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# Illiquidity Transmission from Spot to Futures Markets

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Keywords: illiquidity, liquidity risk, futures markets

JEL Classification: G10, G13

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# Illiquidity Transmission from Spot to Futures Markets

**Abstract**

We develop a model of illiquidity transmission from spot to futures markets that formalizes the derivative hedge theory of Cho and Engle (1999). The model shows that spot market illiquidity does not translate one to one to the futures market but, rather, interacts with price risk, liquidity risk, and the risk aversion of the market maker. The model's predictions are tested empirically with data from the stock market and markets for single-stock futures and index futures. The results support our model and show that the derivative hedge theory provides an explanation for the liquidity link between spot and futures markets.

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# I Introduction

Spot and futures markets are closely related because prices are exposed to a common risk factor. For the liquidity of both markets to be linked is therefore a natural conjecture. This link is relevant to investors, exchange operators, and regulators alike. Investors seek to follow a strategy that minimizes their illiquidity costs and exchange operators try to attract these investors. Regulators need to understand illiquidity spillover and contagion effects to assess the impact of regulatory measures, such as short-sale bans, on the liquidity of both markets.

Surprisingly little is known about the relation between spot market liquidity and futures market liquidity. There are two opposing views. The first argues that the two markets are substitutes, while the alternative view argues that they are complements. If substitution dominates, some investors will migrate from one market to the other if the relative costs in the two markets change. This results in an inverse relation between spot market liquidity and futures market liquidity, the so-called substitution hypothesis. Subrahmanyam (1991) develops a model of such migration effects, arguing that the introduction of stock index futures lowers the liquidity of the corresponding spot markets because uninformed traders move to the futures market to avoid adverse selection costs.[1] Jegadeesh and Subrahmanyam (1993) investigate the liquidity of the Standard & Poor's 500 stocks around the introduction of the Standard & Poor's 500 index futures contract and find evidence in support of an inverse liquidity relation between the equity and futures markets.

[1] Berkman, Brailsford, and Frino (2005) provide empirical support for the hypothesis that asymmetric information is low in index futures markets.

However, Choi and Subrahmanyam (1994) do not find a similar effect upon the introduction of the CBT's Major Market Index futures. Complementary empirical evidence in favor of substitution is provided by Benzennou, Gwilym, and Williams (forthcoming). These authors analyze single stock futures (traded on the London Stock Exchange) written on stocks listed on NYSE Euronext. During the 2008-2009 short-sale ban for the underlying stocks (an event that negatively affected liquidity in the stock market) the liquidity of the corresponding single-stock futures contracts is found to improve.

The idea that spot and derivatives markets are complements was first formulated for option markets. In a seminal paper, Cho and Engle (1999) propose what they call the derivative hedge theory. It is based on the argument that an illiquid spot market increases the hedging costs of market makers in the options market, causing the liquidity in the two markets to move in parallel. Kaul, Nimalendran, and Zhang (2004), Engle and Neri (2010), Wei and Zheng (2010), Goyenko, Ortahanlai, and Tang (2015) and Guillaume (2015) provide empirical support for a positive relation between spot market liquidity and options market liquidity. The empirical results of Battalio and Schultz (2011) and Grundy, Lim, and Verwijmeren (2012) point in the same direction. They investigate how the 2008 short-sale ban for certain stocks in the U.S. affected the corresponding options markets and find that the liquidity in the options market was lower during the ban. The empirical evidence for stock options does not immediately transfer to futures, however, because options and futures differ in two important aspects. First, since stocks and futures are both linear instruments, they should be closer substitutes for each other than stocks and options. Second, the hedging cost argument is less important for futures than for options, where the variation in delta calls for a dynamic hedging strategy.

Our paper is the first one to investigate the derivative hedge theory for futures. Its first contribution is the development of a theoretical model of the illiquidity transmission from spot to futures markets that formalizes the derivative hedge theory. The model shows that the illiquidity of the spot market does not translate one to one to the futures market but, rather, interacts with liquidity risk, price risk, and the risk aversion of the market maker. Our model provides hypotheses on the drivers of futures market illiquidity. These hypotheses are tested in an empirical study, which is the second contribution of the paper. We use data from the stock market and the market for single-stock futures (SSFs) and find support for the hypotheses derived from our model. Our results thus indicate that the derivative hedge theory is important for the understanding of the liquidity link between spot and futures markets.

In a first set of robustness checks, we consider different control variables. The results indicate that asymmetric information provides a further empirically important connection between stock illiquidity and futures illiquidity. However, even after controlling for asymmetric information, the effects identified by our inventory-based model are still highly significant. In a further robustness check, we repeat the empirical analysis using data from the market for stock index futures. Again we find support for the predictions of our model. However, for index futures, we also find evidence that is consistent with the existence of a substitution effect.

Our paper is related to the empirical and theoretical literature showing that spot market illiquidity has an impact on hedging strategies and derivative prices. In an empirical investigation, Roll, Schwartz, and Subrahmanyam (2007) show that the liquidity of the spot market affects the effectiveness of futures arbitrage and has an impact on the futures basis. Karakaya (2014), Christoffersen, Goyenko, Jacobs, and Karoui (2017), Choy and Wei (2016), and Kanne, Korn, and Uhrig-Homburg (2016) provide empirical evidence on a link between spot market illiquidity and option prices. Liu and Yong (2005), Cetin, Jarrow, Protter, and Warachka (2006), and Lai and Lim (2009) study the pricing and hedging of options when the spot asset is not perfectly liquid, which is in the same spirit as our theoretical model for the futures market. Moreover, our theoretical model is related to the literature on the effects of demand pressure and market makers' inventory risk on derivatives prices, such as the works of de Roon, Nijman, and Veld (2000), Bollen and Whaley (2004), Garleanu, Pedersen, and Poteshman (2009), Jankowitsch, Nashikkar, and Subrahmanyam (2011) and Muravyev (2016). Our study of liquidity builds on a demand-based pricing model that delivers a whole price impact function for the futures market.

The remainder of the paper is organized as follows. Section II develops our model of the illiquidity transmission from spot to futures markets. Section III presents the empirical tests. Finally, Section IV concludes the paper.

# II A Model of Illiquidity Transmission

This section develops a theoretical model of the illiquidity transmission from a spot asset to the corresponding futures.[2] Following the seminal work by Garleanu, Pedersen, and Poteshman (2009) on demand-based option pricing, we focus on a representative market maker in a competitive derivatives market with exogenous demand for derivatives. At time 0, there is a demand $H_D$ for futures contracts with maturity date $T$.[3] This demand is the excess demand of all end users, thus the market maker might not be involved in all trades in the market but clears the excess demand.[4] If $H_D$ is positive (negative), the excess end-user demand is for a long (short) position in the futures market. This demand has to be met in equilibrium by the supply $H_S$ of the market maker.

The market maker can hedge the price risk of her futures positions with positions in the spot market. However, the spot market is not perfectly liquid. The price per unit of the spot asset consists of two components: (i) $P_0$, which is the price prevailing in a perfectly liquid market, and (ii) market impact costs equal to $b_0\,|X|$, where $X$ is the number of assets bought by the market maker and $b_0$ is the slope of the (linear) price impact function.[5] In total, a purchase of $X$ units of the spot asset

[2] Calamia, Deville, and Riva (2016) develop a model of market making in the exchange-traded fund (ETF) market that yields predictions about the relation between liquidity in the ETF market and liquidity in the market for the constituents of the underlying index. Their model differs from ours in two important ways. First, the market maker in their model does not hedge her ETF position in the market for the underlying securities. Second, the authors assume a fixed price impact in the market for the underlying securities and thus do not consider liquidity risk.

[3] We do not distinguish between futures and forwards in our one-period model.

[4] This notion of a market maker reflects the role of the designated market makers in the SSFs market we investigate. They are obliged to maintain sufficient liquidity in the limit order book.

[5] Chung, Liu, and Tsai (2014) and Henderson, Pearson, and Wang (2017) show empirically that

generates a payment at time 0 equal to $-P_0 X - b_0 X^2$. When the futures mature at time $T$, the market maker closes out the spot positions and receives the uncertain amount $\widetilde{P}_T X - \tilde{b}_T X^2$ for the spot assets, where $\widetilde{P}_T$ denotes the (random) spot price at time $T$ in a perfectly liquid market and $\tilde{b}_T$ is the (random) slope coefficient of the price impact function at time $T$.[6] The uncertainty of the coefficient $\tilde{b}_T$ captures the effects of changing liquidity in the spot market.

In addition, the market maker receives a payment of $-H_S(\widetilde{P}_T - F)$ from her futures positions, where $F$ denotes the futures price at time 0 and $\widetilde{P}_T$ is the settlement price at maturity. Further, assume for simplicity that the market maker has access to risk-free lending and borrowing at zero interest rates and the spot asset does not make any payments between time 0 and time $T$.[7] If the market maker has initial wealth $W_0$, the market maker's terminal wealth $\widetilde{W}_T$ at time $T$ is

$$\widetilde{W}_T = W_0 - P_0 X - b_0 X^2 + \widetilde{P}_T X - \tilde{b}_T X^2 - H_S(\widetilde{P}_T - F). \tag{1}$$

The market maker faces two sources of risk: price risk ($\widetilde{P}_T$) and liquidity risk ($\tilde{b}_T$) in the spot market. For simplicity, assume that the two random variables follow

hedging demand for derivatives can indeed have an effect on the underlying spot prices.

6 We implicitly assume that the futures contract is cash-settled. If the contract were physically settled the market maker could simply deliver the spot position rather than closing it and would not incur price impact costs. The single stock futures contracs and the index futures contract that we use in our empirical analysis are cash-settled.

7 The implications of the model are unchanged with non-zero interest rates and non-stochastic dividend payments.

a joint normal distribution

$$\begin{pmatrix} \widetilde{P}_T \\ \tilde{b}_T \end{pmatrix} \sim \mathcal{N}\left[\begin{pmatrix} P_0 + \mu T \\ b_0 \end{pmatrix} \begin{pmatrix} \sigma^2 T & \sigma \eta \rho T \\ \sigma \eta \rho T & \eta^2 T \end{pmatrix}\right],$$

where $\mu$ is a drift parameter, $\sigma$ and $\eta$ are volatility parameters, and $\rho$ denotes the correlation between $\widetilde{P}_T$ and $\tilde{b}_T$.[8]

Further assume that the market maker has constant absolute risk aversion (CARA) preferences with absolute risk aversion $A$. The market maker seeks to maximize the expected utility of terminal wealth with respect to the number of futures contracts supplied ($H_S$) and the number of spot assets bought ($X$). Under our assumptions of CARA preferences and normally distributed terminal wealth, the optimization problem of the market maker becomes

$$\max_{H_S, X} \; E[(\widetilde{W}_T)] - \frac{1}{2} A \, Var[(\widetilde{W}_T)]. \tag{2}$$

Since market makers are competitive and there exists a representative market maker in the futures market, the market clearing condition $H_D = H_S \equiv H_*$ must hold in equilibrium together with the optimality conditions for the representative market maker arising from problem (2). As we show in the Appendix, these conditions lead to the following equilibrium futures price $F_*$:

[8] A simple modification of the model allows for a different scaling of price risk and liquidity risk with $T$. In particular, we tried different scaling rules for the liquidity risk that consider mean reversion of the slope coefficient of the price impact function. The effects of a changing $T$ under the different scaling rules are qualitatively identical.

$$F_* = P_0 + 4\,b_0 X_* + \frac{1}{2} A\,\left[3X_*^3\,\eta^2\,T - 2(X_*^2 - X_* H_*)\,\sigma\,\eta\,\rho\,T\right], \tag{3}$$

with $X_*$ being the equilibrium spot position. The variable $X_*$ is available in closed form and is given in the Appendix. In general, it depends on $H_*$ and all model parameters. Equation (3) therefore provides a relation between the futures price and trade size $H_*$, which allows us to study illiquidity in the futures market. The pricing equation is the basis for our illiquidity measure $ILM(H_*)$, defined as

$$ILM(H_*) = \frac{F_*(H_*) - F_*(0)}{H_*}\,, \tag{4}$$

where $ILM(H_*)$ measures the price impact per unit for a trade of size $H_*$. It takes on its minimum value, zero, if the futures market is perfectly liquid. The variable $ILM(H_*)$ is conceptually equivalent to the price impact parameter $\lambda$ in Kyle (1985). It allows us, in particular, to assess the role of spot market illiquidity for the liquidity of the futures market. We proceed step by step and distinguish three cases.

