Exchange Rates and Prices in the Netherlands and Britain over the Past Four Centuries

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Exchange Rates and Prices in the Netherlands and Britain over the Past Four Centuries

During the course of the last two decades, economists' views on exchange rate behavior and the performance of purchasing power parity have undergone a gradual but nevertheless substantial change. As the 1990s began, the consensus view was that real exchange rates simply were too variable and otherwise ill behaved for purchasing power parity to have any merit either as a predicative tool or in analysis of historical behavior. Today, as a result of the large body of supportive evidence amassed in the interim, most international economists see PPP as a useful first approximation, at least over the long run.[2]

How useful is, however, a question that continues to be debated. One issue that has been raised is whether the existing evidence is representative of behavior more generally. Sample selection bias, it has been argued, has resulted in overly optimistic conclusions about PPP, since much of the evidence in its favor has come from studies of countries at similar stages of economic development (Froot and Rogoff, 1995). The scope for real variables to operate in these samples has therefore been much more limited than in the population as whole, or so it has been claimed.[3] A closely related question concerns the actual effects of such variables on the PPP relationship – whether real variables such as productivity growth and the terms of trade do in fact cause changes in real exchange rates that are truly permanent, as theoretical discussions often assume, or merely persistent but in the end transitory. A third question is the effect of the exchange-rate regime, whether the regime itself matters and, if so, in which ways. Much of the recent evidence supporting PPP comes from studies using long historical time series. Without

[2] See, e.g., Diebold, et al, (1991), Lothian and Taylor (1996) and the reviews of this literature in Rogoff (1996), Taylor (2003) and Taylor and Taylor (2004) .

[3] On this issue see Taylor (2002) who uses a broad sample of countries and obtains results very similar to those obtained for the highly industrialized countries used in most other studies.

spelling out why differences in regime over such periods are likely to be a source of problems, a number of economists have asserted that they in fact are.

The problem in each of these instances is largely one of experimental design, of obtaining the appropriate data and of applying the appropriate t tests to investigate these issues. Standard time-series methods generally require long spans of data, often a century or more in length, simply to detect the mean-reverting behavior in real exchange rates indicative of long-run PPP (Lothian and Taylor, 1997). As the literature has evolved, the span of data used to test for mean reversion has increased. Many of the early studies used data from Lee (1978) who covers the period from 1900 to 1972. Subsequent research has extended the span covered to 1870. Taylor (2002), for example, provides data for twenty countries for this period. For the most part, the studies have found strong evidence of mean reversion.

Using such methods to test or otherwise evaluate how the behavior of real exchange rates may have changed through time – say, as a result of differences in monetary regimes – or to test the possible influence of slowly-evolving real factors on real exchange rates such as productivity growth differentials can require even longer samples. Lothian and Taylor (1996) looked at real exchange rate behavior for three economies, the US, the UK and France over the perspective of two centuries. This study is unique as it covers the modern and pre-modern eras.[1] This paper reports our initial findings using data for an even longer span. We collect exchange-rate and price-level data for the long period 1590-2009 for the Netherlands and United Kingdom (earlier the Dutch Republic and England), countries that at various times over this more than four century span have differed substantially in terms of the pace at which their economies were developing, have operated under a variety of exchange rate regimes, and have been subjected to an extremely wide variety of real shocks.

[1] The really long-run data is important for another reason as Engel (2000) shows that data spans of a century of more may not be enough to reject nonstationarity.

We find strong evidence supporting long-run PPP. In work, now underway we are investigating further the behavior of the real exchange in the period in the late decades surrounding the start of the nineteenth century. This period is somewhat problematic due to a variety of factors – both data-related and economic. The first potential data problem is the presence of a break in the nominal guilder-sterling exchange-rate series. We have accounted for this by using cross-rates derived from data on Swedish vs. Dutch and Swedish vs. British exchange rates from historical data in Edvinson (2010). A second data-related problem is the existence of multiple Dutch price series beginning in this period. We are currently in the process of rechecking both the exchange-rate and price data for this period and comparing them against alternative series. We are also extending our econometric work to control for the potential effects of two major economic factors operating during these years – the onset of the British industrial revolution and the invasion and takeover of the Dutch Republic by the French in 1795.

1. Theoretical considerations

In exchange rate theory, as elsewhere in economics, the distinction between nominal and real is of crucial analytical importance. In the simplest model, the nominal exchange rate is posited to respond fully to changes in monetary variables over the long run. The real exchange rate, in contrast, is viewed as depending solely on real variables such as the terms of trade and productivity growth over such long time horizons.

To see the relation between the nominal and real exchange rates and the link between them and purchasing power parity consider the following identity:

$$q_t \equiv s_t - p_{ne,t} + p_{uk,t} , \qquad (1)$$

where q_t is the log of the real exchange rate, s_t is the log of the nominal exchange rate, the foreign currency price of a unit of the domestic currency (here the guilder price of one pound

sterling), and $p_{ne,t}$ and $p_{uk,t}$ are the logarithms of the foreign (Dutch) and domestic (UK) price levels.

For purchasing power parity (PPP) to hold, in the sense of being a useful predictive device, q_t has to be relatively stable over the time horizon of interest. If it were perfectly so, then q_t would equal some constant θ, and we could rewrite (1) as:

$$p_{ne,t} - s_t = \theta + p_{uk,t}, \tag{2}$$

in which case the two price levels expressed in terms of a common currency – in this instance, sterling – are equalized up to the constant value θ.

Under floating exchange rates, PPP provides a description of nominal exchange rate behavior, with changes in the nominal exchange rate bearing a one-to-one relationship to changes in the log price level differential. In this case (2) can be written more conveniently as:

$$s_t = \theta + p_{ne,t} - p_{uk,t} . \tag{2a}$$

Under fixed exchange rates, s_t by definition is a constant, call it ε, and (2) can be rewritten as

$$p_{uk,t} = \lambda + p_{ne,t} , \tag{2b}$$

where $\lambda = \theta + \varepsilon$. Here PPP provides a description of international price behavior.

A stochastic version of equation (2) that can be used to investigate behavior under both types of regimes is:

$$pa_{ne,t} = \alpha_1 + \beta_1 p_{uk,t} + u_t, \tag{3}$$

where $pa_{ne,t} \equiv p_{ne,t} - s_t$, the exchange-rate adjusted Dutch price level, α and β_1 are coefficients to be estimated, t denotes the time period and u is an error term.

The first issue of interest is the behavior of that error term. For long-run PPP to hold the effects of shocks ultimately have to dissipate and $pa_{ne,t}$ and $p_{uk,t}$ have to be cointegrated. If u_t follows the autoregressive process

$$u_t = \rho\, u_{t-1} + \eta_t\,, \tag{4}$$

this implies a value of ρ less than unity. The second issue is the value of β_1, the coefficient of $p_{uk,t,}$. If β_1 equals unity then, the exchange-rate-adjusted log Dutch price level and the log UK price level will converge, and correspondingly, their algebraic sum, the real exchange rate, will revert to a constant mean value of α.

In principle, however, the real exchange rate can undergo permanent shifts. Factors such as differential rates of productivity growth, changes in the terms of trade and government intervention in trade have all been posited to have such effects. The fact that tests based on long time series data generally reject the hypothesis that $\rho = 1$ suggests, however, that the permanent components generally are small relative to the transitory components, though not necessarily zero.[2] One situation in which this is likely to be the case, and in which the transitory components therefore will dominate is when growth in money supply in one country has been both rapid and far in excess of growth in money supply in the other.

