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A STABLE MODEL FOR EURO AREA MONEY DEMAND

REVISITING THE ROLE OF WEALTH

by Andreas Beyer

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In 2009 all ECB publications feature a motif taken from the €200 banknote.

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1 The views expressed in this paper do not necessarily reflect those of the European Central Bank or the Eurosystem. Empircal analyses for this paper were carried out by using the software programs "OxMetrics" (by Doornik, 2006), "CATS in RATS" (by Dennnis, Juselius, Johansen and Hansen, 2008) and "Structural VAR" (by Warne, 2009). I wish to thank Björn Fischer, Mika Tujula, Riccardo Bonci and Frauke Skudelny for providing me with data on wealth and for many insightful explanations on technical details with regard to the data. I am grateful to Gabriel Fagan, Dieter Gerdesmeier, Wolfgang Lemke, Anders Warne, participants of the 2008 ECB's Money Demand Expert Workshop and an anonymous referee for comments on earlier drafts of this paper.

2 European Central Bank, Directorate General Research, Kaiserstrasse 29, D-60311 Frankfurt am Main, Germany; e-mail: Andreas.Beyer@ecb.europa.eu

Address
Kaiserstrasse 29
60311 Frankfurt am Main, Germany

Postal address
Postfach 16 03 19
60066 Frankfurt am Main, Germany

Telephone
+49 69 1344 0

Website
http://www.ecb.europa.eu

Fax
+49 69 1344 6000

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Abstract

In this paper we present an empirically stable money demand model for Euro area M3. We show that housing wealth is an important explanatory variable of long-run money demand that captures the trending behaviour of M3 velocity, in particular its shift in the first half of this decade. We show that the current financial crisis has no impact on the stability of our money demand model.

Keywords: Money Demand, Parameter Constancy, Wealth, Cointegration, Vector Error Correction Model

JEL Classification: C22, C32, E41

Non-technical Summary

In this paper we establish an empirically stable model for the Euro area which contains a stable money demand equation. The two building blocks of the model are a stable long run relationship for money demand together with a long run wealth equation. We estimate the model using data from 1980 until the end of 2007. We show that housing wealth plays an important role in capturing the trending behavior of money in the first decade of this century. Housing wealth enters therefore the set of variables in the model and we show that from an empirical point of view alternative wealth aggregates such as financial and total wealth are not suited for that purpose. Within the econometric framework of an overidentified Vector Error Correction Model we are able to identify not only a money demand equation. The model contains also equations for real GDP, inflation, interest rates and housing wealth. Although not strictly "structural" from a theoretical point of view the model might nevertheless represent a small-scale macro model for monetary transmission mechanisms in the Euro area. The model allows for prediction and economic interpretation via its long-run structure and plausible dynamic long-run properties.

Regarding money demand we find strong evidence for wealth effects and substitution effects but we show that housing wealth is not explained by any other variable in the system, neither via short-run dynamics nor via long-run equilibria. On the other hand, wealth is entering other equations of the model. We interpret this as strong evidence that the ECB's monetary policy has no direct impact on movements in housing wealth.

We also use preliminary data for wealth and GDP for 2008 to check the impact of the latest financial crisis for the stability properties of our money demand model. It turns out that parameter constancy of our money demand model is neither affected by the latest financial turmoil nor by the subsequent economic crisis.

Given its remarkable empirical stability over a sample of nearly thirty years without using any dummy variables or outlier corrections in the data we are highly confident that the estimated money demand model can serve as a device to create a benchmark for excess liquidity in the Euro area and hence will help to reliably identify risks to price stability.

The model therefore appears to be well suited to accommodate the three key-functions of money demand models within the ECB's monetary analysis: providing complementary information; distinguishing short run versus long run dynamics; and creating a benchmark for liquidity.

"Notwithstanding the complications created by an increasingly complex international financial system, money has been, is and will remain an important indicator of inflation." (Jürgen Stark, Member of the Executive Board of the ECB)[1].

1 Introduction

Achieving and maintaining price-level stability in the medium and long term in the Euro area is the single ultimate goal of the ECB's monetary policy. The evidence that, in the long-run, variation in inflation is explained by long-run variation of money is hardly disputable and has recently again been underlined e.g. by Benati, see Benati (2008, 2009). For the conduct of monetary policy the ability to assess risks to price stability in the medium to long term is of utmost importance. A convenient analytical framework to examine the relationship between inflation and money growth in the long run would be a model in which money and prices interact with a limited amount of policy relevant key variables. Precisely for this purpose, money demand models have a long tradition as analytical tools for monetary policy purposes and they have been widely used at Central Banks. However, for those analyses to be reliable, such models have to be stable over time. Predictability in a statistical context is a key property for which parameter constancy is a necessary condition.

For money demand models that have been estimated for the Euro area the period after 2002 was particularly challenging as velocity for the key monetary aggregate M3 shows a break in the slope of its downward long-run trend around that period.

Therefore, the aim of this paper is to establish an empirically stable model for money demand in the Euro area which contains a stable long run money demand relationship. We estimate the model using data from 1980 until the end of 2007. We will show that housing wealth plays an important role to capture the trending behavior of money in the first decade of this century. Housing wealth enters therefore the set of variables in the model and we show that from an empirical point of view alternative wealth aggregates such as financial and total wealth are not suited for that purpose. Within the econometric framework of an overidentified Vector Error Correction Model (VECM) we are able to identify not only a money demand equation. The model contains also equations for real GDP, inflation, interest rates and housing wealth. Although not strictly "structural" from a theoretical point of view the model might nevertheless be seen as a small-scale macro model for monetary transmission mechanisms in the Euro area. The model allows for prediction and economic interpretation via its long-run structure and plausible dynamic long-run properties.

[1] Dinner speech on the occasion of the ECB workshop on "The external dimension of monetary analysis" in Frankfurt am Main, 12 December 2007.

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The remainder of the paper is organized as follows. Section 2 gives a brief overview over the role and developments of money demand models at the ECB with a particular focus on the performance of its previous "work horse model". Section 3 motivates the role of wealth in money demand models, both from a theoretical and an empirical point of view. In Section 4 we present a long-run money demand model as part of a cointegrated VAR analysis. We test extensively for parameter constancy and check robustness across alternative wealth aggregates. Section 5 presents a small macro model for the Euro area, which contains a money demand equation. Again, the model is tested extensively and we provide an economic interpretation regarding the transmission of monetary policy. Section 6 examines the impact of the recent financial crisis on the properties of the empirical model and Section 7 concludes.

2 Money Demand Models at the ECB

As it is well documented, the ECB's monetary policy strategy is based on two pillars: economic and monetary analysis; see e.g., amongst many others, ECB (2004) or Issing (2008). With regard to the role of money demand models in the monetary analysis an excellent documentation and analysis can be found in Fischer, Lenza, Pill and Reichlin (2008) where they evaluate the role of money in the ECB's monetary policy process. Following their description the role of money demand models within the analytical framework of the ECB's monetary analysis can be summarized along three aspects. First, through the variables in money demand functions the dynamics in monetary aggregates are monitored and the impact that those variable have on the monetary aggregates are seen as complementing the information coming from the economic analysis. Secondly, money demand models allow to distinguish between short run and long run movement in the dynamics of monetary aggregates. And thirdly, money demand models allow to create a benchmark for liquidity along equilibrium levels of money demand. Earlier, Masuch *et al* (2001) refer to the econometric role that money demand models play in the evaluation of the monetary policy: "Typically, the stability of the relationship between money and prices is evaluated in the context of a money demand equation. The existence of a stable long-run money demand equation implies that the relationship between money and the price level, conditional on developments in other key macroeconomic variables such as interest rates and real GDP, is stable over the longer-term."(p. 121). Several money demand models such as e.g. Coenen and Vega (2001), Cassola and Morana (2002), Bruggeman, Donati and Warne (BDW, 2003), Brand and Cassola (2004) or De Santis, Favero and Roffia (DFR, 2008) were developed and used at the ECB and played more or less important roles in the monetary analysis; again, see Fischer *et al* (2008) for a detailed description.

By far the most prominent role was attached to the ECB's workhorse model developed by Alessandro Calza, Dieter Gerdesmeier and Joaquim Levy ("CGL", see Calza *et al*, 2001). The CGL model is a quarterly model which was estimated over the sample period 1980Q1 until 1999Q4 and did not show signs of parameter instability within sample. Soon after 2001, however, the CGL model specification suffers from parameter instabilities when the model is re-estimated over an extended data sample, see Table 1 below. While on use in the monetary analysis at the ECB, its parameters were "frozen" after 2001 and the model was interpreted as "historical benchmark". Money demand instability relative to that benchmark was then seen as being captured by the error term. That error term was supposed to "represent identifiable economic factors beyond the conventional determinants of money demand. The analysis then focus on capturing this term through the judgemental assessment of portfolio shifts " (Fischer *et al*, p.112). Below, in this paper we go one step further. We offer an economic identification of those economic factors and show, once they are taken properly into account, that an "extended CGL model" remains remarkably stable.

2.1 The Original CGL Model

CGL (2001) have estimated their model as a cointegrated VAR with one cointegrating vector. This long-run relationship is identified and interpreted as a standard long-run money demand function

$$(m - p) = \beta_0 + \beta_1 y + \beta_2 (RS - RO), \quad (1)$$

where log of real balances are a function of log of real GDP y; and the difference between the short-term interest rate (RS) and the "own rate" of return, (RO), of components within M3. The spread represents the opportunity cost of holding M3 balances. Over the sample period 1980q1-1999q4 CGL in their equation (3) estimate an income elasticity β_1 of 1.34 and an interest rate semi-elastitcity β_2 of -0.86. CGL also report that a coefficient on long term interest rate would not be significant. We have re-estimated the model and the results can be replicated with high precision. As can be seen from the recursively estimated long-run coefficients presented in Figure 1 the model is sufficiently stable over the original sample period. However, from end of

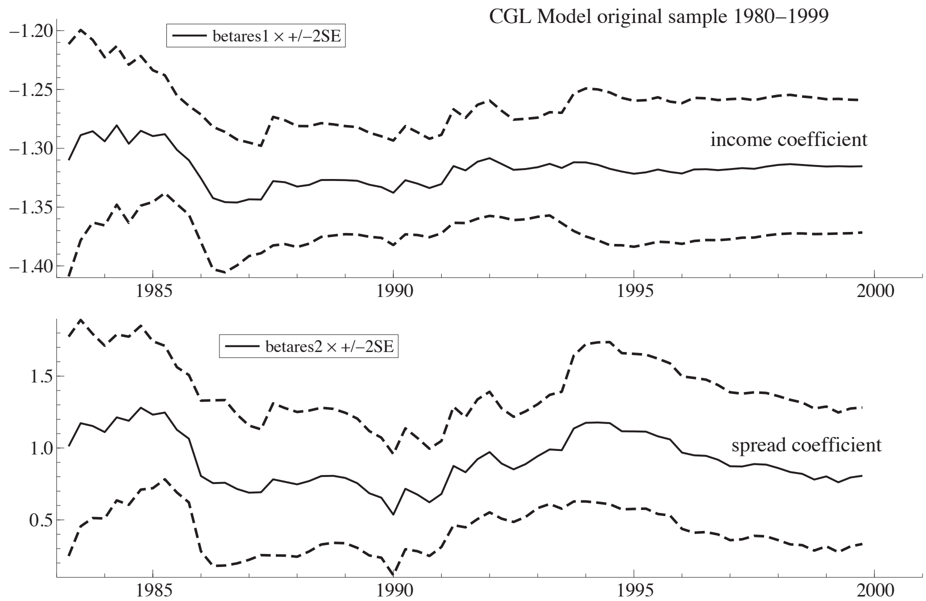


Figure 1: CGL Model: recursive long-run coefficients

2003 onwards, the parameters of the model become dramatically unstable, see Table 1.

2.2 CGL: Out of Sample Instability

The "collapse " of the CGL model is closely related to the behavior of velocity which is shown in Figure 2. Around 2001 - 2002 the approximation of the trending behavior in velocity by just introducing a single linear trend is clearly insufficient, see also Brand *et al.* (2002).

	01Q4	02Q4	03Q4	04Q4	05Q4	06Q4	07Q4
βy	1.30	1.29	1.22	1.03	0.70	52.24	0.01
s.e.	0.026	0.028	0.050	0.109	0.213	16.441	0.391
β_S	-0.74	-0.98	-2.00	-4.36	-8.10	557.51	-12.94
s.e.	0.242	0.272	0.473	1.030	2.008	157.93	3.812
Point estimates and their standard errors below							

Table 1: CGL Model, extended sample: recursive point estimates

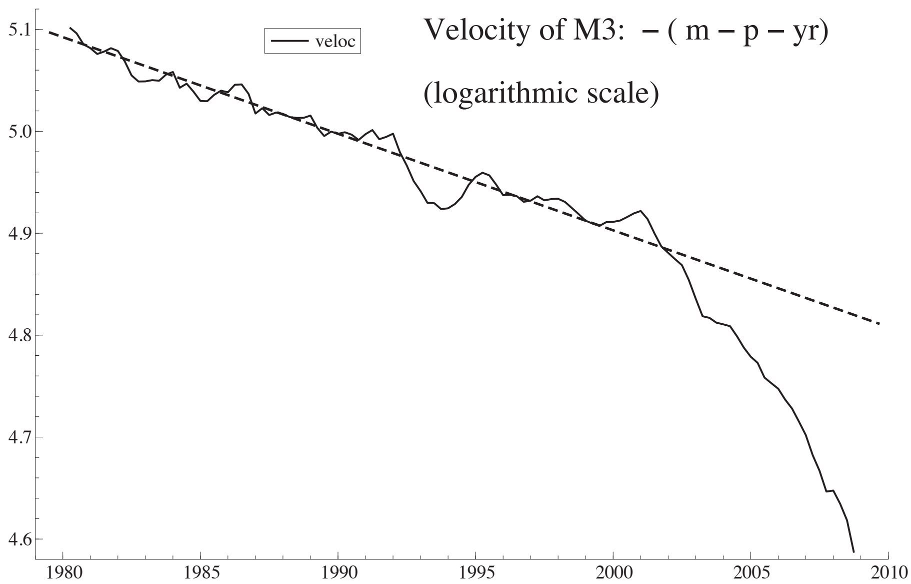


Figure 2: The break of trend-velocity M3

But what has caused this shifting behavior in trend-velocity - and how can it be modeled? One way to address the shift in velocity trend is by means of deterministic variables. Surely, this would yield a better empirical fit but is not really helpful for policy analysis in particular in "real time" as dummy variables are only a proxy for otherwise unexplained behavior and therefore carry a high degree of ad-hoc judgements. An alternative strategy is to extend the information set of economic variables in order to explain the shift from an economic perspective. This is the avenue that we will pursue below. We argue that enhancing the information set of conventional money demand specifications beyond the "usual" set of variables will re-establish empirical stability. We will show that by introducing housing wealth as an additional variable beyond CGL's information set we are able to estimate an economically meaningful model that hosts an empirically stable money demand model.

3 Money Demand and Wealth

In this section we will briefly motivate the relevance of wealth for modelling money demand both, from a theoretical and empirical point of view. The literature on wealth and money demand is rich and well known. Gerdesmeier (1996) provides an excellent overview of various theoretical motivations and presents an early empirical example on European (i.e. German) data. For a more detailed and technical exposition, see e.g. the textbooks by Patinkin (1966) or Laidler (1985).