*Case (i): Perfectly liquid spot market.* If the spot market is (always) perfectly liquid, both $b_0$ and $\eta$ equal zero. Consequently, $\tilde{b}_T$ is also equal to zero. Equation (3) implies that $F_*$ equals $P_0$ in this case. The model then reduces to the standard cost-of-carry model and the futures market, as the spot market, is perfectly liquid. This result is very intuitive. If the equilibrium price were to deviate from the cost-of-carry price, the market maker would make a risk-free profit (or loss), which contradicts the assumption of a competitive derivatives market. With perfectly liquid spot markets, the market maker takes the role of the arbitrageur in the classical no-arbitrage valuation framework.

*Case (ii): Illiquid spot market without liquidity risk.* If $b_0$ is positive but $\eta$ equals zero, we have an illiquid spot market without liquidity risk. Consequently, $\tilde{b}_T$ is equal to $b_0$. In this case, the optimal spot position of the market maker[9] is $X_* = \frac{\mu T}{4b_0 + A\sigma^2 T} + H_* \frac{A\sigma^2 T}{4b_0 + A\sigma^2 T}$ and, according to equation (3), the futures price equals

$$F_* = P_0 + 4b_0 \left( \frac{\mu T}{4b_0 + A\sigma^2 T} + H_* \frac{A\sigma^2 T}{4b_0 + A\sigma^2 T} \right). \tag{5}$$

With futures prices from equation (5), the illiquidity measure becomes

$$ILM(H_*) = \frac{4b_0 A\sigma^2 T}{4b_0 + A\sigma^2 T} \quad . \tag{6}$$

Note that $ILM$ does not depend on $H_*$, that is, the price impact function is linear. Two components drive the liquidity of the futures market. The first is the illiquidity of the spot market, $b_0$. The second is the product of the market maker's risk aversion ($A$), the price risk ($\sigma^2$), and the time to maturity of the futures ($T$). It is easy to show that illiquidity increases in both components. Therefore, our model implies that illiquidity in the futures market increases in the illiquidity of the spot market, the risk aversion of the market maker, the volatility in the spot market, and the time to maturity of the futures contract.

9 The optimal spot position is obtained by setting $\eta = 0$ in equation (10) in the Appendix and solving for $X$.

*Case (iii): Illiquid spot market with liquidity risk.* If both $b_0$ and $\eta$ are positive, we have an illiquid spot market with liquidity risk. A first question to address is whether the effects of the current spot market illiquidity ($b_0$), the risk aversion of the market maker ($A$), the spot market volatility ($\sigma$), and the futures' time to maturity ($T$) are still similar in the presence of liquidity risk. Closed-form solutions for the futures price and the illiquidity measure are available to answer this question.[10] However, the structure of these solutions is quite complex. In particular, the introduction of liquidity risk leads to a dependence of $ILM$ on $H_*$, that is, the price impact function is no longer linear. This complexity leads us to a graphical presentation of a comparative static analysis. Figure 1 shows comparative static results for the $ILM(H_*)$ measure with respect to changes in $b_0$, $A$, $\sigma$, and $T$, respectively. The base case parameters for the distributions of $\widetilde{P}_T$ and $\tilde{b}_T$ are set to $\mu = 5\%$ per year, $\sigma = 30\%$ per year, $b_0 = 0.5\%$, and $\eta = 0.2\%$ per year, which is in line with the characteristics of the typical DAX30 stocks that we investigate in our empirical study. The additional base case parameters are set to $\rho = 0$, $A = 4$, and $T = 1$.[11]

*[ Insert Figure 1 about here ]*

Figure 1 shows that the previous results for the case without liquidity risk are confirmed qualitatively. The illiquidity of the futures market is increasing in the current illiquidity of the spot market, the risk aversion of the market maker, the

[10] Equation (11) in the Appendix provides the equilibrium spot position $X_*$ to be used in equation (3). Substitution of futures prices according to equation (3) into equation (4) delivers the illiquidity measure.

[11] The online Appendix provides complementary results for several alternative parameter sets. The resulting effects on the futures' illiquidity are qualitatively unchanged.

price risk, and the time to maturity of the futures contract. Moreover, we see that illiquidity increases in the absolute value of $H_*$.

A second question is how liquidity risk ($\eta$), the correlation between price risk and liquidity risk ($\rho$), and the expected price change of the spot asset ($\mu$) affect the liquidity of the futures. Figure 2 provides some comparative static results.

*[ Insert Figure 2 about here ]*

Illiquidity in the futures market is clearly increasing in the liquidity risk in the spot market. This effect is weak for small absolute values of $H_*$ but becomes more pronounced for larger absolute values of $H_*$. In our view this is an important result because it is not obvious and is not easily derived from alternative models of futures market illiquidity. Therefore, empirical findings consistent with the prediction that liquidity risk in the spot market has a weak [strong] impact on futures market illiquidity for small [large] order sizes would be strong evidence in favor of our model.

The effects of a variation of the expected spot price change and the correlation between spot price and spot market liquidity are asymmetric. Higher values of $\mu$ reduce the illiquidity in the futures market for negative values of $H_*$ but increase illiquidity for positive values of $H_*$. A rationale for the asymmetric effect of the expected price change in the spot market is the following. If there is a demand for long futures ($H_* > 0$), the market maker takes the corresponding short position and hedges it in the spot market. However, because of spot market illiquidity, the market maker doesn't hedge the exposure fully.[12] Consequently, the market maker has a net short position. The more spot prices are expected to rise, the more costly this short position becomes, requiring a higher compensation in terms of higher futures prices. Consequently, for positive values of $H_*$, the illiquidity in the futures market is increasing in $\mu$. The reverse holds for negative values of $H_*$. In this case, the market maker has a net long position. Increasing values of $\mu$ make this long position more profitable, lowering the required additional compensation in terms of lower futures prices and reducing the price impact of demand, thus making the futures market less illiquid. In both cases, the quantitative effects of the expected price change, $\mu$, on the illiquidity in the futures market are small, however.

The intuition for the asymmetric impact of the correlation $\rho$ on illiquidity is related to the previous argument. As noted above, the market maker will take a net short position when $H_*$ is positive. This short position loses money when the spot price increases. The market maker also loses money when the illiquidity in the spot market increases. If price risk and liquidity risk are positively correlated, the market maker is more strongly exposed to large losses. Due to the market maker's risk aversion, she will require a compensation for these large risks, leading to more illiquid futures markets. By a similar argument, a negative correlation results in a less illiquid futures market since liquidity risk provides a natural hedge of price risk and reduces the total risk of the market maker. Consequently, for positive values

[12] Whenever the expected price change in the spot market is non-zero, i.e., whenever $\mu$ is non-zero, the market maker will also take a speculative position in addition to the hedge position. The conclusions about illiquidity transmission, however, remain qualitatively unchanged by this speculative component in the market maker's portfolio. This can be checked by solving the model for $\mu = 0$.

of $H_*$, the illiquidity of the futures market is increasing in $\rho$. For negative values of $H_*$, the market maker holds a net long position and the effect is reversed. As a result, the futures market is less illiquid for higher values of $\rho$.

In summary, our model shows how illiquidity is transmitted from the spot market to the futures market. Both current spot market illiquidity and liquidity risk play an important role and futures market illiquidity increases with these factors. The transmission is not one to one, however, because there are interactions with other effects. The volatility of the spot price, the risk aversion of the market maker, and the time to maturity of the futures contract turn out to be important, too. If spot markets are more volatile, the model predicts that futures markets are less liquid and liquidity is lower for futures with longer maturities. In addition, the correlation between price risk and liquidity risk and the expected spot price change have an impact on the futures' liquidity. However, the direction of the corresponding effects depends on whether there is a net demand for long futures or for short futures.

# III Empirical Study

## A Data and Hypotheses

To test the predictions of our model empirically, we need to select appropriate spot and futures markets. The most basic futures contracts are SSFs. They are ideal instruments for our purpose for three reasons: First, the hedging of an SSF can be done naturally with a single instrument, the underlying stock, which is in line with our model. Second, the liquidity of both the underlying stock and the SSF is rather easy to measure. For index futures, for instance, there is no canonical measure of the underlying's liquidity. Third, because SSFs are available for different stocks, we can construct a panel data set, thereby exploiting both the time series and the cross-sectional variability in the data.

Although SSFs are known to be less liquid than the underlying stocks (e.g. Fung and Tse (2008)) it has been shown that they contribute significantly to price discovery (Fung and Tse (2008) and Shastri, Thirumalai, and Zutter (2008)), and that they are used as a substitute for the underlying stock during a short-selling ban (Benzennou, Gwilym, and Williams (forthcoming)).

Our model makes predictions about the whole price impact function. The results imply that liquidity effects are often more pronounced for larger (absolute) values of $H_*$, as shown in Figures 1 and 2. This is particularly true for the relation between liquidity risk and futures market liquidity (see Figure 2A). Therefore, the ideal liquidity measure for the purpose of our analysis is one that considers liquidity not only at the best bid and ask quotes, but also further up and down in the book. Irvine, Benston, and Kandel (2000) develop the cost of a round trip $CRT(D)$, which is an ex ante liquidity measure that covers both market breadth and market depth. The $CRT(D)$ is based on the weighted average prices at which a buy and a sell order of given size $D$ can be executed. The measure expresses the difference between these two prices as a percentage of the quote midpoint. Following the same logic, Deutsche Börse AG developed the liquidity measure $XLM$,[13] which is similar to $CRT(D)$.

[13] For details, see Gomber and Schweickert (2002) or Gomber, Schweickert, and Theissen (2015).