Historically such episodes have been of considerable, albeit sporadic, importance. As Officer (1982) has perceptively argued, purchasing power parity usually has come to the fore intellectually at precisely those times when money supply behaved erratically and PPP worked well empirically. This is true of its initial formulation in sixteenth century Spain by the priest moral theologians and philosophers associated with the University of Salamanca (Grice-

[2] The evidence using really long-run data is sparse. Lothian and Taylor (2008) find evidence that real income growth is associated movements in the real exchange rate using two centuries of data for the UK and US. Lothian (1997) finds a stronger effect for the Japanese/US real exchange rate.

Hutchison, 1952, 1975; Lothian, 1997) and of its subsequent pre-twentieth-century restatements, first by Gerard de Malynes in early Stuart England, then later in eighteenth century France and Sweden and finally during the Bullionist Controversies in early nineteenth century England and Ireland. All of these episodes had one thing in common.[3] In each, inflationary monetary shocks were a source of major disturbances, both to prices and to the exchanges. In Spain the inflow of specie from America was the principle source of the problem, in Tudor times the debased coinage, and in the other episodes the over-issuance of paper currency. In the twentieth century, the story has been much the same. The gold-produced inflation at the start of the century, the fiat-currency fueled increases in inflation in World War I and its aftermath, and the US-engendered inflation in the late 1960s and early 1970s all led to renewed interest in and restatements of, the PPP theorem.

The other situation in which (3) is apt to work well empirically is if the real factors usually regarded as sources of permanent shocks have effects that are merely persistent but not permanent. In such instances, they will not matter to any great extent empirically when viewed over very long time horizons.[4]

Even if real variables have a permanent impact on the equilibrium real exchange rate, relative PPP in the form of the following differenced version of equation (2) may hold over the long run:

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[3] One of the Salamncan writers, Martín Azpilcueta Navarro (1565), provided what arguably is the first statement of PPP and the quantity theory of money. He wrote:

> [O]ther things being equal, in countries where there is great scarcity of money all other saleable goods, and even the hands and labor of men, are given for less money than where it is abundant. Thus we see by experience that in France, where money is scarcer than in Spain, bread, wine, cloth and labor are worth much less. And even in Spain, in times when money was scarcer, saleable goods and labor were given for very much less tan after the discovery of the Indies, which flooded the country with gold and silver. The reason for this is that money is worth more where and when it is scarce than where it is abundant.

[4] This latter possibility has both theoretical and empirical appeal. It is one of the implications of the neo-classical growth model. It also is characteristic of the very long-term relative price series investigated by Froot, Rogoff and Kim (2001). They investigate the law of one price using English and Dutch commodity price data over seven centuries. They compare prices with silver ratios rather than the market exchange rates used in this study.

$$\Delta p_{ne,t} - \Delta s_t = \Delta p_{uk,t}. \quad (5)$$

This clearly would be the case if the real shocks affecting the real exchange rate had one-time effects. It also would be the case if the real shocks were periodic but had effects that over time proved small in magnitude relative to those produced by nominal monetary shocks.

The simplest way to test this version of PPP is to run regressions of the following general form and test the restrictions that $\alpha_2 = 0$ and $\beta_2 = 1$:

$$\Delta pa_{ne,t-k} = \alpha_2 + \beta_2 \Delta p_{uk,t-k} + v_{t-k}, \quad (6)$$

where $\Delta pa_{ne,t} \equiv \Delta p_{ne,t} - \Delta s_t$, the exchange-rate adjusted Dutch inflation rate, α and β_1 are coefficients to be estimated, t-k denotes the time period over which the data have been differenced and v is an error term.[5]

II. Empirical evidence

Our sample period begins in 1590, at the tail end of the price revolution that began in the early decades of the sixteenth century. During the years that follow the British and Dutch economies play a central role in the creation in the modern world. The Dutch economy is arguably the first modern economy (De Vries and Van der Woude (1997)) and England is the site of the industrial revolution. A catalogue of major historical events during these four centuries, events likely to give rise to real shocks of one sort or another, is lengthy indeed. In the purely economic realm, the period saw the rise of the Dutch Republic as a major trading nation

[5] See Flood and Taylor (1996) and Lothian and Simaan (1998) for applications of this test. Coakley, et al (2005) use an alternative, more elaborate set of tests.

and financial center, the subsequent industrialization of Britain beginning in the mid-eighteenth century and the later eclipse of Amsterdam by London as the seat of world finance.
The broader economic list includes in addition the historically unprecedented increases in standards of living over the period and profound shifts in industrial structure, earlier from agriculture as the dominant sector to manufacturing, and more recently from manufacturing to services. These countries also saw some of the most famous events in financial history. For example, Tulip mania strikes the Dutch Republic in 1619. The South Sea Bubble occurs in London in 1720 and so on. [6]

Politically these four centuries saw the rise and fall of the Dutch and British colonial empires, the start, end, and now in the past two decades gradual return to free trade. The many wars of the period include the two World Wars of the twentieth century, the English Civil War, the Thirty Years War, the four Anglo-Dutch Wars – three in the seventeenth century, the fourth in the eighteenth – the American Revolution, the War of Spanish Succession, and the Napoleonic Wars.

This extraordinary diversity in economic, and political experience, provides the opportunity for subjecting the basic theory of exchange rate behavior to a very rigorous test. Uncovering evidence that real exchange rates are well behaved across such diversity would provide strong testimony of the robustness of one of the simplest and most basic postulates of economic theory.

[6] The real shocks hitting the economies differ greatly over the pre and post modern period. Most notably, the British and to a lesser extent the Dutch suffered greatly from harvest failures due to weather shocks. England had severe harvest failures in 1596, 1597, 1661, 1693, 1697, 1709, 1740, 1756, 1771, 1772, 1773 and 1792. Other real shocks include the plague.

II.A. Data

The data we use are annual data for consumer prices and the guilder-sterling exchange rate. We describe these data and their sources in greater detail in an appendix. As noted earlier, Lothian and Taylor (1996) is the previous long-run study of PPP spanning the modern and pre-modern eras. Our price data differ in two respects. First, our price indices are consumer price indices whereas Lothian and Taylor (1996) are wholesale price indices. In addition, our indices cover identical commodities and have the same weights for most years.

Figure 1 provides an overview of these data. Plotted there are annual observations of the log real exchange rate and the logs of the two countries' price indices for the period 1590 to 2009. What immediately strikes the eye is the contrast between the behavior of the two price series and the real exchange rate. Over the full sample period and for much of the four centuries individually prices are noticeably more variable than the real exchange rate and in the last century of the period with its two bouts of wartime inflation and the Great Inflation of the 1970s and early '80s markedly so. This difference in the behavior of the two nominal series and the real series is a small but, we believe, rather powerful bit of evidence supportive of PPP as a long-run equilibrium condition. An additional feature of the data brought out in Figure 1 is the sometimes substantial variations in the real exchange rate over shorter, but nevertheless rather lengthy, subperiods.

