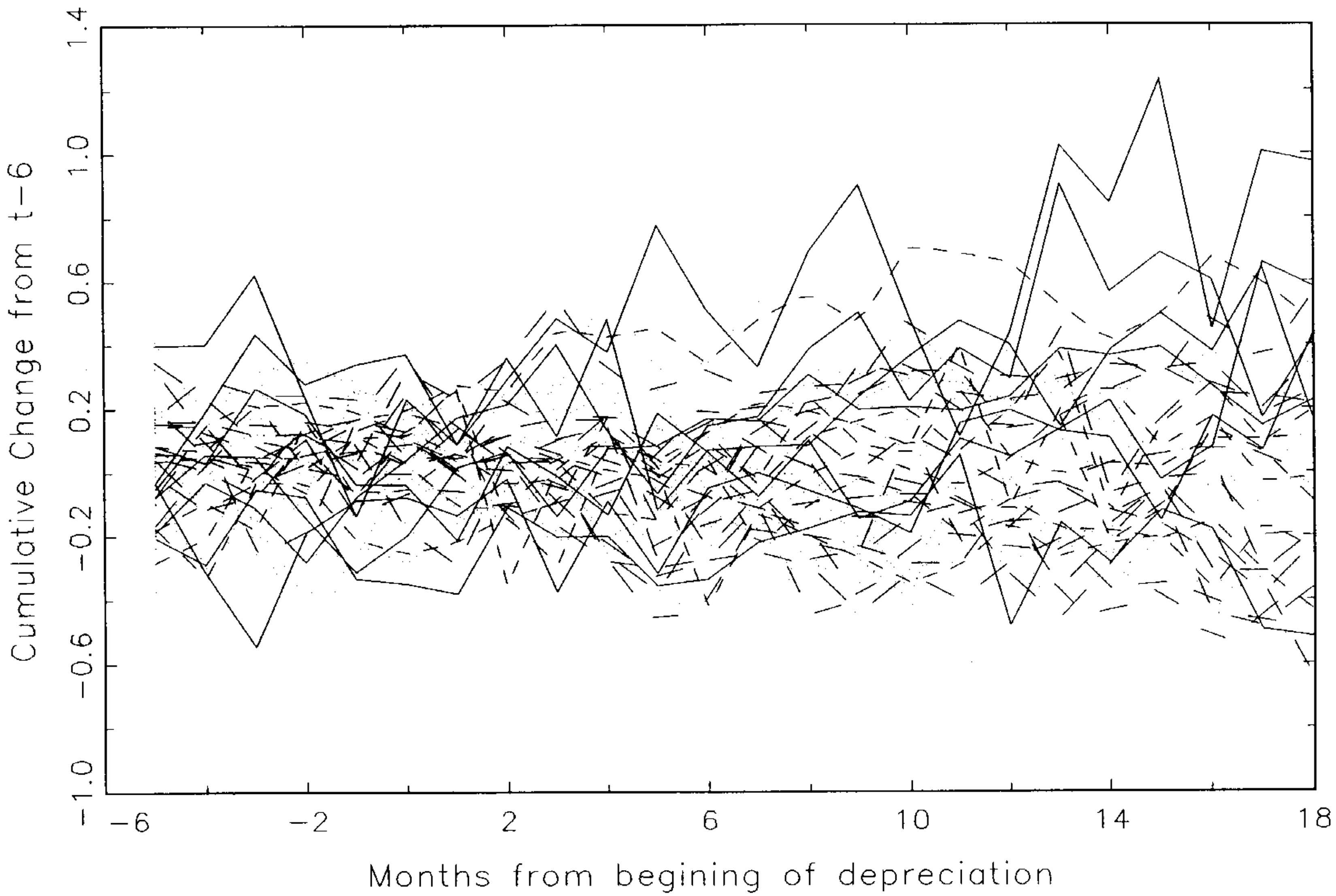


Figure 3a: Cumulative exports for largest home currency depreciation



Fiugre 3b: Cumulative exports for largest home currency apreciation

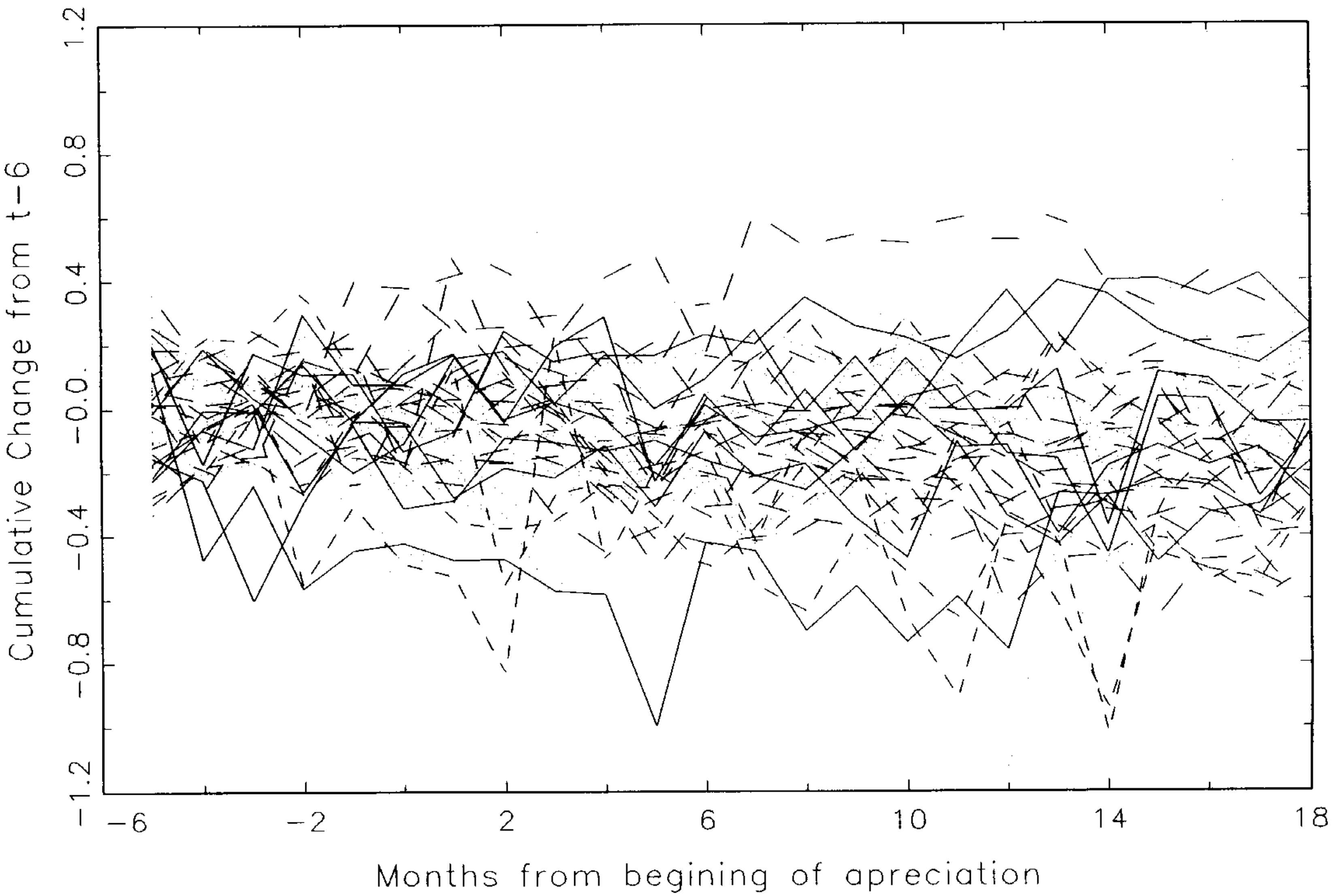