Calculations of $XLM$ use snapshots of the entire order book (including the hidden part of iceberg orders), taken every second during trading hours. In our analysis, we use the daily averages of these intradaily values. Our liquidity measure for day $t$ thus captures the average illiquidity costs, measured in basis points (bps), that would be incurred by a round-trip trade of a given size on that day.[14] It is an ideal measure for our purposes, because it closely matches the $ILM$ derived in our model. Both measures provide the illiquidity costs per unit for an order of a given size. The only difference is that $XLM$ measures size by the euro volume rather than by the number of contracts traded. This, however, is a desirable feature because our empirical study includes different stocks with different price levels. Deutsche Börse calculates $XLM$ for German stocks and the corresponding SSFs.[15] This allows us to use a consistent illiquidity measure for both the spot and the futures markets.

The $XLM$ measure is our central measure of illiquidity because it is ideally suited for our purpose. As a robustness check, we also repeat all our analyses using the quoted bid–ask spread.[16] Such a robustness check is interesting for two reasons. First, the bid–ask spread is the most widely used measure of liquidity in the academic literature. Second, our model predicts that some variables have a sizable impact on futures liquidity for large values of $H_*$, but not for small values. We can test these predictions by comparing the results for the $XLM$ measure (which corresponds to a large value of $H_*$) to those for the bid–ask spread (which corresponds to a small value

[14] We use the amounts of 50,000 euros and 100,000 euros in our study.

[15] We obtained the $XLM$ data from Deutsche Börse. Note that the $XLM$ measure for SSFs is only available until the end of 2011.

[16] The quoted bid–ask spread and the $XLM$ measure are conceptually consistent with each other. The spread is equivalent to the $XLM$ for small trades.

of $H_*$). We obtain a data set that, for both the stock market and the SSFs market, contains the quoted spread at 4 pm. The data for the equity market come from Deutsche Börse while the data for the SSFs market were obtained from Thomson Reuters Tick History.

German SSFs trade on EUREX, one of the most important trading venues for SSFs worldwide. In 2013, 19% of the worldwide trading volume in SSF contracts was generated on EUREX (946 million contracts).[17] Since the introduction of SSF trading at EUREX in October 2005, the trading volume has risen constantly. The majority of SSFs traders are institutional investors. At EUREX, SSFs can be traded either over the counter via the EurexOTC Trade Entry services or on a central limit order book. To maintain sufficient liquidity in the limit order book market, SSFs written on DAX30 stocks have designated market makers.[18] The existence of these market makers assures that the market structure in the EUREX SSFs markets is similar to the market structure assumed in our model. We therefore concentrate on SSFs on DAX30 stocks.[19] The stocks constituting the DAX are the most important German stocks and account for approximately 83% of the total market capitalization of the German stock market.[20] Our data set consists of the entire DAX30 universe from January 2010 to December 2011. More recent data are unavailable because dissemination of the $XLM$ measure for SSFs was terminated at year-end 2011. For

[17] Eurex (2014) provides additional information on EUREX SSFs.
[18] Eldor, Hauser, Pilo, and Shurki (2006) show that such designated market makers can improve the liquidity and efficiency of order-driven electronic markets significantly.
[19] The composition of the DAX changed in 2010; our sample contains both the stock that left the index and the stock that was added to the index. Thus, our sample consists of 31 stocks.
[20] The figure is for year-end 2009 (the beginning of our sample period) and is from the Factbook 2009 of Deutsche Börse AG.

each stock and each day, we consider the futures contracts with the shortest time to maturity and the second shortest time to maturity. In the following, we will simply call the next-to-delivery contract the short-term contract and the second-next-to-delivery contract the long-term contract. The use of futures contracts on the same underlying that differ in their times to maturity allows us to test the maturity effects on liquidity predicted by our theoretical model.

The objective of our analysis is to test hypotheses about the illiquidity transmission from spot to futures markets. Therefore, our dependent variable is futures market illiquidity as measured by $XLM$. We denote the $XLM$ measure for the SSFs market by $XLM_F$.

Our model predicts that futures market illiquidity depends on spot market illiquidity. We therefore include the illiquidity measure for the spot market, denoted $XLM_S$, as an explanatory variable. According to the derivative hedge theory (on which our model is based), futures market illiquidity increases in spot market illiquidity. This follows from the complementary nature of both markets, which are linked by the hedging activities of the market maker. However, an alternative view posits that investors can use SSFs as substitutes for the underlying stocks. An attractive feature of SSFs is that they require less capital. According to this view, spot and futures markets are substitutes. Consequently, the substitution hypothesis predicts an inverse relation between spot and futures market illiquidity.

According to the model, the product of the market maker's risk aversion and spot market volatility, $A\sigma^2$, is positively related to the illiquidity of the SSFs markets. We do not consider these two variables separately, because the market maker's risk aversion is difficult to measure. Further, several studies have shown that risk aversion is usually high when volatility is also high (Bekaert, Hoerova, and Lo Duca, 2013). Therefore, we use a measure of volatility to proxy for $A\sigma^2$. Our volatility measure ($Volatility$) is the annualized standard deviation of stock returns in bps, estimated from daily data (obtained from Datastream) over a rolling window of 30 trading days. Our model predicts that volatility is positively related to illiquidity because the market maker faces higher risk when volatility is high. There are also arguments in favor of the reverse effect. Historically, the high volatility of certain spot markets was a major impetus for the development of large and liquid futures markets, because of the increasing demand to hedge spot price risk.[21]

A third explanatory variable derived from the model is liquidity risk in the spot market ($LiquidityRisk$). We measure it as the standard deviation of the daily $XLM_S$ values for each stock, estimated over a rolling 30-day window. This variable captures the liquidity risk that the market maker faces. Liquidity risk contributes to the costs of a risk-averse market maker and, according to the model, higher liquidity risk leads to more illiquid futures markets. The substitution hypothesis predicts exactly the opposite. If spot and futures markets were substitutes, higher liquidity risk in the spot market makes the spot market relatively less attractive and should lead some investors to switch from the spot to the futures market. The now relatively more attractive futures market should therefore become more liquid.

[21] For example, crude oil futures started trading on NYMEX in 1986 after a period of price turbulence in world oil markets.

To capture maturity effects, we use a dummy variable ($Maturity$) that takes a value of zero if the future is a short-term contract and a value of one if it is a long-term contract. Our model predicts a positive coefficient for this variable, since liquidity should be lower for contracts with longer maturities.

The correlation between price risk and liquidity risk and the expected price change also affect futures market liquidity, according to our model. However, the effects depend on whether there is a demand for short or long positions. Since our illiquidity measure does not distinguish between the effects of a seller-initiated and a buyer-initiated order, we are unable to test the corresponding model predictions and do not consider these variables in our empirical analysis.

## B Descriptive Statistics

The illiquidity measures $XLM_S$ and $XLM_F$ are the main building blocks of our analysis. Accordingly, we provide some information on their properties. Table 1 shows descriptive statistics of the $XLM_S$ measure for the 31 stocks in our sample. The $XLM_S$ values refer to trade sizes of 50,000 euros and 100,000 euros, respectively, and show the price impact measured in basis points. The reported statistics are based on a filtered data set that excludes values above 1,000 bps. Such values occur for less than 1% of the observations.[22]

*[ Insert Table 1 about here ]*

[22] In the extreme, the data set contains $XLM_S$ values of more than 10,000 bps. The filtering removes such observations, which are economically meaningless.

For the most liquid stocks, the mean price impact is about six bps, with Siemens as the most liquid stock, on average (5.24 bps for a trade size of 50,000 euros and 5.90 bps for 100,000 euros). The less liquid stocks have a mean $XLM_S$ value of about 15 bps, with Heidelberg Cement as the most illiquid stock. The mean and median are usually quite close, indicating that the impact of extreme values is not very large. As the number of observations (N) shows, $XLM_S$ measures are not always available. For instance, E.ON, which was in the DAX during the whole sample period (which contains 521 daily observations), has 13 missing values.

Table 2 reports the corresponding descriptive statistics for the futures market based on the $XLM_F$ measure. Again, we use a filter that excludes values above 1,000 bps. We choose the SSFs with the shortest and second shortest times to maturity. To avoid the noise due to expiration-day effects during the last trading month, however, all observations in the delivery month are discarded from the sample, as in the study of Bialkowski and Jakubowski (2012). The average time to maturity of the short-term futures is about 34 days and the average time to maturity of the long-term futures is about 65.5 days. Close to 54% of the $XLM$ measures refer to short-term contracts and about 46% to long-term contracts.

*[ Insert Table 2 about here ]*

The results show that the SSFs market is far more illiquid than the stock market, with a mean market impact ranging from about 24 bps to 290 bps for a volume of 50,000 euros. The difference between the mean and the median is usually positive and larger than in the spot market, indicating a right-skewed distribution.

Moreover, we note a larger number of missing values for the SSFs market than for the spot market.

Table 3 shows the mean and median values of the bid–ask spreads in the equity and the SSFs markets. The result that the stock market is far more liquid than the SSFs market is confirmed. While the bid–ask spreads in the stock market range between 4.6 bps and 20.8 bps, the corresponding minimum and maximum values for the SSFs market are 29.2 bps and 269.8 basis points, respectively.[23]

*[ Insert Table 3 about here ]*

## C Determinants of Futures Illiquidity

### C.1 Base Case

To test the predictions of our model we use fixed effects panel regressions. The regression model has the form

$$XLM_{F\,i,t} = \alpha_i + \beta x_{i,t} + \epsilon_{i,t}, \tag{7}$$

where $XLM_{F\,i,t}$ is the illiquidity measure for the SSFs written on stock $i$ on day $t$, $\alpha_i$ is a stock fixed effect, $\beta$ is the row vector of regression coefficients, and $x_{i,t}$

[23] There are occasions when the quoted bid–ask spread is larger than the $XLM$ measure for an order size of 50,000 euros. There are two reasons why this could happen. First, while the $XLM$ data we use consists of daily averages provided by the exchange, the bid–ask spread data consists of snapshots taken at 4 p.m. Second, the $XLM$ measure is, in a sense, a conditional measure. It can only be calculated when the order book is thick enough to accommodate an order of the respective size (e.g., 100,000 euros for the $XLM$(100,000)). Consequently, illiquid periods during which the order book is thin do not enter the calculation of the $XLM$ measure.

denotes the column vector of explanatory variables, corresponding to stock $i$ on day $t$. In our base case regressions, these explanatory variables are $XLM_S$, $Volatility$, $LiquidityRisk$, and $Maturity$, as introduced in Section III.A. The error term $\epsilon_{i,t}$ is assumed to have mean zero and to be independent of $x_{i,t}$. Note that we have an unbalanced panel data set because the illiquidity measures are not always available.

*[ Insert Table 4 about here ]*

Our base case regression results are reported in Table 4. They use $XLM$ measures for orders of 50,000 euros and 100,000 euros, respectively. Together with the parameter estimates, we provide p-values in parentheses.[24] The results strongly support the predictions of our model. For an order size of 50,000 euros, all four determinants derived from the model are statistically significant and have the predicted sign. Increasing spot market illiquidity, spot price volatility, and liquidity risk all lead to a more illiquid futures market. Moreover, longer times to maturity of the futures render the contract less liquid.