Plotted in Figure 2 are centered nine-year standard deviations of the logarithms of the real exchange rate over the full sample period. Throughout we see episodes of high real exchange rate variability followed by other, generally longer, episodes of lower variability. The recent float is merely the latest such high-variability episode. Contrary to what many seem to believe, it does not appear to be at all unique either from the standpoint of the amplitude of real rate

fluctuations or their duration. The Napoleonic War period, the decade or so surrounding the British resumption of specie payments, and several earlier episodes (1646-57 and 1710-17, in particular) all saw real rate fluctuations of rather substantial magnitude. In the twentieth century, the World War I years, much of the inter-war period, the World War II years and the end of Bretton-Woods era were all marked by very similar, and in the inter-war case actually much greater, variability of q than during the recent float. Indeed, if any era appears somewhat different from the rest of the sample it is not the current floating-rate period per se, but the twentieth century as a whole vis-à-vis earlier centuries.

For the long period in which the two countries were on specie standards, nominal exchange rates showed relatively little variation. Fluctuations in q during this span of years, which encompassed the bulk of the period from the 1590 until World War I, with few exceptions were due largely to fluctuations in the relative price level. After World War I, however, the picture changed and changes in the nominal exchange rate assumed a more important role.

II.B. Evidence from Rates of Growth

Figure 3 and Tables 1, 2 and 3 provide additional information on the phenomena identified above. Shown in the four panels of Figure 3 are scatter plots of changes in the logarithm of the exchange-rate adjusted Dutch price level against changes in the logarithm of the British price level over various time horizons. Figure 3a is based on the yearly data; Figure 3b on non-overlapping five-year averages of the yearly data; Figure 3c on similar ten-year averages and Figure 3d on similar twenty-year averages. Table 1 reports summary statistics for the four sets of inflation series and their algebraic sums, the rate of the change of the real exchange rate.

Table 2 reports the results of two-way analyses of variance of the four real-exchange-rate series while Table 3 reports the regression results for the corresponding inflation-rate data.

We show as a point of reference in each of thse four charts the regression of Dutch against UK prices expressed in the same currency. Three features of these charts stand out. The first is the progressive decrease in the variability of both inflation series in going from the yearly data to the twenty-year averages. The second is the corresponding increase in the strength of the relationship between them. The third is the extremely close relationship observed in the plot of the twenty-year averages in Figure 3d.

The standard deviations and the ranges reported in Table 1 simply add a bit of numerical precision to some of the impressions gleaned from the charts. Comparing the five-year averages to the yearly data, we see a close to halving of the standard deviations of the inflation rates and an almost two-thirds reduction in the standard deviation of the rate of growth of the real exchange rate. Comparing the standard deviations of twenty-year averages and the yearly data, we see even larger reductions – reductions of two thirds in the case of the inflation rates and a reduction of over ninety per cent in the case of real-exchange-rate growth. The proportionate decreases in variability as measured by the ranges are much greater still.

The decrease in variability that comes with averaging very likely has two sources. The first and more obvious is the mitigation of the effects of measurement error, both in the price series and the exchange rate series. The second is the canceling out of the effects of other stochastic factors that influence real exchange rates over shorter but not longer periods..

A simple way to test PPP centers on these differences in variability in the averaged and the raw yearly data. To that end we conducted three two-way analyses of variance using the three respective bodies of averaged data as the "groups." We report these results in Table 2. In

none of the three is the difference in the period averages even close to statistically significant even at the ten per cent level as measured by the associated F tests.

In Table 3, we report the results of OLS regressions of the one inflation rate on the other for the yearly data and for the three bodies of averaged data. Given what are liable to be sometimes sizable measurement errors in these data, particularly in the earlier centuries, we ran these regressions two ways, first with Δpa_{ne} as the dependent variable and Δp_{uk} as the independent variable and then with the two reversed.

The estimated slope coefficients in all four regressions are positive and statistically significant. The relationship in the yearly data, however, is very weak, an R^2 of .13 and estimated slope coefficients are between .3 and .4. But with averaging the picture improves dramatically. The slope coefficients and R^2s progressively increase and the standard errors of estimate progressively decrease. In the regressions using five year averages, the R^2 rises to .54 and the estimated slope coefficients are .7 and .8. The standard errors fall to less than half their values in the yearly regressions. In the regressions using ten-year and twenty-year averages, the results improve further. Three of the four estimated slope coefficients are both close to and insignificantly different from unity. The fourth is over .8. The R^2s are .78 and .93, respectively. The standard errors of the regressions in going from the five-year to the ten-year to the twenty-year averages are halved and then halved again. Further consistent with the theory, the estimated intercepts in all of the regressions with the averaged data are close in value to and insignificantly different from zero.

In short, the regressions like the scatter plots displayed in Figure 2, provide rather strong evidence in support of relative PPP as a description of long-run equilibrium. That they do so over such long and economically and socially diverse period strikes us as nothing short of remarkable.

Whatever the shocks to the level of the real exchange rate, they matter very much less when the data are differenced and viewed over long horizons.

We now turn to an analysis of the data in level form.

II.B. Evidence from levels of the data

Table 4 presents further evidence on long-run behavior of the real exchange rate. The particular question that is addressed is whether the real exchange rate is stationary or contains a unit root. This, in turn, amounts to a test of cointegration between pa_{ne} and $p_{uk,}$ given the constraint of a unitary coefficient of cointegration.

The augmented Dickey-Fuller test used to test the null hypothesis of a unit root is based on the following regression:

$$\Delta q_t = \mu + \lambda q_{t-1} + \Delta q_{t-1} + \ldots + \Delta q_{t-k} + u_t \,. \qquad (8)$$

The question at issue here is whether λ is significantly less than zero. If it is, the unit root null can be rejected.

The results of this test and of a similar battery of unit root tests applied to pa_{ne} and p_{uk} are presented in Table 4. In each instance we conducted both augmented Dickey-Fuller tests and Phillips-Perron tests for both the levels and first differences of the variables. The Phillips-Perron tests have the advantage of being robust in the presence of heteroskedasticity, which over this long historical period is liable to pose a problem. The results for both price series were similar. In both cases the unit root null could be rejected for the first differences but not for the levels of the variables. The tests suggest, therefore, that both variables are I(1), and hence integrated of

the same order. This in turn is a necessary condition for them to be cointegrated and for the unit-root tests of the real exchange rate to make sense.

The results of the unit root tests for the real exchange rate are reported in the right-most column of Table 4. Using both the augmented Dickey-Fuller test and the Phillips-Perron test we can reject the unit-root null both for q_t and for its first difference. As a first approximation, therefore, q_t appears to be mean reverting and $pa_{ne,t}$ and $p_{uk,t}$ to be cointegrated.

II.C. Effects of other variables on the real exchange rate

A final set of issues is the potential effect of other factors -- real variables and the exchange-rate regime itself -- on the behavior of real exchange rates. For the long span of years covered by these data there are no readily available continuous real data series for national income or the external terms of trade. To see whether real variables might have exerted an influence, we have instead used dummy variable regressions. We generated a set of dummy variables for the eight fifty-year subperiods from 1590 to 1989 and for the twenty-year period thereafter and included eight of the nine as additional variables in a regression of q_t on q_{t-1}. These regressions took the form:

$$q_t = \mu + \rho q_{t-1} + \psi_1 D2 + \ldots D9\psi_9 + u_t, \qquad (9)$$

where the D's are the dummy variables for the second through the eighth 50-year subperiod and for the twenty-year period following, μ, ρ and the ψ's are coefficients to be estimated and u_t is a disturbance term.

