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Hedging Costs and Joint Determinants of Premiums and Spreads in Structured Financial Products*

Oliver Entrop[1] and Georg Fischer[2]

Abstract

This paper is the first to analyze the joint determinants of premiums and spreads in structured financial products, while also focusing on issuers' hedging costs. We evaluate more than 396,000 single stock discount certificates on an intraday basis in the German secondary market. We find that premiums and spreads are endogenous and negatively related to each other, and depend on different key determinants. The economically significant determinants of the premiums are mainly profit-related, i.e. dividends of the underlying, issuers' credit risk, lifecycle effect and competition, whereas hedging costs and risks are economically less important. However, initial hedging costs are also priced into the premium in the case of large inventory changes. The spread is mostly determined by hedging costs and risk components, such as initial hedging costs, rebalancing costs, volatility, scalper risk, and overnight gap risk, but also depends on dividends. Initial hedging costs appear to be more relevant than rebalancing costs.

Keywords: Discount certificates; Derivatives; Pricing; Market microstructure; Trading costs; Hedging

JEL Classification: D40, G12, G21

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1. Introduction

A prominent and well-studied phenomenon of listed retail structured products – also commonly referred to as "(investment) certificates" – is their overpricing in the secondary market, i.e. both bid and ask quotes (as well as traded prices) exceed their mathematically "fair" theoretical values.[1] This is reflected in a positive premium defined as the relative difference between mid-quote and "fair" value.[2] A variety of studies have analyzed the determinants of this premium, the key results of which can be summarized as follows: The premium diminishes over a certificate's lifetime; this is commonly referred to as the "life cycle hypothesis" (e.g. Entrop et al., 2009; Stoimenov and Wilkens, 2005; Wilkens et al., 2003; Wilkens and Stoimenov, 2007). Issuers adjust the premium in accordance with the order flow they expect, i.e. they increase (decrease) the premium in phases of positive (negative) net expected investors' buying pressure ("order flow hypothesis") (Baule, 2011; Wilkens et al., 2003). Furthermore, the premium decreases with higher competition between issuers (e.g. Baule, 2011; Entrop et al., 2016; Schertler, 2016), and increases with a higher issuer's credit risk (e.g. Baule et al., 2008; Entrop et al., 2016; Schertler, 2016), higher dividend yields of the underlying (e.g. Entrop et al., 2016), a higher volatility of the underlying (e.g. Entrop et al., 2016; Szymanowska et al., 2009) and higher unhedgeable risk (e.g. Baller et al., 2016). Issuers can extract significant economic rents from these products via overpricing due to the special market design. In fact, issuers are obliged to guarantee liquidity via market making and setting binding – not indicative – quotes; a specific product can only be traded with its issuer and short selling is de facto impossible or explicitly forbidden.[3]

[1] The overpricing can be found for a variety of certificates and local markets, see, e.g. the German certificate market (Baule, 2011; Baule et al., 2008; Baule and Tallau, 2011; Entrop et al., 2016; Schertler, 2016; Stoimenov and Wilkens, 2005; Wilkens et al., 2003), structured equity products in the U.S. (Benet et al., 2006; Henderson and Pearson, 2011), the Netherlands (Szymanowska et al., 2009) and Switzerland (Burth et al., 2001; Wallmeier and Diethelm, 2009).
[2] The premium is also commonly referred to as "margin" or "mark-up".
[3] See, e.g., Baule (2011) and Baller et al. (2016) for detailed market descriptions.

While the literature acknowledges that the reported premiums do not represent issuers' net earnings, as premiums have to cover issuers' costs, respective studies do not explicitly incorporate the issuers' cost side in their empirical analyses. Further, the bid/ask spread is ignored.

While the bid/ask spread usually serves as a market maker's compensation for costs (e.g. transaction costs, hedging costs) and risks (e.g. informed traders, illiquidity) in standard markets such as the equity, bond or options markets, it can additionally serve as a further source of profit for the issuer in the market for structured products. Given its market design, the theoretical model by Baller et al. (2016) shows that there should be a substitution effect between premium and bid/ask spread.[4] This implies that each determinant of the premium and the bid/ask spread, respectively, is a potential determinant of the other one.

This paper aims at deepening our understanding of the market for retail structured products. To the best of our knowledge we are the first to incorporate the issuers' cost side into the empirical analysis of determinants of premiums and bid/ask spreads and also the first to consider the spread at all.

Our analysis builds on a large quote and trade data set with 396,249 discount certificates on DAX stocks that were tradable on the Euwax between January 2006 and December 2013.[5] From out tick data we form five time bars each day to keep the analysis numerically manageable, which still results in more than 80 million observations while most studies only observe daily quotes or quotes at issuance. For calculating the premium we use a structural model by Baule et al. (2008) that relaxes the standard Hull and White (1995) assumption of

[4] Baller et al. (2016) find in fact a positive influence of the spread on the premium in their empirical analysis. They consider highly speculative short-term knock-out products, however, and do not consider spread determinants.

[5] The Euwax (European Warrant Exchange) is the trading segment of the Boerse Stuttgart, where nearly all structured products offered in Germany can be traded.

independence between the market risk of the underlying of discount certificate and issuer's credit risk. The relative bid/ask spread can be observed directly from the quotes.[6]

Our econometric design is a 2-equation system where premium and spread are the dependent variables and the potential determinants are the independent variables. We also add the spread as an explanatory variable to the premium-equation and vice versa. To account for the resulting endogeneity, we use GMM-2SLS as well as GMM-3SLS approaches to estimate our equations.

We group potential determinants into three categories. The first one is *hedging costs*. We borrow from the literature on options (see e.g. Boyle and Vorst, 1992; Huh et al., 2015; Leland, 1985; Wu et al., 2014) and warrants (see e.g. Petrella, 2006; Petrella and Segara, 2013), and split hedging costs into initial hedging and rebalancing costs.[7] Initial hedging costs (IHC) are the costs associated with setting up and liquidating a delta-neutral position. Rebalancing costs (RC) represent the costs of rebalancing the position to keep it delta-neutral throughout the certificate's lifetime.

