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Modelling short-run money demand for the US

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Nowadays, modeling long-term money demand is largely unambiguous. There is a vast amount of empirical evidence concerning a cointegrating relationship between money demand, some kind of interest rate and income (see e.g. Hofman and Rasche, 1991, or Stock and Watson, 1993). In contrast to this, short-run dynamics are still opaque. In the existing literature, the return to steady state is modeled quite differently. Simple error correction models have failed in some cases to explain short-run dynamics adequately. Partial-adjustment models - as used by Goldfeld (1973) or Ball (2002) - allow for a smooth return to equilibrium as costs for adjusting real money balances lead to a sticky behavior of actual money. Other authors like Teräsvirta and Eliasson (2001), Escribano (2004) or Chen and Wu (2005) model the return to steady state in a non-linear error correction form, instead.

All these models consider disequilibria by the gap between money demand and its steady state of only the last period, disregarding disequilibria in periods before. Ignoring deviations from steady state occurred further in the past miss to account for money stockpiling activities of economic agents. Positive deviations from steady state of past periods can be accrued and used for transaction or saving purposes in the current period without making necessary to balance the deviation of the most recent past.

Granger and Lee (1989) presented a model where past deviations from steady state are summed up with equal weights till the starting period of the time series. The new series emerging from this accumulation form a further cointegrating relationship called multicointegration. Instead, I use a model where weights for cumulating are geometrically decreasing the more they are located in the past. According to Koyck (1954) such models possess an ARMA (1,1) representation. The combination of the Koyck-model with the error correction approach leads to an ARMAX model which is shown to be capable in some cases to track money demand short-run dynamics better and more parsimony than partial-adjustment models.

JEL classification: E41, C22

Key words: Short-run money demand, cumulative error-correction model

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1. Introduction

Nowadays, modeling long-term money demand is largely unambiguous. There is a vast amount of empirical evidence concerning the existence of a cointegrating relationship between real money demand, some kind of interest rate and income. Examples for the US are Hoffman and Rasche (1991) or Stock and Watson (1993), for the UK Ericsson, Hendry and Prestwich (1998) and Täresvirta and Eliasson (2001) or for the euro area Calza and Zaghini (2006) or Dreger and Wolters (2010).

In contrast to this, short-run dynamics are still opaque. Theoretically, the existence of portfolio adjustment costs is frequently used to explain the sluggish return to steady state. In this case the money amount held by the economic agent acts as a "buffer stock" (Laidler, 1984) for smoothing the differences between income and expenditure streams. In the empirical literature, there exist many different approaches to model the inertia of the adjustment process back to the long-run relation. Goldfeld (1973) applied a so called partial-adjustment model by including a lagged dependent variable to model inertia of return. With the upcoming popularity of error correction models, Baba, Hendy and Starr (1992) and Duca (2000) are prominent examples of attempts to model short-run dynamics in money demand. As in several cases simple error correction models could not report satisfying statistical results, some authors applied non-linear versions. Hendry and Ericsson (1991) and Escribano (2004) tested a cubic polynomial error correction model. Examples for regime dependent adjustment dynamics are Lütkepohl, Täresvirta and Wolters (1999) or Täresvirta and Eliasson (2001).

The reason for the large amount of different approaches for modeling the return to steady-state could lie in the way the disequilibrium - which has to be balanced by economic agents - is not defined correctly. All these models consider disequilibrium to be balanced by short-run dynamics as the gap between money demand and its steady state of only the last period, disregarding disequilibria in periods before. But there seems to be no convincing argument why anybody should balance only the disequilibrium of the most recent past period. This goes especially for cases with higher frequent data (like daily, weekly, monthly or quarterly data). Ignoring deviations from steady state occurred further in the past miss to account for money stockpiling activities of economic agents. Positive deviations from steady state of past periods can be accrued and used for transaction or saving purposes in the current period without making it necessary to balance the deviation of the most recent past.

