BANK OF GREECE
EUROSYSTEM

Working Paper

Exchange rates and prices in the Netherlands and Britain over the past four centuries

James R. Lothian
John Devereux

135

JULY 2011

BANK OF GREECE
Economic Research Department – Special Studies Division
21, E. Venizelos Avenue
GR-102 50 Athens
Tel: +30210-320 3610
Fax: +30210-320 2432

www.bankofgreece.gr

Printed in Athens, Greece
at the Bank of Greece Printing Works.

ISSN 1109-6691

EXCHANGE RATES AND PRICES IN THE NETHERLANDS AND BRITAIN OVER THE PAST FOUR CENTURIES

James R. Lothian
Fordham University

John Devereux
Queens College, CUNY

ABSTRACT

This paper examines exchange-rate and price-level data for the long period 1590-2009 for the Netherlands and the United Kingdom (earlier the Dutch Republic and England), countries that at various times over this near 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. The principal conclusion of this study is the resiliency of the simple purchasing-power-parity model and of the law of one price at the microeconomic level. Both take some heavy blows during this close to four-century long sample period. In the end, however, they emerge surprisingly unscathed. Real factors at times appear to have had substantial effects on real exchange rates and hence PPP, but such effects ultimately dissipate. As a long-run equilibrium condition, PPP holds up remarkably well.

*Acknowledgemen*t: This paper circulated earlier under the title "Movements in Exchange Rates and Relative Price Levels in the Netherlands and Britain over the Past Four Centuries," with Lothian as the sole author. We would like to thank Michael Edelstein, Barry Goodwin., Thomas Grennes, Larry Sjaastad, Alan Taylor and participants at workshops at the University of Chicago and North Carolina State University for their comments on that version of this paper, and participants at workshops at Fordahm University for their comments on an earlier draft of this paper. The views expressed in the paper are those of the authors and do not necessarily reflect those of the Bank of Greece.

Correspondence:
James R. Lothian
Graduate School of Business
Fordham University
New York, NY 10023
Tel. 1 212 636-6147; fax 1 212 765-5573;
email: lothian@fordham.edu; jrmlothian@aol.com

1. Introduction

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.[1]

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.[2] 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 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

[1] 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)

[2] 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.

or more in length, simply to detect the mean-reverting behavior in real exchange rates indicative of long-run PPP (Lothian and Taylor, 1997). 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.

To that end, we have collected 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.

In this paper, we report our initial findings. 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.

2. 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:

$$p_{ne,t} - s_t = \theta + p_{uk,t}, \qquad (2)$$

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:

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

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

$$p_{uk,t} = \lambda + p_{ne,t}\ , \qquad (2b)$$

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:

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

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. 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-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:

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

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 $\beta_2 = 1$:

[3] One of the Salamncan writers, Martín Azpilcueta Navarro (1565), provided what arguably was 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).

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

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]

3. 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. 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 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.

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.

[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.

3. 1 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.

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 features 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.

3.2 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.

Shown as a point of reference in each of the four charts is a forty-five degree line drawn through the origin. 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 .11 and estimated slope coefficients only slightly greater than .3. 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 .57 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 .80 and .94, 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.

3.3 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. the variance of q. The other models, moreover, add virtually nothing to that statistically.

3.4 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. 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.

These 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 an increase in the real value of sterling.[6] Additionally we find evidence of a downward shift very much later in the sample period. The first of these may reflect the political and economic turmoil that took place following the French Revolution and the subsequent French takeover of the Dutch Republic. The

[6] 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).

second is more difficult to explain. 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.

The surprise in these result is the lack of any noticeable productivity related movements, either in the period 1590 t0 1670 when the Dutch Republic experienced its golden age or a century later when the British industrial revolution got underway. One might well have expected the first to be associated with an overvaluation of the guilder relative to PPP and the second with an overvaluation of sterling.

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 .847, implying a half life of adjustment to equilibrium of four years. In the regression including the dummies the estimated coefficients, in contrast, is .710 implying a half life of adjustment roughly twice as fast.

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.

4. 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.

Appendix A: Data and Sources

Prices.

For the period 1590 to 1910, prices are Allan's (2001) measures of consumer prices for Amsterdam and London. We linked the first of these to the Dutch consumer price index as reported on the International Institute of Social History website for the period 1911 to 2008 on their page "Value of the Guilder / Euro." We updated this in turn using the consumer price series reported in the *International Financial Statistics*. We linked the London series to the Lawrence Officer's (2008) consumer price series reported for the period 1911 to 2007 for the United Kingdom and updated the resultant series using the consumer price series reported in the *International Financial Statistics*.

