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Random walks and cointegration relationships in international parity conditions between Germany and USA for the post Bretton-Woods period

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Abstract

This paper is based on a recent paper by Juselius and MacDonald (2000, 2003) and two `Journal of Econometrics' article s by Juselius (1995) and Johansen and Juselius (1992). The basic feature in all these articles is that the joint modelling of international parity conditions, namely *ppp* and *uip*, produces stationary relations showing an important interaction between the goods and the capital markets. We replaced the consumer price index (CPI) considered by Juselius and MacDonald with the producer price index (PPI) to check whether the international parity relationships still cointegrate. To our surprise we outstandingly produced similar results to those by Juselius and MacDonald, suggesting that the cointegration relationships in the international parity conditions hold also if we use different measures of prices. What is striking in our results is that even if there is no direct cointegration relation between CPI and PPI both in Germany and USA, the cointegration relation found between *ppp* and *uip* still holds notwithstanding of how *ppp* is measured.

JEL Classifications: E31, E43, F31, F32.
Keywords: *ppp*, *uip*, Fisher parity.

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[1] This paper benefited from in-depth comments and helpful advises by Katarina Juselius and Annetta Binotti. Responsibility for any mistakes and misapprehensions rests solely upon me.

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1 Introduction

Recently, basic issues in international monetary economics concerning the validity of parity conditions are receiving a growing interest also in econometrics.

Seemingly simple questions about the determinants of exchange rates between for instance Europe and USA, do not still find adequate responses rigorously grounded on empirical data. Is the exchange rate determined by the level of prices as the Purchasing Power Parity (*ppp*) theory suggests? Is the exchange rate determined by the spread between the interest rates in the two countries as the Uncovered Interest Rate Parity (*uip*) theory claims? How prices respond to changes in exchange rates and interest rates?

Answering to these issues becomes problematic when economic theory assumes that *ppp* and *uip* hold while both are empirically found non stationary in the short and medium-long run such as a span of 20-25 years (Rogoff 1996). Indeed it has been difficult to prove that there was any convergence toward *ppp* and *uip* in the long run. Rogoff refers to this problem as 'the Purchasing Power Parity Puzzle' and talks about 'the embarrassment of not being able to reject the random walk model' for the *ppp* while other authors doubt about the usefulness of both the *ppp* and *uip*[1].

This paper aims to show that the *ppp* and *uip* relations are indeed extremely interesting when they are jointly modelled and we should not be embarrassed when we deal with 'random walk' parity conditions. Indeed, just because *ppp* and *uip* behave in a non stationary way, we may investigate cointegration relations between the two parities i.e. the stationary long run relations between pseudo random walks (the *ppp* and the *uip*) that share common trends.

This paper is based on a recent paper by Juselius and MacDonald (2000, revised in 2003) and two 'Journal of Econometrics' articles by Juselius (1995) and Johansen and Juselius (1992). The basic feature in all these articles is that the joint modelling of international parity conditions, namely *ppp* and *uip*, produces stationary relations showing an important interaction between the goods (via the *ppp*) and the capital markets (via the *uip*)[2].

Since there is no 'right' *ppp* measure (Rogoff 1996)[3], we replaced the consumer price index

[1] See Colombo and Lossani (2000).
[2] See Juselius 1995.
[3] Rogoff (1996) put forward the idea to use even the McDonald's 'Big Mac' index to produce a PPP measure

(CPI) considered by Juselius and MacDonald with the producer price index (PPI) to check whether the international parity relationships still cointegrate. To our surprise we outstandingly produced similar results to those by Juselius and MacDonald, suggesting that the cointegration relationships in the international parity conditions hold also if we use different measures of prices. What is striking in our results is that even if there is no direct cointegration relation between CPI and PPI both in Germany and USA, the cointegration relation found between *ppp* and *uip* still holds notwithstanding of how *ppp* is measured.

The paper is organized as follows. In Section 2 we define the international parity conditions. In Section 3 we discuss the choice of the variables, the data set and we provide some preliminary visual analysis of the variables and the parity conditions. In Section 4 we explain the statistical model we use to test the parities. In Section 5 we test parity conditions using a model with a minimal number of variables, which excludes the short interest rates. In Section 6 we extend the model including also the short term interest rates. Using the moving average (MA) representation, the weakly exogenous variables and the long run impacts of shocks are also discussed. Section 7 concludes and summarizes the main results.

2 International parities conditions

2.1 The absolute *ppp*

The absolute *ppp* states that, once converted to a common currency, the price levels in the two countries should be equal (Rogoff 1996). The log of the absolute *ppp*, is defined as:

$$p_t - p_t^* - s_t = 0 \tag{1}$$

with the data provided by The Economist. We found this idea not only very entertaining, but worth to be analyzed. In fact the Big Mac being essentially the same in all countries, is a homogeneous completely standardized good such as gold, silver and oil but, differently from gold, silver and oil, it is a nontradeble good. The Big Mac is in fact locally produced and its price may well reflect the differences in raw material and unit labor costs.

Being a nontradeble but a homogeneous standardized good, the Big Mac index may be used as a proxy to compare the relative costs and indirectly prices in each country through nominal exchange rates. In this sense the Big Mac index may be used to determine under or overvaluation of currencies relative to another currency.

Unfortunately the actual dataset would not allow us to use VAR (longer time series would be needed) and cointegration techniques in a reliable way. The Big Mac index data set by The Economist contains only the data of the last decade on a semester basis so that VAR modelling and cointegration are by now precluded.

where p_t is the log of the domestic price level (in our case the German producer, wholesale, price level index), p_t^* is the log of the foreign price level (in our case the producer, wholesale, price level index in USA), s_t denotes the log of the spot exchange rate (home currency price of a unit of foreign currency).

If the *ppp* holds empirically, we would expect that:

$$p_t - p_t^* - s_t \sim I(0)$$

where $I(0)$ stands for zero order integrated process.

The empirical analysis confirms two main aspects:

- The *ppp* is a relation valid only in the very long run (temporal horizon of more than 50 years). On a shorter temporal horizon we observe persistent deviation from *ppp* (Rogoff 1996).

The nature of the empirical support for *ppp* is very dependent on the sample period. If a relatively long span of data is used such as a century, there is mounting evidence that *ppp* is valid, although the adjustment speed of *ppp* is too slow to be consistent with a traditional version of *ppp* (Rogoff 1996) and for the recent floating experience there is little evidence that *ppp* behaves like a $I(0)$ process.

Juselius and MacDonald suggest that there are a number of possible reasons why the *ppp* has a so little empirical support in the short and medium run. One reason could lie in the rather weak correspondence between the measured prices series used by researchers - usually the CPI index - and the true theoretical prices; other variables not mentioned by theory, such as institutional factors, might also be relevant. Another reason, which is an objection to traditional *ppp* is that there may be important real determinants (such as productivity shocks, differences in technology and preferences), which are responsible for introducing a stochastic trend into real exchange rates which in turn are likely to be linked to the current account of the balance of payments constraint (MacDonald 2000, Juselius and MacDonald 2003). As long as a deficit (surplus) in the current account implies a lower (higher) future consumption, no country can indefinitely run current account deficits without going bankrupt, both the current account and the *ppp* cannot drift without any boundary although temporary imbalances are permissible. Thus, both the current account and *ppp* should eventually mean revert but with a so small coefficient in the very long run to be statistically significant.

2.2 The *uip*

Current account deficits have to be financed through the capital and financial account or a change in reserve assets. As there is no change in reserve assets in case of no foreign exchange market intervention as implied in a floating exchange rate regime, the *ppp* should indirectly be linked to the capital and financial account which in turn is likely to be linked with the *uip* (MacDonald 2000).

The condition of *uip*, is defined as:

$$E_t \Delta_m s_{t+m}/m - i_t^l + i_t^{l*} = 0 \tag{2}$$

where i_t^l denotes a long term bond yield with maturity $t+m$, or simplifying $t+1$, E_t denotes the conditional expectations operator on the basis of time-t information set. The *uip* states that, in the capital market, the interest rate differential between the two countries is equal to the expected change in the spot exchange rates (Juselius 1995). Hence, once converted to a common currency, the interest rates in the two countries should be equal. If this were not, investors would have the incentive to move capitals from the country where the interest rate is lower to the country where the interest rate is higher till equilibrium. Thus, the *uip* is an arbitrage relation that describes an equilibrium in the capital markets (Colombo and Lossani 2000).

If the *uip* hold empirically, we would expect that:

$$E_t \Delta_m s_{t+m}/m - i_t^l + i_t^{l*} \sim I(0)$$

Juselius (1995) and Juselius and MacDonald (2000) maintain that empirical tests by other authors (Cumby and Obstfeld 1981) have confirmed that the *uip*, like the *ppp*, is a non stationary relation. These empirical tests are usually carried out testing and estimating the coefficients of the following relation

$$\Delta s_{t+1} = \alpha + \beta \left(i_t^l - i_t^{l*} \right) + v_t \tag{3}$$

with α and β the coefficients and v_t unpredictable *i.i.d.* shock,.

The *uip* requires $\beta = 1$, lower (higher) domestic interest rates would require an exchange rate appreciation (depreciation). However most of the empirical studies have found that the *uip* in industrialized countries is systematically rejected and the estimated β is -0.88 (Colombo and Lossani 2000), signifying that high interest rates were related with appreciating rather than depreciating currencies. This unexpected result however can be explained as long as higher interest rates are an incentive to move financial capitals from the country where the interest rate is lower to the country where the interest rate is higher increasing the currency demand for the country with higher interest rates and increasing the currency supply for the country with a lower interest rate. Higher currency demand induces currency appreciation while an increase of currency supply a currency depreciation, higher (lower) interest rates may be related with an exchange rate appreciation (depreciation) in conformity with empirical results and contravening the *uip* theory. Thus, the *uip* would not be rejected only in the special case that countries have the same net interest rates and no incentive to move capitals from one country to the other.

2.3 Combining the *ppp* with the *uip*

In this paper we also will add evidence that *ppp* and *uip* as such do not find empirical support, however, our aim is to check whether a linear combination of the two parities are able to generate a stationary relation.

Before arriving to a final equation to test that includes both parities, from the *uip* equation:

$$i_t^l - i_t^{l*} = E_t \Delta s_{t+1} \tag{4}$$

If speculators form exchange rate expectations on the basis of inflationary prediction, given the *ppp* equation, differencing and taking the expected change of exchange rate:

$$E_t \Delta s_{t+1} = E_t \Delta p_{t+1} - E_t \Delta p_{t+1}^* \tag{5}$$

Thus:

$$i_t^l - i_t^{l*} = E_t \Delta p_{t+1} - E_t \Delta p_{t+1}^* \tag{6}$$

and

$$i_t^l - i_t^{l*} - E_t \Delta p_{t+1} + E_t \Delta p_{t+1}^* = 0$$

i.e., real interest rates are thought to be arbitraged together as if people expected more inflation in one currency than in the other and a higher nominal interest rate were required to attract investors to hold assets in that currency.

A relation which assumes proportionality (ω is a parameter to be estimated)[4] between *ppp* and *uip* may be written as:

$$i_t^l - i_t^{l*} - E_t \Delta p_{t+1} + E_t \Delta p_{t+1}^* = \omega \left(p_t - p_t^* - s_t \right) \tag{7}$$

or alternatively:

$$i_t^l - i_t^{l*} = E_t(\Delta p_{t+1} - \Delta p_{t+1}^*) + \omega ppp_t$$

that would find empirical support if:

$$i_t^l - i_t^{l*} - \omega ppp_t - E_t(\Delta p_{t+1} - \Delta p_{t+1}^*) \sim I(0)$$

and this would be the case of either:

$$i_t^l - i_t^{l*} \sim I(0),\ ppp_t \sim I(0) \text{ and } E_t(\Delta p_{t+1} - \Delta p_{t+1}^*) \sim I(0)$$

or:

$$\begin{gathered} i_t^l - i_t^{l*} \sim I(1)\ ,\ ppp_t \sim I(1) \text{ and } E_t(\Delta p_{t+1} - \Delta p_{t+1}^*) \sim I(1) \\ \text{but } i_t^l - i_t^{l*} - \omega ppp_t - E_t(\Delta p_{t+1} - \Delta p_{t+1}^*) \sim I(0). \end{gathered}$$

If we assume agents do not make systematic forecast errors in inflation rates:

$$E_t(\Delta p_{t+1} - \Delta p_{t+1}^*) = (\Delta p_t - \Delta p_t^*) + v_t$$

with v_t unpredictable *i.i.d.* shock and:

$$i_t^l - i_t^{l*} = (\Delta p_t - \Delta p_t^*) + \omega ppp_t + v_t \tag{8}$$

[4]The parameter ω might be interpreted as the responsiveness of the capital movements that enter in the capital and financial account to *uip*. A small value of the parameter ω may imply a large responsiveness of capital movements to the net interest rate differential.

Testing:

$$(i_t^l - i_t^{l*}) - (\Delta p_t - \Delta p_t^*) - \omega ppp_t \sim I(0) \tag{9}$$

is equivalent to test whether or not equation (8) finds empirical support.

The last equation can also interpreted as the log of the real exchange rate proportional to the spread between the real interest rates in the two countries:

$$\left(i_t^l - \Delta p_t\right) - \left(i_t^{l*} - \Delta p_t^*\right) = \omega ppp_t \tag{10}$$

If *ppp* is decomposed into prices and the nominal exchange rate, we might even come up with a relation, which might be interpreted like an equation for the determinants of the exchange rate, that shows the nominal exchange rate in function of the spread of prices and the spread of real interest rates:

$$s_t = (p_t - p_t^*) - \tfrac{1}{\omega}(i_t^l - \Delta p_t) + \tfrac{1}{\omega}(i_t^{l*} - \Delta p_t^*)$$

a relation which shows that the nominal exchange rate appreciates (depreciates) when domestic real interest rates exceed (are less than) foreign real exchange rates.

The relation expressed in (9) is the fundamental relation that we test and would be satisfied either in the case that:

$$i_t^l - i_t^{l*} \sim I(0),\ ppp_t \sim I(0) \text{ and } (\Delta p_t - \Delta p_t^*) \sim I(0)$$

or:

$$i_t^l - i_t^{l*} \sim I(1)\ ,\ ppp_t \sim I(1) \text{ and } (\Delta p_t - \Delta p_t^*) \sim I(1).$$

Before starting the tests, a rationale choice of the variables, the sample period and the data set will be discussed in the next section.

3 Choice of the variables, data set and a visual analysis

3.1 Choice of the variables and data set

The variables that enter in equation (8) are:

- p_t, the home price index

- p_t^*, the foreign price index

- i_t, the home interest rate

- i^*, the foreign interest rate

- s_t, the spot exchange rate

In this paper, our analysis focuses only on two 'big' countries, namely Germany and USA and is referred to the recent float period after the end of the Bretton-Woods system (1975-1998)[5].

The choice of the countries and the sample period may be justified in the following way:

- It is always worth not to mix different regimes. An economic relation might have economic meaning in one period and be nonsense for another in which a different regime prevails. Often it is worth to divide the sample in regime periods, and conduct a different analysis for the post war era and for the post Bretton-Woods period.

- The two countries, Germany and USA, are to be considered two 'big' countries during the last thirty years. In the last 25-30 years, a change in one of the two countries would likely have affected the other. Conversely, if we refer to the immediate post war period, we would expect that Germany follows the changes in the US economy, i.e. we would expect to consider Germany a small country and USA a big one.

Our analysis faces also other issues concerning which category of prices and interest rates should be analyzed. Should we consider the CPI or the Big Mac index? Generally the CPI is chosen, but there is no right answer to that question; we chose the PPI. Although producer prices are often seen as a leading indicator of the consumer prices, the relation between the two indices is not so close and may be relevant to check whether cointegration relationships are robust to changes with respect to the indices used. The two indices are made up with different subindices,

[5]Actually the end of the Bretton Woods system, the monetary regime based on convertibility indirectly linked to gold, is generally dated between 1971 and 1973.

different weighting and a different method of questioning is used. Differently from the consumer price index, the producer price index does not include profit margins and wholesales and retail costs as well as taxes due on sales and imports are also excluded (BLS 1997). In our specific case, this might imply the exclusion for those dummies that measure the effect on German prices of various excise taxes introduced to pay the German reunification.

If there is no right *ppp* measure, there is no right measure for the *uip* too. Shall we consider the long or the short interest rate? Generally the long interest rate is chosen, we will consider both.

