Tjalling C. Koopmans Research Institute

Discussion Paper Series nr: 06-15

Non-linear target adjustment in corporate liquidity management: an endogenous thresholds approach

Allard Bruinshoofd, Clemens Kool

Universiteit Utrecht

Utrecht School of Economics

Tjalling C. Koopmans Research Institute
Utrecht School of Economics
Utrecht University

Janskerkhof 12
3512 BL Utrecht
The Netherlands
telephone +31 30 253 9800
website www.koopmansinstitute.uu.nl

The Tjalling C. Koopmans Institute is the research institute and research school of Utrecht School of Economics. It was founded in 2003, and named after Professor Tjalling C. Koopmans, Dutch-born Nobel Prize laureate in economics of 1975.

In the discussion papers series the Koopmans Institute publishes results of ongoing research for early dissemination of research results, and to enhance discussion with colleagues.

Please send any comments and suggestions on the Koopmans institute, or this series to M.deSwart-Gijsbers@econ.uu.nl

ontwerp voorblad: WRIK Utrecht

How to reach the authors

Please direct all correspondence to the first author.

Allard Bruinshoofd
De Nederlandsche Bank
Research Division
P.O. Box 98
1000 AB Amsterdam
The Netherlands
E-mail: w.a.bruinshoofd@dnb.nl

Clemens Kool
Utrecht University
Utrecht School of Economics
Janskerkhof 12
3512 BL Utrecht
The Netherlands.
E-mail: c.kool@econ.uu.nl

Utrecht School of Economics
Tjalling C. Koopmans Research Institute
Discussion Paper Series 06-15

Non-linear target adjustment in corporate liquidity management: an endogenous thresholds approach

Allard Bruinshoofd[a]
Clemens Kool[b]

[a]De Nederlandsche Bank
Research Division

[b]Utrecht School of Economics
Utrecht University

January 2006

Abstract
We provide new empirical evidence on non-linear liquidity management in Dutch firms. Our results reveal that liquidity adjustment from below the target is significantly faster than from above. We find no evidence for bands of inaction around the target.

Keywords: Corporate Liquidity Management, Non-linear Adjustment, Endogenous Thresholds, Panel Approach

JEL classification: C33, E41, G3

Acknowledgements
We thank Jaap Bos, Bertrand Candelon, Leo de Haan, Alain Hecq, Wilko Letterie, Michiel van Leuvensteijn, Jean-Pierre Urbain, Tom van Veen, as well as participants of the CAED 1999, the NAKE Research Day 1999, the European Monetary Forum 2002, the Maastricht University Economics Lustrum Conference 2004 and seminar participants at De Nederlandsche Bank for helpful comments. The research is supported by a grant from the Maastricht Research School of Economics of Technology and Organizations (METEOR) and was partially carried out at the Center for Research of Economic Micro-data (Cerem) of Statistics Netherlands. The views expressed are those of the individual authors and do not necessarily reflect official positions of Statistics Netherlands or De Nederlandsche Bank.

1. Introduction

While there is by now considerable empirical evidence to support the existence of optimal target levels for long-run corporate liquidity holdings (e.g. Kim et al., 1998; Opler et al., 1999; Ozkan and Ozkan, 2004; Bruinshoofd and Kool, 2004), little evidence exists on possible non-linearities in the speed of adjustment towards these targets. This is particularly surprising since such non-linearities – motivated by liquidity or financing constraints – play an important role in the related corporate investment literature (e.g. Ono, 2003; Pratap, 2003). Obviously, such arguments should straightforwardly extend to the cash management literature.