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 fir 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 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, 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.

Coakley, Jerry, Robert P. Flood, Ana M. Fuertes and Mark P. Taylor. 2005. Purchasing Power Parity and the Theory of General Relativity: the First Tests. *Journal of International Money and Finance* 24, 293-316.

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, 37–63.

Diebold, Francis X., Stephen Husted and Mark Rush. 1991."Real Exchange Rates under the Gold Standard," *Journal of Political Economy*. 99, 1252-71

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.

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.

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

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

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

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

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

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

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.

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* 104, 488-509.

Lothian, James R. and Mark P. Taylor, 1997. Real Exchange Rate Behavior. *Journal of International Money and Finance* 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, 1742-1763.

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. 2008. What Were the UK Earnings and Prices Then? MeasuringWorth, 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.

Taylor, Mark P. 2006. Real Exchange Rates And Purchasing Power Parity: Mean-Reversion In Economic Thought, Applied Financial Economics 16, 1–17

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

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

Variable	Yearly data			5-year averages			10-year averages			20-year averages		
	p_{uk}	pa_{ne}	q	p_{uk}	pa_{ne}	q	p_{uk}	pa_{ne}	q	p_{uk}	pa_{ne}	q
Minimum	-0.284	-0.249	-0.428	-0.099	-0.070	-0.090	-0.029	-0.031	-0.043	-0.018	-0.015	-0.019
Maximum	0.345	0.314	0.271	0.147	0.149	0.068	0.118	0.139	0.029	0.094	0.093	0.009
Range	0.628	0.564	0.699	0.247	0.220	0.159	0.147	0.170	0.072	0.112	0.109	0.028
Std Dev	0.077	0.080	0.091	0.040	0.044	0.030	0.031	0.033	0.015	0.025	0.026	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, 1590-2009

Data	Variables				R^2	
	Dependent	**Constant**	**Δln(Pne/S)**	**Δln(p_{uk}**	**)**	**SEE**
Yearly	**Δln(pa_{ne})**	0.010		0.344	0.109	
		2.546		7.114	0.076	
				(-13.560)		
	Δln(p_{uk})	0.008	0.317		0.109	
		2.167	7.114		0.073	
			(-15.359)			
5-year	**Δln(pa_{ne})**	0.004		0.816	0.569	
		1.305		10.412	0.029	
				(-2.351)		
	Δln(p_{uk})	0.002	0.698		0.569	
		0.800	10.412		0.027	
			(-4.507)			
10-year	**Δln(pa_{ne})**	0.002		0.970	0.804	
		0.947		12.799	0.015	
		0.000		(-0.403)		
	Δln(p_{uk})	0.001	0.829		0.804	
		0.231	12.799		0.014	
		0.000	(-2.640)			
20-year	**Δln(pa_{ne})**	0.002		1.012	0.941	
		1.003		17.474	0.006	
				(0.213)		
	Δln(p_{uk})	-0.001	0.930		0.941	
		-0.476	17.474		0.006	
			(-1.317)			

Note: Conventional t statistics are immediately below the coefficients; figures in parenthesis are t statistics to test the hypothesis that the value of the coefficient is different from unity.

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

Tests	$pa_{ne,}$	$\mathbf{p_{uk,t}}$	$\mathbf{q_t}$
Levels			
ADF	3.257	2.984	-4.400***
P-P	4.022	3.347	-5.394***
First differences			
ADF	-16.253***	-14.232***	-19.067***
P-P	-16.078***	-16.410***	-32.276***

Note: P-P is the Phillips-Perron test statistic and ADF the augmented Dickey-Fuller test statistic. In conducting the first two tests allowance was made for up to fourth-order serial correlation in each instances. 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.

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**
0.070	0.711	-0.008	-0.021	-0.009	0.073	0.017	0.005	-0.036	-0.060	0.734
4.806	20.473	-0.447	-1.231	-0.527	3.828	0.990	0.267	-2.021	-2.785	.086
	(-8.320)									
.036	.847									.711
4.704	32.082									.089
	(-5.790)									

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. The Dickey-Fuller test statistic is in parentheses.