Our database consists of the following variables:

- p_t, the German, or 'home', producer price index
- p_t^*, the US, or 'foreign', producer price index
- i_t^l, the German long bond yield (10 years)
- $i_t^{l^*}$, the US long bond yield (10 years)
- s_t, the spot exchange rate, USdollar/Deutschemark
- i_t^s, the German three month Treasury bill rate
- $i_t^{s^*}$, the US three month Treasury bill rate

This database was provided by Prof. Juselius and was extracted from the International Monetary Fund CD-rom 1998. Data sources such as Datastream also contain the same and updated values. All the data are monthly, not seasonally adjusted. The starting date of our sample is July 1975, because short term interest rate for Germany are available only from that date. We transformed prices and the exchange rate with their natural log, the yearly interest rates were taken in percentage (i.e. divided by 100) and divided by 12 to obtain the monthly rates while *ppp* was divided by 100.

3.2 Visualizing data

The visual inspection of the data is a critical first step in any econometric analysis (Enders 1995). The graphs of the time series of all the variables relevant for the paper are shown in levels and differences[6].

[6] The software CATS in RATS by Hansen H. and Juselius K., 2000, was used for all computations and graphical output in this Part.

Prices and inflation rates

In this subsection we want to show that prices may seem to be $I(2)$, inflation rates $I(1)$ but $(\Delta p_t - \Delta p_t^*) \sim I(1)$.

Prices and its differences, i.e. inflation rates, show a rapid increase in the 1970s and a slowing down pattern since 1979 till 1986 and a more stable pattern for the subsequent period both in Germany (see Fig. 1, LGEWPI time series, we call LGEWPI, the log of German producer price index)

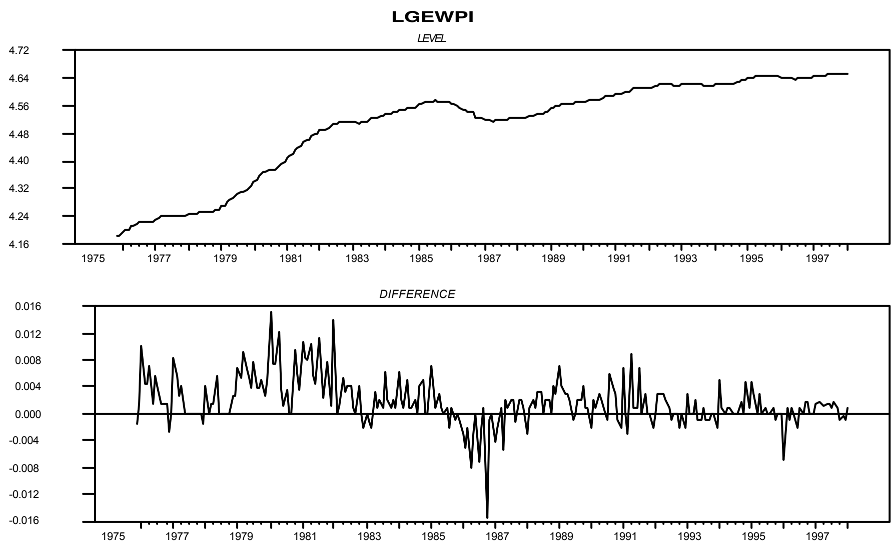

Fig. 1: The log of PPI index in Germany.

and in USA (see Fig. 2 LUSWPI time series, we call LUSWPI, the log of the US producer price index).

It can also noticed that in the beginning of the 80s prices in the USA became already much more stable. This was the successful result of the board lead by the newly appointed (by President J. Carter) chairman of the Board of Governors of the Federal Reserve System, P. Volcker, whose intent was a restrictive monetary policy to reduce two digits inflation (Dunn and Mutti 2004). The efforts of the FED were reinforced by government interventions of the Reagan Administration for a significant tax cut, a marked expansion of public deficit and a market deregulation aimed to increase competition (Trapp 1987). An evident effect of the tight monetary policy and the fiscal policy was the remarkable appreciation of the US dollar.

The appreciation of the dollar was not simply due to an unconditional reliance in the fast growing US economy. Rather probably was the result of the large US fiscal deficit that became too large to be financed by American investors. The fiscal deficit required borrowing from saver nations such as Germany. US securities were widely purchased by Germans who had to demand for US dollars, driving up the dollar. The appreciation of the dollar fuelled German inflation because of higher import prices. A tight monetary and fiscal policy were also followed in Germany to reduce inflation, of which the substantial costs in terms of economic welfare loss became acknowledged. During 1984 the Reagan administration began to worry about the loss of competitiveness due to the strong dollar (Trapp 1987). At the Plaza Hotel Accord in New York in September 1985, the USA agreed to intervene in the foreign exchange market (Dunn and Mutti 2004), plainly contravening a freely floating exchange rate system. In the subsequent year the US dollar quickly lost the former gain against the German mark. During 1986 it was argued that the exchange rates with the dollar was already *reasonable* and there would likely been negative inflation for that year in Germany (Trapp 1987). The forecasted negative inflation that actually occurred was simply due to lower imported prices caused by a cheaper US dollar (Trapp 1987) beyond a slight imported deflation from the USA. The decline in the price level in 1986 was of short duration and indeed caused by an exchange related fall in import prices (Deutsche Bundesbank 2003).

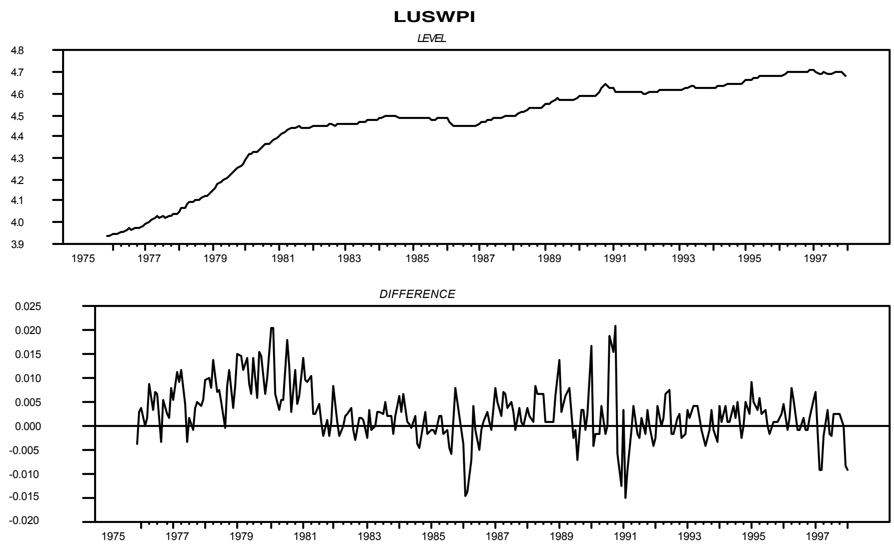

Fig. 2: The log of PPI index in the US.

We also noticed that the producer price index is much more volatile than the consumer price index, which is shown in the next two figures for Germany and USA (see Fig. 3, LGECPI time series, we call LGECPI, the log of the consumer price index in Germany; in Fig. 4 see LUSCPI where we call LUSCPI the log of the US consumer price index). It is interesting to note that in Germany consumer prices seem less affected by the deflation occurred in 1986 compared to producer prices, while inflation rates calculated with consumer prices become much higher after the German reunification.

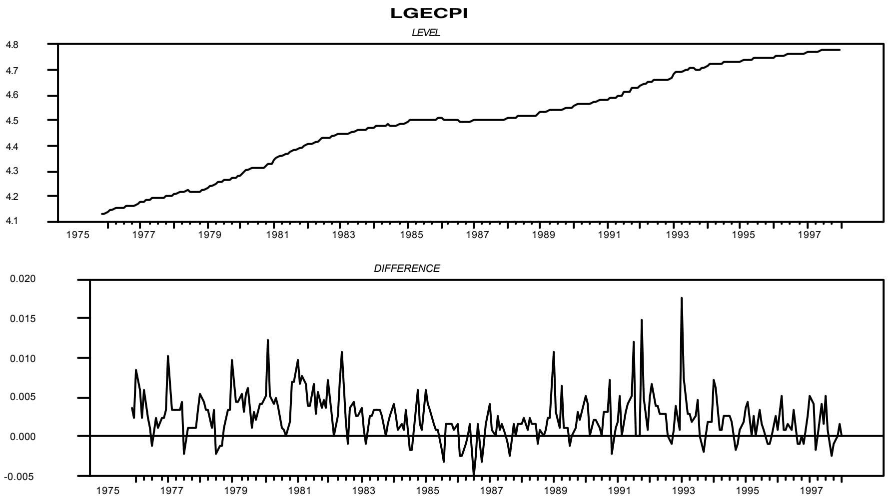

Fig. 3: The log CPI index in Germany.

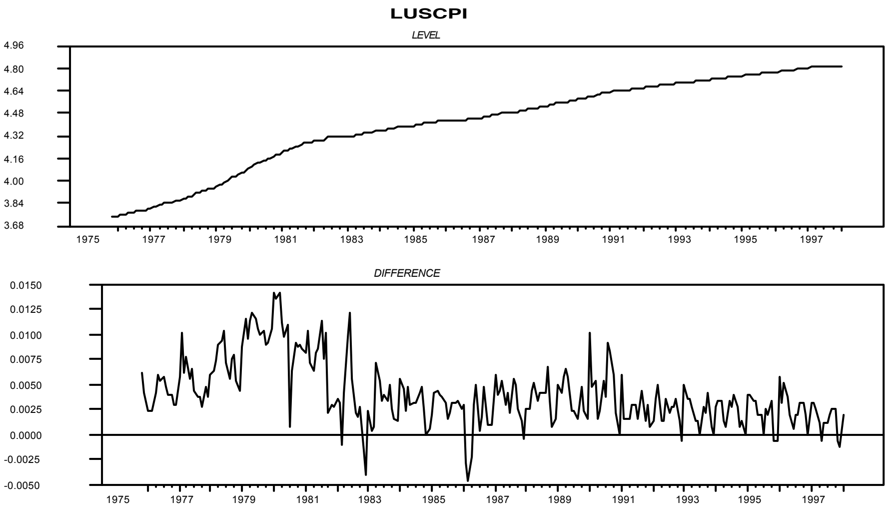

Fig. 4: The log of CPI index in the US.

The common feature in Fig. 1-4 is that prices show a decidedly positive trend or drift throughout the whole period, while their first differences i.e. inflation rates, have a positive mean.

If we compare the relation between PPI and CPI in Germany (see Fig. 5, LGEPWC time series, we call LGEPWC the spread between the log of the producer and consumer price indices in Germany) and in USA (see Fig. 6, LUSPWC time series, we call LUSPWC the spread between the log of the producer and consumer price indices in USA) we observe a smooth trending behavior showing that consumer price indices have averagely higher than producer price indices.

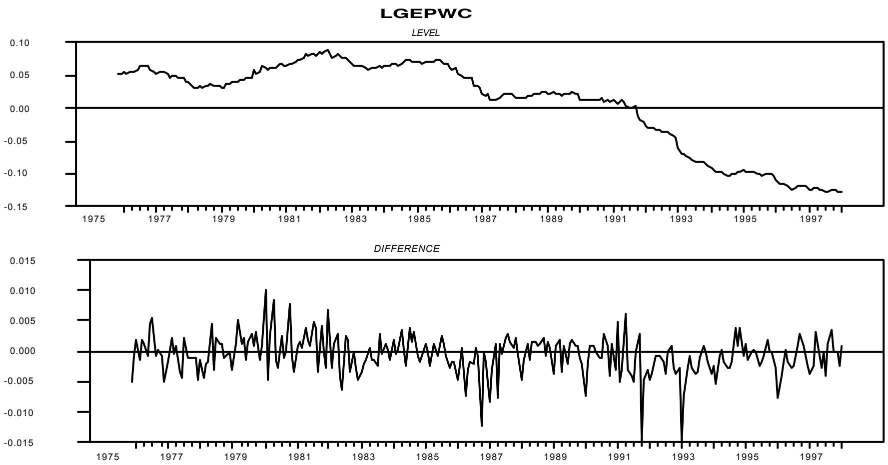

Fig. 5: The spread between price indices in Germany

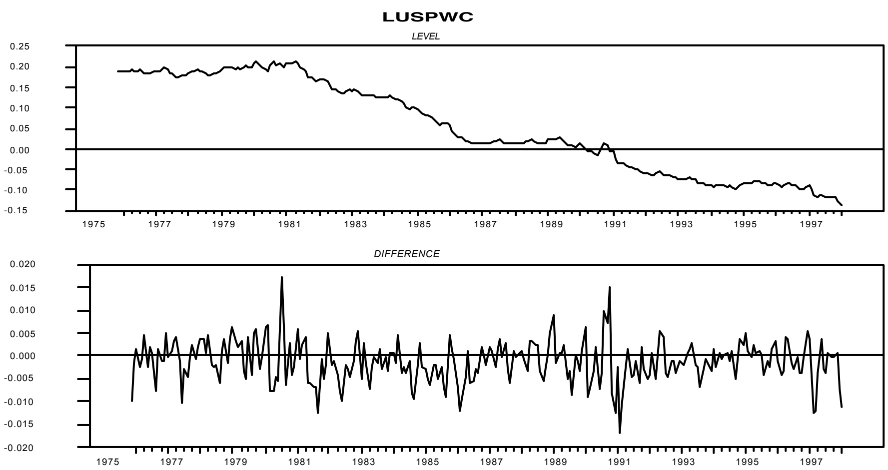

Fig. 6: The spread of price indices in the US.

Moreover, if we look to the relation $(p_t - p_t^*)$ (see Fig. 7, GEUSPR time series, we call GEUSPR the spread of the log of the producer price indices between Germany and USA), we also notice a trending behavior characterized by a strong autocorrelation and a rather smooth pattern (due to a non zero acceleration rate) which sometimes may be found in $I(2)$ processes. We surmise that $p_t \sim I(2)$, $p_t^* \sim I(2)$ and $(p_t - p_t^*) \sim I(2)$, that is, prices alone do not cointegrate. Therefore, we may think that $(\Delta p_t - \Delta p_t^*) \sim I(1)$ and will test this hypothesis later.

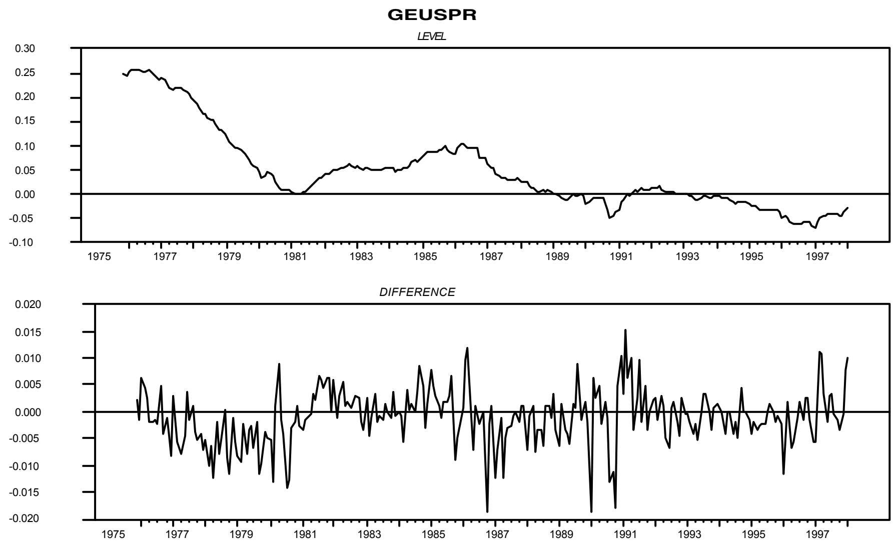

Fig. 7: The price spread between Germany and US.

Exchange rates and *ppp*

We have noticed that prices may contain structures higher than $I(1)$. Also exchange rates may conceal $I(2)$ components. Its behavior is rather smooth, with prolonged periods of appreciation and periods of depreciation, with a trend tendency. However if we closely look at Fig. 8 (see LDMUSD time series, we call LDMUSD the log of exchange rate of the German Mark against the US Dollar) and Fig. 7, we may notice that the exchange rate and the spread of prices may follow a similar trend in the long run. The sharp rise of exchange rates occurred between the end of 1979 and 1985 could be explained as an effect of different factors, such as the tight monetary policy pursued by the FED to cure inflation and the increase of US fiscal deficit reinforced by a speculative bubble of world-wide dimension.