The results of this regression are summarized in Table 5. The DF test of the hypothesis $\rho = 1$ is a test for unit root in q; tests of the hypotheses that the ψ's are zero are tests for the absence of shifts in the mean of q. As earlier, we can reject the unit-root null. However, it is also possible to reject the hypothesis that the intercept of the regression is unchanged through time. We see a sizable upward shift in the real exchange rate near the end of the eighteenth century, and hence a increase in the real value of sterling.[7] The real appreciation is persistent with some evidence that it fades towards the middle of the twentieth century.

Later we shall look more closely at the real events that could explain the real appreciation of Sterling. In any event, as a comparison of the regressions with and without the dummy variables indicates, there is only a slight improvement in fit between the one and the other – a reduction in the standard error of the regression of only .003.

An additional point to notice here is the lower estimated autoregressive coefficient in the regressions including the dummy variables. In the regression without dummy variables the coefficient was .904, implying a half life of adjustment to equilibrium of seven years. In the regression including the dummies the estimated coefficients, in contrast, is .745 implying a half life of adjustment of two and a half years.

The difference between the two sets of estimates suggests that one reason for the generally slow estimated speeds of adjustment found in most studies may be failure to account for shifts of the sort seen in these data. In the presence of persistent (though not permanent) shocks to the real exchange rate, simple autoregressive models like those used here and in many other empirical studies of PPP, will be subject to specification bias and will imply slower adjustment to transitory shocks than is actually the case.

[7] David Papell in a series of coauthored papers has documented similar phenomena for other time periods and other exchange rates. See, for example, Culver and Papell (1995).

II.D The real appreciation of the pound

What explains the real appreciation of sterling for the late eighteenth century? There are two candidates. The first is the British industrial revolution. The second is the eclipse of Amsterdam as an important financial center as the Dutch Republic is occupied and looted by the French.

A more precise dating of the break points will help us narrow the possibilities. To find the break date (or dates), we use the Bai and Perron (1998, 2001, 2003a and 2003b) test. We apply this test to the log of the real excahnge rate as well as to logs of relative rents. We assume that the logs both series are stationary and follow simple AR(1) processes with time varying intercepts. The Bai and Perron approach first tests the hypothesis that there are no breaks. If it rejects the null it then moves to determining the number of breaks using sequential tests. The advantage of their approach is that it allows for multiple structural breaks and it determines the dates of the breaks endogenously. It also allows for serial correlation in the error terms, and different distributions for the data and errors across segments.

The Bai and Perron test finds just one break for the guilder/pound real exchange rate. This occurs in 1771 where there is a permanent increase in the British price level relative to the Dutch. Most accounts date the decline of Amsterdam as a financial sector to the years after 1780 and the American declaration of independence and the final Dutch war with Britain. The real appreciation also occurs well before the French invasion in 1795.

In sum, the timing of the real appreciation is consistent with the industrial revolution. One problem with this explanation is that if the real appreciation of the pound is due to

economic growth in Britain why we do not see a corresponding appreciation of the guilder during the Dutch Golden age where the Dutch income lead is larger. [8]

The Balassa-Samuelson model suggests a possible explanation. In the Balassa-Samuelson setting, changes in the real exchange rate occur when there are differential rates of factor productivity growth across sectors. We expect a real exchange rate appreciation if tradables experience higher rates of factor productivity than other sectors and vice versa. Suppose that growth in the Golden Age of the Dutch Republic is extensive in that it occurs in all sectors of the economy. The Dutch had an efficient agriculture during the Golden Age but they also innovated in financial services and transportation. In this case, the large income leads enjoyed by the Dutch during the Golden Age need not have led to a real exchange rate appreciation.

Suppose now that the industrial revolution in England is associated with increases in total factor productivity specific to manufacturing and mining and to a lesser extent agriculture. In the Balassa-Samuelson setting, this would lead to a real appreciation of the pound.

We can shed some further light on this question by looking at behavior of housing rents. Our price indices contain rents for Amsterdam and London respectively. Figure 4 gives relative rents expressed in sterling from 1590 to 1910 where 1788 = 100.

[8] Broadberry et al (2010) summarize what we know about long-run growth for England and Holland. After starting out with fairly equal income per capita, Holland strides ahead after 1570. By 1650, the peak of the Dutch Golden age, English income is down to one third of Dutch levels. English growth quickens after 1650 and particularly after 1800 but at its height British lead over the Dutch during the nineteenth century was probably only thirty percent.

The results show little change in the ratio of rents in London to Amsterdam during the Dutch Golden age. We see what appears to be a break in the series in the later eighteenth century. By 1870, London rents had increased fourfold relative to Amsterdam.[9]

III. Conclusions

The principal conclusion of this study is the resiliency of the simple purchasing-power-parity model and relatedly, of the law of one price at the macroeconomic level. Perhaps not surprisingly, both take some a few blows during this close to four-century-long sample period. In the end, however, they emerge surprisingly unscathed. Real factors, which over this long span of years have undergone truly major changes, appear at times to have had some effects on real exchange rates and hence PPP, but these effects do not seem to have lasted. As a long-run equilibrium condition PPP holds up remarkably well.

In on-going work, we are looking more closely at the reasons for departures from PPP that we have uncovered and at possible differences across exchange-rate regimes. We are also checking and reexamining our basic data for possible inconsistencies.

[9] Applying the Bai and Perron procedure we find a single break. This occurs in 1788, similar to the break for the overall price level considered earlier.

Appendix A: Data and Sources

Prices.

Our starting point is Allen (2001) who compares price levels across European cities using consumer price indices with a common set of items. He provides price data from 1264 to 1830 for England (London) and 1500 to 1910 for Holland (Amsterdam).

We modify his index in two ways. Allen (2001) compares price levels with a pre-modern basket that excludes rent. We change his weights make them more representative of consumption patterns in England and the Netherlands for more recent. Below are our common weights for 1590 to 1810 for the Dutch and British consumer price indices.

Table A
Expenditure Weights 1590-1820

Bread	36.82
Beans	0.57
Meat	11.78
Butter	8.10
Cheese	2.21
Sugar	4.53
Eggs	1.00
Beer	11.00
Fuel	4.00
Light/Soap	1.00
Clothing	8.00
Rent	11.00
Total	100.00

The weights are from Feinstein (1998) with some modifications introduced by Allen (2007). The weights are representative of consumption patterns for unskilled English workers around 1780.

England/UK

1590-1820 We calculate the CPI using price data from Allen (2001) supplemented to include sugar and rent using the weights in Table A. *Sugar***:** 1590 to 1659 is from the data appendix to Clark (2005). We use Allen (2001) thereafter. *Rent* is from Clark (2002) and relates to London. He provides quality adjusted rents from 1640. We use average rents for London before 1640. We splice the London series to quality controlled rents from 1640. Clark's evidence suggests that quality did not change between 1590 and 1640.

Our CPI accords closely with Allen (2001) between 1590 and 1820. The new CPI also is close to Allen (2007) broader based indices between 1780 and 1830. It is also close to Officer (2009).

1820-1869: Allen (2007). The commodity coverage and weights from Allen (2007) are almost identical to those used our CPI from 1590 to 1810.

1870-2008: Officer (2009) [10]. Officer constructs his series using Feinstein's (1991, 1995, 1998) CPI for most of the period. He uses the official UK CPI for recent years.

