Hedging Costs vs. Counterparty Risk: What Explains the Pricing of Structured Products During the 2007-2009 Financial Crisis? *

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Abstract

I examine the effect of Lehman Brothers' bankruptcy on the prices of exchange traded structured index products during the financial crisis of 2007-2009. I document a significant drop in their premia, as well as an asymmetric widening of their bid-ask spreads in the post September 2008 period. The effect is most pronounced in structured products on indices that are difficult to hedge. The results suggest that market maker hedging costs have become a major trading cost component of structured products following the default of Lehman Brothers. Issuer credit risk does not explain the drop in the premia.

1 Introduction

Exchange-traded structured products issued by financial institutions have become a global multi-trillion dollar market.[1] Institutional and retail investors use structured products to receive tailor-made payoff structures, or to complement their portfolios with exotic assets in which they could otherwise not invest. Despite their increasing popularity, structured products are considered opaque, and have remained underinvestigated in academic research. The financial crisis of 2007-2009 has prompted investors and financial regulators to scrutinize the market more closely.[2] In particular, there is a lack of understanding of the secondary market price determinants in conditions of market turmoil. In this paper, I provide evidence that market maker hedging costs have been a substantial trading cost component of structured products during the financial crisis.

Structured products can replicate a security, an index, or a basket of securities. They may include derivatives, such as a call option to increase the upside potential or a put option to provide principal protection. In contrast to other tracking products, e.g. closed-end funds or exchange traded funds, structured products are synthetic. That is, issuers of structured products only *promise* investors a one-to-one participation in the performance of the underlying, but they do not need to own the underlying assets nor provide any collateral. Typically, issuers replicate the performance of the underlying via derivatives but there are no disclosure requirements regarding the replication approach. Structured products are listed on separate warrant segments of an exchange. Academic studies refer to these exchange-listed structured products as "structured notes" (Bergstresser 2008), "structured equity products" (Henderson and Pearson 2011), "covered warrants" (Petrella 2006) or "derivative warrants" (Li and Zhang 2011).[3]

[1] The global open interest is estimated to be approximately $2tn. "Industry aims to keep it simple(r)" by Telis Demos, 14 May 2012, Financial Times.

[2] "SEC Staff Issues Summary Report of Sweep Examination of Structured Products Sold to Retail Investors", SEC press release no. 2011-157, 27 July 2011.

[3] Synonymous names can be exchange traded (structured) notes, equity-linked notes, structured

After the default of Lehman Brothers, when structured products issued by Lehman Brothers, known as the Lehman Notes, became worthless, the public media speculated that issuer credit risk should have become a price determinant of structured products. While bank default risk had played a relatively minor role before the financial crisis, the demise of Lehman Brothers led to a reassessment of bank risk. Since the issuing financial institutions guarantee the performance replication of the underlying without any collateral, one would expect that the prices of structured products issued by relatively riskier banks have declined more after Lehman's default than those of similar products issued by less riskier banks. Such a price adjustment has been observed in the Over-The-Counter (OTC) market for credit default swaps (CDS) (Arora, Gandhi, and Longstaff 2012, Shachar 2012), but no such evidence exists for structured products.

Due to the unique trading mechanisms in the structured products market, another price determinant that may have gained importance during the financial crisis is market maker hedging costs. Exchange operators typically require the issuing bank to be the market maker for its own products, and to provide continually updated, actionable quotes on the exchange. Because the secondary market volume of structured products is generally low, most of the time investors end up trading with the market maker, which is the issuing bank. In order to keep a neutral trading position without speculating in either direction of the underlying, issuers engage in hedging transactions to keep their portfolio value immune from changes in the value of the underlying. After the default of Lehman Brothers when many markets suffered from extreme illiquidity, risk-hedging could have become more costly for issuers and ultimately affected the pricing of structured products. While no such evidence exists for structured products, research in the options market suggests that market maker hedging costs can be an important trading cost component (Engle and Sarkar 2010).

securities products or structured retail products.

This paper analyzes how structured products were impacted by the financial crisis of 2007-2009, and tries to identify which of these two determinants is most relevant in explaining the prices of structured products after the default of Lehman Brothers. I employ a unique dataset of structured index products listed in Germany. In terms of the number of securities listed, the German market is the largest structured products market in the world.[4] In Germany, structured products are called "certificates" (*Zertifikate* in German). I will use the term throughout the paper.[5]

These index certificates have only an index as their underlying. Examining structured index products is advantageous because their intrinsic prices can be calculated without error.[6] Their value is fixed to the index price by a certificate-specific conversion ratio. For example, with a typical conversion ratio of 0.01, an index price of 10,000 EUR yields an intrinsic certificate price of 100 EUR.

The sample consists of 371 open-end index certificates, based on 203 different underlying indices, issued by 21 financial institutions. The index certificates are listed on the European Warrant Exchange (Euwax) in Germany over the period 2007-2009. The total number of end-of-day observations is 206,305. The main dependent variable in the analysis is the certificate premium, the percentage difference between the certificate price and its intrinsic price. The end-of-day bid-ask mid quotes are used as certificate closing prices. In the empirical analysis, the period March 2007 to August 2008 is treated as the pre-Lehman period, and 2009 as the post-Lehman period.

I begin by documenting that the default of Lehman Brothers had a significantly negative impact on the certificate premium. The average premium declined from 0.141%

[4]http://www.world-exchanges.org

[5]Note that the German certificates are not related to the certificates of deposit in the U.S. Certificates in the U.S. are protected by the FDIC coverage. Although the data is from Germany, the market characteristics described in this paper are very similar to those in the U.S. (Bergstresser 2008) and Hong Kong (Li and Zhang 2011).

[6]Henderson and Pearson (2011) and Ruf (2011) analyze structured products with embedded options. Valuing the options may introduce a measurement error into the intrinsic price estimate.

in the pre-Lehman period to -0.146% in the post-Lehman period, suggesting that certificates traded at a discount to their fair market value. A first hypothesis is that the prices of certificates issued by riskier issuers dropped more, thereby causing the premium decline.

However, the certificate discount post-Lehman continues to exist after controlling for issuer credit risk, as measured by the daily 5-year credit default swap spreads (CDS). Additionally controlling for certificate- and underlying-specific characteristics such as past index return and index return volatility, the premium decline ranges between -0.29 and -0.31 percentage points for an issuer with average credit risk. Interestingly, the relation between CDS spreads and certificate premium is weakly significantly negative in the pre-Lehman period, indicating that riskier issuers charged a lower premium for their products. In the post-Lehman period, however, the CDS spreads seem to have had a positive effect on the premium, suggesting that certificates of riskier issuers have traded at a less negative discount. Importantly, the cross-sectional variation in issuer credit risk does not seem to explain the decline in the certificate premium following Lehman's bankruptcy. A negative premium contradicts prior literature, which has established that structured products typically trade above their fair value (Chen and Kensinger 1990, Chen and Sears 1990, Henderson and Pearson 2011).

To better understand the determinants of the premium decline, I analyze next how the relative bid-ask spread has changed post-Lehman. I also decompose the premium into a bid- and ask-premium based on the bid and ask quotes, respectively. This helps to identify differences in the bid and ask side determinants of the premium. The default of Lehman Brothers caused an increase in the relative bid-ask spread by approximately 0.18 percentage points, which is an increase of about 20% from the pre-Lehman average. Analyzing the bid and ask sides of the premium separately reveals that the bid quotes declined by about -0.38 percentage points, while the ask quotes declined by around -0.21

percentage points. This suggests that the premium decline is mainly driven by a decline in the bid-quotes. An asymmetric change in the bid-ask spread has been documented in a few prior studies, which identified hedging costs as the main cause.[7]

Issuers as market makers try to maintain a certain risk exposure in their trading book. If the market maker post-Lehman has to buy back more index certificates than she sells, buying back index certificates may create for the issuer an unwanted long position in the index. The most convenient way to neutralize the position is to short-sell the whole index. The lower liquidity in financial markets post-Lehman (Brunnermeier 2009) may have made it more expensive for issuers of index certificates to offset their trading positions. This expense may be greater if the index is exotic and difficult to short.

To test the hedging cost hypothesis, I use the existence of index Exchange Traded Funds (ETFs) as a proxy for the ease of shorting that index. Index ETFs differ from index certificates in two important ways. First, they are not exposed to issuer credit risk. Second, ETFs can be sold short. ETFs, therefore, proxy for the replicability and shortability of an index. I am able to match 62 indices from the certificates sample with 133 index Exchange Traded Funds (ETFs).

For the hedging cost hypothesis to hold, the relative bid-ask spread of index certificates should be relatively less affected in the matched ETF sample. The regression results support this intuition. The asymmetric change in the bid-ask spread is most severe in certificates for which no ETFs on the underlying index exist. The bid-ask spreads of the matched ETFs are not affected, indicating that order processing costs are not the driver of the results (Engle and Sarkar 2006). The availability of index futures and options is not as effective in reducing the hedging costs.

Instead of hedging costs, the lowering of the bid quotes may represent market maker monopoly rents. An examination of transactions data suggests that post-Lehman,

[7]Bossaerts and Hillion (1991), Deuskar, Gupta, and Subrahmanyam (2011), Battalio and Schultz (2011).

a higher proportion of transactions were sales to the market maker. Anticipating the sales, the market maker may simply offer lower bid quotes to exploit investor demand for liquidity. I analyze whether the asymmetric change in the bid-ask spread is more severe if only one certificate on an index exists so that investors have no competing products to invest in. I also condition it on the availability of substitute assets such as ETFs. While it is impossible to rule out market maker monopoly, I do not find conclusive evidence in support of this hypothesis.

In the final section of the paper, I rule out alternative causes that could be driving the results in this study. One plausible explanation could be the time since issuance. Prior studies have found that certificates are issued at a premium that slowly decreases over time in the secondary market (Henderson and Pearson 2011). Indeed, I find that the decline in the premium is most severe for certificates that were issued in the pre-Lehman sample period. Many of those indices were also exotic indices that were neither replicated by index ETFs nor by index futures and options. However, the increase in the relative bid-ask spread, and the asymmetric change in the bid-ask spread, also exist for certificates issued before 2007. This indicates that the findings are not restricted only to recently issued certificates.

The paper is the first to show that hedging costs play a substantial role in the market making of structured products when markets are in turmoil. The findings are of particular significance for investors whose primary interest in structured products is to gain exposure to exotic instruments. Exotic structured products, which are difficult to hedge for the issuer, will trade at substantially lower prices in turmoil times, when investors may have the greatest need to sell. While the literature on household finance typically focuses on difficult-to-understand products (Carlin 2009, Gabaix and Laibson 2006), the findings in this paper highlight that easy-to-understand, but difficult-to-replicate, products can involve unforeseen costs that investors must consider. Finally,

the paper adds to literature on index products of which exchange traded funds are typically analyzed (Elton, Gruber, Comer, and Li 2002). Synthetic index replication has recently become topical, and this paper is the first to provide evidence on how synthetic products are affected by market crises.

The paper proceeds as follows: Section 2 explains the institutional setting for structured products in Germany, and it details the differences between index certificates and index ETFs. Section 3 describes the data sources, cleaning procedures and sample characteristics. Section 4 examines the effect of Lehman's default on certificate premia and bid-ask spreads. Section 5 uses a matched sample of index ETFs, index futures and options to investigate issuer hedging costs as a determinant of certificate prices. Section 6 rules out alternative explanations for the findings. Section 7 concludes.

2 Market and Product Details

Exchange-listed structured products take on different names in academic papers and across countries. In the U.S., they are referred to as "structured notes" (Bergstresser 2008) or "structured equity products" (Henderson and Pearson 2011). In Italy, they are named "covered warrants" (Petrella 2006), and in Hong Kong they are called "derivative warrants" (Li and Zhang 2011).[8] In Germany, structured products are referred to as "certificates" (*Zertifikate* in German). While this section focuses on the German certificates market, its characteristics are comparable to other countries.[9]. In fact, German banks have also been reported to be the most active issuers in other countries such as the U.S. (Bergstresser 2008) and Hong Kong (Li and Zhang 2011).

Certificates are mainly an investment vehicle for retail investors although anecdotal

[8] Colloquial names that one may also encounter are exchange traded (structured) notes and structured securities products.

[9] Bethel and Ferrell (2007) provides an overview of the state of regulation for structured products in the U.S.

evidence suggests that some wealth management firms also invest in them.[10] Certificates provide investors a tailored payoff structure, or they give them access to exotic assets they could otherwise not invest in. They can have various degrees of complexity. They are often an equity security combined with an option either to increase the upside or limit the downside price change potential. They can also simply promise to replicate the performance of an index. Index certificates provide an ideal laboratory to better understand the certificates market. Their theoretical fair price, i.e. their intrinsic price, is a fixed fraction of the underlying index price. It can therefore be easily calculated with available data. The low product complexity makes index certificates trade at narrow bid-ask spreads between 0%-1%.

Index certificates appear similar to index ETFs: both replicate the performance of an index. However, they differ in important ways that make ETFs a suitable control group for the empirical analysis of this paper. I describe in the Appendix all differences in detail. Most important for this study are two differences. Firstly, index certificates and index ETFs differ in their exposure to issuer credit risk. In ETFs, the underlying securities become part of the "special assets" that serve as collateral in the event that the issuer defaults.[11] Certificates, on the other hand, are promissory notes in which the investor becomes an unsecured lender to the issuing bank. Hence, he is exposed to issuer default risk. Because issuers are the main trading counterparty for investors, I use the terms issuer credit risk and counterparty risk interchangeably.