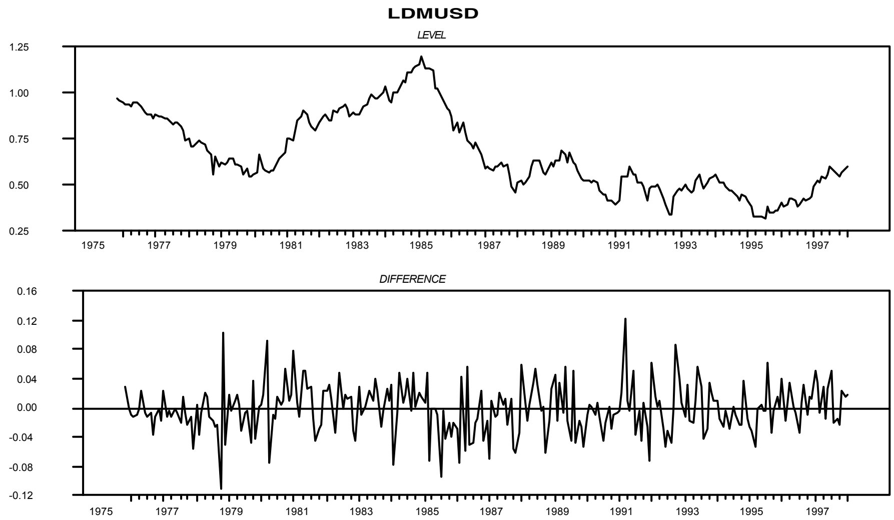

Fig 8: The log of exchange rate

In the case that spread in prices (which may be $I(2)$) share the same trend of exchange rate (which may also be $I(2)$), we might find that they cointegrate from $I(2)$ to $I(1)$, i.e. they are $CI(2,1)$. In Fig. 9 (see the PPPWGE time series, we call PPPWGE the *ppp* calculated with the producer prices) we do not notice a typical trending behavior of $I(2)$ processes and we might think that *ppp* behaves like a $I(1)$ process. As Enders (1995) pointed out referring to the *ppp*, the series seems to meander in a fashion characteristic of a random walk process, i.e. *ppp* is a $I(1)$ process, although the only reliable way to detect $I(1)$-ness is testing.

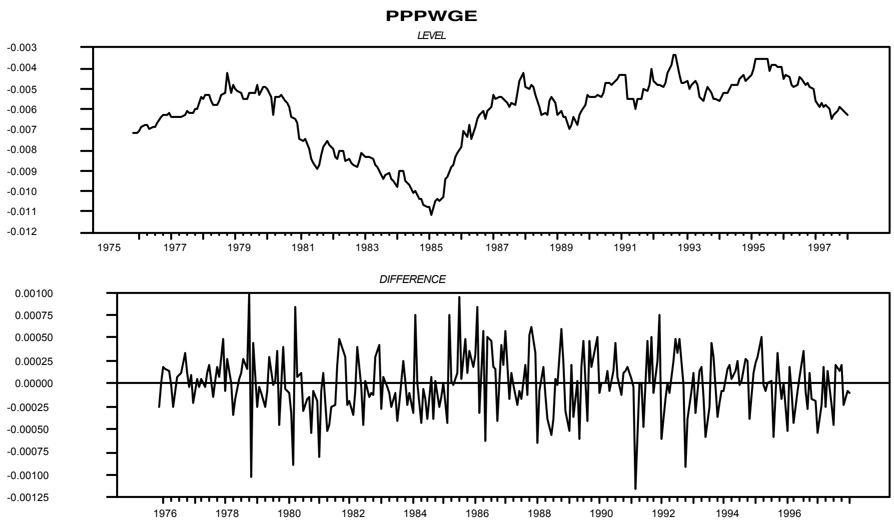

Fig. 9: Purchasing Power Parity.

The interest rates and their spread

Let us see first the spread of interest rates. As noticed by Juselius and MacDonald, the spread between long bond interest rates follows a dynamics that is somewhat similar to the one of *ppp* (compare Fig. 10 with Fig. 9; see the BONDSP time series, we call BONDSP the spread of the long term interest rates in the two countries). From the graph the bond spread could seem a $I(1)$ process affected by some heteroskedasticity (see lower panel).

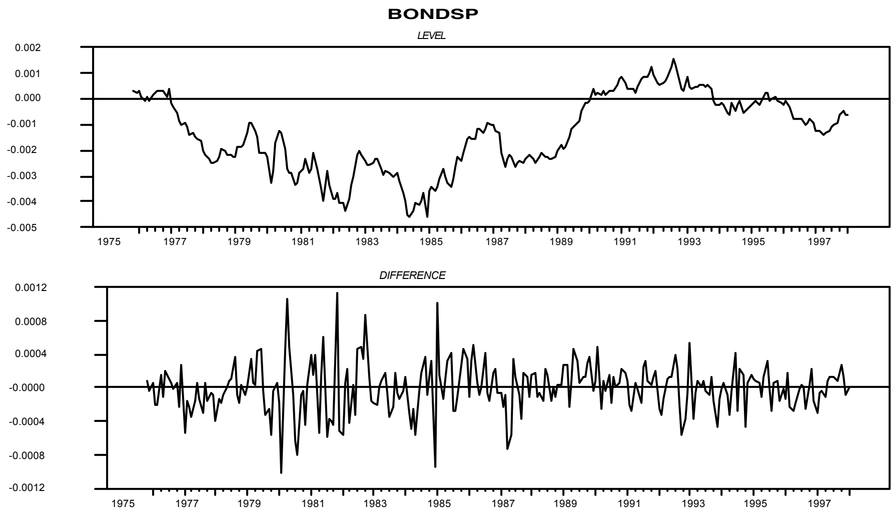

Fig. 10: The bond rate spread.

If we look at the Treasury Bill rates we notice a strong heteroskedasticity (see lower panel Fig. 11; we called BILLSP the time series of the spread between Treasury Bill rates in the two countries), and a quite irregular pattern. The short term interest rate spread might be a $I(1)$ process affected by some ARCH structure.

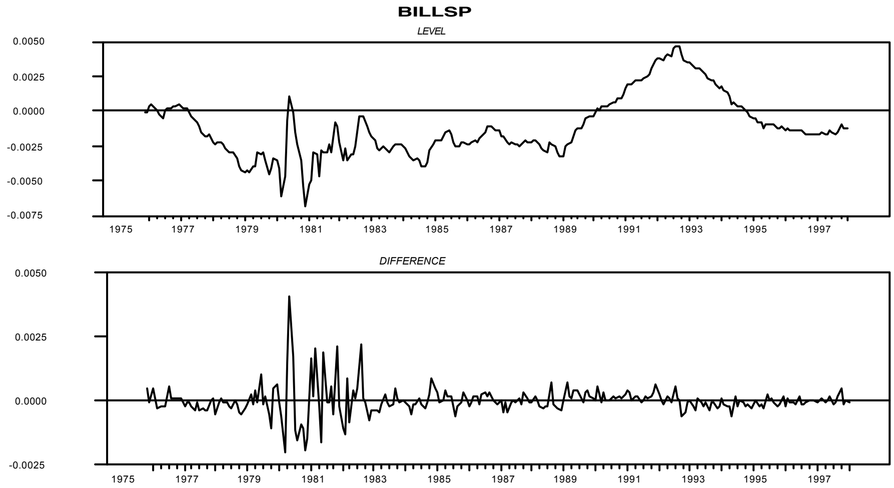

Fig. 11: The Treasury Bill rate spread.

Now, if the spread of interest rates are $I(1)$ they could be the result of the fact that the interest rates in the two countries are $I(1)$ and they do not cointegrate.

Fig. 12 and 13 suggest that both time series are affected by ARCH structures but they do not show neither the typical smooth and prolonged trending behavior of $I(2)$ time series nor linear trends in the data which would otherwise conflict with the assumption of rational behavior in financial efficient markets for which a systematic prediction for interest rates should be ruled out. Similar consideration may apply to the time series of treasury bill rates (Fig. 14 and 15), so all interest rates seem to be $I(1)$ processes with strong heteroskedasticity and they do not cointegrate by themselves.

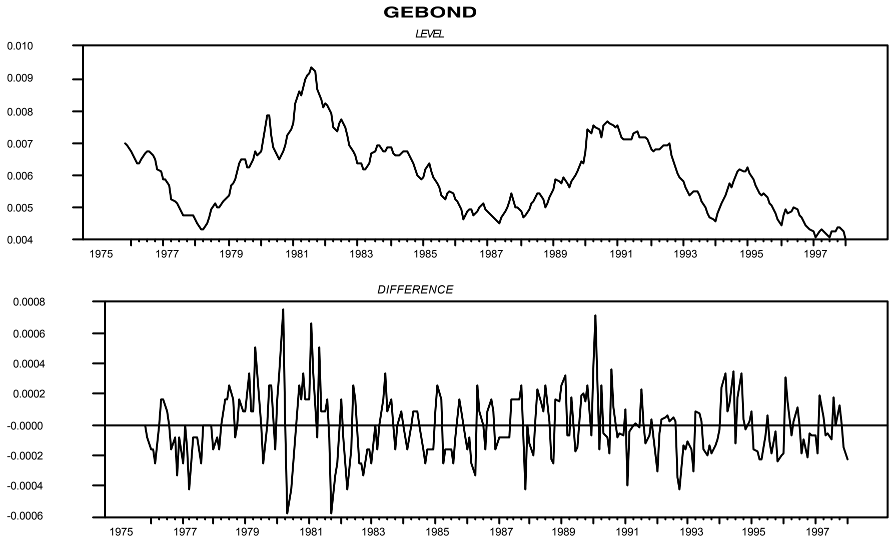

Fig. 12: The long term interest rate in Germany.

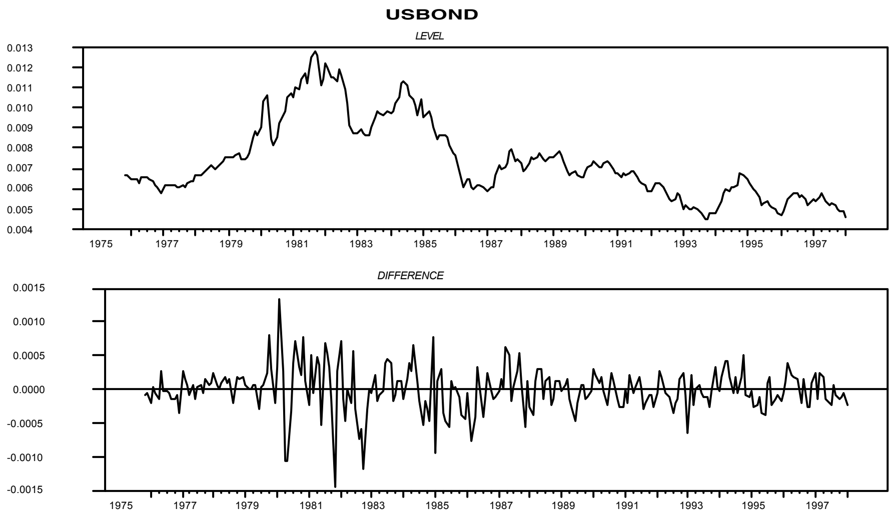

Fig. 13: the long term interest rate in the US.

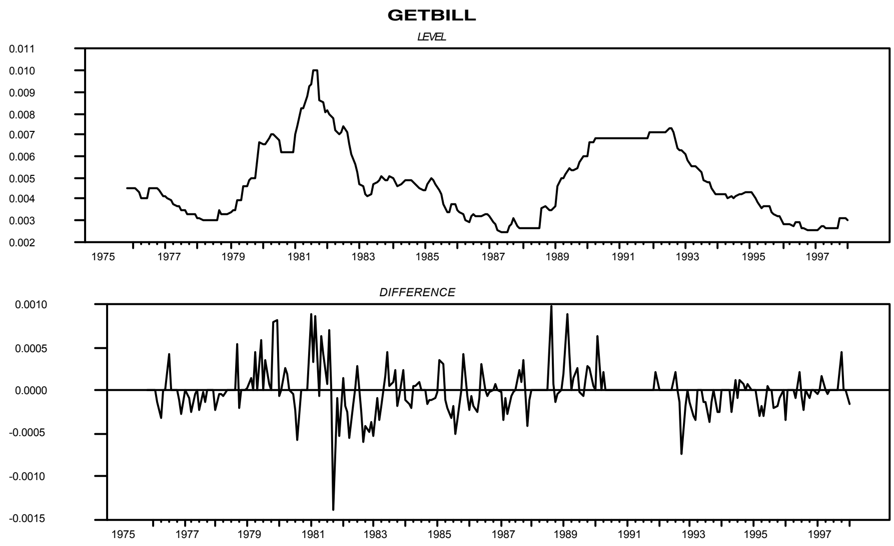

Fig. 14: Treasury Bill rate in Germany.

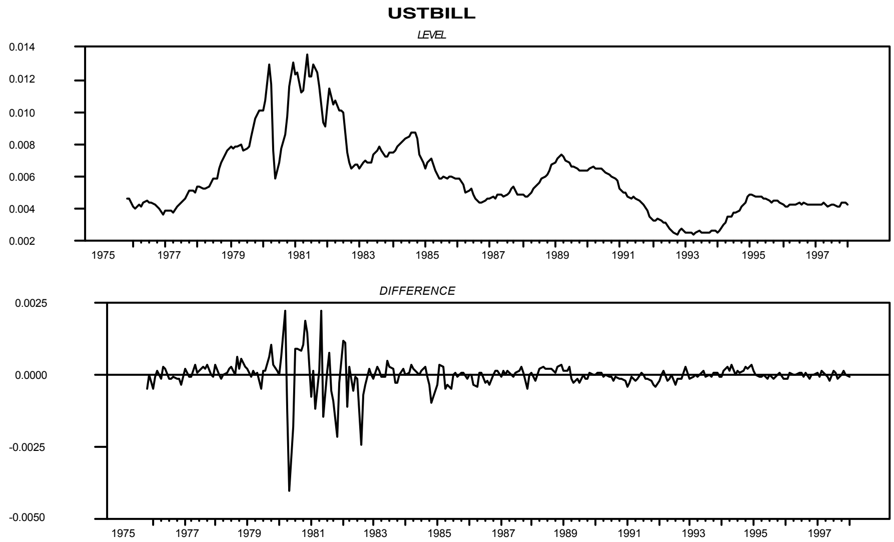

Fig. 15: The US Treasury Bill rate.

The degree of integration of the analyzed data

Summarizing, from a simple visual inspection of the data and provisionally before testing, it appears that:

- $p_t \sim I(2)$, $p_t^* \sim I(2)$, $(p_t - p_t^*) \sim I(2)$ and $s_t \sim I(2)$

- $\Delta p_t \sim I(1)$, $\Delta p_t^* \sim I(1)$, $(\Delta p_t - \Delta p_t^*) \sim I(1)$
- $\Delta s_t \sim I(1)$
- $ppp_t \sim I(1)$
- $i^l \sim I(1)$, $i^{l^*} \sim I(1)$, $(i^l - i^{l^*})$, $I(1)$, and $i^s \sim I(1)$, $i^{s^*} \sim I(1)$, $(i^s - i^{s^*}) \sim I(1)$

If some variables, such as prices and the exchange rate, are $I(2)$ and others, like inflation rates or interest rates, are $I(1)$, all the variables $(\Delta p_t, \Delta p_t^*, i_t^l, i_t^{l*}, i_t^s,$

$i_t^{s*}, ppp_t)$ in the fundamental relation (9) should be $I(1)$ variables. Thus in order to test relation (9), the $I(1)$ procedure, the so called 'Johansen procedure', should be sufficient[7].

4 The I(1) model

The I(1) model can be formulated in two equivalent forms: the vector autoregressive model VAR and the vector moving average representation VMA. While the VAR model enables us to single out the long run relations in the data, the VMA representation is useful for the analysis of the common trends that have generated the data (Juselius 1995).

