The Limits of Arbitrage: Trading frictions and Deviations from Purchasing Power Parity

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This paper builds on the argument that frictions in international markets for goods limit the opportunity to exercise arbitrage, thereby creating a band of inaction around the Purchasing Power Parity (PPP) value of the real exchange rate. Applying a threshold autoregression framework that explicitly captures the notion of the band of inaction, I estimate the width of the band and the speed of adjustment to the edge of the band for a large set of bilateral real exchange rates. I proceed to demonstrate that the width of the band is related to a variety of trading frictions.

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1 Introduction

Absolute Purchasing Power Parity (PPP) says that once converted to a common currency national price levels should be equal. Relative PPP asserts that the real exchange rate, defined as the ratio of national price levels expressed in a common currency, should be constant over time. The focus of this paper is on relative PPP. As was documented in numerous studies, the real exchange rate can be quite volatile in the short run, implying large deviations from PPP. Does PPP hold in the long run? The empirical validity of long-run PPP has been tested extensively and support for it has waxed and waned over the years. Although no clear verdict has emerged yet, a large number of studies conducted since the early 1990s find that PPP tends to hold in the long run but that deviations from this relationship are very persistent. In many cases the half life of deviations from PPP is estimated to be in the range of three to five years.[1]

In an article reviewing the PPP literature, Rogoff (1996) has pointed out that it is difficult to reconcile the fact that real exchange rates are volatile in the short run with the finding that deviations from PPP tend to die out very slowly. This led him to announce the existence of a "Purchasing Power Parity Puzzle". Standard macroeconomic arguments can account for the volatility of the real exchange rate in the short run. Since prices and wages are rigid in the short run, so the typical argument goes, monetary and financial shocks can lead to nominal exchange rate overshooting and thus to large swings

[1] Froot and Rogoff (1995) and Taylor and Sarno (2002) provide excellent surveys of the PPP literature. Killian and Zha (2002) report results of a survey they conducted in 1999 among economists with an interest in the PPP debate. The average survey response displayed a single peak at about four years (p. 110).

in the real exchange rate.[2] Yet it is difficult to argue that prices and wages are rigid enough to be able to account for half lives of deviations from PPP in the order of magnitude of three to five years. An explanation for the persistency of deviations from PPP could be that real shocks (such as shocks to tastes and technology) are predominant, but it seems unlikely that such shocks would be able to account for the observed volatility of the real exchange rate in the short run.

In the conclusion of his review article Rogoff (1996, pp. 664-5) suggested that trading frictions might offer an avenue for resolution of the "Purchasing Power Parity Puzzle":[3]

> International goods markets, though becoming more integrated all the time, remain quite segmented, with large trading frictions across a broad range of goods. These frictions may be due to transport costs, threatened or actual tariffs, non-tariff barriers, information costs, or lack of labor mobility. As a consequence of various adjustment costs, there is a large buffer within which nominal exchange rates can move without producing an immediate proportional response in relative domestic prices.

In raising this argument, Rogoff essentially forces us to reexamine the building blocks of and rationale for PPP. The basic building block of PPP is the Law of One Price which says that a good should have the same (common currency) price in different countries. The rationale for the Law of One Price is that of arbitrage. Since the price

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[2] Dornbusch (1976). See Chari, Kehoe and McGrattan (2002) for an attempt to resolve the PPP puzzle using a model that assumes price stickiness.

[3] Obstfeld and Rogoff (2001) make a similar claim.

indices that are used in the construction of real exchange rates are weighted averages of prices of individual goods, the same arbitrage rationale should also apply to PPP. The introduction of trading frictions, however, changes the picture. A plausible interpretation of Rogoff's argument is that trading frictions lead to the creation of a band of inaction around the Law of One Price and PPP relationships.

The idea that trading frictions limit the adjustment to PPP is in fact not new. As Obstfeld and Taylor (1997, p. 443) point out, in 1916 Heckscher already proposed the idea of Commodity Points for relative prices. The Commodity Points - in essence the edges of the band of inaction - mark the limits of arbitrage opportunities in international markets for goods. The existence of a band of inaction implies a discrete nonlinear adjustment process of the real exchange rate: Inside the band, where there are no arbitrage opportunities, the real exchange rate exhibits no central tendency; arbitrage activity translates into fast real exchange rate adjustment outside the band.

This paper is a contribution to the emerging literature that studies the connection between trading frictions and deviations from PPP. Applying a threshold autoregression framework that explicitly captures the notion of the band of inaction, I simultaneously estimate the width of the band of inaction and the speed of adjustment to the edge of the band for a large set of bilateral real exchange rates. I then demonstrate that the width of the band is related to a variety of trading frictions and that the adjustment of the real exchange rate to the edge of the band is rapid. The paper therefore provides empirical evidence supporting Rogoff's suggested solution to the "Purchasing Power Parity Puzzle".

The rest of the paper is structured as follows. Section 2 positions the paper within the literature that studies the connection between trading frictions and deviations from PPP and highlights the paper's main findings. Section 3 first presents a simple analytical framework to make the notion of the band of inaction more concrete. It then outlines the econometric technique used to capture the implied nonlinear real exchange rate adjustment process and describes the data that will be used in the empirical investigation. Section 4 presents and discusses empirical results and section 5 concludes.

2 Related literature

The connection between trading frictions and deviations from PPP has been examined in the past several years by a number of related lines of research. One group of studies attempts to relate the volatility and persistence of deviations from PPP to trading frictions. A second group tests the hypothesis that trading frictions imply a smooth nonlinear adjustment to PPP. Studies in a third group, to which this paper belongs, assert that trading frictions imply a discrete nonlinear adjustment to PPP. In contrast to studies in the first group those in the third put the idea of the band of inaction to a direct, rather than an indirect, empirical test; in contrast to studies in the second group those in the third explicitly estimate, rather than assume, the relationship between the adjustment process of the real exchange rate and trading frictions.

2.1 Trading frictions and the volatility and persistence of deviations from PPP

Engel and Rogers (1996) provided one of the first studies of the connection between real exchange rate volatility and trading frictions. Their study complemented the research on the Border Effect in trade by investigating the effect of the border on deviations from PPP. The Border Effect in trade is the finding that trade within nations is much more intensive than trade between nations, controlling for distance between trading partners and their economic size.[4] Engel and Rogers used data on different categories of consumer prices for U.S. and Canadian cities to study the extent of deviations from PPP, measured by the variability over time of changes in the relative prices of similar goods in different locations. They found that the variability in relative prices is much higher for two cities located in different countries than for two equidistant cities in the same country, hence the Border Effect. Later studies, including Engel and Rogers (1998, 2001a and 2001b), Engel and Rose (2002), and Parsley and Wei (2001a and 2001b), continued this line of investigation by examining different datasets and studying the effects of other trading frictions on real exchange rate volatility.

Parsley and Wei (1996) focused on explaining the persistence, rather than the volatility, of deviations from PPP. Examining price data for a large set of cities in the U.S. they found that rates of adjustment to PPP are slower for cities farther apart. Engel and Rose (2002) found similar results in an international context. Papell and Theodoridis (2001) studied whether the choice of base currency matters in panel unit root tests of PPP. They reported that the choice of base currency does matter and that the ability to find evidence for PPP is inversely related to distance and nominal exchange rate volatility between the base country and the other countries. This finding can be interpreted as providing further evidence for a connection between trading frictions and the persistence of deviations from PPP.