2. Holland/Netherlands

1590-1870: The source for the individual price data is Allen (2001). We use the weights in Table A. We add rent and sugar. Rent is from Van Zanden (2005) who adjusts for quality change. The rents refer to Amsterdam. Sugar prices to 1800 are from Allen (2001). Afterwards, they are from Van Riel (2008). Allen has no data on clothing after 1799. We take these prices from Van Riel (2008).

Our Dutch CPI differs from standard Dutch CPI's such as Van Riel (2008) after 1826. What explains the different trends? Closer investigation suggests that English and the Dutch CPI's differ as the Dutch CPI uses much broader commodity coverage. The weights in the Dutch CPI are also very different. For Van Riel (2008) the bread share is 0.20 while our index is 0.37. Meat is 0.05 while our index is 0.12. Beer is only 0.008 in Van Riel while it is 0.10 in our weights.

1870-1910: Given the large differences in weighting and coverage between the Dutch and the English CPI, we calculated a new CPI for the Netherlands using the same weights as Feinstein (1991) uses for England while our underlying Dutch data is from Van Riel (2008).

The weights in the revised Dutch index are as follows.

Table A
Dutch Weights 1871-1910

Bread	27.36
Beans	0.42
Meat	8.75
Butter	6.02
Cheese	1.64
Sugar	3.37
Eggs	0.74
drink	14.73
Tobacco	3.27
clothing	7.80
cleaning items	0.90
Fuel	3.91
Light	0.69
Furniture etc	3.00
Travel	4.30
Other services	4.40
Rent	8.70
Total	100.00

The weights come from Feinstein (1991) are identical to those in the English CPI.

1910-2006: Van Zanden (2010)

[10] http://www.measuringworth.com/ukearncpi/

Exchange rates

The exchange rate data for the period 1590-1899 were provided by Global Financial Data in an Excel file and were taken by them from Nicolass W. Posthumus, *Inquiry into the history of prices in Holland*, Leiden: E. J. Brill, 1946-64 and Jürgen Schneider, Oskar Schwarzer and Friedrich Zellfelder. *Wahrungen der Welt*, Stuttgart: F. Steiner, 1991. We cross checked these data against those in John J. McCusker, *Money and Exchange in Europe and North America, 1600-1775 A Handbook*, Chapel Hill: University of North Carolina Press, 1978. Exchange rates for the period 1900-1970 were derived as cross rates from dollar-sterling and guilder-dollar rates provided by Phillipe Jorion. Observations for 1797 to 1799 were missing. We made alternative estimates using Swedish-Dutch and Swedish-British exchange rates reported in Rodney Edvinsson (2010) "Foreign exchange rates in Sweden 1658-1803," in Rodney Edvinsson, Tor Jacobson, and Daniel Waldenström (eds.), *Monetary and Financial Statistics for Sweden: Exchange rates, prices, and wages, 1277-2008*, Sveriges Riksbank, Tables A5.23 and A5.24. Data for 1971 to 1998 are cross rates derived from the U.S. dollar rates reported in the *International Financial Statistics* and for the period thereafter using the guilder-euro conversion factor and euro exchange rates from that publication.

References

Allen, Robert C. 2001. The Great Divergence in European Wages and Prices from the Middle Ages to the First World War. *Explorations in Economic History* 38, 411-447.

Allen, Robert C., 2007. Pessimism Preserved: Real Wages in the British Industrial Revolution. Oxford University, Department of Economics, Working Paper 314.

Bai, J. and P. Perron (1998) "Estimating and Testing Linear Models with Multiple Structural Changes" Econometrica, 66: 1383-1414

Bai, J. and P. Perron (2001) "Multiple Structural Change Models: A Simulation Analysis" Unpublished

Bai, J. and P. Perron (2003a) "Computation and Analysis of Multiple Structural Change Models" Journal of Applied Econometrics, 18: 1-22

Bai, J. and P. Perron (2003b) "Additional Critical Values for Multiple Structural Change Tests" Econometrics Journal, 6: 72-78

Coakley, Jerry, Robert P. Flood, Ana M. Fuertes and Mark P. Taylor, Purchasing power parity and the theory of general relativity: the first tests, *Journal of International Money and Finance* 24 (2005) 293-316

Carlos, A, and L. Neal (2011) "Amsterdam and London as Financial Centers in the Eighteenth Century," Financial History Review 18 (2011), 21-46.

Clark, Gregory (2002). "Shelter from the Storm: Housing and the Industrial Revolution, 1550-1909," *Journal of Economic History*, Vol. 62, pp. 489-511.

Clark, Gregory (2005). "The Condition of the Working Class in England, 1209-2004," *Journal of Political Economy*, Vol. 113, pp. 1307-1340.

Culver, Sarah E. and David H. Papell, 1996. "Real Exchange Rates under the Gold Standard: Can They Be Explained by the Trend Break Model?" *Journal of International Money and Finance* 14, 539-548.

Dehing, P. and M.'t Hart. 1997. Linking the fortunes: currency and banking, 1550–1800. In: t Hart, M., Jonker, J., van Zanden, J.L. (Eds.), *A Financial History of the Netherlands*. Cambridge University Press, Cambridge and New York, pp. 37–63.

de Vries, J., van der Woude, A. (1997). *The First Modern Economy: Success, Failure, and Perseverance of the Dutch Economy, 1500–1815*. Cambridge University Press, New York.

Diebold, Francis X., Stephen Husted and Mark Rush. 1991."Real Exchange Rates under the Gold Standard," *Journal of Political Economy.* 99, 1252-71
Engel (2000) shows that data spans of a century of more may not be enough to reject nonstationarity.

Edvinsson, Rodney, (2010) Foreign exchange rates in Sweden 1658-1803, in Rodney Edvinsson, Tor Jacobson, and Daniel Waldenström (eds.), *Monetary and Financial Statistics for Sweden: Exchange rates, prices, and wages, 1277-2008*, Sveriges Riksbank

Einzig, Paul. 1970. *A History of Exchange Rates*, second ed., London: St. Martins Press.

Engel, C. 2000. Long-Run PPP May Not Hold After All. *Journal of International Economics*.. 51; 243-273

Evans, Martin D.D. and James R. Lothian (1993) "The Response of Exchange Rates to Permanent and Transitory Shocks under Floating Exchange Rates," *Journal of International Money and Finance* 11, 563-586.

Feinstein, Charles H. 1972. *National Income, Expenditure and Output of the United Kingdom, 1855-1965.* Cambridge: Cambridge University Press, 1972.

Feinstein, Charles H. (1991). "A New Look at the Cost of Living, 1870-1914." In James Foreman-Peck, ed., *New Perspectives on the Late Victorian Economy: Essays in Quantitative Economic History, 1860-1914*, pp. 151-179. Cambridge: Cambridge University Press.

Feinstein, Charles H. (1995). "Changes in Nominal Wages, the Cost of Living and Real Wages in the United Kingdom over Two Centuries, 1780-1990." In P. Scholliers and V. Zamagni, eds., *Labour's Reward: Real Wages and Economic Change in 19th and 20th-Century Europe*, pp. 3-36, 258-266. Aldershot: Edward Elgar.

Feinstein, Charles H. (1998). "Pessimism Perpetuated: Real Wages and the Standard of Living in Britain during and after the Industrial Revolution." *Journal of Economic History* 58 (September), pp. 625-658.