As delta-hedging strategies are usually carried out in discrete time for reasons of transaction costs, they are not perfect and issuers have to bear the remaining risk. Additionally, there is risk such as jump risk that cannot be hedged or only with high costs. These remaining risks also affect issuers' cost side as they result in opportunity costs. Therefore, our second category is *risks*. Here we subsume overnight gap risk and downside jump risk. We also add volatility as a broad measure for uncertainty. Additionally, we consider scalper risk, which is the risk of informed trading against the market maker. Our third category, *other variables,* captures the commonly analyzed determinants from the structured product literature, i.e.

[6] For simplicity, we use the term "spread" in the following instead of "relative bid/ask spread", if not stated otherwise.
[7] Issuers' price-setting behavior for warrants also exhibits overpricing, i.e. quoted prices above the theoretical fair value or option quotes (e.g. Bartram et al., 2008; Baule and Blonski, 2015; Horst and Veld, 2008; Li and Zhang, 2011).

issuer's credit risk, order flow, competition, lifecycle effect and dividends. We also add perfect hedge opportunities via the option market.

Our empirical results can be summarized as follows: We find strong evidence that premium and spread are negatively related and endogenous to each other, i.e. premium and spread serve as substitutes. However, the respective key determinants still differ. Both dividends of the underlying and the issuer's credit risk influence the premium positively, meaning that investors are not fully compensated for the respective negative effects on the value of discounts certificates. Together with the life cycle hypothesis, that we also find support for, this reveals a clearly profit-related behavior when setting premiums. The premium is reduced by stronger competition between the issuers, which is plausible and in line with the literature. Hedging costs and risks are of less importance for the premium while, among the risk factors, the most important one is volatility, which influences the premium positively. However, initial hedging costs are also priced into the premium if there are (large) inventory changes.

Analyzing the determinants of the spread, the cost side and risks are most important. Initial hedging costs, rebalancing costs, volatility, scalper risk, and overnight gap risk are all priced consistently. However, initial hedging costs are economically much more significant than rebalancing costs. Higher competition negatively affects the spread. Interestingly, we find a negative influence of the underlying's dividends. Together with its positive influence on the premium, this finding also supports the substitution effect between premiums and spreads. In fact, it is often hard for retail investors to assess the "fairness" of a quote and, thus, to judge the size of the premium while the spread can directly be observed. This may give issuers an incentive to reduce the spread and increase the premium to attract additional investors. Bartram and Fehle (2005) and in a similar vein Baller et al. (2016) argue for warrants and highly speculative knock-out products, respectively, that investors are more sensitive to the spread than overpricing as they hold these products for only a very short time and trade often. In contrast, discount certificates are much less often traded and often held until maturity (Baule, 2011). Analyzing investors' product choices from very similar discount certificates of different issuers, Entrop et al. (2016) find that investors turn out to be a bit more sensitive to the spread than to premiums in one of their analyses, although the main decision variables are behavioral, such as issuer and product familiarity.

The remainder of this paper is structured as follows: Section 2 describes discount certificates while Section 3 provides the potential determinants and variables of premiums and bid/ask spreads in the three categories hedging costs, risks and other variables. Section 4 presents the dataset and Section 5 explains the valuation method we use. Our empirical analysis is the subject of Section 6 and Section 7 concludes.

2. Discount Certificates

In this paper we focus on discount certificates, which are the most popular type of investment certificates in Germany. They had an outstanding volume of EUR 4.4bn as of December 2017, and the total trading volume was almost EUR 8.0bn on the Euwax and Boerse Frankfurt Zertifikate AG exchanges during 2017, which accounts for a 39% share in all investment certificates.[8]

A discount certificates DC is an unsecured bond issued by financial institutions whose payoff basically equals the minimum of the price of an underlying asset and a fixed cap at maturity T, i.e. the promised payoff is given by:

$$DC_T = \alpha \min\{S_\tau; X\} \tag{1}$$

[8] See the website of the German Derivatives Association, available at www.deutscher-derivate-verband.de.

$$= \alpha(X - \max\{X - S_\tau; 0\}). \quad (2)$$

τ is the reference date on which the repayment is fixed (usually a few days before maturity, thus $\tau \leq T$), S_τ is the underlying price at date τ, X is the cap and α denotes the cover ratio, as the certificate can refer to a fraction or a multiple of the underlying. Obviously, the investor's upside benefits are limited for an increasing underlying price, and discount certificates will therefore trade at a discount compared to the underlying. The product is thus attractive for investors expecting sideways or slightly downward price movements.

Equation (2) reveals that the payoff of a discount certificate can be duplicated by an (unsecured) long zero bond, with a face value X and maturity T, and a respective short European put option with a strike price X. Alternatively, the combination of a long position in the underlying, adjusted for intertemporal dividend payments, and a short European call option with a strike price X can be used.

3. Determinants of Premiums and Spreads

In this section we consider the potential determinants of discount certificates' relative premiums and relative spreads. We divide the variables into three categories: hedging costs (Section 3.1), risks (Section 3.2) and other variables (Section 3.3), the latter including dividends, lifecycle effect, competition and perfect hedge opportunities amongst others.

3.1. Hedging Costs

Similar to Huh et al. (2015), Petrella (2006), Petrella and Segara (2013) and Wu et al. (2014), we split total hedging costs into initial hedging costs IHC_t and rebalancing costs RC_t.[9] We can

[9] We examine the individual hedging costs for each certificate over time. Alternatively, issuers might apply netting by combining different positions and hedge the entire portfolio.

explicitly measure the dynamics of hedging costs over time because we observe the bid and ask prices throughout the lifetime of a certificate (rather than only at issuance) and also the respective bid/ask spreads in the underlying.