4.1 The VAR representation and the long run relations

The specification of VAR model formulated in the error correction form we are going to use in our analysis is:

$$\begin{aligned}\Delta x_t = \Gamma_1 \Delta x_{t-1} + ... + \Gamma_{k-1} \Delta x_{t-k+1} + \Pi x_{t-1} + \alpha\beta_0 + \alpha\beta_1 DS_t + \\ + \gamma_1 DS + \Psi_0 Dp_t + \Psi_1 Dtr_t + \Psi_2 Dq_t + \varepsilon_t\end{aligned} \tag{11}$$

$$\varepsilon_t \sim N_p(0, \Sigma),\ t = 1, ..., T$$

where $p = 5$ (or 7 for the extended model that includes short run interest rates) is the dimension of the VAR model, $x_t' = \left[\Delta p_t, \Delta p_t^*, i_t^l, i_t^{l*}, ppp_t\right]$ (or $x_t' = \left[\Delta p_t, \Delta p_t^*, i_t^l, i_t^{l*}, i_t^s, i_t^{s*}, ppp_t\right]$), $x_t' \sim I(1)$, k is the lag length ($k = 3$ in our case), DS_t is a vector of mean shift dummy variables which accounts for a mean in Δx_t and cumulates to a broken trend in x_t serving to capture

[7]The $I(1)$ procedure can be applied only to the variables that are 'at most' $I(1)$. This means that not all the individual variables x_t have to be $I(1)$. They can be also $I(0)$, but not more than $I(1)$. This was the reason why it was necessary to build a model with variables that were integrated not more than $I(1)$.

regime shifts, Dp_t a vector of deterministic components with permanent effect such as intervention dummies, Dtr_t a vector of transitory shock dummy variables, Dq_t centered seasonal dummies which sum to zero in samples comprising complete years, Γ_1,..., Γ_{k-1}, Ψ matrices of freely varying parameters and:

$$\Pi = \alpha\beta'$$

where α and β are $p \times r$ matrices of full rank, r is the rank of the Π matrix, and $\beta' x_t$ is stationary, i.e. the stationary relations among non stationary variables such as relation (9). β_0 and γ are parameters. The constant is restricted to lie in the cointegration space and the shift dummy was decomposed in two new vectors to allow one of them to lie in the cointegration space. This model does not allow for linear trends in the data and in the cointegration relations as no reason for their existence was suggested by economic theory. Conversely it takes into account of transitory shocks, permanent interventions and regime shifts grounded on historical facts. The rank of the Π matrix is fundamental since it is equal to the number of stationary relations between the levels of the variables, i.e. the number of long run steady states towards which the process starts adjusting when it has been pushed away from the equilibrium (Hansen and Juselius 2000).

4.2 The VMA representation

The VMA representation is used to analyze the common trends that have generated the data, i.e. the pushing forces from equilibrium that create the non stationary property in the data.

The VMA representation is the following:

$$\begin{aligned} x_t = C \sum_{i=1}^{t-1} \varepsilon_i + C \sum_{i=1}^{t-1} (\alpha\delta_0 + \delta_1) DS_i + C \sum_{i=1}^{t-1} \Psi_0 Dp_i + C \sum_{i=1}^{t-1} \Psi_1 Dtr_i + \\ + C^* (L) (\varepsilon_t + (\alpha\delta_0 + \delta_1) DS_t + \Psi_0 Dp_t + \Psi_1 Dtr_t + \alpha\beta_0 + \gamma_0) + X_0 \end{aligned} \tag{12}$$

where

$$C = \beta_\perp \left(\alpha'_\perp \left(I - \sum_1^{k-1} \Gamma_i \right) \beta_\perp \right)^{-1} \alpha'_\perp$$

$\alpha_\perp$ and $\beta_\perp$ are $(p-r) \times (p-r)$ matrices orthogonal to α and β, while the C matrix is of reduced rank of order $(p-r)$ and X_0 the initial values. $C^*(L)$ is an infinite polynomial in the lag operator L.

The component $C\sum_{i=1}^{t-1}\varepsilon_i$ represents stochastic trends of the process, $C\sum_{i=1}^{t-1}(\alpha\delta_0+\delta_1)\,DS_i$ captures a broken trend in x_t while $C\sum_{i=1}^{t-1}\Psi_0 Dp_i$ and $C\sum_{i=1}^{t-1}\Psi_1 Dtr_i$ are a shift in the level of x_t and a temporary change in x_t respectively. The C matrix is also of great importance as, although the number of common trends can be guessed sometimes by means of economic considerations, the rank of the C matrix may be informative about the stochastic trends that are in the process. The rank of the C matrix is equal to the number of stochastic trends that push economic variables away from steady states. The VMA representation is of valuable help since it shows how common trends affect all the variables in the system.

4.3 'General to specific' and 'specific to general' approach

We adopt a 'general to specific' principle in statistical modelling and a 'specific to general' approach in the choice of variables. By imposing restrictions on the VAR such as reduced rank restrictions, zero parameter restrictions and other parameter restrictions, the idea is to arrive to a parsimonious model with economically interpretable coefficients (Juselius and MacDonald 2000).

In the system represented by relation (9) the vector x_t is composed by five variables but it may be extended to seven if interest rates of different maturity are also considered. It had rather better to begin to analyze small models since for each added variable we have $(2p+1)*k$ new parameters in the system. Of course when the sample is small (less than 100 observations for instance, like quarterly macroeconomic models) it is often impossible to estimate the model because the number of parameters to estimate is greater than the number of observations. As we have about 270 observations, we might estimate directly also system with seven variables if only few lags are necessary to remove significant autocorrelations in the residuals. However it may be not advantageous estimate it directly. Reducing at minimum the number of variables often helps in identifying the cointegration relations and cointegration relations remain valid in a more extended model. This property is called 'invariance' of cointegration relations in extended sets. If cointegration is found within a small set of variables, the same cointegration relations should be valid within any larger set of variables. The gradual expansion of the information set facilitates a sensitivity analysis of the results associated with the 'ceteris paribus' assumption. This strategy is known as 'specific to general' approach in the choice of variables (see Hendry and Juselius 2000, Juselius and MacDonald 2000). We first analyze the small model ($x_t' = [\Delta p_t, \Delta p_t^*, i_t^l, i_t^{l*}, ppp_t]$) excluding short term interest rates before analyzing the extended model with all the seven variables ($x_t' = [\Delta p_t, \Delta p_t^*, i_t^l, i_t^{l*}, i_t^s, i_t^{s*}, ppp_t]$).

4.4 Deterministic components

Since the asymptotic distribution of the test for cointegration depends on the assumptions made on the deterministic components, namely dummies and constant term, its choice may be crucial for inference. Without going into the details about the issues relating to the deterministic components in the cointegrated model, we need to make a sensible choice of the deterministic components in our $I(1)$ model.

We decided to set no trends both in the data and in the cointegration relations. There is no reason that is economically justified to expect trends in $\Delta p_t, \Delta p_t^*, i_t^l, i_t^{l*}, ppp_t$. The VAR, thus, was estimated with a constant restricted to the cointegration space. The only deterministic components, except the dummies allowed in our model in the data and a shift dummy allowed to lie in the cointegration space, were the intercepts in the cointegration relations.

Dummies

The likelihood-based inference methods on cointegration are derived upon the gaussian likelihood but the asymptotic properties of the methods depend on the *i.i.d.* assumption of the errors (Johansen 1995 p. 29). Thus the fact that the residuals are not distributed normally is not so important. Simulation studies have in fact shown that some assumptions are more important for the properties of the estimates than normality in the residuals. Generally if we reject the normality hypothesis (which is the null hypothesis of a test for normality) we should check the skewness and the kurtosis to see whether the residuals are well-behaved. If we do not include any dummy we would get highly bad-behaved residuals especially for which regards skewness, and all the inference would result heavily distorted. To secure valid statistical inference we need to take into account for shocks that fall outside the normality confidence level. We set a dummy variable whenever the residual was larger than $|3.5\sigma_\varepsilon|$. We have used three types of dummies, transitory, permanent and what could be called a 'temporary shift dummy' (shown below) aimed to capturing the restrictive monetary policy between the fall of 1979 and 1986. This agrees, we think, with the findings by Hansen and Johansen in 1999 that at least part of the period, 1979-1982, defined a structural different regime (Juselius and MacDonald 2003). The shift dummy we chose just aimed at capturing this different regime shift.

5 The 'small' model

We needed the following dummy variables for the small model:

$$D\prime_t = \begin{bmatrix} DS7986, \Delta DS79.11, \Delta DS86.10, D80.02, Di80.03, D80.05, D80.07, D80.11, \\ Di81.05, D81.07, D81.10, Di81.11, D82.08, D82.10, Di84.12, D86.04 \\ D88.01, D90.01, D90.08, D90.11, D91.02, D91.03, D92.10, D96.01 \end{bmatrix}$$

where:

$Dixx.yy$ is 1 at $19xx.yy_t$, -1 at $19xx.yy_{t+1}$ and 0 otherwise measuring a transitory shock.

$Dxx.yy$ is 1 at $19xx.yy_t$ and 0 otherwise measuring a permanent intervention shock.

$DS7986$ is 1 from November 1979 till October 1986 and zero otherwise. $DS7986$ aims to capture the structurally different regime of the period characterized a restrictive monetary policy.

$\Delta DS79.11$ and $\Delta DS86.10$ are $\Delta DS7986$ measured respectively in November 1979 and October 1986 and serve to remove the permanent effect generated by the shift dummy.

We tested whether these dummies were significant and hence necessary. All of them were significant for at least one of the variables (see Tab. 1 for the t-values for transitory and permanent dummies):

Tab. 1: t-values of transitory and permanent dummies

	$\Delta DS79.11$	$D80.02$	$Di80.03$	$D80.05$	$D80.07$	$D80.11$	$Di81.05$	$D81.07$
Δp_t	**−5.68**	1.22	−0.51	−0.39	0.18	0.41	−0.02	**2.47**
Δp_t^*	0.05	1.76	−0.63	−0.69	**3.93**	−1.30	−1.83	0.73
i_t^l	1.21	0.09	**3.50**	**−3.42**	−0.79	0.83	**2.55**	0.78
i_t^{l*}	−0.22	**4.03**	**2.67**	**−2.96**	1.59	**2.88**	1.85	**4.43**
ppp_t	−0.44	−0.33	**−4.41**	0.63	−0.68	0.36	−0.73	−1.38
	$D81.10$	$Di81.11$	$D82.08$	$D82.10$	$Di84.12$	$D86.04$	$\Delta DS86.10$	$D88.01$
Δp_t	0.70	−1.18	−1.16	1.03	−0.84	**−3.75**	−1.31	**−4.37**
Δp_t^*	−0.28	−1.37	−0.45	0.19	0.15	−0.86	**2.25**	−0.84
i_t^l	**−3.13**	−0.79	−1.72	−1.42	−0.83	−1.08	1.99	−0.97
i_t^{l*}	0.47	**−6.43**	**−2.35**	**−4.76**	**6.37**	−1.27	0.31	−1.69
ppp_t	1.26	1.79	−0.23	−1.20	−1.13	1.70	**−2.16**	−1.22
	$D90.01$	$D90.08$	$D90.11$	$D91.02$	$D91.03$	$D92.10$	$D96.01$	
Δp_t	**−4.07**	**2.76**	**−2.66**	−1.47	−1.17	−1.25	**−5.26**	
Δp_t^*	2.67	**5.40**	**−4.18**	**−4.77**	−0.53	−0.80	−0.32	
i_t^l	**3.49**	**3.49**	−0.15	**−3.27**	1.87	−1.76	−0.77	
i_t^{l*}	1.76	1.02	−1.15	−1.46	**2.42**	0.70	−0.15	
ppp_t	−0.16	0.14	0.63	−0.39	**−4.48**	**−3.95**	−0.96	

the shift dummy is modeled in the VAR model like an exogenous variable. The differences of the exogenous variables, in this case the shift dummy, were significant with a maximal t-value of 6.58. The component of the shift dummy that enters in the cointegration space, as will be shown also later, was found significant with t-value of 2.15 in our final choice for the restricted cointegration space.

5.1 Lag length and misspecification tests

Probably the most important requirement for unbiased results is that estimated residuals show no serial correlation. If serial correlation is found adding one lag may be sufficient to remove it. Changing the number of lags may require a change in the dummies. The dummies above were based on a VAR model with three lags.

To provide an overall picture of the adequacy of the model we report some univariate and multivariate misspecification tests in Tab. 2. A significant test statistic is given in bold font (the $\chi^2(3)$, at 5% significance level has a critical value of 7.82).

Tab. 2: Misspecification tests

Multivariate tests					
Residual autocorr. $LM(1)$	$\chi^2\,(25)$	$=$	30.9	$p-val.$	0.19
Residual autocorr. $LM(4)$	$\chi^2\,(25)$	$=$	16.2	$p-val.$	0.91
Normality	$\chi^2\,(10)$	$=$	38.1	$p-val.$	**0.00**
Univariate tests	$\Delta^2 p_t$	$\Delta^2 p_t^*$	Δi_t^l	Δi_t^{l*}	Δppp_t
ARCH(3)	3.82	5.04	2.69	3.19	6.11
JB(3)	**17.97**	5.35	**8.45**	7.04	4.76
Skewness	0.28	–0.12	0.33	0.21	0.06
Ex. Kurtosis	**1.39**	0.60	**0.79**	0.72	0.56
$\hat{\sigma}_\varepsilon \times 0.01$	0.18	0.36	0.01	0.02	0.03
R^2	0.76	0.58	0.50	0.56	0.35

Looking at Tab. 2 it seems that there are not any problems with autocorrelations of first and fourth order since $LM(1)$ and $LM(4)$ test statistics suggest that the null hypothesis for zero autocorrelation cannot be rejected. Normality is rejected as often happens, but the rejection was mainly due to an excess of kurtosis rather than skewness. This is rather important because the properties of the cointegration estimators are more sensitive to deviation from normality due to skewness. The Jarque-Bera test statistics (distributed like a $\chi^2(3)$) suggests that the rejection from normality was mainly due to excess of kurtosis. The $ARCH(3)$ (also distributed like a $\chi^2(3)$) statistic shows that significant heteroskedasticity for any variables was not found. The R^2 measures the improvement in the explanatory power of the model compared to a random walk hypothesis. The model is able to explain more about changes in inflation rates than changes in interest rates and purchasing parity.

To support that the model is quite well specified Fig. 16-20 are provided. Fig. 16-20 give four plots for each endogenous variable: the actual and the fitted values, the standardized residuals, a histogram of the standardized residuals with the histogram of the standardized

Normal distribution as background and the correlograms for lag 1 to $T/4$. Fig. 16-20 show that the standardized residuals are reasonably well behaved thanks to the selection of dummies and lags.

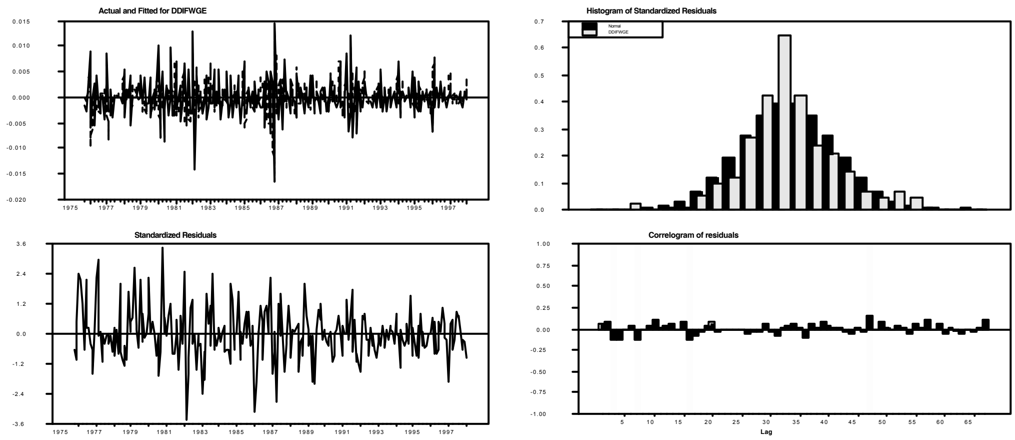

Fig. 16: Estimated residuals in the German inflation.

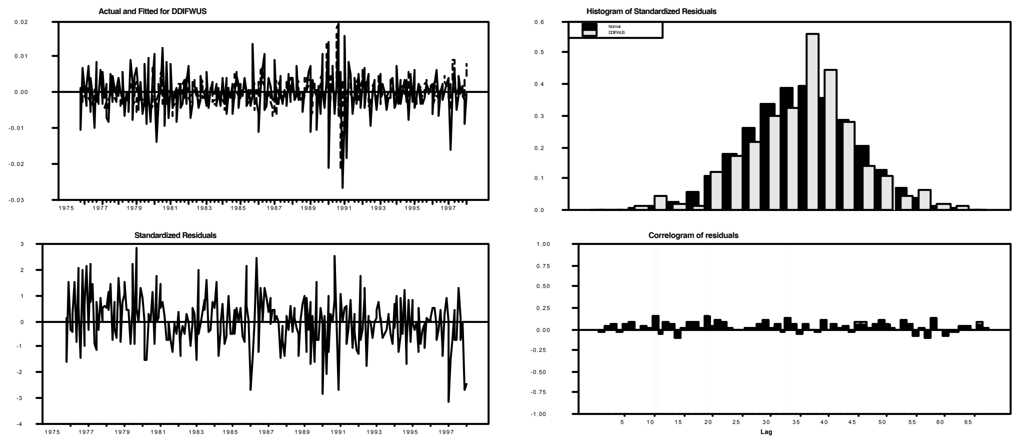

Fig. 17: Estimated residuals in the US inflation.