Opler et al. (1999) theoretically demonstrate that the respective shapes of the marginal cost and benefit curves of liquidity holdings in combination with the structure of adjustment costs determine the speed of corporate liquidity adjustment. In their view, target adjustment from below may be faster than from above, due to a flat marginal cost of liquidity curve and a convex marginal benefit curve. At the same time, their setup supports the hypothesis that adjustment speed rises with the size of target deviations, especially on the lower side. Milne and Robertson (1996) and Pratap (2003) provide a theoretical argument for the case where firms are significantly below target, which is based on increasing risk aversion when threatened by liquidation. On the other hand, Myers and Rajan (1998) provide an argument for quick run-downs of too high liquidity because creditors may dislike overly liquid debtors. Bar-Ilan et al. (2004) argue that fixed adjustment costs may lead to non-monotonous adjustment through bands of inactivity around the target. Indirect adjustment costs may also arise because funds directed to the stock of liquid assets cannot be used as a source of funds elsewhere in the firm. Ozkan and Ozkan (2004) discuss the consequences of liquidity adjustment for the level of dividend payments, while Almeida et al. (2004) focus on the consequences for future investment opportunities. To the best of our knowledge Almeida et al. (2004) are the only ones to explicitly test such non-linearities empirically. They split their sample of firms into a liquidity-constrained part and an unconstrained part. Liquidity dynamics of constrained firms are shown to differ from unconstrained firms.

The present paper significantly extends this literature through its empirical focus on non-linear corporate liquidity adjustment towards long-run targets. We apply an innovative endogenous threshold regression model to a balanced panel of 450 Dutch non-financial firms for the period 1986-1997.[2] Table 1 describes the variables used in the analysis. We refer to the table for the definition of the variables.

Table 1

Descriptive statistics

Variable	# Obs.	Percentiles					Standard
		10	25	50	75	90	deviation
Liquidity ratio (%)	5400	0.21	0.89	4.45	15.90	37.02	28.77
Liquidity	5400	–6.14	–4.72	–3.11	–1.84	–0.99	2.08
Δ Liquidity	4950	–1.50	–0.60	–0.01	0.51	1.35	1.35
Return on assets	5400	–0.00	0.02	0.05	0.10	0.15	0.10
Δ Return on assets	4950	–0.06	–0.02	0.00	0.02	0.06	0.10
Size	5400	10.44	10.83	11.52	12.51	13.78	1.34
Δ Size	4950	–0.14	–0.06	0.03	0.12	0.23	0.20
Interest rate	5400	0.00	0.02	0.04	0.06	0.10	0.12
Δ Interest rate	4950	–0.03	–0.01	–0.00	0.01	0.03	0.09

Notes: liquidity ratio (%) is cash and marketable securities over net assets. Liquidity is the logarithm of cash and marketable securities over net assets and Δ is the first-difference operator. Return on assets is earnings after depreciation, interest, taxes and extraordinary gains and losses, but before dividend payments to net assets; Size is the logarithm of net assets expressed in 1990 prices; Interest rate is interest expenses as a fraction of total debt, excluding debts to subsidiary companies.

[2] We refer to the appendix for details on sample selection.

2. Estimating conditional adjustment with endogenous thresholds

For the empirical analysis of conditional target adjustment in corporate liquidity holdings we specify liquidity dynamics as:

$$\begin{aligned}\Delta Liquidity_{it} = \alpha_i + \beta' Controls_{it} + \gamma_1 Deviation_{i(t-1)} I_1(Deviation_{i(t-1)} \leq \varphi) \\ + \gamma_2 Deviation_{i(t-1)} I_2(Deviation_{i(t-1)} > \varphi) + \varepsilon_{it}\end{aligned}, \qquad (1)$$

where $Controls_{it}$ and β' represent the vectors of control variables and corresponding coefficients, respectively, $Deviation_{i(t-1)}$ denotes initial liquidity holdings relative to the target level, α_i denotes firm-specific intercepts, and ε_{it} is an *iid* error term.[3] Our focus is on the conditional adjustment speed γ_j, which depends on the indicator function I_j. I_j in turn partitions the data using the – unobservable – threshold φ.