Here a model is presented which cares not just for the most recent deviation from the long-run relation in the short-run adjustment process but also for such disequilibria happend in the past. With this type of model no assumptions concerning sluggish adjustment due to adjustment costs are necessary. Only the fact that deviations from steady state located further in the past than in the most recent period can count, too. The outline of the paper is as follows. Section 2 presents the so-called cumulative error correction model. In Section 3 this model is applied to the dataset as used by Ball (2002) where the same long-run relationship is used and just short-run dynamics are compared. Section 4 concludes.

2. A cumulative error correction model

The idea of accounting also for disequilibria further in the past than in the most recent period within the framework of error correction models is not new. Granger and Lee (1989) presented a model where all past deviations from steady state are summed up with equal weights till the starting period of the time series. In their example the mismatch between production and sales ant any lag leads to stock piling of inventories. The application of a standard ECM would result in a misspecification error[1], in this case. Apart from the cointegrating relationship between the flows (first-level cointegration) there may be another coming from stock levels which the authors called second-level cointegration. This new series emerging from the accumulation of past disequilibria form a further cointegrating relationship called multicointegration. Whereas usually the number of cointegrating relationships among n variables is at most n–1, it can be n as well within this framework. A drawback of this approach is that the second-level cointegrating relationship contains I(2) variables constructed by the summation of flow variables which are usually I(1) what complicates the estimation process.

Suppose that y_t and x_t are both I(1) and are cointegrated CI(1,1) so that

$$z_t = y_t - \phi x_t \tag{1}$$

is I(0). (1) forms the so-called first-level cointegration relationship. Granger and Lee (1989) propose to sum up all past deviations from steady state with the same weight 1 to a new stock variable $s_t = \Sigma z_t$. If now s_t cointegrates with either Σx_t or Σy_t we get another cointegration relationship (called second-level cointegration) so that $s_t - \kappa y_t$ forms again a stationary relationship

$$s_t - \kappa y_t = \sum_{j=1}^{t} y_t - \phi \sum_{j=1}^{t} x_t - \kappa y_t \tag{2}$$

with s_t being I(1) and Σy_t and Σx_t being I(2) as both are summed I(1) variables.[2] Granger and Lee (1989) solved the estimation problem by a two step method as typically used for CI(1,1) variables. In a first step they estimated the first-level cointegration relation. The residuals representing deviations from steady state were summed up and in a second stage they were regressed on the cumulated variables (summed y_t) for estimating the second order cointegrating relationship.

However, Engsted et al. (1997) have shown that in case of a two step method the first cointegrating relationship (of flows) must not be estimated. Otherwise the test statistics of the

[1] See for this Engsted and Johansen (1997) or Lee (1992)

2 In the case of multicointegration the corresponding ECM considers adjustment mechanisms for the stock as well as the flow variables with $\Delta x_t = c + \alpha_1 (s_{t-1} - \kappa y_{t-1}) + \alpha_2 \xi_{t-1} + lagged(\Delta x_t, \Delta y_t) + u_t$

second one will have a different limiting distribution compared to normal settings. Furthermore, for I(2) based models usual asymptotic χ^2 inference is invalid and Johansen (2006) pointed out that it can be used only if a multicointegration relation is assumed with properties hardly met in reality.

The model presented here instead, uses weights for cumulation which are geometrically decreasing the more the disequilibria are located in the past. According to Koyck (1954) such models possess an ARMA (1,1) representation. The combination of the Koyck-model with the error correction approach leads to an ARMAX model which is shown to be capable in some cases to track money demand short-run dynamics better and more parsimony than partial –adjustment models. Probably, adjustment structures modeled by non-linear ECM can be explained better by this model type.

This model has recently been put forward by Scheiblecker (2012) for the empirical application of modeling private consumption in the US.

The typical ECM

$$\Delta y_t = \alpha \xi_{t-1} + \gamma \Delta x_t + c + u_t \tag{3}$$

with y_t and x_t being observed flow variables, c a scaling factor, u_t an iid error term and $\xi_{t-1} = y_{t-1} - y^*_{t-1}$ which measures the distance between the steady state y^* and the time series y one period ago. As usually, the EC parameter ($0>\alpha>-1$) partly settles deviations occurred at time t–1 in t.