Initial Hedging Costs

The initial hedging costs, i.e. the quantity that needs to be traded in the underlying market to establish or unwind a delta-neutral position times the relative costs, are given by:

$$IHC_t = |\Delta_t| \cdot \alpha \cdot spr_t^{UL} \tag{3}$$

with

$$spr_t^{UL} = \frac{ask_t^{UL} - bid_t^{UL}}{0.5\,(ask_t^{UL} + bid_t^{UL})}. \tag{4}$$

Δ_t is the certificate's delta which is the sensitivity of its value to changes in the underlying asset price according to the Black-Scholes option pricing model (Black and Scholes, 1973) and spr_t^{UL} is the relative spread of the underlying stock. Because a discount certificate can be decomposed into a long zero bond (with a delta of zero) and a short European put option (with a positive delta) as described in Section 2, the certificate holder has a positive delta position, while the issuer has a negative one. As we measure the issuer's hedging costs, we take the absolute value $|\Delta_t|$. Analogous to the warrant literature, higher IHC can be expected to have a positive effect on the spread because the issuer increases the ask and reduces the bid price due to the higher costs of setting-up or unwinding a delta-neutral position.

As the issuer naturally holds a short position in discount certificates, any buy (sell) by an investor will increase (decrease) the issuer's negative inventory in absolute terms. As the pass-through of hedging costs into the spread might depend on the issuer's inventory (see e.g. Muravyev, 2016; Wu et al., 2014) we also interact IHC with the order flow as defined below:[10]

[10] As we do not know the level of the inventory we estimate its change via the order flow.

$$IHCxOF_t = IHC_t \cdot OrderFlow_t \tag{5}$$

with

$$OrderFlow_t = \log\left(1 + Volume_t^{InvBuy}\right) - \log(1 + Volume_t^{InvSell}). \tag{6}$$

$Volume_t^{InvBuy}$ is the accumulated trading volume, measured in euros, of investors buying the certificate in t (in the time interval $t-1$ to t) and $Volume_t^{InvSell}$ is the equivalent trading volume for investors selling the certificate back to the issuer.

Additionally, investors are likely to be more sensitive to the spread compared to the premium as they can observe the spread directly while it is hard for them to assess the "fairness" of the premium (Baller et al., 2016). This might give issuers an incentive to "hide" (parts of) increased IHC in the premium rather than widening the spread.

Rebalancing Costs

Rebalancing costs (RC) represent the costs of rebalancing the position to keep a delta-neutral position. In previous studies on warrants and options, rebalancing costs are measured from past or current observations via, for example, the standard deviation of the underlying (e.g. Petrella and Segara, 2013) or the current gamma (e.g. Petrella, 2006; Petrella and Segara, 2013; Wu et al., 2014), i.e. the sensitivity of delta with respect to changes in the underlying price. Then, for example, the empirical analysis examines how the current snapshot of rebalancing costs affects the spread.

As investors often hold discount certificates until maturity (e.g. Baule, 2011),[11] issuers should include the expected RC over the certificate's lifetime in their price-setting. We proxy the RC over the certificate's lifetime by:[12]

$$RC_t = \alpha \cdot \int_t^T \Gamma_t(s)\, ds, \tag{7}$$

where $\Gamma_t(t)$ is the Black-Scholes gamma in t and $\Gamma_t(s)$ with $s > t$ is calulated like the gamma in t but with a remaining time to maturity of $T - s$.

Like in the case of IHC, the pass-through of rebalancing costs may depend on the inventory which is why we also form – analogously to IHC – the interaction between rebalancing costs and the order flow:

$$RCxOF_t = RC_t \cdot OrderFlow_t, \tag{8}$$

where $OrderFlow_t$ is defined as in Equation (6).

Like in the case of IHC, rebalancing costs can be expected to be priced in the spread. However, there are also good reason to price RC into the premium. Clearly, the higher the expected rebalancing costs over the certificate's lifetime, the higher should be the ask price to cover future rebalancing costs. However, then, the bid price is also positively affected by RC: if the certificate is sold back to the issuer before maturity, the issuer can offer a higher bid price because future rebalancing costs cease to be relevant. All else being equal, this would induce a reduction of the premium over a certificate's lifetime. This effect is thus very similar to the standard life cycle hypothesis discussed later in Section 3.3. However, it should be noted that the life cycle hypothesis is based on a profit-maximizing argument, i.e. issuers set prices to

[11] This stands in contrast to warrants, which are more popular for short-term speculative investors, who reverse their position before expiration, thus making the spread more important than the relative overpricing (e.g. Bartram and Fehle, 2005).

[12] For example, the bandwidth cost component in Whalley and Wilmott (1997) and Whalley (2011) is also a function of absolute Gamma integrated over the time to maturity of a warrant.

optimally extract economic rents from their customers, rather than an argument of costs-pass-through as here.

3.2. Risks

Issuers are also exposed to changes in the underlying, which cannot be hedged away or are likely to be too costly to hedge. In this case, inventory management affects the cost side of issuers because delta-hedging does not remove all risks (Stoikov and Sağlam, 2009). In the following, we consider different sources of remaining risks after having established a delta-hedge, which should be priced into issuers' spreads and/or premiums as they have a direct impact on issuers' cost side.

Overnight Gap Risk

Overnight gap risk results from the difference between the closing and opening price of the underlying. We define overnight volatility as a proxy for the overnight gap risk in line with Baller et al. (2016). For each underlying, we generate a total return time series based on the closing and opening price (overnight). Then, we fit a GARCH(1,1) model to each time series (Bollerslev, 1986; Engle, 1982) and obtain an overnight volatility forecast for each point in time.