[4] See McCallum (1996) and Helliwell (1998).

2.2 Smooth nonlinear adjustment to PPP

Testing the empirical validity of long run PPP is typically carried out by a unit root test, such as the Dickey-Fuller test. This test assumes a linear adjustment process of the real exchange rate: The speed of adjustment to PPP is independent of the size of deviations. Michael, Nobay and Peel (1997) claimed that the presence of transaction costs in goods trade implies a smooth nonlinear adjustment process of the real exchange rate. Using monthly data for the interwar period and annual data spanning two centuries for several countries they were able to reject the conventional linear adjustment framework in favor of a smooth transition autoregressive process: Large deviations from PPP tend to die out quickly while small deviations are very persistent.

O'Connell and Wei (1997) presented a model that included both fixed and variable market frictions and demonstrated that it implies a nonlinear adjustment to the Law of One Price. Analyzing retail goods price data for U.S. cities they too found evidence supporting a model of smooth nonlinear adjustment to the Law of One Price. Similar analysis was provided by O'Connell (1998), who studied a set of bilateral real exchange rates among advanced countries during the modern floating-rate era. O'Connell's reported results were surprising: Large deviations from PPP appeared to be at least as persistent as small ones.

More recently, Taylor, Peel and Sarno (2001) provided strong evidence of nonlinearity in the adjustment process to PPP. The authors fitted a smooth transition autoregressive model to real exchange rates of four industrial countries against the U.S. dollar. Their results implied an equilibrium level of the real exchange rate in the neighborhood of which the behavior of the real exchange rate is close to a random walk, becoming increasingly mean reverting with the absolute size of the deviations from equilibrium. Another recent study that applies smooth transition autoregressive techniques and provides similar results is Sollis, Leybourne and Newbold (2002).

2.3 Discrete nonlinear adjustment to PPP

In a fascinating study Asplund and Friberg (2001) examined deviations from the Law of One Price in Scandinavian duty-free stores. They concluded that the pattern of price adjustment in the duty-free outlets suggests the existence of a band of inaction, so that small deviations from the Law of One Price may persist, but that large deviations quickly lead firms to adjust relative prices.

Obstfeld and Taylor (1997) was the first study that specifically assumed and tested using actual data a model of discrete nonlinear real exchange rate adjustment to PPP. The concept of the band of inaction was captured by thresholds: Deviations of the real exchange rate from PPP that are larger than the thresholds are arbitraged away while smaller deviations induce no arbitrage. Applying a threshold autoregression to data from 32 city and country locations they were able to identify both the thresholds and the speed of adjustment to the threshold.[5]

Obstfeld and Taylor showed that if the adjustment process to PPP takes this form of nonlinearity, then estimates of speeds of adjustment obtained by conventional tests of

[5] O'Connell (1998) also tested a model of discrete nonlinear adjustment, but assumed rather than estimated the value of the thresholds.

PPP using a linear specification will be downward biased.[6] Taylor (2001) studied this problem further using simulated data and reached the same conclusion.

Assuming a discrete rather than a smooth nonlinear adjustment process has two advantages. First, it better corresponds with the notion of the band of inaction. Second, it allows estimation of threshold levels. Once threshold levels are estimated their values can be related to trading frictions. Obstfeld and Taylor did exactly that. They found some evidence that estimated threshold levels are related to distance and nominal exchange rate volatility.[7]

This paper takes over where Obstfeld and Taylor (1997) and Taylor (2001) left off. Applying a threshold autoregression framework that explicitly captures the notion of the band of inaction to data from two sources and at different frequencies, I estimate the width of the band of inaction and the speed of adjustment to the edge of the band for a large set of bilateral real exchange rates. The estimated width of the band is stable at the range of 20-25 percent on average. I further demonstrate that the width of the band depends on the degree of "tradability" of the underlying price indices: Real exchange rates based on more "tradable" price indices are associated with narrower bands. The analysis continues by providing, for the first time in the PPP context, evidence of a temporal aggregation bias. Taking this bias into account I conclude that the half life of deviations from the edge of the band is at most two thirds of a year. The paper then proceeds to demonstrate that the width of the band and a related measure of deviations

[6] Michael, Nobay and Peel (1997), O'Connell and Wei (1997), and Taylor, Peel and Sarno (2001) make the same argument assuming a smooth transition process.

[7] Similar results were reported recently by Imbs, Mumtaz, Ravn and Rey (2003).

from PPP are strongly related to a variety of trading frictions including transport costs, tariff barriers, and nominal exchange rate volatility.

3 The band of inaction

3.1 Analytical framework

The exact way the real exchange rate would behave in the presence of transaction costs depends on the assumptions of the specific theoretical model being considered. Several types of possible dynamics have been proposed in the literature.[8] This paper adopts the notion of a band of inaction because of its simplicity and because it allows estimation of threshold levels which can then be related to trading frictions.

In order to clarify the notion of the band of inaction and to motivate the empirical analysis I present here some simple analytical arguments. Consider the existence of arbitrage opportunities between two countries, Home (H) and Foreign (F). Both Home and Foreign produce and sell the same good. Producer prices at Home and Foreign are P_H and P_F. Producers in both countries can sell the good domestically or export it. There are several frictions in international trade. First, there are transport costs, TC, which are assumed to be symmetric. Second, there are tariff barriers: TB_H and TB_F, which are not necessarily symmetric. Third, there is a (symmetric) exchange risk factor, ERF, that is related to nominal exchange rate volatility. Nominal exchange rate volatility constitutes a trading friction because it is either impossible or costly to hedge exchange rate risks.

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[8] See Taylor, Peel and Sarno (2001) and Taylor and Sarno (2002) for discussions.

This setup establishes the following conditions for goods market arbitrage: The good will be shipped from Home to Foreign if $P_H(1+TC)(1+TB_F)(1+ERF) < P_F$ and will be shipped from Foreign to Home if $P_F(1+TC)(1+TB_H)(1+ERF) < P_H$. No arbitrage opportunities exist if: $1/(1+TC)(1+TB_H)(1+ERF) \le P_F/P_H \le (1+TC)(1+TB_F)(1+ERF)$.

Let the real exchange rate be defined by $P_F/P_H \equiv Q$, or in logarithms $\ln(P_F/P_H) \equiv q$. Taking logarithms of the no-arbitrage condition and using the definition of the real exchange rate yields the following expression defining the band of inaction: $-TC - TB_H - ERF \le q \le TC + TB_F + ERF$. In this paper I refer to c, one half of the difference between the upper and lower limits of the band of inaction, as the width of the band: $c = TC + (TB_F + TB_H)/2 + ERF$. In the current setup the width of the band is a simple linear function of transport costs, tariff barriers in the two countries and an exchange risk factor associated with nominal exchange rate volatility.

