D MEASURING FINANCIAL MARKET LIQUIDITY AND RISK AVERSION INTERDEPENDENCE

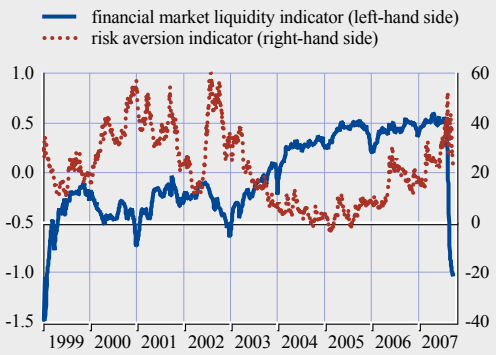
The relationship between risk aversion and financial market liquidity is usually found to be negative – i.e. higher risk aversion is typically associated with lower market liquidity. However, this is not the case all of the time. Indeed, there have been rather lengthy periods when higher financial market liquidity has been associated with increasing risk aversion. This Special Feature examines the co-movement of these series for the euro area from the beginning of 1999 until late 2007. The analysis suggests that close monitoring of financial market risks is needed when financial market liquidity is rising but risk aversion is increasing. Even though such states can persist for a considerable period, they seem to be followed by periods of higher risk aversion and reduced market liquidity as has been the case from July 2007 onwards.

INTRODUCTION

When strains start to emerge in financial markets, as was the case from late July 2007 onwards, the risk appetite of investors is usually eroded quickly and financial market liquidity often evaporates (see Chart D.1).[1] Episodes such as these often lead to the conclusion that periods of high risk aversion are usually associated with low financial market liquidity and vice versa. However, this does not always seem to be the case. Indeed, there have been relatively lengthy periods when financial market liquidity was rising when the risk aversion of investors was declining. For instance, several past issues of the FSR called attention to risks associated with a hunt for yield that had been set in motion in the course of 2003 when investors with strengthening risk appetites were faced with historically low long-term government bond yields and relatively cheap and abundant sources of credit. Investors had responded by seeking out alternative instruments with higher yields but also greater risk and this led to a deepening of financial market liquidity. As the hunt for yield progressed, there were growing concerns among the global central bank community that it was pushing asset prices above their intrinsic values. While the events that subsequently unfolded after June 2007 suggested that these concerns went unheeded, it was notable that the risk appetite of investors had already started to wane from 2005 onwards. Yet, market liquidity continued to deepen.

Chart D.1 Risk aversion and euro area financial market liquidity indicators

(Jan. 1999 - Sep. 2007)



Sources: Bloomberg, JP Morgan Chase & Co., Moody's KMV, Bank of Canada, UBS, Lehman Brothers, Westpac, Dresdner Bank, Bank of America, Goldman Sachs, Credit Suisse, State Street Corporation and ECB calculations.

When the degree of heterogeneity among investors – in terms of nature and degree of regulatory oversight, risk tolerance, investment horizon preferences, ability to leverage, etc – in a market is wide, this generally implies that a higher number of buyers and sellers will be willing to trade under different market conditions. When markets have this characteristic, securities transactions can be executed without triggering large changes in their prices and the underlying markets are generally more stable. In contrast, markets become illiquid when objectives become homogeneous: when everyone believes that everyone else will sell, financial market liquidity effectively vanishes. This is what happens when "trades are crowded". If a shock causes a critical mass of investors to reassess positions that are, on aggregate, crowded, then

1 For descriptions of the two series shown in the Chart, see ECB (2007), "Measuring investors' risk appetite", *Financial Stability Review*, June and Box 9 in the same issue of the FSR.

a "rush for the exit" normally ensues, bringing adverse market dynamics and much larger asset price volatility than might otherwise have been expected, given the size of the shock.

The widening of investor diversity over the past few years seemed to have contributed to greater stability in financial markets. By making them more liquid, greater investor diversity had contributed to a significant decline in market volatility. At the same time, lower volatility had helped reduce investor uncertainty, boosting confidence in the smooth functioning of markets, and, as a result, a greater number of buyers and sellers were attracted into the markets, thereby further enhancing liquidity.