Downside Jump Risk

The downside jump risk explicitly captures the risk of any sudden spread widenings in the underlying due to illiquidity (Chordia et al., 2001). A downside jump of the underlying price level will increase $|\Delta_t|$ and issuers need to adjust their hedging position by increasing their long position in the underlying.[13] The effect of a downside jump risk is twofold: on the one

[13] The payoff profile for the discount certificate buyer is concave due to the short put option component (see Section 2), whereas it is convex for the discount certificate issuer. Hence, the issuer has a downward sloping demand curve for the quantity of required shares to maintain a delta-neutral position: the discount certificate issuer has an initial long position in the underlying to neutralize the negative delta of the long put position ($\Delta_{put}^{long} < 0$)

hand, if issuers fully dynamically hedge their positions at discrete time intervals throughout the certificate's lifetime, a negative expected jump will increase the costs (spreads) in the underlying, and thus increase the risk of high hedging costs. On the other hand, a downside jump in the price level reduces the required frequency of discrete time steps at which the issuer needs to buy the underlying to remain hedged, and thus avoids recurrent trading costs (spreads) in the underlying market.

The risk of a downside jump in the underlying is measured by the implied volatility slope, following Baller et al. (2016). The slope measures the difference in the implied volatility of an out-of-the-money (OTM) put and an at-the-money (ATM) call option: $SlopeSmile = \sigma_{put}^{imp}(0.98) - \sigma_{call}^{imp}(1)$, where $\sigma_{put}^{imp}(0.98)$ is the implied volatility of a put option with a time to maturity of 30 days and a fraction of strike to underlying price of 0.98, and $\sigma_{call}^{imp}(1)$ is the implied volatility of a call option with a time to maturity of 30 days where the strike equals the underlying price. The implied volatility is calculated from the Eurex options.[14] We interpolate the implied volatility if no exact maturity and/or moneyness exist as described in Section 5.2.

Scalper Risk

Scalper risk is the risk of informed traders entering the market with more information about future price changes than the market-makers, which is also referred to as adverse-selection risk (see e.g. Huh et al., 2015). Scalpers profit from small frequent trades and do not carry inventory overnight. Although, discount certificates are not the first choice for speculating on price trends, issuers can protect themselves against the potential of adverse selection by establishing a minimum reservation spread. Petrella (2006) defines a minimum spread, which protects the issuer by a one tick positive change in the underlying:

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and must e.g. reduce positive delta (selling shares) if the share price rises. Hence, the issuer's demand for buying the underlying is anti-cyclical to the share price movement.

[14] The Eurex is the largest European exchange for options and futures.

$$Scalper_t = \alpha \frac{Tick_t^{UL} \cdot |\Delta_t|}{0.5\,(ask_t^{UL} + bid_t^{UL})}, \tag{9}$$

where $Tick_t^{UL}$ is the underlying's tick size on the Xetra trading venue at time t (Xetra, 2016). It should be noted that scalpers can only profit from price increases because short selling is not possible in the market we consider.

Volatility

As a more general measure of risk, we use the underlying's implied volatility level ($Vola_t$). Discount certificates are a popular way to bet on sideways movements (low volatility) and issuers might use different channels to hide increasing costs to maintain the attractiveness of discount certificates in periods of turmoil, by for example increasing the premium rather than the spread, which the retail investor is less likely to notice.

3.3. Other Variables

Credit Risk

Baule et al. (2008) and Entrop et al. (2016) find that the issuers' credit risk is a key component of premiums, as issuers do not (fully) pass the negative-value effect of credit risk to the investors when setting prices. We therefore follow Entrop et al. (2016) and include the credit risk premium (defined in Section 5.3) to control for that empirical finding.

Order Flow

Issuers may anticipate systematic patterns in investors' trading behavior and adjust premiums accordingly to extract higher economic rents (Baller et al., 2016; Baule, 2011; Wilkens et al., 2003). We therefore include the order flow as defined in Equation (6) to control for this potential effect.

Perfect Hedge

To account for the fact that the issuer may wish to (perfectly) hedge a certificate's position via the option market if possible, we add two dummy variables indicating such a potential hedge. Issuers can perfectly hedge their certificates' position by (i) a zero bond and shorting a put or (ii) going long in the underlying and shorting a call as described in Section 2. If an Eurex option exists on a specific day for the same underlying, where the cap is identical to the option's strike and the reference date is identical to the option's maturity date, the dummy is set to 1 for the remaining lifetime of the certificate, or is otherwise 0. Separate dummies are created for American and European type options at Eurex. Of course, only European options will establish a genuine perfect hedge.

Competition

A negative effect of competition on the premium of discount certificates has been examined by several studies, such as Baule (2011), Entrop et al. (2016) and Schertler (2016). Bartram et al. (2008) report analogous results for warrants. A respective negative effect can be expected on the spread as well, because investors can easily compare the spread of similar products by different issuers. We include a measure of competition following Baule (2011) and Entrop et al. (2016) with:

$$Comp_t = 1 - \frac{1}{n_t}, \tag{10}$$

where n_t is the number of similar certificates offered by other issuers. Similar certificates have the same underlying, a similar cap level (± 5%) and similar time to maturity (± 14 days). Thus, $Comp_t$ may take the value 0 (low competition) to 1 (high competition).

Lifecycle Effect

The lifecycle effect, i.e. the finding that issuers lower the premium over the certificate's lifetime, is well established and reported in many studies such as Entrop et al. (2009), Stoimenov and Wilkens (2005), Wilkens et al. (2003) and Wilkens and Stoimenov (2007). This typical structure in the price-setting allows issuers to earn economic rents from a certificate, independent of the points in time investors buy and sell the certificate back (see also Baller et al., 2016). The lifecycle hypothesis should be confirmed in a positive coefficient of the remaining time to maturity. Thus, we set:

$$TtM_t = T - t \tag{11}$$

as independent variable with *T* being the certificate's maturity date and *t* the current point in time.

Dividends

As investors in discount certificates to not participate in the dividends of the underlying until maturity, higher expected dividends decrease the value of discount certificates. As investors do not have the same ability and information to assess expectations about future dividend payments and the "fairness" of prices, issuers may use dividends to increase profits and hide overpricing. In fact, Entrop et al. (2016) reveal that investors are not compensated enough for the level of expected dividend payments via price reduction which has a positive effect on the premium. To control for this potential effect, we include:

$$DIV_t = \frac{Div_t}{S_t} \tag{12}$$

in our analyses, where Div_t are the aggregate discounted dividend payment estimates between t and τ.