If arbitrage was immediate the real exchange rate would have been confined to continuously stay within the limits of the band. This is the approach adopted by Caves, Frankel and Jones (2002, pp. 371-5) in describing possible patterns of deviation from PPP. It is also implicitly assumed by some of the studies mentioned earlier. Under this assumption the edges of the band are said to be “reflecting”. It seems quite natural, however, to assume that in the presence of imperfect information and other factors arbitrage is not immediate. Accordingly, I assume that the real exchange rate can deviate from the confines of the band. Since inside the band the forces of arbitrage do not operate, the real exchange rate would tend to behave there like a random walk: Any shock would have a permanent influence on the real exchange rate as long as the latter has not crossed the edge of the band. Whenever the real exchange rate deviates from the limits of the band, however, arbitrage forces would lead to adjustment towards the edge of the band.

3.2 Methodology

The behavior of the real exchange rate described above can be captured econometrically by a threshold autoregression. Following Obstfeld and Taylor (1997) and Taylor (2001) I choose to employ a very simple threshold autoregression specification:

$$\Delta q = \begin{cases} l\,(q_{t-1} - c) + e_t & if \quad q_{t-1} > c \\ e_t & if \quad c \geq q_{t-1} \geq -c \\ l\,(q_{t-1} + c) + e_t & if \quad -c > q_{t-1} \end{cases}$$

where c is the width of the band, ? is the speed of adjustment to the edge of the band, and e_t *is* $N(0, s^2)$.

According to this specification the change in the value of the real exchange rate between the previous period and the current period is a function of the value of the real exchange rate in the previous period. If the value of the real exchange rate in the previous period is higher than the upper limit of the band or lower than the lower limit of the band, the real exchange rate will tend to adjust to the edge of the band at a speed of ?. If, for example, ?=-0.5, then 50 percent of the gap between the value of the real exchange rate and the edge of the band will be closed by the next period, abstracting from the influence of the stochastic shock. On the other hand, if the value of the real exchange rate in the previous period falls within the confines of the band then the change in the value of the real exchange rate between the previous period and the current period will be purely random.

Figure 1 illustrates the idea of the band of inaction with simulated data. One hundred observations were simulated (T=100) with an initial value q=0; the width of the band was set at 20 percent (c=0.2); the speed of adjustment was set at 50 percent per period (?=-0.5); the standard deviation of the stochastic shock was set at 0.2 (s=0.2). Figure 1 plots the simulated real exchange series along with the upper and lower limits of the band.

The threshold autoregression is executed in several steps. First, the (log) real exchange rates series are adjusted to each have a mean of zero. This adjustment is common in the PPP literature and reflects the fact that deviations from Relative PPP, rather than from Absolute PPP, are being studied.[9] Second, for each real exchange rate series I split the sample according to the one-period lagged value of the real exchange rate to inside-the-band and outside-the-band observations. I then run a separate ordinary least squares regression for each group of observations. For inside-the-band observations I regress the change in the real exchange rate against a constant. Regressing the change in the real exchange rate on a constant means that I am capturing none of the variation in the left-hand-side variable, as is implied by the random walk hypothesis. For the outside-the-band observations I regress the change in the real exchange rate against the gap between the lagged value of the real exchange rate and the edge of the band. This regression yields an estimate of the speed of adjustment to the edge of the band (?).

[9] See, for example, Taylor (2002).

Third, I sum up the residual sum of squares from the first and second regressions. Minimizing this sum serves as the objective function for a best-fit grid-search over the width of the band (c).[10] The search over the width of the band is conducted with steps of 0.001 (i.e. one tenth of a percentage point deviation from PPP). In order to obtain a reasonably accurate estimate of the speed of adjustment there is a need to constrain the search over possible widths of the band to allow a certain number of observations to fall outside the band. Since the data contains relatively long time-series (37 years), I have chosen the minimal number of observations outside the band to be ten in annual data and the corresponding number of observations for that span in quarterly and monthly data.[11] The search procedure allows for a band of zero width. In this case the threshold autoregression model is essentially equivalent to a simple first-order autoregressive process ($\Delta q_t = l q_{t-1} + e_t$). This type of regression, known as a Dickey-Fuller unit root test, is the most commonly used method to test for PPP and assumes a linear real exchange rate adjustment process.

3.3 Data Sources

The main source of real exchange rate data used in the analysis is the Penn World Tables (PWT), Mark 6.0.[12] The PWT contains a set of national accounts economic time

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[10] See Obstfeld and Taylor (1997, pp. 452-454) for a discussion of alternative objective functions.

[11] Further analysis revealed that results are not very sensitive to the choice of the minimal number of observations outside the Band.

[12] For a detailed description of a previous version of the dataset (PWT 5.0), see Summers and Heston (1991). The latest version of dataset can be found at http://pwt.econ.upenn.edu/. Oh (1996) and Parsley and Popper (2001) also use real exchange rate data from the PWT in PPP tests.

series. Its expenditure entries are denominated in a common set of prices and in a common currency so that real quantity comparisons can be made, both between countries and over time. PWT data is annual. The analysis here focuses on 108 countries in the period 1960-1996. All the 5778 combinations of real exchange rates among these countries are examined. The real exchange rate for each pair of countries was constructed from the price levels of gross domestic product and nominal exchange rates against the U.S. dollar, using cross-rates whenever necessary.

Obstfeld and Taylor (1997) argue (footnote 21, p. 460) that using all combinations of real exchange rates is inappropriate because "linearly dependent combinations of real exchange rates so derived contain no additional econometric information." While this argument is valid for a standard, linear, econometric technique of determining whether a set of real exchange rates is stationary, it is invalid if one assumes a nonlinear adjustment process. To clarify this argument let us assume that the width of the Band is determined solely by transport costs, which are captured by distance. From knowing the distance between A and B and between A and C we cannot deduce the distance, and therefore the behavior of the real exchange rate, between B and C. The same rationale is valid for other trading frictions that might influence the width of the Band of Inaction. It is thus clear that the behavior of each of the three possible combinations of real exchange rates in the above example is a legitimate object of inquiry.

For comparison purposes and to test the sensitivity of the results I also constructed annual, quarterly and monthly real exchange rate series for the period 1960-1996 from data provided in the International Monetary Fund's International Financial Statistics (IFS) CD-ROM. The real exchange rate series were derived in this case from consumer price indices and end-of-period nominal exchange rates against the U.S. dollar. A complete list of the countries covered and their availability in the PWT and IFS datasets is provided in appendix 1. Other data sources are described with the empirical results.

4 Trading frictions and deviations from PPP

4.1 The width of the band and the speed of adjustment

The average estimated width of the band in the sample of 5778 observations obtained from the PWT is 0.23, with a standard deviation of 0.21. On average, real exchange rate deviations from PPP that are larger than 23 percent tend to be arbitraged away; trading frictions inhibit arbitrage for smaller deviations.

The average value of the adjustment speed parameter (?) estimated using the threshold autoregression is -0.45 (with a standard deviation of 0.42), implying a half life of deviations from the edge of the band of 1.18 years. In contrast, the average value of the adjustment speed parameter estimated using the more conventional Dickey-Fuller unit root test is -0.17 (with a standard deviation of 0.14), implying a much higher half life of deviations: 3.65 years. Note that this value falls within the "consensus" range mentioned in the introduction: 3 to 5 years.

Table 1 compares estimates of the width of the band and implied half life of deviations from the edge of the band obtained using PWT data with those obtained using IFS annual, quarterly and monthly data. The average estimated width of the band is stable across data sources and frequencies at the range of 20 to 25 percent.

