Money and inflation in the euro area during the financial crisis

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Abstract: This paper explores the stability of the relation between money demand for M3 and inflation in the euro area by including the recent period of the financial crisis. Evidence is based on a cointegration analysis, where inflation and asset prices are allowed to enter the long run relationship. By restricting the cointegrating space, equations for money and inflation are identified. The results indicate that the equilibrium evolution of M3 is still in line with money demand. In the long run, inflation is affected by asset prices and detrended output. Excess liquidity plays an important role for inflation dynamics. While the hypothesis of weak exogeneity is rejected for real money balances and inflation, real income, real asset prices and the term structure do not respond to deviations from the long run equilibria. A single equation analysis derived from this system still provides reliable information for the conduct of monetary policy in real time, since the error correction terms are very similar to those obtained by the system approach. To monitor the monetary development, a single money demand equation is sufficient, at least as a rough indication.

Keywords: Money demand, inflation, excess liquidity, cointegration analysis

JEL Classification: C22, C52, E41

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1 Introduction

During the financial crisis, the interbank market collapsed and the ECB as well as other central banks had to inject a huge amount of liquidity at low interest rates. Despite the spectacular increase in the monetary base, however, the broad money stock in the euro area did not show any noticeable increase. As the interbank market did not allow for a redistribution of liquidity between banks, central banks had to design unconventional policy measures (Freixas, 2009). While these interventions have been successful in avoiding a sudden meltdown of the financial system, many analysts have argued that they have laid the foundation to destabilise inflation expectations and generate future inflation pressures.

A major goal of central banks throughout the world is to keep inflation at low and stable rates. Especially at the longer horizons, inflation is inherently a monetary phenomenon (Benati, 2009). As money serves to define the unit of account, monetary developments are integral to the determination of the price level and the rate of inflation. The close link between money growth and inflation over the medium and long run has been confirmed by numerous studies. In addition, excessive liquidity and credit growth can provide early signals for the emergence of speculative bubbles in asset prices with potential risks to inflation and the real economy, see Borio (2007) and Adalid and Detken (2007). Therefore, monetary developments play a prominent role in the two pillar strategy of the ECB. While one pillar is based on the economic analysis of price risks in the short term, the other one is built on the analysis of risks to price stability in the medium and long run. A reference value for money growth is announced, which is based on the inflation rate that is seen to be consistent with price stability, potential output growth and a negative trend in money velocity.

The prime function of the monetary analysis is to provide a nominal anchor for the overall framework of price stability and cross-check of the outcome of the economic analysis with respect to a medium and long term perspective. The explicit reliance on money as a guide for monetary policy is a distinguishing feature of the ECB's framework compared to that of other central banks (Berger, Harjes and Stavrev, 2010). However, while monetary conditions became abnormally loose well even before the crisis, inflation did not accelerate at all. Due to repeated surges of M3 growth beyond its reference value, financial markets have put less and less weight on the signals stemming from the monetary analysis, and focused mostly on the economic analysis. This is clearly inefficient, as real time information on potential inflation risks is not properly adressed.

In general, money could not be considered as exogeneous. While central banks control the issuance of the legal currency and exert significant influence on bank deposits as well, other M3 components such as money market funds and debt securities are largely determined by financial markets. From a theoretical perspective, the concept of money demand is crucial for an appropriate interpretation of the monetary conditions in an economy, see Fischer, Lenza, Pill and Reichlin (2008). The money demand function links the monetary development to its fundamental determinants, such as the price level, real income and the opportunity costs of holding money. By comparing the actual money stock with its long run equilibrium according to money demand, measures of excess liquidity are derived and are used to assess risks to future price stability. However, excess liquidity measures rely on the assumption of a stable money demand relationship at least in the long run. The continued failure to meet the ECB reference value after the introduction of the euro to the public has raised doubts on the stability of money demand. As a result of heigthened financial uncertainty and portfolio shifts into M3, stable relationships between the money stock and its fundamental determinants do not seem to exist any longer, see Greiber and Lemke (2005) and Carstensen (2006).

For the purpose of policy preparation, ECB staff have used different models of money demand, such as those of Coenen and Vega (2001) and Brand and Cassola (2004). Since 2001Q1 the Calza, Gerdesmeier and Levy (2001) approach has been chosen as the workhorse for monitoring the monetary development. Because of portfolio shifts in response to the collapse of the dotcom bubble and the terrorist attacks of September, 11, 2001 the parameters in money demand models may be distorted. Therefore, from 2001Q4 onwards, the long run parameters of the Calza, Gerdesmeier and Levy (2001) model have been frozen to their values estimated for the period 1980Q1-2001Q2. As the function indicated increasing deviations from the actual evolution, ad hoc corrections to the short run dynamics have been introduced time by time (Fischer, Lenza, Pill and Reichlin, 2008, p164). As an alternative headline M3 can be corrected to remove unusual events. Due to end of sample filter problems, these strategies are hardly operable from a policy perspective. The results of an ECB research program launched in 2007 with the aim to improve the information content of the monetary pillar are published in a volume edited by Papademos and Stark (2010). Two approaches are developed with respect to money demand, see Chapter 3. While De Santis, Favero and Roffia (2008) include international capital flows, the analysis of Beyer (2009) refers to financial wealth as a scaling variable in addition to income. Overall, these results reinforce the relevance of the monetary pillar in the ECB strategy.

Dreger and Wolters (2010a) have demonstrated that cointegration in a money demand relation can be restored if inflation enters as part of the opportunity costs. The inclusion of the inflation rate is an important step towards a robust money demand function, see also Wolters, Teräsvirta and Lütkepohl (1998) for a German money demand function. However, since portfolio shifts between money and other assets have affected the long run parameters over the last decade, financial wealth has become increasingly important to explain the evolution of real money balances (Greiber and Setzer, 2007 and Beyer, 2009). Dreger and Wolters (2009) have provided evidence on the impact of wealth on money velocity, i.e. they restrict the income elasticity to unity. The wealth effect is often proxied by real house prices, as this specification tends to be superior over alternatives like stock prices. However, little is known when the most recent period of the financial crisis is taken into account. As an exception, Beyer (2009) has reported evidence for a stable money demand function for M3 using preliminary data until the end of 2008. Similar to Dreger and Wolters (2010a, 2010b and 2010c), the opportunity costs of money holdings cover the inflation rate.

This paper investigates whether the linkages between money and inflation have remained stable over an extended period covering the recent financial crisis. Evidence is based on a cointegration analysis, where inflation and real house prices are allowed to enter the long run money demand relationship. It is shown that the cointegration rank is not unique. By restricting the cointegration space, a money demand and an inflation equation can be identified. This system is used to examine the joint dynamics of money and inflation. Several conclusions emerge from the analysis. The results indicate that the evolution of M3 is still in line with money demand, thereby underpinning the relevance of monetary developments in the ECB strategy. While the weak exogeneity hypothesis is rejected for real money balances and inflation, real income, house prices and the term structure of interest rates do not respond to long run deviations. Hence, money does not seem to be a leading indicator for short run fluctuations in asset markets. Similarly, Dreger and Wolters (2011) found causality from real house prices to liquidity, but not in the reversed direction. Furthermore, inflation is affected by house prices and detrended output. A conditional single equation analysis derived from the system results still provides reliable information for monetary policy in real time, because the error correction terms are similar to those obtained by the system approach. To monitor the monetary development, a money demand equation is sufficient, at least as a rough indication.

The rest of the paper is organized as follows. Section 2 reviews the specification of the money demand function. In section 3 the time series used in the analysis are discussed. Evidence regarding the cointegration space and weak exogeneity are provided in section 4. Section 5 presents the conditional error correction money demand equation. Finally section 6 concludes.

2 Specification of money demand

A widely used specification of money demand is chosen as the starting point of the anlysis, see Ericsson (1998) and Beyer (2009). This specification of money demand leads to a long run relationship of the form

$$(1) \qquad (m-p)_t = \delta_0 + \delta_1 y_t + \delta_2 w_t + \delta_3 rl_t + \delta_4 rs_t + \delta_5 \pi_t$$

where m denotes nominal money balances taken in logs, p is the log of the price level, y is log of real income, representing the transaction volume in the economy, and w is log of real financial wealth. Opportunity costs of holding money are proxied by nominal long (*rl*) and short (*rs*) term interest rates and the annualized inflation rate, i.e. $\pi=4\Delta p$, in case of quarterly data. The index *t* denotes time.