Figure 1

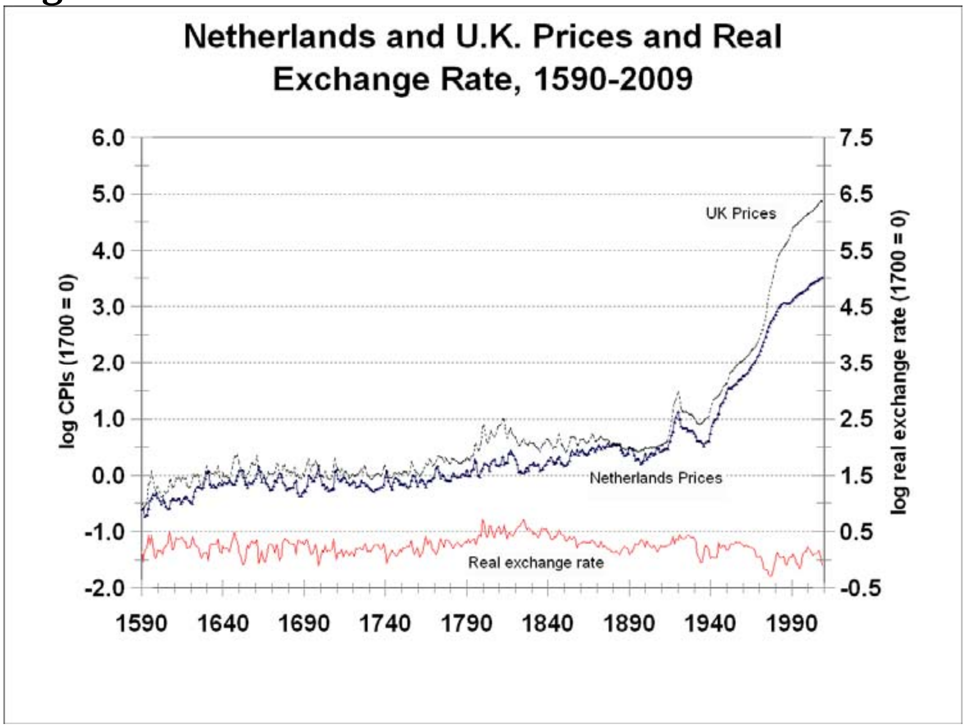
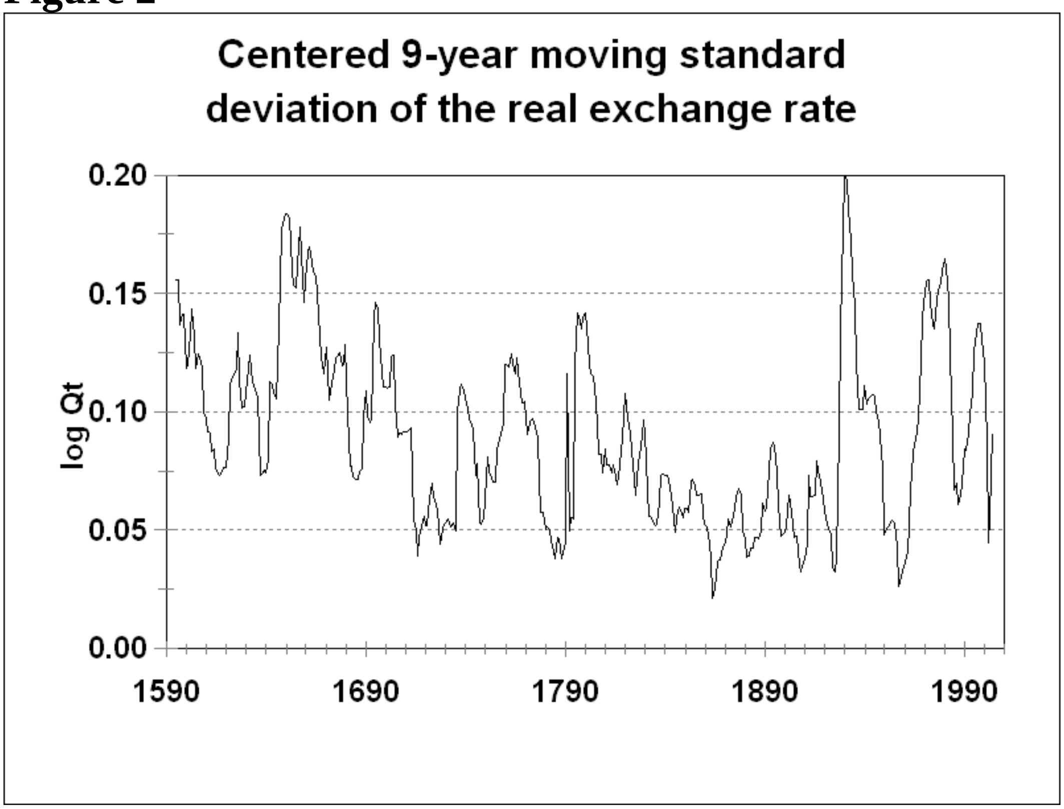