Different goods and services should in principle have bands of different widths associated with them. This implies that the composition of the price index being examined matters. The price level of gross domestic product and the consumer price index (which are used in this paper to construct real exchange rates) contain a large component of what is conventionally termed "non-tradables" relative to the wholesale price index and the producer price index.[13] One can therefore expect real exchange rates based on more "tradable" price indices to have narrower bands.

To check whether this is indeed the case I studied a smaller sample of real exchange rates for the seven largest industrial countries (the G7). Real exchange rate series were constructed for each of the 21 possible pairs of countries using monthly data on both the consumer price index and the wholesale price index (or the producer price index when the wholesale price index was unavailable) and end-of-month nominal exchange rates. The period covered was January 1950 - June 2002 and the source of the data was Global Financial Data.[14]

The average width of the band was estimated at 23 percent for real exchange rates based on the consumer price index but only 13 percent for real exchange rates based on the wholesale price index. This demonstrates the argument that the composition of the price index being examined indeed matters and that price indices that are more "tradable" are associated with narrower bands.

[13] See Froot and Rogoff (1995, p. 1655) and Obstfeld and Rogoff (2001, p. 373) for a discussion of this issue.

[14] http://www.globalfindata.com/.

Returning to Table 1, one notices a pattern of a declining implied half life of deviations as the frequency of real exchange rate observations increases: from 1.18 and 0.82 years in the annual PWT and IFS data, to 0.73 and 0.66 years in the quarterly and monthly IFS data.[15] What is the explanation for the negative relationship between data frequency and estimated half life? One explanation could be that this is simply an artifact of the difference in samples. Whereas the PWT data covers 108 countries, the annual, quarterly and monthly IFS data covers 59, 49 and 43 countries only. To check whether this is indeed the case I conducted the same comparison using an identical sample covering 861 observations (42 countries). Results are reported in Table 2. The table exhibits the same negative correlation between data frequency and estimated half life, implying that the reason for the correlation is not the difference in samples.[16]

An alternative, and a more likely, explanation for the negative correlation is a temporal aggregation bias in PPP tests, an issue that was rigorously analyzed by Taylor (2001).[17] A first step in tests of PPP is the construction of real exchange rate series from price indices and nominal exchange rates. In most cases reported price indices are based

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[15] Half-lives were computed in all cases from the average values of the adjustment speed parameter. These averages (standard deviations) are: PWT (annual): -0.45 (0.42); IFS annual: -0.55 (0.48); IFS quarterly: -0.21 (0.26); IFS monthly: -0.08 (0.11).

[16] Estimating the adjustment speed with a conventional Dickey-Fuller test using the identical sample also yields a negative relationship between implied half life and data frequency. The implied half lives (computed from the average value of the adjustment speed parameter) are: PWT (annual): 3.87; IFS annual: 3.00; IFS quarterly: 2.47; IFS monthly: 2.18.

[17] A different type of bias, involving the aggregative nature of the price indices used in PPP tests, was recently analyzed by Imbs, Mumtaz, Ravn and Rey (2002).

on an averaging over time (month, quarter, year etc.) of price data. In some cases the nominal exchange rate data is also averaged over time. Using simulated data Taylor demonstrated that there is an upward bias in half life estimates derived from such real exchange rate series, and that the bias increases with the degree of temporal aggregation. In other words, in those circumstances one can expect to find a negative correlation between data frequency and estimated half lives.

This argument applies to the datasets used here. Consumer price indices reported in the IFS are period averages. On the other hand, the IFS nominal exchange rates used in this paper are end-of-period values. In the PWT dataset both prices and exchange rates are period averages.[18]

Tables 1 and 2 therefore seem to provide evidence of a temporal aggregation bias. To the best of my knowledge this is the first time the temporal aggregation bias has been demonstrated with actual (as opposed to simulated) data in the PPP context. Since the bias increases with the degree of temporal aggregation and since the highest frequency examined here is monthly, it is clear that the true half life of deviations from the edge of the band cannot be higher than two thirds of a year. This value contrasts sharply with typical estimates of half lives of deviations from PPP, which are in the range of 3 to 5 years.

[18] This difference may help to explain the finding that the estimated half lives obtained from the annual PWT data are higher than those obtained from the annual IFS data.

4.2 Trading Frictions and the Width of the Band

The next step in the empirical analysis is an exploration of the relationship between the width of the band of inaction and trading frictions. Following the discussion in the previous section the three trading frictions that will be studied first are transport costs, tariff barriers and exchange rate volatility. As is common in the empirical international trade literature, transport costs will be proxied by distance, measured here by the "greater circle distance" between capital cities in kilometers.[19] The effect of distance on transport costs is likely to be concave and therefore regressions will include as explanatory variables both distance and distance squared. Distance is expected to affect positively and distance squared to affect negatively the width of the band.

Tariff barriers are proxied by the share of import taxes in the total value of imports.[20] Data is available for 101 of the 108 countries for which PWT data is available. For each pair of countries I sum the average (over time) tariff barrier measure. It is important to note at this stage that the proxy used for tariff barriers is not really bilateral because it implicitly assumes that each country treats all other countries equally. I chose to use this measure because of the unavailability of comprehensive bilateral tariff data. Below I offer a correction for this deficiency by taking into account preferential trading arrangements between pairs of countries.

Nominal exchange rate volatility is measured by the standard deviation of the one-period (year, quarter or month, depending on the specification of the regression)

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[19] Source: http://www.wcrl.ars.usda.gov/cec/java/lat-long.htm.

[20] Source: World Bank's World Development Indicators CD-ROM

change in log nominal exchange rate.[21] Summary statistics for the three explanatory variables in the benchmark regression are presented in Table 3.

Table 4 displays results of an ordinary least squares regression of the width of the band (obtained using the PWT data) on the three measures of trading frictions. Results conform to expectations. All variables enter the regression significantly and with the expected signs: distance with a positive sign, distance squared with a negative sign, tariff barriers with a positive sign and nominal exchange rate volatility with a positive sign.

The results displayed in Table 4 imply that a one standard deviation increase in distance between two countries that are initially 500 kilometers apart will lead to a 1.5 percentage point increase in the width of the band (or 7 percent of the standard deviation of the width of the band). When the initial distance is 1,500 kilometers, the same increase in distance will lead to a somewhat smaller increase in the width of the band: 1.0 percentage points (or 5 percent of the standard deviation of the width of the band). As a concrete example of the influence of distance on the width of the band consider two pairs of cities. The distance between Lisbon and Madrid is 500 kilometers and that between Lisbon and Washington D.C. is 5,742 kilometers. This difference in distance alone would account for an increase of 1.6 percentage points in the width of the band for the Portugal-United States real exchange rate relative to the Portugal-Spain real exchange rate.

A one standard deviation increase in the tariff variable results in a 1.3 percentage point increase in the width of the band (or 6 percent of the standard deviation of the width of the band). Finally, a one standard deviation increase in nominal exchange rate

[21] Sources: PWT and IFS.

volatility results in a 4.1 percentage point increase in the width of the band (or 20 percent of the standard deviation of the width of the band).