Price homogeneity is imposed as a long-run restriction to map the money demand analysis into a system of I(1) variables; see Holtemöller (2004). The income variable exerts a positive effect on nominal and real money balances. Often, its impact is restricted to unity on theoretical grounds, see Dreger and Wolters (2009) for a discussion. Money holdings are also related to portfolio allocation decisions. For example, a surge in asset prices may trigger a rise in demand for liquidity due to an increase in net household wealth. While the scale effect points to a positive impact of wealth, the substitution effect works in the opposite direction, as higher asset prices make assets more attractive relative to money holdings. If the opportunity costs of money holdings refer to earnings on alternative financial assets, possibly relative to the own yield of money balances, their coefficients should enter with a negative sign. For the inclusion of the inflation rate see also Dreger and Wolters (2010a). It is part of the opportunity costs as the inflation rate represents the costs of holding money in spite of holding real assets. Its inclusion provides a convenient way to generalize the short run homogeneity restriction imposed between money and prices. In addition, adjustment processes in nominal or real terms can be distinguished (Hwang, 1985).

The parameters $\delta_1>0$and δ_2 denote the elasticities of money demand with respect to the scale variables, income and wealth. The impact of the return of other financial assets and inflation is captured by the semielasticities $\delta_3<0$, δ_4 and δ_5, respectively. The parameter δ_4 should be positive when *rs* is mainly a proxy for the own rate of interest of holding money balances, but negative otherwise. Due to the ambuigity in the interpretation of the wealth and inflation variables, the signs of their impact cannot be specified a priori on theoretical grounds.

3 Data and preliminary analysis

Since the introduction of the euro in 1999, the ECB is responsible for the monetary policy in the euro area. As the time series under the new institutional framework are too short to draw robust conclusions, they have to be extented by artificial data. Euro area series prior to 1999 are obtained by aggregating national time series (Artis and Beyer 2004). By comparing different aggregation methods, Bosker (2006) and Beyer and Juselius (2010) stressed that differences are substantial prior to 1983, especially for interest rates and inflation. However, they are almost negligible from 1983 onwards. In addition, the European Monetary System started working in 1983 and financial markets have become more integrated since then. Moreover, Juselius (1998) reports evidence in favour of a change in the monetary transmission mechanism in March 1983 for some European countries. Therefore, 1983Q1-2010Q4 is chosen as the observation period. To cover initial values, the data already start in 1981Q1. Quarterly seasonally adjusted series are used[2].

Nominal money balances for M3 are taken from the ECB monthly bulletin database and quarterly data refer to end-of-period values. The short and long term interest rates *rs* and *rl* come also from this source and are defined by the end-of-period 3-month Euribor and ten-year government bond rates, respectively. In contrast to averaging over the quarter, this approach does not create distortions with respect to lead-lag relations as has been shown by Rajaguru and Abeysinghe (2008). Real GDP, as a proxy for income, is taken

[2] Computations have been performed with EViews 6 and CATS in RATS.

from Eurostat, defined as chain-linked volumes with 2000 as the reference year. The GDP deflator (2000=1) is also taken from Eurostat. GDP volume and deflator information prior to 1995 is based on Brand and Cassola (2004), as these data yield stable and economically interpretable results. To derive real money balances, nominal money stocks are deflated with the GDP deflator. Real financial wealth is approximated by nominal house prices deflated by the GDP deflator. Nominal house prices are taken from the Bank of International Settlement (Borio and Lowe, 2002) and interpolated to the quarterly frequency. Figure 1 shows the evolution of the time series in levels (A) and first differences (B).

-Figure 1 about here-

According to the DF-GLS test, all level variables appear to be integrated of order 1, I(1), implying that they are nonstationary in levels, but stationary in first differences, see Table 1[3]. The exception is the inflation rate, where unit root tests reject the hypothesis of nonstationarity at the 0.1 level, but KPSS tests reject the null of stationarity at the 0.01 level. Contrary to the data generating process for unit root tests, where high positive autocorrelation is assumed, the starting point for stationarity tests is a sum of two components, one is stationary and the other one a random walk (see e.g. Kirchgässner and Wolters, 2007). This can lead to different results in testing stationarity versus nonstationarity. The cointegration analysis presented below provides indirect evidence for the nonstationarity of the GDP inflation rate, as this variable is important to get a coin-

[3] The DF-GLS test is more efficient than the standard ADF test in estimating the deterministic terms. See Elliott, Rothenberg and Stock (1996).

tegration vector that can be interpreted as a money demand relationship. For the term structure, i.e. the difference between the long and short term nominal interest rate, the nonstationarity hypothesis is rejected at the 0.01 level.

-Table 1 about here-

Outliers are detected in the real money balances, see Figure 1B. The first one (1990Q2) is due to the German unification, while the other one (2001Q1) reflects the stock market turbulences in the aftermath of the new economy bubble, see Kontolemis (2002). In the subsequent analysis, these outliers are acknowledged by two impulse dummies. They are equal to 1 in the respective period and 0 otherwise ($d902$ and $d011$). Breaks are also relevant in the income elasticity, see Figure 2. In particular, the parameter has risen after the introduction of the euro to the public (2002Q1), see Dreger and Wolters (2010b). There has been also a sharp increase because of the financial crisis. Despite the fact that monetary developments have been largely favourable, massive production losses occurred.

-Figure 2 about here-

In Dreger and Wolters (2010c), two models to capture the break have been discussed. One is to measure the change in the income elasticity from 2002Q1 onwards. As an alternative, wealth is included in the money demand function to capture the break. It has been shown that the second approach leads to a very stable relationship that might reflect the rising presence of wealth in money demand. A variable w^* is introduced, which is defined as the product of w and a step dummy $s021$ equal to 1 from 2002Q1 onwards and 0 before. Other dummies are not introduced at all.

4 Cointegration analysis in the system of variables

The empirical analysis is based on a VAR model in levels which is equivalently rewritten as a vector error correction model

$$(2) \qquad \Delta \boldsymbol{Y}_t = \boldsymbol{\alpha\beta}' \boldsymbol{Y}_{t-1} + \sum\nolimits_{j=1}^{p-1} \boldsymbol{\Gamma}_j \Delta \boldsymbol{Y}_{t-j} + \boldsymbol{D}_t + \boldsymbol{\varepsilon}_t$$

where $\boldsymbol{\alpha}$ denotes the matrix of feedback parameters, $\boldsymbol{\beta}$ the matrix of the cointegrating relations and $\boldsymbol{D}_t$ the deterministic terms. The cointegration properties of different sets of variables are explored using the Johansen (1995) trace test. The lag length p of the VAR in levels is determined by the Akaike criterion and set equal to two throughout the analysis. The specification investigated by Dreger and Wolters (2010a) serves as a starting point, implying $\boldsymbol{Y}=(m\text{-}p, y, \pi)'$. It comprises real money balances, real income and the inflation rate. An unrestricted constant and a linear time trend restricted to the cointegrating space are embedded and might allow for possible changes in the long run vectors over the sample period.

-Table 2 about here-

The three variables are cointegrated, where the cointegrating rank is equal to one, see Table 2. As the sample period is not very large both the standard trace test (Johansen

1995) and the small sample Bartlett corrected trace statistics (Johansen, 2000) are presented. Although the cointegration property can be established even in small systems of variables, the long run parameters are not very convincing, according to economic theory. Because of the permanent break in the income elasticity from 2002Q1 onwards, they are quite unstable.

Therefore, as discussed above the system is enlarged by the w^* variable to account for wealth effects in money demand. In the extended specification, $\boldsymbol{Y}=(m\text{-}p, y, w^*, \pi)$, the cointegration rank increased by one, i.e. it is equal to two. To estimate the long run parameters with higher precision, the model can be further enlarged by the term structure of interest rates, $\boldsymbol{Y}=(m\text{-}p, y, w^*, \pi, rl\text{-}rs)$. The term structure can be interpreted as the net opportunity costs of holding money; i.e. the interest rate adjusted for the own rate of money holdings[4]. Its inclusion leads to an increase in the cointegration rank using the standard trace test, but the result is only borderline (0.12) with the Bartlett corrected version. As this further cointegrating relation exists only because of the stationarity of the term structure, the following analysis is restricted to the more interesting first two long run vectors shown in the left part of Table 3. The normalization is on the coefficients of real money balances and inflation, respectively.