3.1 Theoretical Background and Empirical Applications

In the earlier literature which deals mostly with US data there are numerous examples in which wealth variables have been used as explanatory variables for models of money demand, see e.g. Meltzer (1963), Brunner and Meltzer (1963), Laidler (1966), Mankiw and Summers (1986) or Rasche (1986). The usual proxies that have been used for wealth are expected or permanent income and physical wealth (extracted from balance sheet data). Also in the earlier pre-EMU money demand literature wealth has already occasionally been suggested as additional explanatory variable, see Gerdesmeier (1996) for an empirical illustration that fed into Bundesbank (1995). Other empirical examples are those by Kole and Meade (1995), Beyer (1998) or Fase and Winder (1998). For an excellent overview of pre-EMU studies on money demand in Europe see also the volume by Monticelli and Papi (1996). However, the importance of wealth in empirical studies for money demand in Europe has not been particularly strong in the past. There are basically two main reasons why this might be the case. Firstly, often money demand models just did not require any additional variables beyond "conventional" specification as they were often sufficiently stable. Secondly, it is fair to say that, in particular for most European countries reliable empirical and statistical measures for various wealth aggregates were hardly available. More recently the use of wealth has regained interest in the empirical money demand literature. Based on Friedman (1988) who has suggested an approach to analyze the impact of prices in stock markets with respect to money demand various authors have examined the role of financial wealth for money demand. Bruggeman *et al* (2003) present a stable money demand model for the period 1980 - 2001 but they found that asset market behavior, represented by real stock prices, had no significant additional explanatory power. By contrast, Carstensen's (2003) model for money demand in the Euro area includes variables for equity return and volatility. Greiber and Lemke

(2005) use indicator variables that are based on financial market data and estimate the path of underlying macroeconomic uncertainty. They show that those variable can help to explain the increase in euro area M3 over the period 2001 to 2004. De Santis *et al* (DFR, 2008) estimate money demand embedded in a model for international portfolio allocation and Boone *et al* (2004) estimate money demand using a geometric weighted average of equity and property prices as wealth variable. Very recently, De Bondt (2009) has estimated long-run money demand using financial wealth and labor market data and Dreger and Wolters (2009) have estimated a velocity equation which includes house prices. Focussing on real assets, Greiber and Setzer (2007) estimate cointegrated VARs for the Euro area and the US. They provide evidence that housing variables (house prices and housing wealth) are important explanatory variables that help explain money demand. Greiber and Setzer provide an interesting analytical motivation by describing three different channels through which money and housing wealth might interact: money demand channel, asset inflation channel and credit channel. The different channels imply different directions of causality. Whereas the money demand channel is determined by the impact of wealth on money the asset inflation channel is identified by the impact of money on wealth. The credit channel acts as a money supply channel and captures the role of loans; see also the recent volume by Goodhart and Hofmann (2007). Greiber and Setzer do not provide a theoretical model but we will make use of their description as a device for the economic interpretation of our model further below. We will focus in particular on what they refer to as "money demand channel". This channel encompasses three different effects: wealth effects; transaction effects; and substitution effects. Whereas the former two are positively related to, the latter is negatively related to money demand.

3.2 Empirical Motivation

In Section 2.2 we have discussed the break in trend-velocity. We will show that wealth as additional variable in a money demand specification might be able to explain that behavior. One would expect that such a variable rises relative to GDP over the relevant sample period. In principle the ratio of such a variable to GDP should then be able to capture the behavior in velocity over the entire sample.

There are four different wealth aggregates for the Euro area that have become available recently. These are financial wealth (whf) and housing wealth of households (whh) which sum up to total gross wealth ($whtg$). A variant of $whtg$ is total net wealth ($whtn$) which is $whtg$ net of household debts. Notice that whh is net wealth at current replacement costs i.e. depreciations are taken into account. Financial wealth comprises financial assets of households and non profit institutions serving households.

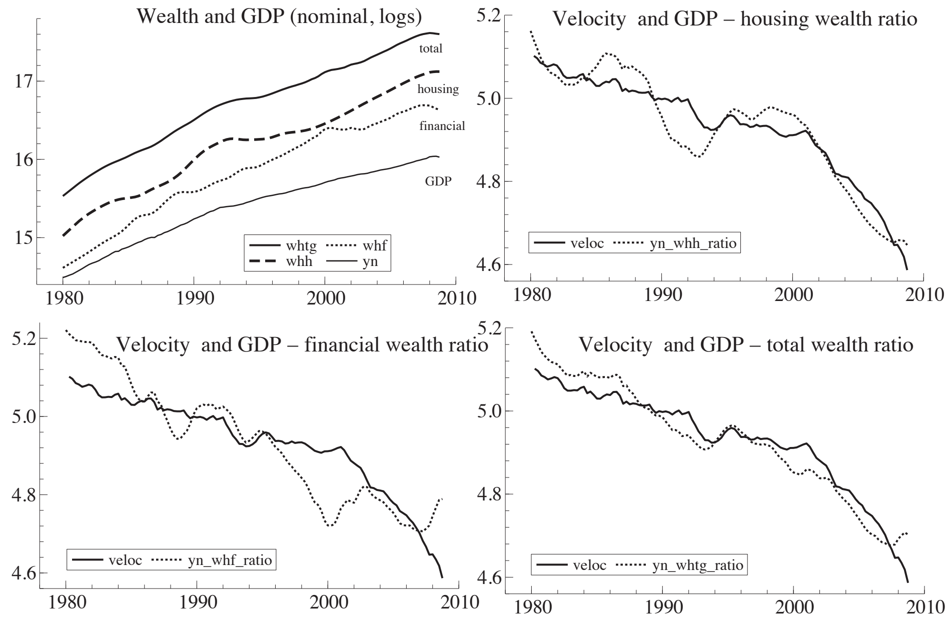


Figure 3: Wealth, Velocity and GDP

A detailed description of sources and technical details on the construction of the series can be found in Skudelny (2009) or Sousa (2009). Figure 3 shows the series together with velocity and GDP. The graphs, which are suitably scaled suggest that housing wealth seems to be indeed a promising candidate that captures the behavior of velocity. There are, however, a few caveats to bear in mind. Firstly, the pre-EMU data might be subject to the aggregation issues analyzed in Beyer, Doornik and Hendry (2001) who criticize level-aggregation across different countries in a regime of flexible exchange rates. Secondly, Skudelny (2009) and De Santis *et al* (2008) are sceptical regarding the quality of the available Euro area wealth data. Basically, the original series are at annual frequency. Quarterly data are backcasted and interpolated. As robustness check we will therefore examine closely the comparative performance of models when different wealth aggregates are used. In the first step of the empirical analysis we establish empirically stable long-run relations based on cointegration. We analyze the stability properties for each of the four wealth aggregates in connection with the other variables.

variable	data series	integration
m	nominal money stock M3	I(2)
p	GDP deflator	I(2)
$m-p$	real money stock M3	I(1)
whh	nominal housing wealth	I(2)
Δwhh	growth of housing wealth	I(1)
y	real GDP	I(1)
RS	3 Month Money Market interest rate	I(1)
RO	own rate M3	I(1)

Table 2: The Data

4 Modeling Long-run Money Demand For the Euro Area

4.1 The Model Data

For the estimation of our money demand system we use the same variables as in CGL and - except the long-run interest rate- as in BDW, albeit with a much longer extended sample. And we introduce housing wealth into the information set. At the time when we developed the model data for wealth was available just until 2007Q4. However, we will use preliminary data for wealth and GDP until 2008Q4 to check what impact the financial and economic crisis that started in 2007 had in particular for the stability properties of the money demand model. Hence, we start with a system of quarterly data from 1980Q1 until 2007Q4 for money, output, prices, housing wealth and interest rates in the Euro area and we assume that these variables form the following process $\{X_t\} = \{(m-p)_t,\ y_{t,}\ \Delta whh,\ \Delta 4p_t,\ RS_t,\ RO_t\}$. Lower case letters denote variables in logs where $(m-p)$ represents the log of real money stock M3; y is log of real output, Δwhh is growth in nominal housing wealth, $\Delta 4p$ is the annual inflation rate, RS is the annualized short-term three month money market interest rate; and RO is the annualized own rate of M3. Apart from the interest rates all data are seasonally adjusted. Figure 4 shows the data. Table 2 documents the time series that have been used and shows the order of integration corresponding to the results of univariate ADF tests (not reported here) and a formal test within the cointegration analysis, see Table 4 and discussion below.

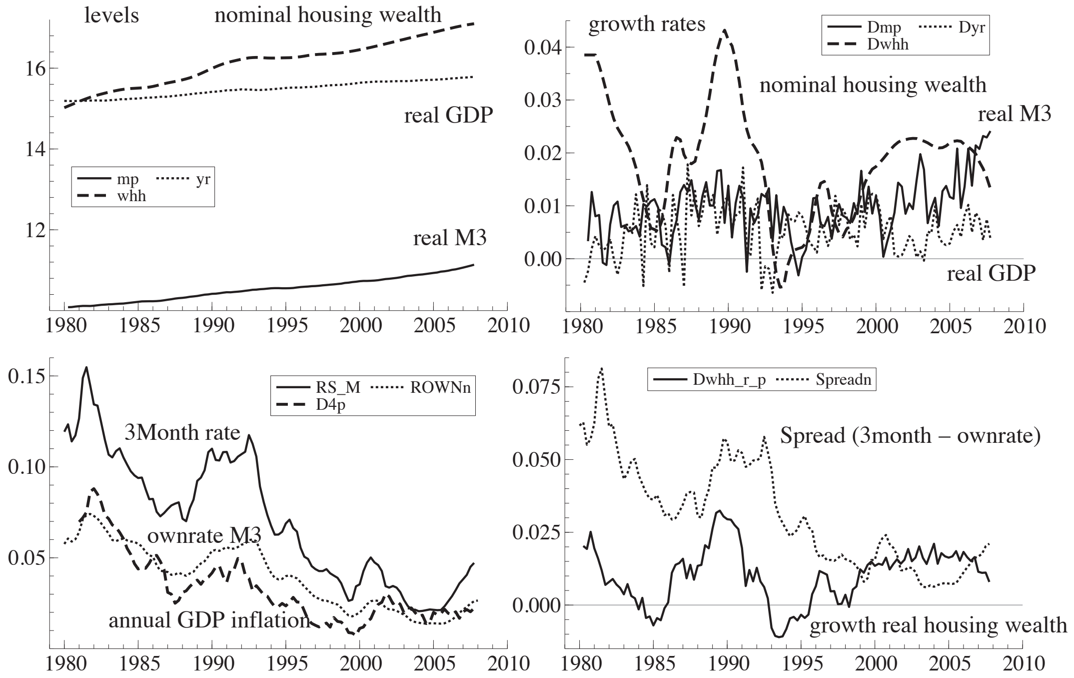


Figure 4: Graphs of the time series

4.2 The Statistical Model

For modelling the $p-$ dimensional process $\{X_t = (m-p)_t,\ y_t,\ \Delta whh,\ \Delta 4p_t,\ RS_t,\ RO_t\}$ consider its autoregressive VAR representation

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + ... + \Pi_k X_{t-k} + \Phi D_t + \epsilon_t, t = 1, ..., T. \quad (2)$$

It is assumed that $\{\epsilon_t\}$ is a sequence of independent Gaussian variables with zero mean and covariance matrix Ω. The VAR representation (2) can then be reparameterized as an observational equivalent Vector Error-Correction Model (VECM)

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \Phi D_t + \epsilon_t \quad (3)$$

where $\Pi = \sum_{i=1}^{k} \Pi_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{k} \Pi_j$. It is assumed that the characteristic polynomial

$$A(z) = I - \sum_{i=1}^{k} \Pi_i z^i \quad (4)$$

satisfies the condition that if $|A(z)| = 0$, then either $|z| > 1$ or $z = 1$.

Let $\Pi = \alpha\beta'$ where the matrix Π is $(p \times p)$ and α, β are each $(p \times r)$ and have full rank r. Then the r columns of β are cointegrating vectors and α is the loading matrix. The elements of α determine the strength with which each of the cointegrating vectors enters each equation of the VECM such that (3) becomes

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \alpha\beta^{*\prime} \begin{pmatrix} X_{t-1} \\ t \end{pmatrix} + \mu_0 + \epsilon_t. \tag{5}$$

Given that $(m-p)_t$, and $y_{t,}$ are trending, we restrict the deterministic trend to lie in the cointegrating space and leave the constant μ_0 unrestricted, see Johansen (1996). We will show below that the alternative specification without trend but unrestricted constant which has been chosen by CGL is now strongly rejected over the extended sample period. Equation (5) is therefore the baseline model along which the empirical model will be developed.

4.3 Determining Lag Length and Cointegrating Rank

First we establish the dimension of the VAR in equation (2). We start with a lag length of four which we sequentially reduce to two. The F-statistic for excluding jointly all lag-4 variables is not rejected by a p-value of around eight percent (F(36,323) = 1.3855 [0.075]). However, further reducing the model to a VAR(2) yields an F(36,349) = 1.5671 test statistic with p-value [0.023]. Reducing the VAR(4) directly to a VAR(2) is rejected by an F(72,402) = 1.4934 test statistic with a p-value of below one percent.

The usual information criteria (SC, HQ and AIC) would slightly favour a VAR(2). However, as it will turn out below, when transforming the VAR into a VECM a lag length of just one for the short run dynamics is not sufficient to capture the underlying dynamics in the data. Hence we model the process as a VAR(3).

The next step of the analysis is to estimate the rank of the long run matrix $\Pi = \alpha\beta^{*\prime}$ and hence to determine the number of cointegrating vectors. To determine the cointegrating rank of Π for the underlying model we apply the Johansen trace test. Table 3 presents the trace-test statistics

$$Q_r = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i) \tag{6}$$

for estimating the cointegrating rank r. For the null hypothesis "rank $\Pi \leq r$" the table reports the standard trace statistic together with 95 percent quantiles and p-values. We also report the Bartlett-corrected trace statistic with corresponding

I(1)-Analysis								
p-r	r	Eig.Value	Trace	Trace*	Frac95	P-Value	P-Value*	largest non-unit eig.value[a]
6	0	0.43	153.83	116.66	117.45	0.00	0.05	0.93
5	1	0.25	94.30	68.35	88.55	0.01	0.57	0.92
4	2	0.21	63.90	50.93	63.65	0.04	0.37	0.87
3	3	0.15	39.12	30.18	42.77	0.11	0.49	0.95
2	4	0.14	21.27	16.25	25.73	0.17	0.48	0.94
1	5	0.04	4.86	n.a.	12.44	0.62	n.a.	1.00

[a] of the "companion matrix" of the characteristic polynomial when (p-r) unit roots have been imposed

Table 3: Trace teststatistics for cointegrating rank

p-values which are marked with an asterisk. Bartlett-corrected trace statistics are applied to take into account small sample biases which often yield over-sized tests, see Johansen (2000, 2002*a, b*) As can be seen from Table 3 the standard test statistic rejects clearly the hypotheses of at most zero or at most one cointegrating vector ($r =$ 0, 1). The existence of at most two cointegrating vectors is borderline rejected at around 5%, pointing towards a third relationship. Applying the Bartlett correction, however, one could conclude to find one cointegrating vector only. An important decision criterion for the choice of the cointegrating rank is the largest non-unit eigenvalue of the companion matrix of the characteristic polynomial (4) after imposing $(p-r)$ unit roots according to the corresponding cointegrating rank r. It is desirable for the largest non-unit eigenvalue to be as small as possible, see e.g. Chapter 3 in Juselius (2006). Interestingly, there is a local minimum behavior for $r = 2$ with an eigenvalue of 0.87. Analyzing three cointegrating vectors appears attractive from a statistical point of view, but at the end did not yield an economically meaningful and statistically acceptable identification scheme. We therefore chose a cointegrating rank of two. Before estimation however, we present formal unit root tests for stationarity of the individual variables that are modelled in X_t. Table 4 shows χ^2 test statistics for each variable under the null hypothesis that a variable is a single cointegrating vector "in itself ". For $r = 2$ this is rejected for all variables. Only inflation is borderline stationary at 5%. We proceed under the I(1) assumptions for all variables in X_t and for the following empirical analysis we will identify and estimate two cointegrating relationships.