Based on considerations that deviations located further in the past than t-1 could influence current balancing activities, a transformation of (3) in

$$\Delta y_t = \beta \sum_{i=0}^{\infty} \lambda^i \xi_{t-1-i} + \gamma \Delta x_t + c + u_t \tag{4}$$

with the weight $\lambda <1$, is proposed.

Koyck (1954) was first putting forward the transformation of an ADL model of the type

$$F_t = c + \delta \sum_{j=0}^{\infty} \lambda^j S_{t-j} + \varepsilon_t \tag{5}$$

into an ARMAX(1,1) model

$$F_t = (1-\lambda)c + \delta \lambda^0 S_{t-0} + \lambda F_{t-1} + \varepsilon_t - \lambda \varepsilon_{t-1} \tag{6}$$

where λF_{t-1} represents the autoregressive [AR] part, $-\lambda \varepsilon_{t-1}$ the moving average [MA] part and S_t the exogenous regressor, which is therefore called the Koyck model. The summing weights λ (called the retention rate) are defined over $0 \leq \lambda \leq 1$ so as their size is decreasing geometrically giving less weight to more distant observations.

If we replace S_{t-i} in equation (5) and (6) for ξ_{t-i-1} (so that $S_t = \xi_{t-1}$) F_t corresponds to the right hand side of equation (4)[3]. So (4) can be transformed into

$$\Delta y_t = (1-\lambda)c + \beta\xi_{t-1} + \lambda\Delta y_{t-1} + \gamma\Delta x_t - \lambda\varepsilon_{t-1} + \varepsilon_t \qquad (7)$$

which is the ARMAX representation of our cumulative ECM given in (5). It is immediately clear that as long as λ <1 all terms on either side of the equation are I(0) and hence the usual test statistics can be applied in order to determine the cointegrating relationship.

This approach is also very parsimony as just one parameter more (the retention parameter λ) than in the conventional ECM has to be estimated. It is further noticeable that if the parameter δ in (6) is zero (i. e. no cointegration exists between the two series) then the retention parameter λ can not be retrieved from the model. On the other side, if λ is zero the conventional ECM results and if it is 1 the multicointegration method with equal weights as proposed by Granger and Lee (1989) emerges.[4]

This time series representation of an ECM reconciles somewhat the blame of ARIMA models – as introduced by Box and Jenkins (1970) – for their lack of theoretic content. At least this form seems to be based on economic theory as good as the conventional ECMs and the multicointegration method, as the retention rate λ is located between both approaches. Equation (7) is an ARMAX model type which includes implicitly I(1) variables in levels – as represented by their I(0) deviations from steady state – as well as an AR and an MA term. The only difference to a typical ARMAX model is that (8) demands the AR parameter to equal the MA one with different signs and that both terms are restricted to be of order one.

Scheiblecker (2012) has shown that this type of model has interesting features concerning its stability, defined as the situation where a time series is only driven by its exogenous short term variables (Δxt) and the error term (εt). For the conventional ECM this is the case if the error of the past period was zero. For the cumulated ECM it is the case if the weighted sum of disequilibria of the past is zero. Such a situation can even be reached away from steady state, at least for a short time.

3. Modeling US short-run money demand

Ericsson, Hendry and Prestwich (1998) emphasized the notion that one of the reasons for what money is demanded is to act as an inventory in order to smooth differences between income and expenditure streams. If this is true, it makes sense to care not just for the inventory of money emerged from the disequilibrium of the most recent past but also for those happened before. For this reason, a cumulated ECM (cumECM) makes sense and is applied to model the short run money demand for the US.

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[3] Disregarding for a moment the regressor Δx_t.

[4] In this case the specification of the model is not exactly correct because the second-level cointegrating relationship is not considered explicitly here.

As given in the introduction, modeling short-run movements around the long-run path of money demand is not straight forward. Many economists tried to model this relation by very different models. As the intention of this paper is not to challenge the existence or structure of possible long-run relationships but just to concentrate on short-run dynamics, I use the same data set as well as the same steady state parameters as published by Ball (2002).