-Table 3 about here-

The first vector may be a money demand function, while the second one can be consistent with an inflation equation. For identification, zero restrictions are put upon the re-

[4] This system is able to capture the dynamics of all variables, as the residuals do not show any signs of autocorrelation.

spective long run parameters. In particular, the trend coefficient is set equal to zero in the first relationship. In the second vector, real money balances and the term structure are excluded. The corresponding likelihood ratio test is distributed as chi-squared with one degree of freedom. The test statistic is 1.836, with a *p*-value of 0.175. Thus, the identifying restrictions cannot be rejected. The restricted cointegrating vectors are reported in the right part of Table 3. All parameters are significant.

The variables in the money demand function bear the theoretically expected signs, and the long run coefficients are not implausible. For housing wealth, the scale effect dominates the substitution effect. The linear time trend in the inflation equation accounts for the secular decline of inflation, but it might be also interpreted as a rough indicator of potential output. In that case, inflation would depend on detrended output and real house prices. Thus, monetary policy should closely monitor the price evolution in asset markets, as it could have implications for the overall price development. The fact that real money balances is excluded from a restricted inflation equation does not imply that money is irrelevant for inflation. This can be inferred from the feedback coefficients, see Table 4.

-Table 4 about here-

Both real money balances and the inflation rate respond significantly to deviations from the two cointegrating relationships, and the adjustment coefficients are all well signed. In contrast, real income and the term structure of interest rates do not adjust to equilibrium errors and can be considered as weakly exogeneous. The evidence with respect to real house prices is ambigious, as the *t*-values are in the range of 2. However, according to Dreger and Wolters (2011), money reacts to changes in house prices, but the reversed direction is not relevant for the euro area. Hence, real house prices could be exogeneous as well. In fact, a joint test for weak exogeneity of real income, house prices and the term structure cannot be rejected. The corresponding likelihood ratio test is distributed as chi-squared with 7 degrees of freedom. The test statistic is 10.052, with a *p*-value of 0.186. To obtain more efficient estimates, the bivariate error correction model for money and inflation is evaluated in the following. The other variables (income, wealth and the term structure) are treated as exogenous. The identified cointegrating vectors and adjustment parameters are displayed in Table 5. As expected, excess liquidity has a significant positive effect on inflation.

-Table 5 about here-

To examine the robustness of the results, forward recursive tests are applied to determine whether the parameters in the restricted model are constant. Since the main issue is to test whether the relations are stable after the identified problems of financial uncertainty and portfolio shifts, the baseline sample runs from 1983Q1 to 2001Q4. Moreover, as the focus is on the stability of the long run parameters, the results for the so called *R*-form are preferred (Juselius, 2008). This is the concentrated model version, where the short run dynamics estimated from the full sample have been removed.

Figure 3 displays the eigenvalues of the system. The idea is to investigate whether the more recent observations are also generated by the baseline model. The test provides general information with regard to the constancy and non constancy of the cointegration space, because the eigenvalues can be expressed as quadratic functions of the feedback and cointegration parameters (Juselius, 2008). If both are constant, the eigenvalues will share this property. In fact, they show only minor variation, and the fluctuations are not significant. Figure 4 displays the Nyblom test for constancy of the cointegrating space, as suggested by Hansen and Johansen (1999). The test statistic is divided by the 0.95 quantile of the distribution under the null hypothesis of a constant parameter regime. Two variants are considered, i.e. a test either based on the full model or the concentrated version. In both cases, the test statistic is well below the rejection line of 1.0. Therefore, the full sample estimates of the cointegration vectors are in the space spanned by the long run relationships in each subsample.

-Figures 3 to 6 about here-

Figures 5 and 6 reveal the recursively estimated individual coefficients related to the cointegrating vectors and the feedback parameters. All parameters are highly significant and the size of the variation can be neglected. Overall, the results are robust, even in the financial crisis period. Hence, the joint dynamics of money and inflation during the operation of the ECB have been very stable and therefore, the system can serve as a starting point for monetary policy analysis.

5 Conditional error correction modelling

Since monetary policy has to be conducted in real time, a model based on a system of variables might not be the optimal strategy to proceed. Given the identification problems in full systems with multiple cointegrating vectors, a conditional single equation analysis can produce similar insights, but is much easier to handle. In general a conditional model may lead to constant coefficients even if a shift occurs in the reduced form (Johansen, 1995). The conditional error correction model for money demand is estimated by ordinary least squares in one step, where the long run parameters are obtained jointly with the short run dynamics (Stock, 1987). At the initial stage, the contemporaneous and the first four lags of the changes of all variables, a constant and the two impulse dummies are included in addition to the one period lagged levels of the variables from the cointegration vector. The variables with the lowest and insignificant *t*-values are eliminated subsequently, where a 0.1 level is used.

-Table 6 about here-

The relevance of the long run money demand relationship can be inferred from the highly significant negative coefficient of the lagged real money term. The residuals are well behaved, as they are normally distributed, homoscedastic and do not show autocorrelation. Moreover, the test of the functional form do not reveal problems. Additionally, Chow forecast tests for the period of the financial crisis do not indicate any instabilites. The final equation confirms the results of the multivariate analysis, as the implied cointegration vectors are similar (Table 6). This is also shown in Figure 7, where the error correction terms for both approaches are plotted.

While there are some deviations due to different estimates in the semielasticities of real money balances with respect to inflation and the term structure of nominal interest rates, the essentials are captured by both approaches. The correlation between the two error correction terms is 0.96. During to the financial crisis period, both appoaches show substantial excess liquidity which has been reduced thereafter. Hence a money demand equation is sufficient to monitor the monetary development, at least as a rough indication.

-Figure 7 about here-

6 Conclusion

This paper explores the stability of the relation between money demand and inflation in the euro area by including the recent period of the financial crisis. Evidence is based on a cointegration analysis, where inflation and asset prices are allowed to enter the long run relationship. By restricting the cointegration space, a money demand and inflation equation are identified. The results indicate that the evolution of M3 is still in line with money demand. In the long run, inflation is affected by asset prices and detrended output. Excess liquidity plays an important role for inflation dynamics. While the hypothesis of weak exogeneity is rejected for real money balances and inflation, real income, real asset prices and the term structure do not respond to deviations from the long run equilibria. A single equation analysis still provides reliable information for the conduct of monetary policy in real time, since the error correction terms are similar to those obtained by the system approach. To monitor the monetary development, a money demand equation is sufficient, at least as a rough indication.

The analysis also shows a significant impact of money and inflation over the long run. Currently, the euro area monetary multiplier defined as the ratio between M3 and M0 is 20 percent below its level at the outbreak of the crisis. If financial intermediation returns to normality, the precautionary demand for liquidity will decline, implying that the huge accumulation of reserve balances can result in a rapid increase in the money stock and subsequent inflation pressures. Therefore, the ECB should continue to switch to a less expansionary path.