4. Data

4.1. Discount Certificates

Our study focuses on discount certificates written against the stocks that were included in the German DAX30 index between 2006 and 2013. The data consists of quote and trade data for 396,249 certificates on DAX stocks that were tradable on the Euwax between January 2006 and December 2013. These data as well as respective data for the stocks were sourced from SIRCA Thomson Reuters Tick History (TRTH) database. The base data on discount certificates were provided by the financial data provider Deriva GmbH.

4.2. Quote Data

Discount certificates are tradable on the EUWAX between 9:00 a.m. and 8:00 p.m., resulting in 9.7bn single binding quotes (timestamp in milliseconds) in our time period. We sample each certificate's quotes in time bars where the observed close bid and ask prices correspond to the quotes at 9:30 a.m., 12:30 p.m., 3:30 p.m., 5:35 p.m. and 8:00 p.m.[15] Likewise, we form bars for each underlying's Xetra quotes. We calculate the moneyness of a discount certificate as:

$$Money_t = \frac{S_t - X}{X}, \tag{13}$$

where X is the certificate's cap and S_t is the underlying's stock price at time t as above. Time to maturity is measured in years and is defined as in Equation (11). As we observe bid and ask quotes for all certificates, we are able to calculate each certificate's relative spread as:

$$Spread_t = \frac{P_t^{ask} - P_t^{bid}}{0.5\left(P_t^{ask} + P_t^{bid}\right)}, \tag{14}$$

where P_t^{bid} and P_t^{ask} are the certificate's quoted bid and ask price at time bar t, respectively.

[15] We eliminate quote bars where bid or ask quotes are zero, contain missing values or the ask quote is less than or equal to the bid quote.

Statistics on the certificates' issuances per year, moneyness, time to maturity and spread at issuance are presented in Table I. The number of issued discount certificates on DAX stocks on the Euwax from 2006 through 2013 increased progressively across the sample period. The number of issued certificates jumped upwards in the crises periods 2008 and 2011, whereas it felt slightly in the successive years after the crises settled down. Most discount certificates are issued with a cap below the underlying price at issuance with an average moneyness of 11.96%. The time to maturity at issuance, with an average of 1.17 years, decreased due to a change in German tax rules after 2008 (see e.g. Baule, 2011; Entrop et al., 2016). At the issuance day, discount certificates have an average spread of 0.19% that are larger during economic turmoil.

[Insert Table I about here.]

4.3. Trade Data

The trade data contains the exact timestamp of executed trades as well as the volume and trade price at which the trade has been executed at the Euwax. We apply the quote rule to classify each single trade into a sale or buying decision from the perspective of a retail investor (see Chakrabarty et al., 2007). We match the trades with the current quote data. If there is no quote available for the day, we omit the trade. The trade is classified as a sale from the investor's perspective if the trade price is equal to or lower than the bid quote. If the trade price is equal to or higher than the ask quote, the trade is classified as a buy from the investor's perspective. We follow Baule (2011) and omit the trade if the trade price lies between the bid and ask quote or if all three values are identical.[16] Figure 1 shows the development of the order flow, i.e. the difference between the weekly average buy and sell trading EUR volume in millions. The order

[16] By doing so, we refrain from classifying 9.75% of the trades to minimize the error due to classifying trades inside the quotes (Ellis et al., 2000).

flow was highly negative after the Lehman Brothers' default in 2008, while it was positive during nearly all other times. The latter indicates that many certificates are held until maturity.

[Insert Figure 1 about here.]

5. Valuation

5.1. Valuation Framework

The certificate's spread and premium are taken from the sampled quote database and the end of each time bar (see Section 4.2). While the relative spread can easily be calculated using Equation (14), the fair value of discount certificates needs to be determined to quantify the premium at the end of each time bar t. We measure two theoretical fair values: the default-free value applying the Black-Scholes option pricing model (Black and Scholes, 1973) and a structural model (Baule et al., 2008) that takes the issuer's default risk into account.

We apply the Black-Scholes formula to estimate the default-free value of a discount certificate:

$$\begin{aligned} DC_t^{df} &= \alpha e^{-r(T-\tau)}\left(e^{-r(\tau-t)}X - p_t\right) \\ &= \alpha e^{-r(T-\tau)}\left(e^{-r(\tau-t)}X + (S_t - Div_t)N(-a_1) - e^{-r(\tau-t)}XN(-b_1)\right) \end{aligned} \quad (15)$$

with

$$a_1 = \frac{\log\left((S_t - Div_t)/X\right) + (r + \sigma^2/2)(\tau - t)}{\sigma\sqrt{\tau - t}}, \quad (16)$$

$$b_1 = a_1 - \sigma\sqrt{\tau - t}, \quad (17)$$

$$Div_{t,t<\tau_1<\tau_2<\tau} = e^{-r(\tau_1-t)}Div_1 + e^{-r(\tau_2-t)}Div_2, \quad (18)$$

where p_t is the value of a European put option written on the certificate's underlying with maturity τ and strike price X at time t. $N(\cdot)$ represents the cumulative distribution function of the standard normal distribution. Div_t denotes the aggregate discounted dividend payment estimates (τ_1, τ_2) between t and τ, r denotes the risk-free rate and σ the volatility of the underlying.