The economically large and statistically very significant influence of nominal exchange rate volatility on the width of the band tends to raise the question of whether the width of the band has changed over time with changes in nominal exchange rate volatility. Nominal exchange rate volatility has increased markedly over time in the PWT sample. For example, for the sub-period 1960-78 the average value of the volatility measure is 0.12; in contrast, for the sub-period 1979-96 the corresponding figure is 0.39. Applying the threshold autoregression technique to the two sub-periods yielded a corresponding increase in the average width of the band: 0.19 in the first sub-period versus 0.33 in the second.

Table 5 reports results of regressions of the width of the band, obtained using the IFS annual, quarterly, and monthly data, on trading frictions. The results are qualitatively similar to those displayed in Table 4. All the explanatory variables have the expected signs and are highly significant. The overall fit of the regressions presented in Table 5, and especially the one that uses annual data, is much better than the corresponding figure in Table 4. Because the PWT has much larger country coverage than the IFS, however, I continue the analysis using the former dataset.

It is now time to augment the benchmark regression with additional explanatory variables. These variables also attempt to capture the effect of trading frictions on the width of the band. The motivation for including them comes from the empirical trade literature which often applies a "gravity equation" to explain bilateral volumes of trade.[22]

[22] For an excellent discussion of the rationale for the "gravity equation" see Frankel (1997).

According to the "gravity equation" the volume of bilateral trade is a function of the economic size of the countries involved and the distance that separates them. The basic specification is usually augmented by other explanatory variables, many of which represent trading frictions. I chose to augment the regression explaining the width of the band by a set of variables that ex-ante seemed to have the potential to affect price differentials.

The first two variables to be added to the benchmark regression equation are dummies for landlocked countries and for adjacent countries. The first takes the value of one if at least one of the countries in a pair is landlocked and zero otherwise. The second takes the value of one if the two countries in the pair share a land boundary.[23] Below I will refer to these variables as the landlocked dummy and the adjacency dummy. Overall there are 1950 pairs in which the landlocked dummy takes the value of one and 131 pairs in which the adjacency dummy takes the value of one.

The rationale for including the landlocked dummy in the regression is that countries that lack access to the sea have to rely more on shipping by land and air which tends to be more expensive than sea transport.[24] The adjacency dummy is included in the regression because having a common land boundary is associated with the availability of direct point to point shipment methods (truck and rail) implying a minimum of costly mode switching.[25]

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[23] The source of the data for the two variables is the Central Intelligence Agency's World Factbook 2001.

[24] Hummels (1999).

[25] Op. Cit.

The first two columns in Table 6 demonstrate that, as expected, country pairs for which the landlocked dummy takes the value of one tend to have wider bands and country pairs for which the adjacency dummy takes the value of one tend to have narrower bands. The value of the landlocked dummy coefficient implies that a pair for which at least one of the countries is landlocked has a band that is on average 3 percentage points wider. The value of the adjacency dummy coefficient implies that pairs of neighboring countries have bands that are on average 4 percentage points narrower.

The third column in Table 6 includes a common language dummy variable. This variable takes the value of one if the main language is identical for the two countries in a pair and zero otherwise.[26] Overall there are 794 pairs of countries sharing the same main language. The motivation for including this variable also comes from the "gravity equation" literature. Lack of a common language, so the argument goes, should be thought of as a trading friction. In the current application this argument fails to hold, as the coefficient on the common language dummy is statistically insignificant.

The next two columns include dummy variables for preferential trading arrangements and currency unions. The preferential trading arrangement dummy takes the value of one if the two countries in a pair belong to the same preferential trading arrangement and zero otherwise.[27] The currency union dummy takes the value of one if the two countries in a pair belong to the same currency union and zero otherwise.[28] Lists

[26] Source: Central Intelligence Agency's World Factbook 2001.

[27] Source: Frankel (1997).

[28] Source: Engel and Rose (2002).

of countries belonging to preferential trading arrangements and currency unions are provided in appendices 2 and 3. Overall there are 149 pairs of countries belonging to preferential trading arrangement and 100 belonging to currency unions.

The preferential trading arrangement dummy corrects for the fact that the tariff measure used here is not genuinely bilateral. Including this variable in the regression allows me to investigate whether pairs of countries that in fact impose lower (presumably zero) bilateral tariff barriers have narrower bands of inaction. The rationale for including a currency union dummy in the regression is that currency unions tend to stimulate international trade.[29] It has to be noted, however, that belonging to a currency union implies no volatility in the nominal exchange rate, an effect which is already captured by the nominal exchange rate volatility variable. Indeed, the mean (median) volatility is 0.05 (0.00) for countries that belong to currency unions and 0.33 (0.19) for countries that do not.[30] The currency union dummy therefore tests whether belonging to a currency union has an effect on the width of the band beyond the one that comes through elimination of nominal exchange rate volatility.

Table 6 confirms that belonging to a preferential trading arrangement has a statistically and economically significant effect on the width of the band. Countries belonging to preferential trading arrangements have bands that are on average 11 percentage points narrower. The (marginally significant) coefficient on the currency union dummy implies that, controlling for nominal exchange rate volatility, joining a

[29] Rose and Van Wincoop (2001) and Frankel and Rose (2002).

[30] The reason that the mean volatility is not zero for countries that belong to currency unions is change in membership during the period under investigation. See appendix 3.

currency union tends to lower the width of the band by 3 percentage points. Using the difference in mean nominal exchange rate volatility between country pairs belonging to currency unions and country pairs that do not and the coefficient on nominal exchange rate volatility reported in Table 6, the effect of reducing exchange rate volatility by joining a currency union turns out to be a 3 percentage points drop in the width of the band. The overall effect of joining a currency union is therefore a 6 percentage points reduction in the width of the band.

The last column in Table 6 reports results of a regression that includes all the dummy variables discussed so far. The coefficients for the adjacency, common language and currency union dummies are statistically insignificant at conventional levels. In contrast, the landlocked and the preferential trading arrangement dummies still have the expected signs and are statistically significant.[31]

4.3 Trading Frictions and Absolute Deviations from PPP

In order to test the robustness of the results presented above I proceed to examine the relationship between trading frictions and another variable that measures deviations from PPP and is correlated with the width of the band of inaction. The literature that studies the connection between trading frictions and deviations from PPP has measured deviations in various ways. One measure that has received almost no attention is mean

[31] In the fourth and the sixth (last) columns the coefficient on distance is statistically insignificant. This is probably a result of including several variables that are highly correlated with distance, such as the dummies adjacency, preferential trading arrangement, and currency union.

absolute deviation from PPP.[32] For the sample of 5778 real exchange rates obtained from the PWT the average mean absolute deviation is 0.27 (i.e. 27 percent) and the standard deviation is 0.13.

The size of deviations from PPP as measured by mean absolute deviation is obviously related to the parameters that were at the focus of the analysis so far: the width of the band of inaction and the speed of adjustment to the edge of the band. Intuitively, the wider the band is the more time the real exchange rate spends inside it and thus the larger the average absolute magnitude of deviations. Holding the width of the band constant, it is clear that whenever the real exchange rate is outside the band a lower speed of adjustment to the edge of the band translates into larger average absolute deviations.