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Figure 1A: Variables in levels

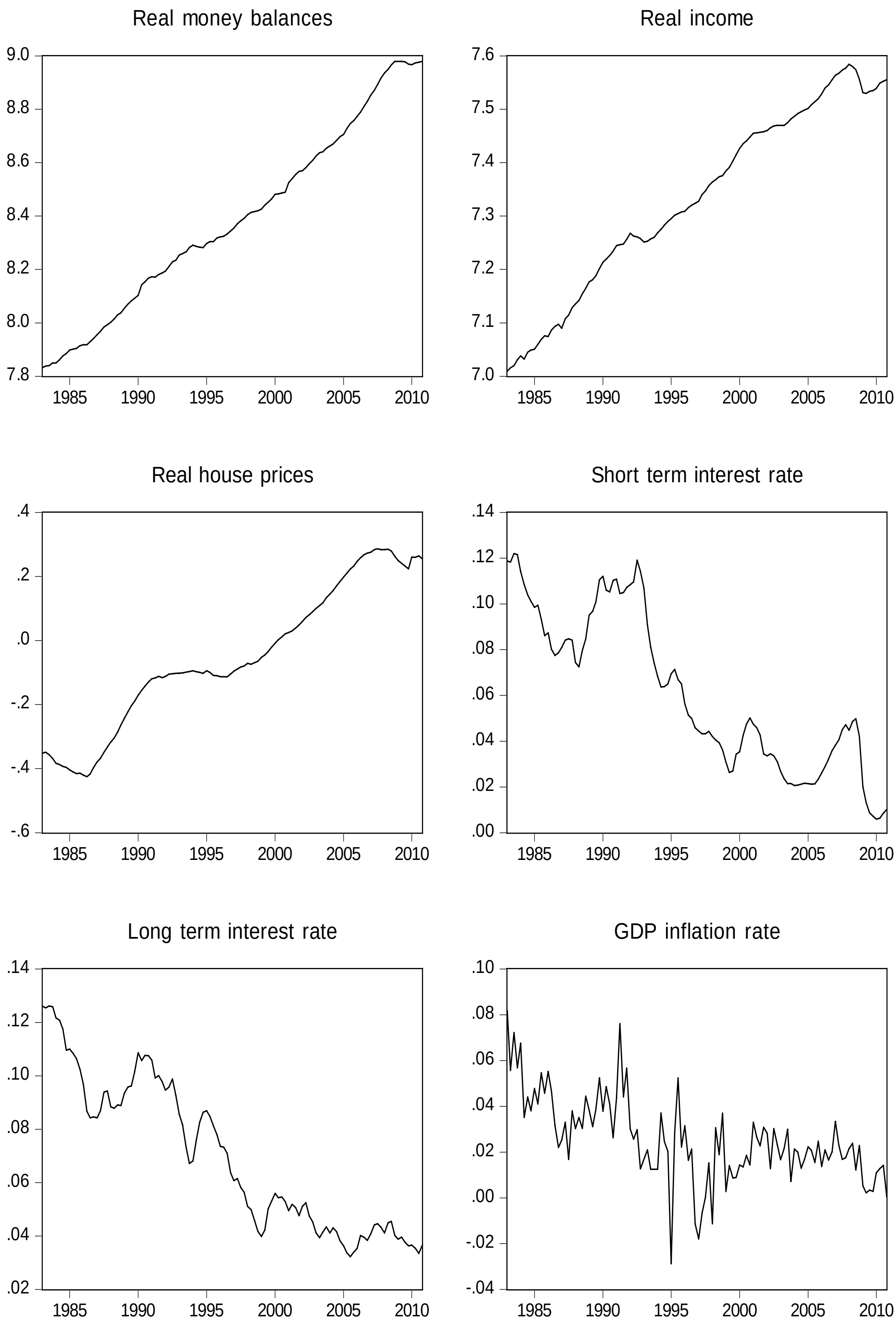
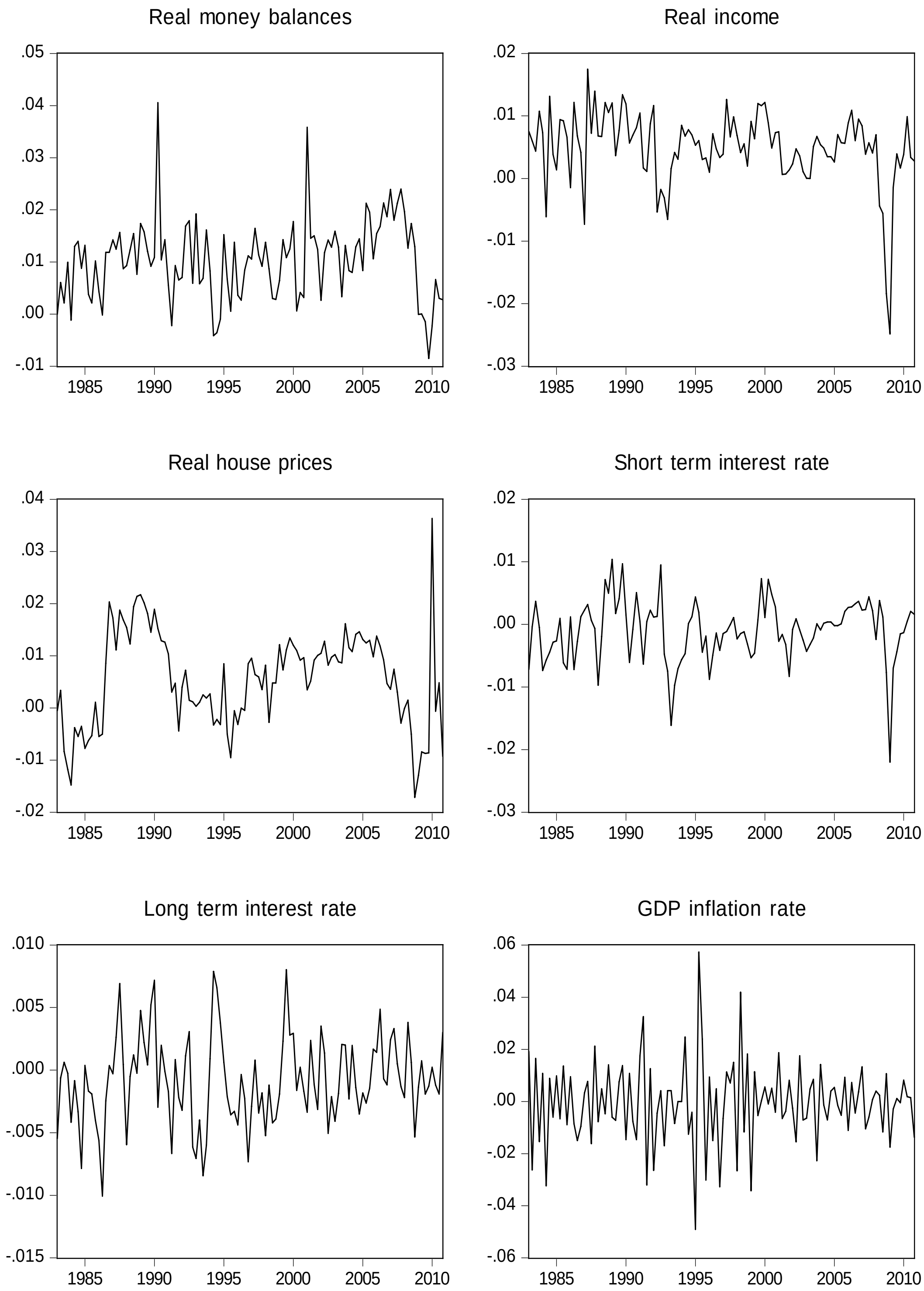
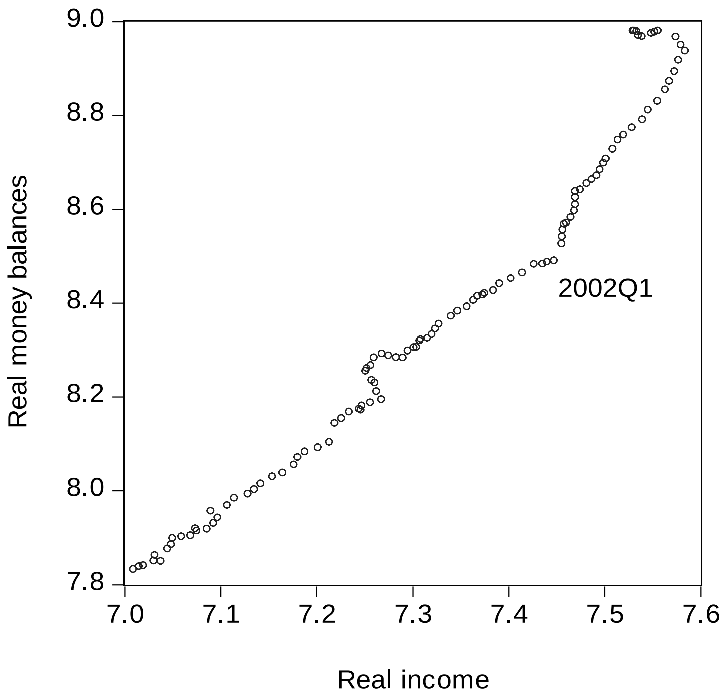