The results for an order size of 100,000 euros are fully consistent with the results presented above. All the coefficient estimates retain their sign and significance. The slight increase of the p-values for spot market illiquidity and spot price volatility may be due to the lower number of observations for this order size.

The last column in Table 4 shows the results when we use the bid–ask spread rather than the $XLM$ as our dependent variable, providing a robustness check.

[24] The p-values are based on standard errors clustered at the firm level, as suggested by Petersen (2009).

The results are very similar to those obtained for the $XLM$. In particular, the spread in the futures market is significantly positively related to the spread in the market for the underlying stock and is also significantly positively related to return volatility, our measure of price risk. Further, the spreads for the long-term futures contracts are significantly larger than those for the short-term contracts. The only difference to the results obtained for the $XLM$ measure is that the spreads in the SSFs market are not related to our measure of liquidity risk. The corresponding coefficient is negative and far from significant. This finding, however, is consistent with our model. The model predicts (see Figure 2.A) that liquidity risk has a sizable positive impact on illiquidity in the futures market for large values of $H_*$, while the effect for small values of $H_*$ is marginal and unlikely to be identifiable empirically.

### C.2 Effects of Alternative Risk Measures

Our base case regression uses the standard deviation of returns as a measure of price risk and the standard deviation of the $XLM$ as a measure of liquidity risk. In this section, we perform two robustness checks to test whether our results depend on these specific risk measures. A standard argument in finance states that it is systematic risk and not total risk that matters, because unsystematic risk can be eliminated by diversification. This argument could, to some degree, apply to market makers in the SSFs market if they trade in different stocks and attain at least some level of diversification. Therefore, in a first robustness check, we replace total risk (volatility) by systematic risk. Specifically, we use the covariance between the daily stock returns and the index returns, estimated over the 30 previous trading days, as a measure of price risk (*Syst_Risk*) and the covariance between stock illiquidity and market illiquidity (average illiquidity of the DAX stocks) as a measure of liquidity risk (*Syst_LiquidityRisk*). Panel A of Table 5 provides the corresponding regression results, which are very similar to those in Table 4. In particular, price risk and liquidity risk are still significant, with the expected signs, in the model specifications that use $XLM$ as a measure of illiquidity, while only price risk is significant in the spread regression.

*[ Insert Table 5 about here ]*

In a second robustness check, we use an alternative robust estimator for both stock return volatility and the volatility of the illiquidity measure. In particular, we employ the inter-quartile range (IQR) instead of the standard deviation. The major difference between the two estimators is that the IQR gives no weight to extreme values. Stated differently, it does not react strongly to transitory "price shocks" or "liquidity shocks". Panel B of Table 5 provides the regression results for this alternative specification. The impact of spot market illiquidity, liquidity risk, and time to maturity on the illiquidity of the SSFs market is unchanged. The coefficients for the price risk are positive (as predicted by our model) in all three regressions and are significant in the models that use $XLM$ for a trade size of 50,000 euros and the spread as illiquidity measures. In the $XLM$(100,000) regression the coefficient just falls short of being significant (p-value of 0.12). Taken together, these results imply that our empirical findings are robust to the alternative measures of price and liquidity risk.

### C.3 Effects of Dividends

An important trading motive for SSFs is dividend stripping, because dividends accrue to the holder of stocks but not to the holder of futures. Accordingly, Bialkowski and Jakubowski (2012) show that the trading volume in SSFs rises around ex-dividend dates.[25] The additional demand for trading around ex-dividend dates could have a positive or negative effect on futures market liquidity. One argument is that trading by dividend strippers is uninformed, resulting in higher liquidity because of lower adverse selection costs. On the other hand, if there is a lack of competition between market makers, these could exploit the higher trading demand around ex-dividend dates to increase their profits, resulting in higher market impact costs and thus lower futures market liquidity.[26]

Our base case regression does not control for an effect on liquidity of increased trading activity around ex-dividend dates. As a robustness check, we include a dummy variable that is equal to one for every day in a window set symmetrically around the ex-dividend date (*Dividends*). To further assure the robustness of our results, we use two different windows. The results shown in Panel A of Table 6 are based on a 10-day window, whereas those presented in Panel B are based on a 40-day window.

*[ Insert Table 6 about here ]*

The results in both panels of Table 6 show a positive sign of the dividend

[25] In untabulated results, we find the same effect in our sample.

[26] Baule (2011) shows that market makers anticipate and exploit additional demand in the market for discount certificates.

dummy. This is consistent with the notion that imperfect competition between market makers in the SSFs market allows them to exploit the extra trading demand caused by dividend stripping. However, the coefficients are statistically significant only for the bid–ask spread. Most importantly, the signs and significance levels of all four illiquidity drivers derived from the model are unchanged in both panels, indicating the robustness of our base case results.

### C.4 Effects of Asymmetric Information

Our model describes a specific channel of illiquidity transmission, resulting in a positive relation between spot illiquidity and futures illiquidity. Such a positive relation could, however, also occur for other reasons. A more illiquid spot market for one stock compared to another may just reflect a higher degree of asymmetric information about the stock (Glosten and Milgrom, 1985). Due to the close linkage between spot- and futures prices, this differential in asymmetric information should also affect the corresponding futures markets, resulting in a positive cross-sectional relation between stock illiquidity and futures illiquidity.[27] The same reasoning applies to a single stock when the degree of asymmetric information is time varying, leading to a positive co-movement of stock- and futures illiquidity over time.

To control for the effects of asymmetric information, we include a proxy for the information content of a spot market trade ($InfoCont$) in our regressions. Huang and Stoll (1996) propose to measure the information content of a trade by the

[27] The fixed effects model accounts for such cross-sectional differences to the extent that they are time-invariant.

difference between the effective spread and the realized spread. We adopt their approach. Specifically, we follow Venkataraman (2001) and estimate this difference directly as the (percentage) mid-quote change over a given time interval after a trade, multiplied by the sign of the trade (negative for a seller-initiated trade and positive for a buyer-initiated trade). To ensure the robustness of our results we use two different time horizons (5 minutes and 60 minutes) to calculate the mid-quote changes. Our panel regressions require a daily measure for each stock. We therefore consider all trades on a particular day and calculate a volume-weighted average of the corresponding mid-quote changes.

*[ Insert Table 7 about here ]*

The regression results when considering $InfoCont$ as an additional control are presented in Table 7. Panel A shows the results when the information content of a trade is measured over a 5-minute interval and Panel B shows the corresponding results for a 60-minute interval. A first important finding is a clear effect of the information content of trades in the spot market on futures illiquidity. In all six regressions we obtain significant coefficients with the expected positive sign. If a stock shows a higher degree of asymmetric information, the futures market tends to be more illiquid. However, a second important result is that all variables from the base case specification (Table 4) retain their sign and significance, i.e., our previous results remain stable. The main conclusion from Table 7 thus is that asymmetric information is a driver of futures market illiquidity, but that our inventory-based model also captures important aspects of futures illiquidity. Even after controlling for asymmetric information, our results still support the derivative hedge theory as a (partial) explanation for the positive illiquidity relation between spot and futures markets.

### C.5 Index Futures

We argued in Section III.A that the market for SSFs is very well suited to test the predictions of our model. Market makers in the SSFs market have, in accordance with our model's assumptions, a natural hedging instrument: the underlying stock. Since the SSFs contracts in our sample have designated market makers, the market structure corresponds to that assumed in our model. Further, because SSFs on different stocks are traded on EUREX, we can exploit the cross-sectional dimension of the data. However, there are also two potential drawbacks to using SSF data. First, as documented in Section III.B, the liquidity of the SSFs market is much lower than the liquidity in the market for the underlying stock. Consequently, the SSF contract may not be a very attractive substitute for the underlying. Second, one argument brought forward by Subrahmanyam (1991) in favor of the substitution hypothesis is that informed traders usually hold information on individual stocks and therefore prefer to trade in the spot market for that stock. Uninformed traders, on the other hand, migrate to the index futures market to avoid the adverse selection risk present in the market for individual stocks. This argument does not apply to the SSFs market, because informed traders do not have a natural preference for trading in the market for the underlying. Accordingly, the migration from the component stocks to the index futures is more likely than the migration from a stock to its corresponding SSF, i.e., the substitution effect is likely to be stronger for index futures than for SSFs.

We therefore perform an additional analysis in which we use data for the DAX futures contract. The dependent variables are the bid–ask spread and the $XLM$ measure for the DAX futures contract. Because one DAX futures contract refers to a much larger size (in euros) than one SSF contract, we use the $XLM$ measures for orders of 250,000 euros and 500,000 euros (instead of 50,000 euros and 100,000 euros, respectively). As before, we include data for the short-term and long-term contracts. The independent variables are defined analogously to those used in our main analysis. We measure the liquidity of the underlying by the weighted average of the $XLM_S$ measures of the DAX component stocks.[28] The price and liquidity risk are measured by the standard deviation of daily DAX returns and the standard deviation of the weighted average of the $XLM_S$ measures, both calculated over a rolling 30-day window. We also include a dummy variable that identifies observations for the second-next-to-delivery futures contract. Finally, we use the value-weighted average information content ($InfoCont^{Index}$) of the component stocks as an additional control for asymmetric information effects. The sample period covers the years 2010 and 2011.

Our results are presented in Table 8. In Panel A [Panel B] we measure the information content of trades over 5-minute intervals [60-minute intervals]. With

[28] Rather than considering the markets for index futures and the component stocks, we could consider the index futures market and the market for DAX ETFs. There are two reasons why we discarded this alternative. First, the $XLM$ measure is not available for DAX ETFs. Second, the ETF, like the index futures contract, is a basket. Therefore, informed traders would again have no incentive *a priori* to prefer one market over the other.

two important exceptions they are consistent with the results for SSFs presented earlier. As before, and consistent with the predictions of our model, liquidity in the index futures market as measured by $XLM$ is positively related to the price and the liquidity risk in the spot market. Further, longer-term index futures are less liquid than the next-to-delivery contracts. Also consistent with our earlier theoretical and empirical results, liquidity risk becomes much less important when liquidity is measured by the bid–ask spread rather than by $XLM$.[29]

There are two differences to the results for SSFs, however. First, the average information content of spot market trades does not affect futures market illiquidity when illiquidity is measured by the $XLM$. This is likely to be due to the fact that private information in the spot market for individual stocks is firm-specific and largely cancels out at the index level. Consequently, the liquidity of the index futures contract may (unlike the SSFs markets) not be affected by changes in stock-level informational asymmetries.

Second, the results differ from those for the SSFs with respect to the relation between liquidity in the spot and futures markets. When liquidity is measured by the bid–ask spread, a positive and significant relation exists, as before. However, no such relation is found when liquidity is measured by $XLM$. The latter finding is inconsistent with the predictions of our model. There are two potential explanations for this finding. First, as noted above, informed traders holding private information about individual stocks trade in the spot market or the SSFs market. Uninformed

29 The corresponding coefficient even becomes negative but is only marginally significant at the 10% level.

traders can migrate to the index futures market and have an incentive to do so when the adverse selection risk in the spot market is high (Subrahmanyam, 1991). This results in a negative relation between liquidity in the spot and futures markets. This negative relation is superimposed on the positive relation between liquidity in both markets caused by the market maker's hedging needs. If both effects are of similar strength, they may cancel each other out. It is worth noting, in this context, that the substitution hypothesis and the derivative hedge theory (on which our model is based) are not mutually exclusive.