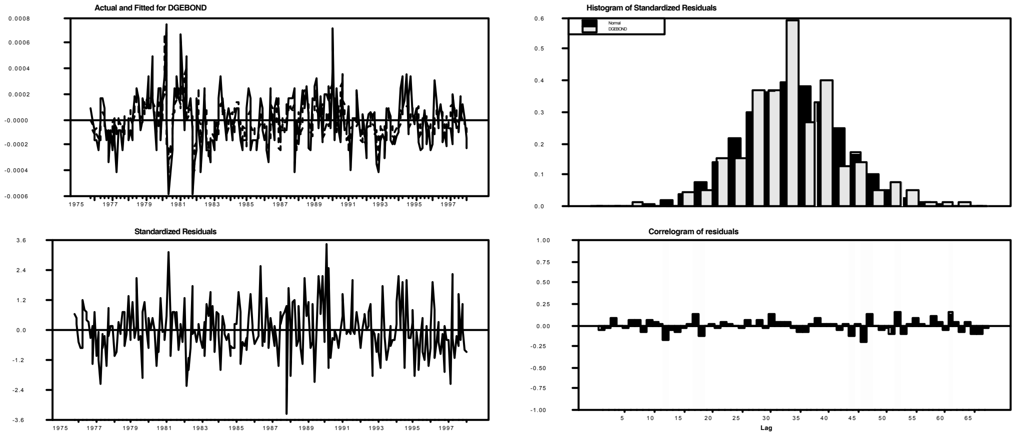

Fig. 18: Estimated residuals in the German bond rate.

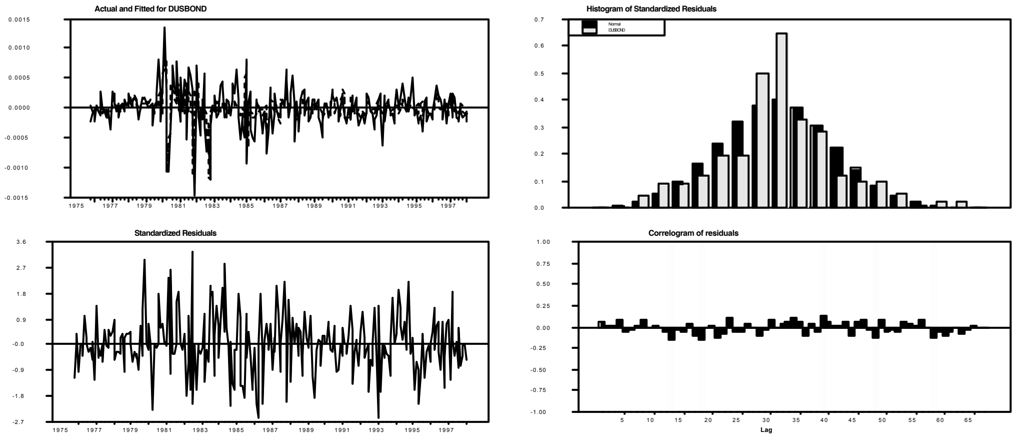

Fig. 19: Estimated residuals in the US bond rate.

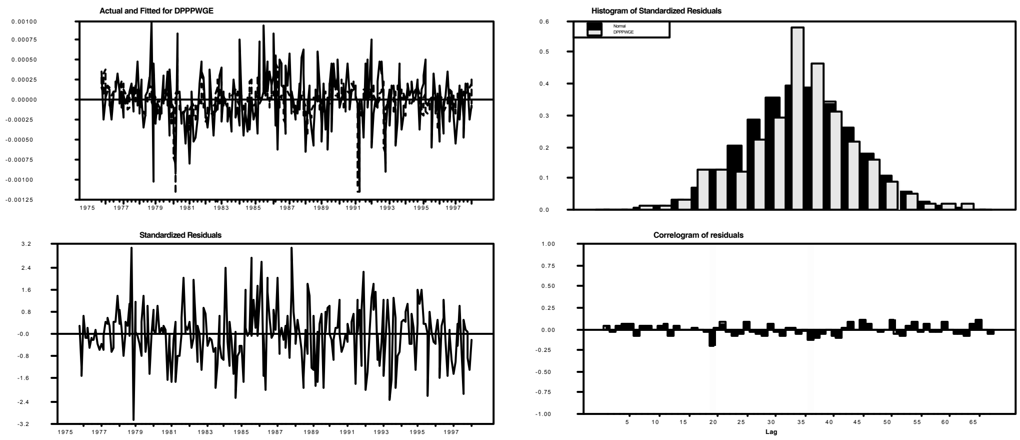

Fig. 20: Estimated residuals in the *ppp*.

5.2 Determination of the cointegration rank

The Eigenvalues of the Π matrix are reported in Tab. 3. We notice that three eigenvalues are quite close to zero. How many of them are significantly different from zero? This question is fundamental since the rank of the Π matrix is equal to p less the number of zero eigenvalues.

If we could set three eigenvalues to zero, it would mean that the rank is equal to $5 - 3 = 2$, i.e. there would be two linearly independent stationary relations.

To discriminate zero eigenvalues from non-zero eigenvalues, i.e. to calculate the cointegration rank, we use the $Trace$ test. Tab. 3 shows that the null hypothesis of the $Trace$ test, $r \leq 2$ against $r > 2$ cannot be rejected at 10% significance level.

Because the asymptotic distributions of these statistics can be rather bad approximations to the true small sample distributions we calculate in Tab. 4 the five largest roots of the companion matrix of Π to help us in the choice of the cointegration rank. Either in case the model is unrestricted, or the rank of Π is set to 2 or 3, there are 3 roots that are equal or very close to one. Since the number of roots of the companion matrix of Π is complementary to the rank of the Π, since $p = 5$, $r = 2$ and $p - r$ are roots of the companion matrix set to one, $r = 2$ is our choice.

TAB. 3: EIGENVALUES OF THE Π MATRIX AND RANK TESTS

Eigenvalues of the Π matrix	0.24	0.18	0.07	0.01	0.00
r	0	1	2	3	4
$Trace\ test$	**148.2**	**75.9**	21.9	3.0	0.8
Trace 90	71.7	49.9	31.9	17.8	7.5

TAB. 4: THE EIGENVALUES OF THE COMPANION MATRIX

Modulus of 5 largest roots					
Unrestricted model	0.99	0.98	0.92	0.78	0.64
$r = 3$	1.00	1.00	0.90	0.80	0.64
$r = 2$	1.00	1.00	1.00	0.75	0.65

Once restricted the cointegration rank $r = 2$, and normalized the first eigenvector by Δp_t, the second by Δp_t^*, we obtained the estimated α, β and Π with the respective t-values (Tab. 5, 6 and 7). In this work ppp_t was multiplied by 0.01 to avoid to show very small but significant estimates. A smaller (bigger) parameter for *ppp* may point out that the flow of financial capital is bigger (smaller) to changes in *uip*, once that proportionality between *ppp* and the current account and between the *uip* and the capital account are ascertained.

Tab. 5: beta transposed

	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	ppp_t	$DS7986$	$constant$
β_1'	1.000	−0.239	−0.621	−0.296	0.197	0.002	−0.000
β_2'	0.000	1.000	0.551	−1.396	−1.048	0.002	−0.000

Based on the estimated α coefficients we note that:

1) the first relation is significantly adjusting in the German inflation rate.

2) the second relation is significantly adjusting in the German and US inflation rates and possibly to the US interest rate.

We note that the rows correspondent to Δi_t^l and Δppp_t in Tab. 6 are not significant. This implies that the equations for Δi_t^l and Δppp_t do not contain information about the long run parameters β, i.e. i_t^l and ppp_t are weakly exogenous. We also notice that the t-value for Δi_t^{l*} is rather borderline.

Tab. 6: ALPHA, T-VALUES FOR ALPHA

	$\hat{\alpha}_1$	$\hat{\alpha}_2$
$\Delta^2 p_t$	**-0.531** −7.02	**-0.011** −3.12
$\Delta^2 p_t^*$	0.182 1.24	**-0.468** −6.63
Δi_t^l	0.002 0.37	0.004 1.56
Δi_t^{l*}	−0.017 −1.93	**0.009** 2.24
Δppp_t	−0.014 −1.30	−0.002 −0.33

In the Π matrix, the rows give the estimates of the combined effect of the two cointegration relation. The inflation rates are both equilibrium error correcting, while the German interest rate and the ppp_t are not. Again the t-values for i_t^{l*} are borderline.

Tab. 7: Π matrix and t-values

	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	ppp_t	$DS7986$	$constant$
$\Delta^2 p_t$	**-0.531** -7.02	0.013 0.33	**0.267** 5.23	**0.316** 5.68	0.015 0.36	$\mathbf{-0.001}$ -7.56	**-0.000** 7.02
$\Delta^2 p_t^*$	0.182 1.24	**-0.511** -6.49	**-0.371** -3.75	**0.599** 5.56	**0.526** 6.62	$\mathbf{-0.001}$ -2.67	-0.000 -1.24
Δi_t^l	0.002 0.37	0.004 1.23	0.001 0.27	-0.007 -1.57	-0.004 -1.31	-0.000 1.18	-0.000 -0.372
Δi_t^{l*}	-0.017 -1.93	**0.014** 2.87	**0.016** 2.66	**-0.008** -1.28	**-0.013** -2.79	-0.000 -0.35	0.000 1.93
Δppp_t	-0.014 -1.297	0.002 0.29	0.008 1.06	0.007 0.82	-0.001 -0.17	-0.000 -1.26	0.000 1.30

The long run weak exogeneity test is formulated as a zero row in α and the null hypothesis is that the variable is weakly exogenous. If the null hypothesis is accepted, the variable pushes the system without being pushed and can be considered a driving force in the system. We notice that i_t^l and ppp_t turned out to be weakly exogenous and i_t^{l*} assumes again a borderline value (Tab. 8). Considering i_t^{l*} weakly exogenous is consistent with our choice of the rank $r = 2$. A joint test for weak exogeneity, restricting the α parameters for the bond rates and *ppp*, after having fully identified the long run structure as will be shown later was accepted with a $p - value = 0.14$ in conformity with the rank restriction $r = 2$.

Tab. 8: Test for Weak Exogeneity

	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	ppp_t	$\chi^2(\nu)$
Long run weak exogeneity	39.1	33.0	**2.0**	8.0	**1.5**	$\chi^2(2)$=5.99

5.3 Single cointegration hypothesis

Looking for cointegration relations means to search for stationary linear combinations of the variables x_t. Single cointegration tests test whether a restricted relation can be accepted leaving the other relation unrestricted. If the hypothetical relations exists empirically, this procedure maximizes the chance to find them (Juselius and MacDonald 2000).

$\mathcal{H}_1$ to $\mathcal{H}_4$ are hypothesis on pairs of variables, such as relative inflation ($\mathcal{H}_1$), relative interest rates ($\mathcal{H}_2$), and stationary real interest rates ($\mathcal{H}_3$ and $\mathcal{H}_4$) (Tab. 9). Although some were accepted the $p - value$ for three of them are not very high. Compared to a former work by Bevilacqua and Daraio (2001) using the same data but using a significant shift dummy for the period of M3 targeting we notice that the evidence for the Fisher parity condition for Germany has dropped from $p-value = 0.83$ to just 0.14 so that support for stationary real interest rates is in this analysis much less evident.

$\mathcal{H}_5$ is a combination of $\mathcal{H}_1$ with $\mathcal{H}_2$ while $\mathcal{H}_6$ is a combination of $\mathcal{H}_3$ with $\mathcal{H}_4$ and in both cases as expected the $p-values$ are not very high. $\mathcal{H}_7$ is interesting as it may be considered as the *uip* condition. Support for *uip* is very modest with a $p-value$ lower than relative inflation.

Hypothesis tests from $\mathcal{H}_8$ to $\mathcal{H}_{11}$ combine relative inflation, the interest rate spread and Fisher parity conditions with *ppp*. With the exception of the US real interest rate combining these parities with the *ppp* does not produce more significant stationary relationships. $\mathcal{H}_{12}$ instead combines the *uip* condition shown in $\mathcal{H}_7$ with the *ppp* producing an outstanding stationary relation accepted with a $p - value$ of 0.80. $\mathcal{H}_{13}$, accepted with a $p - value$ of 0.30, describes a homogeneous relationship (that is coefficients sum to zero) between German and US inflation and the German bond rate, which captures the effects of imported inflation from the US to Germany. It is interesting to note that notwithstanding producer price indices do not include prices for imported goods, both the producer price and the consumer price indices have very similar estimated parameters (they are exactly 1, -0.34 and -0.66 in Juselius and MacDonald 2000!), suggesting that imported goods used for production affect producer prices in the same way imported goods do directly with consumer prices. Exchange rate movements directly affects domestic prices of imported goods and with it consumer price indices and, if the exchange rate appreciates (depreciates), the price of imported goods tend to fall (grow) reducing (increasing) consumer price inflation directly. However, if these imports are used as inputs into the production process, lower (higher) prices for inputs feed through into lower (higher) producer prices. In general, the effects on imported inflation may be expected to depend on how open the economy is to international trade (ECB 2004).

Testing $\mathcal{H}_{12}$ is the equivalent of testing our fundamental relation (9). It is interesting to note that $\mathcal{H}_{12}$ can be interpreted in many ways.

$\mathcal{H}_{12}$ can be interpreted like a linear long-run relationship between *ppp* and *uip*:

$$
\begin{aligned}
(-\Delta p_t + \Delta p_t^*) + (i_t^l - i_t^{l*}) &= \omega ppp_t \\
-uip_t &= \omega ppp_t
\end{aligned}
$$

but also as the log of real exchange rate (which is *ppp*) proportional to the spread between the real interest rates in the two countries:

$$(i_t^l - \Delta p_t) - (i_t^{l*} - \Delta p_t^*) = \omega ppp_t$$

If *ppp* is decomposed into prices and the nominal exchange rate, we might even come up with a relation, which might be interpreted like an equation for the determinants of the exchange rate, that shows the nominal exchange rate in function of the spread of prices and the spread of real interest rates:

$$s_t = (p_t - p_t^*) - \tfrac{1}{\omega}(i_t^l - \Delta p_t) + \tfrac{1}{\omega}(i_t^{l*} - \Delta p_t^*)$$

a relation similar to equation (6) in MacDonald (2000) that can be derived with few assumptions directly from the balance of payments and can be thought as a very general representation of an equilibrium exchange rate in that it satisfies balance of payments equilibrium under floating exchange rates (MacDonald 2000). The last equation shows that high nominal interest rates, combined with low inflation rates, produce high real interest rates which attract demand for the local currency inducing nominal appreciation for the domestic currency, infringing the *uip* theory.

Alternatively $\mathcal{H}_{12}$ can be interpreted as an international real interest rate parity which shows that the US real interest rate is lower than the German real interest rate when *ppp* is positive and the US real interest rate increases when *ppp* is negative, i.e. when the US prices are greater than German prices:

$$(i_t^{l*} - \Delta p_t^*) = (i_t^l - \Delta p_t) - \omega ppp_t$$

Whatever the interpretation, $\mathcal{H}_{12}$ is accepted with a very high $p - value$ meaning that relation (9) is empirically valid with $\omega = 1.061$. A very similar value for ω, $\omega = 1.01$, was found by Juselius and MacDonald (2000) using consumer price indices and a different shift dummy. This shows a remarkable robustness of the validity of the relation found by Juselius and MacDonald to changes in price indices and even to the different shift dummy that was in this case needed.

Tab. 9: Cointegration relations

	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	ppp_t	$D7986$	$constant$	$\chi^2(\nu)$	$p-val$
$\mathcal{H}_1$	1	-1	0	0	0	-0.002	-0.000	5.26 (3)	**0.15**
$\mathcal{H}_2$	0	0	1	-1	0	0.002	-0.000	48.43 (3)	0.00
$\mathcal{H}_3$	1	0	-1	0	0	0.001	-0.000	5.40 (3)	**0.14**
$\mathcal{H}_4$	0	1	0	-1	0	0.005	-0.000	3.81 (3)	**0.28**
$\mathcal{H}_5$	1	-1	-0.327	0.327	0	-0.002	0.000	4.74 (2)	0.09
$\mathcal{H}_6$	1	0.766	-1	-0.766	0	0.005	-0.000	2.89 (2)	**0.24**
$\mathcal{H}_7$	1	-1	-1	1	0	-0.004	-0.000	6.83 (3)	0.08
$\mathcal{H}_8$	1	-1	0	0	0.568	0.000	-0.000	3.57 (2)	**0.17**
$\mathcal{H}_9$	0	0	-1	1	1.052	0.001	-0.000	35.27 (2)	0.00
$\mathcal{H}_{10}$	1	0	-1	0	0.219	0.002	−0.000	4.64 (2)	**0.10**
$\mathcal{H}_{11}$	0	1	0	-1	-0.827	0.002	0.000	0.79 (2)	**0.67**
$\mathcal{H}_{12}$	1	-1	-1	1	1.061	-0.001	0.000	0.45 (2)	**0.80**
$\mathcal{H}_{13}$	1	-0.345	-0.655	0	0	0	0.000	3.70 (2)	**0.30**

The ppp term has been divided by 100

5.4 Fully specified cointegrating relations

We are now ready to test jointly $\mathcal{H}_{12}$ (equivalent to relation (9)), which shows a cointegration relationship between *uip* and *ppp*, with $\mathcal{H}_{13}$, which shows the imported US inflation in Germany.