A second difference is the way in which fair pricing is established, as well as the associated costs. ETFs trade close to their net asset value (NAV) because of a creation and redemption process in cash and in kind. Selected institutional investors can deposit

[10] Kevin Dugan, "Investors Prefer Options to Structured Notes Amid Low Volatility", Bloomberg.com, 27 August 2012.

[11] The European Fund Regulation (UCITS III) allows that a maximum of 10% of the ETFs prevailing net asset value is allowed to be part of a swap agreement between the ETF provider and the swap partner. The swap partner is typically the parent bank. Anecdotal evidence suggests that the 10% maximum is never fully exploited, and ETFs are over-collateralized (DeutscheBank 2010).

the underlying securities with the fund itself to create the ETF shares, or they can redeem their fund shares to receive the underlying securities (Gastineau 2001).[12] If order processing costs in the underlying securities are high, the costly arbitrage process will be reflected in wider bid-ask spreads, and more persistent ETF premia and discounts (Engle and Sarkar 2006). In addition, ETFs can be shorted while certificates cannot.

The price of index certificates, on the other hand, is a contractually guaranteed fixed fraction ("conversion ratio") of the underlying index price. The issuing bank typically replicates the index synthetically through derivatives. The aim of the bank is to keep a neutral trading position, which requires entering positions in assets that offset the exposure to their index certificate. The cost of this hedging will be reflected in the bid-ask spreads. Since the issuing bank has a quasi-monopoly on the market making, in theory, it could set unreasonable quotes to increase their profit. This is unlikely, however, because it would damage business, and issuing certificates is an important financing source for banks (Deuskar, Gupta, and Subrahmanyam 2011).[13] To avoid trading at potentially unreasonable quotes, on specified exercise days, normally one day per quarter, investors can also return their open-end index certificates to the issuer at the conversion ratio (Doll 2009, p. 131).[14]

In terms of market design, the market for exchange-listed structured products shares characteristics with the options market and the foreign exchange market. It shares with the foreign exchange market the feature of being a quote-driven dealer market. The market makers are large financial institutions that also take positions in the securities underlying the structured products as part of their other banking activities (Bessembinder 1994). The issuing banks are typically the market makers for their own

[12]Ben-David, Franzoni, and Moussawi (2012) describes the arbitrage process in more detail.

[13]In the generic offer document of one certificate, the issuer writes that "the net proceeds (prior to offering expenses) from the issue of the Certificates, expected to be approximately [...] EUR, will be used by the Issuer for general corporate purposes". 28 December 2001, WKN 827425, ABN Amro.

[14]In the Appendix, I provide an excerpt from a certificate prospectus, which highlights the most important legal issues.

products. Investors usually trade with the market maker because the secondary market trading volume is very low (Henderson and Pearson 2011). It shares with the options market that the value of a structured product is derived from an underlying. The market maker typically posts quotes around the intrinsic value of the product (Deuskar, Gupta, and Subrahmanyam 2011).

3 Data and Methodology

3.1 Main Measures and Controls

I examine the determinants of the prices of exchange-traded structured index products during the financial crisis of 2007-2009. My pricing measure for the index certificates is the certificate premium defined as

$$Premium_c = 100 \times \frac{Price_c - Price_{c,fair}}{Price_{c,fair}}$$

This is the percentage difference between the actual price of the certificate, $Price_c$, and its fair market price, $Price_{c,fair}$.[15] I follow the convention in the literature by using the daily closing bid-ask mid quote as the certificate closing price. The fair market price is the price of the underlying index, $Price_i$, multiplied by a certificate-specific conversion ratio, usually 0.01. In other words, $Premium_c$ sets the certificate price relative to its underlying index price. A negative $Premium_c$ indicates that the certificate is trading at a discount relative to its fair value. In the paper, I will refer to all certificate-specific variables with the subscript c, all ETF-specific variables with the subscript e, and all index-specific variables with the subscript i. For simplicity, I will refer to index certificates as "certificates".

[15] Similar measures are used in Henderson and Pearson (2011) and Li and Zhang (2011).

Figure 1 plots the daily average of $Premium_c$ across all sample certificates from March 2007 to December 2009. The zero line represents the normalized intrinsic price of the certificates. The plot indicates that, on average, certificates traded at a premium relative to their intrinsic price before September 2008, and at a discount during the entire year 2009. The drop in the daily average premium could indicate that counterparty risk has become priced after the default of Lehman Brothers. The average premium is significantly different between September 2008 and December 2008. Therefore, I exclude the months September to December 2008 from the regression analysis. I define the period March 2007 to August 2008 as the pre-Lehman period, and the year 2009 as the post-Lehman period.[16] The downward trend in the certificate premium observed before the default of Lehman Brothers is in line with spread measures in other markets, for example, the options market (Battalio and Schultz 2011).

To identify the determinants of the certificate premium during the financial crisis period, I employ the following baseline regression model.

$$y_{cijt} = \alpha_c + \beta_1 PostLehman_t + \beta_2 CDS_{jt} + \beta_3 (cds_{jt} \times PostLehman_t) + \gamma' X_{it} + \varepsilon_{cijt},$$

where c indexes certificates, i indexes the underlying index, j indexes issuing banks, and t indexes trading days. y_{cijt} is the dependent variable of interest, i.e. either the certificate premium, the relative certificate bid-ask spread, or the bid- or ask-premium. α_c is a certificate fixed effect. $PostLehman_t$ is a dummy variable equal to one for the period January 2009 until December 2009, and zero for the period March 2007 until August 2008. CDS_{jt} is the 5-year credit default swap spread (CDS) of the issuing financial

[16]It should be noted that the default of Lehman Brothers was one of many significant events that took place in September 2008. However, it is generally agreed that, for financial markets, Lehman's collapse was the most significant. "WaMu is seized, sold off to JP Morgan, in largest failure in US banking history ", Wall Street Journal, 26 September 2009.

institution j on day t to proxy for issuer credit risk [17], cds_{jt} is CDS_{jt} minus its sample mean, as I will explain shortly. X_{it} is a vector of time-varying index control variables, and ε_{cijt} is the error term.

The variables in X_{it} are the standard deviation of the daily index returns over the previous 20 trading days to control for the volatility of the underlying (Rossetto and Bommel 2009), and the 1 day lagged underlying return to control for a possible demand prediction of the market maker (Ruf 2011). The certificate fixed effect α_c captures time invariant characteristics, such as whether the certificate is exchange-rate protected ("quanto certificate"), or whether the underlying is a performance index that reinvests dividends.[18]

In a regression with the β_3 interaction effect, β_1 measures the post-Lehman period effect on certificates as the level of CDS spreads goes to zero. Since there are no banks in the sample with zero CDS spreads, the size of the coefficient would not be informative. Therefore, I subtract the sample mean of CDS_{jt} before computing the interaction term ($cds_{jt} \times PostLehman_t$). Doing so changes only the coefficient of the Post-Lehman dummy and its standard error (Wooldridge 2009). β_1 then measures the change of the certificate premium from the pre-Lehman to the post-Lehman period at the sample mean of CDS_{jt}. β_2 and β_3 measure the effect of CDS spreads on the certificate premium in the pre-Lehman and post-Lehman period, respectively.

For any given level of CDS spreads, the effect of the Lehman Brothers default is $\beta_1 + \beta_3 CDS$. Investors will pay a lower premium for certificates from riskier issuers post-Lehman if they expect those issuers to have a higher likelihood of bankruptcy. Therefore, β_3 should be negative if counterparty risk has become more significantly priced after the

[17] Jorion and Zhang (2007) explains that the 5-year CDS contracts are the most liquid, and constitute over 85% of the CDS market.

[18] The certificate trading volume as a measure of liquidity is available only for approximately half of the observations. Therefore, I do not include it in the reported regressions. Unreported regressions confirm that the results do not change.

default of Lehman Brothers. β_2 will be negative if the certificate premium of riskier issuers had already been lower before Lehman's collapse.

In all regressions, I cluster standard errors at the underlying level. The returns of certificates that replicate the same index are exposed to the same underlying shock so that cross-sectional correlation may be of concern. The clustered standard errors take account of the possible correlation across certificates on the same index at the same time and over time. The clustered standard errors also account for serial-correlation within the same certificate over time.

3.2 Data and Summary Statistics

I obtain the master dataset on index certificates from Ariva.[19] Ariva is a bank-independent provider of capital markets information. It receives its certificates data directly from the exchanges and issuers. The Ariva master file contains the structured products and underlying security identification numbers, the currencies of the products, the name of the issuing bank, and the date of the initial certificate listing of certificates listed in Germany between March 2007 and December 2009. I use Thomson Reuters Tick History (TRTH) to obtain the end-of-day bid and ask quotes for index certificates, and the end-of-day closing prices of the underlying indices.[20] Exchange rate data are from Eurostat, the statistical office of the European Union. CDS spreads of the certificate issuing banks are from the Markit Group.[21]

I keep index certificates that have a German securities identification number and an ISIN and for which the ISIN of the underlying index is provided. I focus on certificates without expiry date ("open-end") to prevent the time to expiry impacting on the pricing

[19]There is a variety of names provided by the issuer that can refer to index certificates. The most commonly used terms are "index certificates", "open-end certificates" and "tracker certificates".

[20]Access to TRTH is granted through Sirca Limited, the Securities Industry Research Centre of Asia-Pacific.

[21]The sample consists of public quotes, not OTC quotes.

as found in Henderson and Pearson (2011). I retain only certificates that are listed on Euwax, the warrants segment of the Stuttgart Stock Exchange. There are more bid-ask quotes available in Thomson Reuters Tick History for Euwax. The trading volume in my sample is higher than for the Frankfurt Stock Exchange. I apply a cleaning filter to remove certificates with special features, and to remove seemingly erroneous data points.[22]

The final sample consists of 371 long, open-end index certificates. These certificates are based on 203 different indices as underlying, and they are issued by 21 different financial institutions.[23] Table 1 presents the sample summary statistics. The average certificate premium is 0.019%. As expected, the premium is positive, and it is small because index certificates are easy to value products. The mean (median) relative bid-ask spread of all sample certificates is 0.925% (0.804%). The number of observations differs across variables on account of variations in data availability. This number ranges from a maximum of 206,253 for the relative bid-ask spread to a minimum of 110,749 for the certificate trading volume. As trading volume is available only for approximately half of the sample observations, I will not use it in the regression analysis. However, it is interesting to note that, as identified in prior studies (Henderson and Pearson 2011), the secondary market trading volume is low with a mean (median) of 652 (0) certificates per day.

The name of the issuers and various sample statistics, including the CDS spreads,

[22]I omit short certificates, which gain in value when the underlying falls. I exclude certificates for which $Premium_c$ is in the upper or lower 5% tail of its sample distribution on 50% or more of their trading days. This cleaning measure filters out certificates for which the mid-quote and/or intrinsic price is consistently recorded with error. I also exclude observations for which $Premium_c$ is either smaller than -40% or larger than 40%, as these most likely represent erroneous data points. Looking at the data suggests 40% as a cut-off point. However, winsorizing $Premium_c$ at the 1% tails as an alternative way to deal with outliers obtains similar results. Finally, I remove two outlier observations for which the daily certificate return exceeds 100%. Of particular importance for the correct calculation of the intrinsic price of the certificate is the conversion ratio and the currency of the underlying. I hand-check this data by going through the prospectus of each certificate, and by checking the Euwax website. I amend the raw data where it is found to be incorrect.

[23]In cases where a bank subsidiary appears as a separate issuer, I report it under the parent name.

are shown in Table 2. Several of the issuers were taken over during the financial crisis. While the issuer name in my certificate dataset does not change, it is necessary to take account of the new owner when they are matched with their CDS spreads. For example, ABN AMRO was acquired by Royal Bank of Scotland (RBS) on 05 October 2007. RBS officially became the parent bank for the certificate business. Prior to the takeover, no CDS spreads existed for ABN AMRO. This is why the field is empty in the table. Another example is Citigroup. On 11 July 2008, the French cooperative bank Credit Mutual acquired the German structured products branch of Citigroup. From that point onwards, I replace the CDS spreads of Citigroup with the CDS spreads of Credit Mutuel. I conducted an internet search to identify whether issuing banks or their German branches were taken over. I recorded the earliest takeover completion date found and used the new owner to match with the CDS spreads.

Table 3 provides a list of the 11 most popular indices whose performance is replicated by at least 5 certificates (Panel A), and a random selection of 11 exotic indices that are only replicated by one certificate (Panel B). Among the most popular indices with the number of certificates in parentheses are the DAX (14), Nikkei 225 (14), S&P500 (12), TecDAX (12), and the Dow Jones Industrial Average (7). Indices that are replicated only by one certificate are sector indices like the AMEX Defense index or the Dow Jones Stoxx 600 Banks index, country indices like the Bovespa Brazilian index or the RTX Russian Traded index, or specialized indices like the S-BOX Insider Europe index. Of the 203 indices in the sample, 133 are replicated by only one certificate.

4 Effect of Lehman Default on Certificate Premia

4.1 Differences in Premium Means Before and After Lehman

In this section, I first examine if the descriptive statistics change before and after the default of Lehman Brothers. I test for the differences in means of the main variables for which a change is to be expected: certificate premium, certificate bid-ask spread, certificate trading volume, underlying return, underlying return volatility, and issuer CDS spread.