In the June 2007 issue of the FSR, the importance for financial system stability of market liquidity remaining durable under stress was emphasised. In this respect, a key factor in determining the durability of financial market liquidity appears to be the risk appetite of investors. Against this background, this Special Feature empirically examines the relationship between risk aversion and financial market liquidity in order to pinpoint conditions where the durability of market liquidity may be vulnerable.

MEASURING THE RELATIONSHIP BETWEEN LIQUIDITY AND RISK AVERSION

A casual inspection suggests that the relationship between a composite measure of risk aversion and euro area market liquidity is predominantly negative and that this is especially the case when risk aversion suddenly increases (see Chart D.1). During such episodes rises in risk aversion have been associated with declining financial market liquidity. The predominance of a negative relationship is confirmed by various correlation measures calculated over various data frequencies (see Table D.1).

Dependence in a multivariate setting

A closer examination of the nature of the relationship between risk aversion and financial market volatility is possible with a scatter plot of the joint distribution of the two variables (see Chart D.2). This analysis reveals, overall, that the broad relationship between the two variables (considering the concentrations of points) is negative, supporting the view that high levels of risk aversion are broadly associated with low levels of financial market liquidity. However, the joint density has multiple peaks, suggesting the existence of distinct states in the relationship between the two variables over the sample period considered. Indeed, in some periods the relationship between the two has been relatively loose and in others it has even been positive.

Table D.1 Simple correlation measures for risk aversion and financial market liquidity at different data frequencies

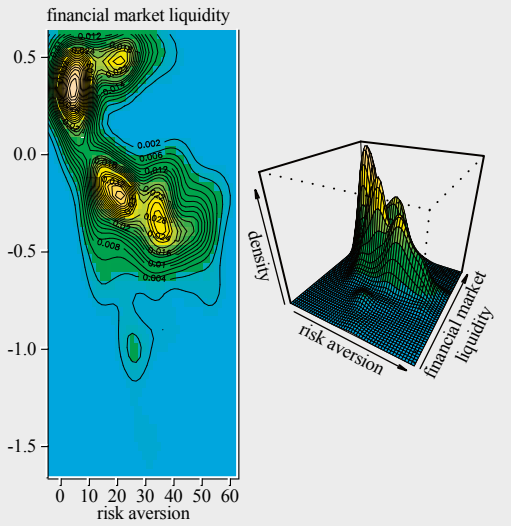
(Jan. 1999 - Sep. 2007)

Frequency	Correlation measure		
	Pearson	Kendall	Spearman
monthly	-0.595	-0.407	-0.601
weekly	-0.581	-0.398	-0.588
daily	-0.581	-0.395	-0.580

Source: ECB calculations.

Chart D.2 Joint distribution of risk aversion and financial market liquidity

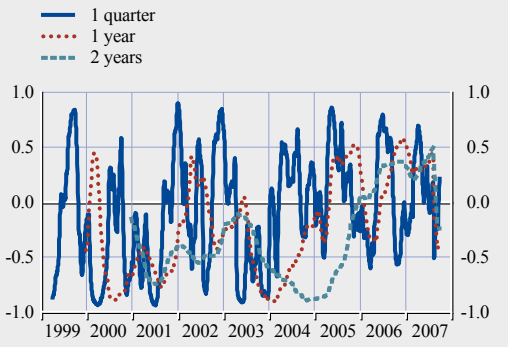
(Jan. 1999 - Sep. 2007; daily observations)



Source: ECB calculations.
Note: Non-parametric kernel density estimation of a level plot (right) and a 3-D surface (left). A higher level denotes higher concentration of points.

Chart D.3 Rolling correlations of financial market liquidity and risk aversion for the euro area

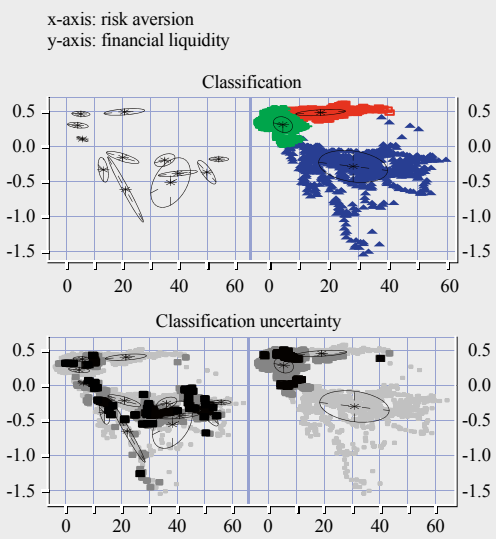
(Jan. 1999 - Sep. 2007; quarterly, yearly and bi-yearly windows)



Source: ECB calculations.