To estimate equation (1) we apply the method set out in Hansen (1999). For any given φ the slope coefficients can be estimated by OLS. Let φ_0 be the true threshold value and $\hat{\varphi}$ its least squares estimate. The least squares estimate is obtained where the value of the error sum of squares (ESS) is minimized:

$$\hat{\varphi} = \arg\min_{\varphi} ESS(\varphi) .$$

As $ESS(\varphi)$ depends on φ only through the indicator functions $I_j(.)$ it is a step function with at most nT steps, where n is the number of firms and T the number of years per firm in the

[3] The *iid* assumption forbids the use of lags of the dependent variable among the explanatory variables. As we shall see shortly, adjustment of liquidity holdings is reasonable fast so that we do not expect this restriction to

data. To reduce the number of regressions involved, a grid search for values of φ corresponding to the quantiles of $Deviation_{i(t-1)}$ is applied, using the quantiles {1.00%, 1.25%, 1.50%, ... , 89.50%, 89.75%, 99.00%}.

Two issues of inference should be addressed. First, we need to determine the statistical significance of the threshold effect, i.e. evaluate the hypothesis $H_0 : \gamma_1 = \gamma_2$. Since φ is not identified under the null, we use bootstrapping to simulate the asymptotic distribution of the likelihood ratio test. P-values constructed from the bootstrap are asymptotically valid for $n \to \infty$, a condition satisfied in our data where n equals 450 (firms). Second, we need a measure of precision of our estimate of φ_0. As $\hat{\varphi}$ is a consistent estimate of φ_0, for each φ evaluated in the grid search we may evaluate $H_0 : \varphi = \hat{\varphi}$. Confidence intervals are defined as a 'no rejection region' using the likelihood ratio statistic for tests on φ ($LR(\varphi)$). A test of $H_0 : \varphi = \hat{\varphi}$ rejects at the asymptotic level α if $LR(\varphi)$ exceeds the critical value $c(\alpha)$. Hence the 'no rejection region' of confidence level $1-\alpha$ is the set of φ such that $LR(\varphi) \leq c(\alpha)$. Note that $LR(\varphi)$ is a re-normalization of the error sum of squares for each value of φ and therefore a by-product of model estimation. The method extends in a natural manner to models with multiple thresholds. We refer to Hansen (1999) for technical details.

3. Results

In our empirical framework we define the target liquidity ratio as firm-level average liquidity holdings over the sample period. This is consistent with the sensitivity analysis in Bruinshoofd and Kool (2004) that reveals strong firm-specific components in corporate liquidity targets.

have a large impact on our results.

Table 2

Threshold effects, threshold estimates, and regression results

PANEL A: Test statistics for threshold effects		
Single threshold (P-value)	41.6	(0.00)
Double threshold (P-value)	16.2	(0.00)
Triple threshold (P-value)	13.7	(0.01)
PANEL B: Threshold estimates		
$\hat{\varphi}_1$ (95% confidence interval)	–2.86	(–3.03; –2.73)
$\hat{\varphi}_2$ (95% confidence interval)	0.85	(–0.58; 1.50)
$\hat{\varphi}_3$ (95% confidence interval)	3.05	(2.86; 3.05)
PANEL C: Regression results [a]		
Δ Return on assets $_{i,t}$	0.71	(0.36)
Δ Size $_{i,t}$	–1.20	(0.11)
Δ Interest rate $_{i,t}$	–0.36	(0.26)
Deviation $_{i,t-1} \times$ I(Deviation $_{i,t-1} \leq \hat{\varphi}_1$)	–0.87	(0.06)
Deviation $_{i,t-1} \times$ I($\hat{\varphi}_1 <$ Deviation $_{i,t-1} \leq \hat{\varphi}_2$)	–0.68	(0.03)
Deviation $_{i,t-1} \times$ I($\hat{\varphi}_2 <$ Deviation $_{i,t-1} \leq \hat{\varphi}_3$)	–0.45	(0.04)
Deviation $_{i,t-1} \times$ I($\hat{\varphi}_3 <$ Deviation $_{i,t-1}$)	–0.66	(0.10)
Firm-specific intercepts	YES	

[a] Dependent variable is Δ Liquidity. All variables are defined as before. White standard errors are in parentheses.