Test of stationarity for individual variables as single cointegrating vectors								
r	Dof	5% c.v.	m-p	y	Δwhh	$\Delta 4p$	RO	RS
1	5	11.070	41.947 [0.000]	40.145 [0.000]	39.220 [0.000]	36.679 [0.000]	39.002 [0.000]	37.361 [0.000]
2	**4**	**9.488**	**14.045** [0.007]	**13.108** [0.011]	**11.138** [0.025]	**9.149** [0.057]	**15.020** [0.005]	**16.641** [0.002]
3	3	7.815	8.524 [0.036]	7.612 [0.055]	5.558 [0.135]	4.000 [0.261]	9.128 [0.028]	9.165 [0.027]
4	2	5.991	5.831 [0.054]	2.731 [0.255]	5.411 [0.067]	1.624 [0.444]	4.081 [0.130]	3.561 [0.169]
5	1	3.841	2.714 [0.099]	0.415 [0.519]	3.145 [0.076]	0.154 [0.695]	2.330 [0.127]	1.805 [0.179]
LR-test, $\chi^2(6-r)$, p-values in brackets								

Table 4: Test for stationarity

4.4 Identification of the Long-run Structure

The identification of parameters in VARs, SVARS and VECMs has been discussed extensively in the literature, see e.g. Sims (1980), Johansen and Juselius (1994), Watson (1994), Hendry (1995), Johansen (1996) Pesaran and Smith (1998), Pesaran, Shin and Smith (2000), Garratt, Lee, Pesaran and Shin (2006) or Juselius (2006) - to mention only a few. Here we follow closely the approach suggested by Johansen and Juselius (1994). For identification of the parameters within cointegrated VARs, Johansen and Juselius (1994) distinguish three categories, namely generic, empirical, and economic identification. These categories apply separately to the short-term dynamics and to the long-term parameters of the cointegration relationships. Generic identification is related to the statistical model, i.e. the estimability of the parameters with respect to certain rank conditions, see also Fisher (1966). Empirical identification is related to estimated parameters, their significance, and if imposed overidentifying restrictions are statistically validated. Economic identification is related to economic interpretability of the estimated model, i.e. interpretable signs and magnitudes of estimated parameters and plausible dynamic properties. For example dynamic simulations can reveal whether a transformed VECM converges to steady state growth rates, see also below in Section 5. To achieve generic identification of the two cointegrating vectors, we first estimate an exactly identified system. We further impose three overidentifying restrictions on each of the cointegrating vectors. Table 5 shows the final estimates. Parameters in bold are restricted and standard errors in parentheses.

The joint test statistic for these restrictions is asymptotically distributed as χ^2 which is not rejected by a $\chi^2(6) = 5.0261$ with asymptotic p-value of 54%. Over-

Estimated cointegrating relationships[a]							$\chi^2(\nu)$
$(m-p)$	y	Δwhh	$\Delta_4 p$	RS	RO	$trend$	[p-values]
1	-1.70	**4.11**	-4.11	**0**	**0**	**0**	$\chi^2(3)$ 2.94
(-)	(0.041)	$(-)$	(0.242)	(-)	(-)	(-)	[0.401]
0	-0.84	**1**	**-1**	**1.37**	-1.37	**0.005**	$\chi^2(3)$ 3.17
(-)	(0.013)	(-)	(-)	(-)	(0.084)	(-)	[0.365]
joint over-identifying restrictions on two cointegrating vectors:							$\chi^2(6)$ 5.02 [0.540]

[a] Linear trend restricted to lie in the cointegrating space. Trend coefficient in CI_2 restricted to 0.005: normalization by $\beta_{2y} = 0.84$ (0.005/0.84=0.0059) yields average quarterly GDP growth. This corresponds to average annual GDP growth of 2.3%; restricted coefficients in bold, standard errors in round brackets and p-values in squared brackets. All p-values are asymptotic χ^2

Table 5: Identified cointegrating relationships

The Loading Factors α						
$\Delta(m-p)$	Δy	$\Delta\Delta whh$	$\Delta\Delta_4 p$	ΔRS	ΔRO	
-0.039	0.11	*0.010*	0.042	0.102	*0.008*	CI_1
(0.029)	(0.029)	*(0.007)*	(0.021	(0.023)	*(0.007)*	
0.252	-0.27	*-0.037*	*-0.078*	-0.343	*-0.023*	CI_2
(0.109)	(0.110)	*(0.027)*	*(0.080)*	(0.088)	*(0.026)*	

β restricted as above, standard errors in brackets, weakly signif. coef. in italics

Table 6: Loading coefficients of the two cointegrating relationships

identifying restrictions imposed on each individual cointegrating vector yield asymptotic p-values of around 40% and are not rejected either. The corresponding loading factors for restricted β are shown in Table 6 together with their standard errors in brackets. Some of the coefficients (in italics) appear to be only weakly significant. This evidence will guide us when we test overidentifying restrictions and estimate a VECM in Section 5 further below. Notice also that for the first cointegrating vector to be a money demand relationship one would expect an "error-correcting" and hence negative and significant α-coefficient in the corresponding $\Delta(m-p)$ equation. With an estimate of -0.04 this is indeed the case although, at this stage, the coefficient is not very tightly estimated and we will get back to this point again further below.

Hence the long-run parameters are generically and empirically identified. Following the economic motivation above, the two cointegrating vectors $CI_i,\ i=1,2$ might be "economically identified" as representing equilibrium relationships for desired real money demand and real wealth such that

$$CI_1 : (m-p)^* = Const(1) + 1.7y - 4.11(\Delta whh\_r) \qquad (7)$$

$$CI_2 : \Delta whh\_r^* = Const(2) + 0.84y - 1.37(RS-RO) - 0.005Trend. \qquad (8)$$

The income elasticity in (7) is 1.7 and significantly bigger than unity. This is a rather common finding in the empirical euro area money demand literature: CGL's estimate is 1.3; BDW's is close to 1.4; and DFR's is even bigger than 1.8; see de Bondt (2009) for a recent overview. An exception, however, is the model by Artis and Beyer (2004) in which income elasticity is restricted to unity. Their sample ends, however, already in 2000.

The money demand relationship (7) is an enhanced velocity-type equation, that is similar to the long-run relationship labeled as "M9" and estimated by BDW but without wealth. Here the negative coefficient on growth of real wealth might be interpreted as a proxy for the substitution channel of wealth. We will come back to this when we interpret the full VECM further below in Section 5.

Similar to BDW we estimate a variant of money demand also with the spread variable included. Restricting the coefficients of the interest rates to be zero is nevertheless not rejected and does not change the estimated income and wealth elasticities either. BDW in their study present a similar result suggesting that the semi-elasticities on the interest rates in the money demand relation are imprecisely estimated when using classical ML since the likelihood function might be flat over a large section of the parameter space, see also Warne (2006).

Another argument put forward by BDW is that given the strong trends in real money and output it is perhaps not surprising that it is difficult to obtain precise information about the relevance of the interest rates for long-run money demand. BDW suggest in this context that identification of a money supply function in another cointegration relationship would help solving the identification problem for money demand.

Whereas economic identification of money demand in a system with just one cointegrating vector is rather straightforward, if elasticities are of plausible magnitudes and signs, it is obvious that in a system of more than one relationship economic identification is tricky. In a cointegrating system basically any linear relationship of cointegrating vectors could potentially yield another valid cointegrating relationship. Identifying one single relationship in isolation as, say, "money demand" is by no means unique and bears by construction always an arbitrary element. One possible criterion as an informal plausibility check is to examine what velocity function would be implied by the system of cointegrating vectors that have been estimated and how these velocity functions can explain e.g. the defined "Quantity Theory" version for velocity, i.e. -(m-p-y). In Figure 5 we present two "versions" of velocity. "$Veloc1$ Ci" is just the right-hand side when CI_1 is "solved " for -(m-p-y). "$Veloc2$ Ci" is velocity implied by the linear combination of both cointegrating vectors. Multiplying CI_2 by 0.8328 and subtracting it then from CI_1 implies an income elasticity of unity. Notice that this is *not* a stationary cointegrating relationship. Both measures can explain theoretical velocity fairly well. Running standard OLS regressions of velocity on each of the velocity functions shows that the linear combination of both cointegrating vectors yields an R^2 of 0.81 whereas the velocity function $Veloc1Ci$ that results from only the first cointegration relation yields an R^2 of 0.70. Another plausibility check is to examine how the long-run relationships feed into the equations of the VECM representation, i.e. the α coefficients in equation (5) which are reported in Table 6.

The second cointegrating vector invites for an interpretation as a long-run wealth growth relationship. Real wealth growth is - also by definition - positively related to real GDP and negatively related to the interest rate spread. Notice that disequilibria in real wealth growth do not enter significantly the nominal wealth equation for $\Delta\Delta whh$ and neither does the long-run money demand relationship. Hence, nominal wealth growth is weakly exogenous w.r.t. the long-run parameters of the cointegrated VAR - indeed a strong indication against the relevance of asset-inflation and credit channels. We will discuss the economic implications of weak exogeneity further below in the context of the VECM in Section 5.

Finally, comparing our identified cointegrated VAR with the model by CGL notice that not letting enter a trend in the cointegrating space and leaving the constant unrestricted would also be compatible with trending variables and this is indeed the specification CGL have used. However, this is a testable restriction which is very strongly

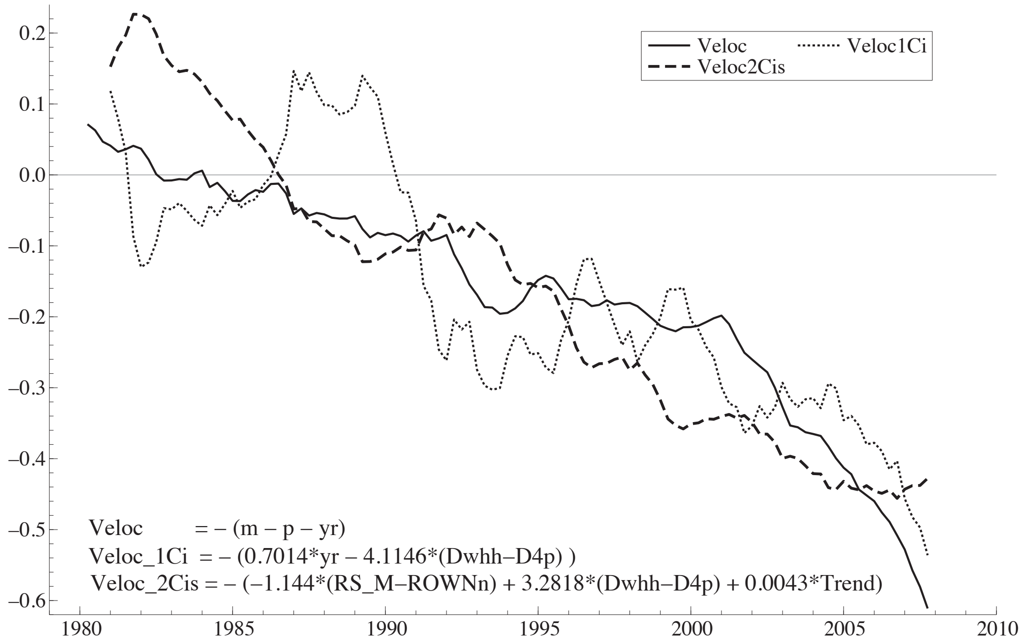


Figure 5: M3 Velocity: theoretical and implied

rejected for all possible rank assumptions. In our model when rank(Π) = 2 the test statistic is distributed as a $\chi^2(2) = 19.46$ which yields a p-value of much less than one thousandth. Hence, three modifications are sufficient to avoid the dramatic collapse of CGL: it is necessary to add housing wealth to the set of variables; to increase the dimension of the cointegration space to two; and to change the specification of the deterministic variables w.r.t the cointegration space.

4.5 Stability and Robustness of the Money Demand System

In this section we perform a set of tests that check for misspecification and empirical stability of our estimated cointegrated VAR. First we analyze the properties of the estimated model. Then we carry out a robustness check with regard to three alternative wealth aggregates which are shown in Figure 3, i.e financial wealth and total gross and net wealth.

4.5.1 Misspecification

First we briefly discuss tests for misspecification of the VAR in levels when restrictions on β are imposed that lead to (7) and (8). None of the equations suffers from ARCH

	ARCH, Serial Correlation, Normality[a]						
	Null hypothesis: no ARCH in equation k,						
k	$(m-p)$	y	Δwhh	$\Delta_4 p$	RS	RO
LM test (ARCH)	1.72	1.50	17.42	3.81	0.01	1.90
1 d.o.f. [p value]	[0.18]	[0.22]	[0.00]	[0.05]	[0.90]	[0.16]
LM test (ARCH)	3.36	4.54	18.96	8.73	6.79	4.54
4 d.o.f. [p value]	[0.49]	[0.33]	[0.00]	[0.07]	[0.14]	[0.33]
	Null hypothesis: no non-normality					
	1.60	4.96	1.72	3.14	7.22	11.50
	[0.44]	[0.08]	[0.42]	[0.20]	[0.03]	[0.00]
	Null hypothesis: no serial correlation					
no serial correlation	LM test: LM(36) = 41.52 [0.24]					
no non-normality	Wald test, W(6): Skewness: 16.19 [0.01], Kurtosis: 40.5 [0.00]					
	[a]3 lags, rank(β) = 2, β restricted					

Table 7: Misspecification tests

effect, except - as expected - the Δwhh equation, see Table 7. This is not surprising given the nature of the interpolated wealth data. But, the impact onto the entire model is not dramatic as wealth is at least weakly exogenous w.r.t the parameters of the cointegration space, i.e. none of the cointegrating vectors enters the wealth equation in the VECM. Test statistics for non-normality are rejected in particular for the level equation of the own rate, which again is not a surprise given that this is a constructed interest rate. Finally, a system-wide test for non-serial correlation does not reject with a p-value of 24%. Notice again that we have not used any dummy variables to account for outliers etc. in the data. Next, we examine the empirical stability of the model.

4.5.2 Recursive Estimates of the Cointegrating Vectors

The recursive estimates of the freely estimated β coefficients together with their ± 2 standard error bands and the recursive $\chi^2(6)$ test statistic for the restrictions that we have imposed earlier are shown in Figure 6, see Doornik (2006) for technical details on the estimation and testing techniques. The coefficients are stable over time and there are no signs of structural breaks. The recursive $\chi^2(6)$ test statistic for restrictions on β and also the $\chi^2(11)$ test statistic for additional restrictions on α which - according to the results in Table 6 - are not significant (see bottom right panel) are insignificant far below the 5% asymptotic critical value. Given that in cointegrated systems the asymptotic χ^2 tests tend to be over-sized in small samples and given that we have not used any dummy variable for outlier correction in the estimation of the model, this is a major achievement.

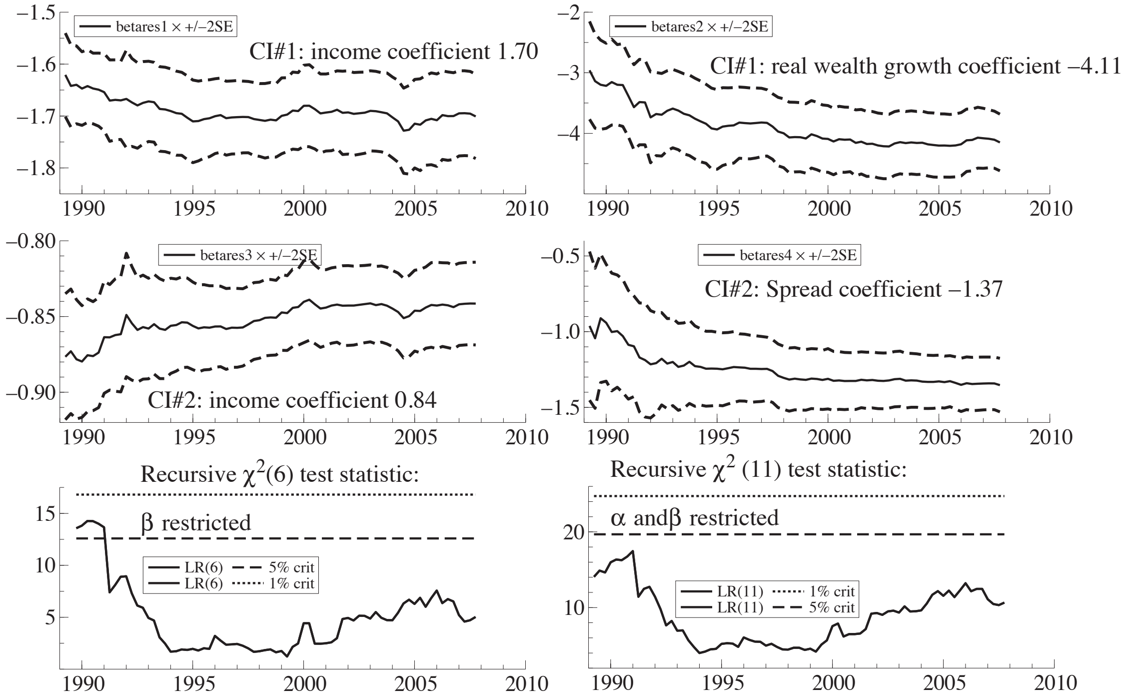


Figure 6: Recursive coefficients of cointegrating vectors

4.6 Estimating and Comparing Models Using Alternative Wealth Aggregates

Next, we examine the point estimates for the other three wealth aggregates, financial wealth and total wealth (gross and net of household debt). As can be seen from the results reported in Table 8 the point estimates of beta are rather similar and the parameters of the different models are tightly estimated. Estimated income elastitcities are within a narrow range, the highest being 1.78 when we use financial wealth. This is very close to the one of around 1.8 that DFR report in their international portfolio allocation model. From a statistical point of view the housing wealth specification is clearly dominant. It shows the highest value of the log-likelihood. And it has by far the highest p-value for validity of the imposed over-identifying restrictions on β. Compare e.g. the 54% p-value of the $\chi^2(6)$ test statistic with 1% p-value of the financial wealth model. For comparison we show in Figure 7 the recursive estimates of the corresponding $\chi^2(6)$ test statistics when we estimate β for alternative wealth aggregates under the same identification scheme. It turns out that for all wealth aggregates other than whh the recursive test statistic is significant almost over the entire sample. Only at the end of the sample, i.e. after also the CGL model suffered from a structural break, the $\chi^2(6)$ test is not rejected for both measures of total wealth but is borderline rejected for financial wealth. Hence, when judging the validity of overidentifying restrictions, it is of utmost importance to check recursive properties of the test statistic. Yet again, from these informal recursive tests it appears that housing wealth delivers by far the best stability properties. The informal procedures we have applied in this section are helpful because they provide a first "visual" test. However, it is well known that a χ^2 test for over-identifying restrictions that is based on asymptotic critical values is biased towards empirical instability. Nevertheless, that also means, that if such a test does *not* reject under the null of valid restrictions the modeler is on "the safe side " with regard to assuming stability. Next we apply more formal procedures for testing parameter stability in cointegrated systems.