The results in Table 4 show that the averages of all the variables become significantly different following the default of Lehman Brothers. In the table, I abbreviate the pre-Lehman period (March 2007 to August 2008) by "Pre" and the post-Lehman period by "Post". While the descriptive statistics for the whole sample show that the average certificate premium is close to zero, it actually decreases from 0.141% in the pre-Lehman period to -0.146% in 2009. In the following sections, I use multiple regressions to examine in more detail whether this premium decline is due to counterparty risk or market maker risk hedging. The relative bid-ask spread of the certificates increases by approximately 30% from 0.82% to 1.06%. The average certificate trading volume decreases from 2,154 pre-Lehman to 257 post-Lehman. This may be a result of the wider bid-ask spreads. The number of available observations for trading volume pre-Lehman is only 23,051. This is approximately 20% of the possible 118,566 observations in the pre-Lehman period. Consequently, I do not include trading volume as a control variable in the multiple regressions. The average rolling underlying return standard deviation over the past 20 trading days increases from 1.41 to 1.92. This highlights the importance to control for index volatility. Finally, the CDS spreads of the issuers increase substantially from 56.81 before September 2008 to 120.34 in 2009. This is in line with the observation that the default of Lehman Brothers lead to a reassessment of risk (Zingales 2008).

4.2 Determinants of the Certificate Premium

Next, I examine how Lehman's default has affected the certificate premium, while holding other determinants of the premium constant. I employ the baseline regression model from above, using pooled OLS with certificate fixed effects and/or underlying and issuer fixed effects. Standard errors are clustered at the underlying level to account for cross-sectional and time-series correlation of certificates that replicate the same index. The dependent variable is $Premium_c$, the percentage premium of the certificate over its intrinsic value, as defined above. I run four regressions differing by the inclusion of the $cds \times PostLehman$ interaction effect and the various fixed effects. The results are displayed in Table 5. The Post-Lehman dummy is significant and negative in all four regression specifications.

All four regressions control for the standard deviation of the daily index return over the previous 20 trading days, and the 1 day lagged daily logarithmic return of the underlying index. In addition, regression 1 includes bank CDS spreads and certificate fixed effects.

In regression 1, the post-Lehman dummy coefficient is -0.2914. It is significant at the 1% level. It indicates that moving from the pre- to the post-Lehman period reduces the certificate premium by 0.29 percentage points for an issuer with average credit risk, holding other determinants of the premium constant. This is an economically large decline given that the average certificate premium in the pre-Lehman period was 0.1412%. The effect of issuer credit risk on the premium, however, is small (-0.0001), and statistically insignificant.

Regressions 2-4 also include the interaction effect between CDS spreads and the post-Lehman dummy ($cds_{j,t} \times PostLehman_t$). Their inclusion assists with examination of whether the effect of issuer credit risk has changed post-Lehman. The interaction effect should be significant if the pricing of counterparty risk has changed post-Lehman.

Interestingly, the results indicate that issuer credit risk was associated negatively with the certificate premium pre-Lehman, but has had a positive impact on the premium post-Lehman. Since the average premium is negative post-Lehman, it implies that riskier issuers had a less negative premium following the default of Lehman Brothers. The hypothesis that counterparty risk has become more significantly negatively related to the certificate premium after the default of Lehman Brothers is rejected. The cross-sectional variation in issuer credit risk does not explain the decline in the certificate premium post-Lehman.

4.3 The Impact of Lehman's Default on Certificate Bid-Ask Spreads

Using the bid-ask midquote as the certificate closing price assumes that the quotes are symmetric around the certificate's fair value. Evidence from the options market suggests that this may not be the case (Battalio and Schultz 2011, Deuskar, Gupta, and Subrahmanyam 2011). Battalio and Schultz (2011) shows that the U.S. short sale ban for financial stocks during the financial crisis increased the relative bid-ask spread of options on those stocks, mainly caused by lower bid quotes. They find similar results for options on stocks that are not banned but hard to borrow. It suggests that the market maker is willing only to buy back options on those stocks at lower bid prices on account of the higher hedging costs of shorting the stock. This finding is consistent with Engle and Sarkar (2010) who show that market maker hedging costs are an important determinant of the relative bid-ask spread in the options market, even before the short-sale ban.

To examine how the bid-ask spread has changed post-Lehman, I employ the baseline regression model using the relative bid-ask spread as the dependent variable. The relative bid-ask spread is defined as the absolute bid-ask spread divided by the bid-

ask mid-quote. Additionally, I follow the approach in Battalio and Schultz (2011) and Deuskar, Gupta, and Subrahmanyam (2011) by analyzing if the decline in the certificate premium is influenced more by lower bid quotes or lower ask quotes. I calculate the certificate premium based on the bid quotes, $Premium_{c,bid}$, and the ask quotes, $Premium_{c,ask}$, and I run the regression separately for both dependent variables.

The results for the three regressions are displayed in Table 6. The regression estimates in the first column show that the default of Lehman Brothers had a significant positive impact on the relative bid-ask spread. Controlling for all other determinants, the relative bid-ask spread has increased by 0.18 percentage points in the post-Lehman period. Given a pre-Lehman average of 0.82%, it represents an economically significant increase of 22%. The second and third column of Table 6 show the determinants of the bid premium and the ask premium, respectively. For an issuer with average credit risk, the premium based on bid quotes has declined by 0.38 percentage points, and the premium based on ask quotes has declined by 0.21 percentage points. The larger decline in the bid premium indicates that the decrease in the certificate premium from the previous regressions is caused by an asymmetric change in the bid-ask spread, driven by lower bid quotes. To confirm these findings graphically, Figure 3 plots the weekly average of the bid and ask premium over the sample period. It can be seen that both the bid and ask premia decrease over time. The bid premium seems to decline more than the ask premium after the Lehman collapse. The asymmetric widening of the bid-ask spread is most severe in the first three months of 2009, when bid quotes drop most significantly and ask quotes show little variation.

The finding of an asymmetric change in the bid-ask spread is consistent with higher hedging costs. That is, the higher hedging costs of neutralizing the index position cause the market maker to pay less for buying back index certificates. The findings are consistent with the results in Battalio and Schultz (2011), Deuskar, Gupta, and

Subrahmanyam (2011) and Engle and Sarkar (2010). The findings are also consistent with the theory advanced in Bossaerts and Hillion (1991). They find an asymmetry in the forward bid-ask spread because of expected government interventions in the spot market. They show, theoretically and empirically, that the asymmetry will be accompanied by an increase in the bid-ask spread.

In the next section, I provide more evidence supporting the hedging costs hypothesis. I use the existence of exchange traded index funds (index ETFs) as a proxy for indices that are more liquid, easier to replicate and to short and, therefore, easier to hedge.

5 Hedging Costs in Difficult-to-Hedge Indices

5.1 Motivation

Index ETFs are similar to open-end index certificates in that they replicate the performance of an index, and they typically trade close their net asset value (NAV). In contrast to certificates, however, ETFs can be shorted and they must hold the underlying stocks. The ETF arbitrage mechanism, which ensures the fair pricing of ETFs, is established through an in-cash or in-kind creation and redemption process. This arbitrage process requires that the underlying shares of an ETF are fairly liquid (Poterba and Shoven 2002, Ben-David, Franzoni, and Moussawi 2012). A more thorough comparison of ETFs and index certificates is presented in Table 7.

When the issuers buy back their index certificates, they need to keep a neutral trading position. While there is no evidence of how issuers of structured products carry out their risk hedging, they can either unwind previous hedging positions or engage in offsetting trades. Battalio and Schultz (2011) finds that options on stocks that are hard to borrow have wider bid-ask spreads. I follow an opposing approach here. Indices that

are replicated by ETFs are easier to hedge. The issuing bank can short the ETF or sell the constituent stocks more easily. The existence of an ETF can, therefore, be regarded as a proxy for the ease of shorting and replicating an index. I expect that the asymmetric widening of the bid-ask spread will be more pronounced in certificates on indices that are not replicated by an ETF.

I construct a matched sample of index certificates and ETFs that replicate the same indices. First, I confirm that ETF premia and ETF bid-ask spreads are not affected by the default of Lehman Brothers. I then run regressions of the bid-ask spread and certificate premium separately for the certificate-ETF matched sample ("matched sample"), and the index certificates that have no matching ETF ("unmatched sample").

5.2 Data and Methodology

Germany is the biggest ETF market in Europe with 337 primary listings and US$89.74bn in assets under management in primary listings by January 2010. As a comparison, the second biggest market is the U.K. has 156 primary listings and US$46.69bn in assets under management in primary listings (ETF-Landscape 2010). To examine how ETF premia and bid-ask spreads are affected by the default of Lehman, I employ a similar baseline regression model as above:

$$y_{eit} = \alpha_e + \beta_1 PostLehman_t + \gamma' X_{it} + \varepsilon_{eit}$$

y_{eit} is either the ETF premium ($Premium_e$), that is, the ETF price over its indicative net asset value (iNAV)[24], or the relative bid-ask spread ($BAspread_e$) of ETF e on index i trading on day t. Following Engle and Sarkar (2006) and the calculation of the certificate

[24]The German Stock Exchange calculates the iNAV on behalf of ETF issuers every 15 seconds or every minute. Source: http://www.dax-indices.com/EN/index.aspx?pageID=17, accessed 01 November 2012. Engle and Sarkar (2006) calls it the indicative optimized portfolio value (IOPV).

premium above, I measure the ETF premium as the percentage difference between the end-of-day ETF bid and ask quote midpoint, and its iNAV. X_{it} are the index-specific control variables also used for the index certificates. I use $TradeVol_e$ to control for the number of ETFs traded. α_e is an ETF fixed effect. ε_{eit} is the error term. Standard errors are clustered at the underlying level.

I use Thomson Reuters Tick History to obtain the end-of-day bid and as quotes for all ETFs that traded on German stock exchanges between 2007 and 2009, as well as their end-of-day iNAV. I match the underlying identifiers of the ETFs with the indices in the certificate sample, considering the listing dates of the ETFs. The matched certificate subsample consists of 198 certificates and 62 indices. For the matched ETFs subsample, I take only ETFs trading on Stuttgart Stock Exchange. This yields a subsample of 61 indices and 133 ETFs.

Table 8 lists the ETF providers, their parent company, and several ETF sample characteristics. The most active issuer of index ETFs in Germany is the parent company BlackRock, with their ETF brand iShares. Between 2007 and 2009, BlackRock had 49 index ETFs listed in Germany. BlackRock is closely followed by Commerzbank and their ETF provider, Comstage, with 24 index ETFs. This is followed by Societe Generale's Lyxor Asset Management (22 ETFs) and Deutsche Bank's x-trackers (18 ETFs). These top 4 index ETF providers together own 85% of the index ETFs listed in Germany. I also report the average relative bid-ask spread, and the average trading volume per ETF provider.

5.3 Analysis of Certificate and ETF Premia

Table 9 compares the relative bid-ask spread of ETFs with those of certificates. The first two columns of the table show the matched sample regression with ($BAspread_e$) and ($BAspread_c$) as the dependent variables. Column 3 shows regression estimates for cer-

tificates whose underlying index has no matching ETF. The results show that the effect of widening spreads does not exist in ETFs, and it is mainly present in the subsample of certificates whose underlying index is not replicated by an ETF. This seems to support the hedging cost hypothesis. Among the control variables, the volatility of the underlying is positive and significant in all three regressions. This confirms that index volatility is an important determinant of the ETF bid-ask spread. The graphical illustration in Figure 4 affirms that the relative bid-ask spread in the unmatched certificate sample has increased significantly more following Lehman's default.

Next, I analyze the bid and ask side determinants of the premium for ETFs and the ETF-matched and unmatched sample of certificates. Confirming the results from the previous regression, the first two columns in Table 10 show that neither the bid nor ask premia of ETFs change post-Lehman. Neither of the other control variables significantly determine the ETF premium either. This is expected as the arbitrage mechanism in ETFs should keep the premium close to zero on average and over a long period. In the matched certificate regression, the bid premium significantly declines by 0.14 percentage points while the ask premium is negative but insignificant. In the unmatched certificate sample, both the bid premium and the ask premium drop significantly by 0.64 and 0.40 respectively. It confirms that the asymmetric widening of the bid-ask spread is mainly present in certificates with indices that are not replicated by an ETF.

The results are graphically illustrated in Figure 5. This shows the weekly average bid and ask premium over the sample period for the matched and the unmatched subsample, respectively. In the matched sample (Panel A), the bid and ask quotes post symmetrically around the intrinsic price of the certificate, with the exception of the four months following the Lehman default. The certificates with no matched ETF index, on the other hand, have high bid and ask quotes in the pre-Lehman period, and low bid and ask quotes post-Lehman.

Several factors may cause the ask quotes to decline as well: First, lower quotes can alleviate the hedging requirement of issuers by enticing more investors to buy the certificates. Second, during the financial crisis, issuers were required by the Euwax exchange to commit themselves to a maximum bid-ask spread. The maximum allowed bid-ask spreads are not made public, and issuers can request to ease this restriction under special market circumstances. The fact that Euwax has now removed this requirement may indicate that it limited issuers in their flexibility to post bid-ask quotes during the financial crisis.

5.4 ETFs, Index Futures and Options

Issuers could also hedge their certificate exposure via index futures or options. Such a hedge would be imperfect because the sample certificates can run indefinitely, whereas futures and options expire, creating a rollover hedging problem (Lien and Tse 2002). Since the hedging practices of issuers are not well understood, I examine how the availability of index options and futures impact the results.

The introduction and ceasing dates of index futures and options on the sample indices were obtained from Datastream [25] I estimate the baseline regression with the relative bid-ask spread, the bid-premium and the ask-premium as dependent variables, respectively. I estimate the model for five sample subgroups, conditional on whether one of the following index products is available on the same certificate underlying: 1) ETF or Futures/Options, 2) ETF and Futures/Options, 3) ETF and No Futures/Options, 4) No ETF and Futures/Options, 5) No ETF and No Futures/Options.