The test statistic $\chi^2(5)$ was found equal to 3.72 with a $p-value$ of 0.59. The first vector has been normalized on the German inflation rate and the second on the German interest rate. The first vector is given by:

$$\Delta p_t = 0.343\Delta p_t^* + 0.657 i_t^l \tag{13}$$

while the second representing relation (9) is:

$$(i_t^{l*} - \Delta p_t^*) = (i_t^l - \Delta p_t) - 0.006 ppp_t + 0.002 DS7986 \tag{14}$$

In Tab. 10, a structural representation of the cointegration space is finally given. The adjustment coefficients and t-values are reported. What is noticeable is that none of the adjustment parameters referring to interest rates and *ppp* are significant while they are all significant for inflation rates, suggesting that interest rates and *ppp* are not adjusting to the two steady state relations as we would expect from weakly exogenous variables.

TAB. 10: A STRUCTURAL REPRESENTATION OF THE COINTEGRATION SPACE

	$\hat{\beta}_1$	$\hat{\beta}_2$		$\hat{\alpha}_1$	$\hat{\alpha}_2$
Δp_t	**1**	**1**	$\Delta^2 p_t$	**−0.757** (−7.60)	**0.250** (4.39)
Δp_t^*	**−0.343** (−3.59)	**−1**	$\Delta^2 p_t^*$	**−0.568** (−2.93)	**0.690** (6.24)
i_t^l	**−0.657** (−11.49)	**−1**	Δi_t^l	0.008 (1.04)	−0.007 (−1.62)
i_t^{l*}	0	**1**	Δi_t^{l*}	−0.004 (−0.36)	−0.012 (−1.86)
ppp_t^1	0	**0.583** (2.08)	Δppp_t	−0.014 (−0.96)	0.005 (0.59)
$DS7986$	0	**−0.002** (−2.15)			
constant	−0.000	−0.000			

The ppp term has been divided by 100

We report in Fig 21 the result of recursive estimation for testing the constancy of the cointegration space. The value *1* corresponds to a test with 5% significance level. It appears that the restricted model shows a remarkable β constancy as the test supports the hypothesis of parameter constancy for the period we investigated (see the lower line which corresponds to the restricted cointegration space).

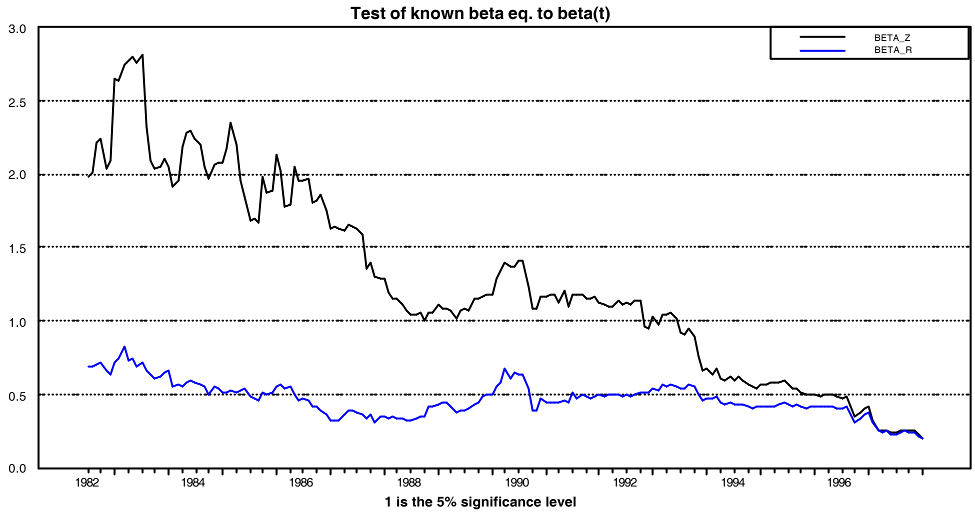

Fig. 21: Cointegration space constancy test.

5.5 Common trends

Weak exogeneity was accepted for the interest rates and *ppp*, although with a $p - value$ of only 0.07 for the US bond rate. Weak exogeneity for German bond rate and *ppp* were more apparent (respectively $p - value$ of 0.52 and 0.71). Joint weak exogeneity among bond rates and *ppp* were always accepted with $p - values$ of 0.11 (among i_t^l and i_t^{l*}), 0.65 (among i_t^l and *ppp*), 0.10 (among i_t^{l*} and *ppp*) and 0.14 (among i_t^l, i_t^{l*} and *ppp*). Thus, there is some evidence that interest rates and *ppp* are the driving forces of the system.

We report the VMA (common trends) representation for two different cases: (i) based on the fully specified cointegrating relations restricted VAR model for $r = 2$ (the model with unrestricted β show similar values with the exception that a *ppp* shock would have no significant impact on German inflation), (ii) based on (i) but after having fully specified cointegrating relations with weak exogeneity of i_t^l, i_t^{l*} and ppp_t imposed on α.

The estimates of the C matrix in Tab. 11 measure the total impact of permanent shocks to each of the variables on all other variables. A row of the C matrix gives an indication of which variables have been particularly important for the stochastic trend behavior of the variable in the row.

TAB. 11: THE ESTIMATES OF THE LONG RUN IMPACT MATRIX C

C	$\sum \hat{\varepsilon}_{\Delta p_t}$	$\sum \hat{\varepsilon}_{\Delta p_t^*}$	$\sum \hat{\varepsilon}_{i_t^l}$	$\sum \hat{\varepsilon}_{i_t^{l*}}$	$\sum \hat{\varepsilon}_{ppp_t}$	$\sum \hat{\varepsilon}_{i_t^l}$	$\sum \hat{\varepsilon}_{i_t^{l*}}$	$\sum \hat{\varepsilon}_{ppp_t}$
Δp_t	-0.016 -1.02	**0.022** 2.52	**0.814** 5.51	**0.538** 7.24	**0.283** 4.03	**0.715** 4.77	**0.667** 8.27	**0.364** 5.23
Δp_t^*	-0.054 -1.93	0.031 2.00	-0.362 -1.36	**1.294** 9.64	**1.057** 8.32	-0.497 -1.80	**1.457** 9.79	**1.17** 9.08
i_t^l	0.004 0.23	0.017 1.72	**1.428** 8.56	1.044 1.70	-0.121 -1.52	**1.426** 8.84	**0.204** 2.35	-0.106 -1.42
i_t^{l*}	-0.028 -1.55	**0.029** 2.80	0.036 0.21	**1.044** 11.87	0.081 0.97	-0.019 -0.11	**1.162** 12.37	0.065 0.80
ppp_t	-0.010 -0.48	-0.004 -0.35	0.370 1.87	**-0.248** -2.50	**0.983** 10.429	0.357 1.84	**-0.259** -2.48	**0.969** 10.74

We note that cumulative shocks to inflation rates in Germany have no significant long run impact on any other variable. Estimated cumulative shocks to the US inflation rate assume boundary $t - values$ in the unrestricted VAR model, while cumulative shocks to long term interest rates and to *ppp* are often highly significant.

Given the results from Tab. 11, the restricted VMA representation may be simplified as:

$$\begin{bmatrix} \Delta p_t \\ \Delta p_t^* \\ i_t^l \\ i_t^{l*} \\ ppp_t \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ 0 & c_{22} & c_{23} \\ c_{31} & c_{32} & 0 \\ 0 & c_{42} & 0 \\ 0 & c_{52} & c_{53} \end{bmatrix} \begin{bmatrix} \sum \varepsilon_{i_t^l} \\ \sum \varepsilon_{i_t^{l*}} \\ \sum \varepsilon_{ppp_t} \end{bmatrix} + \begin{array}{c} \text{stationary and} \\ \text{deterministic} \\ \text{components} \end{array}$$

The VMA representation suggests that:

- Inflation rates are adjusting

- German inflation rate is pushed by home and US interest rates and *ppp*, while US inflation is not pushed by the German interest rate.

- Shocks to the German long term interest rate speed up the German inflation only.

- Shocks to the US long term interest rate have an impact on both the German and US inflation rates.

- Shocks to *ppp* affect the inflation rates in the two countries.

6 The 'extended model'

The 'extended model' includes the Treasury Bill rates that are more closely linked to the monetary policy than long term interest rates as bond rates with a maturity of ten years. In fact, given its monopoly over the creation of base money, the central bank can fully determine the official interest rate and exert a dominant influence on money market conditions steering money market interest rates having an impact on short term interest rates (ECB 2004). Conversely, the impact of money market rate changes on interest rates at long maturities (e.g. government bond yields) is less direct as these rates depend to a large extent on market expectations for long term growth and inflation trends (ECB 2004). In general, changes in the central bank's official rates do not normally affect long term rates unless they lead to a change in market expectations on long term economic trends (ECB 2004). Extending the small model including short term interest rates, we can test whether short term interest rates shocks normally do not lead to changes in long term interest rates as the ECB maintains unlike the standard expectations model of the term structure for which short rates drive long rates[8]. Including the short term interest rates in the system allows also to test whether the spread of inflation rates might be linked to the spread between domestic and foreign yield gap and a number of other plausible relationships.

We needed the following dummy variables for the extended model:

$$\begin{bmatrix} DS7986, \Delta DS7911, \Delta DS8610, D7912, Di8003, D8005, D8007, \\ D8011, D8101, D8103, Di8105, D8110, Di8111, D8203, D8208, \\ D8411, Di8412, D8604, D8808, D8902, D9008, D9102, D9601 \end{bmatrix}$$

We tested whether these dummies were significant, and hence necessary and we found that all of them were significant for at least one of the variables (not shown here).

6.1 Lag length and misspecification tests

Three lags and a different set of dummies were not sufficient to remove first order autocorrelation, however, just restricting the cointegration rank there was no significant first order autocorrelation without the need to increase the lag length. We decided for a model with three

[8]See Juselius and MacDonald (2003) about these issues.

lags as it has the advantage to have fewer parameters to estimate than a model with more lags. Fourth order autocorrelation was no problem altogether.

To provide an overall picture of the adequacy of the model we report some univariate and multivariate misspecification tests in Tab. 12. A significant test statistic is given in bold font (the $\chi^2(3)$, at 5% significance level has a critical value of 7.8).

TAB. 12: MISSPECIFICATION TESTS

MULTIVARIATE TESTS							
Residual autocorr. $LM(1)$	$\chi^2(49)$	$=$	71.1	$p-val.$	$=$	0.02	
Residual autocorr. $LM(4)$	$\chi^2(49)$	$=$	39.6	$p-val.$	$=$	0.83	
Normality	$\chi^2(14)$	$=$	126.1	$p-val.$	$=$	**0.00**	
UNIVARIATE TESTS	$\Delta^2 p_t$	$\Delta^2 p_t^*$	Δi_t^l	$\Delta i_t^{l^*}$	Δi_t^s	$\Delta i_t^{s^*}$	Δppp_t
ARCH(3)	3.4	**24.9**	7.5	2.1	1.01	6.3	3.4
JB(3)	**27.1**	**9.4**	4.1	3.5	**10.7**	**26.9**	**12.7**
Skewness	0.06	-0.22	0.28	0.08	0.23	0.23	-0.08
Ex. Kurtosis	**1.72**	**0.89**	0.31	0.45	**0.96**	**1.78**	**1.06**
$\hat{\sigma}_\varepsilon \times 0.01$	0.19	0.37	0.01	0.02	0.02	0.02	0.03
R^2	0.73	0.57	0.50	0.52	0.65	0.84	0.28

Normality is rejected, but the rejection was mainly due to an excess of kurtosis rather than skewness. The Jarque-Bera test statistics (distributed like a $\chi^2(3)$) suggests that the rejection from normality was mainly due to excess of kurtosis. The $ARCH(3)$ (also distributed like a $\chi^2(3)$) statistic shows that there is significant heteroskedasticity only in US inflation. However, as cointegration estimates are not very sensitive to $ARCH$ structures (Gonzalo 1994, Rahbek *et Al.* 2002), we are not be forced to use to a VAR model that takes into account $ARCH$ non linearities.

The R^2 measurements for the improvement in the explanatory power of the model compared to a random walk hypothesis are reported.

To support that the model is rather adequately specified Fig. 22-28 are provided. Fig. 22-28 show that the standardized residuals are well behaved thanks to a proper choice of dummies and lags.

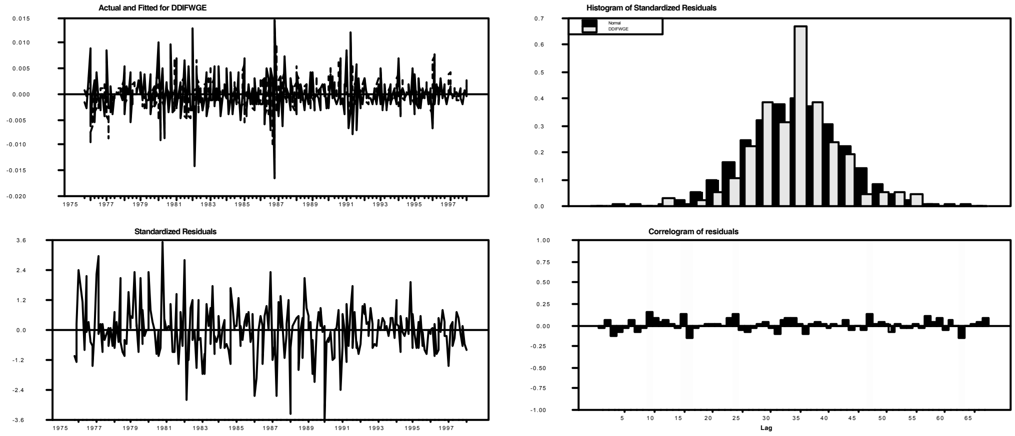

Fig. 22: The estimated residuals of German inflation.

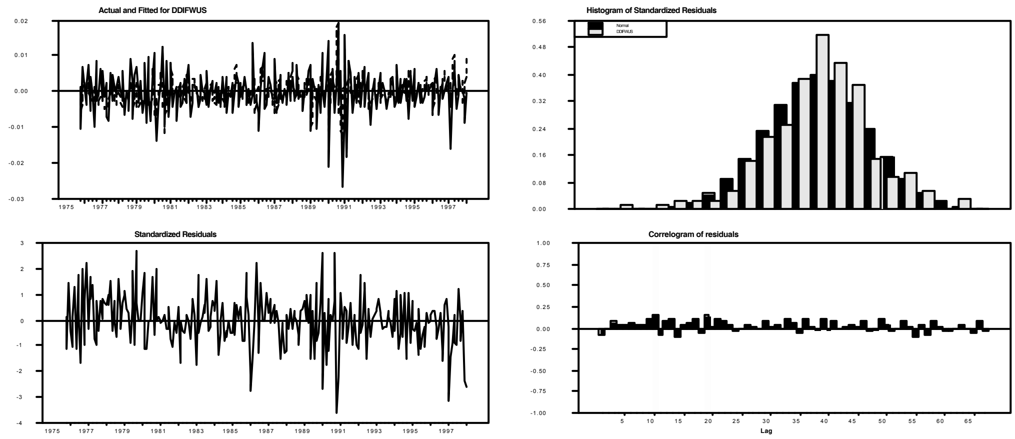

Fig. 23: The estimated residuals of US inflation.