The second explanation we offer is more prosaic. It may simply be the case that market makers in the index futures market don't hedge their positions in the market for the underlying stocks but, rather, in the ETF market. Unfortunately, the $XLM$ measure is unavailable for the ETF markets. Therefore, we cannot test whether the $XLM$ measures in the markets for index futures and ETFs are positively related.[30]

*[ Insert Table 8 about here ]*

# IV Conclusions

In a frictionless world, spot and futures markets are perfectly liquid and the prices in the two markets are linked by the cost-of-carry relation. In contrast, real-world markets are characterized by illiquidity and liquidity risk. Given the close connection between prices in spot and futures markets, liquidity in the two markets is likely to

[30] Calamia, Deville, and Riva (2016) relate ETF liquidity to the average liquidity of the stocks contained in the ETF. They find a significantly positive relation only for low-volume ETFs. They do not relate ETF liquidity to the liquidity of index futures.

be linked, too. In this paper, we explore this link both theoretically and empirically.

We develop a model of market makers in a competitive futures market who face an exogenous demand and hedge their positions in the spot market. Trading in the spot market is subject to illiquidity, liquidity risk, and price risk. Our model can be thought of as a formalization of the derivative hedge theory proposed by Cho and Engle (1999).

We solve the model for a representative market maker with CARA utility and obtain the equilibrium futures price as a function of the demand for futures. The demand sensitivity of the futures price provides a natural measure of futures illiquidity. According to our model, futures market illiquidity depends on spot market illiquidity and liquidity risk, as well as the risk aversion of the market maker, spot price volatility, and the time to maturity of the futures contract. The effect of the correlation between liquidity risk and price risk is more subtle. It has an asymmetric impact on buy- and sell-side liquidity in the futures market.

We use a panel data set from the German equity market and the market for single stock futures to test the predictions of our model empirically. We find that illiquidity in the futures market is increasing in spot market illiquidity, the liquidity risk in the spot market, spot price volatility, and the futures' time to maturity. These results are consistent with the derivative hedge theory in general and our model in particular. They still hold after controlling for effects of asymmetric information, which provides an alternative explanation for a positive relation between spot illiquidity and futures illiquidity. At the same time, they are clearly inconsistent with the substitution hypothesis, which posits that spot and futures markets are substitutes and their liquidity should be negatively related. In a robustness check, we repeat the empirical analysis using data from the equity market and the market for stock index futures. The results again support our model. However, the relation between illiquidity in the index futures market and the equity market is no longer significant. There are two potential explanations for this finding. First, market makers in the stock index futures markets may not be hedging their positions in the equity market (but, rather, in the ETF market). Second, there may be a substitution effect in the spirit of Subrahmanyam (1991) that counterbalances the positive relation predicted by the derivative hedge theory.

Our findings contribute to a better understanding of liquidity spillovers between spot and futures markets. This is important for investors, exchange operators, and regulators alike. In particular, our results suggest that the quality of quotes set by market makers in derivatives markets cannot be assessed in isolation. Our findings also suggest several promising avenues for future research. The model could be extended to study the liquidity linkage between futures contracts with different maturities. In this case, the market maker has to handle a portfolio of futures contracts rather than a single contract. Similarly, the analysis could be extended to non-linear derivatives, such as options.

# Appendix

This appendix derives the equilibrium futures price $F_*$ and the equilibrium spot market position $X_*$. The optimization problem of the market maker is

$$\max_{H_S, X} \; E[(\widetilde{W}_T)] - \frac{1}{2} A \, Var[(\widetilde{W}_T)]. \tag{8}$$

Using the wealth equation (1) and the joint distribution of $\widetilde{P}_T$ and $\tilde{b}_T$, the expectation and variance of $\widetilde{W}_T$ become

$$E[\widetilde{W}_T] = W_0 + \mu T \, X - 2b_0 X^2 - H_S(P_0 + \mu T - F) \, ,$$

$$Var[\widetilde{W}_T] = (X - H_S)^2 \sigma^2 T + X^4 \eta^2 \, T - 2 \, (X - H_S) \, X^2 \sigma \, \eta \, \rho \, T \, .$$

With these moments, the first-order conditions of the optimization problem read

$$\begin{aligned} & \frac{\partial \big( E[(\widetilde{W}_T)] - \frac{1}{2} A \, Var[(\widetilde{W}_T)] \big)}{\partial H_S} \stackrel{!}{=} 0 \\ \Leftrightarrow \quad & -P_0 - \mu T + F - \frac{1}{2} \, A \, \big[ -2(X - H_S) \sigma^2 T + 2 \, X^2 \sigma \eta \rho \, T \, \big] = 0 \, , \end{aligned} \tag{9}$$

$$\begin{aligned} & \frac{\partial \big( E[(\widetilde{W}_T)] - \frac{1}{2} A \, Var[(\widetilde{W}_T)] \big)}{\partial X} \stackrel{!}{=} 0 \\ \Leftrightarrow \quad & \mu T - 4 b_0 X \\ & -\frac{1}{2} \, A \, \big[ 2(X - H_S) \sigma^2 T + 3 X^3 \eta^2 \, T + (4 H_S X - 6 X^2) \sigma \eta \rho \, T \, \big] = 0 \, . \end{aligned} \tag{10}$$

Equation (9) can be solved for $F$. Substitution of $\mu T$ from equation (10) into equation (9) together with the market clearing condition provides the expression in equation (3). Equation (10) is a third-order polynomial in $X$. It has a unique (real) solution $X_*$, which is as follows:

$$\begin{aligned} X_* &= -\frac{1}{6}\frac{-3^{\frac{1}{3}}(-(N_1+M_1-\sqrt{3}\sqrt{\frac{N_2+M_2}{AT}})A^2T^2)^{\frac{2}{3}}+N_3+M_3}{\eta T(-(N_1+M_1-\sqrt{3}\sqrt{\frac{N_2+M_2}{AT}})A^2T^2)^{\frac{1}{3}}} \\ &\quad +\frac{1}{2}\frac{\sigma\rho AT(-(N_1+M_1-\sqrt{3}\sqrt{\frac{N_2+M_2}{AT}})A^2T^2)^{\frac{1}{3}}}{\eta T(-(N_1+M_1-\sqrt{3}\sqrt{\frac{N_2+M_2}{AT}})A^2T^2)^{\frac{1}{3}}}, \end{aligned} \tag{11}$$

with

$$N_1 \equiv 36\sigma\rho b_0 + 9\sigma^3\rho AT - 18\eta Tm - 9\sigma^3\rho^3 AT,$$

$$M_1 \equiv (18\sigma^2\rho^2 A\eta T - 18\eta TA\sigma^2)H_*,$$

$$\begin{aligned} N_2 \equiv [&512b_0^3 + 384b_0^2A\sigma^2 - 144b_0^2\sigma^2\rho^2A + 96b_0A^2\sigma^4T - 72b_0A^2\sigma^4\rho^2T - 432A\sigma\rho b_0\eta\mu T \\ &- 9A^3\sigma^6\rho^2T^2 + 108A\eta^2\mu^2T^2 + 8A^3\sigma^6T^2 - 108A^2\sigma^3\rho\eta\mu T^2 + 108A^2\eta\mu\sigma^3\rho^3T^2]T, \end{aligned}$$

$$M_2 \equiv [768b_0^2 A\sigma\eta\rho T + 216A^2T^3\eta^2\mu\sigma^2 - 216A^2T^3\sigma^2\rho^2\eta^2\mu + 72A^3\sigma^5T^3\eta\rho^3$$
$$- 48b_0A^2\sigma^3T^2\eta\rho - 60A^3\sigma^5T^3\eta\rho - 144b_0A^2\sigma^3\eta\rho^3T^2 - 120A^3\sigma^4T^3\eta^2\rho^2H_*$$
$$- 36A^3\sigma^4\eta^2\rho^4T^3H_* + 108A^3T^3\eta^2\sigma^4H_* + 384b_0A^2\sigma^2\eta^2\rho^2T^2H_*$$
$$+ 64A^3\sigma^3\eta^3\rho^3T^3H_*^2]H_*,$$

$$N_3 \equiv 83^{\frac{2}{3}}ATb_0 + 23^{\frac{2}{3}}A^2T^2\sigma^2 - 33^{\frac{2}{3}}A^2T^2\sigma^2\rho^2,$$

$$M_3 \equiv 43^{\frac{2}{3}}A^2T^2\sigma\eta\rho H_*.$$

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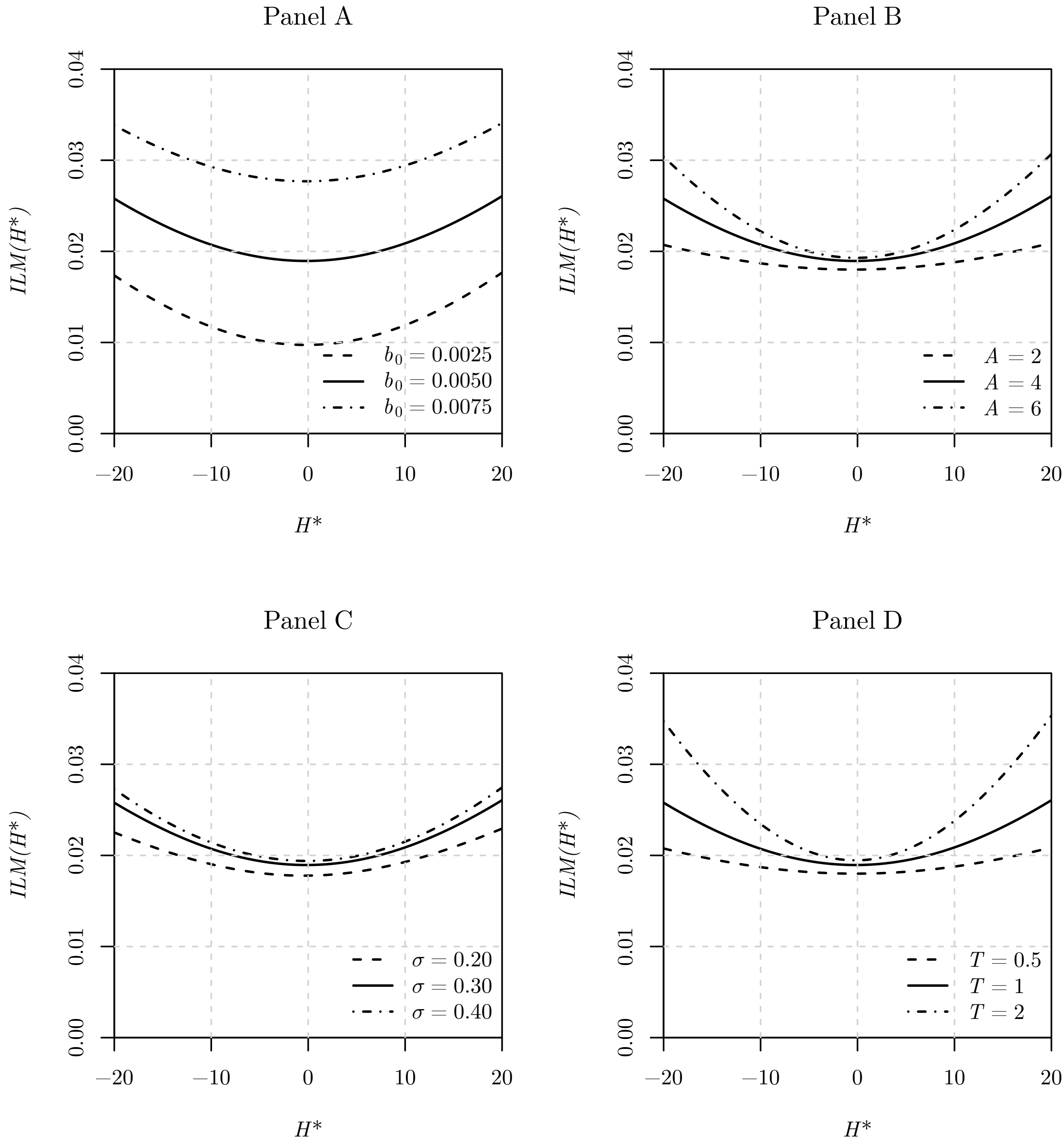