Table 11 shows the regression estimates of the Post-Lehman dummy, its t-statistics are based on standard errors clustered at the index level, and the number of regression ob-

[25]Thomson Reuters kindly provided me with the identifiers of the matched index futures and options. For index options, only the introduction year is available.

servations for the five subsamples. For an issuer with average credit risk, the relative bid-ask spread increases significantly by 0.131 percentage points if ETF or Futures/Options are available, and by 0.137 percentage points if ETF and Futures/Options are available. The relative bid-ask spread does not change significantly if ETFs are available but no index futures/options exist. If no ETFs are available, but index futures/options are available, the relative bid-ask spread significantly increases by 0.245 percentage points, and the bid-premium decreases by 0.237 percentage points. As a comparison, the absence of both ETFs and index futures/options cause the relative bid-ask spread to increase by 0.267 percentage points, the bid-premium to drop by 0.79 percentage points, and the ask-premium to decline by 0.54 percentage points.

The results suggest that the availability of index futures/options is not as effective a hedging device as ETFs. Compared to certificates for which no ETFs and no index futures/options are available, the bid quotes do not drop as much, but the increase in the relative bid-ask spread is almost of a similar size.

5.5 Evidence From Transactions Data

Although exchange transactions of structured products are rare, examining the proportions of buy and sell orders for index certificates can provide insights into whether the lower bid quotes of the market maker are driven by inventory control motives. Changes in the bid-ask spread driven by market maker inventory management are caused by sudden and significant increases in the amount of sell orders the market maker has to absorb.

Thomson Reuters Tick History was used to obtain the transactions data. I follow the Lee and Ready (1991) procedure to identify whether a certificate trade is a buy or a sell.[26] Using quotes at least 5 seconds before the trade, I code a transaction as a

[26]It should be kept in mind that using the Lee and Ready (1991) procedure based on the quoted mid-

purchase if it occurs above the quote mid-point, and as a sell if it is below the quote mid-point. For transactions that occur exactly at the quote mid-point, I use the tick test. Following this test, a transaction is a buy if the trade price is higher relative to the previous changed trade price. The converse also holds.

Figures 6 and 7 show the weekly average number of buy transactions (dashed line) and sell transactions (solid line) across all certificates whose underlying is replicated by an ETF or not replicated by an ETF, respectively. The figures highlight that there was no wave of sell orders in the post-Lehman period that could have caused the lower bid quotes. However, it can be seen that, in the pre-Lehman period, the market maker may have had lower hedging needs, on account of there being some opportunities to balance sell with buy orders. Post-Lehman, however, there are fewer buy orders so that the market maker has a greater need to hedge.

5.6 Market Maker Monopoly Pricing?

Supporting the hedging-cost hypothesis, Comerton-Forde, Hendershott, Jones, Moulton, and Seasholes (2010) shows that the balance sheets of NYSE specialists are a significant determinant of liquidity provision. However, the findings so far could also be interpreted as supporting market maker monopoly pricing. Since a higher proportion of transactions are sell orders, the market maker may anticipate it and quote lower bid quotes to earn monopoly rents.

In this section, I test whether monopoly pricing is indeed present. Demsetz (1968) argues and Moulton and Wei (2009) finds evidence that the existence of substitute securities lowers the bid-ask spread. Adapting their findings to the context of this paper, the existence of competing certificates or ETFs on the same underlying index

point assigns more trades as sells in the pre-Lehman period, and more trades as buys in the post-Lehman period.

could prevent market makers from charging lower bid quotes after the default of Lehman Brothers. Consequently, the widening of the bid-ask spread and the lowering of the bid quotes post-Lehman should be most severe in certificates that have only been issued by one financial institution. The effect should be even more severe if no ETFs exist as substitute assets.

Table 12 presents the post-Lehman dummy coefficients from the baseline regression model, their t-statistics based on standard errors clustered at the index level, and the number of regression observations in brackets, conditional on the availability of ETFs and/or futures/options. Restricting the sample to indices for which only one certificate exists leads to relatively few observations. Across the five subgroups mentioned above, the number of observations ranges from 843 to 37,845 so that some of the results may not be so representative.

Generally, we would expect that the coefficients of the post-Lehman dummy should be larger across all subgroups compared to the case when competing certificates are available, such as Table 11. However, the change in the relative bid-ask spread is insignificant in most of the subgroups, and it is sometimes even negative. For example, the absence of competing certificates, combined with the absence of ETFs as the closest substitute products, should obtain some of the most severe results if monopoly pricing played a role. In contrast, in the case where no competing certificates exist, no ETFs exist, but index futures/options are available, the relative bid-ask spread is -0.174 and insignificant.

As expected, the asymmetric widening of the relative bid-ask spread is most pronounced if neither ETF nor futures/options are available. The sign of the coefficient, however, is not much different from the scenario in Table 11, regardless of whether competing certificates are available. The increase in the relative bid-ask spread, and the lowering of the bid quotes, appear to be due to the higher costs that issuers face to hedge their positions, rather than due to monopoly rents. While monopoly pricing cannot be

ruled out, it does not seem to be the main driver of the results.

6 Robustness Checks

6.1 Time Since Issuance

Prior research suggests that structured products are issued at a premium that slowly disappears over time in the secondary market (Henderson and Pearson 2011). The relatively high ask quotes in Panel B of Figure 5 suggest that this may be the case.

To examine this supposition, I run the baseline regression separately for certificates issued during the pre-Lehman sample period (March 2007 to August 2008) and for certificates issued before March 2007. I use the relative bid-ask spread and the bid-ask premium as dependent variables. The results are presented in Table 13. Columns one to three show the regression estimates for the sample of certificates issued before March 2007; columns four to six for certificates issued between March 2007 and August 2008.

The asymmetric widening of the bid-ask spread is present in both subsamples, and it is of similar size. The relative bid-ask spread of certificates issued before March 2007 increases significantly by 0.166 percentage points, while trading costs of certificates issued between March 2007 and August 2008 increase by 0.22 percentage points.

There is a substantial difference in the size of the drop in the bid and ask premia. For certificates issued before March 2007, bid premia decrease significantly by 0.22 percentage points, and ask premia do not change significantly. In certificates issued during the pre-Lehman sample period, bid premia decrease by 0.92 percentage points, and ask premia decrease by 0.73 percentage points. However, this subsample of certificates only represents around 20% of the sample observations (34,318 observations).

The evidence confirms that part of the bid and ask premium decline is caused by certificates issued during the 18 months before the default of Lehman Brothers.

However, the asymmetric change in the bid-ask spread, caused by lower bid quotes, exists independent of when the certificates were issued. This adds further support to the hedging cost hypothesis.

6.2 Alternative Explanations

In this section, after ruling out five other possible causes, I show that the decline in the certificate premium persists. I briefly motivate the robustness tests below, and I present the regression results in Table 14.

First, in regression 1 of Table 14, I winsorize $Premium_c$ at the 5% level to exclude possible remaining outliers. The data cleaning measures already remove extreme values of the certificate premium. The descriptive statistics show, however, that its distribution is not perfectly symmetric. This indicates that outliers may still be present.

Second, the end-of-day prices of the indices, and the end-of-day prices of the certificates, are not synchronized in time if the index is from a different time zone. If markets move in one direction over longer periods of time, it could artificially inflate or deflate the premium, depending on the direction of the bias. In order to address the issue of time differences, I use only indices denominated in EUR in regression model 2. That is, this model includes only certificates whose underlying is an index whose constituents are stocks from a country of the European currency union, which is part of the same time zone.

Third, it can be expected that the hedging costs of the market maker are higher during the period shortly after the Lehman collapse. In regression 3, I define January 2009 to June 2009 as the post-Lehman period, and in regression 4, I use July 2009 to December 2009 as the new post-Lehman period.

Fourth, short-sale bans had been implemented around the world shortly after Lehman Brothers went bankrupt. Battalio and Schultz (2011) finds that the short-

sale ban in the U.S. significantly increased the bid-ask spread for options on the banned stocks. It may also explain the change in the certificate premia. Based on Beber and Pagano (2012), I identify indices that may have included banned stocks. In regression 5, I follow a conservative approach: I exclude all indices that may include potentially banned financial stocks, and use only the second half of 2009 as the post-Lehman period, since many bans had been lifted by 01 June 2009.

In all five robustness regressions, the post-Lehman dummy remains negative and statistically significant, ranging in size between -0.31 to -0.41. Compared to the pre-Lehman period, the premium declines by -0.41 percentage points in the first half of 2009, and by -0.28 in the second half of 2009 for issuers with median CDS spreads. The fact that the premium decline is present throughout all of 2009 indicates that the effect is not a typical short-term market maker adjustment to inventory positions or asymmetric information. The premium decline of -0.34 percentage points after excluding possibly banned stocks indicates that the short-sale ban of financial stocks is not the driver of the certificate premium decline.

7 Conclusion

Investors are increasingly using structured products to hedge risks, buy tailored security payoffs, or gain access to exotic assets in which they can otherwise not invest. However, the secondary market pricing of structured products is not well understood. My results suggest that market maker hedging costs have become a significant trading cost component of structured products following the default of Lehman Brothers.

I find an asymmetric widening of the certificate relative bid-ask spread through lower bid quotes, in particular, when no ETFs on the same index exist. Investors in certificates of difficult-to-hedge indices who sold their certificates in 2009, instead of

before the Lehman collapse, were, on average, 0.64 percentage points worse off, holding everything else constant.

Issuer credit risk, which has often been argued to be a main determinant of the certificate post-Lehman, does not explain the observed effects. In contrast, while riskier issuers had lower premia in the pre-Lehman period, there is some evidence that riskier issuers had less negative premia post-Lehman. The results seem to suggest that investors pay too much for the level of risk to which they are exposed.

While the results hold independent of time of issuance, due to being issued at a premium, certificates issued in the pre-Lehman sample period have the largest decline in the bid quotes. It cannot be ruled out that market maker monopoly plays a role, but it does not seem to be the main driver of the results.

The findings highlight that it is important for investors in structured products to consider the ease of replicating and shorting an index. This study is the first to show that structured products on difficult-to-hedge indices can incur additional trading costs when markets are in turmoil.

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Appendix

Appendix 1: Comparison of Index Certificates and Index ETFs

Below I describe in more detail the differences between index certificates and index ETFs regarding trading, arbitrage, dividends, taxes and counterparty risk. These differences are listed in bullet form in Table 7.

Trading. Similar to ETFs, certificates can be traded on the exchange during the normal exchange trading hours. Their prices are set by supply and demand. In contrast to ETFs, however, the secondary market trading volume of structured products is very low (Henderson and Pearson 2011). In order to ensure liquidity, the exchange rules require the issuing bank to act as a market maker for their own products. The market maker role requires the provision of actionable quotes to investors. Investors can trade certificates either on the exchange or directly with the issuer over the counter (Wilkens and Stoimenov 2007). The exchanges have also put in place a specialist as an intermediary. The specialist is responsible for an orderly trading process. The specialist can also step in if the market maker does not provide the necessary number of certificates to execute an order. However, it has bee noted that the specialist has mainly a supervisory role (Lammersdorf, Burghardt, and Wagener 2010). Hence, the market for structured products is characterized by a monopolistic market maker as in Rust and Hall (2003). While the ETF price is related to its net asset value (NAV) and therefore subject to a tracking error, index certificate are a promissory note and their price is related to the index price by a fixed ratio.

Arbitrage. ETFs also allow for an in-kind creation and redemption process. Selected institutional investors, so called authorized participants, can deposit the underlying securities with the fund itself to create the ETF shares, or they can redeem their fund

shares to receive the underlying securities (Gastineau 2001).[27] This arbitrage facility ensures that the ETF price trades close to its NAV. Hence, ETFs combine the creation and redemption facility of open-end funds with the intraday tradability of closed-end funds (Deville 2008). As a promissory note, index certificates do not need an arbitrage mechanism. However, as a monopolistic market maker the issuing bank could set unreasonable quotes. There are two reasons why this is unlikely. First, issuing certificates is an important financing source for banks.[28] As noted by Deuskar, Gupta, and Subrahmanyam (2011) in the options OTC, providing prices disadvantageous to investors would damage their business. In addition, certificates can be returned to the issuer at the conversion ratio on certain exercise days of the year as defined in the prospectus. Normally, it is one day per quarter (Doll 2009, p. 131).

Dividends. ETF investors receive dividends either in cash if the underlying is a price index or the dividends are reinvested if the underlying is a performance index. Investors in index certificates never receive a cash dividend. They only benefit from dividends if the underlying index is a performance index and dividends are reinvested.

Taxes. In 2009, Germany introduced a capital gains tax of 25%. That is, if ETFs were bought before 31 December 2008 and held for 12 months they would have bee capital gains tax free. If they are bought from 2009 onwards, they are taxed at 25% or the lower personal tax rate. For certificates, the tax took effect 5 months earlier. Certificates bought on or before 31 July 2008 and held for 12 months were capital gains tax free. After 31 July 2008, they are also taxed at 25% or the lower personal tax rate.

Finally, ETFs and certificates differ in how they are affected by issuer credit risk. In the case of ETFs, the underlying securities become part of the "special assets" that serve as collateral in the case of the issuer's default. Only up to 10% of the ETF performance

[27]Ben-David, Franzoni, and Moussawi (2012) describe the arbitrage process in more detail.

[28]In the prospectus of one certificate, the issuer writes that "the net proceeds (prior to offering expenses) from the issue of the Certificates, expected to be approximately EUR will be used by the Issuer for general corporate purposes". 28 December 2001, WKN 827425, ABN Amro.

can be based on swap agreements but usually ETFs are over-collateralized. Certificates, on the other hand, are a promissory note so that the investor becomes a lender. Although they appear to be a derivative, certificates are not traded on a derivative exchange via a clearing house. They are traded on the cash market like stocks or bonds, and investors are subject to issuer default risk. Hence, while ETFs are backed by their underlying assets, certificates are only a promise of the issuing bank to deliver the performance of the index.