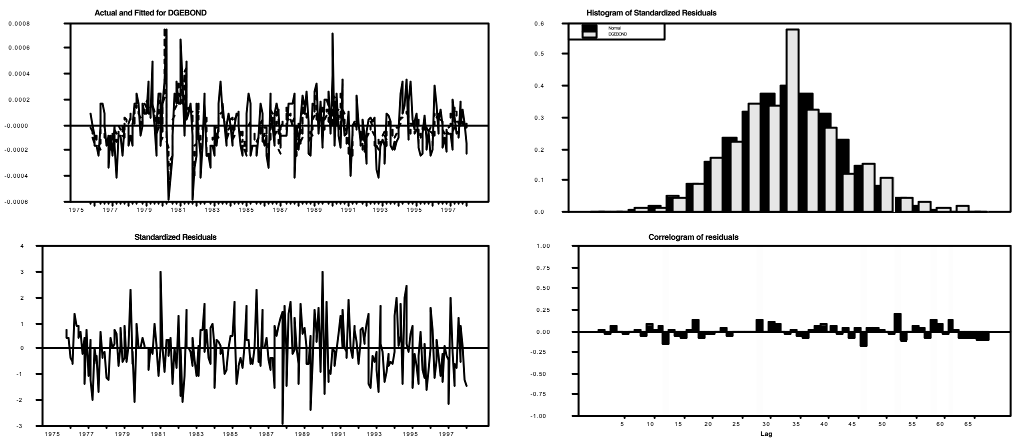

Fig. 24: The estimated residuals of the German bond rate.

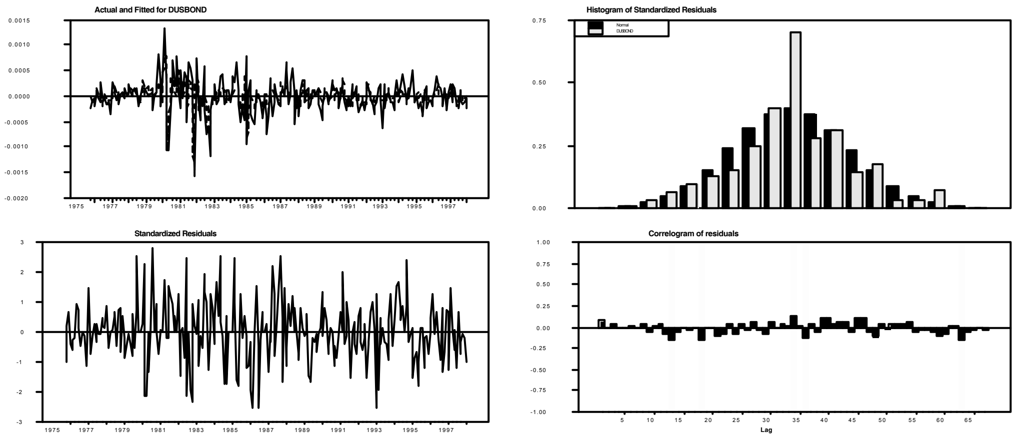

Fig. 25: The estimated residuals of the US bond rate.

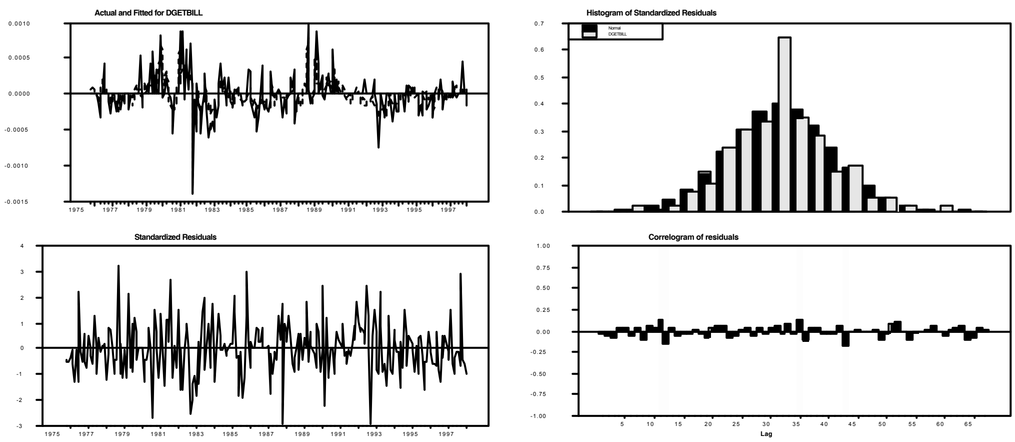

Fig. 26: The estimated residuals of the German treasury bill rate.

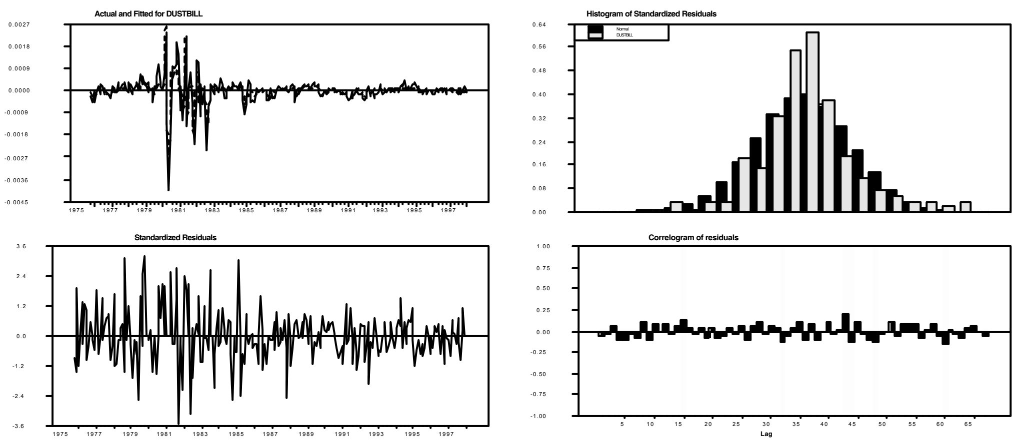

Fig. 27: The estimated residuals of the US treasury bill rates.

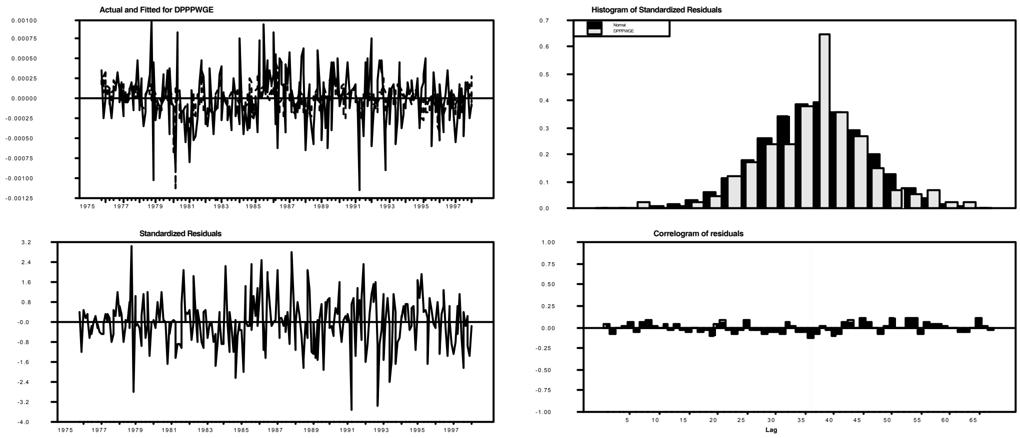

Fig. 28: The estimated residuals of the *ppp*.

6.2 Determination of the cointegration rank

The Eigenvalues of the Π matrix are reported in Tab. 13. We notice that at least three eigenvalues are quite close to zero.

Tab. 13 shows that the null hypothesis of the $Trace$ test, $r \leq 3$ against $r > 4$ cannot be rejected at 10% significance level.

If $r = 3$, $p - r = 4$; including short term interest rates have introduced one additional stochastic trend. This means that the short term interest rates can be jointly cointegrated or cointegrated by with the remaining variables of the system.

TAB. 13: EIGENVALUES OF THE Π MATRIX AND RANK TESTS (EXTENDED MODEL)

Eigenvalues of the Π matrix	0.27	0.23	0.11	0.09	0.03	0.03	0.00
r	0	1	2	3	4	5	6
Trace test	**228.42**	**143.71**	**71.69**	40.42	14.78	7.02	0.09
Trace 90	126.71	97.17	71.66	49.91	31.88	17.79	7.50

As the asymptotic distributions of the trace test statistics can be rather bad approximations to the true sample distributions and should be used with caution in particular in the case of special dummy variables (Hansen and Juselius 1995) such as the shift dummy we have used we further checked the eigenvalues of the companion matrix. Keeping the restrictions of the cointegrating vectors in the small model and calculating the rank with $r = 3$ we obtain a fifth root of 0.85, which is a rather high remaining root but still much lower than the case $r = 4$. Both the trace test and the analysis of the eigenvalues of the companion matrix support the rank restriction $r = 3$ (Tab. 14).

TAB. 14: THE EIGENVALUES OF THE COMPANION MATRIX

MODULUS OF 5 LARGEST ROOTS					
$r = 4$	1.00	1.00	1.00	0.94	0.94
$r = 3$	1.00	1.00	1.00	1.00	0.85

6.3 Single cointegration hypothesis

An advantage of the 'specific to general' approach is that we can in principle keep unchanged the two cointegration relations found for the small model in the extended model. The impact of the two new variables, the short term interest rates, should involve an additional cointegrating relation. To have some idea about the new cointegration relation we first estimate the partially restricted long run structure keeping two cointegration relation unchanged ($\mathcal{H}_{12}$ and $\mathcal{H}_{13}$) but leaving unrestricted the third one. The hypothesis was accepted with a $p-value$ of 0.25. This third cointegrating relation could contain information about the spread between long and short interest rates in the two countries or about the spread of real interest rates (Tab. 15). We notice that the parameter for ppp is much smaller than all the others, which assume values around 1 or -1 depending on the normalization. Before making further parameter restrictions we test the single cointegration hypothesis for the extended model to see which relations hold both for the small and the extended model and to find the third cointegration vector that will allow to form a restricted but significant (both in statistical and economic terms) cointegration space.

TAB. 15: THE THIRD UNRESTRICTED COINTEGRATING RELATION

	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	i_t^s	i_t^{s*}	ppp_t	$DS7986$	$const.$	$\chi^2(\nu)$	$p-val$
$\mathcal{H}$	1.000	-1.515	1.512	-1.169	-1.375	1.683	0.156	-0.006	-0.000	9.11	0.25

$\mathcal{H}_1$ to $\mathcal{H}_9$ are hypothesis on pairs of variables, such as relative inflation ($\mathcal{H}_1$), relative interest rates ($\mathcal{H}_2, \mathcal{H}_3$), stationary real interest rates ($\mathcal{H}_4, \mathcal{H}_5, \mathcal{H}_6$ and $\mathcal{H}_7$) (Tab. 16) and the spread between interest rates ($\mathcal{H}_8, \mathcal{H}_9$). Although some were accepted, the $p-values$ were not very high.

$\mathcal{H}_{10}$ is a combination of $\mathcal{H}_1$ with $\mathcal{H}_2$, $\mathcal{H}_{11}$ is a combination of $\mathcal{H}_4$ with $\mathcal{H}_5$, $\mathcal{H}_{13}$ is a combination of $\mathcal{H}_1$ with $\mathcal{H}_3$, $\mathcal{H}_{14}$ is a combination of $\mathcal{H}_6$ with $\mathcal{H}_7$. In these cases, but $\mathcal{H}_{13}$, the $p-values$ are not very high. $\mathcal{H}_{12}$ and $\mathcal{H}_{15}$ may be considered as the *uip* condition. Support for *uip* is not very evident although using the short term interest rates the hypothesis would be accepted with a $p-value$ of 0.20. $\mathcal{H}_{16}$ and $\mathcal{H}_{17}$ combine $\mathcal{H}_2$ with $\mathcal{H}_3$, i.e. the spread among interest rates between the two countries. $\mathcal{H}_{17}$ can also be seen as a combination of the term spreads ($\mathcal{H}_8$ and $\mathcal{H}_9$). Both $\mathcal{H}_{16}$ and $\mathcal{H}_{17}$ are rejected.

$\mathcal{H}_{18}$ to $\mathcal{H}_{26}$ combine the pairs of variables described from $\mathcal{H}_1$ to $\mathcal{H}_9$ with *ppp*. With the exception of the long term interest rate spread, combining these parities with the *ppp* does not produce more significant stationary relationships.

$\mathcal{H}_{27}$ instead combines the *uip* condition shown in $\mathcal{H}_{12}$ with the *ppp* producing a stationary relation accepted with a $p-value$ of 0.30. $\mathcal{H}_{29}$, accepted with a $p-value$ of 0.72, describes a homogeneous relationship (that is coefficients sum to zero) between German and US inflation and the German bond rate, capturing the effects of imported inflation from the US to Germany. As it was for the small model, it is interesting to note that notwithstanding producer price indices do not include prices for imported goods, both the producer price and the consumer price indices have very similar estimated parameters (they are exactly 1, -0.34 and -0.66 in Juselius and MacDonald 2003!).

Testing $\mathcal{H}_{27}$ is the equivalent of testing our fundamental relation (9) and can be interpreted similarly to $\mathcal{H}_{12}$ for the small model.

$\mathcal{H}_{27}$ can be interpreted as:

- A linear long-run relationship between *ppp* and *uip*:

$$(-\Delta p_t + \Delta p_t^*) + (i_t^l - i_t^{l*}) = \omega ppp_t, \text{ i.e. } -uip_t = \omega ppp_t.$$

- The log of real exchange rate proportional to the spread between the real interest rates in the two countries:

$$(i_t^l - \Delta p_t) - (i_t^{l*} - \Delta p_t^*) = \omega ppp_t.$$

- An equation for the determinants of the exchange rate that shows the nominal exchange rate in function of the spread of prices and the spread of real interest rates:

$$s_t = (p_t - p_t^*) + \tfrac{1}{\omega}(i_t^l - \Delta p_t) - \tfrac{1}{\omega}(i_t^{l*} - \Delta p_t^*).$$

- An international real interest rate parity which shows that the US real interest rate is lower than the German real interest rate when ppp is positive and the US real interest rate increases when ppp is negative, i.e. when the US prices are greater than German prices:

$$(i_t^{l*} - \Delta p_t^*) = (i_t^l - \Delta p_t) - \omega ppp_t.$$

A very similar relation was found by Juselius and MacDonald (2000) using consumer price indices. This shows a remarkable robustness of the validity of the relation found by Juselius and MacDonald to changes in price indices.

$\mathcal{H}_{28}$ is the restricted third cointegration relation we were trying to find. It can be interpreted in many ways as it combines $\mathcal{H}_1$,$\mathcal{H}_2$ and $\mathcal{H}_3$, $\mathcal{H}_{17}$ and $\mathcal{H}_1$, $\mathcal{H}_{15}$ and $\mathcal{H}_2$, $\mathcal{H}_{24}$,$\mathcal{H}_{23}$ and $\mathcal{H}_2$ or other hypothesis. Thus, $\mathcal{H}_{28}$ can be seen as:

$$\left(i_t^l - i_t^{l*}\right) - (i_t^s - i_t^{s*}) = -\left(\Delta p_t - \Delta p_t^*\right) \tag{15}$$

which shows that if the spread between actual domestic and foreign inflation is non stationary, then the spread between domestic and foreign yield gap would also have to be non stationary. Alternatively $\mathcal{H}_{28}$ may be interpreted as:

$$(i_t^{s*} - \Delta p_t^*) = (i_t^s - \Delta p_t) - \left(i_t^l - i_t^{l*}\right) \tag{16}$$

which shows the short term real interest rate parity as a stationary relation whenever the long term bond spread were stationary. $\mathcal{H}_{28}$ is accepted with a $p-value$ of 0.85.