**Figure 1: Futures illiquidity: Effects of spot market illiquidity, risk aversion, spot market volatility, and time to maturity.** This figure shows $ILM(H)$ for different levels of spot market illiquidity ($b_0$, Panel A), different levels of risk aversion of the market maker ($A$, Panel B), different spot market volatilities ($\sigma$, Panel C), and different times to maturity of the futures ($T$, Panel D). The base case parameters are $\mu = 5\%$ per year, $\sigma = 30\%$ per year, $b_0 = 0.5\%$, $\eta = 0.2\%$ per year, $\rho = 0$, $A = 4$, and $T = 1$.

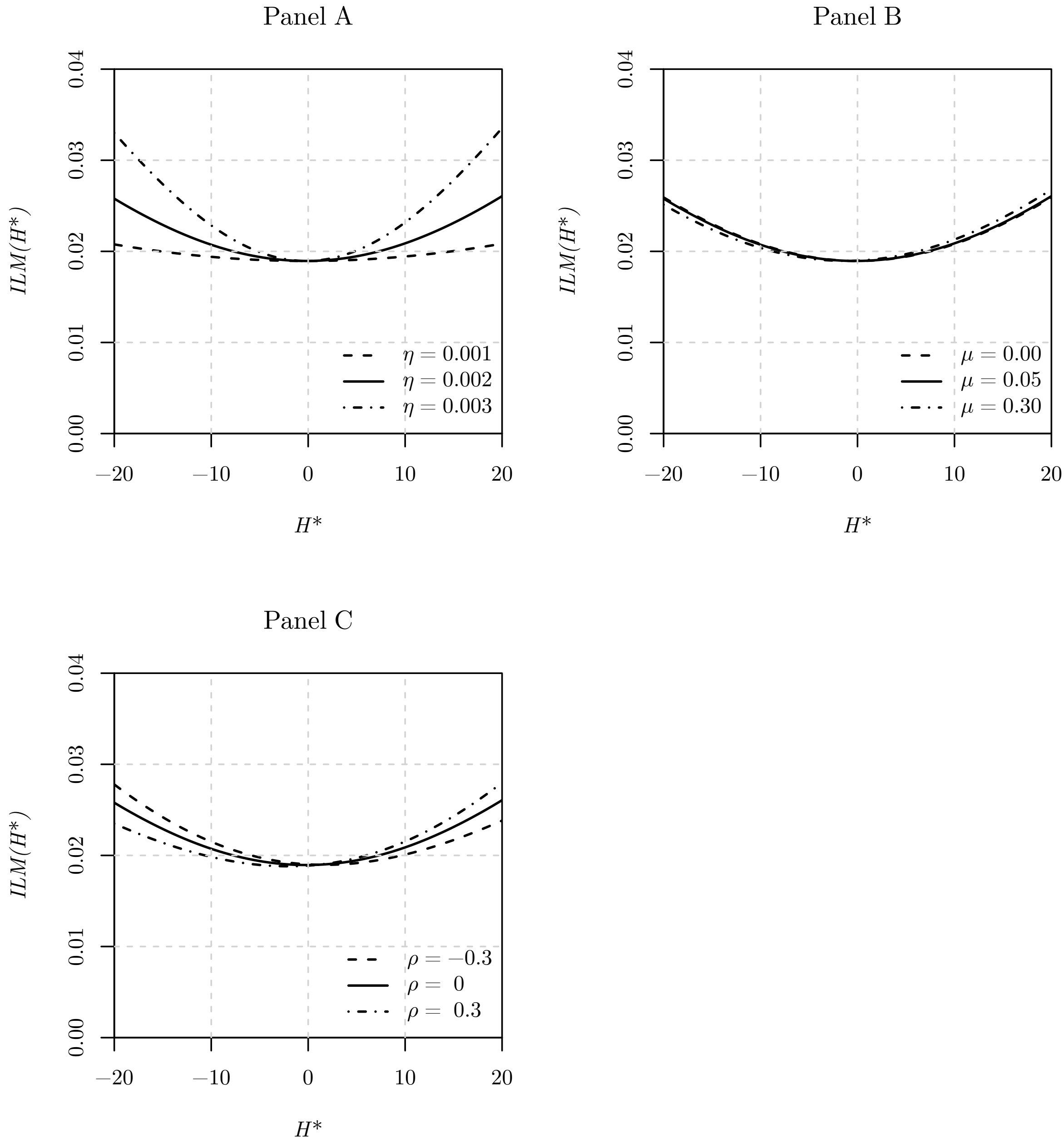


**Figure 2: Futures illiquidity: Effects of illiquidity risk, the expected spot price change, and the correlation between price risk and illiquidity risk.** This figure shows $ILM(H)$ for different levels of liquidity risk ($\eta$, Panel A), different expected price changes of the spot asset ($\mu$, Panel B), and different correlations between price risk and liquidity risk ($\rho$, Panel C). The base case parameters are $\mu = 5\%$ per year, $\sigma = 30\%$ per year, $b_0 = 0.5\%$, $\eta = 0.2\%$ per year, $\rho = 0$, $A = 4$, and $T = 1$.

| | Illiquidity Measure Stocks ($XLM_S$ in bps) | | | | | |
|---|---|---|---|---|---|---|
| | 50,000 euros | | | 100,000 euros | | |
| | Mean | Median | N | Mean | Median | N |
| Siemens | 5.24 | 4.68 | 510 | 5.90 | 5.63 | 509 |
| SAP | 5.77 | 5.00 | 510 | 6.62 | 6.11 | 509 |
| Deutsche Telekom | 5.94 | 6.15 | 509 | 6.94 | 7.01 | 509 |
| E.ON | 6.13 | 5.18 | 508 | 6.97 | 6.25 | 507 |
| BASF | 6.25 | 5.65 | 510 | 7.16 | 6.84 | 509 |
| Allianz | 6.29 | 5.77 | 509 | 7.57 | 6.99 | 509 |
| RWE | 6.46 | 5.52 | 510 | 7.59 | 6.84 | 509 |
| Deutsche Bank | 6.46 | 5.75 | 510 | 7.92 | 7.01 | 510 |
| Daimler | 6.61 | 6.12 | 509 | 8.12 | 7.42 | 509 |
| Bayer | 6.69 | 5.87 | 509 | 7.57 | 7.06 | 508 |
| BMW | 7.88 | 7.49 | 510 | 9.21 | 9.17 | 509 |
| Munich Rück | 8.14 | 7.74 | 510 | 9.10 | 8.95 | 509 |
| Fresenius | 9.16 | 8.28 | 509 | 11.06 | 10.38 | 509 |
| Adidas | 9.29 | 8.81 | 509 | 11.69 | 11.14 | 509 |
| Linde | 9.44 | 8.70 | 510 | 10.94 | 10.40 | 509 |
| Thyssen Krupp | 9.45 | 8.26 | 510 | 11.36 | 10.41 | 509 |
| Deutsche Börse | 9.53 | 8.66 | 509 | 11.82 | 10.58 | 509 |
| Merck | 9.56 | 8.92 | 509 | 11.99 | 11.43 | 509 |
| Henkel | 9.83 | 9.09 | 510 | 11.94 | 11.51 | 509 |
| Deutsche Post | 9.89 | 9.46 | 509 | 12.01 | 11.49 | 509 |
| Beiersdorf | 9.93 | 9.49 | 509 | 12.37 | 11.81 | 509 |
| Metro | 10.00 | 8.91 | 509 | 12.15 | 11.31 | 508 |
| K+S | 10.09 | 9.30 | 509 | 12.63 | 11.91 | 509 |
| Volkswagen Vz | 10.09 | 10.07 | 509 | 12.46 | 12.20 | 509 |
| MAN | 10.30 | 9.19 | 509 | 12.84 | 11.47 | 509 |
| Infineon | 10.57 | 10.10 | 508 | 13.53 | 13.04 | 508 |
| Fresenius Medical Care | 10.88 | 10.77 | 508 | 13.63 | 13.43 | 507 |
| Lufthansa | 11.55 | 10.87 | 509 | 14.28 | 13.47 | 509 |
| Salzgitter | 11.96 | 11.88 | 118 | 14.78 | 14.83 | 118 |
| Commerzbank | 12.88 | 11.94 | 509 | 16.87 | 16.34 | 509 |
| Heidelberg Cement | 13.10 | 11.71 | 392 | 16.06 | 15.76 | 391 |

**Table 1: Descriptive Statistics of the Illiquidity Measure for the Spot Market.** This table reports the mean, median, and number of daily observations (N) of the $XLM_S$ illiquidity measure for sizes of 50,000 euros and 100,000 euros for different stocks. The sample period ranges from January 2010 to December 2011.