Appendix 2: Sample Excerpt From a Certificate Prospectus

The securities issues of Raiffeisen Centrobank AG are subject to these General Securities Terms. The Final Terms (see Chapter VI of the Base Prospectus of 21 July 2006) will contain any supplementary information specific to the individual securities. Raiffeisen Centrobank AG retains the right to change these Securities Terms.

SECURITIES TERMS
(to FT No. 141 of 2nd April 2007)
of
Raiffeisen Centrobank AG
for Open End Investment Certificates (see Final Terms, line 1)

§ 2 General Risks

3. The value of structured securities is influenced not only by the changes to the price of the underlying instrument, but additionally by a number of other factors such as the maturity of the structured securities (and other product-specific parameters) as well as by the frequency and intensity of price fluctuations (volatility) of the underlying instrument. A reduction in the value of a structured security may occur even if the price of the underlying instrument remains constant.

§ 6 Influence of Trades, especially of Hedging Transactions by the Issuer, on the Structured Securities

The issuer has the right to buy or sell on the open market or in non-public transactions the structured products at any time during the term of the structured securities. Within the scope of its regular business activities, the issuer engages in trading in the underlyings of the structured securities and furthermore hedges fully or in part against the financial risks related to the structured securities by entering into hedging transactions in the respective underlying instruments.

§ 9 Exercise/Redemption

2. In the case of investment certificates without a predefined maturity (open-end), the issuer shall have the right for the first time after three calendar years as of the issue date to determine a maturity date for the certificates on any exchange-trading day, with the remaining time to maturity of the certificates having to be at least one calendar year. The fixing of the maturity is published indicating the maturity date pursuant to § 22 .

§ 12 Redemption date/Due Date of Payment

4. A ”banking business day” in the meaning of these General Securities Terms is - unless otherwise specified or supplemented in the Final Terms - a day on which commercial banks are open for business in Austria and Germany.

§ 16 Termination

a. In the case of issues on indices or index baskets: If the underlying instrument is an index, the issuer is also entitled to terminate the security stating the termination amount if in its opinion liquidity is very low in the shares included in the index on the relevant exchange/price-fixing entity or on the primary exchange or on a derivatives exchange on which futures or options contracts on such index are traded.

PREMATURE REDEMPTION/TERMINATE OF OPEN-END SECURITIES

The holder of a structured security is entitled for the first time after four calendar years of the start of the issue to terminate a structured security prematurely on every first banking business day of a month (termination date). These redemption rights may be exercised only for at least one hundred (100) structured securities with the same ISIN or security identification number or a multiple thereof in whole numbers.

To be effective, the issuer must have received the notice of termination on the last banking business day before a termination date prior to 12:00 noon (local time Vienna).

Vienna, 2nd April 2007

Figure 1: Daily Average of the Certificate Premium

This figure shows the daily (cross-sectional) average of the certificate premium in percent. The premium is the percentage difference between the certificate's actual price and its theoretical (intrinsic) price. Shown is the period March 2007 to December 2009.

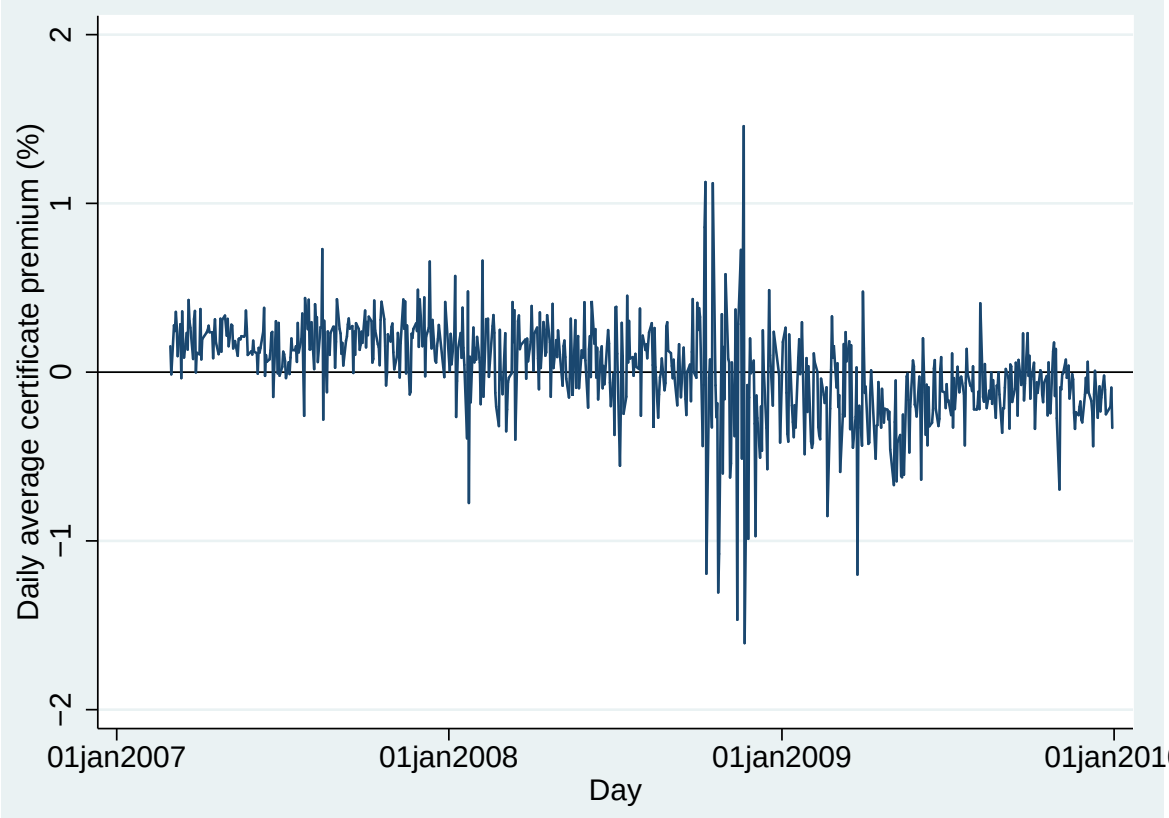


Figure 2: Monthly Average of the Certificate Premium

This figure shows the monthly (cross-sectional) average of the certificate premium in percent. The premium is the percentage difference between the certificate's actual price and its theoretical (intrinsic) price. Shown is the period March 2007 to December 2009.

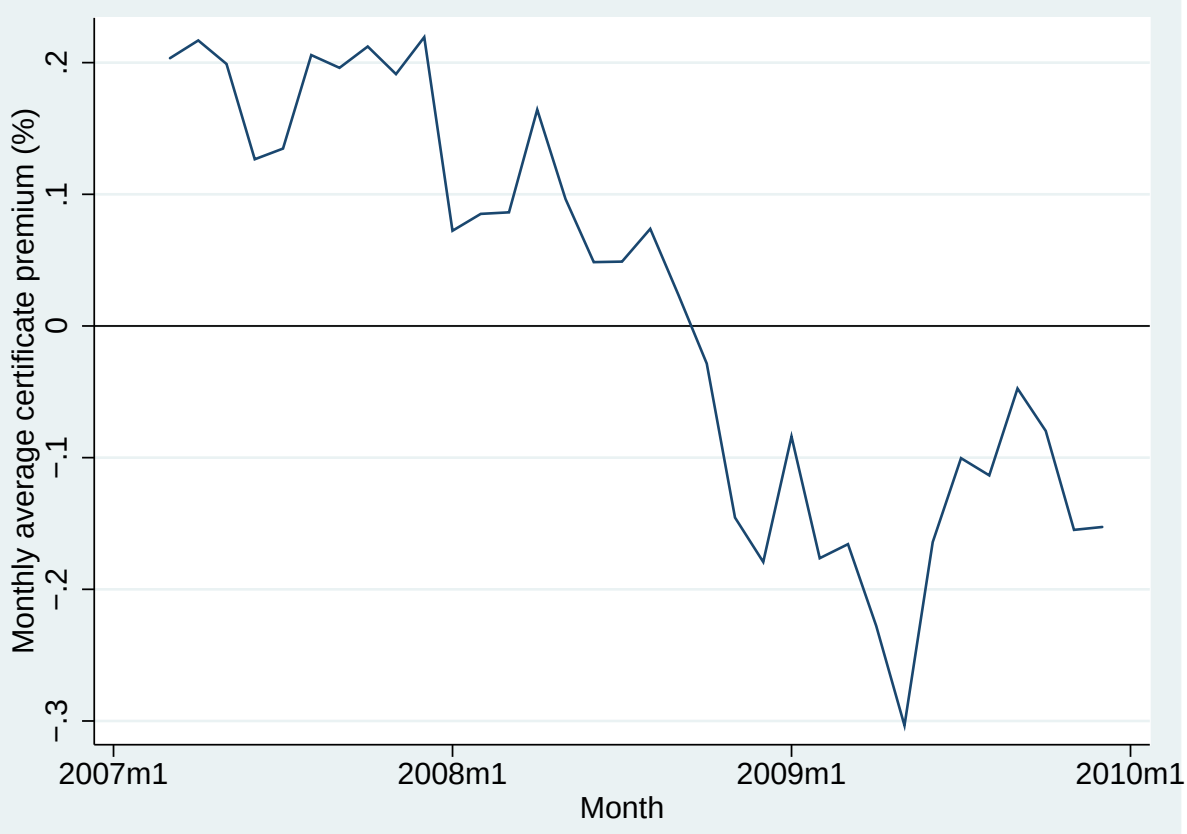


Figure 3: Weekly Average of the Certificate Bid- and Ask-Premium

This figure shows the weekly (cross-sectional) average of the certificate premium, decomposed into a bid and ask premium in percent. The bid (ask) premium is the percentage difference between the certificate's actual end-of-day bid (ask) quote and its intrinsic price. Shown is the period March 2007 to December 2009.

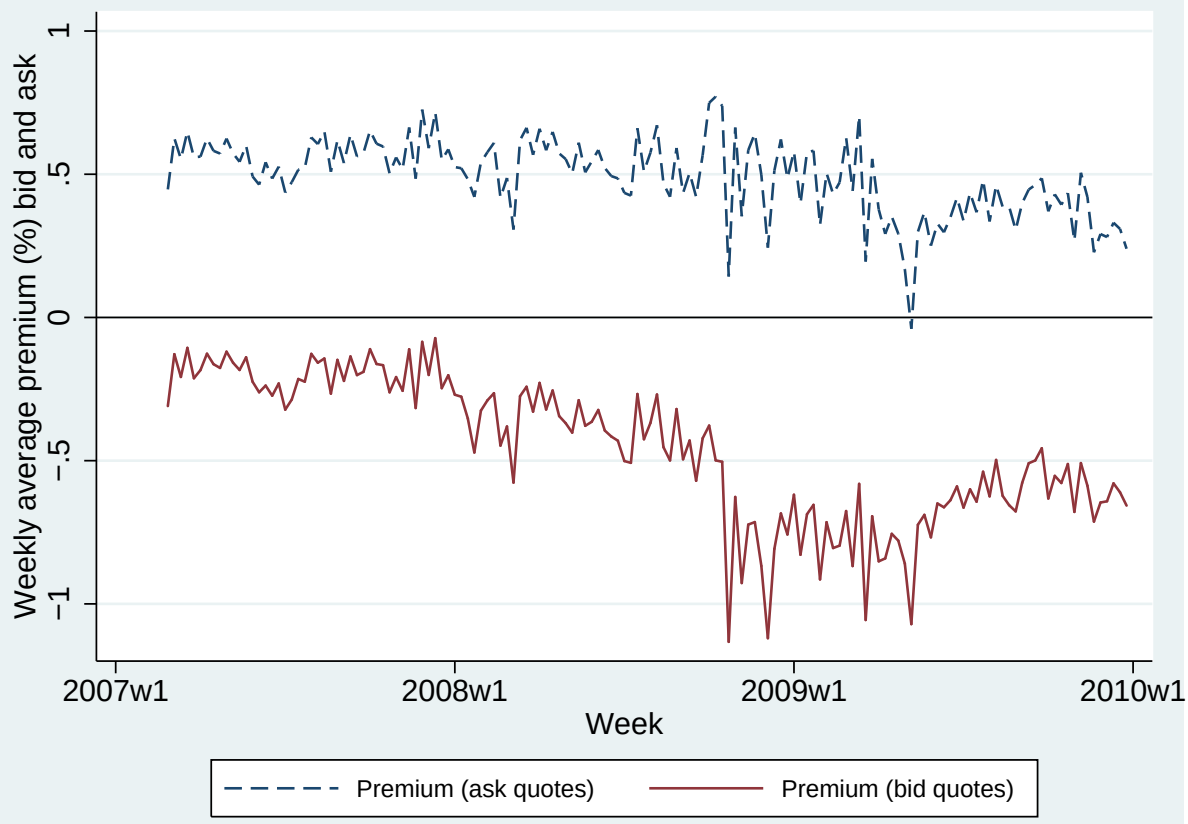


Figure 4: ETF Matched and Unmatched Certificate Bid-Ask Spread

Weekly (cross-sectional) average of the certificate relative bid-ask spread (%) for a subsample of index certificates whose underlying is replicated by at least one ETF ("Matched") and the remaining sample certificates whose underlying index is not replicated by an ETF ("Unmatched"). Shown is the period March 2007 to December 2009.