Feaveryear, Albert.1963. *The Pound Sterling*, second ed. Oxford: Clarendon Press, 1963.

Flood, R.P., Mark P. Taylor. 1996. Exchange rate economics: what's wrong with the conventional macro approach? In: Frankel, J.A., Gallia, G., Giovanni, A. (Eds.), *The Microstructure of Foreign Exchange Markets*. Chicago University Press, Chicago.

Froot, Kenneth and Kenneth Rogoff. 1995. Perspectives on PPP and long-run real exchange rates. In *Handbook of International Economics* 3, ed. G.M. Grossman and K. Rogoff.

Froot, Kenneth, Michael Kim and Kenneth Rogoff, 2001. "The Law of One Price over 700 Years," Unpublished working paper, Harvard University.

Grice-Hutchison, Marjorie, *The School of Salamanca: Readings in Spanish Monetary Theory, 1544-1605*. Oxford: Clarendon Press, 1952.

Grice-Hutchison, Marjorie, *Early Economic Thought in Spain, 1177-1740*, London: Allen and Unwin, 1975.

Hamilton, James D. *Time Series Analysis*. Princeton: Princeton University Press, 1994.

International Institute of Social History, web page entitled "Value of the Guilder / Euro." http://www.iisg.nl/hpw/calculate.php, data downloaded January 26, 2009.

Israel, Jonathan I. *The Dutch Republic: Its Rise, Greatness and Fall, 1477-1806*. Oxford: Clarendon Press, 1995.

Jastram, Roy W. 1977. *The Golden Constant*, New York: John Wiley and Sons.

Kindleberger, Charles P. 1996. *World Economic Primacy*. Oxford and New York: Oxford University Press.

Lee, M. H., *Purchasing Power Parity* (New York: Marcel Dekker, 1978).

Lothian, James. 1990. "A century plus of Japanese exchange rate behavior". *Japan and the World Economy* 2, 47-50.

Lothian, James R. 1997. "What Salamanca scholastics can teach our social thinkers today," *The Brandsma Review*, 29, 1-4

Lothian, James R. and Mark P. Taylor, 1996."The Recent Float from the Perspective of the Past Two Centuries," *Journal of Political Economy*, June, 104: 488-509.

Lothian, James R. and Mark P. Taylor, 1997. "Real Exchange Rate Behavior," *Journal of International Money and Finance*, December, 15: 945-954.

Lothian, James R., and Mark P. Taylor."2008. Real Exchange Rates Over the Past Two Centuries: How Important is the Harrod-Balassa-Samuelson Effect?" *Economic Journal,* October, 118: pp. 1742-1763.

Lothian, J. R., Simaan, Y., 1998. International financial relations under the current float: Evidence from panel data. *Open Economies Review* 9, 293–313.

Mitchell, B. R. 1975. *European Historical Statistics, 1750-1970.* New York: Columbia University Press.

Officer, Lawrence. 1982. *Purchasing Power Parity and Exchange Rates: Theory, Evidence and Relevance*, Greenwich, CT: JAI Press.

Officer, Lawrence H, "What Were the UK Earnings and Prices Then?" MeasuringWorth, 2008. URL: http://www.measuringworth.org/ukearncpi/ data downloaded January 26, 2009.

Ó Gráda, Cormac. 2005. The Tortoise and the Hare: Economic Growth in Britain and the Netherlands c. 1500-1800. UCD Centre for Economic Research, Working Paper WP05/24.

Rogoff, Kenneth. 1996. The purchasing power parity puzzle. *Journal of Economic Literature* 34, 647-68.

Taylor, Alan (2002), "A Century of Purchasing-Power Parity," *Review of Economics and Statistics*, 84, 139-150.

Taylor, Alan and Mark Taylor. 2004. The purchasing power parity debate. *Journal of Economic Perspectives* 18, 135-58

Taylor, Mark P. 2006. Real exchange rates and Purchasing Power Parity: mean-reversion in economic thought Applied Financial Economics, 2006, 16, 1–17

Taylor, Mark P. 2003. "Purchasing Power Parity," *Review of International Economics*, Issue 3, 11, 436–452.

Van riel (2008) "Constructing the nineteenth-century cost of living deflator (1800-1913)" Working document project on the reconstruction of the national accounts of the Netherlands http://www.iisg.nl/hpw/brannex.php

Van Zanden, J. (2005) "What happened to the standard of living before the Industrial Revolution? New evidence from the western part of the Netherlands." In *Living Standards in the Past: New Perspectives on Well-Being in Asia and Europe*, edited by Robert C. Allen, Tommy Bengtsson, and Martin. Dribe, 174-194, Oxford: Oxford University Press

Table 1: Summary statistics for rates of change of prices and the real exchange rate, 1590-2009

	Yearly data			5-year averages			10-year averages			20-year averages		
Variable	p_{uk}	pa_{ne}	**q**	p_{uk}	pa_{ne}	**Q**	p_{uk}	pa_{ne}	**q**	p_{uk}	pa_{ne}	**q**
Minimum	-0.227	-0.342	-0.390	-0.091	-0.078	-0.090	-0.031	-0.031	-0.048	-0.018	-0.023	-0.010
Maximum	0.278	0.287	0.273	0.147	0.144	0.057	0.118	0.139	0.033	0.094	0.093	0.014
Range	0.629	0.564	0.663	0.238	0.222	0.147	0.150	0.170	0.081	0.112	0.116	0.025
Std Dev	0.070	0.080	0.086	0.037	0.040	0.028	0.030	0.031	0.015	0.025	0.020	0.007

Table 2. Analyses of variance of the rate of change of the real exchange rate

Source of variation	Sums of squares	DF	Mean squares
5-year averages			
Period averages	0.363	83	0.004
Error	3.077	334	0.009
Total	3.440	417	
F ratio			0.475
10-year averages			
Period averages	0.094	41	0.002
Error	3.347	376	0.009
Total	3.440	417	
F ratio			0.255
20-year averages			
Period averages	0.023	20	0.001
Error	3.418	397	0.009
Total	3.440	417	
F ratio			0.130

The F test is based on the ratio of the mean square for the period averages to the mean square error. It tests the hypothesis of no differences in the period averages.

Table 3. Regressions of rates of change, 1590-2008

Data	Variables				R^2
	Dependent	Constant	$\Delta\ln(p_{ne}/S)$	$\Delta\ln(p_{uk})$	SEE
Yearly	$\Delta\ln(pa_{ne})$	0.007		0.416	0.129
		1.89		7.17	0.076
	$\Delta\ln(p_{uk})$	0.008	0.311		0.129
		2.70	7.86		0.065
5-year	$\Delta\ln(pa_{ne})$	0.002		0.792	0.542
		0.63		9.8	0.027
	$\Delta\ln(p_{uk})$	0.004	0.684		0.542
		1.47	9.80		0.025
10-year	$\Delta\ln(pa_{ne})$	0.001		0.918	0.776
		0.33		11.77	0.015
	$\Delta\ln(p_{uk})$	0.002	0.845		0.776
		0.88	11.76		0.014
20-year	$\Delta\ln(pa_{ne})$	-0.001		0.985	0.925
		-0.03		15.31	0.007
	$\Delta\ln(p_{uk})$	-0.001	0.940		0.925
		-0.58	15.30		0.007s

Note: t statistics are immediately below the coefficients.