Table 2 presents the results of the joint estimation of thresholds and regression coefficients. Panel A presents formal threshold effects test results, which suggest a triple threshold model. Panel B of the table reports the threshold estimates themselves along with 95% confidence bands. Here we see that the middle threshold is positive but insignificantly different from zero. Unreported results show that our estimates are only marginally affected by restricting the second threshold to equal zero. For the remainder of the discussion we shall therefore interpret the second threshold as being zero. The first and third threshold estimates are particularly low and high, corresponding with liquidity shortfalls of more than 95% below the target and liquidity surpluses of over 2000% above the target, respectively. Although the third threshold effect is statistically significant, the regime above the third threshold contains only about 50 observations and the estimated threshold estimate is implausibly high. We check the robustness of this threshold by alternately winsorizing and censoring the data. We winsorize our data by removing firms from the sample in such a way that a minimum number of firms is deleted while a maximum number of extreme target deviations is removed from the sample.[4] We censor our data by replacing the deviations of the top and bottom 1% of the deviations distribution with the 99th and the 1st quantile values, respectively.[5] The results of these sensitivity checks – presented in table 3 – show that in either case the third threshold effect loses statistical significance, while the other thresholds effects as well as the regression coefficients remain broadly unchanged.

Table 3

Estimation results using winsorized and censored data

	Winsorized, uncensored sample		Full, censored sample	
PANEL A: Test statistics for threshold effects				
Single threshold (P-value)	55.0	(0.00)	67.0	(0.00)
Double threshold (P-value)	16.3	(0.01)	12.9	(0.04)
Triple threshold (P-value)	6.4	(0.33)	7.8	(0.15)
PANEL B: Threshold estimates				
$\hat{\varphi}_1$ (95% confidence interval)	–2.98	(–2.99; –2.77)	–2.99	(–2.99; –2.99)
$\hat{\varphi}_2$ (95% confidence interval)	0.85	(–1.22; 1.50)	0.85	(–1.72; 1.54)
$\hat{\varphi}_3$ (95% confidence interval)	-		-	
PANEL C: Regression results [a)]				
Δ Return on assets $_{i,t}$	1.18	(0.26)	0.77	(0.33)
Δ Size $_{i,t}$	–1.16	(0.11)	–1.21	(0.11)
Δ Interest rate $_{i,t}$	–0.22	(0.23)	–0.33	(0.26)
Deviation $_{i,t-1}$ × I(Deviation $_{i,t-1} \leq \hat{\varphi}_1$)	–0.95	(0.07)	–1.00	(0.07)
Deviation $_{i,t-1}$ × I($\hat{\varphi}_1$ < Deviation $_{i,t-1} \leq \hat{\varphi}_2$)	–0.67	(0.03)	–0.67	(0.03)
Deviation $_{i,t-1}$ × I($\hat{\varphi}_2$ < Deviation $_{i,t-1} \leq \hat{\varphi}_3$)	–0.49	(0.04)	–0.51	(0.04)
Deviation $_{i,t-1}$ × I($\hat{\varphi}_3$ < Deviation $_{i,t-1}$)	-		-	
Firm-specific intercepts	YES		YES	

[a)] Dependent variable is ΔLiquidity. All variables are defined as before. White standard errors are in parentheses.

[4] The Hansen (1999) methodology is tailored to balanced panels, while it is unsure whether its asymptotic properties extend to unbalanced panels. We therefore aim to keep the panel balanced and remove seventeen firms entirely from the sample rather than unbalancing our panel by removing individual observations.

[5] We have also censored at the 2nd and 98th quantile. This hardly affects the outcomes.

The regression coefficients are in Panel C of table 2. Regarding the control variables – changes in earnings, size and interest rates – we note that the coefficient signs are in line with the literature. Our main finding is that the speed of adjustment towards the target significantly differs across regimes. The differences are not only significant in a statistical sense, but are also economically meaningful. Specifically, our results reveal that firms respond to liquidity shortages considerably faster than they do to liquidity surpluses. Roughly speaking, firms correct liquidity surpluses at a rate of about forty-five percent per year, while they remove liquidity shortages at a rate of nearly seventy percent. For liquidity positions that fall particularly far short of the target ($Deviation_{i(t-1)} \leq \hat{\varphi}_1$), we even find nearly full target adjustment within a year. The latter result, however, may reflect survivorship effects stemming from our use of a balanced panel. Consequently, it may not generalize to other samples. We also find that firms respond to particularly large liquidity surpluses ($Deviation_{i(t-1)} > \hat{\varphi}_3$) faster than they do to more moderate surpluses. Due to the caveats discussed in footnote 4, however, we caution against strong conclusions from this observation. Lastly, our results do not support the notion of a range of inaction around target liquidity holdings.