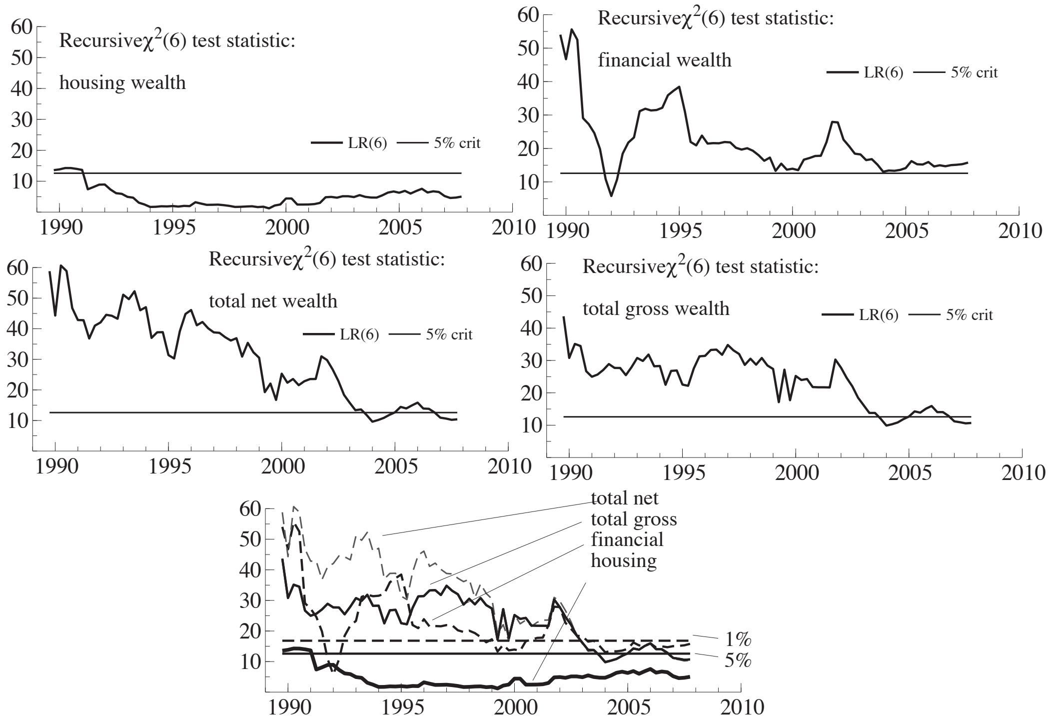


Figure 7: Alternative wealth aggregates: recursive tests for the validity of identification scheme

Estimated cointegrating relationships[a]: housing, financial and total wealth (net and gross)							$\chi^2(\nu)$
$(m-p)$	y	Δwhh	$\Delta_4 p$	RS	RO	$trend$	[p-values]
1	-1.70	**4.11**	-4.11	**0**	**0**	**0**	$\chi^2(3)$ 2.94
(-)	(0.041)	(−)	(0.242)	(-)	(-)	(-)	[0.401]
0	-0.84	**1**	**-1**	**1.37**	-1.37	**0.005**	$\chi^2(3)$ 3.17
(-)	(0.013)	(-)	(-)	(-)	(0.084)	(-)	[0.365]
	joint over-identifying restrictions on two cointegrating vectors:						$\chi^2(6)$ 5.02
	Likelihood: L = 3042.		-T/2log|Ω| = 3936.2				[0.540]
$(m-p)$	y	Δwhf	$\Delta_4 p$	RS	RO	$trend$	
1	-1.78	**3.62**	-3.62	**0**	**0**	**0**	$\chi^2(3)$ 5.38
(-)	(0.078)	(−)	(0.172)	(-)	(-)	(-)	[0.145]
0	-0.87	**1**	**-1**	**1.41**	-1.41	**0.005**	$\chi^2(3)$ 3.26
(-)	(0.022)	(-)	(-)	(-)	(0.084)	(-)	[0.352]
	joint over-identifying restrictions on two cointegrating vectors:						$\chi^2(6)$ 15.7
	Likelihood: L = 2848.3		-T/2log|Ω| = 3742.0				[0.015]
$(m-p)$	y	$\Delta whtn$	$\Delta_4 p$	RS	RO	$trend$	
1	-1.73	**4.06**	-4.06	**0**	**0**	**0**	$\chi^2(3)$ 3.69
(-)	(0.050)	(−)	(0.277)	(-)	(-)	(-)	[0.296]
0	-0.85	**1**	**-1**	**1.40**	-1.40	**0.005**	$\chi^2(3)$ 1.33
(-)	(0.015)	(-)	(-)	(-)	(0.089)	(-)	[0.722]
	joint over-identifying restrictions on two cointegrating vectors:						$\chi^2(6)$ 10.3
	Likelihood: L = 2922.4		-T/2log|Ω| = 3816.3				[0.1096]
$(m-p)$	y	$\Delta whtg$	$\Delta_4 p$	RS	RO	$trend$	
1	-1.74	**4.08**	-4.08	**0**	**0**	**0**	$\chi^2(3)$ 3.79
(-)	(0.051)	(−)	(0.286)	(-)	(-)	(-)	[0.284]
0	-0.86	**1**	**-1**	**1.41**	-1.4	**0.005**	$\chi^2(3)$ 1.25
(-)	(0.015)	(-)	(-)	(-)	(0.091)	(-)	[0.740]
	joint over-identifying restrictions on two cointegrating vectors:						$\chi^2(6)$ 10.6
	Likelihood: L = 2934.1		-T/2log|Ω| = 3828.2				[0.0983]

[a] Linear trend restricted to lie in the cointegrating space. Trend coefficient in CI#2 restricted to 0.005. Normalization by $\beta_{2y} = 0.84$ (0.005/0.84=0.0059) yields average quarterly GDP growth. This corresponds to average annual GDP growth of 2.3% (1980-2007, Euro area); restricted coefficients in bold, standard errors in round brackets and p-values in squared brackets.

Table 8: Cointegrating relationships using different wealth aggregates

4.7 Formal Stability Tests

In this section we go beyond "visual inspection " and apply formal tests for parameter instability. We present results for the fluctuation test by Hansen and Johansen (1999) which is a test on empirical stability of the non-zero eigenvalues. We then test formally for parameter constancy of the coefficients in the cointegrating vectors β by applying Hansen and Johansen's (1999) version of Nyblom's (1989) test for parameter stability. And we test for constancy of the constant Φ, the "short-run" coefficients Γ_i and loading coefficients α of the cointegrated system (3) by applying the Ploberger, Krämer and Kontrus (PKK, 1989) test. To perform these tests we have used Anders Warne's software program "*Structural VAR* ", see Warne (2009) in which they are implemented. See also BDW for a detailed discussion and applications of these tests. We test parameter stability of our *whh* model and we provide again a comparative analysis for the other three wealth aggregates maintaining the assumption of cointegration rank $r = 2$. Asymptotic critical values usually yield rejection of stability too often due to small sample biases and over-sized test statistics, see BDW. We therefore simulated critical values from the empirical distributions and present corresponding p-values as well.

4.7.1 Recursive Eigenvalues

Applying the Hansen and Johansen (1999) test we present results for two versions of the recursive eigenvalue tests when both eigenvalues are estimated without imposing any restrictions on β. First, we leave the short run parameters Γ fixed at their full sample estimates. The results are presented in Table 9. While *whh* eigenvalues are stable, there is clearly evidence for instability for the other wealth aggregates. Looking at the asymptotic critical values stability is clearly rejected, either for the second cointegrating vector for *whf* or for both vectors for *whtg*. The test for stability of the sum of both cointegration vector is rejected for all three other wealth aggregates, but not for *whh*. Looking at the bootstrapped p-values stability is still rejected for *whtg* but could be borderline accepted for *whf* and *whtn*.

Another version of the test is to update the short run parameters Γ at each observation during recursion. For this version of the test we would expect stability to be rejected much more often. Indeed, the results in Table 10 show instability for all wealth aggregates when tests are based on asymptotic critical values. For bootstrapped p-values however, *whh* shows again that it has superior stability properties. Stability is not rejected for any of both eigenvalues and neither of their sum. For the other three wealth aggregates in particular tests for stability of the second eigenvalues show clearly signs of instability. For illustration we show the recursive eigenvalues and

Hansen-Johansen fluctuation tests				
	wealth aggregate			
	Δwhh	Δwhf	$\Delta whtn$	$\Delta whtg$
Test on individual eigenvalues[a]				
test eigenvalue (1)	0.96	0.87	1.35	1.65
p-value, asymptotic	0.316	0.426	0.051	0.008
p-value, bootstrap	0.460	0.492	0.080	0.080
test eigenvalue (2)	0.97	2.08	1.83	2.35
p-value, asymptotic	0.304	0.000	0.002	0.000
p-value, bootstrap	0.520	0.051	0.090	0.020
Test for sum of eigenvalues[b]				
test sum eigenvalues	1.15	1.62	1.92	2.36
[p-value, asymptotic]	0.136	0.000	0.000	0.000
[p-value, bootstrap]	0.561	0.130	0.050	0.040

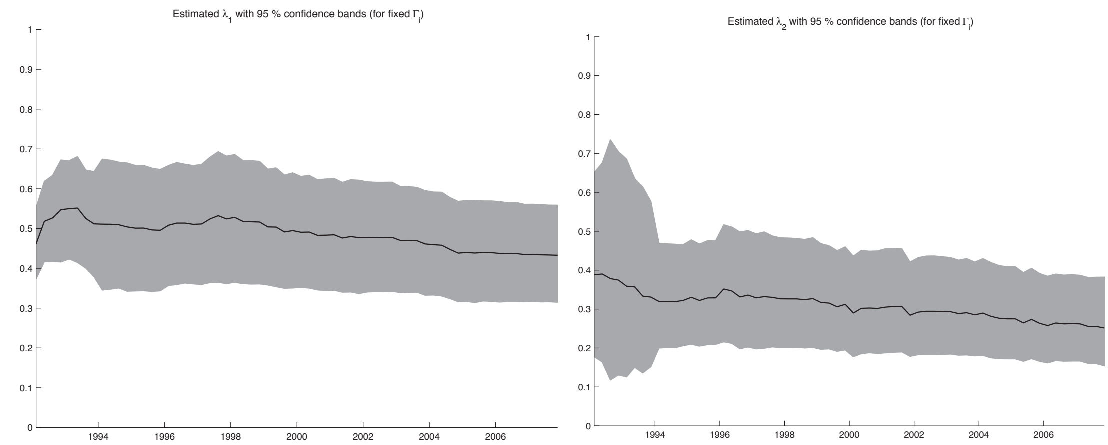
For rank = 2, 3 lags, Γ_i fixed, unrestricted beta parameters
[a]Null hypothesis: eig(i) is constant
Test statistic: HJ(i,1) = sup_{t=1992:1,...,2007:4} tau(eig(i)), i=1,...,2
[b]xi=log[eig(i)/(1-eig(i))], i=1,...,2
Null hypothesis: sum(xi;1,...,2) is constant
Test statistic: sup_{t=1992:1,...,2007:4} tau(sum(xi);1)

Table 9: Hansen-Johansen fluctuation test (I)

Hansen-Johansen fluctuation tests				
	wealth aggregate			
	Δwhh	Δwhf	$\Delta whtn$	$\Delta whtg$
Test on individual eigenvalues[a]				
test eigenvalue (1)	1.68	1.77	2.16	1.84
p-value, asymptotic	0.006	0.003	0.000	0.002
p-value, bootstrap	0.571	0.531	0.111	0.040
test eigenvalue (2)	2.42	3.26	3.27	3.06
p-value, asymptotic	0.000	0.000	0.000	0.000
p-value, bootstrap	0.251	0.020	0.040	0.060
Test for sum of eigenvalues[b]				
test sum eigenvalues	2.43	3.07	3.28	2.90
[p-value, asymptotic]	0.000	0.000	0.000	0.000
[p-value, bootstrap]	0.672	0.252	0.091	0.291

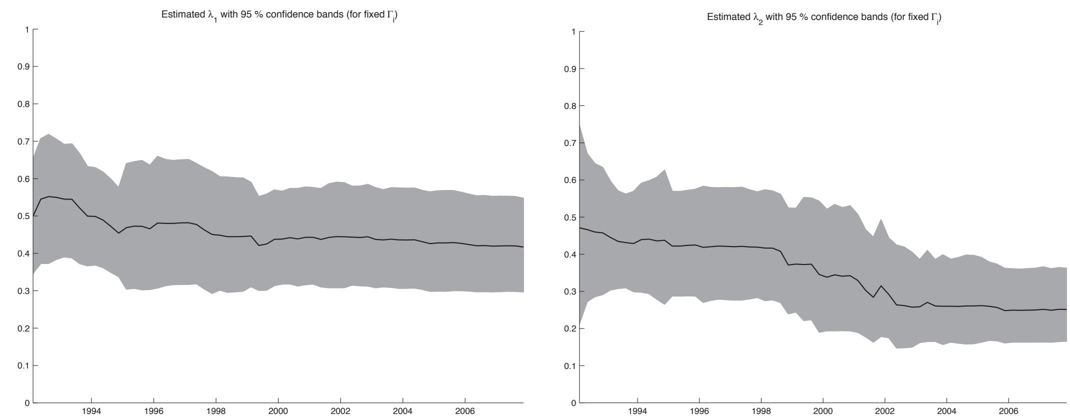
For rank = 2, 3 lags, Γ_i updated, unrestricted beta parameters
[a]Null hypothesis: eig(i) is constant
Test statistic: HJ(i,1) = sup_{t=1992:1,...,2007:4}
tau(eig(i)), i=1,...,2
[b]xi=log[eig(i)/(1-eig(i))], i=1,...,2
Null hypothesis: sum(xi;1,...,2) is constant
Test statistic: sup_{t=1992:1,...,2007:4} tau(sum(xi);1)

Table 10: Hansen-Johansen fluctuation test (II)