| | Illiquidity Measure Futures ($XLM_F$ in bps) | | | | | |
|---|---|---|---|---|---|---|
| | 50,000 euros | | | 100,000 euros | | |
| | Mean | Median | N | Mean | Median | N |
| K+S | 27.51 | 28.25 | 13 | - | - | - |
| Salzgitter | 29.58 | 29.77 | 8 | - | - | - |
| Henkel | 32.87 | 23.80 | 31 | - | - | - |
| Volkswagen Vz. | 49.17 | 38.03 | 576 | 48.90 | 37.48 | 555 |
| RWE | 63.32 | 41.27 | 991 | 67.93 | 45.05 | 982 |
| Merck | 64.26 | 66.95 | 330 | 77.20 | 95.61 | 282 |
| Deutsche Börse | 66.10 | 36.02 | 550 | 88.29 | 84.09 | 250 |
| E.ON | 70.52 | 46.02 | 801 | 80.26 | 53.71 | 660 |
| BASF | 71.84 | 57.84 | 899 | 73.47 | 57.74 | 828 |
| Siemens | 74.06 | 41.97 | 1006 | 71.49 | 44.84 | 987 |
| SAP | 74.70 | 58.69 | 312 | 45.58 | 29.91 | 204 |
| Allianz | 76.41 | 44.13 | 359 | 80.85 | 51.72 | 333 |
| Daimler | 78.47 | 46.38 | 971 | 87.81 | 76.13 | 966 |
| Beiersdorf | 79.11 | 50.28 | 483 | 95.06 | 96.19 | 99 |
| Bayer | 81.21 | 67.77 | 972 | 84.86 | 76.16 | 956 |
| BMW | 81.40 | 64.83 | 965 | 107.17 | 107.80 | 944 |
| Münchener Rück | 86.87 | 56.53 | 361 | 59.03 | 37.17 | 293 |
| MAN | 87.58 | 94.80 | 687 | 104.69 | 105.96 | 649 |
| Linde | 100.07 | 94.62 | 950 | 115.79 | 113.22 | 932 |
| Fresenius | 108.96 | 81.33 | 346 | 131.10 | 117.58 | 293 |
| Lufthansa | 119.52 | 111.10 | 858 | 176.15 | 141.92 | 292 |
| Deutsche Bank | 120.58 | 113.68 | 617 | 125.35 | 115.02 | 616 |
| Deutsche Telekom | 130.50 | 77.23 | 925 | 67.42 | 45.88 | 600 |
| Metro | 134.47 | 128.28 | 919 | 144.04 | 133.74 | 909 |
| Deutsche Post | 134.99 | 114.82 | 926 | 169.98 | 161.44 | 242 |
| ThyssenKrupp | 135.06 | 122.86 | 937 | 157.44 | 135.69 | 861 |
| Fresenius Medical Care | 145.06 | 137.83 | 922 | 153.90 | 146.46 | 920 |
| Heidelberg Cement | 150.49 | 141.54 | 727 | 159.48 | 148.01 | 724 |
| Infineon | 160.06 | 151.49 | 396 | 167.33 | 157.19 | 91 |
| Commerzbank | 290.14 | 194.21 | 340 | 244.59 | 119.61 | 106 |

**Table 2: Descriptive Statistics of the Illiquidity Measure for the Futures Market.** This table reports the mean, median, and number of daily observations (N) of the $XLM_F$ illiquidity measure for order sizes of 50,000 euros and 100,000 euros for different SSFs. The data refer to the futures contracts with the shortest and second shortest maturities. However, no observations from the maturity month are included. The sample period ranges from January 2010 to December 2011.

| | Bid–Ask Spread (in bp) | | | | | |
|---|---|---|---|---|---|---|
| | Stocks ($Spread_S$) | | | Futures ($Spread_F$) | | |
| | Mean | Median | N | Mean | Median | N |
| Siemens | 4.64 | 4.15 | 497 | 137.73 | 109.82 | 990 |
| SAP | 5.17 | 4.77 | 497 | 137.03 | 104.97 | 994 |
| RWE | 5.19 | 4.37 | 497 | 117.83 | 112.84 | 975 |
| BASF | 5.60 | 4.95 | 497 | 147.76 | 108.58 | 926 |
| Allianz | 5.72 | 4.91 | 497 | 122.95 | 105.29 | 994 |
| E.ON | 5.94 | 4.59 | 497 | 133.31 | 102.71 | 959 |
| Deutsche Bank | 5.94 | 4.90 | 497 | 167.48 | 114.05 | 982 |
| Daimler | 5.99 | 5.61 | 497 | 160.22 | 112.56 | 956 |
| Bayer | 6.05 | 5.22 | 497 | 164.74 | 117.13 | 966 |
| BMW | 7.36 | 6.59 | 497 | 152.95 | 114.83 | 948 |
| Fresenius Medical Care | 7.38 | 6.47 | 497 | 139.76 | 139.90 | 939 |
| ThyssenKrupp | 7.45 | 6.79 | 497 | 131.87 | 117.09 | 983 |
| Münchener Rück | 7.71 | 8.05 | 497 | 269.87 | 132.13 | 382 |
| Henkel | 7.94 | 7.02 | 497 | 34.90 | 34.90 | 6 |
| Linde | 8.05 | 8.18 | 497 | 140.11 | 140.09 | 942 |
| Merck | 8.19 | 6.68 | 497 | 46.99 | 28.15 | 596 |
| Metro | 8.40 | 6.97 | 497 | 178.47 | 132.22 | 937 |
| Adidas | 8.47 | 7.03 | 497 | 138.48 | 133.51 | 941 |
| K+S | 8.84 | 7.41 | 497 | 29.23 | 28.04 | 429 |
| MAN | 9.08 | 7.24 | 497 | 102.95 | 115.31 | 711 |
| Volkswagen Vz. | 9.08 | 8.20 | 497 | 43.73 | 28.12 | 574 |
| Beiersdorf | 9.13 | 7.31 | 497 | 60.03 | 39.83 | 812 |
| Deutsche Post | 10.30 | 7.96 | 497 | 112.58 | 109.79 | 942 |
| Deutsche Telekom | 10.81 | 9.99 | 497 | 132.25 | 106.82 | 990 |
| Heidelberg Cement | 11.12 | 8.76 | 379 | 155.73 | 149.10 | 742 |
| Salzgitter | 11.16 | 10.27 | 118 | 35.45 | 32.90 | 20 |
| Lufthansa | 11.20 | 8.89 | 497 | 131.23 | 114.96 | 937 |
| Deutsche Börse | 12.42 | 7.52 | 497 | 66.04 | 28.31 | 613 |
| Fresenius | 15.70 | 11.57 | 497 | 78.82 | 28.09 | 596 |
| Infineon | 18.02 | 17.04 | 497 | 186.13 | 116.63 | 994 |
| Commerzbank | 20.82 | 16.88 | 497 | 202.43 | 120.64 | 761 |

**Table 3: Descriptive Statistics of the Bid–Ask Spread for the Spot and Futures Markets.** This table reports the mean, median, and number of daily observations (N) of the $Spread_S$ and $Spread_F$ illiquidity measures for different stocks and SSFs. The sample period ranges from January 2010 to December 2011.

## Table 4: Determinants of Futures Illiquidity: Base Case Results.

| | $XLM_F$ | | | $Spread_F$ |
|---|---|---|---|---|
| | 50,000 euros | 100,000 euros | | |
| $XLM_S$ | 0.223*** | 0.936** | $Spread_S$ | 0.841*** |
| | *(0.000)* | *(0.016)* | | *(0.001)* |
| $Volatility$ | 0.006*** | 0.004** | $Volatility$ | 0.025*** |
| | *(0.002)* | *(0.036)* | | *(0.000)* |
| $LiqRisk$ | 0.002*** | 0.002*** | $LiqRisk_{Spread}$ | -0.005 |
| | *(0.000)* | *(0.000)* | | *(0.956)* |
| $Maturity$ | 0.173*** | 0.149*** | $Maturity$ | 0.121*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $Constant$ | 0.729*** | 0.755*** | $Constant$ | 0.503*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 18,886 | 15,189 | | 21,988 |
| within-$R^2$ | 0.0216 | 0.0627 | | 0.0480 |

This table reports the results of fixed effects panel regressions with the illiquidity of the futures market as the dependent variable. The dependent variable of the first two regressions is $XLM_F$ for volumes of 50,000 euros and 100,000 euros, respectively. The explanatory variables are $XLM_S$, $Volatility$, $LiqRisk$, and $Maturity$. The dependent variable of the third regression is $Spread_F$. The explanatory variables are $Spread_S$, $Volatility$, $LiqRisk_{Spread}$, and $Maturity$. The value reported as $Constant$ is the mean fixed effect. The p-values are in parentheses. They are obtained from clustered standard errors using a clustering by firms. The data period is January 2010 to December 2011. The superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

## Table 5: Determinants of Futures Illiquidity: Effects of Alternative Risk Measures.

**Panel A: Systematic Risk**

| | $XLM_F$ | | | $Spread_F$ |
|---|---|---|---|---|
| | 50,000 euros | 100,000 euros | | |
| $XLM_S$ | 0.226*** | 0.970** | $Spread_S$ | 0.864*** |
| | *(0.002)* | *(0.013)* | | *(0.001)* |
| $Syst\_Risk$ | 0.031*** | 0.020** | $Syst\_Risk$ | 0.148*** |
| | *(0.001)* | *(0.035)* | | *(0.000)* |
| $Syst\_LiqRisk$ | 0.007*** | 0.006*** | $Syst\_LiqRisk_{Spread}$ | -75.995 |
| | *(0.000)* | *(0.000)* | | *(0.200)* |
| $Maturity$ | 0.173*** | 0.149*** | $Maturity$ | 0.120*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $Constant$ | 0.853*** | 0.834*** | $Constant$ | 0.945*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 18,860 | 15,189 | | 21,988 |
| within-$R^2$ | 0.0192 | 0.0640 | | 0.0532 |

**Panel B: Robust Risk Estimators**

| | $XLM_F$ | | | $Spread_F$ |
|---|---|---|---|---|
| | 50,000 euros | 100,000 euros | | |
| $XLM_S$ | 0.228*** | 0.974** | $Spread_S$ | 1.056*** |
| | *(0.001)* | *(0.015)* | | *(0.000)* |
| $IQR\_Volatility$ | 0.003*** | 0.002 | $IQR\_Volatility$ | 0.013*** |
| | *(0.005)* | *(0.112)* | | *(0.000)* |
| $IQR\_LiqRisk$ | 0.392** | 0.226** | $IQR\_LiqRisk_{Spread}$ | 0.096 |
| | *(0.032)* | *(0.047)* | | *(0.236)* |
| $Maturity$ | 0.173*** | 0.150*** | $Maturity$ | 0.120*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $Constant$ | 0.732*** | 0.759*** | $Constant$ | 0.662*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 18,860 | 15,189 | | 21,988 |
| within-$R^2$ | 0.0399 | 0.0738 | | 0.0416 |

This table reports the results of fixed effects panel regressions with the illiquidity of the futures market as the dependent variable. The dependent variable of the first two regressions is $XLM_F$ for volumes of 50,000 euros and 100,000 euros, respectively. The explanatory variables are $XLM_S$, $Syst\_Risk$ (Panel A), $Syst\_LiqRisk$ (Panel A), $IQR\_Volatility$ (Panel B), $IQR\_LiqRisk$ (Panel B), and $Maturity$. The variable $Syst\_Risk$ is defined as the covariance between stock returns and index returns, estimated over the 30 previous trading days, and $IQR\_Volatility$ is the inter-quartile range of the stock returns. The variable $Syst\_LiqRisk$ is the covariance between stock illiquidity and market illiquidity (average illiquidity of the DAX stocks), estimated over the 30 previous trading days, and $IQR\_LiqRisk$ denotes the inter-quartile range of the daily $XLM_S$ measures of the previous 30 trading days. The dependent variable of the third regression is $Spread_F$. The explanatory variables are $Spread_S$, $Syst\_Risk$ (Panel A), $Syst\_LiqRisk_{Spread}$ (Panel A) , $IQR\_Volatility$ (Panel B), $IQR\_LiqRisk_{Spread}$ (Panel B), and $Maturity$. The value reported as $Constant$ is the mean fixed effect. The p-values are in parentheses. They are obtained from clustered standard errors using a clustering by firms. The data period is January 2010 to December 2011. The superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