Ball (2002) used a quarterly data set covering the period between 1960 and 1993. Instead of using the Treasury Bill rate or a commercial paper rate as a proxy for short-term market interest rate, the author constructed an average return rate of "near monies". The interest rate for "near money" should better reflect the opportunity cost of holding money than other short-term interest rates. It includes interest rates for all non-M1 components of M2, except time deposits. This synthetic interest rate represents a weighted average of interest rates for saving accounts with zero maturity, retail money market mutual funds and money market deposit accounts. These opportunity costs are necessary to explain the sluggish adjustment in partial-adjustment models. Here the same interest rate is used but the inertia does not stem from opportunity costs of adjustment but from stock piling of past periods.

Based on this, Ball (2002) estimated for the US a semi-logarithmic long run money demand function of the form

$$m - p = \alpha + \theta_y y + \theta_R R + \varepsilon \qquad (8)$$

where price homogeneity is assumed to be valid in the long-run. m represents the logarithm of M1, p the logarithm of the GDP deflator, y the log of real US-GDP, R is the interest rate of "near money" and ε the error term showing deviations from steady state. Ball (2002) estimated the cointegrating relationship by Dynamic OLS as introduced by Stock and Watson (1993) getting a long-run income elasticity θ_y of 0.47 and an interest rate semi-elasticity θ_R of -0.082.

For modeling short-run dynamics around the steady state, the author used a partial adjustment model where desired money holdings deviate from its steady state value (m^*) and can be represented by $m^*+\eta$ with η being a shock which is assumed to follow an AR(2) process. The reasoning behind this is that adjustment of money stock is costly and therefore takes place only gradually towards the desired equilibrium.

Ball (2002) has furthermore shown that his approach possesses an ECM representation of the form

$$\begin{aligned}\Delta m = {} & k(1-\rho_1-\rho_2) + \mu(1-\rho_1-\rho_2)(m*_{-1} - m_{-1}) \\ & + (\rho_1 - \mu\rho_1 - \mu\rho_2)\Delta m_{-1} + (1-\mu)\rho_2 \Delta m_{-2} \\ & + \mu \Delta m * + \mu\rho_2 \Delta m *_{-1} + \mu\upsilon \end{aligned} \qquad (9)$$

with restrictions to the used parameters as compared to a conventional ECM. In this formula k is a scaling parameter, μ the speed of adjustment of money holdings, ρ_1 and ρ_2 the two parameters of the AR(2) process determining the development of η over time and υ an iid error term. (m^*_{-1} - m_{-1}) is the traditional EC-term which only considers the deviation from steady state in the most recent past (period t-1). This ECM is supplemented with an AR(2) process in order to capture residual auto-correlation stemming from sluggish adjustment.

Due to the fact that an MA(1) process possesses an AR(∞) representation, the cumECM nests also the partial adjustment model as there lags of any auto-regressive order are considered. In order to quantify (9) six parameters have to be estimated to model short-run dynamics of this form.

The cumulative ECM used here for estimating short-term movements of US money demand is

$$\Delta m_t = (1-\lambda)c + \beta\xi_{t-1} + \lambda_{AR}\Delta m_{t-1} - \lambda_{MA}\varepsilon_{t-1} + \gamma_y \Delta Y_t + \gamma_R \Delta R_t + \varepsilon_t \qquad (10)$$

with m_t being the log of real M1, $(1-\lambda)c$ a constant scaling parameter, ξ_{t-1} the deviation of real M1 from its steady state as estimated by Ball (2002), Y the log of real GDP and R the interest of near money.

According to this approach, five parameters have to be estimated: the constant (if necessary at all), the EC parameter β, the retention rate λ and the income elasticity γ_Y and the interest semi-elasticity γ_R. It has to be noticed that the retention rate appears twice in (10). Once as an AR-parameter (λ_{AR}) and the second time with the same value but with a different sign as the MA-parameter ($-\lambda_{MA}$).

In practice, for estimation there are two possibilities. Either to restrict the parameters to be equal with different signs ($\lambda_{AR} = -\lambda_{MA}$) or to estimate them independently. The first approach has the advantage that one parameter can be saved but at a cost of a more complicated estimation procedure. Fransens and van Oest (2007) have shown that such a restriction requires maximum likelihood estimation and errors are non-normally distributed because of the so-called Davies (1987) problem. They propose several alternative test statistics of which here the average absolute t-statistics has been chosen in order to test the significance of the estimated parameters.