Table 4. Unit root tests for the real exchange and its components

Tests	$pa_{ne,}$	$p_{uk,t}$	q_t
Levels			
ADF	3.06	3.00	-3.56***
P-P	3.58	3.64	-4.19***
First differences			
ADF	-15.81***	-16.49***	-18.60***
P-P	-15.61***	-16.52***	-30.17***

Note: P-P is the Phillips-Perron test statistic and ADF the augmented Dickey-Fuller test statistic. The .01, .05 and .10 critical values for these tests are -3.446; -2.868 and -2.570, respectively. The symbol *** denotes significance at the .01 level or better. We chose log length using the Schwarz criterion.

Table 5. Real exchange rate regressions

		1640	1690	1740	1790	1840	1890	1940	1990	RSQ
Constant	**q_{t-1}**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**SEE**
-0.0020	0.745	0.001	-0.021	-0.011	0.101	0.059	0.068	0.019	0.013	0.83
-0.002	23.26	0.06	-1.33	-0.71	5.08	3.26	3.77	1.17	0.60	.080
0.001	0.904									0.82
4.704	43.57									.083

Note: D2 to D8 are dummy variables taking the value 1 for 50-year periods beginning on the dates indicated in the row above while D9 is a dummy variable for the 20-year period beginning in 1990 and are zero otherwise; t values are beneath the coefficients.

Figure 1
Netherlands and UK prices and real exchange rates 1590-2009

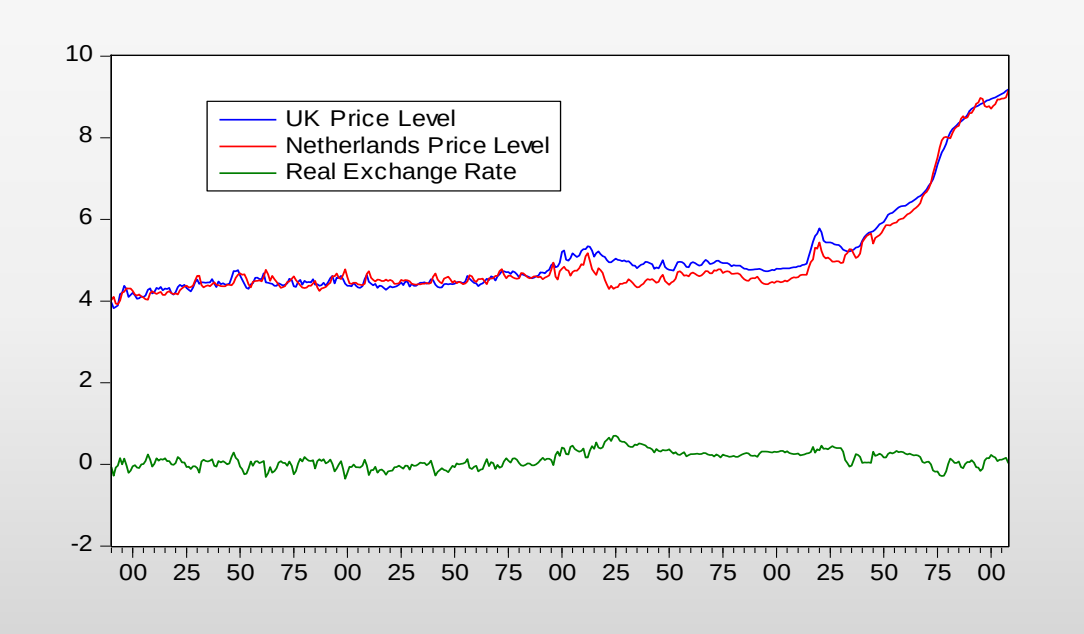
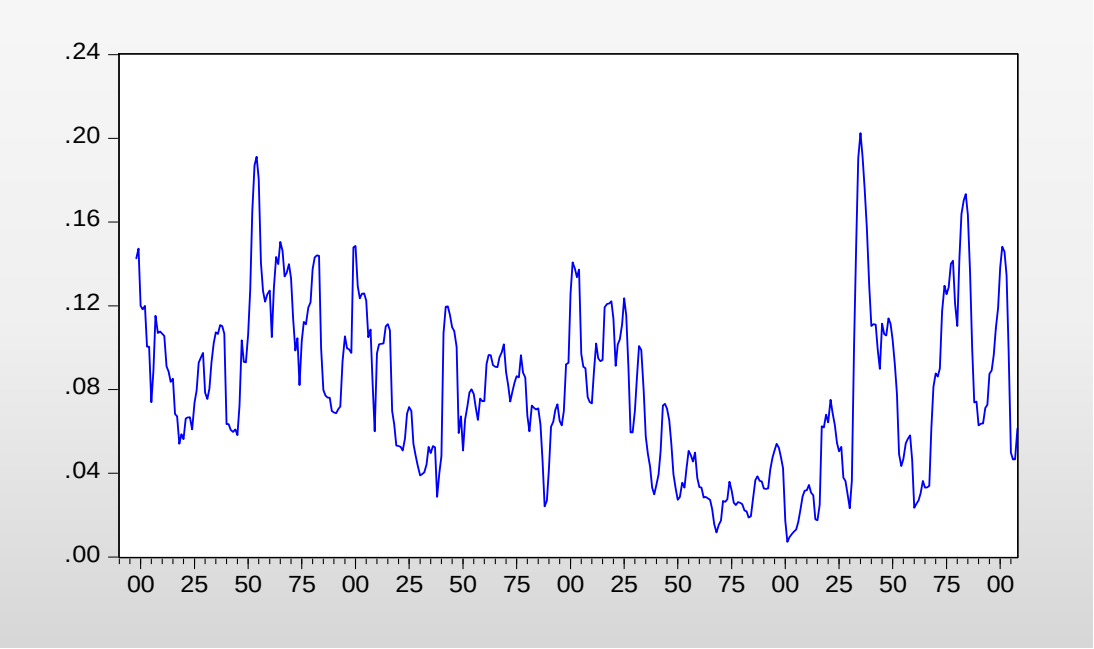