Chart D.4 Classification and uncertainty of normal mixtures fitted to the joint distribution of risk aversion and financial market liquidity

(Jan. 1999 - Sep. 2007; daily observations)



Source: ECB calculations.
Notes: On the basis of the Bayes information criteria (BIC), 12 ellipsoidal normal mixtures with variable volume, shape and orientation were selected as the best model (top left; see bottom left for its associated uncertainty in the assignment of observations). However, the BIC values do not differ greatly across a number of fitted normals: a mixture of three normals has a BIC value which is not much lower (top right) and seemingly less uncertainty (bottom right).

Taking account of time-variation in the relationship between financial market liquidity and risk aversion by calculating the bivariate correlation coefficient over windows of different lengths reveals considerable variation (see Chart D.3). In periods of relative market tranquillity (prior to March 2001 and between mid-2005 and the summer of 2007), the relationship was generally weaker – the Pearson correlation being closer to zero – and even became positive over the longer windows considered. In contrast, periods of greater market uncertainty have tended to be characterised by the correlation coefficient turning distinctly negative, thus supporting the view that risk appetite and financial market liquidity disappear in tandem under market stress.

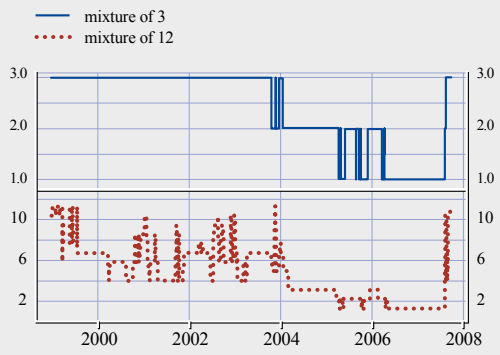
As both the joint density of the two variables and the rolling correlations suggest the presence of different states – i.e. periods when there is a negative association and others where there is either no or even a positive association – some insight can be gained by examining whether the data can be classified according to mixtures of elementary (normal) distributions. For instance, if there are two of such distributions present, then part of the time the joint distribution may be best described by one of them and for the remainder by the other. A clustering model based on normal mixtures provides evidence that there may be several of such distributions in the data examined here so that the relationship between risk aversion and financial market liquidity is not stable over time (see Chart D.4).[2] A few clusters show relatively little association between financial market liquidity and risk aversion, especially in states with either high market liquidity or risk aversion – capturing periods of a relatively stable relationship between the variables (at low and medium stress levels, as depicted by the levels of market liquidity).

The cluster analysis also appears to show some "transition" states where vulnerabilities of shifting to another state seem highest. In these states, the two variables are strongly and

2 The normal mixture modelling procedure estimates via an expectation-maximisation algorithm the most suitable model (on the basis of the Bayes information criteria) across a family of normal mixture models with a variety of covariance structures. For more details about the MCLUST package used, see http://www.stat.washington.edu/mclust.

Chart D.5 Time transitions between different components of the mixtures of 3 and 12 normal distributions

(Jan. 1999 - 28 Sep. 2007; daily observations)



Source: ECB calculations.
Note: The vertical values denote a (numerical) classification of the clusters identified in the respective figures in Chart D.4. High numbers were given to points in clusters closer to the lower right corner and low numbers to those in clusters near the upper left corners of Chart D.4.

negatively correlated but it seems that, when in these states, even very marginal fluctuations in risk aversion are accompanied by substantial variation in financial market liquidity. Indeed, the intuition behind this informal ordering of states or clusters is strengthened when looking at the transitions across states through time (see Chart D.5).