Figure 1B: Variables in first differences



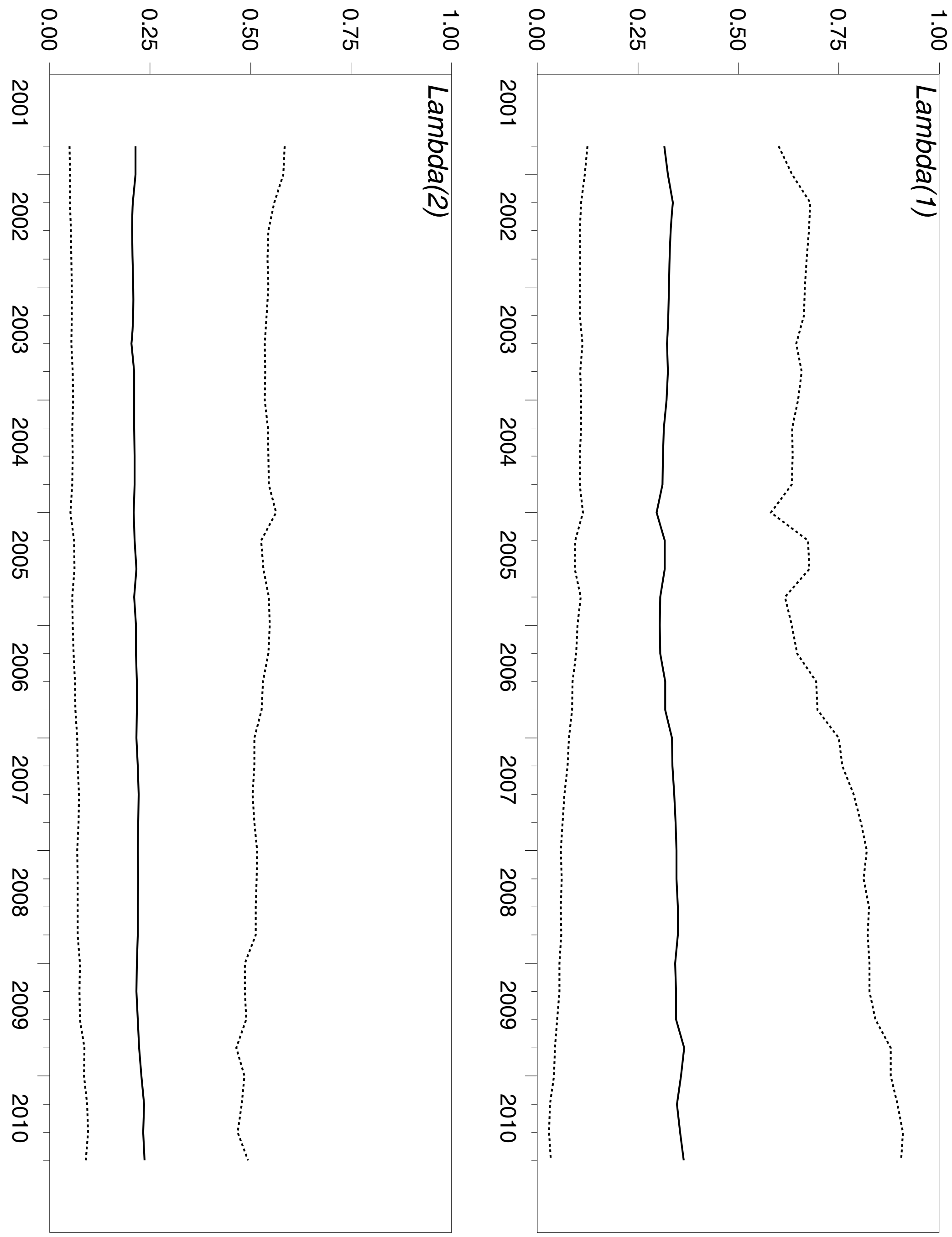
Note: Sample period 1983.1-2010.4. Real money, real GDP and real house prices in logs. Inflation q-o-q change in the GDP deflator (2000=1), annualized.

Figure 2 Structural break in income elasticity



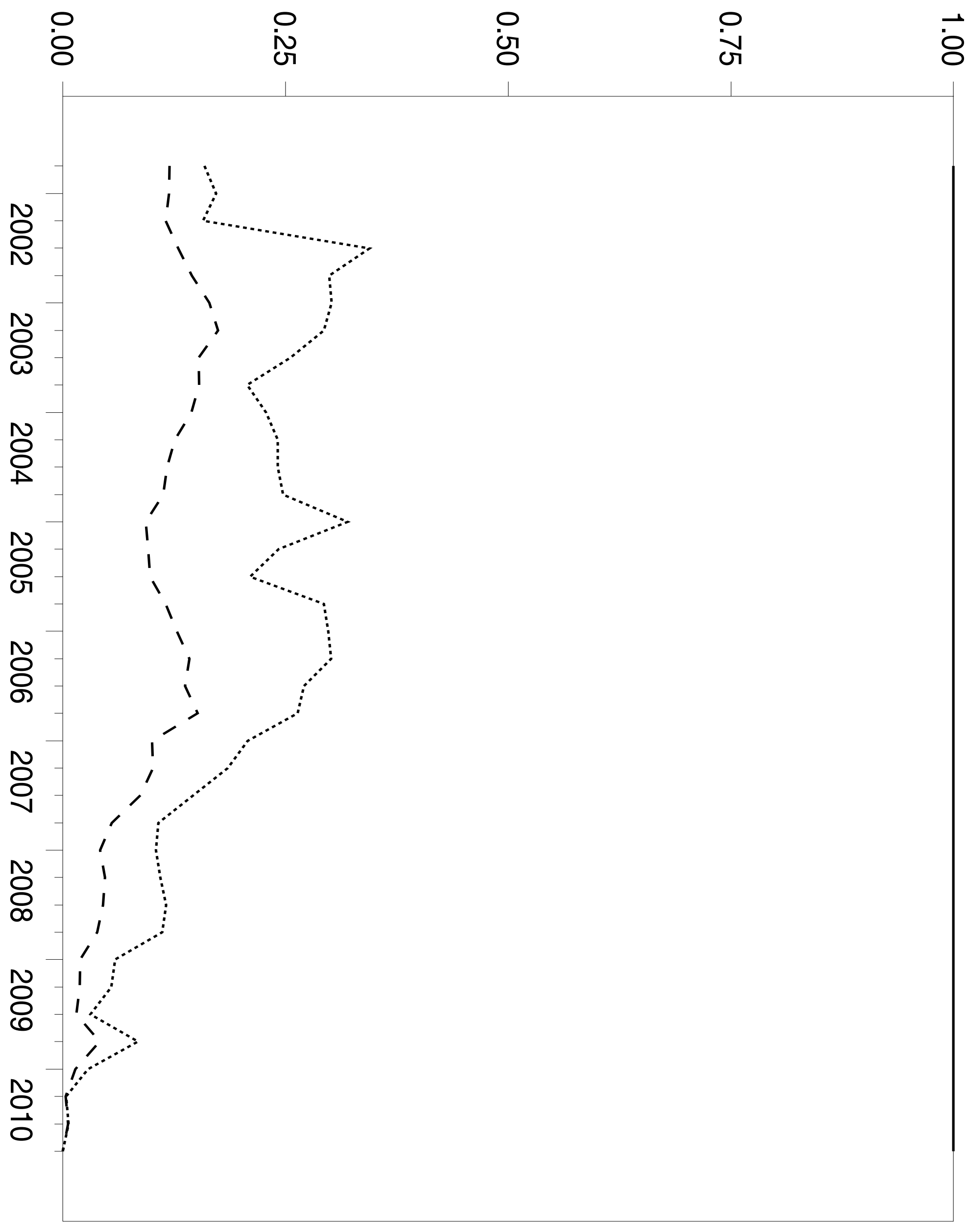
Note: Sample period 1983.1-2010.4.

Figure 3: Eigenvalues of the system



Note: Recursively calculated first two eigenvalues of the restricted cointegration system. Dotted lines are 0.95 confidence bands.