As certificates are unsecured securities, the fair value of certificates depends on the issuer default risk. For example, Entrop et al. (2016) find that the credit risk explains up to 42% and on average 39%, respectively, of discount certificate overpricing. Hull and White (1995) account for issuer credit risk by discounting the default-free value with the issuer's credit spread s, thus obtaining the value of the defaultable security. The model requires the crucial assumption that market risk (underlying price) and credit (default) risk of the issuer are independent. During periods of turmoil, the correlation between issuers' assets and underlying prices tend to increase, resulting in an overestimation of the value-impact of credit risk, i.e. the fair value is discounted too excessively. A more sophisticated approach to incorporate credit risk is the structural model provided by Baule et al. (2008) that assumes that the issuer's default is driven by its asset value:

$$\begin{aligned} DC_t^{SM} &= \alpha e^{-r(T-\tau)}\left(e^{-(r+s)(\tau-t)}X - p_t^{SM}\right) \\ &= \alpha e^{-r(T-\tau)} \begin{pmatrix} e^{-r(\tau-t)}\big(1 + (\delta - 1)N(-b_2)\big)X \\ +(S_t - Div_t)\Big(N\big(-a_1, a_2, -\rho_{I,S}\big) + \delta N\big(-a_1, -a_2, \rho_{I,S}\big)\Big) \\ -e^{-r(\tau-t)}X\Big(N\big(-b_1, b_2, -\rho_{I,S}\big) + \delta N\big(-b_1, -b_2, \rho_{I,S}\big)\Big) \end{pmatrix} \end{aligned} \tag{19}$$

with

$$a_1 = \frac{\log\big((S_t - Div_t)/X\big) + (r + \sigma^2/2)(\tau - t)}{\sigma\sqrt{\tau - t}}, \tag{20}$$

$$b_1 = a_1 - \sigma\sqrt{\tau - t}, \tag{21}$$

$$a_2 = b_2 + \rho_{I,S}\, \sigma\sqrt{\tau - t}, \tag{22}$$

$$b_2 = N^{-1}\left(\frac{\delta - e^{-s(\tau-t)}}{\delta - 1}\right), \tag{23}$$

where p_t^{SM} is the value of a vulnerable put option. Compared to the default-free model above, the additional input parameters are $\rho_{I,S}$, the correlation between issuer's assets and the underlying, δ, the recovery rate of the issuer's assets in case of default, and s is the issuer's credit spread. $N(\cdot,\ \cdot, \rho_{I,S})$ represents the bivariate normal cumulative distribution function with correlation $\rho_{I,S}$. A positive correlation value lowers the impact of credit risk, and hence positively affects the certificate's value. If the correlation ($\rho_{I,S}$) takes the value zero, the fair value coincides with the Hull and White model. Moreover, the certificate's value of a default-free issuer, i.e. a recovery rate (δ) equal to one, coincides with the default-free Black-Scholes model.

5.2. Calibration

We estimate the value of every discount certificate via standard calibration procedures. The certificate's fair value is estimated on each trading day between its issuance and maturity at 9:30 a.m., 12:30 p.m., 3:30 p.m. and 5:35 p.m. Because stock options with a time to maturity of more than two years are scarce and dividend forecasts are only available for two subsequent payments, we exclude discount certificates' valuation days with a remaining time to maturity of more than two years. For S_t, we use the certificates' underlying stock price, matched to a second with each quote, which we obtained from the SIRCA Thomson Reuters Tick History (TRTH) database. The default-free spot rate (r) is the government spot rate curve, estimated by the Deutsche Bundesbank, using the Svensson (1994) function as an extension of the Nelson and Siegel (1987) approach. For periods of less than one year, we use linearly interpolated

EUREPO rates. For dividend estimates, we use monthly I/B/E/S consensus analyst forecasts for the two successive dividend payments on each valuation date from Thomson Reuters.[17] The expected dividend payment dates are the days after the expected shareholders' meeting dates.

The volatility σ of the underlying stocks is estimated by extracting the implied volatilities from daily settlement prices of stock options listed at Eurex, that were provided by the Karlsruher Kapitalmarktdatenbank of the Karlsruhe Institute of Technology. As Eurex stock options are of American type, we estimate the implied volatility by using the Leisen-Reimer binomial tree model (Leisen and Reimer, 1996). The model improves the convergence in comparison to the Cox, Ross and Rubinstein model (1979). We apply a daily discretization and allow for two discrete dividend payments. The implied volatility is the volatility that equates the option's binomial tree price with the Eurex option settlement price by applying a root-searching algorithm (Brent, 1973). We estimate the implied volatility for American put (with and without dividend payments) and call options (with dividend payments); for call options without dividend payments, we apply the Black-Scholes formula. Moreover, as we estimated the implied volatility from Eurex option chains, only the volatility of out-of-the-money Eurex options is used, which is common practice (e.g. Taleb, 1997, p. 164). The implied volatility is assigned to each discount certificate, matching the same underlying, strike (cap) and maturity. If we do not find an exact match, we bilinearly interpolate the estimated implied volatility from the four options with the same underlying, the nearest (lower and higher) strikes and (shorter and longer) maturities to the certificate (see e.g. Baule, 2011; Horst and Veld, 2008).

The structural model additionally requires the issuer's credit spread as an input. We obtain issuer-specific one- and two-year CDS spreads for senior debt from Datastream.[18] For each day and each issuer, a spread curve is interpolated for a time to maturity of up to two years. For

[17] Recall that German stocks pay dividends yearly.
[18] In our sample period, CDS spreads are not available for some issuers (BHF-Bank, BW-Bank, Interactive Brokers Financial Products, LBB, Lang & Schwarz, Sal. Oppenheim, Vontobel, WGZ Bank).

each trading day, the credit spread with the congruent time to maturity and issuer is used for each certificate. As a proxy for the correlation ($\rho_{I,S}$) between the asset returns of the issuers and the returns of the underlying, we use the equity correlation between issuer and underlying firms from historical continuously compounded daily stock returns over a 125-day period. The recovery rate (δ) takes the default value of 0.4.

5.3. Premiums of Discount Certificates

Based on the fair theoretical values, the default-free premium DFP_t, the credit risk premium CRP_t, and the total premium TP_t are defined as in Baule et al. (2008):

$$DFP_t = \frac{DC_t^{mid} - DC_t^{df}}{DC_t^{df}}, \tag{24}$$

$$CRP_t = \frac{DC_t^{df} - DC_t^{SM}}{DC_t^{SM}}, \tag{25}$$

$$TP_t = \frac{DC_t^{mid} - DC_t^{SM}}{DC_t^{SM}}, \tag{26}$$

where DC_t^{mid} is the certificate's mid quote (average of bid and ask quotes) at 9:30 a.m., 12:30 p.m., 3:30 p.m. and 5:35 p.m. on the Euwax.