Figure 2
Centered 9-year moving standard deviation of the real exchange rate



Rates of Growth, 1590-2009
Inflation: Adjusted Dutch vs. British

Figure 3a
Annual data

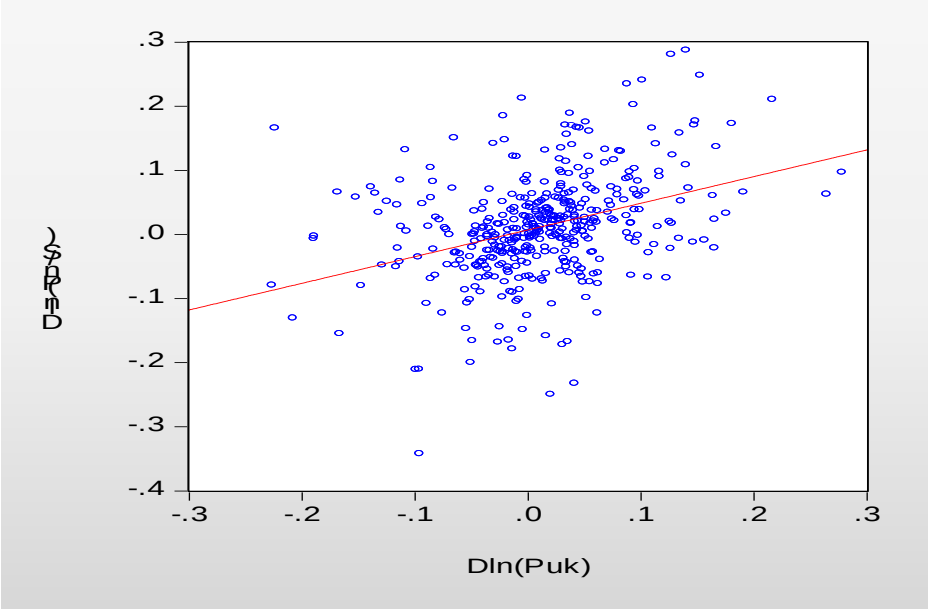


Figure 3b
5 year Averages

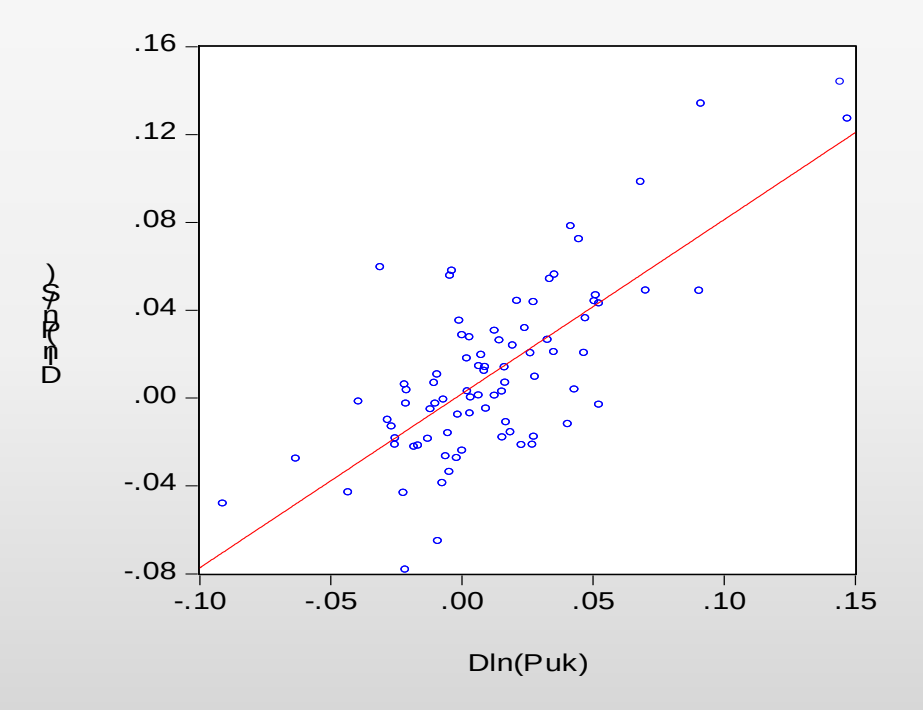


Figure 3c
10-year averages

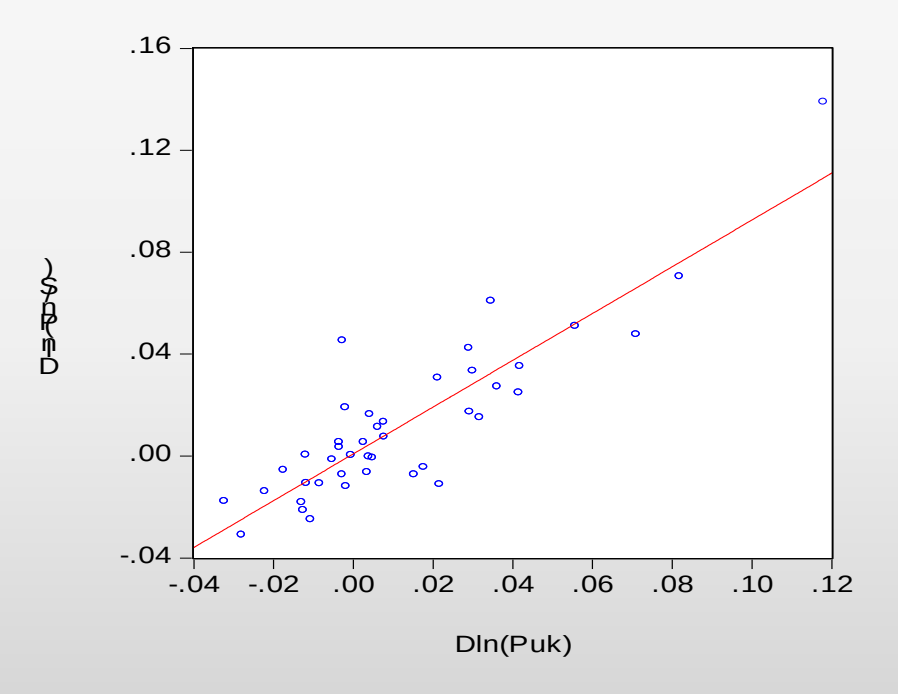


Figure 3d
20-year averages

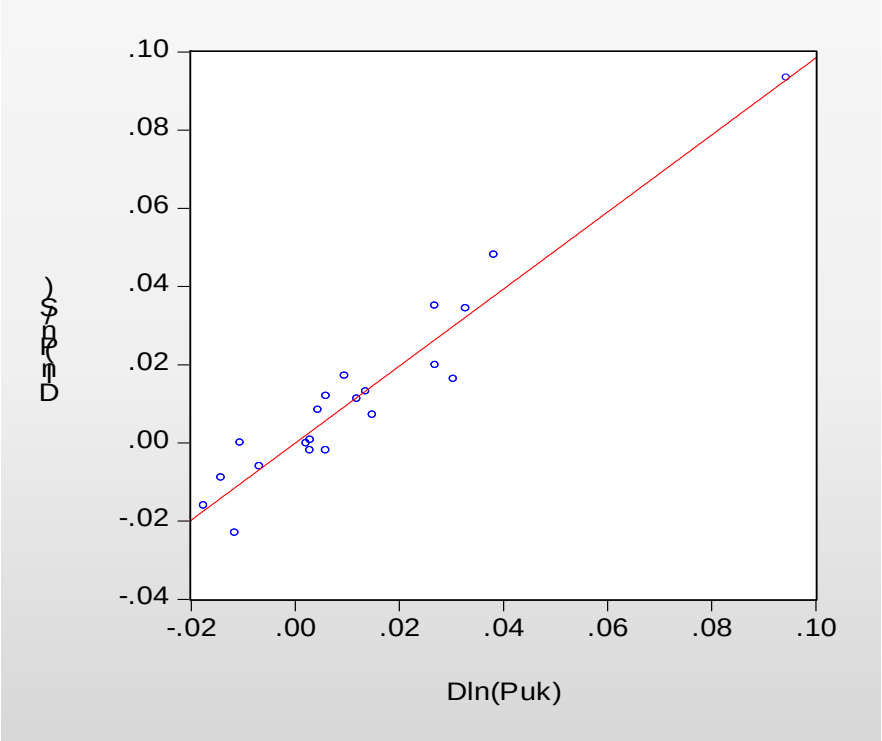


Figure 4
Relative Rents London/Amsterdam
1788 = 100