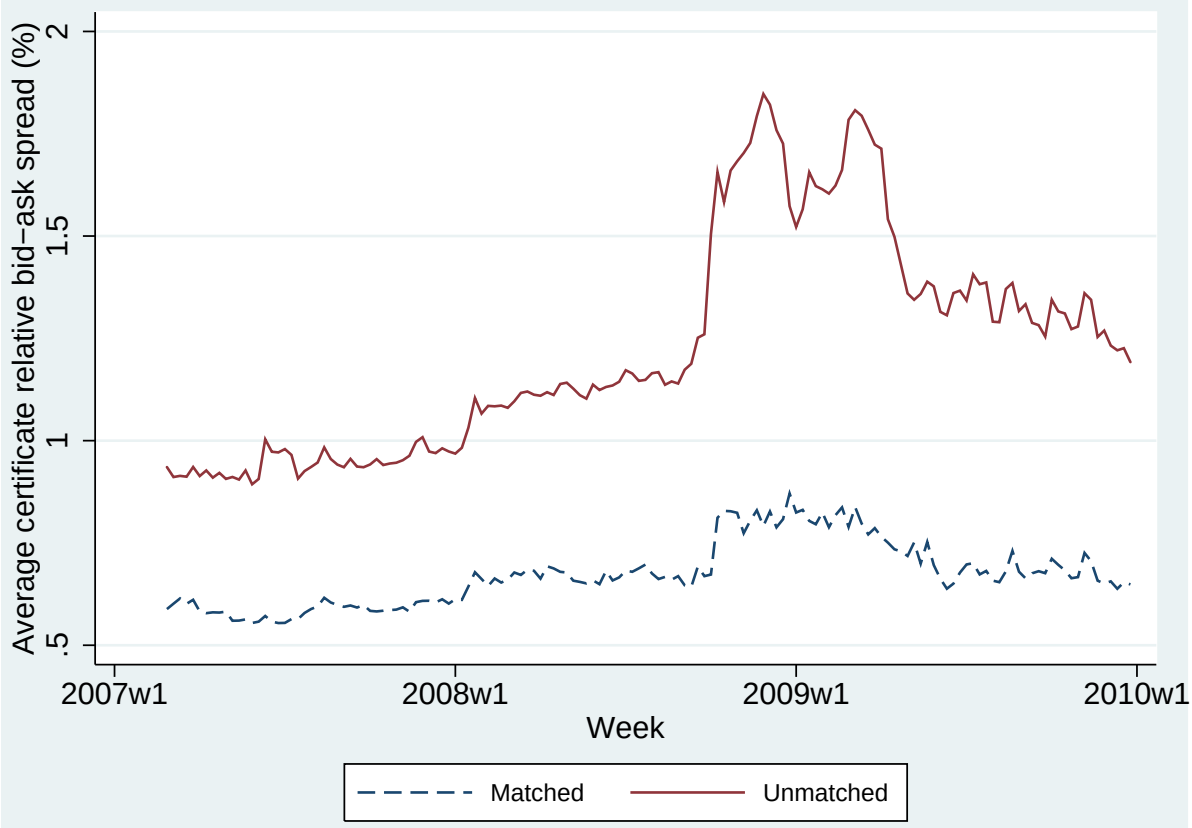
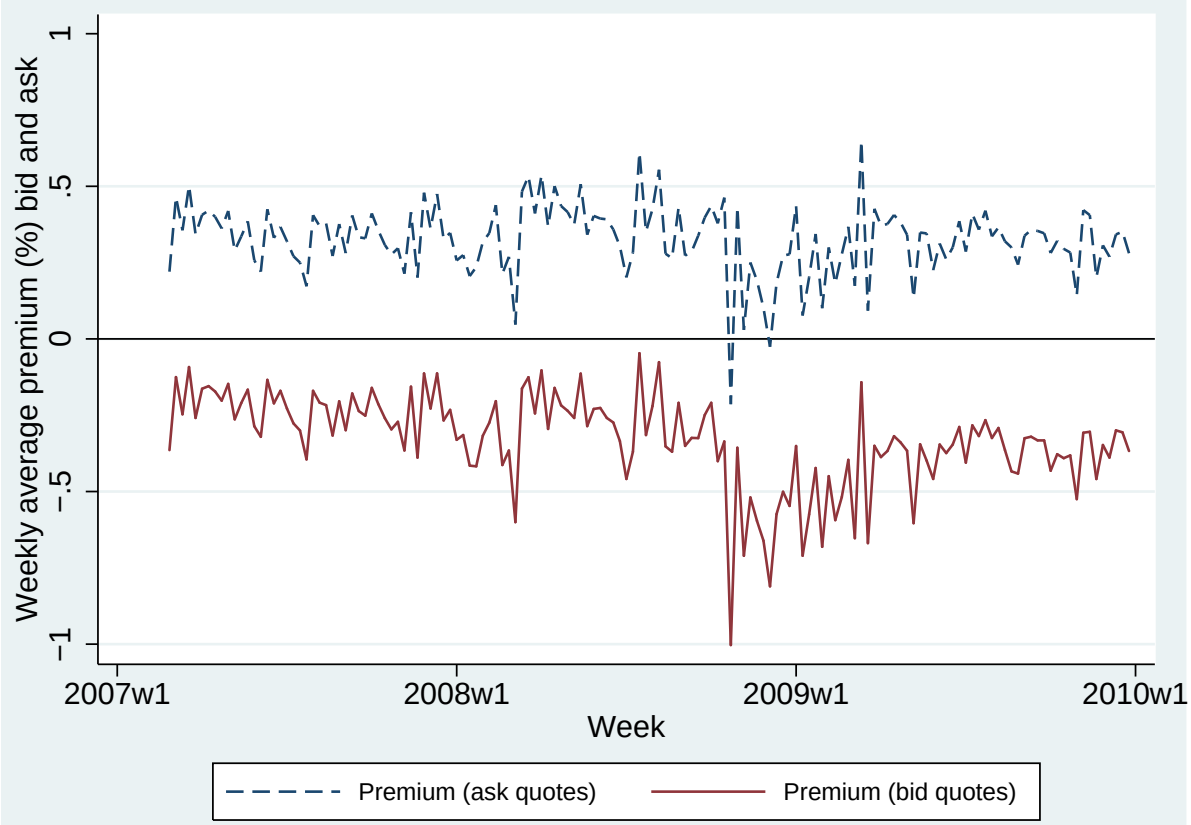


Figure 5: ETF Matched and Unmatched Certificate Bid and Ask Premium

Panel A: ETF Matched Certificate Bid and Ask Premium

Subsample of certificates whose underlying is replicated by at least one ETF. The figure shows the weekly (cross-sectional) average of the certificate premium, decomposed into a bid and ask premium in percent. The bid (ask) premium is the percentage difference between the certificate's actual end-of-day bid (ask) quote and its intrinsic price. Shown is the period March 2007 to December 2009.



Panel B: ETF Unmatched Certificate Bid and Ask Premium

Subsample of certificates whose underlying is not replicated by an ETF. The figure shows the weekly (cross-sectional) average of the certificate premium, decomposed into a bid and ask premium in percent. The bid (ask) premium is the percentage difference between the certificate's actual end-of-day bid (ask) quote and its intrinsic price. Shown is the period March 2007 to December 2009.

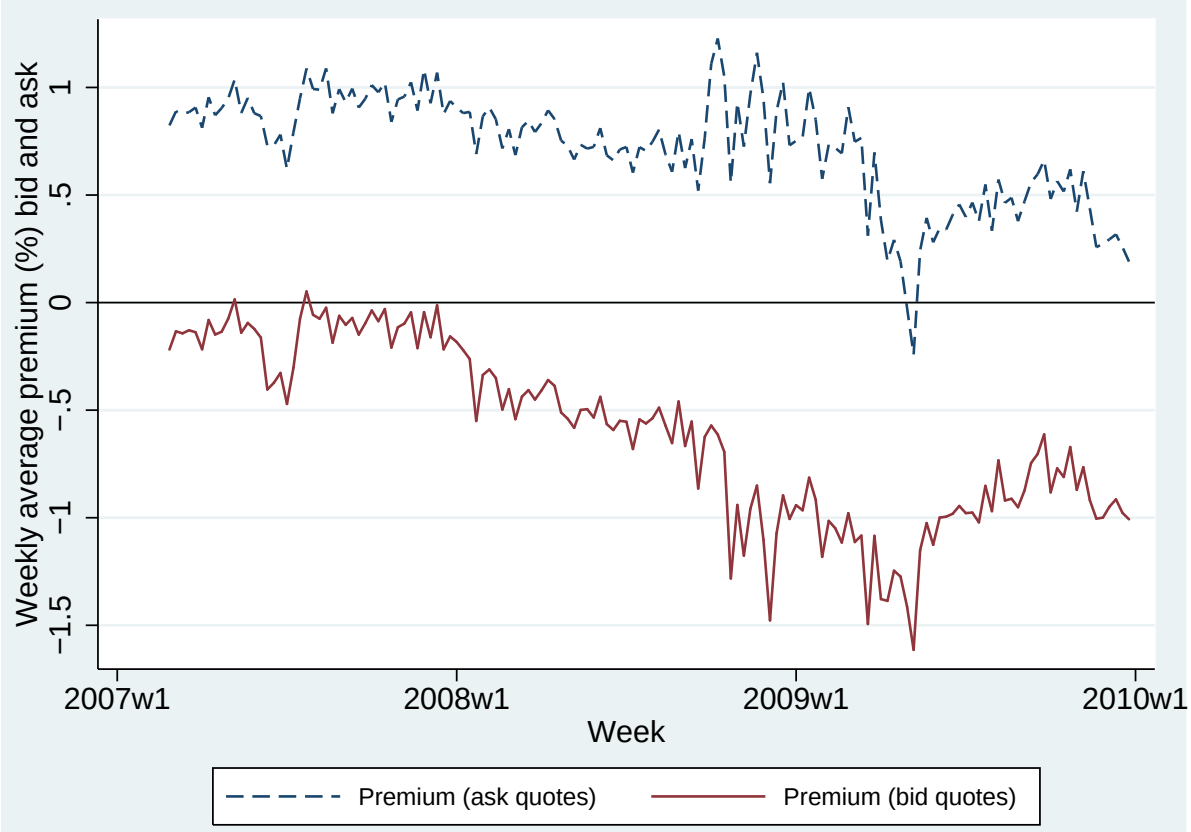


Figure 6: Matched Certificate Buys and Sells

Subsample of certificates whose underlying is replicated by an ETF. The figure shows the weekly average number of sell transactions (solid line) and buy transactions (dashed line). Shown is the period March 2007 to December 2009.

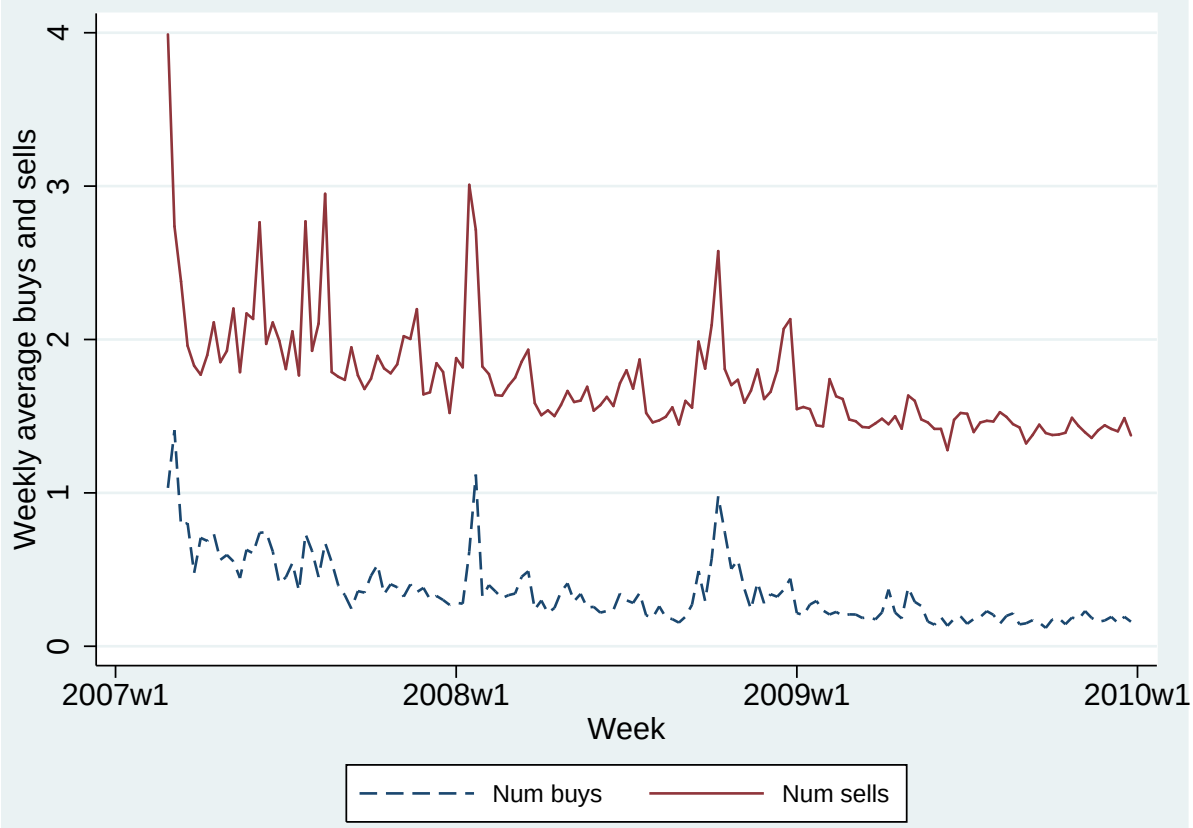


Figure 7: Unmatched Certificate Buys and Sells

Subsample of certificates whose underlying is not replicated by an ETF. The figure shows the weekly average number of sell transactions (solid line) and buy transactions (dashed line). Shown is the period March 2007 to December 2009.