Contrary to this, estimating both parameters independently allows to test whether they have the same value apart from the sign and hence the appropriateness of assuming geometrically decreasing weights. Here, both approaches are followed and the results are given in Table 1.

Table 1: Reults of cumulative ECM

	Unrestricted	Restricted[5]
ß	-0.024 ***	-0.016 ***
λ_{AR}	0.701 ***	0.701 ***
λ_{MA}	-0.431 ***	-0.701 ***
γ_y	0.167 ***	0.165 ***
γ_R	-0.018 ***	-0.019 ***

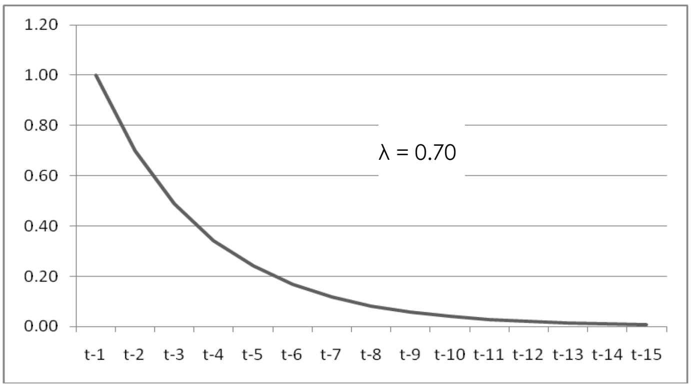
*** = significant at a 1% confidence level

[5] Critical values for testing ß=0 are taken from Fransens and van Oest (2007) Table 2 page 294. For a sample size of 1000 the critical value of a 95% confidence level is 1.80.

All estimated parameters have been found to be highly significant. Furthermore in none of the approaches the outlier in 1980q3 - as found by Ball (2002) - turned out to be significant. The EC parameter β is somewhat higher with -0.024 in the unrestricted case than in the restricted (-0.016). From (9) one can derive Balls EC-parameter of t-1 which gives 0.05 and is higher than in the cumECM case. The short-term income elasticity and the interest semi-elasticity are practically the same in both approaches. According to them, a one percent rise in income leads in the US to a higher demand for real M1 of around 0.167 percent. A one percentage point higher interest rate for near monies leads to a reduction of real M1 of 0.018 percent.

In the unrestricted approach the AR parameter λ_{AR} and the MA parameter λ_{MA} are quite differently, apart from their sign. Unfortunately, the 5% confidence intervals did not overlap so the Wald-test for testing the equality of parameters failed. This inconsistency hints to a retention rate which is not decreasing according to a geometric pattern but some other kind e. g. triangular. Interestingly the restricted model supports a retention rate of the same magnitude like the unrestricted AR parameter. Usually, in this case the restricted form gives a parameter located somewhere in the middle between the unrestricted AR and MA parameter (see e. g. Scheiblecker, 2012). Nevertheless, the restricted retention rate turned out to be highly significant. Figure 1 shows the decrease of the weights over time given to past deviations from steady state with a retention rate of 0.70.

Figure 1: Retention rate



In the first period t-1 the retention rate λ is one (λ^0) so that the attraction toward steady state is fully determined by the EC parameter β like in conventional ECMs. In the period before (t-2), the retention rate reduces the weight of the EC parameter by the factor 0.7 and so on. In the current period deviations from steady state happened 8 quarters in the past still have a weight of around 0.10. After 14 quarters the effect has completely faded out and disequilibria before this do not influence short-term movements in the current period.

The Jarque-Bera statistics concerning the residuals of the restricted and the unrestricted model gave a value of 1.281 (probability: 0.527%) or 0.730 (probability: 0.694%), respectively. So their normality in distribution could not be rejected by far. Furthermore, no auto-correlation in the residuals was found.

It is difficult to compare the results with those of Ball (2002) as different parameters have been estimated there. Furthermore, the author did not report many test statistics apart from those concerning the single parameters. In order to compare the quality of the models I use several information criteria as suggested in the literature for discrimination between alternative models. As no values for such criteria are given in Ball (2002) his model had to be re-estimated for calculating three information criteria: the Akaike information criteria, the Schwarz criterion and the Hannan-Quinn criterion. Table 2 gives the results for them.