## Table 6: Determinants of Futures Illiquidity: Effects of Dividends.

**Panel A: 10 Days around the Dividend Date**

| | $XLM_F$ | | | $Spread_F$ |
|---|---|---|---|---|
| | 50,000 euros | 100,000 euros | | |
| $XLM_S$ | 0.224*** | 0.940** | $Spread_S$ | 0.848*** |
| | *(0.000)* | *(0.016)* | | *(0.001)* |
| $Volatility$ | 0.006*** | 0.004** | $Volatility$ | 0.025*** |
| | *(0.002)* | *(0.034)* | | *(0.000)* |
| $LiqRisk$ | 0.002*** | 0.002*** | $LiqRisiko_{Spread}$ | -0.000 |
| | *(0.000)* | *(0.000)* | | *(0.998)* |
| $Maturity$ | 0.173*** | 0.150*** | $Maturity$ | 0.120*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $Dividends_{10days}$ | 0.099 | 0.068 | $Dividends_{10days}$ | 0.122*** |
| | *(0.211)* | *(0.408)* | | *(0.000)* |
| $Constant$ | 0.723*** | 0.750*** | $Constant$ | 0.487*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 18,860 | 15,189 | | 21,988 |
| within-$R^2$ | 0.0216 | 0.0629 | | 0.0486 |

**Panel B: 40 Days around the Dividend Date**

| | $XLM_F$ | | | $Spread_F$ |
|---|---|---|---|---|
| | 50,000 euros | 100,000 euros | | |
| $XLM_A$ | 0.229*** | 0.956** | $Spread_A$ | 0.897*** |
| | *(0.000)* | *(0.016)* | | *(0.000)* |
| $Volatility$ | 0.006*** | 0.004** | $Volatility$ | 0.025*** |
| | *(0.001)* | *(0.032)* | | *(0.000)* |
| $LiqRisk$ | 0.002*** | 0.002*** | $LiqRisiko_{Spread}$ | 0.027 |
| | *(0.000)* | *(0.000)* | | *(0.729)* |
| $Maturity$ | 0.173*** | 0.149*** | $Maturity$ | 0.121*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $Dividends_{40days}$ | 0.095 | 0.056 | $Dividends_{40days}$ | 0.286*** |
| | *(0.121)* | *(0.334)* | | *(0.000)* |
| $Constant$ | 0.708*** | 0.742*** | $Constant$ | 0.441*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 18,860 | 15,189 | | 21,988 |
| within-$R^2$ | 0.0218 | 0.0634 | | 0.0498 |

This table reports the results of fixed effects panel regressions with the illiquidity of the futures market as the dependent variable. The dependent variable of the first two regressions is $XLM_F$ for volumes of 50,000 euros and 100,000 euros, respectively. The explanatory variables are $XLM_S$, $Volatility$, $LiqRisk$, $Maturity$, $Dividends_{10days}$ (Panel A), and $Dividends_{40days}$ (Panel B). The variable *Dividends* denotes a dummy variable that takes the value of one if the corresponding day falls within a 10-day (40-day) window around the ex-dividend date. The dependent variable of the third regression is $Spread_F$. The explanatory variables are $Spread_S$, $Volatility$, $LiqRisk_{Spread}$, $Maturity$, $Dividends_{10days}$ (Panel A), and $Dividends_{40days}$ (Panel B). The value reported as *Constant* is the mean fixed effect. The p-values are in parentheses. They are obtained from clustered standard errors using a clustering by firms. The data period is January 2010 to December 2011. The superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

## Table 7: Determinants of Futures Illiquidity: Effects of Asymmetric Information.

**Panel A: Information content measured over 5-minute intervals**

| | $XLM_F$ | | | $Spread_F$ |
|---|---|---|---|---|
| | 50,000 euros | 100,000 euros | | |
| $XLM_S$ | 0.219*** | 0.890** | $Spread_S$ | 0.830*** |
| | *(0.000)* | *(0.017)* | | *(0.001)* |
| *Volatility* | 0.006*** | 0.003* | *Volatility* | 0.025*** |
| | *(0.004)* | *(0.066)* | | *(0.000)* |
| *LiqRisk* | 0.002*** | 0.002*** | $LiqRisiko_{Spread}$ | -0.014 |
| | *(0.000)* | *(0.000)* | | *(0.895)* |
| *Maturity* | 0.178*** | 0.156*** | *Maturity* | 0.121*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $InfoCont_{5min}$ | 0.097*** | 0.074*** | $InfoCont_{5min}$ | 0.110* |
| | *(0.002)* | *(0.003)* | | *(0.088)* |
| *Constant* | 0.731*** | 0.759*** | *Constant* | 0.501*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 18,175 | 14,593 | | 21,821 |
| within-$R^2$ | 0.0216 | 0.0629 | | 0.0486 |

**Panel B: Information content measured over 60-minute intervals**

| | $XLM_F$ | | | $Spread_F$ |
|---|---|---|---|---|
| | 50,000 euros | 100,000 euros | | |
| $XLM_A$ | 0.217*** | 0.888** | $Spread_A$ | 0.828*** |
| | *(0.000)* | *(0.017)* | | *(0.001)* |
| *Volatility* | 0.006*** | 0.004* | *Volatility* | 0.025*** |
| | *(0.005)* | *(0.067)* | | *(0.000)* |
| *LiqRisk* | 0.002*** | 0.002*** | $LiqRisiko_{Spread}$ | -0.014 |
| | *(0.000)* | *(0.000)* | | *(0.891)* |
| *Maturity* | 0.178*** | 0.149*** | *Maturity* | 0.121*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $InfoCont_{60min}$ | 0.129*** | 0.105*** | $InfoCont_{60min}$ | 0.166** |
| | *(0.001)* | *(0.000)* | | *(0.036)* |
| *Constant* | 0.723*** | 0.759*** | *Constant* | 0.500*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 18,175 | 14,593 | | 21,821 |
| within-$R^2$ | 0.0218 | 0.0634 | | 0.0498 |

This table reports the results of fixed effects panel regressions with the illiquidity of the futures market as the dependent variable. The dependent variable of the first two regressions is $XLM_F$ for volumes of 50,000 euros and 100,000 euros, respectively. The explanatory variables are $XLM_S$, *Volatility*, *LiqRisk*, *Maturity*, $InfoCont_{5min}$ (Panel A), and $InfoCont_{60min}$ (Panel B). The variable $InfoCont_{5min}$ denotes the weighted average (weighted by trade size) signed (with respect to buyer- or seller initiated trades) mid-quote change of the corresponding stock over a 5-minute period after a trade. $InfoCont_{60min}$ is the analogous variable for a 60-minute period. The dependent variable of the third regression is $Spread_F$. The explanatory variables are $Spread_S$, *Volatility*, $LiqRisk_{Spread}$, *Maturity*, $InfoCont_{5min}$ (Panel A), and $InfoCont_{60min}$ (Panel B). The value reported as *Constant* is the mean fixed effect. The p-values are in parentheses. They are obtained from clustered standard errors using a clustering by firms. The data period is January 2010 to December 2011. The superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

## Table 8: Determinants of Futures Illiquidity: Results for Index Futures.

**Panel A: Information content measured over 5-minute intervals**

| | $XLM_F^{Index}$ | | | |
|---|---|---|---|---|
| | 250,000 euros | 500,000 euros | | $Spread_F^{Index}$ |
| $XLM_S^{Index}$ | 0.9924 | 1.0834 | $Spread_S^{Index}$ | 0.0435*** |
| | *(0.543)* | *(0.396)* | | *(0.000)* |
| $Volatility$ | 0.0165*** | 0.0184*** | $Volatility$ | 0.0003*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $LiqRisk$ | 0.7034*** | 0.6287*** | $LiqRisk_{Spread}$ | -0.0033* |
| | *(0.009)* | *(0.002)* | | *(0.084)* |
| $Maturity$ | 1.1149*** | 1.4140*** | $Maturity$ | 0.0086*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $InfoCont_{5min}^{Index}$ | -1.8963 | -0.9697 | $InfoCont_{5min}^{Index}$ | 0.0200** |
| | *(0.202)* | *(0.504)* | | *(0.039)* |
| $Constant$ | -0.476*** | -0.6516*** | $Constant$ | 0.0041*** |
| | *(0.001)* | *(0.000)* | | *(0.000)* |
| Observations | 917 | 888 | | 930 |
| adj.-$R^2$ | 0.3547 | 0.4160 | | 0.5184 |

**Panel B: Information content measured over 60-minute intervals**

| | $XLM_F^{Index}$ | | | |
|---|---|---|---|---|
| | 250,000 euros | 500,000 euros | | $Spread_F^{Index}$ |
| $XLM_S^{Index}$ | 0.5324 | 0.8171 | $Spread_S^{Index}$ | 0.0452*** |
| | *(0.745)* | *(0.517)* | | *(0.000)* |
| $Volatility$ | 0.0171*** | 0.0190*** | $Volatility$ | 0.0003*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $LiqRisk$ | 0.7338*** | 0.6442*** | $LiqRisk_{Spread}$ | -0.0032* |
| | *(0.008)* | *(0.002)* | | *(0.094)* |
| $Maturity$ | 1.1150*** | 1.4141*** | $Maturity$ | 0.0086*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| $InfoCont_{60min}^{Index}$ | -0.4297 | 0.4428 | $InfoCont_{60min}^{Index}$ | 0.8794 |
| | *(0.738)* | *(0.769)* | | *(0.345)* |
| $Constant$ | -0.4902*** | -0.6649*** | $Constant$ | 0.0044*** |
| | *(0.000)* | *(0.000)* | | *(0.000)* |
| Observations | 917 | 888 | | 930 |
| adj.-$R^2$ | 0.3536 | 0.4159 | | 0.5167 |

This table reports the results of regressions with the illiquidity of the index futures market as the dependent variable. The dependent variable of the first two regressions is $XLM_F^{Index}$ for volumes of 250,000 euros and 500,000 euros, respectively. The explanatory variables are $XLM_S^{Index}$, $Volatility$, $LiqRisk$, $Maturity$, $InfoCont_{5min}^{Index}$ (Panel A), and $InfoCont_{60min}^{Index}$ (Panel B), where $XLM_S^{Index}$ is the weighted average $XLM$ measure of the component stocks and $Volatility$ and $LiqRisk$ are the volatility and illiquidity risk of the index futures, respectively. The variable $InfoCont_{5min}^{Index}$ denotes the weighted average of the corresponding measures for the component stocks. $InfoCont_{60min}^{Index}$ is the analogous variable for a 60-minute period. The dependent variable of the third regression is $Spread_F^{Spread}$. The explanatory variables are $Spread_S^{Index}$, $Volatility$, $LiqRisk_{Spread}$, $Maturity$, $InfoCont_{5min}^{Index}$ (Panel A), and $InfoCont_{60min}^{Index}$ (Panel B), where $Spread_S^{Index}$ is the weighted average bid-ask spread of the component stocks and $LiqRisk_{Spread}$ is the volatility of the spread. The data period is January 2010 to December 2011. The superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

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