[Insert Table II about here.]

Table II depicts the average yearly spreads (see Equation (14)) and premiums for 317,062 discount certificates and more than 279 million observations. The table contains all certificates of issuers listed on the stock exchange and observations were truncated at a 1% level regarding the default-free premium.[19] The number of outstanding certificates and issuers from which

[19] Public issuers are Barclays, BNP Paribas, Commerzbank, Citibank, Deutsche Bank, Goldman Sachs, HSBC Trinkaus, ING, Merrill Lynch, Macquarie Oppenheim, Morgan Stanley, RBS, Société Générale, UBS and UniCredit. Non-public issuers are BayernLB, Dresdner Bank, DZ Bank, LBBW and WestLB.

investors could choose increased steadily over the sample period 2006-2013. The average spread is 0.16% for the whole sample period. The spread was the highest in 2008 and 2009, after the Lehman Brothers default occurred, with 0.33% and 0.44%, respectively. For listed issuers, discount certificates are priced 0.66% above the fair value. The average credit risk premium accounts for 56% of the structural model's total premium with an average default-free premium of 30 basis points.[20] Figure 2 shows the development of the weekly average total premiums (TP) and spreads over the sample period. Interestingly, the overpricing of discount certificates surged during both economic crises (2008/09 and 2011/12), whereas spreads were only raised during the global financial crisis in 2008/09.

[Insert Figure 2 about here.]

6. Empirical Analysis

6.1. Empirical Design

To empirically analyze the determinants of the total premium TP (see Equation (26)) and of the spread as defined in Equation (14), respectively, we estimate the following two equations in several variants and methodological settings:

[20] For comparison, when calculating the total premium by the method of Hull and White (1995), we find that the average estimated credit risk premium (and consequently the total premium) for the structural model is 0.11 percentage points lower than in the Hull and White model. As expected, the difference between both models is higher (e.g. 23 basis points in 2009) when market risk, and thus correlations and spreads, increases.

$$TP_{ijt} = \mu + \beta\ Spread_{ijt} + \sum_k \gamma_k\ HedgingCosts_{kijt} + \sum_l \theta_l\ Risks_{lijt} + \sum_m \xi_m\ OtherVariables_{mijt} + \sum_n \phi_n\ Controls_{nijt} + \epsilon_{ijt} \tag{27}$$

$$Spread_{ijt} = \mu' + \beta'\ TP_{ijt} + \sum_k \gamma'_k\ HedgingCosts_{kijt} + \sum_l \theta'_l\ Risks_{lijt} + \sum_m \xi'_m\ OtherVariables_{mijt} + \sum_n \phi'_n\ Controls_{nijt} + \epsilon'_{ijt}, \tag{28}$$

where TP_{ijt} denotes the total premium of discount certificate i of issuer j in t and the other variables are indexed analogously. As the total premium and the spread are likely to be substitutes as mentioned in the introduction, we add the spread and the total premium as first variable in Equations (27) and (28), respectively. The remaining independent variables are those defined in Sections 3.1 to 3.3.

We also add some controls. As premiums and spreads might be influenced by the moneyness (defined as in Equation (13)), we include the moneyness at quotes and its square root in the model (Baule, 2011; Baule and Blonski, 2015; Jameson and Wilhelm, 1992). Furthermore, the implied volatility was calculated by using daily settlement prices of Eurex options rather than intraday prices. Wallmeier (2015) shows that 95% of the implied volatility intraday variations are explained by changes in the underlying level. To control for intraday changes of the volatility, we follow Baller et al. (2016) and include the return of the underlying prices from the quote time until the settlement time of the same day in our model. Furthermore, we include issuer-fixed effects, underlying-fixed effects and monthly time-fixed effects.

In Sections 6.2 and 6.3 we estimate the regression equations above separately, where we include in Section 6.3 *all* variables and leave interaction terms out in Section 6.2. In both sections we at first use the high-dimensional fixed effects estimator of Correia (2016) and Newey-West heteroskedasticity- and autocorrelation-consistent (HAC) standard errors (Newey and West, 1987). However, the results may be biased due to the endogeneity between the premium and the spread.

To account for this, we additionally re-estimate the regressions by applying a GMM-2SLS approach. As instruments for the spread in Equation (27), we follow Baller et al. (2016) and utilize (i) the average spread over all products with the same underlying of the prior day and (ii) the first difference of the ratio between the spread of the most similar product of a different issuer and the average spread of the same day for the same underlying. The most similar certificate is the product, which has the same underlying, the same time bar, and the smallest Euclidean distance with regard to time to maturity and moneyness. This procedure is applied analogously to the total premiums in Equation (28). For each instrumental variables (IV) regression, we report validity tests for underidentification, weak identification and overidentification (Hansen, 1982; Kleibergen and Paap, 2006). The test statistics indicate that the instruments are correlated with endogenous regressors, are not weak instruments and are uncorrelated with the error term as well as correctly excluded from the estimated equation.

Finally, the previous single equation models are also estimated simultaneously (Section 6.4). We follow Roll et al. (2010) and examine average premiums, spreads and certificate characteristics, where the average is taken over all certificates with the same underlying and issuer per day, i.e. we have one observation per each underlying-issuer combination per day. The reason for using daily time periods is twofold: first, the size of our dataset makes it numerical challenging to apply a GMM estimator in a 3SLS-setting. Secondly, it allows us to examine average, “representative” discount certificates, which should reduce the impact of noise on the single-certificate level. As additional instruments to the exogenous explanatory variables common to all equations, we include the previously used instruments from the individual IV regressions. The system is estimated by using the GMM-3SLS estimator which allows for HAC standard errors and different instruments in different equations (Schmidt, 1990; Wooldridge, 2010).