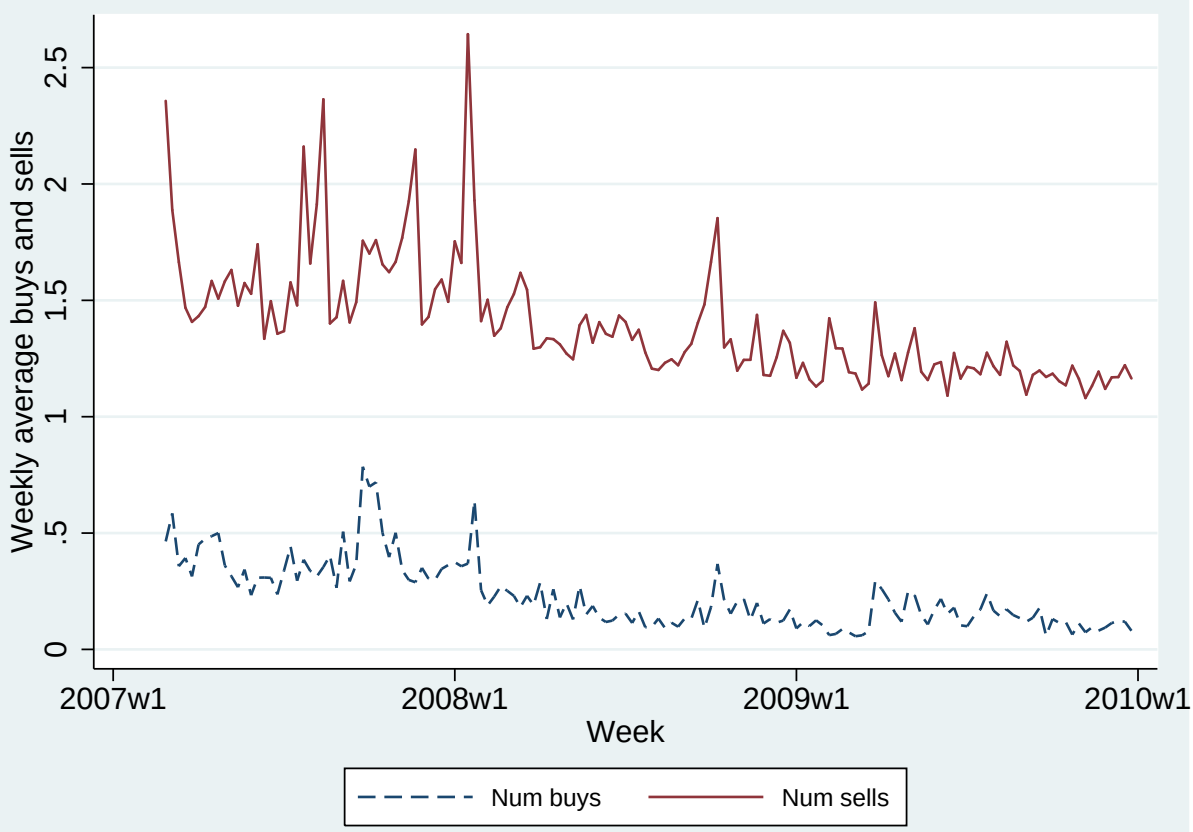


Table 1: Descriptive Statistics

Descriptive statistics for 371 index certificates and their underlying indices over the period March 2007 to December 2009. $Premium_c$ is the percentage difference between the actual certificate price and its fair market value in percent. $BAspread_c$ is the relative bid-ask spread in percent, i.e. the absolute bid-ask spread divided by the bid-ask midpoint in percent. Ret_i is the daily logarithmic return of the underlying index in percent. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. CDS is the 5-year credit default swap spread of the issuing bank. $IssueNum_c$ is the number of certificates registered to be issued by the issuer. $TradeVol_c$ is the number of certificates traded.

	Obs	Mean	Median	S.D.	Min	Max
$Premium_c$ (%)	206,001	0.019	0.006	1.98	-38.85	30.76
$BAspread_c$(%)	206,253	0.925	0.804	0.862	0	16.52
Ret_i (%)	193,541	0.014	0.0472	1.795	-52.600	43.48
$varRet_i$	206,193	1.625	1.445	0.856	0	17.47
CDS	186,927	85.04	80.71	54.24	4.99	724
$IssueNum_c$	205,683	1,781,549	500,000	5,834,407	1,000	100,000,000
$TradeVol_c$	110,749	652	0	5,495	0	822,952

Table 2: Index Certificate Issuer Characteristics

This table shows characteristics of the certificate issuing banks in the sample. $Premium_c$ is the percentage difference between the actual certificate price and its fair market value in percent. $BAspread_c$ is the relative bid-ask spread in percent, i.e. the absolute bid-ask spread divided by the bid-ask midpoint multiplied by 100. CDS is the 5-year credit default swap spread of the issuing bank.

Issuing bank	Issued certificates	Obs	Average		
			$Premium_c$	$BAspread_c$	CDS
ABN AMRO	71	9,569	0.894	1.07	
BNP Paribas	1	431	0.062	0.12	40.15
Bayerische Landesbank	2	1,253	-0.027	0.36	74.51
Bear Stearns	4	806	-0.058	0.57	218.16
Citigroup	12	3,974	0.146	0.33	67.54
Commerzbank	59	29,150	-0.268	0.99	74.32
Credit Mutuel	12	3,334	0.159	0.63	103.18
DZ Bank	1	604	0.461	0.12	85.33
Deutsche Bank	25	10,986	-1.344	2.11	83.52
HSBC	24	14,418	0.329	0.81	67.47
JP Morgan	5	400	-0.955	2.30	62.51
Landesbank Berlin	22	13,307	-0.001	0.46	39.04
Morgan Stanley	3	1,059	0.415	0.11	213.81
Raiffeisen Centrobank	2	1,166	0.018	1.43	143.68
Royal Bank of Scotland	74	34,077	0.808	1.25	119.77
Sal. Oppenheim	2	1,167	0.082	0.23	
Societe Generale	37	20,927	-0.351	0.89	66.74
UBS	26	13,972	-0.606	0.68	100.06
UniCredit	63	37,642	0.008	0.74	79.30
Vontobel	2	1,114	-0.565	0.99	
WestLB	13	6,645	0.059	0.50	91.36

Notes: There have been four bank acquisitions during the sample period. ABN Amro was acquired by Royal Bank of Scotland; Bear Stearns was acquired by JP Morgan; Citigroup sold its German certificate segment to Credit Mutuel; Sal. Oppenheim was acquired by Deutsche Bank. The branch of UniCredit that issues certificates in Germany is Hypovereinsbank.

Table 3: Sample Indices

This table shows the 11 most popular indices whose performance is replicated by at least 5 certificates (*Panel A: Popular indices*) and a random selection of 11 exotic indices that are only replicated by one certificate (*Panel B: Exotic indices*).

Index name	Number of certificates
Panel A: Popular indices	
DAX	14
Nikkei 225	14
S&P 500	12
TecDAX	12
Dow Jones Industrial Average	7
HSCEI - Hang Seng China Enterprises Index	6
MDAX	6
NASDAQ 100	6
AMEX Biotechnology	5
Dow Jones Stoxx 50	5
SMI - Swiss Market Excess Return Index	5
Panel B: Exotic indices	
AMEX Defense	1
BEL 20 - Bruessels Stock Exchange	1
BOVESPA - Sao Paulo Stock Exchange	1
DAXGlobal BRIC Index	1
DivDAX	1
Dow Jones Euro Stoxx	1
Dow Jones Retail Titans 30 Index	1
Dow Jones Stoxx 600 Banks	1
Nasdaq Biotechnology Index	1
RTX Russian Traded Index	1
S-BOX Insider Europe	1
Total number of indices: 203	
Total number of certificates: 371	

Table 4: Differences in Means Before and After Lehman's Default

This table shows the results of a t-test of the differences in means of selected variables before and after the default of Lehman Brothers. *Pre* is the period March 2007 to August 2008 and *Post* is January 2009 to December 2009. $Premium_c$ is the percentage difference between the actual certificate price and its fair market value in percent. $BAspread_c$ is the relative bid-ask spread, i.e. the absolute bid-ask spread divided by the bid-ask midpoint. $TradeVol_c$ is the number of certificates traded. Ret_i is the daily logarithmic return of the underlying index in percent. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. CDS is the 5-year credit default swap spread of the issuing bank.

	Pre		Post		t-test		
	Obs	Mean	Obs	Mean	Δ Mean	t-stat	p-value
$Premium_c$ (%)	118,561	0.1412	87,440	-0.1459	-0.2870	-31.26	0.00
$BAspread_c$ (%)	118,565	0.8223	87,688	1.0637	0.2414	58.85	0.00
$TradeVol_c$	23,051	2,154	87,698	257	-1,897	-29.34	0.00
Ret_i (%)	114,094	-0.0426	79,447	0.0946	0.1373	15.71	0.00
$varRet_i$	118,566	1.4137	87,494	1.9158	0.5021	124.04	0.00
CDS	103,740	56.81	83,187	120.24	63.43	302.43	0.00

Table 5: Effect of Lehman's Default on Certificate Premium

Dependent variable is the certificate premium, $Premium_c$, the percentage difference between the actual certificate price and its fair market value in percent. *PostLehman* is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. *cds* is CDS minus its sample mean. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. $lagRet_i$ is the 1 day lagged daily logarithmic return of the underlying index in percent. t-statistics based on robust standard errors clustered at the underlying level are in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% levels, respectively.

	Certificate premium			
	(1)	(2)	(3)	(4)
PostLehman	-0.2914***	-0.2969***	-0.3090***	-0.3039***
	(-5.1260)	(-5.1242)	(-5.1787)	(-5.1815)
CDS	-0.0001	-0.0009***	-0.0009**	-0.0008**
	(-0.4732)	(-2.6197)	(-2.5879)	(-2.2985)
cds*PostLehman		0.0015**	0.0016**	0.0015**
		(2.5213)	(2.5834)	(2.4441)
$varRet_i$	-0.0015	-0.0012	-0.0020	-0.0027
	(-0.0693)	(-0.0548)	(-0.0923)	(-0.1288)
$lagRet_i$	0.0025	0.0020	0.0020	0.0023
	(0.6614)	(0.5353)	(0.5410)	(0.5993)
Certificate FE	Yes	Yes	Yes	No
Index FE	No	No	No	Yes
Issuer FE	No	No	Yes	Yes
Observations	163,382	163,382	163,382	163,382
$adjR^2$	0.7137	0.7140	0.7142	0.5825

Table 6: Bid and Ask Side Determinants of the Bid-Ask Spread

Determinants of the relative bid-ask spread ($BAspread_c$), the bid premium ($Premium_{c,bid}$) and the ask premium ($Premium_{c,ask}$) of index certificates. $BAspread_c$ is the relative bid-ask spread defined as the Euro spread divided by the average of the end-of-day bid and ask quotes of the index-certificates in percent. $Premium_{c,bid}$ ($Premium_{c,ask}$) is the percentage difference between the actual certificate end-of-day bid (ask) quotes and the certificate's fair market price in percent. *PostLehman* is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. *cds* is CDS minus its sample mean. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. $lagRet_i$ is the 1 day lagged daily logarithmic return of the underlying index in percent. t-statistics based on robust standard errors clustered at the underlying level are in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% levels, respectively.

	$BAspread_c$	$Premium_{c,bid}$	$Premium_{c,ask}$
PostLehman	0.1781***	-0.3825***	-0.2113***
	(4.6487)	(-5.8239)	(-3.8021)
CDS	0.0001	-0.0010**	-0.0008**
	(0.6191)	(-2.5300)	(-2.4290)
cds*PostLehman	-0.0000	0.0015**	0.0015**
	(-0.0955)	(2.4474)	(2.4424)
$varRet_i$	0.0744***	-0.0383	0.0360
	(2.9981)	(-1.5062)	(1.5456)
$lagRet_i$	-0.0033***	0.0037	0.0004
	(-3.1952)	(0.9716)	(0.0919)
Certificate FE	Yes	Yes	Yes
Observations	163,532	163,382	163,382
$adjR^2$	0.7357	0.6935	0.7354

Table 7: Characteristics Index ETFs vs. Index Certificates

This table displays differences between exchange traded index funds (index ETFs) and index certificates.

	Index ETF	Index certificates
Trading	• Trade continuously. • Price set by supply and demand close to NAV. • Subject to tracking error.	• Limited secondary market liquidity. • Issuer is the only market maker. • Issuer is required to provide continuous, actionable quotes. • No tracking error.
Arbitrage	• Creation and redemption facility in cash and in kind for selected institutional investors ("authorized participants") • Can be shorted.	• No arbitrage opportunity. • Cannot be shorted. • Investor has return right on certain days of the year.
Dividends	• Either reinvested if underlying is performance index or paid out.	• Only reinvested if underlying is performance index. • No pay out.
Taxes	• If bought before 31/12/2008 and held longer than 12 months, capital gains tax free. • If bought after 31/12/2008, taxed at 25% of lower personal tax rate.	• If bought before 15 March 2007 and held longer than 12 months, capital gains tax free. • If bought after 15 March 2007, held longer than 12 months and sold before 30 June 2009, capital gains tax free. • If bought after 15 March 2007 and sold after 30 June 2009, or if bought after 30 June 2008 and sold any time after, taxed at 25% or lower personal tax rate.
Counterparty risk	• No. Issuer acquires underlying assets. • Max. 10% of fund can be based on swap agreement.	• Yes. Similar to promissory note. • Investor becomes unsecured lender.