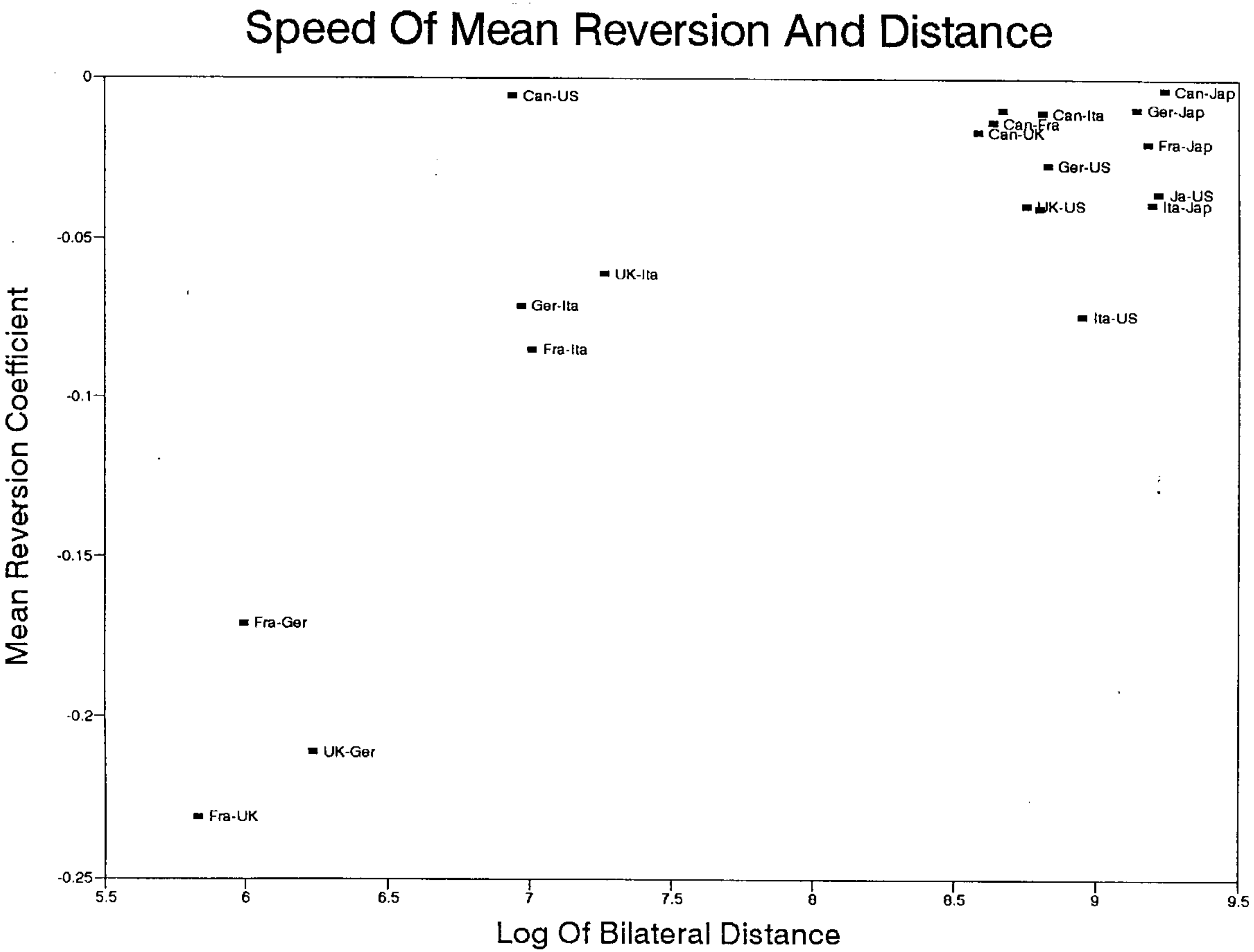
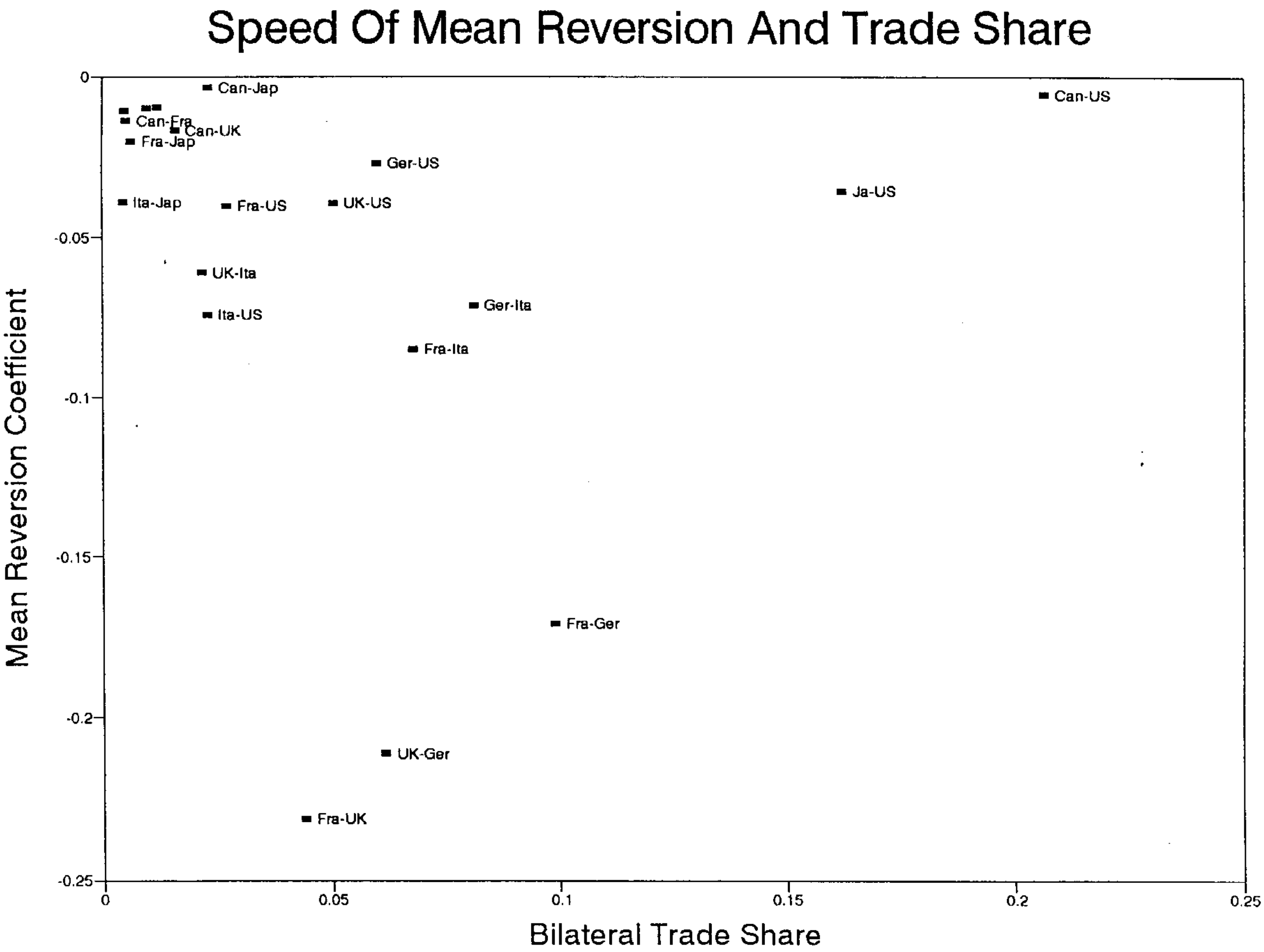


Figure 4a:



Speed Of Mean Reversion And Distance
Mean Reversion Coefficient
Log Of Bilateral Distance
0
-0.05
-0.1
-0.15
-0.2
-0.25
5.5
6
6.5
7
7.5
8
8.5
9
9.5
Can-US
UK-Ita
Ger-Ita
Fra-Ita
Fra-Ger
UK-Ger
Fra-UK
Can-Ita
Can-Fra
Can-UK
Ger-US
UK-US
Ita-US
Can-Jap
Ger-Jap
Fra-Jap
Ja-US
Ita-Jap

Figure 4b:



Speed Of Mean Reversion And Trade Share
Mean Reversion Coefficient
Bilateral Trade Share
0
-0.05
-0.1
-0.15
-0.2
-0.25
0.05
0.1
0.15
0.2
0.25
Can-Jap
Can-Fra
Can-UK
Fra-Jap
Ger-US
Ita-Jap
Fra-US
UK-US
UK-Ita
Ita-US
Ger-Ita
Fra-Ita
Fra-Ger
UK-Ger
Fra-UK
Ja-US
Can-US