Figure 2



Rates of Growth, 1590-2009

Figure 3a

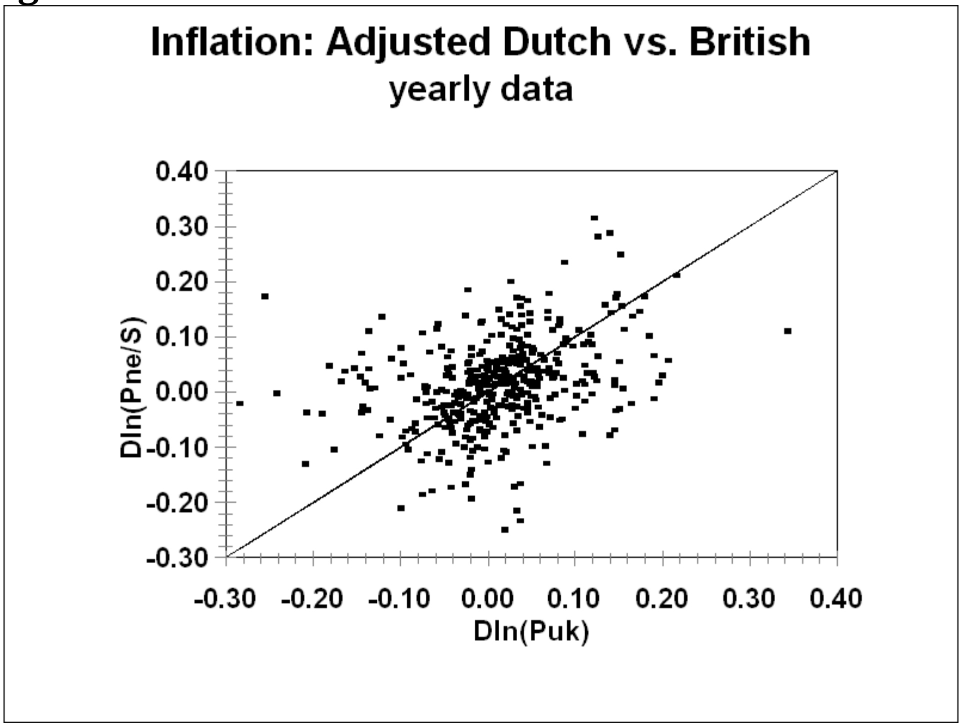


Figure 3b