Table 8: ETF Issuer Characteristics

This table shows characteristics of the issuers of exchange traded index funds (index ETFs) in the matched certificate-ETF sample. The 133 index ETFs in the matched sample have an underlying that is also replicated by at least one index certificate. *ETF provider* is the company name of the ETF issuer. *ETF parent* is the parent company of the ETF issuer. *Num. ETF* is the number of ETFs in the matched sample. *Mean BASpread* is the average relative bid-ask spread. *Mean TradeVol* is the average number of ETFs traded.

ETF provider	ETF parent	Num. ETF	Mean BAspread	Mean TradeVol
ComStage	Commerzbank	24	0.2276	2150.4
Credit Suisse Asset Management	Credit Suisse	1	2.3422	144.4
ETF Securities	ETF Securities	1	0.0829	55.2
ETFlab Investment	ETFlab	3	0.4071	4075.5
EasyETF	BNP Paribas	5	0.8106	16.6
Lyxor Asset Management	Societe Generale	22	1.3097	1270.5
Powershares	Invesco	1	0.7076	276.9
RBS Market Access	Royal Bank of Scotland	2	3.0565	911.8
Source Markets	Source Holdings	3	0.1858	3.8
State Street Global Advisors	State Street Corporation	1	0.0640	176.8
UBS Global Asset Management	UBS	3	0.7103	3227.2
db x-trackers	Deutsche Bank	18	0.7077	7219.8
iShares	BlackRock	49	0.9767	4110.2

Table 9: Certificate-ETF Matched and Unmatched Bid-Ask Spread

Determinants of the relative bid-ask spread ($BAspread$) for a subsample of index certificates whose underlying is tracked by at least one ETF (*Matched*) and for the remaining index certificates in the sample whose underlying is not tracked by an ETF (*Unmatched*). The dependent variable is the relative bid-ask spread either for the ETFs ($BAspread_e$) or for the index certificates ($BAspread_c$). $PostLehman$ is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. *cds* is CDS minus its sample mean. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. $lagRet_i$ is the 1 day lagged daily logarithmic return of the underlying index in percent. t-statistics based on robust standard errors clustered at the underlying level are in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% levels, respectively.

	Matched		Unmatched
	$BAspread_e$	$BAspread_c$	$BAspread_c$
PostLehman	0.0837	0.1058***	0.2599***
	(1.5472)	(2.9754)	(3.6660)
CDS		0.0004*	0.0001
		(1.9177)	(0.2448)
cds*PostLehman		-0.0004	0.0002
		(-1.1215)	(0.2862)
$varRet_i$	0.3474***	0.0548***	0.0832**
	(6.0173)	(2.9516)	(2.4542)
$lagRet_i$	-0.0106***	-0.0022***	-0.0037**
	(-3.8218)	(-2.7519)	(-2.2429)
Certificate / ETF FE	Yes	Yes	Yes
Observations	54,121	81,445	82,087
$adjR^2$	0.1704	0.759	0.6927

Table 10: Certificate-ETF Matched and Unmatched Bid-/Ask-Premium

Determinants of the bid premium ($Premium_{bid}$) and ask premium ($Premium_{ask}$) for a subsample of index certificates whose underlying is tracked by at least one ETF (*Matched*) and for the remaining index certificates whose underlying is not tracked by an ETF (*Unmatched*). $Premium_{bid}$ ($Premium_{ask}$) is the percentage difference between the actual end-of-day bid (ask) quotes and the fair market price of the certificate (subscript c) or the ETF (subscript e) in percent. *PostLehman* is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. *cds* is CDS minus its sample mean. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. $lagRet_i$ is the 1 day lagged daily logarithmic return of the underlying index in percent. t-statistics based on robust standard errors clustered at the underlying level are in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% levels, respectively.

	Matched				Unmatched	
Dependent variable	$Premium_{e,bid}$	$Premium_{e,ask}$	$Premium_{c,bid}$	$Premium_{e,ask}$	$Premium_{c,bid}$	$Premium_{c,ask}$
PostLehman	-1.7426	-1.6459	-0.1357***	-0.0314	-0.6434***	-0.3978***
	(-1.5748)	(-1.4811)	(-2.7072)	(-0.6745)	(-5.3859)	(-3.9617)
CDS			-0.0002	0.0002	-0.0023***	-0.0022***
			(-0.5822)	(0.6488)	(-3.2702)	(-3.8127)
cds*PostLehman			0.0001	-0.0003	0.0035***	0.0037***
			(0.1698)	(-0.6111)	(3.1787)	(3.1726)
$varRet_i$	1.0309	1.4090	-0.0487***	0.0056	-0.02	0.0638*
	(1.0470)	(1.4296)	(-2.6984)	(0.4394)	(-0.5680)	(1.7351)
$lagRet_i$	-0.4129	-0.4276	0.0114***	0.0092**	-0.0031	-0.0068
	(-1.1093)	(-1.1398)	(3.3188)	(2.5633)	(-0.5094)	(-1.1088)
Certificate / ETF FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,269	27,269	81,353	81,353	82,029	82029
$adjR^2$	0.0995	0.0994	0.5691	0.609	0.724	0.7654

Table 11: Post-Lehman Change - ETFs, Index Futures and Options

Shown are the regression estimates of the Post-Lehman dummy from the baseline regression model conditional on the availability of substitute index products (ETFs and/or index futures and options) on the same underlying indices as the certificates. The baseline regression model as used throughout the paper is:

$$y_{cijt} = \alpha_c + \beta_1 PostLehman_t + \beta_2 CDS_{jt} + \beta_3 (cds_{jt} \times PostLehman_t) + \gamma' X_{it} + \varepsilon_{cijt},$$

The dependent variable is either the relative bid-ask spread ($BAspread_c$), or $Premium_{bid}$ ($Premium_{ask}$) i.e. the percentage difference between the actual end-of-day bid (ask) quotes and the fair market price of the certificate in percent. $PostLehman$ is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. cds is CDS minus its sample mean. The index control variables are as defined previously. The t-statistics are based on robust standard errors clustered at the underlying level and shown in parentheses. The number of regression observations are in brackets.

Available substitute products	$BAspread_c$	$Premium_{c,bid}$	$Premium_{c,ask}$
ETF or Futures/Options	0.1308***	-0.1648***	-0.0352
	(3.8811)	(-3.9204)	(-0.8735)
	[110,543]	[110,413]	[110,413]
ETF & Futures/Options	0.1368***	-0.1496**	-0.0120
	(3.2673)	(-2.2176)	(-0.1831)
	[58,118]	[58,025]	[58,025]
ETF & No Futures/Options	0.0132	-0.1109*	-0.0987***
	(0.2183)	(-2.0106)	(-3.3378)
	[23,327]	[23,328]	[23,328]
No ETF & Futures/Options	0.2446**	-0.2371***	0.0029
	(2.4482)	(-2.7718)	(0.0368)
	[29,098]	[29,060]	[29,060]
No ETF & No Futures/Options	0.2659***	-0.7896***	-0.5423***
	(2.8294)	(-4.8429)	(-4.0785)
	[52,989]	[52,969]	[52,969]

Table 12: Post-Lehman Change - Monopoly Pricing?

Shown are the regression estimates of the Post-Lehman dummy from the baseline regression model for indices that are replicated by only one issuer and conditional on the availability of other index products (ETFs and/or index futures and options) on the same underlying indices as the certificates. The baseline regression model as used throughout the paper is:

$$y_{cijt} = \alpha_c + \beta_1 PostLehman_t + \beta_2 CDS_{jt} + \beta_3 (cds_{jt} \times PostLehman_t) + \gamma' X_{it} + \varepsilon_{cijt},$$

The dependent variable is either the relative bid-ask spread ($BAspread_c$), or $Premium_{bid}$ ($Premium_{ask}$) i.e. the percentage difference between the actual end-of-day bid (ask) quotes and the fair market price of the certificate in percent. $PostLehman$ is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. *cds* is CDS minus its sample mean. The index control variables are as defined previously. The t-statistics are based on robust standard errors clustered at the underlying level and shown in parentheses. The number of regression observations are in brackets.

Available index products	$BAspread_c$	$Premium_{c,bid}$	$Premium_{c,ask}$
ETF or Futures/Options	-0.0439	-0.1035	-0.1493**
	(-0.3258)	(-1.4420)	(-2.1445)
	[8,168]	[8,161]	[8,161]
ETF & Futures/Options	0.4568	-0.2639	0.1917
	(1.7127)	(-1.7612)	(1.5535)
	[1,235]	[1,235]	[1,235]
ETF & No Futures/Options	0.0029	-0.1847	-0.1817***
	(0.0398)	(-1.9708)	(-8.6073)
	[843]	[843]	[843]
No ETF & Futures/Options	-0.1740	-0.0465	-0.2228***
	(-1.1576)	(-0.5522)	(-3.2090)
	[6,090]	[6,083]	[6,083]
No ETF & No Futures/Options	0.3155**	-0.7856***	-0.4929***
	(2.5361)	(-3.7202)	(-3.1042)
	[37,845]	[37,829]	[37,829]

Table 13: Time Since Issuance

Determinants of the relative bid-ask spread, bid premium and ask premium conditional on the time of issuance. *BAspread* is the relative bid-ask spread, $Premium_{bid}$ ($Premium_{ask}$) is the percentage difference between the actual end-of-day bid (ask) quotes and the fair market price of the certificate in percent. *PostLehman* is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. *cds* is CDS minus its sample mean. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. $lagRet_i$ is the 1 day lagged daily logarithmic return of the underlying index in percent. t-statistics based on robust standard errors clustered at the underlying level are in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% levels, respectively.

	Issued before Mar2007			Issued btw. Mar2007 - Aug2008		
	BAspread	$Premium_{c,bid}$	$Premium_{c,ask}$	BAspread	$Premium_{c,bid}$	$Premium_{c,ask}$
PostLehman	0.1664***	-0.2247***	-0.0601	0.2216*	-0.9244***	-0.7272***
	(4.8192)	(-4.8374)	(-1.1895)	(1.8428)	(-4.1640)	(-4.8873)
CDS	0.0002	-0.0009**	-0.0007**	0.0005	-0.0036***	-0.0031***
	(0.6484)	(-2.3715)	(-2.2061)	(0.8391)	(-2.8676)	(-3.0895)
cds*PostLehman	-0.0003	0.0008	0.0005	0.0004	0.0050***	0.0055***
	(-0.8307)	(1.2984)	(0.9261)	(0.5463)	(3.2261)	(3.6725)
$varRet_i$	0.0666**	-0.0461*	0.0196	0.1170***	0.0531	0.1738*
	(2.5102)	(-1.9356)	(1.4533)	(3.1305)	(0.7392)	(1.7651)
$lagRet_i$	-0.0020**	0.0102***	0.0083***	-0.0078***	0.0030	-0.0049
	(-2.4904)	(3.3293)	(2.8426)	(-2.7618)	(0.8274)	(-1.3283)
Certificate FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	128,166	128,055	128,055	34,347	34,318	34,318
$adjR^2$	0.7448	0.6770	0.6836	0.7058	0.8243	0.8774

Table 14: Certificate Premium - Robustness Checks

The dependent variable is the certificate premium, $Premium_c$, the percentage difference between the actual certificate price and its fair market value in percent. Regression 1 winsorizes $Premium_c$ at the 5% tails. Regression 2 only includes indices denominated in EUR. Regression 3 defines January-June 2009 as the post Lehman period. Regression 4 defines July-December 2009 as the post Lehman period. Regression 5 excludes indices that may include banned stocks. *PostLehman* is a dummy variable equal to one for the period January to December 2009 and zero for the period March 2007 to August 2008. CDS is the 5-year credit default swap spread of the issuing bank. *cds* is CDS minus its sample mean. $varRet_i$ is the standard deviation of the daily index return over the previous 20 trading days. $lagRet_i$ is the 1 day lagged daily logarithmic return of the underlying index in percent. t-statistics based on robust standard errors clustered at the underlying level are in parentheses. *, **, and *** denotes significance at the 10%, 5%, and 1% levels, respectively.

	5% winsorized	EUR Index	Post = 1st half 2009	Post = 2nd half 2009	No banned stocks
PostLehman	-0.3053***	-0.3582***	-0.4030***	-0.2671***	-0.3221***
	(-5.2836)	(-4.4526)	(-5.5521)	(-4.5397)	(-4.3760)
CDS	-0.0009***	-0.0009**	-0.0011***	-0.0010***	-0.0014***
	(-2.7344)	(-2.0770)	(-3.1596)	(-3.3465)	(-3.8015)
cds*PostLehman	0.0017***	0.0021**	0.0026***	0.0025**	0.0046***
	(2.8906)	(2.5886)	(3.6665)	(2.1612)	(3.3228)
$varRet_i$	0.0059	0.0122	0.0175	0.0024	0.0006
	(0.3084)	(0.5063)	(0.8494)	(0.1476)	(0.0330)
$lagRet_i$	0.0028	-0.0067	0.0012	0.0039**	0.0011
	(0.8046)	(-1.6264)	(0.2623)	(2.1591)	(0.5071)
Certificate FE	Yes	Yes	Yes	Yes	Yes
Observations	163,382	110,644	129,540	129,267	95,948
$adjR^2$	0.7544	0.7740	0.6804	0.7976	0.8383