This rationale was explored by an ordinary least squares regression of mean absolute deviation on the width of the band (c) and the adjustment speed parameter (?) for the entire sample of PWT real exchange rates. Results of this regression are presented in Table 7. As expected, a wider band and a lower speed of adjustment to the edge of the band - equivalent to a higher value of ? - are associated with a higher mean absolute deviation. Both variables are highly significant.[33]

Table 8 reports results of estimating the relationship between mean absolute deviation and trading frictions. They are similar to those presented in Table 6. Distance affects the average size of deviations positively and distance squared negatively; higher taxes on imports and higher nominal exchange rate volatility increase the average size of

[32] An exception is Parsley and Wei (1996), although their focus is on the persistence of deviations and not on mean absolute deviation.

[33] The relationship between mean absolute deviation, the width of the band and the speed of adjustment to the edge of the band was further investigated using simulated data with the same qualitative conclusions.

deviations. When entered separately all the additional (dummy) variables have the correct sign, and all, except common language, are statistically significant. When entered together all the dummy variables maintain the correct signs but only two, the landlocked and preferential trading arrangement dummies, are statistically significant. The decline in the significance level of the additional variables, except the landlocked dummy, is probably due to collinearity.[34] The overall fit of the regressions, while still quite modest, is higher than that obtained when the explained variable was the width of the band.

5 Conclusion

The basic rationale for the doctrine of PPP is arbitrage in international markets for goods. Frictions in those markets limit the opportunity to exercise arbitrage. A likely implication of the existence of trading frictions is that there is a band of inaction around the PPP relationship. This, in turn, implies that the adjustment of the real exchange rate to PPP is nonlinear: Deviations from PPP that are large enough to fall outside the band tend to be arbitraged away rapidly; smaller deviations show no central tendency.

Adopting an empirical framework which explicitly captures the notion of the band of inaction and using data from two different sources and at different frequencies, I examined a large set of bilateral real exchange rates. The estimated width of the band of inaction was stable at the range of 20-25 percent on average. Using a smaller sample of

[34] The simple correlation coefficient between the adjacency and common language dummies is 0.17; between the adjacency and preferential trading arrangement dummies: 0.25; between the adjacency and currency union dummies: 0.20; between the preferential trading arrangement and currency union dummies: 0.21. Additionally, distance is correlated with the dummies adjacency (0.24), common language (0.15), preferential trading arrangement (0.22), and currency union (0.18).

real exchange rates I demonstrated that the width of the band depends on the composition of the underlying price indices: Real exchange rates based on more “tradable” price indices are associated with narrower bands.

The speed of adjustment to the edge of the band was shown to be influenced by the frequency of the data used: the higher the frequency the lower the estimated half life of deviations. I argued that is most likely the result of a temporal aggregation bias and concluded, based on this argument, that the true half life of deviations from the edge of the band cannot be higher than two thirds of a year. This contrasts sharply with typical estimates of half lives of deviations from PPP, which are in the range of 3 to 5 years.

One of the paper's main contributions is to demonstrate that there is a strong relationship between trading frictions and the width of the band of inaction. Transport costs, tariff barriers and nominal exchange rate volatility were shown to be positively related to the width of the band of inaction. Pairs of countries that belong to a preferential trading arrangement or to a currency union tend to have narrower bands. Countries that do not share a land boundary or that do not have access to the sea tend to have wider bands. Finally, the paper has demonstrated that a closely related measure of deviations from PPP, mean absolute deviation, is also strongly associated with the same trading frictions.

APPENDIX 1 – LIST OF COUNTRIES IN THE DATASETS

COUNTRY	PWT	IFS-A	IFS-Q	IFS-M	COUNTRY	PWT	IFS-A	IFS-Q	IFS-M
ANGOLA	*				JAPAN	*	*	*	*
ARGENTINA	*	*	*	*	JORDAN	*			
AUSTRALIA	*	*	*		KENYA	*	*	*	
AUSTRIA	*	*	*	*	KOREA, REP.	*			
BANGLADESH	*				LESOTHO	*			
BARBADOS	*				LUXEMBOURG	*	*	*	*
BELGIUM	*	*	*	*	MADAGASCAR	*			
BENIN	*				MALAWI	*			
BOLIVIA	*	*	*	*	MALAYSIA	*	*	*	*
BOTSWANA	*				MALI	*			
BRAZIL	*				MAURITANIA	*			
BURKINA FASO	*				MAURITIUS	*			
BURUNDI	*				MEXICO	*	*	*	*
CAMEROON	*				MOROCCO	*	*	*	*
CANADA	*	*	*	*	MOZAMBIQUE	*			
CAPE VERDE	*				NAMIBIA	*			
CENTRAL AFR.R.	*				NEPAL	*			
CHAD	*				NETHERLANDS	*	*	*	*
CHILE	*	*	*	*	NEW ZEALAND	*	*	*	
CHINA	*				NICARAGUA	*			
COLOMBIA	*	*	*	*	NIGER	*			
COMOROS	*				NIGERIA	*	*	*	*
CONGO, DEM. REP.	*				NORWAY	*	*	*	*
CONGO, REP. OF	*				PAKISTAN	*	*	*	*
COSTA RICA	*	*			PANAMA	*	*		
COTE d'IVOIRE	*	*	*	*	PAPUA N.GUINEA	*			
CYPRUS	*	*	*		PARAGUAY	*	*	*	*
DENMARK	*	*	*		PERU	*	*	*	*
DOMINICACAN REP.	*	*	*	*	PHILIPPINES	*	*	*	*
ECUADOR	*	*	*	*	PORTUGAL	*	*	*	*
EGYPT	*	*	*	*	ROMANIA	*			
EL SALVADOR	*	*	*	*	RWANDA	*			
ETHIOPIA	*				SENEGAL	*			
FIJI	*				SEYCHELLES	*			
FINLAND	*	*	*	*	SIERRA LEONE		*		
FRANCE	*	*	*	*	SINGAPORE	*	*		
GABON	*				SOUTH AFRICA	*	*	*	*
GAMBIA	*				SPAIN	*	*	*	*
GHANA	*				SRI LANKA	*	*	*	*
GREECE	*	*	*	*	SWEDEN	*	*	*	*
GUATEMALA	*	*	*	*	SWITZERLAND	*	*	*	*
GUINEA	*				SYRIA	*	*		
GUINEA-BISSAU	*				TAIWAN	*			
GUYANA	*				TANZANIA	*			
HAITI		*	*	*	THAILAND	*	*		
HONDURAS	*	*	*	*	TOGO	*			
HONG KONG	*				TRINIDAD&TOBAGO	*	*	*	*
ICELAND	*	*			TURKEY	*	*		
INDIA	*	*	*	*	UGANDA	*			
INDONESIA	*				UNITED KINGDOM	*	*	*	*
IRAN	*	*			UNITED STATES	*	*	*	*
IRELAND	*	*	*		URUGUAY	*			
ISRAEL	*	*			VENEZUELA	*	*	*	*
ITALY	*	*	*	*	ZAMBIA	*			
JAMAICA	*	*	*	*	ZIMBABWE	*			
					TOTAL	108	59	49	43

Note:

A star indicates availability of real exchange rate data for the entire 1960-96 period in the Penn World Tables (PWT) and International Financial Statistics (IFS) annual (A), quarterly (Q), and monthly (M) datasets.