The clusters of observations where financial market liquidity was relatively high (upper left corners in Chart D.4) ran from early 2004 to July 2007, and they encompass a period where there were no prolonged episodes of market stress (lower values in Chart D.5). In contrast, at the beginning and the end of the sample (higher values in Chart D.5), the stability of the relationship between risk aversion and financial market liquidity was weaker (clusters in the vertical middles in Chart D.4). In between there were states with substantial volatility in the relationship between liquidity and risk aversion, generally at stable but lower levels of liquidity and also with negative co-movements between the two variables.

An assessment of the likelihood of remaining in any one state is provided by the frequency of moving across states (distributions). In light of this, low-stress states appear to be persistent. However, they appear to be followed by high-stress states. In moderate to high stress states (when considered jointly), there is stability in the relationship but it is subject to considerable fluctuation across the states composing it.

Dependence in a conditional distribution setting

An examination of the time series properties of the risk aversion and financial market liquidity indicators reveals evidence of non-stationary behaviour (see Table D.2). In particular, the risk aversion indicator exhibits random walk-like behaviour with no apparent drift.

The financial market liquidity series, in contrast, has very distinct characteristics, with the beginning and end of the sample being characterised by sharp movements and the middle showing distinct periods with no apparent positive or negative drift. Indeed, the marginal distribution of this indicator has two distinct peaks at values around 0.4, corresponding to the period between early 2004 and July 2007, and -0.3, corresponding to the earlier period (see Chart D.4). Furthermore, the higher-stress sample shows a wide dispersion from the mean.

Table D.2 Unit root tests

(Jan. 1999 - Sep. 2007)

	Augmented Dickey-Fuller		Phillips-Perron		Elliott-Rothenberg-Stock		DF with GLS detrending		Modified Phillips-Perron	
Null	no unit root		unit root		unit root		unit root		unit root	
indicator	risk	liquidity	risk	liquidity	risk	liquidity	risk	liquidity	risk	liquidity
t-stat	-2.4	-1.33	-2.301	1.605	3.0041	10.1372	-2.0007	-1.8508	-2.0246	-1.954
P-value	0.142	0.88	0.1719	0.9996	0.01<0.05	>0.05	0.01<0.05	>0.05	0.01<0.05	>0.05

Source: ECB calculations.

Table D.3 Tests for the cointegration rank of the vector error-correction model of financial market liquidity and risk aversion

(Jan. 1999 - Sep. 2007)

		Trace			Maximal eigenvalue		
	Eigenvalue	Statistic	1%	5%	Statistic	1%	5%
rank = 0	0.0095	28.3586	15.41	20.04	21.8098	14.07	18.63
rank <= 1	0.0029	6.5488	3.76	6.65	6.5488	3.76	6.65

Source: ECB calculations.
Notes: The model is estimated with seven day lags and deterministic trends with an unrestricted constant. Values for the quantiles of the appropriate asymptotic distributions are taken from M. Osterwald-Lenum (1992), A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Statistics, *Oxford* Bulletin of Economics and Statistics, 54, 461-472.

It would appear pertinent, therefore, to split the sample into periods of "low" and "higher" market stress. In fact, a standard joint test of structural change and non-stationarity[3] suggests that the financial market liquidity series has – in addition to the clear jumps early in and at the end of the sample – a distinct break at 2 January 2004 that is also consistent with the results above. This notwithstanding, the whole sample is used in the analysis below, mindful of the shortcomings of not addressing the structural change more explicitly.

The simplest possible multivariate conditional distribution model that captures a dynamic relationship between two stochastic processes is a vector autoregression (VAR) model.[4] More specifically, a vector error-correction model (VECM) may account at a basic level for the interdependencies of risk aversion and financial market liquidity in the presence of non-stationary variables. Indeed, considering the full sample, a test for cointegration suggests that the distribution of the two series is characterisedby a stationary long-run equilibrium together with temporary disturbances (see Table D.3).[5]

The VECM model that best fits the data explains much of the variation in financial

3 See E. Zivot and D.W.K. Andrews (1992), Further Evidence on the Great Crash, the Oil-Price Shock and the Unit Root Hypothesis. *Journal of Business & Economic Statistics*, 10(3): 251-270, July.