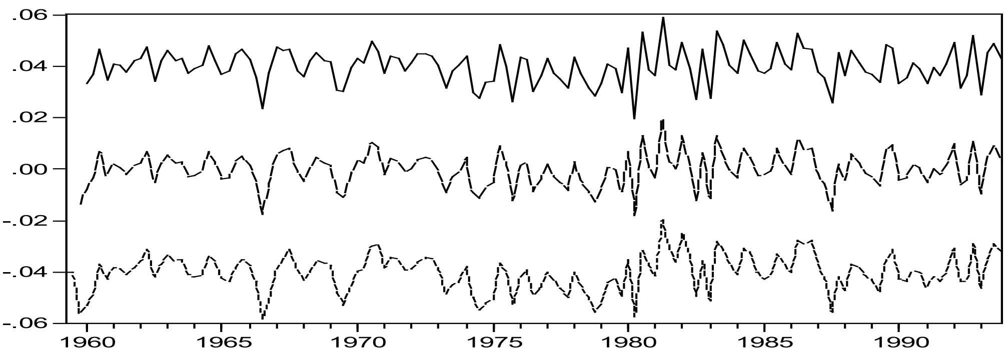
Table 2: Information criteria

	partial adjustment model	cumECM unrestricted	CumECM restricted
Akaike	-7.089652	-7.100734	-6.260050
Schwarz	-6.939736	-6.972852	-6.153482
Hannan-Quinn	-7.028730	-7.048766	-6.216744

As for the unrestricted cumulative ECM all three criteria show lower values than for the partial adjustment model it should be the preferred one. However, the restricted version could not outperform the partial adjustment model as all its values are higher.

Above, it has been shown that the ECM nests the multi-cointegration model, the conventional ECM and the partial adjustment model, too. As the partial adjustment model of Ball (2002) includes an AR(2) process and the cumECM with its ARMA(1,1) process auto-regressive elements of any lag order, it is not astonishing that both models show similar residuals. The partial adjustment model of Ball (2002) cuts-off influences from deviations from steady state located more than three periods in the past. The cumECM instead does not, but especially for low retention rates the weights for those lags are decreasing swiftly. Figure 2 shows the similarity of residuals of the partial adjustment model in the upper part, the restricted ECM in the middle and the unrestricted in the lower part of the graph.[6]

Figure 2: Residuals



[6] The residuals have been shifted with a constant in order to make the better graphically comparable.

4. Conclusion

It could be shown, that the proposed cumulative error correction model has several interesting properties. Differently to the conventional ECM not only the most recent deviation from steady state is considered but also those located further in the past. Unlike the multi-cointegration model as proposed by Granger and Lee (1989), where all past deviations are cumulated with equal weights till the start of the time series, geometrically decreasing weights are assumed (and tested) and the related retention rate – which captures the size of the weights as well as their temporal fading out – is estimated from the data. The common ECM is completely nested as the retention rate can even be zero. On the other hand, if the retention rate is one, the multi-cointegration model emerges, but in this case the cumulative ECM will not be correctly specified as it does not care explicitly for the second-level cointegrating relationship. Likewise the partial adjustment model is nested as the cumECM covers auto-regressive movements of any lag order, due to its ARMA(1,1) representation.

Estimated conventional ECMs sometimes suffer from autocorrelation in their residuals. In practical work it is cared for by including AR-terms, frequently. Sometimes this is done without any theoretical justification and sometimes - like in the case of the partial adjustment model – this is based on adjustment costs leading to sluggish adjustment. In the case of the cumECM these assumptions are not necessary. There, the inclusion of an ARMA process is based only on theoretical reasoning that disequilibria of past periods can matter, too.

In comparison with the partial adjustment model of Ball (2002) for modeling short-term demand of M1 in the US, it was shown here that based on several information criteria the cumECM in its unrestricted form could outperform it. The cumECM turned out to be a flexible tool based on theory capable especially for data frequencies higher than one year.

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