APPENDIX 2 – PREFERENTIAL TRADING ARRANGEMENTS

Preferential Trading Arrangement		Membership
ASEAN	Association of Southeast Asian Nations	Indonesia, Malaysia, Philippines, Singapore, Thailand.
CACM	Central American Common Market	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua.
CARICOM	Caribbean Community	Barbados, Jamaica, Trinidad and Tobago.
CER	Australia-New Zealand Closer Economic Relations	Australia, New Zealand.
CUWAS	Customs Union of West African States	Benin, Burkina Faso, Cote d'Ivoire, Mali, Mauritania, Niger, Senegal.
EC	European Community	Belgium, Denmark, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom.
EFTA	European Free Trade Association	Austria, Finland, Iceland, Norway, Sweden, Switzerland.
LAFTA	Latin American Free Trade Association	Argentina, Brazil, Chile, Mexico, Paraguay, Peru, Uruguay.
SACU	South African Customs Union	Botswana, Lesotho, South Africa.
UDEAC	Economic and Customs Union of the Central African States	Cameroon, Central African Republic, Chad, Congo (Rep. of), Gabon.

Notes:
1. The heading Preferential Trading Arrangement includes Free Trade Areas, Customs Unions and Common Markets.
2. During the period covered in the paper (1960-1996) some preferential trading arrangements were formed, some disintegrated, and the membership of some changed. Decisions regarding inclusion in the dataset were necessarily somewhat arbitrary. Sensitivity analysis revealed no qualitative change relative to the results presented in the paper.
Source: Frankel (1997).

APPENDIX 3 – CURRENCY UNIONS

Currency Union	Membership
Benelux	Belgium, Luxembourg.
CFA (African Financial Community) Franc Zone	Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Comoros, Congo (Rep. Of), Cote d'Ivoire, Gabon, Guinea-Bissau, Mali, Niger, Senegal, Togo.
East Africa	Kenya, Tanzania, Uganda.
Panama	Panama, United States.
South Africa	South Africa, Lesotho, Namibia.
United Kingdom	Britain, Ireland.

Notes:
1. The heading Currency Union includes currency and monetary unions.
2. During the period covered in the paper (1960-1996) some currency unions were formed, some disintegrated, and the membership of some changed. Decisions regarding inclusion in the dataset were necessarily somewhat arbitrary. Sensitivity analysis revealed no qualitative change relative to the results presented in the paper.
Source: Engel and Rose (2002).

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TABLE 1 – WIDTH OF THE BAND AND IMPLIED HALF LIFE OF DEVIATIONS

	PWT Annual	IFS Annual	IFS Quarterly	IFS Monthly
Width of the band	0.23	0.25	0.22	0.22
Implied half life of deviations	1.18	0.82	0.73	0.66
Observations	5,778	1,711	1,176	903
Countries	108	59	49	43

Notes:
1. Width of the band – sample average.
2. Implied half life of deviations – computed from sample adjustment speed (λ) average.
Source: see text.

TABLE 2 - WIDTH OF THE BAND AND IMPLIED HALF LIFE OF DEVIATIONS
IDENTICAL SAMPLE

	PWT Annual	IFS Annual	IFS Quarterly	IFS Monthly
Width of the band	0.20	0.25	0.24	0.23
Implied half life of deviations	1.16	0.90	0.70	0.65
Observations	861	861	861	861
Countries	42	42	42	42

Notes:
1. Width of the band – sample average.
2. Implied half life of deviations – computed from sample adjustment speed (λ) average.
Source: see text.

TABLE 3 - SUMMARY STATISTICS FOR TRADING FRICTIONS VARIABLES

	Distance (kilometers)	Tariffs (%)	Nominal exchange rate volatility
Mean	8,040	24.49	0.32
Median	7,814	23.44	0.19
Maximum	19,946	83.10	2.03
Minimum	4	0.01	0.00
Standard deviation	4,361	12.33	0.33
Observations	5,778	5,050	5,778

Source: see text.

TABLE 4 - TRADING FRICTIONS AND THE WIDTH OF THE BAND
BENCHMARK REGRESSION

Dependent Variable: Width of the Band	
Distance	6.44***
	(3.01)
Distance^2	-5.48***
	(-4.92)
Tariffs	1.02***
	(4.55)
Nominal exchange rate volatility	1.24***
	(14.63)
Observations	5,050
Countries	101
R^2	0.05

Notes:
1. Estimation method – ordinary least squares.
2. Constant included in the regression (not reported).
3. White heteroskedasticity-consistent t-statistics in parentheses.
4. ***, **, * denote significance at the 99%, 95%, and 90% levels.
5. Coefficients in rows 1, 2, 3, and 4 were multiplied by 10^6, 10^{10}, 10^3, and 10.
Source: see text.

TABLE 5 – TRADING FRICTIONS AND THE WIDTH OF THE BAND
IFS DATA

Dependent Variable: Width of the Band	IFS Annual	IFS Quarterly	IFS Monthly
Distance	23.86***	23.31***	15.95***
	(7.95)	(6.83)	(3.77)
Distance^2	-13.25***	-11.34***	-6.83***
	(-8.32)	(-5.99)	(-2.59)
Tariffs	2.53***	1.44***	1.77***
	(5.62)	(2.99)	(3.23)
Nominal exchange rate volatility	2.59***	4.56***	12.54***
	(12.57)	(6.75)	(8.81)
Observations	1,653	1,128	861
Countries	58	48	42
R^2	0.18	0.11	0.15

Notes:
1. Estimation method – ordinary least squares.
2. Constant included in the regressions (not reported).
3. White heteroskedasticity-consistent t-statistics in parentheses.
4. ***, **, * denote significance at the 99%, 95%, and 90% levels.
5. Coefficients in rows 1, 2, 3, and 4 were multiplied by 10^6, 10^{10}, 10^3, and 10.
Source: see text.

TABLE 6 - TRADING FRICTIONS AND THE WIDTH OF THE BAND: AN EXTENSION

Dependent Variable: Width of the Band						
Distance	6.28***	4.65**	6.72***	2.12	5.74***	1.11
	(2.94)	(2.05)	(3.04)	(0.91)	(2.59)	(0.45)
Distance^2	-5.21***	-4.67***	-5.61***	-3.55***	-5.17***	-2.90**
	(-4.69)	(-4.04)	(-4.93)	(-3.01)	(-4.53)	(-2.38)
Tariffs	0.93***	1.02***	1.00***	0.85***	1.07***	0.77***
	(4.11)	(4.56)	(4.44)	(3.76)	(4.66)	(3.26)
Nominal exchange rate volatility	1.25***	1.25***	1.24***	1.21***	1.22***	1.23***
	(14.74)	(14.76)	(14.64)	(14.30)	(14.48)	(14.41)
Landlocked	2.81***					2.81***
	(4.21)					(4.20)
Adjacency		-4.29**				-2.81
		(-2.16)				(-1.38)
Common language			0.54			0.74
			(0.60)			(0.81)
Preferential Trading Arrangement				-10.90***		-10.26***
				(-9.22)		(-8.32)
Currency union					-3.30*	-1.53
					(-1.85)	(-0.83)
Observations	5,050	5,050	5,050	5,050	5,050	5,050
Countries	101	101	101	101	101	101
R^2	0.05	0.05	0.05	0.05	0.05	0.06

Notes:
1. Estimation method – ordinary least squares.
2. Constant included in the regressions (not reported).
3. White heteroskedasticity-consistent t-statistics in parentheses.
4. ***, **, * denote significance at the 99%, 95%, and 90% levels.
5. Coefficients in rows 1, 2, 3, 4, and 5-9 were multiplied by 10^6, 10^{10}, 10^3, 10, and 10^2.
Source: see text.