Tab. 16: Cointegration relations

	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	i_t^s	i_t^{s*}	ppp_t	$DS7986$	$constant$	$\chi^2(\nu)$	$p-val$
$\mathcal{H}_1$	1	-1	0	0	0	0	0	-0.004	0.000	7.77 (4)	0.10
$\mathcal{H}_2$	0	0	1	-1	0	0	0	0.002	-0.000	19.50 (4)	0.00
$\mathcal{H}_3$	0	0	0	0	1	-1	0	0.002	-0.000	15.69 (4)	0.00
$\mathcal{H}_4$	1	0	-1	0	0	0	0	0.000	0.000	6.37 (4)	**0.17**
$\mathcal{H}_5$	0	1	0	-1	0	0	0	0.005	-0.000	11.45 (4)	0.02
$\mathcal{H}_6$	1	0	0	0	1	0	0	-0.003	0.000	21.61 (4)	0.00
$\mathcal{H}_7$	0	1	0	0	0	1	0	0.006	0.000	10.14 (4)	0.04
$\mathcal{H}_8$	0	0	1	0	-1	0	0	-0.001	-0.000	25.95 (4)	0.00
$\mathcal{H}_9$	0	0	0	1	0	-1	0	0.000	-0.000	6.89 (4)	**0.14**
$\mathcal{H}_{10}$	1	-1	-0.421	0.421	0	0	0	-0.004	0.000	6.98 (3)	0.07
$\mathcal{H}_{11}$	1	-0.276	-1	0.276	0	0	0	-0.001	0.000	5.34 (3)	**0.15**
$\mathcal{H}_{12}$	1	-1	-1	1	0	0	0	-0.006	-0.000	8.20 (4)	0.08
$\mathcal{H}_{13}$	1	-1	0	0	-0.576	0.576	0	-0.005	0.000	3.08 (3)	**0.38**
$\mathcal{H}_{14}$	1	-1.401	0	0	-1	1.401	0	-0.008	-0.000	5.33 (3)	**0.15**
$\mathcal{H}_{15}$	1	-1	0	0	-1	-1	0	-0.006	0.000	6.03 (4)	**0.20**
$\mathcal{H}_{16}$	0	0	1	-1	-0.817	0.817	0	0.000	-0.000	11.88 (3)	0.01
$\mathcal{H}_{17}$	0	0	1	-1	-1	-1	0	-0.000	-0.000	12.26 (4)	0.02
$\mathcal{H}_{18}$	1	-1	0	0	0	0	-0.673	-0.006	-0.000	6.84 (3)	0.08
$\mathcal{H}_{19}$	0	0	1	-1	0	0	-0.669	0	-0.000	2.42 (4)	**0.16**
$\mathcal{H}_{20}$	0	0	0	0	1	-1	-2.015	-0.005	–0.000	7.51 (3)	0.06
$\mathcal{H}_{21}$	1	0	-1	0	0	0	0.056	0.000	0.000	6.33 (3)	0.10
$\mathcal{H}_{22}$	0	1	0	-1	0	0	-1.182	0.001	-0.000	8.17 (3)	0.04
$\mathcal{H}_{23}$	1	0	0	0	-1	0	7.693	0.030	-0.000	12.92 (3)	0.00
$\mathcal{H}_{24}$	0	1	0	0	0	-1	-0.556	0.004	0.000	9.54 (3)	0.02
$\mathcal{H}_{25}$	0	0	1	0	-1	0	7.438	0.029	0.000	13.01 (3)	0.00
$\mathcal{H}_{26}$	0	0	0	1	0	-1	0.337	0.001	-0.000	5.78 (3)	**0.12**
$\mathcal{H}_{27}$	1	-1	-1	1	0	0	1.430	0	0.000	4.88 (4)	**0.30**
$\mathcal{H}_{28}$	1	-1	1	-1	-1	1	0	-0.004	-0.000	1.34 (4)	**0.85**
$\mathcal{H}_{29}$	1	-0.360	-0.640	0	0	0	0	-0.001	0.000	1.34 (3)	**0.72**

The ppp term has been divided by 100

6.4 Fully specified cointegrating relations

In Tab. 17 a structural representation of the cointegration space is finally given. The fully specified cointegrating relations were tested with the LR test procedure in Johansen and Juselius (1994) and accepted with a $p-value$ of 0.79.

The adjustment coefficients are also reported. None of the adjustment parameters are significant for the long term interest rates, suggesting they are the weakly exogenous variables that push the system while some of the adjustment parameters referring to ppp are significant meaning that the weak exogeneity for ppp is less evident in the extended than in the small model. Restricting to zero the adjustment parameters for the German and US long term interest rate the hypothesis were respectively accepted with a $p-value$ of 0.90 and 0.76. Restricting both, the $p-value$ was 0.85 (incidentally the same value of Juselius and MacDonald 2003 for similar restrictions). Restricting to zero the adjustment parameters for the long term interest rates and ppp the hypothesis was accepted with a $p-value$ of 0.48, while restricting for the adjustment parameters just for ppp was accepted with a $p-value$ of 0.39. Other restrictions to α produced either very low $p-values$ for the German short term interest rate (0.12) or $p-values$ were close to zero.

Tab. 17: A structural representation of the cointegration space (extended model)

	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$		$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$
Δp_t	1	1	1	$\Delta^2 p_t$	**−0.854** (−7.3)	0.058 (0.7)	**0.272** (3.2)
Δp_t^*	**−0.368** (6.92)	−1	−1	$\Delta^2 p_t^*$	**−0.435** (−2.0)	**0.446** (2.9)	**0.323** (2.0)
i_t^l	**−0.632** (6.56)	−1	1	Δi_t^l	0.006 (0.7)	0.001 (0.2)	−0.005 (−0.7)
i_t^{l*}	0	1	−1	Δi_t^{l*}	−0.004 (−0.3)	0.000 (0.0)	−0.006 (−0.6)
i_t^s	0	0	−1	Δi_t^s	0.003 (0.3)	**−0.018** (−2.9)	**0.021** (3.2)
i_t^{s*}	0	0	1	Δi_t^{s*}	**0.034** (2.7)	**0.021** (2.4)	**−0.042** (−4.5)
ppp_t^1	0	**1.420** (6.56)	0	Δppp_t	0.002 (0.1)	**−0.034** (−2.8)	**0.025** (2.0)
$DS7986$	**−0.001** (4.85)	0	**−0.003** (−2.46)				
$constant$	0.000	−0.000	−0.000				

The ppp term has been divided by 100

We report in Fig 29 the result of recursive estimation for testing the constancy of the cointegration space. The value *1* corresponds to a test with 5% significance level. It appears that the restricted model shows some β constancy as the test supports the hypothesis of parameter constancy for almost all the period we investigated (see the lower line which corresponds to the restricted cointegration space).

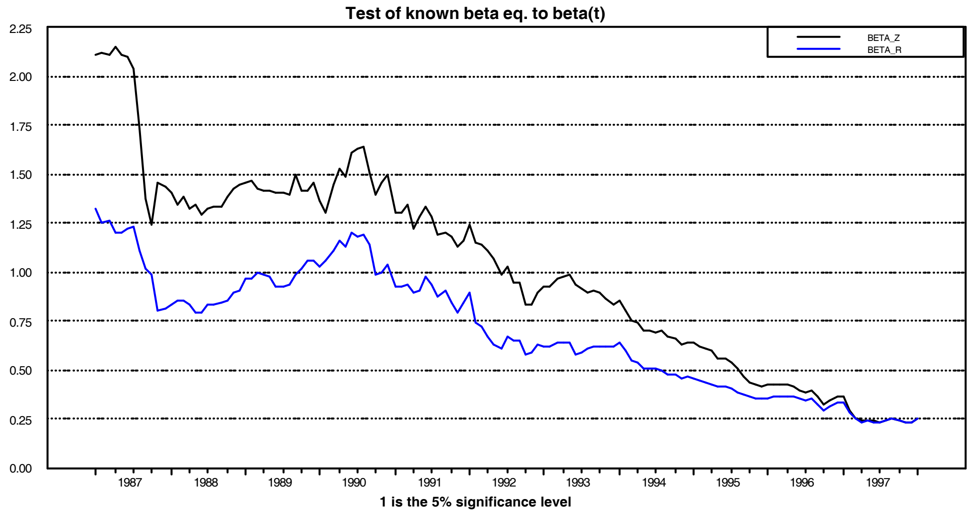

Fig. 29: Cointegration space constancy test.

6.5 Common trends

We report the VMA (common trends) representation for two different cases based on the fully specified cointegrating relations restricted VAR model for $r = 3$ after having fully specified cointegration relations with weak exogeneity of i_t^l, i_t^{l*} imposed on α. The other two driving forces beyond long term interest rates, may be further searched among *ppp* and short term interest rates or a combination of these.

The estimates of the C matrix in Tab. 18 measure the total impact of permanent shocks to each of the variables on all other variables. A row of the C matrix gives an indication of which variables have been particularly important for the stochastic trend behavior of the variable in the row.

Tab. 18: The estimates of the long run impact matrix C

C	$\sum \hat{\varepsilon}_{i_t^l}$	$\sum \hat{\varepsilon}_{i_t^{l*}}$	$\sum \hat{\varepsilon}_{i_t^s}$	$\sum \hat{\varepsilon}_{i_t^{s*}}$	$\sum \hat{\varepsilon}_{ppp_t}$
Δp_t	**0.99**	0.31	-0.20	**0.50**	**0.64**
	3.87	1.63	-1.04	2.94	3.45
Δp_t^*	0.52	0.37	**-0.75**	**1.11**	**1.68**
	1.08	1.01	-2.00	3.47	4.75
i_t^l	**1.28**	0.28	0.14	0.10	-0.02
	6.00	1.73	0.85	0.72	-0.11
i_t^{l*}	-0.18	**1.19**	0.35	0.27	-0.02
	-0.65	5.73	1.62	1.50	-0.10
i_t^s	**1.05**	-0.11	**1.00**	0.33	**-0.50**
	3.59	-0.48	4.40	1.68	-2.34
i_t^{s*}	**-0.88**	**0.86**	**0.66**	**1.12**	0.53
	-2.53	3.31	2.46	4.86	2.09
ppp_t	**0.70**	**-0.61**	**-0.53**	**0.31**	**0.73**
	3.10	-3.55	-3.00	2.09	4.40

The C matrix suggests that:

- Inflation rates are adjusting.[9]

- German inflation rate is pushed by home interest rates and indirectly by long term US interest rates through US short term interest rate and by *ppp*.

- US inflation is not pushed by the German interest rates but by US short term interest rates which is pushed by US long term interest rate and by *ppp*.

- Shocks to long term interest rates have significant effects on short term interest rates, but not the other way round.

- Shocks to short term interest rates had a significant effect on inflation.

- Shocks to the US long term interest rate have an impact on both the German and US inflation rates.

- Shocks to *ppp* affect the inflation rates in the two countries.

6.6 The role of short-term interest rate

To gain a further perspective on the role of the short relative to the long term interest rate Tab. 19 shows a comparative analysis of the combined effect measured by $\hat{\Pi}_r = \hat{\alpha}\hat{\beta}_r$, where the '$r$' stands for the restricted estimates leaving α unrestricted, for both the small system and the extended model which includes short term interest rates.

[9] The columns corresponding to $\sum \hat{\varepsilon}_{\Delta p}$ and $\sum \hat{\varepsilon}_{\Delta p^*}$ are not shown as no value was found significant.

It seems (see the last two columns of Tab. 19) that short term interest rates were significantly important for inflation rates at least in Germany and possibly in the USA, signaling, in principle, the possibility to influence inflation rates steering the short term interest rates. The central bank, being the monopoly supplier of the monetary base is able to influence money market condition and steer short term interest rates. A change in money market interest rates would set in motion a number of mechanisms and actions by economic agents influencing inflation through the monetary policy transmission mechanism (ECB 2004). Our results agree with the view of the ECB, however, the results for short term interest rates show also a significant reaction to long term interest rates. From Tab. 19 appears rather clearly that the short run effects go from bond rates influencing treasury bill rates, influencing inflation rates as Juselius and MacDonald (2003) put forward. Thus, although, monetary policy may steer inflation rates via short term interest rates, this analysis shows that long term interest rates, and with it the perspectives of both growth and inflation, affect significantly short term interest rates, hence, inflation rates.

The weak exogeneity of long term interest rates in the extended model seems rather apparent as they were not significantly affected by any variable in the system, although the weak exogeneity of the US bond rate was less clear in the small model.

In the extended model, the *ppp* seems affected by both short and long term interest rates consistently with the common trends analysis in Tab. 18 and its weak exogeneity is less apparent than in the small model.

TAB. 19: THE COMBINED LONG RUN EFFECT $\hat{\Pi}_r=\hat{\alpha}_r\hat{\beta}_r'$

	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	ppp_t		
$\Delta^2 p_t$	**−0.51** −7.19	0.01 0.25	**0.25** 5.35	**−0.03** −4.39	−0.02 −0.5		
$\Delta^2 p_t^*$	0.12 0.88	**−0.50** −6.37	**−0.32** −6.24	**0.69** 6.24	**0.40** 6.24		
Δi_t^l	0.00 0.17	0.00 1.42	0.00 0.52	−0.00 −1.62	−0.00 −1.62		
Δi_t^{l*}	**−0.02** −2.00	**0.01** 2.95	**0.02** 2.79	−0.01 −1.86	−0.01 −1.86		
ppp_t	−0.01 −0.88	−0.00 −0.21	0.00 0.63	0.01 0.59	0.00 0.59		
	Δp_t	Δp_t^*	i_t^l	i_t^{l*}	ppp_t	i_t^s	i_t^{s*}
$\Delta^2 p_t$	**−0.52** −6.51	−0.02 −0.38	**0.75** 4.13	−0.21 −1.37	−0.08 −0.70	**−0.27** −3.17	**0.27** 3.17
$\Delta^2 p_t^*$	**0.33** 2.22	**−0.61** −7.90	0.15 0.45	0.01 0.50	**0.63** 2.90	**−0.32** −2.01	**0.32** 2.01
Δi_t^l	0.00 0.50	0.00 0.32	−0.01 −0.72	0.01 0.50	0.00 0.22	0.01 0.71	−0.01 −0.71
Δi_t^{l*}	−0.01 −1.09	0.01 1.57	−0.00 −0.16	0.01 0.34	0.03 0.00	0.01 0.61	−0.01 −0.61
ppp_t	−0.01 −0.61	0.01 1.38	**0.01** 2.17	**−0.06** −2.59	**−0.03** −2.84	**−0.03** −2.00	**0.03** 2.00
Δi_t^s	0.01 0.97	−0.00 −1.29	**0.04** 2.65	**−0.04** −3.26	**−0.03** −2.87	**−0.02** −3.17	**0.02** 3.17
Δi_t^{s*}	0.01 1.53	0.01 1.83	**−0.09** −4.27	**0.06** 3.72	**0.03** 2.37	**0.04** 4.50	**−0.04** −4.50

7 Conclusions

Two building blocks of international monetary economics are the *ppp* and *uip* conditions. They are usually assumed stationary, i.e. $I(0)$. Recently, it has been uncovered the non stationarity of both the *ppp* and *uip*. *ppp* and *uip* do behave like most of the economic time series: they move more similarly to random walks as they are found $I(1)$. This matter of fact has been represented just an enigma for many economists.

Juselius (1995) and Juselius and MacDonald (2000), exploiting the $I(1)$ property of the *ppp* and *uip*, put forward the idea that *ppp* and *uip* were linked together producing a stationary relationship. Just because *ppp* and *uip* were $I(1)$, they could eventually produce a stationary relationship like $uip - ppp \sim I(0)$.

This paper provided evidence that the cointegrating international parity relationship discovered by Juselius and MacDonald holds also in the case we used a different price index measure. This result is quite interesting since the producer and the consumer price indices, as shown by Juselius (1999), do not cointegrate by themselves. This shows quite a robustness of the relations found by Juselius and MacDonald (2000 and 2003) with respect to different price indices and a different shift dummy used in the statistical model aimed to capture the different regime due to M3 targeting.

The shift dummy we used aimed to capturing the restrictive monetary policy between the fall of 1979 and 1986. This agrees, we think at least in part, with the findings by Hansen and Johansen in 1999 that the period 1979-1982 defined a structural different regime (Juselius and MacDonald 2003). The shift dummy we chose just aimed to model this regime shift. The similarities of the results and even of the estimated coefficients of our model with the analysis by Juselius and MacDonald are outstanding.

Some main results are the following:

- Inflation rates are adjusting to the other variables of the system, short and long term interest rates and real exchange rates.
- Inflation rates do not affect other variable of the system, in particular they do not push in any way nominal interest rates.
- About one third of the German inflation rate is estimated to be imported from the USA.
- There is no strong support for real interest rate parity in contrast with what is often implied in theoretical macroeconomic models.
- Bond and inflation rate differentials, i.e. the *uip*, form a stationary relation with the *ppp*.
- There is evidence that long term bond rates are the main driving forces.
- There is no evidence that short term interest rates have any impact on long term interest rates.
- There is some evidence that short term interest rates steer inflation rates, but short rates are also affected by long term interest rates. If 10 years bond rate depend on long term growth and inflation expectations as for example the ECB maintains, these factors may

also play some role in the process of decision of the monetary policy and with it the short term interest rates. Although, in principle there is room for the role of central bank policy for controlling inflation, evidence suggests that long term interest rates, hence perhaps expectations for growth and inflation, are the ultimate determinants of actual inflation. This might suggest that one effective channel through which monetary policy could influence inflation rates might work is by influencing long term expectations once the central bank credibility in the commitment to maintain price stability is well established.

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