Eigenvalue 1 whh Eigenvalue 2 whh

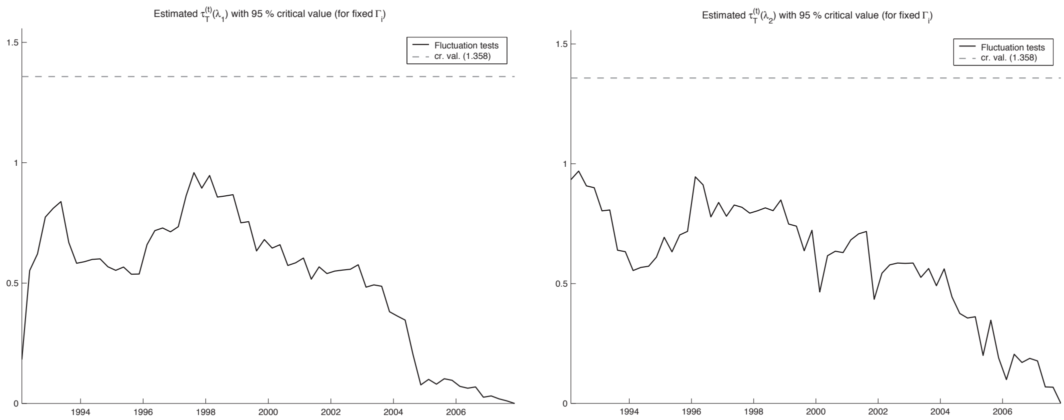
Figure 8: Recursive eigenvalues whh



Eigenvalue 1 whf Eigenvalue 2 whf

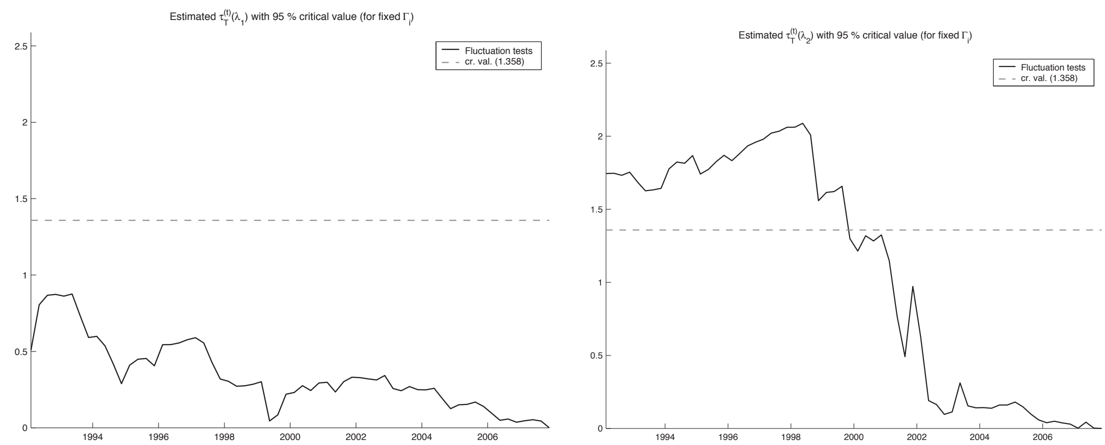
Figure 9: Recursive eigenvalues whf

fluctuation tests for financial wealth and compare with the results for housing wealth. Figures 8 and 9 show both recursive eigenvalues for the two wealth aggregates. The shift in the second eigenvalue for whf is evident. This is reflected by the significant test statistic in the right panel of Figure 11, further below. Figure 11 shows the fluctuation tests for individual eigenvalues, together with the 95% critical value. By contrast, the test statistic is not significant for whh, see Figure 10. Finally, Figure 12 shows for both wealth aggregates the test for stability of the sum of the eigenvalues, together with the 95% critical value. Also here stability for whf is rejected but not for whh.



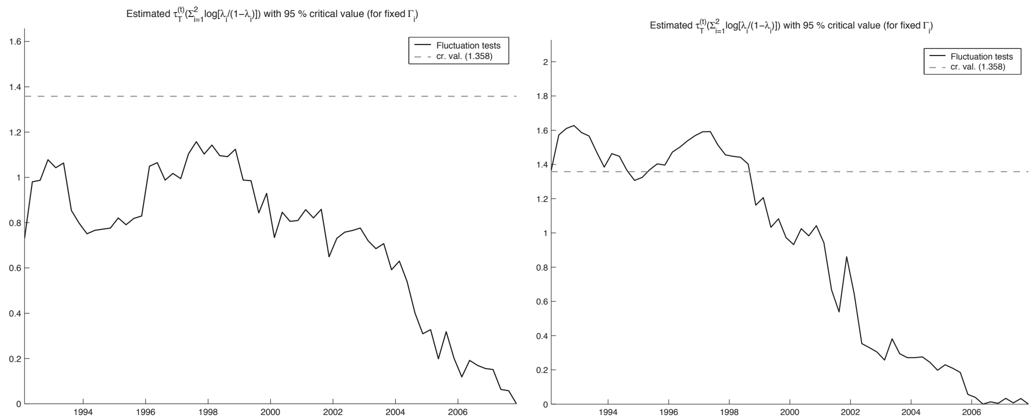
Eigenvalue 1 whh Eigenvalue 2 whh

Figure 10: Fluctuation test whh



Eigenvalue 1 whf Eigenvalue 2 whf

Figure 11: Fluctuation test whf



Sum of Eigenvalues whh Sum of Eigenvalues whf

Figure 12: Fluctuation tTest whh and whf

4.7.2 Nyblom Tests for Stability of Beta

Next, we present the results of the Nybom tests for parameter constancy of β. Again, we apply two different versions of the test, i.e. Γ_i fixed and updated. For each version we test constancy when β is either restricted or unrestricted. The results presented in Table 11 and Table 12 show that constancy of β is not rejected for any of the wealth aggregates. However, for most of the tests whh has the best stability properties, see Figures 13 and 14.

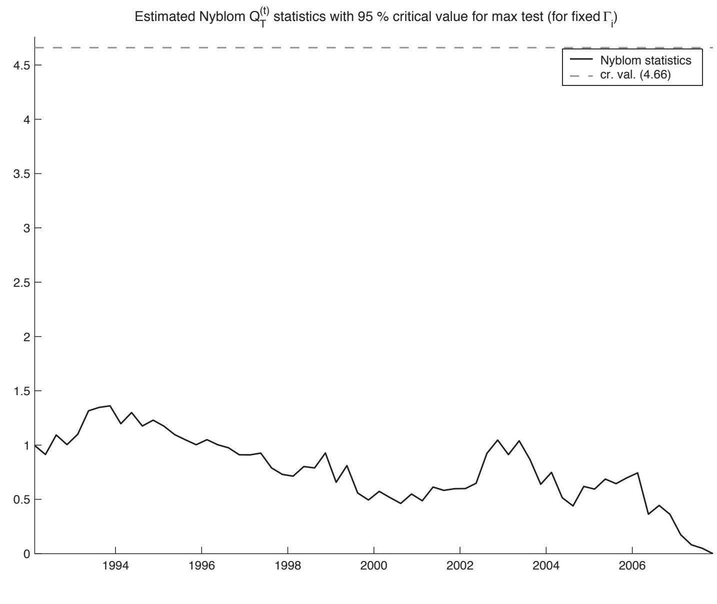


Figure 13: Nyblom Mean_Q test, β unrestricted

Nyblom tests[a] for parameter constancy of β				
	wealth aggregate			
	Δwhh	Δwhf	$\Delta whtn$	$\Delta whtg$
	β unrestricted			
sup _Q	1.36	3.01	2.64	3.12
p-value asymptotic	0.981	0.401	0.564	0.351
p-value bootstrap	0.939	0.161	0.272	0.191
Mean_Q	0.77	1.11	0.65	1.64
p-value asymptotic	0.840	0.530	0.932	0.169
p-value bootstrap	0.757	0.404	0.868	0.111
	β restricted			
sup _Q	0.80	0.88	0.81	0.91
p-value bootstrap	0.828	0.712	0.712	0.636
Mean_Q	0.24	0.37	0.17	0.19
p-value bootstrap	0.888	0.596	0.989	0.939

[a]For rank = 2, 3 lags, Γ_i fixed

Null hypothesis: β is constant,
Test statistics: sup_Q, Mean_Q{t=1992:1,...,2007:4}
Q(t|T=2007:4;endo vars=6,rank=2)
Bootstrap Simulation of Nyblom Tests
1000 replications, 105 draws.

Table 11: Nyblom tests (I) for beta

Nyblom tests[a] for parameter constancy of β				
	wealth aggregate			
	Δwhh	Δwhf	$\Delta whtn$	$\Delta whtg$
	β unrestricted			
sup _Q	2.44	3.93	2.97	4.09
p-value asymptotic	0.651	0.136	0.416	0.11
p-value bootstrap	0.645	0.121	0.484	0.090
Mean_Q	1.17	1.44	0.82	1.64
p-value asymptotic	0.470	0.271	0.812	0.03
p-value bootstrap	0.636	0.414	0.909	0.169
	β restricted beta			
sup _Q	0.65	1.26	0.79	1.22
p-value bootstrap	0.99	0.717	0.909	0.686
Mean_Q	0.25	0.53	0.16	0.36
p-value bootstrap	0.96	0.585	0.99	0.757

[a]For rank = 2, 3 lags, Γ_i updated

Null hypothesis: β is constant,
Test statistics: sup_Q, Mean_Q{t=1992:1,...,2007:4}
Q(t|T=2007:4;endo vars=6,rank=2)
Bootstrap Simulation of Nyblom Tests
1000 replications, 105 draws.

Table 12: Nyblom tests (II) for beta

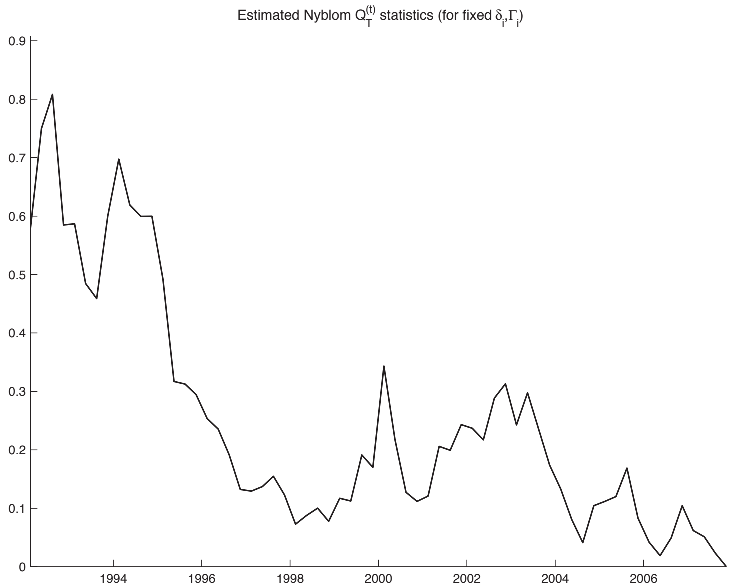


Figure 14: Nyblom Mean_Q test, β restricted, simul.cv.95% 1.02

4.7.3 Short-run Dynamics: Ploberger-Kontrus-Krämer Test

In Tables 13 and 14 we present the results of the PKK tests which is a tests for stability of the short run coefficients Γ. We show results for restricted and unrestricted β. The results for unrestricted β in Table 13 show that stability behavior across different wealth aggregates does not depend on the particular identification scheme we have chosen for β. Whereas the housing wealth model yields the highest test statistics at the beginning of the sample but behaves stable over the rest of the sample the three other models are clearly unstable around EMU. This finding is in line with the results of the recursive χ^2 tests above. Figures 15 and 16 show the PKK tests together with their 95% critical value for housing wealth and, for total gross wealth (representative for the three other wealth aggregates, which all perform similarly bad). In the latter, the break around 2000 in the short run dynamics of all equations of the VECM is evident.

Summing up the results of this section, we found that our specification of the cointegrated VAR in levels with imposed restrictions that yield the cointegrating relationships (7) and (8) is a valid representation of the data and serves as a starting point for mapping the model into a VECM. This is our next step.

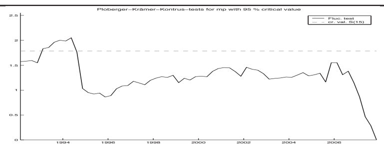
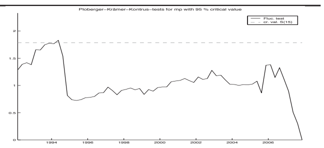
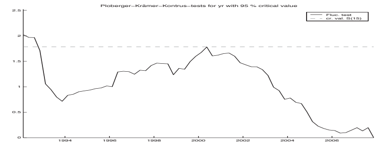
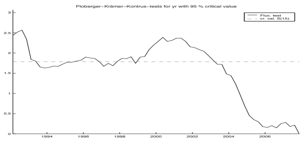
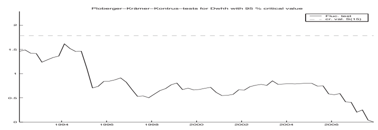
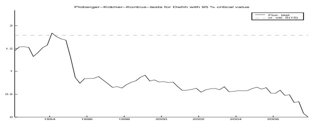
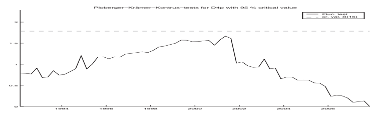
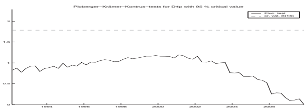
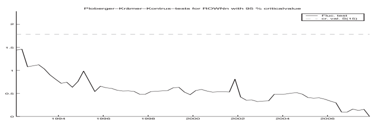
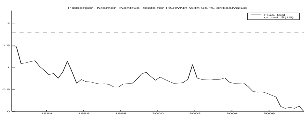
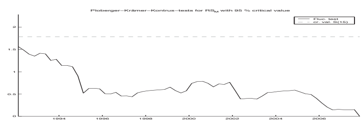
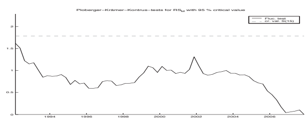
PKK test statistic and 95% c.v.: housing wealth			
	cointegrating rank 2, β unrestricted		cointegrating rank 2, β restricted
$m-p$		$m-p$	
y		y	
$\Delta(whh)$		$\Delta(whh)$	
$\Delta 4p$		$\Delta 4p$	
RO		RO	
RS		RS	

Figure 15: Ploberger-Krämer-Kontrus test statistics

PKK test statistic and 95% c.v.: total gross wealth

cointegrating rank 2, β unrestricted | cointegrating rank 2, β restricted

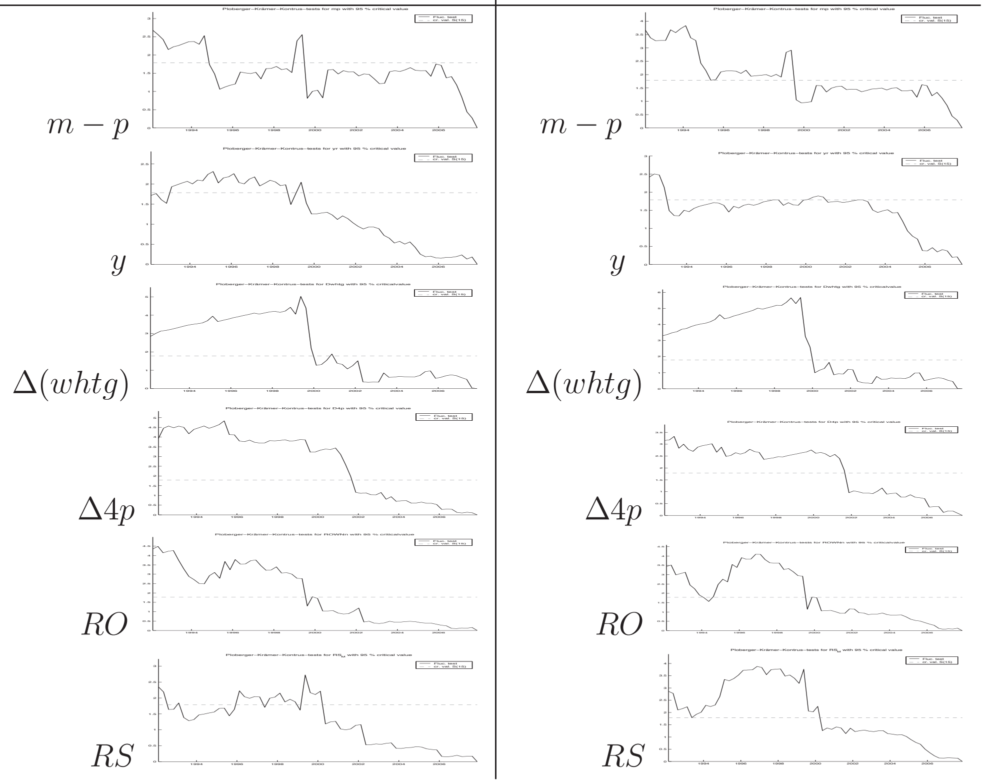


Figure 16: Ploberger-Krämer-Kontrus test statistics

Ploberger-Kontrus-Krämer test: 2 cointegrating vectors, unrestricted						
Null hypothesis: Short run coefficients in equation k are constant for all t in {1992:1,...,2007:4}against non-constancy						
k	$(m-p)$	y	Δwhh	$\Delta_4 p$	RS	RO
S(15) test stat	2.05	2.02	1.61	1.66	1.56	1.46
[p value]	[0.006]	[0.008]	[0.15]	[0.10]	[0.20]	[0.34]
worst period	1994:2	1992:1	1994:1	2001:2	1992:1	1992:2
	$(m-p)$	y	Δwhf	$\Delta_4 p$	RS	RO
S(15) test stat	1.99	3.43	3.97	3.75	2.79	2.12
[p value]	[0.009]	[0.000]	[0.000]	[0.000]	[0.000]	[0.003]
worst period	1994:2	1998:4	1999:2	1999:1	1999:2	1998:3
	$(m-p)$	y	$\Delta whtn$	$\Delta_4 p$	RS	RO
S(15) test stat	3.80	2.14	3.70	5.50	4.12	4.89
[p value]	[0.000]	[0.002]	[0.000]	[0.000]	[0.000]	[0.000]
worst period	1993:2	1992:1	1999:3	1996:1	1992:2	1995:3
	$(m-p)$	y	$\Delta whtg$	$\Delta_4 p$	RS	RO
S(15) test stat	2.67	2.31	5.01	4.83	2.72	4.48
[p value]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.20]
worst period	1992:1	1995:1	1999:2	1995:2	1999:2	1992:2