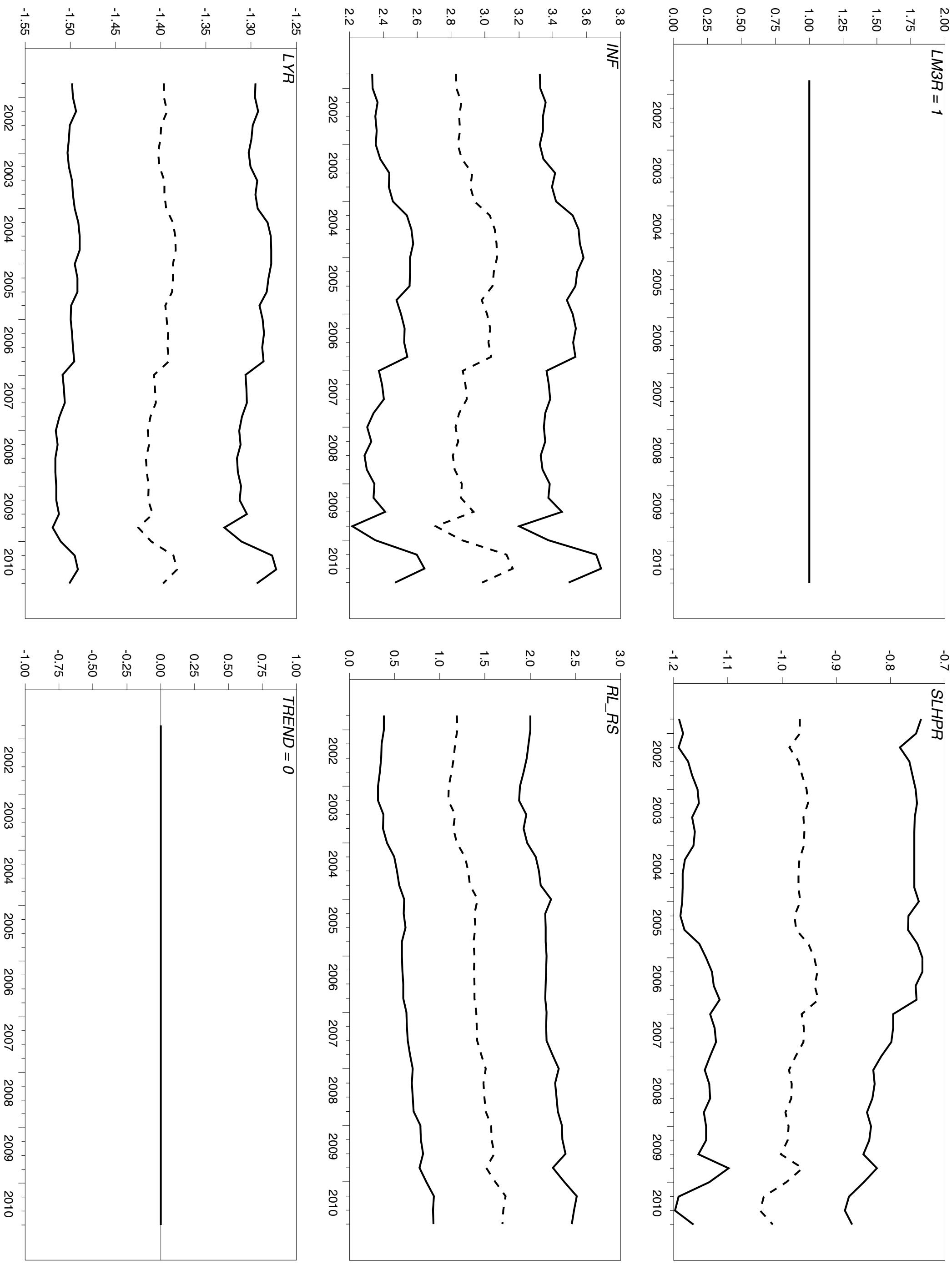
Figure 4: Nyblom test on beta constancy



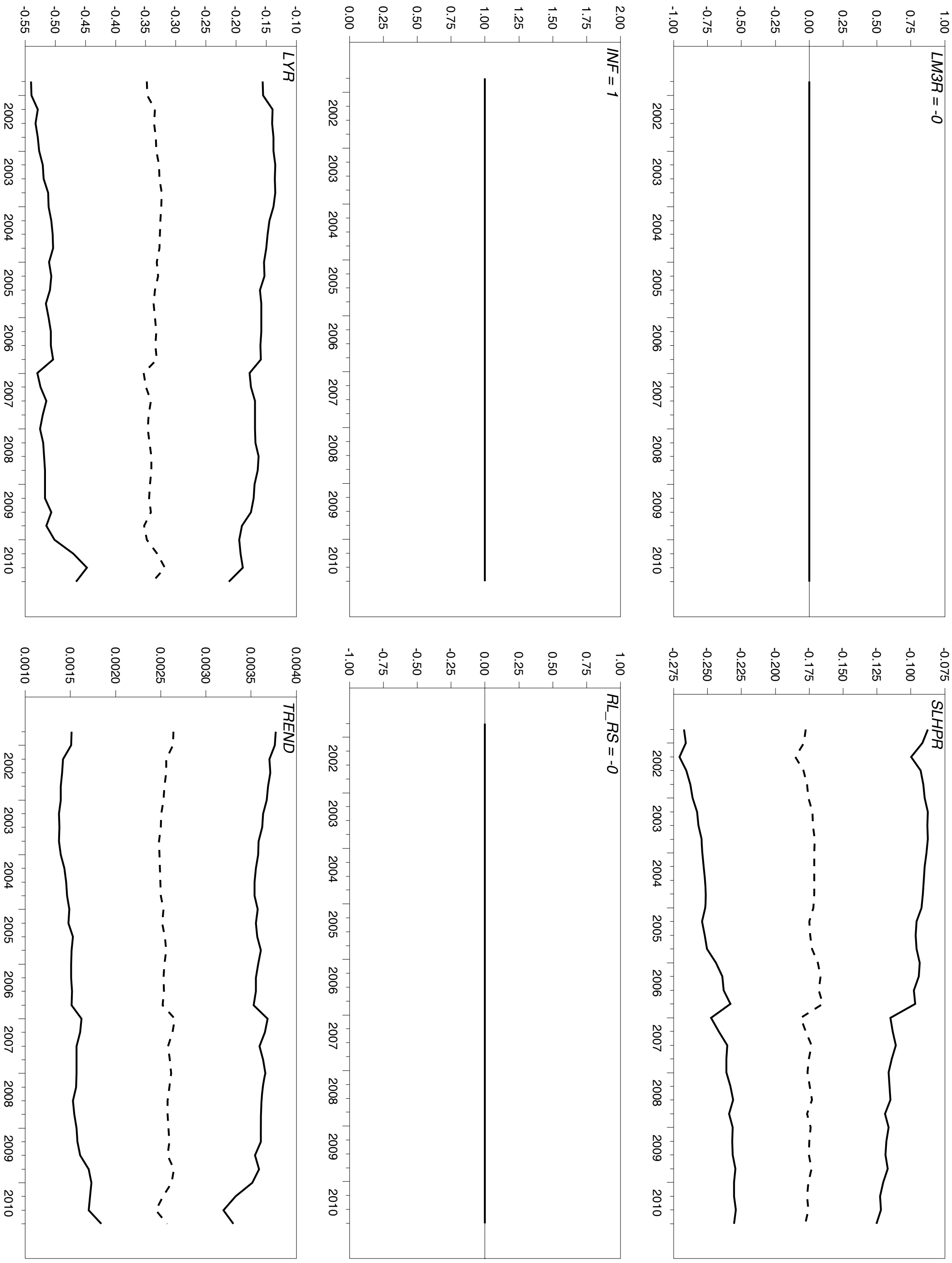
Note: Test statistics above the 1.0 line imply a rejection of the null hypothesis of constancy of the cointegration vectors. The dotted line shows the test statistic obtained for the full model, while the dashed line is calculated on the base of a concentrated model version, where the short run dynamics have been regressed out.