4. Conclusions

The main finding in this paper is that firms bring back liquidity holdings to targeted levels at a faster rate when they are initially below the target than when they start out above the target. No evidence is found to support the existence of bands of inactivity around the target.

Our results reveal a stronger corporate preference for removing liquidity shortages than for removing liquidity surpluses. In relation to the literature on corporate investment and dividend payments, these findings suggests that liquidity shortages are more likely to spill over in the form of curbed investment outlays or cuts to dividend payments than liquidity surpluses are likely to feed additional investment outlays or increases in dividend payments.

References

Almeida, H., Campello, M., Weisbach, M.S., 2004. The Cash Flow Sensitivity of Cash. Journal of Finance 59, 1777-1804.

Bar-Ilan, A., Perry, D., Stadje, W., 2004. A Generalized Impulse Control Model of Cash Management. Journal of Economic Dynamics and Control 28, 1013-1033.

Bruinshoofd, W. A., Kool, C. J. M., 2004. Dutch Corporate Liquidity Management: New Evidence on Aggregation. Journal of Applied Economics 7, 195-230.

Hansen, B. E., 1999. Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference. Journal of Econometrics 93, 345-368.

Kim, C.-S., Mauer, D. C., Sherman, A. E., 1998. The Determinants of Corporate Liquidity: Theory and Evidence. Journal of Financial and Quantitative Analysis 33, 335-359.

Milne, A., Robertson, D., 1996. Firm Behaviour under the Threat of Liquidation. Journal of Economic Dynamics and Control 20, 1427-1449.

Myers, S. C., Rajan, R. G., 1998. The Paradox of Liquidity. Quarterly Journal of Economics 63, 733-771.

Ono, M., 2003. A Computational Approach to Liquidity-Constrained Firms over an Infinite Horizon. Journal of Economic Dynamics and Control 28, 189-205.

Opler, T., Pinkowitz, L., Stulz, R. M., Williamson, R., 1999. The Determinants and Implications of Corporate Cash Holdings. Journal of Financial Economics 52, 3-46.

Ozkan, A., Ozkan, N., 2004. Corporate Cash Holdings: An Empirical Investigation of UK Companies. Journal of Banking and Finance 28, 2103-2134.

Pratap, S., 2003. Do Adjustment Costs Explain Investment-Cash Flow Insensitivity? Journal of Economic Dynamics and Control 27, 1993-2006.

Appendix. Sample selection

Our sample is selected from Statistics Netherlands' data on the Finances of Large Firms (SFGO) covering the period 1977-1997. The SFGO provides company specific financial information at the level of balance sheet and income statement items for all Dutch non-financial firms with a balance sheet length of at least 20 million Dutch guilders (about EUR 9.1 million). On an annual basis, the data cover 80 to 90 percent of the population.

Occasionally, firms do not report in a given year so that missing data entries arise. In some cases, firms may leave due to financial distress raising the issue of survivorship bias or because they drop below the threshold level of assets. However, in many other cases firms do not leave but simply do not report their financial statements to SFGO in one or more years after which they return. We are unable to distinguish between these different cases. As the asymptotic properties of our empirical methodology our known only for balanced panels, we exclude firms with missing data.

In the early years, the number of firms on which Statistics Netherlands reports is quite small. Moreover, data then only cover the manufacturing sector. Data on the services sector start becoming available in 1983 and coverage increases substantially in the first years after. Therefore, we construct our balanced panel starting in 1986. Utilities firms are excluded from the sample and three more firms are removed because they display extreme volatility in liquidity dynamics. At the end of the day we have a balanced panel with 450 firms covering the period 1986-1997.