Table 13: Ploberger-Krämer-Kontrus fluctuation test

Ploberger-Kontrus-Krämer test: 2 cointegrating vectors, restricted						
Null hypothesis: Short run coefficients in equation k are constant for all t in {1992:1,...,2007:4}against non-constancy						
k	$(m-p)$	y	Δwhh	$\Delta_4 p$	RS	RO
S(15) test stat	1.82	2.56	1.83	1.19	1.61	1.46
[p value]	[0.040]	[0.000]	[0.035]	[0.841]	[0.150]	[0.339]
worst period	1994:2	1992:1	1994:1	2001:2	1992:2	1992:1
	$(m-p)$	y	Δwhf	$\Delta_4 p$	RS	RO
S(15) test stat	2.09	2.43	4.46	2.47	2.24	1.74
[p value]	[0.009]	[0.000]	[0.000]	[0.000]	[0.003]	[0.000]
worst period	1994:2	1992:2	1999:2	2000:2	2000:2	2000:2
	$(m-p)$	y	$\Delta whtn$	$\Delta_4 p$	RS	RO
S(15) test stat	3.62	3.66	4.11	5.94	4.23	4.84
[p value]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
worst period	1996:3	1992:3	1999:3	1995:2	1993:1	1993:1
	$(m-p)$	y	$\Delta whtg$	$\Delta_4 p$	RS	RO
S(15) test stat	3.83	2.50	5.68	3.32	3.88	4.09
[p value]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
worst period	1994:1	1992:2	1999:2	1992:3	1996:4	1996:4

Table 14: Ploberger-Krämer-Kontrus fluctuation test

5 From a Reduced Form VAR To a Meaningful VECM

In this Section we transform the VAR in levels into a Vector Error Correction Model in which we maintain our long run relationships (7) and (8). We follow closely the modelling strategy as suggested and illustrated by Hendry and Mizon (1993). First, we estimate an unrestricted VECM which contains all lagged short run dynamics up to order two and both error correction terms. Sequentially reducing the unrestricted VECM yields a parsimonious overidentified VECM that - if restrictions are valid - statistically encompasses the VAR and that allows for some economic interpretation.

5.1 Estimating an Overidentified Model

Starting from the general representation of Model (5) with lag length two after sequentially eliminating insignificant regressors we obtain the following parsimonious VECM in equations (9) - (14).

$$\begin{aligned}\Delta(m-p)_t = \; & \underset{(0.002)}{0.017} \; \underset{(0.09)}{+0.43\Delta(m-p)_{t-1}} \; \underset{(0.08)}{+0.2\Delta y_{t-2}} \; \underset{(0.09)}{-0.34\Delta RS_{t-2}} \\ & \underset{(0.01)}{-0.05\{(m-p)-(m-p)^*\}_{t-1}} \\ & \underset{(0.06)}{+0.31(\Delta whh-\Delta whh^*)_{t-1}}\end{aligned} \tag{9}$$

$$\begin{aligned}\Delta y_t = \; & \underset{(0.002)}{0.002} \; \underset{(0.08)}{-0.21\Delta(m-p)_{t-1}} \\ & \underset{(0.01)}{+0.09\{(m-p)-(m-p)^*\}_{t-1}} \\ & \underset{(0.02)}{-0.17(\Delta whh-\Delta whh^*)_{t-1}}\end{aligned} \tag{10}$$

$$\Delta\Delta whh_t = \underset{(0.08)}{1.27\Delta\Delta whh_{t-1}} \; \underset{(0.08)}{-0.48\Delta\Delta whh_{t-2}} \tag{11}$$

$$\Delta\Delta p_t = \underset{(0.001)}{0.001} \underset{(0.06)}{-0.10\Delta(m-p)_{t-1}} \underset{(0.06)}{-0.08\Delta(m-p)_{t-2}} \underset{(0.21)}{+0.76\Delta\Delta whh_{t-1}} \underset{(0.22)}{-0.71\Delta\Delta whh_{t-2}} \underset{(0.14)}{+0.95\Delta RO_{t-2}} \underset{(0.01)}{+0.03\{(m-p)-(m-p)^*\}_{t-1}} \qquad (12)$$

$$\Delta RO_t = \underset{(0.06)}{+0.33\Delta RO_{t-1}} \underset{(0.01)}{+0.07\Delta y_{t-1}} \underset{(0.01)}{+0.03\Delta y_{t-2}} \underset{(0.02)}{+0.10\Delta RS_{t-1}} \underset{(0.001)}{+0.004(m-p)-(m-p)^*\}_{t-1}} \underset{(0.0001)}{-0.0007} \qquad (13)$$

$$\Delta RS_t = \underset{(0.001)}{-0.012} \underset{(0.07)}{+0.48\Delta RS_{t-1}} \underset{(0.05)}{+0.11\Delta\Delta p_{t-2}} \underset{(0.01)}{+0.09\{(m-p)-(m-p)^*\}_{t-1}} \underset{(0.03)}{-0.29(\Delta whh - \Delta whh^*)_{t-1}} \qquad (14)$$

We experimented with various identification schemes to allow also for contemporaneous explanatory variables in each equation. It turned out, however, that under none of these identification schemes we could obtain a model that would statistically outperform the backward looking VECM (9) - (14).

5.2 Statistical Evaluation

Compared to the unrestricted VAR, we have imposed 60 overidentifying restrictions which are not rejected by a Likelihood-Ratio test with a test statistic $\chi^2(60) = 58.33$ and an asymptotic p-value of 54%. The log-likelihood is 3012 compared to 3042 of the VAR in levels (the latter being estimated with inclusion of both restricted overidentified cointegrating vectors in each equation). All adjustment coefficients of the error correction terms for the cointegrating long run relationships in (9) - (14) are highly significant with p-values mostly below 1%. The same applies, with only very few exceptions to those of the short-run dynamics. By contrast to the estimation results of the cointegration analysis reported in Table 6 above, the first cointegrating vector - representing excess money demand - enters now significantly and with positive sign into the ΔRO_t equation. And, more importantly, excess money demand enters now

	$\mathbf{\Delta(m-p)}$	Δy	$\Delta\Delta whh$	$\Delta\Delta p$	ΔRO	ΔRS
AR $(1-5)$	**0.93**	1.7668	3.46	2.29	2.07	0.35
p-value	**[0.46]**	[0.13]	[0.006]**	[0.05]	[0.08]	[0.87]
Distribution	**F(5,94)**	F(5,96)	F(5,98)	F(5,93)	F(5,94)	F(5,95)
$ARCH$ $(1-4)$	**0.81**	2.5805	4.68	3.20	0.98	0.47
p-value	**[0.51]**	[0.042]*	[0.002]**	[0.02]*	[0.42]	[0.75]
Distribution	**F(4,91)**	F(4,93)	F(4,95)	F(4,90)	F(4,91)	F(4,92)
$HeteroX_i^2$	**1.40**	0.31	1.83	0.76	2.28	0.52
p-value	**[0.19]**	[0.92]	[0.12]	[0.67]	[0.02]*	[0.83]
Distribution	**F(10,88)**	F(6,94)	F(4,98)	F(12,85)	F(10,88)	F(8,91)
$Hetero-X$	**1.10**	0.30	11.46	0.67	1.52	0.56
p-value	**[0.36]**	[0.97]	[0.00]**	[0.87]	[0.10]	[0.88]
Distribution	**F(20,78)**	F(9,91)	F(5,97)	F(27,70)	F(20,78)	F(14,85)
$RESET$	**0.24**	0.68	0.71	0.15	0.05	0.22
p-value	**[0.62]**	[0.40]	[0.40]	[0.69]	[0.81]	[0.63]
Distribution	**F(1,98)**	F(1,100)	F(1,102)	F(1,97)	F(1,98)	F(1,99)
$Normality\ \chi^2(2)$	**2.12**	6.72	2.79	2.36	13.24	12.21
p-value	**[0.34]**	[0.035]*	[0.24]	[0.30]	[0.001]**	[0.002]**

AR $(1-5)$: residual autocorrelation up to 5 lags; $ARCH$ $(1-4)$: conditional heteroscedasticity; $HeteroX_i^2$ / $Hetero-X$: unconditional heteroscedasticity (squared / cross-products of regressors); $RESET$: linearity/omitted variables; (*), (**): significant at 5 or 1 %.

Table 15: Misspecification tests for VECM

highly significant into the $\Delta(m-p)$ equation (9). The other exclusion restrictions, however, match with the findings in Table 6. Tests for misspecification (autocorrelation, conditional (ARCH) and unconditional heteroscedasticity, Ramsey's RESET test for linearity and omitted variables and test for normality) of the VECM are reported in Table 15. In particular equation (9), the equation for real money balances which is the object of highest interest within the model is well specified, none of the tests being significant. Apart from the wealth equation (11) there appear to be no signs of misspecification in the rest of the model. Given the dynamic properties of the wealth series it is probably not surprising to detect residual autocorrelation and heteroscedasticity in the residuals of the wealth equation. Notice however, that serial correlation can be avoided by increasing the lag length in the $\Delta\Delta whh$ equation up to five (the resulting test statistic is F(5,95) = 1.26 with a p-value of almost 30%).

Figure 17 shows the recursive graphs (a)-(f) of the scaled 1-step ahead residuals

	$\Delta(m-p)$	Δy	$\Delta\Delta whh$	$\Delta\Delta p$	ΔRO	ΔRS
$\Delta(m-p)$	*0.0040*					
Δy	−0.049	*0.004*				
$\Delta\Delta whh$	−0.095	0.055	*0.001*			
$\Delta\Delta p$	−0.47	0.063	0.243	*0.002*		
ΔRO	−0.083	0.081	−0.212	−0.133	*0.001*	
ΔRS	0.118	0.057	−0.198	−0.211	0.823	*0.003*

Table 16: Correlation and standard errors of VECM residuals

for each equation of the VECM. The 1-step and N-step joint "Chow" tests for the VECM in panels (g) and (h) which are scaled by their 1% critical values are in no period significant. The same applies to the 1step and N-step breakpoint tests for each individual equation of (9) - (14) which are shown in the upper and lower panels, respectively, of Figure 18. As mentioned above, these are no formal tests but they give a strong indication for the stability properties of the model as passing them at 1% critical values allows to assume stability at very high confidence levels. Table 16

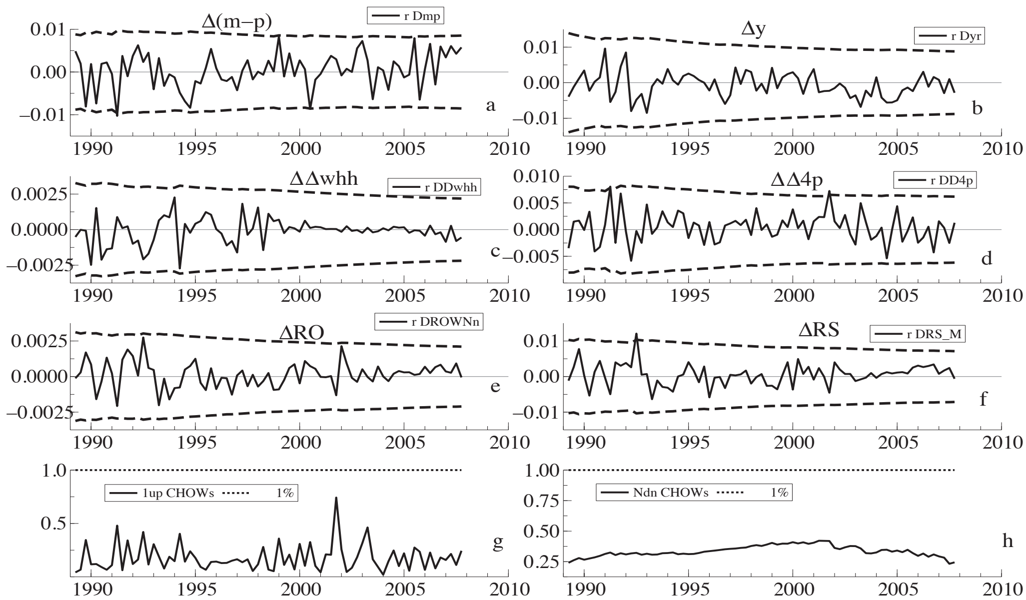


Figure 17: Recursive residuals and "Chow" tests for VECM (9) - (14)

shows the correlation of the model's residuals and their standard errors.

Standard deviations of the equation errors are reported on the diagonal in italics. Notice that, apart from the correlation between $\Delta(m-p)$ and $\Delta\Delta p$ and between the

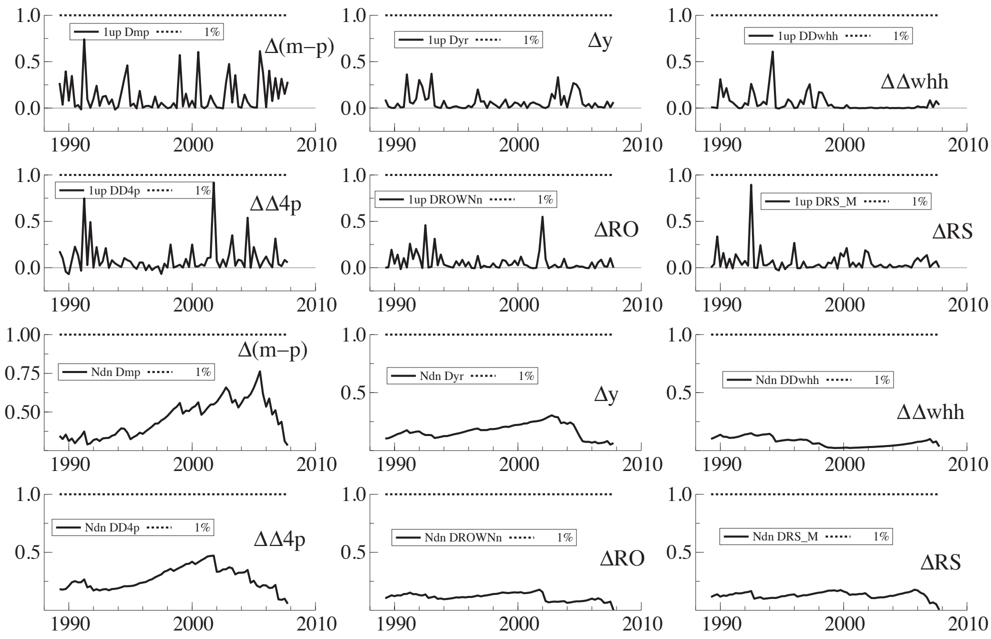


Figure 18: 1-step and N-step breakpoint tests for VECM (9) - (14)

two interest rates, cross equation correlations of the residuals are rather low, many being even close to orthogonality. This allows to some degree for structural economic - albeit not causal - analysis, in which - similar to structural models in which errors are orthogonal by construction - the error terms in the VECM are given an economic meaning. For a quantitative analysis along those lines one would typically calculate impulse-response functions and we will pursue that in a closely related companion paper in which the focus is more on theoretical analysis.