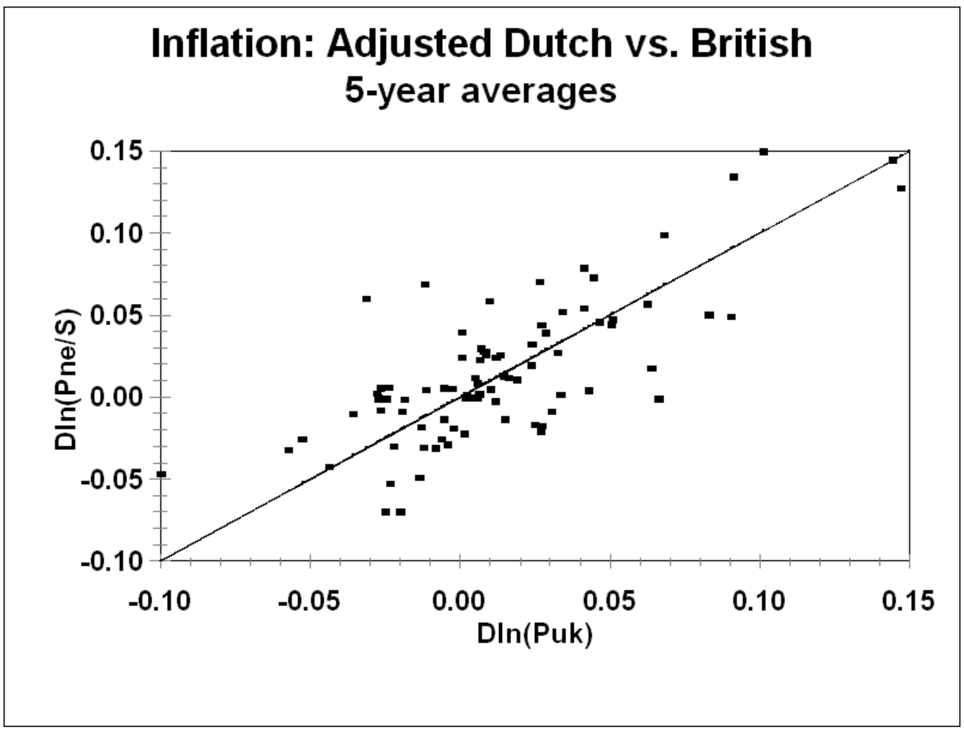


Figure 3c

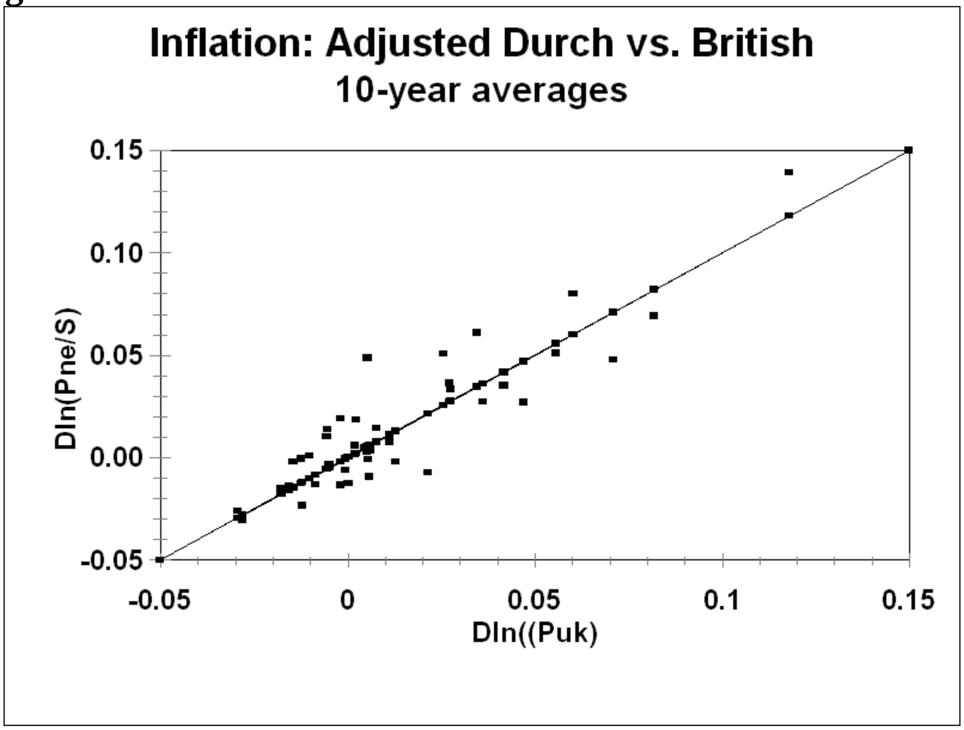
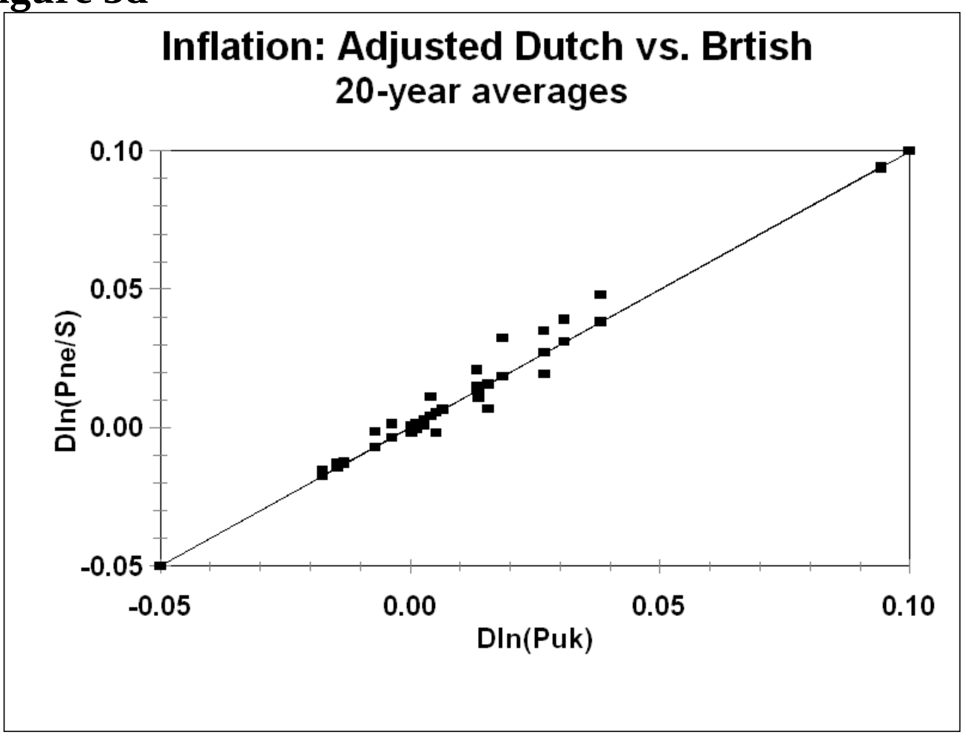