Figure 5: Constancy of individual cointegration parameters

A First cointegration vector (money demand equation)



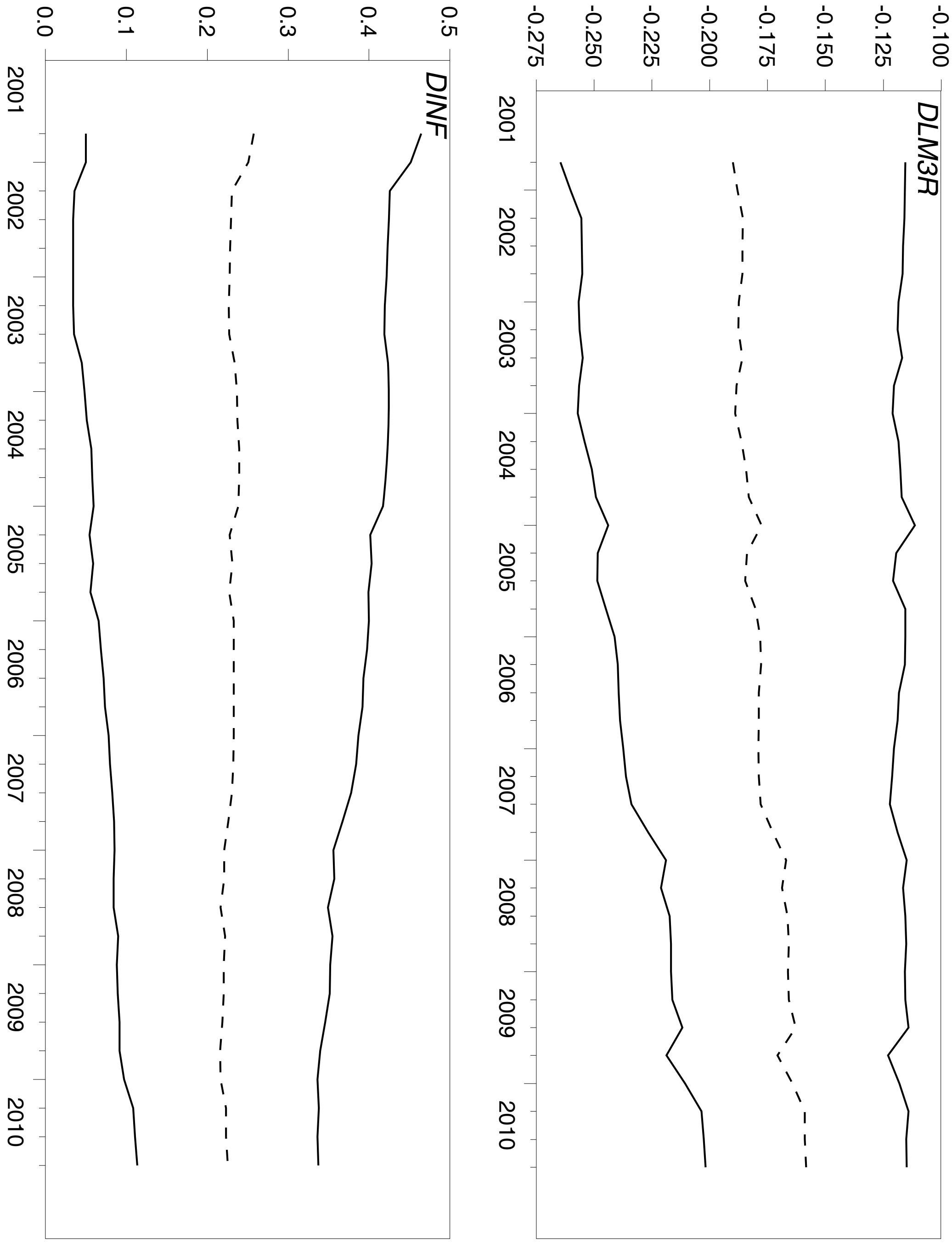
B Second cointegration vector (inflation equation)



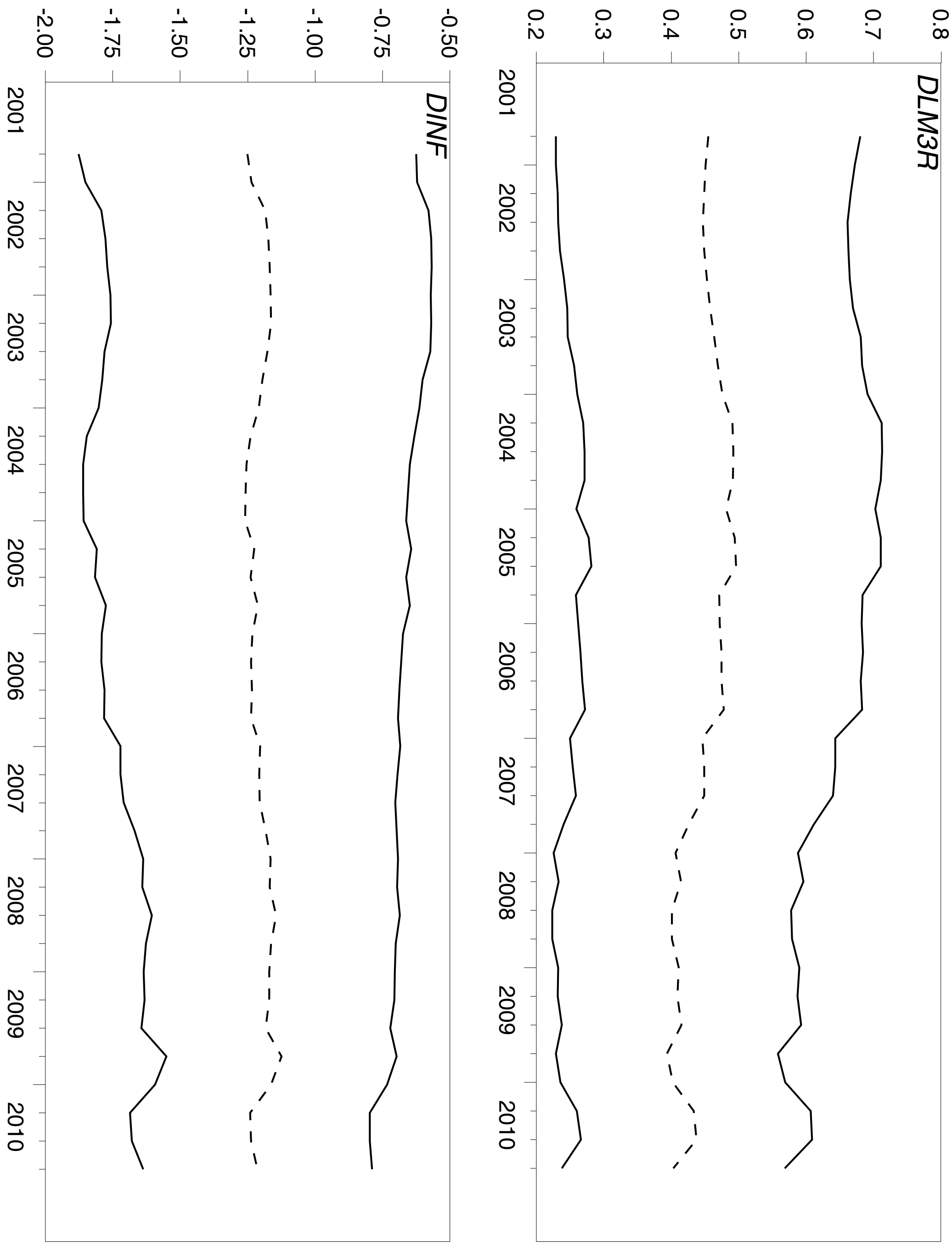
Note: Recursively estimated coefficients based on a concentrated model version. First vector (5A) normalized on real money balances, second vector (5B) on inflation. Solid lines represent 0.95 confidence bands.