5.3 Economic Interpretation

The VECM (9) - (14) is a closed form model that invites for some economic interpretation in particular with regard to the long-run relation ships that enter the equations. Equation (9) appears to be a plausible money demand equation in which real balances are error-correcting to excess long-run money demand and positively related to excess real wealth growth. The latter is of particular interest as it allows for an interpretation of a wealth effect in money demand. This wealth effect is complemented by a substitution effect. The substitution channel of wealth is embedded in the long-run equilibrium wealth relationship itself. There, real wealth is negatively related to the level of real money balances. The interpretation of the GDP and wealth equations

(10) and (11) is rather straightforward. Real GDP is positively related to excess real money balances and is error-correcting to excess long-run growth of real wealth. Notice that nominal wealth growth is at least weakly exogenous with respect to the parameters of the VECM as none of the other variables enters into (11) neither via cointegration relationships nor via short run dynamics. In fact, estimating the model as an open system without modelling $\Delta\Delta whh$ explicitly leaves the point estimates of the remaining equations virtually unaffected. Also the inflation equation allows for a conventional interpretation: lagged excess real balances enter with a positive sign. This supports the view that excess long-run money demand is preceding an acceleration of the inflation rate. Finally, excess real money balances enter both interest rate equations (13) and (14) whereas excess real wealth growth does enter the short rate equation but not the own rate equation. As already noted for the GDP equation (10), excess wealth is negatively related to GDP growth. Hence, a negative sign of excess wealth growth can be translated as a proxy for positive real GDP growth. Together with the positive sign of excess real money balances which is positively related to inflation, the three month interest rate equation (14) does therefore allow to be interpreted as a type of empirical policy rule. Notice that the finding of weak exogeneity of wealth for the parameters of the VECM is of particular interest with regard to the different channels that are described by Greiber and Setzer (2007) and that we discuss in Section 3. The result that no other variable is entering the wealth equation but that, conversely, wealth is entering *inter alia* money demand is strong evidence against the empirical relevance of both an "asset-inflation-channel" and a "credit channel" where the latter predicts that the degree of more or less restrictive monetary policy would affect movements in housing wealth. In contrast to Greiber and Setzer who "identify strong links from liquidity to the housing sector" we do not find any evidence that excess liquidity stemming from excess money holdings could explain movements in housing wealth. Summing up the economic discussion, the estimated VECM offers modest but nevertheless plausible economic interpretations and the statistical properties of the model that we have discussed so far invite for a deeper structural analysis. This, however, as set out from the beginning, is beyond the scope of this paper. Instead, we turn to another interesting exercise to check the empirical stability of the model. In the next section we examine the implications of the most recent financial and economic crisis with a particular focus on our money demand model.

6 The Impact of the 2007 Financial Crisis

The economic recession that has hit the Euro area during and after the financial crisis saw the biggest decline in real GDP after World War II. Whereas real GDP growth was still positive in the first quarter of 2008 it is estimated to have shrunk in the fourth quarter at an annual rate of five percent or even more. Also the decline in wealth, measured by various indicators, is expected to be dramatic. Figure 19 shows the extended time series at quarterly growth rates. What impact has the financial

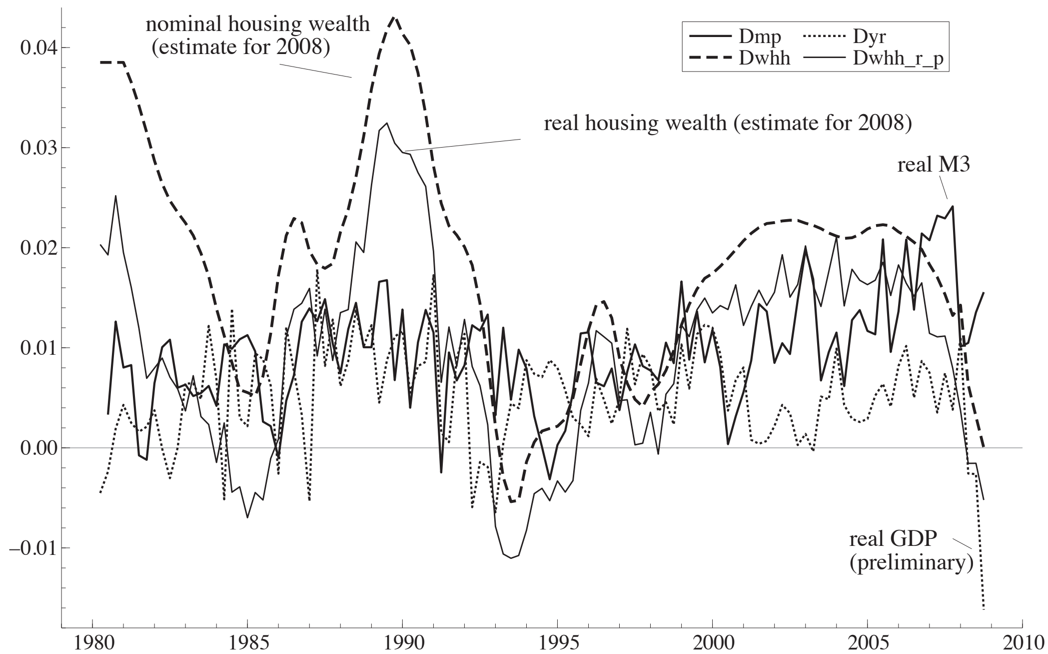


Figure 19: Growth rates (quarterly) for Money, GDP and Wealth

and economic crisis on the properties of our model, and, in particular, on money demand? We use preliminary data for GDP and a preliminary estimate for housing wealth data (based on an estimate of the annual figure for 2008) to check if and how empirical stability of the model might be affected.

6.1 The VECM During The Crisis

6.1.1 Re-estimation

First, when re-estimating the cointegrating vectors over the extended sample the point estimates do not change significantly. For example, the point estimate of income elasticity of long run real money demand is 1.65, compared to 1.70 for the original sample. The asymptotic tests for the eigenvalue stability tests yield p-values of 5 % for the first eigenvalue; 43% for the second eigenvalue; and 5% for stability of the sum of both. Regarding the stability of β the asymptotic Nyblom p-values for unrestricted β dropped from 98% to 20% for the Sup_Q and from 84% to 3% for the Mean_Q test. However, bootstrapped p-values are still at 77% and 74%, respectively. Hence, the drastic changes in particular in GDP and wealth had a certain statistical impact on the cointegrating vectors. However, the test results suggest that they can still be considered as empirically stable. Next, we use the same parameterization of β and re-estimate VECM (9) - (14) over the extended sample until 2008Q4. The estimated coefficients, even of the short run dynamics, remain virtually unchanged, the only exception being the wealth equation, in which the second lag has become insignificant. The point estimate for $\Delta\Delta whh_{t-1}$ is now 0.8 which nevertheless corresponds to the same long-run dynamics as in the original sample with two lags. The test for overidentifying restrictions is not rejected, yielding a $\chi^2(60) = 66.72$ with an asymptotic p-value of 26%. Alternatively, re-estimating the two cointegrating relationships over the extended sample and estimating the VECM with those modified β yields an even higher p-value of nearly 30% ($\chi^2(60) = 65.56$). Hence, the overall structure of the model has remained remarkably stable.

6.1.2 The Dynamic Long-run Properties

The comparative magnitude of the drop in GDP and wealth growth in the first quarter of 2008 can be gauged from the graphs Figure 20 which show actual observations and dynamic simulations of the VECM (9) - (14) over the whole sample for all six endogenous variables, starting from the first observation of the sample. Notice the huge and unprecedented drop of the GDP growth rate compared to its steady state value in 2008Q1!

The dynamic simulations deliver also a plausibility check for theory consistency of the empirical model. Given that all variables are at least in first differences one would expect that the simulations converge to constant long-run steady state growth rates of the endogenous variables. This is indeed the case: real money balances and real GDP converge to constant growth rates of around 4.4% and 2.6% (per annum) whereas growth of interest rates and growth of inflation and changes in wealth converge to zero. Zero growth, i.e. a constant steady state inflation rate implies obviously a constant steady state growth rate for nominal balances. It is worth noting that the dynamic implications of our model - in particular those for money balances - differ from those by De Santis *et al* (2008): as can be seen from their Figure 13, the DFR money demand model implies a non-constant and increasing simulated steady state

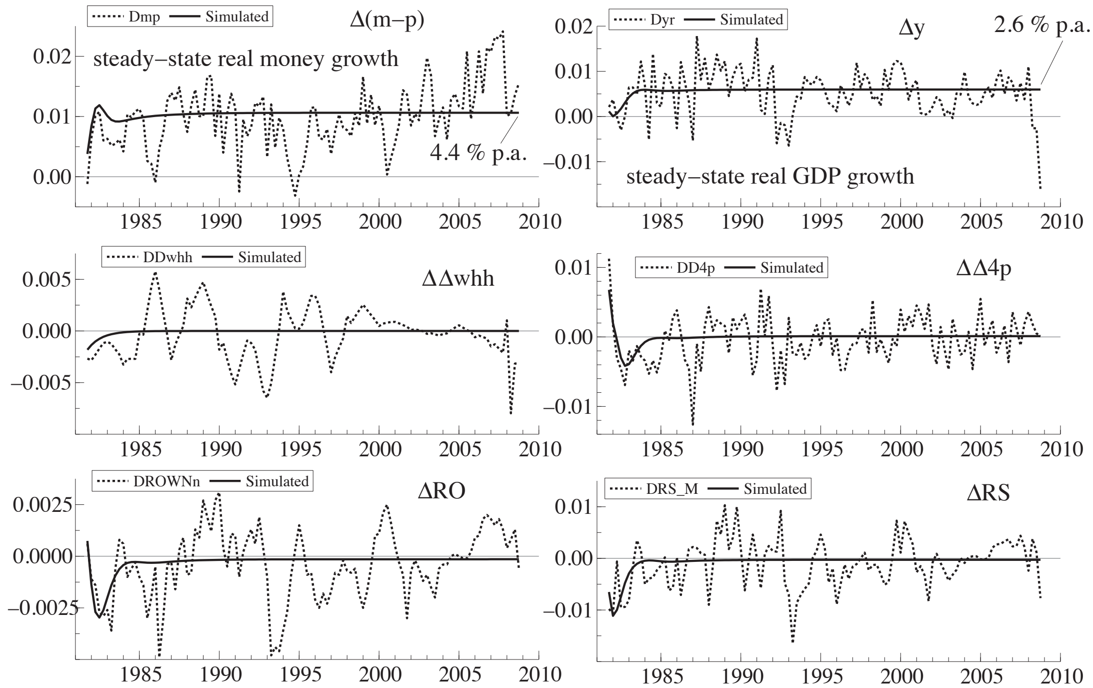


Figure 20: VECM: actual and simulated long-run steady state values

growth rate of (nominal) money.

6.1.3 Parameter Constancy and Structural Breaks

Likewise as in Figure 17 the panels (a) - (f) in Figure 21 show the the recursive graphs of the scaled 1-step residuals and both types of Chow tests (g) and (h) for the entire VECM.

Residuals for real balances (a), inflation (d) and the two interest rates (e) and (f) remain well behaved within their two standard error bounds. However, the residuals for GDP and wealth become dramatically significant after 2008Q1, with error bands in 2008 even widening at the end of the sample! This is also reflected in the graphs for the Chow tests (g) and (h) for the entire VECM. They are clearly significant, signalling a huge structural break around 2008Q1. The significance of these test statistics is clearly dominated by the breaks in the equations for GDP and wealth, as can be seen from the Chow test statistics presented in Figures 22 and 23. For both, Δy and $\Delta\Delta whh$ equations both tests are highly significant after 2008Q1 whereas test statistics for the other equations of the VECM remain insignificant.

To sum up, given the order of magnitude of the drop in real GDP growth and

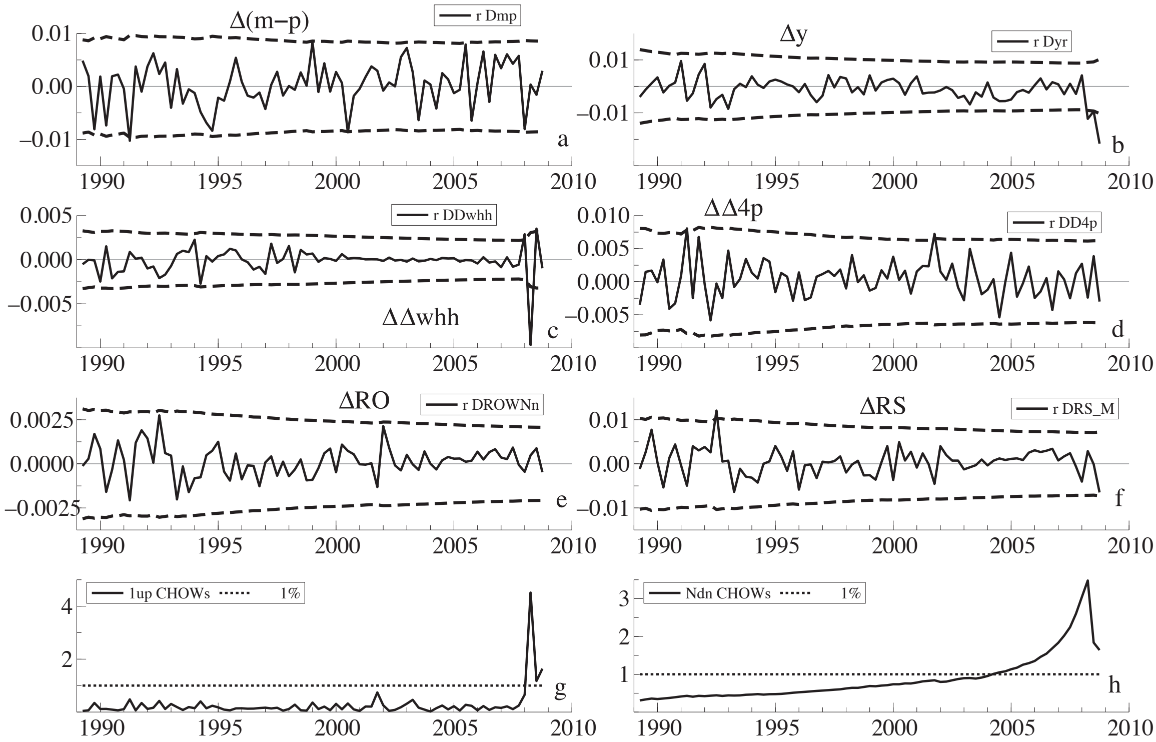


Figure 21: Recursive residuals and "Chow" tests for VECM (9) - (14) estimated until 2008Q4

wealth after the financial and economic crisis instability of the Δy and $\Delta\Delta whh$ equations is not a surprise. It is remarkable, however, that empirical stability of the cointegrating relationships and of the other equations within the VECM - including that of money demand - are not affected by those breaks even though they contain those variables as regressors. For wealth there is clear evidence of super-exogeneity (see Engle, Hendry and Richard, 1983) with respect to the parameters of money demand The statistical role of the wealth variable for stability of money demand seems therefore to be crucial. In the next subsection, we will examine the robustness of money demand after the breaks in wealth and GDP in more detail.