4 The maximum-likelihood method of estimation devised by Johansen is used. See, for example, S. Johansen (1995), *Likelihood Base Inference in Cointegrated Vector Error-Correction Models*, Oxford University Press, Oxford.

5 Both the trace and maximum eigenvalue statistics reject the null of rank being equal to 0 at the 1% level and they reject the null of rank being equal to 1 (one cointegrating vector) only at the 5% level.

Table D.4 Vector error-correction model of financial market liquidity and risk aversion

(Jan. 1999 - Sep. 2007; daily observations)

	Equation							
	Risk aversion				Financial market liquidity			
	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
	0.0014	0.7013			-0.0001	-4.6023		
lag	RA		FL		RA		FL	
-1	0.0891	4.216	-0.3575	-0.217	-0.0009	-3.319	0.2387	11.455
-2	-0.0602	-2.836	1.7415	1.027	-0.0004	-1.597	0.1615	7.537
-3	-0.0169	-0.796	-1.6956	-0.988	0.0000	-0.176	0.0252	1.163
-4	0.0192	0.904	2.6189	1.527	0.0004	1.368	0.0302	1.392
-5	-0.0183	-0.862	-1.0340	-0.602	0.0001	0.438	0.0344	1.585
-6	-0.0540	-2.542	0.9008	0.531	0.0002	0.691	0.0095	0.442
-7	-0.0109	-0.515	-3.0720	-1.892	0.0001	0.370	0.1083	5.276
const.	-0.0300	-0.611			0.0020	3.781		

Source: ECB calculations.
Note: The residual degrees of freedom are 2257, with about 17% of the variation in financial market liquidity explained and only less than 2% of the variation in risk aversion explained.

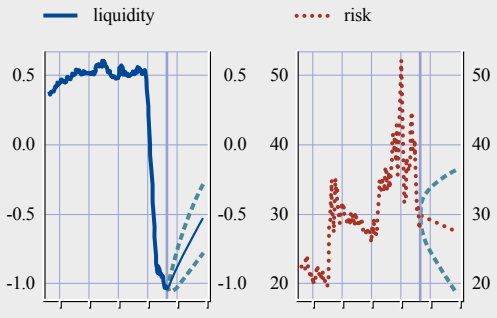
market liquidity but much less of the variation in risk aversion (see Table D.4). Nevertheless, shocks to risk aversion tend to initially overshoot, with only a gradual convergence to a new equilibrium. The findings suggest that risk aversion drives financial market liquidity in the immediacy of a shock, as the new equilibrium is reached through adjustments in market liquidity only. Nevertheless, there appears to be an effect running from market liquidity to risk aversion, but only after five days.

All in all, financial market liquidity appears to be quite responsive to shifts in risk aversion and the relationship is clearly negative: bouts of heightened risk aversion are often followed by liquidity drying up, with the impacts lasting a couple of days. These findings suggest that adverse shocks to risk aversion usually translate into a subsequent decline in financial market liquidity.

Looking forward, the estimated model can be used to assess the likely future direction of these indicators, conditional on an admittedly restricted information set. Based on values of these indicators available by end September 2007, a very gradual recovery in financial market liquidity seemed the most likely prospect (see Chart D.6). At the same time, future patterns of risk aversion were highly uncertain.

Chart D.6 VECM forecasts of financial market liquidity and risk aversion

(Data on 200 days prior to 29 September and 60-day forecast)



Source: ECB calculations.

CONCLUDING REMARKS

While the relationship between risk aversion and financial market liquidity is usually found to be negative – i.e. higher risk aversion is associated with lower market volatility – the interdependence between the two is quite complex. Indeed, there have been periods when higher financial market liquidity has been associated with increasing risk aversion. Based on the co-movement of these series from the beginning of 1999 until late 2007, it appears that when these series decouple in this way the vulnerability of markets to correction increases, perhaps because of complacency or because business risks – i.e. the longer-term risks of not trading – are seen to outweigh the short-term market risks. This would suggest that monitoring patterns in risk aversion and financial market liquidity jointly may contribute to early detection of financial market vulnerabilities.