Figure 6: Constancy of feedback parameters

A First feedback mechanism

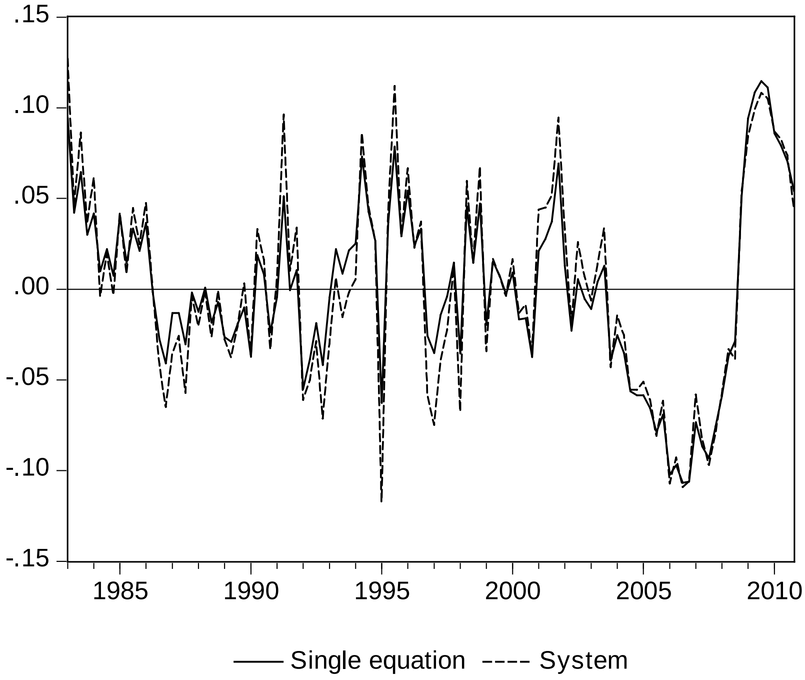


B Second feedback mechanism



Note: Recursively estimated coefficients based on a concentrated model version. First vector (6A) shows feedback parameters to deviations from the long run money demand equation, while the second vector (6B) displays the responses to deviations from the long run inflation relationship. Solid lines represent 0.95 confidence bands.

Figure 7: Error correction terms for system and single equation approach



Note: Sample period 1983.1-2010.4. Error correction terms (mean adjusted) obtained from the restricted system and single equation approach.

Table 1 DF-GLS unit root test

Variables	Lag length	Test statistic
m-p	1 | 0	-1.60 | -7.20***
y	1 | 0	-2.43 | -4.23***
π	1	-1.61*
rl	1 | 0	0.28 | -6.70***
rs	1 | 0	0.01 | -5.94***
rl-rs	1	-2.80***
*w**	0 | 0	-0.94 | -4.31***

Note: Sample period 1983Q1-2010Q4. For *w**, results refer to the 2002Q1-2010Q4 period. Left (right) entry corresponds to level (first difference) of the respective variable. The lag order is determined by the Schwarz criterion. Real money balances, income and housing prices have a constant and linear time trend in the level specification and a constant in the first differences. The interest rates, the term structure and inflation include a constant in their levels, while the first differences do not have any deterministic terms. Critical values are -3.57 (0.01), -3.02 (0.05), -2.73 (0.10) for the model with constant and linear time trend and -2.59 (0.01), -1.94 (0.05), -1.61 (0.10) for the model with a constant. A ***, **, * indicates rejection of the unit root hypothesis at the 0.01, 0.05 and 0.10 level, respectively.

Table 2 Cointegration rank of subsets of variables

Variables	Rank null hypothesis	Trace test	Trace test (Bartlett correction)	Rank decision
m-p, *y*, π	0	44.53 (0.032)	42.02 (0.060)	1
	1	22.77 (0.116)	21.49 (0.161)	
	2	5.81 (0.496)	4.85 (0.624)	
m-p, *y*, *w**, π	0	106.21 (0.000)	98.00 (0.000)	2
	1	53.38 (0.003)	47.05 (0.017)	
	2	21.46 (0.163)	17.83 (0.363)	
	3	6.32 (0.432)	5.95 (0.477)	
m-p, *y*, *w**, π, *rl-rs*	0	136.40 (0.000)	123.86 (0.000)	2-3
	1	84.71 (0.000)	71.50 (0.009)	
	2	45.89 (0.023)	38.87 (0.120)	
	3	21.93 (0.144)	18.75 (0.302)	
	4	6.29 (0.435)	5.90 (0.484)	

Note: Sample period 1983Q1-2010Q4, *p* values in parantheses. All models include the impulse dummies *d*902 and *d*011, an unrestricted constant and a linear time trend which is restricted to the cointegration relationship. The lag order of the VAR in levels is determined by the Akaike criterion and equal to 2 throughout the analysis.

Table 3 Long run vectors in the cointegration space

	Unrestricted model		Restricted model	
	$\boldsymbol{\beta}_1$	$\boldsymbol{\beta}_2$	$\boldsymbol{\beta}_1$	$\boldsymbol{\beta}_2$
m-p	1.000	-0.368	1.000	0.000
y	-1.112	-0.353	-1.402 (0.048)	-0.334 (0.060)
*w**	-0.789	-0.042	-1.009 (0.070)	-0.186 (0.025)
π	1.398	1.000	2.773 (0.253)	1.000
rl-rs	1.146	-1.126	1.595 (0.356)	0.000
trend	-0.003	0.006	0.000	0.003 (0.001)

Note: Sample period 1983Q1-2010Q4. Estimated cointegration vectors in the model including real money balances, real income, real house prices, the inflation rate, the term structure of interest rates and a linear time trend. Standard errors in parantheses.

Table 4: Feedback parameters in the restricted cointegration space

	$\boldsymbol{\alpha}_1$	$\boldsymbol{\alpha}_2$
$\Delta(m\text{-}p)$	-0.147 (0.021)	0.322 (0.077)
Δy	0.028 (0.025)	0.126 (0.087)
Δw^*	-0.069 (0.035)	0.334 (0.126)
$\Delta\pi$	0.191 (0.056)	-1.016 (0.200)
$\Delta(rl\text{-}rs)$	-0.002 (0.018)	0.041 (0.063)

Note: Sample period 1983Q1-2010Q4. Estimated feedback vectors in the model including real money balances, real income, real house prices, the inflation rate, the term structure of interest rates and a linear time trend. Standard errors in parantheses.

Table 5: Restricted feedback parameters and cointegrating vectors

	$\boldsymbol{\alpha}_1$	$\boldsymbol{\alpha}_2$
$\Delta(m\text{-}p)$	-0.158 (0.022)	0.403 (0.084)
$\Delta\pi$	0.225 (0.057)	-1.213 (0.217)

	$\boldsymbol{\beta}_1$	$\boldsymbol{\beta}_2$
m-p	1.000	0.000
y	-1.397 (0.053)	-0.339 (0.065)
*w**	-1.017 (0.075)	-0.178 (0.027)
π	2.982 (0.261)	1.000
rl-rs	1.694 (0.391)	0.000
trend	0.000	0.003 (0.001)

Note: Sample period 1983Q1-2010Q4. Feedback and cointegrating vectors in the bivariate error correction model for real money balances and inflation, treating real income, real house prices, and the term structure of interest rates and a linear time trend as exogeneous. Standard errors in parantheses.

Table 6 One step estimation of the conditional error correction model

Dependent variable $\Delta(m\text{-}p)$

Con	*d*902	*d*011	$(m\text{-}p)_{t\text{-}1}$	$y_{t\text{-}1}$	$w^*_{t\text{-}1}$	$\pi_{t\text{-}1}$	$(rl\text{-}rs)_{t\text{-}1}$
-0.290 (6.531)	0.029 (6.924)	0.026 (6.047)	-0.114 (11.27)	0.171 (10.64)	0.108 (10.67)	-0.213 (5.984)	-0.146 (3.574)

$\Delta\pi_t$	$\Delta(m\text{-}p)_{t\text{-}4}$
-0.168 (5.387)	-0.144 (2.456)

Implied long run relation: $m - p = 1.500y + 0.947w^* - 1.868\pi_t - 1.281(rl - rs)$

R2=0.705, SE=0.004

JB=2.96 (0.23)	ARCH(1)=1.96 (0.16)	ARCH(2)=1.14 (0.32)	LM(1)=1.20 (0.28)
LM(2)=0.63 (0.54)	LM(4)=1.69 (0.16)	LM(8)=1.33 (0.24)	RESET(1)=0.40 (0.53)
RESET(2)=0.38 (0.68)	CF(07.1)=0.88 (0.60)	CF(08.1)=0.73 (0.72)	CF(09.1)=0.88 (0.54)

Note: Sample period 1983.1-2010.4. One-step estimation of the error correction model in the upper part, specification tests in the lower part. R2=R squared adjusted, SE=standard error of regression, JB=Jarque-Bera test, LM(*k*)=Lagrange multiplier test for no autocorrelation in the residuals up to order *k*, ARCH(*k*)= LM test for conditional heteroscedasticity up to order *k*, RESET=Ramsey specification test, CF=Chow forecast test. Upper (lower) part: *t*-values (*p*-values) in parantheses.