Figure 3d



BANK OF GREECE WORKING PAPERS

116. Tagkalakis, A., “Fiscal Policy and Financial Market Movements”, July 2010.
117. Brissimis, N. S., G. Hondroyiannis, C. Papazoglou, N. T Tsaveas and M. A. Vasardani, “Current Account Determinants and External Sustainability in Periods of Structural Change”, September 2010.
118. Louzis P. D., A. T. Vouldis, and V. L. Metaxas, “Macroeconomic and Bank-Specific Determinants of Non-Performing Loans in Greece: a Comparative Study of Mortgage, Business and Consumer Loan Portfolios”, September 2010.
119. Angelopoulos, K., G. Economides, and A. Philippopoulos, “What Is The Best Environmental Policy? Taxes, Permits and Rules Under Economic and Environmental Uncertainty”, October 2010.
120. Angelopoulos, K., S. Dimeli, A. Philippopoulos, and V. Vassilatos, “Rent-Seeking Competition From State Coffers In Greece: a Calibrated DSGE Model”, November 2010.
121. Du Caju, P.,G. Kátay, A. Lamo, D. Nicolitsas, and S. Poelhekke, “Inter-Industry Wage Differentials in EU Countries: What Do Cross-Country Time Varying Data Add to the Picture?”, December 2010.
122. Dellas H. and G. S. Tavlas, “The Fatal Flaw: The Revived Bretton-Woods system, Liquidity Creation, and Commodity-Price Bubbles”, January 2011.
123. Christopoulou R., and T. Kosma, “Skills and wage Inequality in Greece: Evidence from Matched Employer-Employee Data, 1995-2002”, February 2011.
124. Gibson, D. H., S. G. Hall, and G. S. Tavlas, “The Greek Financial Crisis: Growing Imbalances and Sovereign Spreads”, March 2011.
125. Louri, H. and G. Fotopoulos, “On the Geography of International Banking: the Role of Third-Country Effects”, March 2011.
126. Michaelides, P. G., A. T. Vouldis, E. G. Tsionas, “Returns to Scale, Productivity and Efficiency in Us Banking (1989-2000): The Neural Distance Function Revisited”, March 2011.
127. Gazopoulou, E. “Assessing the Impact of Terrorism on Travel Activity in Greece”, April 2011.
128. Athanasoglou, P. “The Role of Product Variety and Quality and of Domestic Supply in Foreign Trade”, April 2011.
129. Galuščǻk, K., M. Keeney, D. Nicolitsas, F. Smets, P. Strzelecki and Matija Vodopivec, “The Determination of Wages of Newly Hired Employees: Survey Evidence on Internal Versus External Factors”, April 2011.
130. Kazanas, T., and. E. Tzavalis, “Unveiling the Monetary Policy Rule In Euro-Area”, May 2011.
131. Milionis, A. E., and D. Patsouri, “A Conditional CAPM; Implications for the Estimation of Systematic Risk”, May 2011

132. Christodoulakis, N., and V. Sarantides, “External Asymmetries in the Euro Area and The Role Of Foreign Direct Investment”, June 2011.

133. Tagkalakis, A., “Asset Price Volatility and Government Revenue”, June 2011.

134. Milionis, E. A., and E. Papanagiotou, “Decomposing the Predictive Performance of the Moving Average Trading Rule of Technical Analysis: the Contribution of Linear and Non Linear Dependencies in Stock Returns”, July 2011.