6.2 Single Equation Money Demand

As a last robustness exercise, let us finally focus on the single equation for real money balances which is embedded in the VECM specification. In addition to the original cointegrating vectors we estimate the $\Delta(m-p)$ equation (9) with updated β until

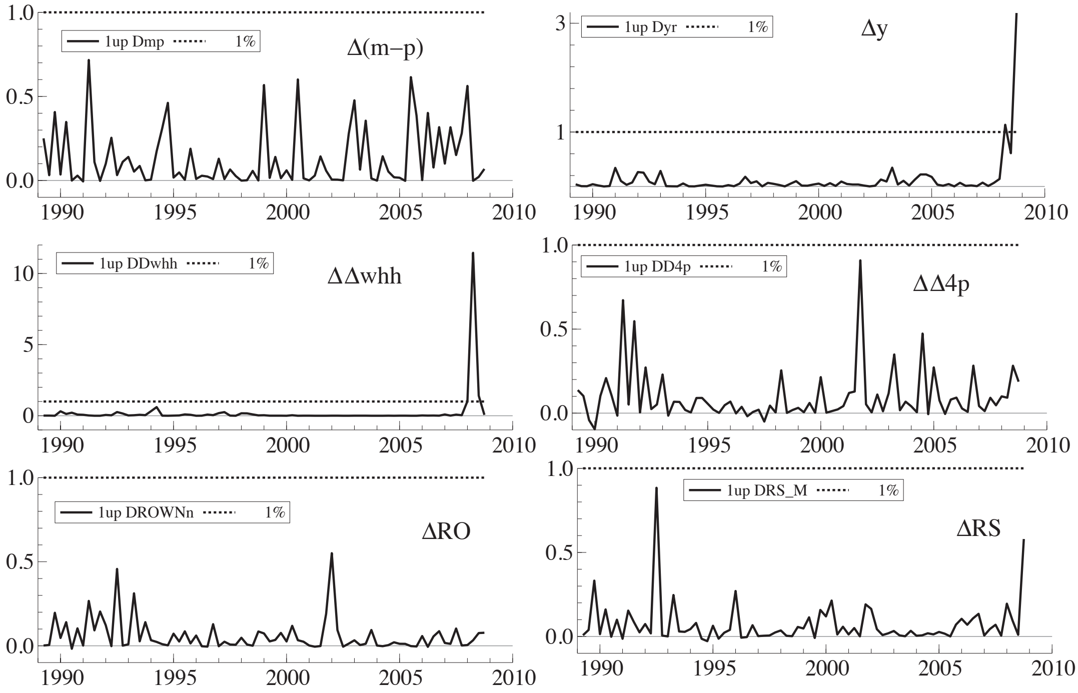


Figure 22: 1-step ahead "Chow " tests for individual equations of the VECM

2008Q4. As can be seen from the results presented in Table 17 the differences of the point estimates are only marginal.

The same applies for the misspecification tests in Table 18. For both estimates the model is well specified as none of the tests is significant with p-values being at high confidence levels.

Figure 24 shows the recursive estimates of the coefficients of the money demand equation, here with original β "frozen" until 2008Q4. The coefficients of the money demand model are stable over the entire sample and, as it is also evident from the Chow tests in the two bottom panels, there are no signs of structural breaks, neither at times when CGL and other models broke down, nor during the episode of the current financial crisis.

The graphs of actual and fitted values of the money demand model in Figure 25 reveal the ability of the model to trace changes in real balances rather well. Of particular interest is the behavior of the model during the selected episodes (I-V) that are marked in Figure 25.

For exposition we have chosen five characteristic periods in time. Episodes I-III are characterized by the period were conventional money demand models failed and

Regressor	original β	β re-estimated
$const$	0.017 (0.003)	0.005 (0.001)
$\Delta(m-p)_{t-1}$	0.408 (0.094)	0.385 (0.094)
Δy_{t-2}	0.193 (0.097)	0.176 (0.096)
ΔRS_{t-2}	-0.350 (0.102)	-0.337 (0.101)
$\{(m-p)-(m-p)^*\}_{t-1}$	-0.049 (0.018)	-0.035 (0.015)
$(\Delta whh - \Delta whh^*)_{t-1}$	0.312 (0.072)	0.257 (0.063)
R^2	0.47	0.47
σ	0.004	0.004
log likelihood	448	447.7

Table 17: Money Demand Equation: β original and updated

	$AR\ (1-5)$	$Normality$	$ARCH\ 4$	$HeteroX_i^2$
original β	1.04[0.40]	2.10[0.35]	0.62[0.64]	1.33[0.18]
β re-estimated	1.10[0.36]	2.44[0.30]	0.67[0.61]	1.16[0.30]
Distribution	$F(5,98)$	$\chi^2(2)$	$F(4,95)$	$F(20,82)$

Table 18: Misspecification tests for money demand equation

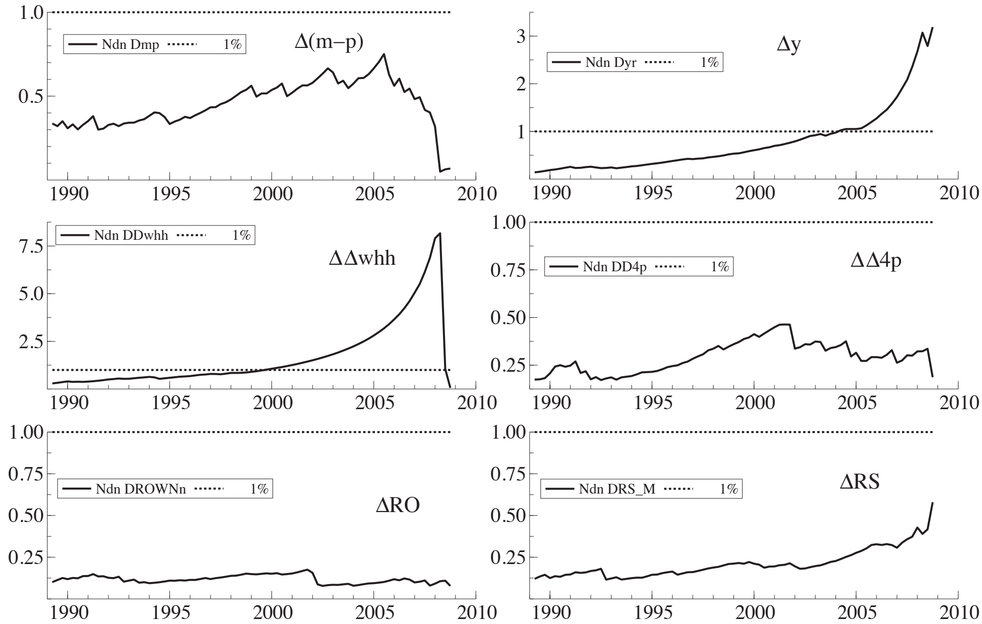


Figure 23: N-step ahead ahead "Chow " tests for individual equations of the VECM

efforts were undertaken to re-establish stability. For example a new aggregate for M3 was constructed that took into account specific portfolio shifts, see Fischer *et al* (2008) for details. During period IV, M3 growth rates were considered being "excessive" with respect to various benchmark statistics. The topic of "excessive global liquidity" gave rise to serious concerns as figures for nominal M3 growth reached unprecedented magnitudes of almost 13% p.a. As Beyer *et al* (2007) point out, for policymakers that base decisions *inter alia* on predictions stemming from money demand models an issue in real time arises when these models produce large residuals: Should these residuals be interpreted as extraordinary large money demand shocks - e.g. due to excess liquidity - or do they signal a permanent structural break in the money demand relationship? The dynamics of the residuals during Period V show that the money demand model presented in this paper is actually able to explain rather well the drop in real money balances that was observed at the beginning of 2008 - precisely when its explanatory variables GDP and wealth faced huge and unprecedented negative shocks. This suggests that our money demand model is indeed stable. Therefore, the model might be suited to providing meaningful benchmarks for measures of excess money and we present two alternative versions in Figure 26. Similar as in Figure 5 excess money could be derived from a partial equilibrium, i.e. the money demand relationship in isolation. Together with the second cointegrating

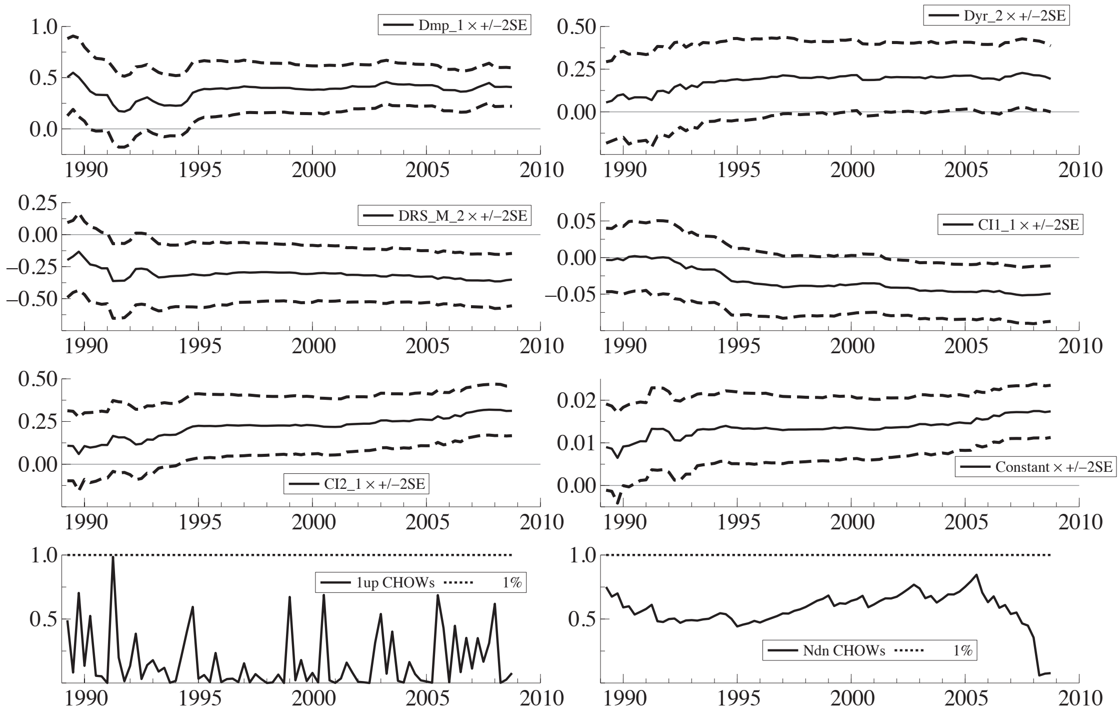


Figure 24: Recursive estimates money demand equation

vector which represents a measure for excess real wealth, this is shown in the upper panel. The lower panel shows the implied linear combination of both cointegrating vectors which is a more persistent measure of excess liquidity. Summing up, the money demand model we presented here has proven to be highly robust in particular when confronted with data from the recent financial crisis. It therefore appears to be well suited to accommodate the three functions of money demand models described in Section 2 above: providing complementary information; distinguishing short run versus long run dynamics; and creating a benchmark for liquidity.

7 Conclusions

In this paper we have estimated an empirically stable money demand system for the Euro area. We have demonstrated that housing wealth is a key variable for capturing important movements in money demand and velocity of M3. We found strong evidence that housing wealth is better suited as wealth aggregate compared with financial and total wealth. Adding housing wealth to a system of cointegrated variables

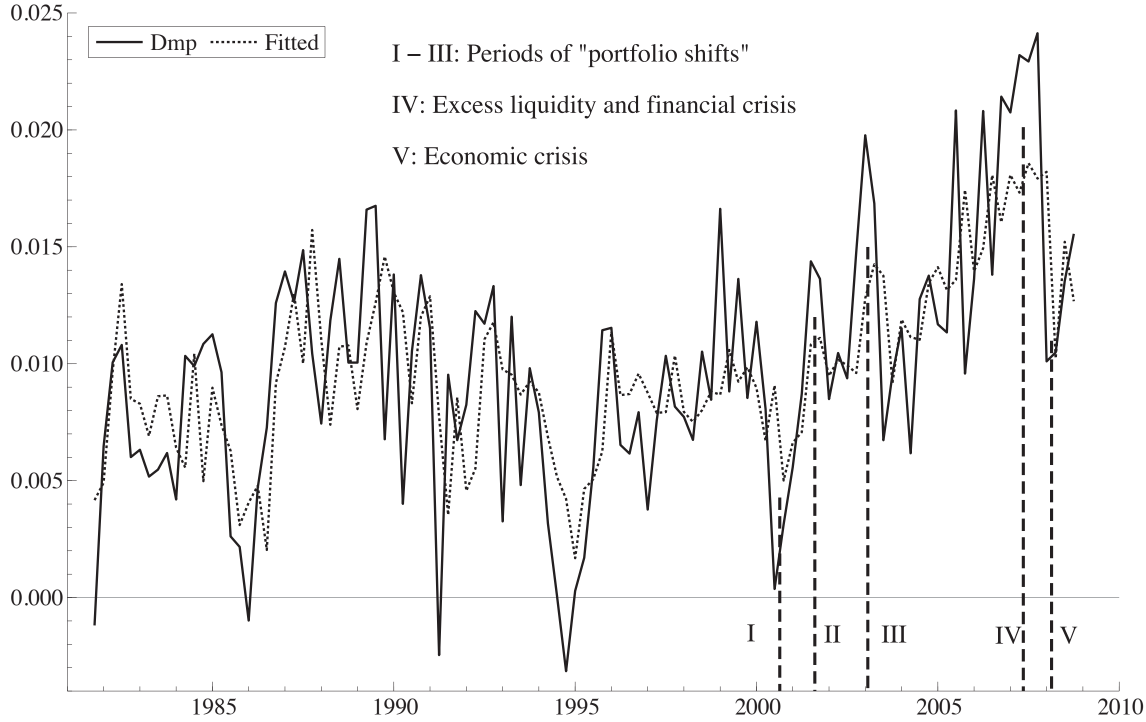


Figure 25: Actual and fitted values of money demand model

that contains M3, GDP, prices and interest rates, helps re-establishing a remarkably stable long-run money demand model. Empirically stable long-run equilibrium relationships for excess real balances and wealth disequilibria feed into the equations of a small-scale macro model which we developed after mapping a cointegrated VAR into a VECM. Within that model portfolio and wealth effects determine the growth of real money balances in opposite directions. Excess money holdings feed with positive sign into the inflation equation. Housing wealth is not explained either by excess money holdings or by any other variable within the system. That is evidence against a direct and even indirect channel from monetary policy to movements in housing wealth, i.e. against so-called asset-inflation and credit channels. Using preliminary data for 2008 we have shown that the latest financial and economic crisis did not have a significant impact on the empirical stability of our money demand model. The model is able to trace the latest movements in the data for money remarkably well and offers therefore a benchmark for (excess-) liquidity, based on its empirically stable long-run equilibrium relationships. The model developed in this paper is essentially a non-structural model and the degree of economic theory that is underlying is rather limited. That

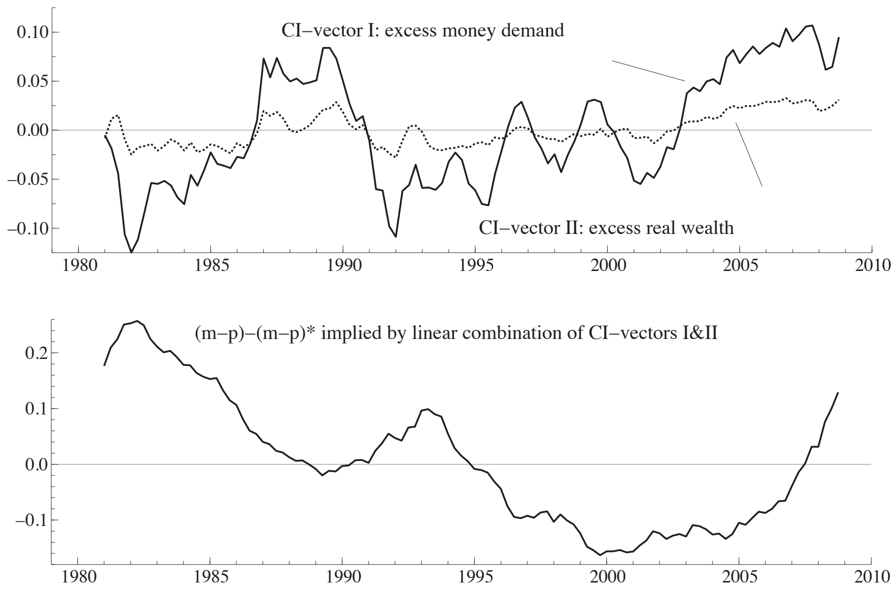


Figure 26: Measures for "excess money "

clearly limits the scope of this model for policy analyses and economic interpretation even though the model has economically plausible simulation dynamics for the long-run. Based on the empirical findings presented in this paper the next natural step would be to develop a more theoretical model that is consistent with the empirical "facts" but which might allow to distinguish empirically the different wealth channels of money and which would provide a theory-consistent analytical framework for gauging qualitative and quantitative relevance of these different wealth channels with respect to the conduct of monetary policy. We keep this on the agenda for future research.

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