TABLE 7 - MEAN ABSOLUTE DEVIATION, WIDTH OF THE BAND, AND ADJUSTMENT SPEED

Dependent Variable: Mean Absolute Deviation	
Width of the band (c)	0.54***
	(109.06)
Adjustment speed (λ)	0.11***
	(29.96)
Observations	5,050
Countries	101
R^2	0.69

Notes:
1. Estimation method – ordinary least squares.
2. Constant included in the regression (not reported).
3. White heteroskedasticity-consistent t-statistics in parentheses.
4. ***, **, * denote significance at the 99%, 95%, and 90% levels.
Source: see text.

TABLE 8 - TRADING FRICTIONS AND MEAN ABSOLUTE DEVIATION

Dependent Variable: Mean Absolute Deviation						
Distance	10.14***	8.94***	10.07***	6.46***	9.51***	5.31***
	(7.27)	(6.02)	(6.96)	(4.32)	(6.59)	(3.37)
Distance^2	-6.71***	-6.36***	-6.87***	-5.26***	-6.62***	-4.55***
	(-9.33)	(-8.46)	(-9.31)	(-6.94)	(-8.98)	(-5.81)
Tariffs	0.95***	1.03***	1.05***	0.88***	1.09***	0.84***
	(6.48)	(7.15)	(7.17)	(6.09)	(7.38)	(5.60)
Nominal exchange rate volatility	0.86***	0.86***	0.85***	0.83***	0.84***	0.84***
	(16.98)	(16.93)	(16.83)	(16.35)	(16.58)	(16.40)
Landlocked	2.66***					2.67***
	(6.53)					(6.58)
Adjacency		-3.24**				-1.65
		(-2.53)				(-1.31)
Common language			-0.43			-0.26
			(-0.76)			(-0.45)
Preferential Trading Arrangement				-9.66***		-9.10***
				(-11.55)		(-10.56)
Currency union					-3.71***	-1.89
					(-2.93)	(-1.51)
Observations	5,050	5,050	5,050	5,050	5,050	5,050
Countries	101	101	101	101	101	101
R^2	0.08	0.07	0.07	0.08	0.07	0.09

Notes:
1. Estimation method – ordinary least squares.
2. Constant included in the regressions (not reported).
3. White heteroskedasticity-consistent t-statistics in parentheses.
4. ***, **, * denote significance at the 99%, 95%, and 90% levels.
5. Coefficients in rows 1, 2, 3, 4, and 5-9 were multiplied by 10^6, 10^{10}, 10^3, 10, and 10^2.
Source: see text.

Figure 1: Illustration of the Band of Inaction

T=100, c=0.2, λ=-0.5, σ=0.2

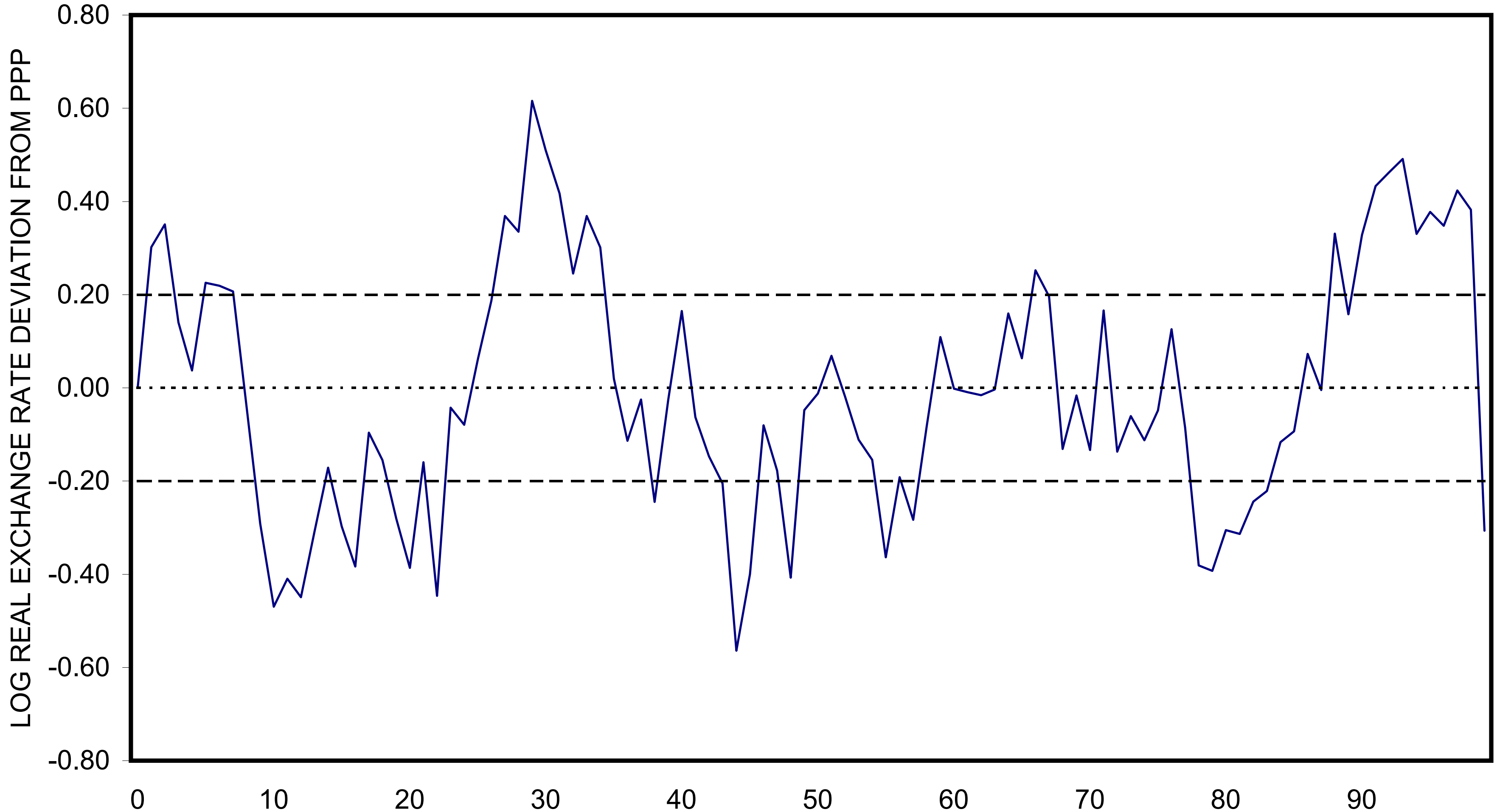

Figure 2: Histogram of the Estimated Width of the Band