6.2. Determinants of Issuers' Total Premiums and Spreads

The results for the first regressions are presented in Table III. We examine the magnitude of issuers' hedging costs, risks and the other variable on either total premium or spread by comparing the standardized coefficients. Columns (1) to (3) show the estimated coefficients with total premium as the dependent variable and columns (4) to (6) with spread as the dependent variable. Columns (2) and (3) as well as (5) and (6) are IV regressions described above.

Columns (1) and (4) neglect the endogeneity between premiums and spreads, and both coefficients for $Total\,Premium$ and $Spread$ are positive. However, the coefficients are negative for IV regressions (columns (2), (3), (5) and (6)), i.e. premiums tend to be higher when spreads are lower and vice versa. This supports our conjecture regarding a substitution effect between spreads and premiums, and is our first important result that is stable across all subsequent analyses.

[Insert Table III about here.]

Hedging Costs

Initial hedging- and rebalancing costs have a positive effect on total premiums, whereas the effect on premiums is slightly more pronounced for RC than IHC (columns (1) and (3)). However, looking at the standardized coefficients, the economic magnitude is minuscule for both hedging costs. This implies issuers do not seem to incorporate future (expected) rebalancing costs in the premiums in the way supposed in Section 3.1.

Examining the determinants of the spread, the coefficients for IHC and RC are positive and much higher. Initial hedging costs, in turn, are more important than rebalancing costs in explaining certificate spreads, which is consistent with the warrant market (Petrella, 2006). Hence, issuers adjust the spread when the initial hedging becomes costlier. Interestingly, IHC is the determinant with the highest influence on spreads across all variables. This indicates that issuers dynamically delta-hedge their positions and that certificates' trading costs are linked to the trading costs in the stock market, because the certificate's delta and the underlying's spread are both components of IHC.

Risks

$GapRisk$, $ScalperRisk$ and $Vola$ increase the total premium, with $Vola$ and $GapRisk$ having the largest economic impact on total premiums within the risk determinants. $JumpRisk$ has a significant and negative coefficient. A downside jump in the underlying price increases the certificate's delta $|\Delta_t|$ and issuers need to adjust their hedging position by increasing their long position in the underlying. Consequently, a downside jump in the price level reduces the required frequency of discrete time steps at which the issuer needs to buy the underlying to remain hedged, and thus avoids recurrent trading costs through spreads in the underlying market as discussed in Section 3.1.

The risk factors have an economically much higher impact on spreads than premiums: $GapRisk$, $JumpRisk$, $ScalperRisk$ and $Vola$ increase the spread, with $Vola$ and $ScalperRisk$ being one of the most economically significant determinants of spreads. Hence, issuers protect themselves against adverse-selection risk, albeit the fact that discount certificates are not the first choice for informed traders. $JumpRisk$ has a positive and economically insignificant relationship with the spread.[21] $Vola$ is the economically most significant risk determinant for premiums as well as spreads. This variable reflects uncertainty in periods of turmoil, which is consequently transferred to retail investors.

Other Variables

In line with the results from Section 5.3, the credit risk premium has the largest impact on total premiums. CRP has also a positive, but small relationship with the spread for model (5) and (6). The $OrderFlow$ – although statistically significant – has an economically irrelevant impact on both total premium and spread. This stands in contrast to the order flow hypothesis (e.g. Baule, 2011), i.e. issuers anticipate systematics in the order flow and increase the premium in phases of positive expected net purchases by investors and vice versa. Limited evidence for the order flow hypothesis is also found by Entrop et al. (2016). Still, order flow will become relevant when we interact it with the hedging costs. Moreover, our empirical finding is consistent with the hypothesis that order processing costs decrease if trading volume increases (Petrella and Segara, 2013).

(Perfect) hedge opportunities, through available Eurex options with the same underlying asset, strike and time to maturity as the discount certificate, reduce issuers' total premiums although the effect is small. For the spread, the perfect hedge variables show mixed results. While the coefficient is negative in the case of a European type option that allows for a real perfect hedge, the hedge opportunity with American type options exhibits a positive relationship with the spread. As expected, the competition among issuers $Comp$ has a negative influence throughout all models, implying lower total premiums (spreads) when there is higher competition while controlling for the spread (premiums).

[21] However, the relationship becomes positive when applying a simultaneous equations model (see Section 6.4).

Time to maturity is positive and significant for the premium supporting the "lifecycle hypothesis". It also has a positive relationship with the spread, however, the economic influence on spreads is not as significant as on total premiums, where the lifecycle effect is a crucial component. We argued in Section 3.1 that decreasing premiums over time could also be explained by hedging costs. However, as rebalancing cost turned out to be of minor importance for the premium, our results imply that the phenomenon of decreasing premiums is indeed primarily profit-related.

When examining the effect on the total premium, the dividend variable DIV is positive (column (3)), supporting previous findings from Entrop et al. (2016). This implies that issuers do not pass the negative-value effect of dividends fully to the investor. Dividends turn out to have the second largest influence on the premium after the credit risk margin. In contrast, the spread exhibits a negative sensitivity to DIV (column (6)) that is small but will become more relevant in the subsequent simultaneous equation model. This implies that issuers increase the premium and decrease the spread. This is plausible if investors are more sensitive to the easily comparable spreads than to the less transparent premiums, as they can hardly assess the financial fair value of a discount certificate.

To summarize our first results, premiums and spreads serve as substitutes. The credit risk premium, dividends, volatility, time to maturity and gap risk are, in descending order, the economically most important determinants of total premium. The economically most significant determinants of spread are, in descending order, initial hedging costs, volatility, scalper risk, and gap risk − but also the dividends of the underlying influence the spread.

6.3. Hedging Costs and Changes in Inventory

In this section we examine the simultaneous impact of hedging costs and changes in issuers' inventory, by including two new interaction terms in our regressions: first, the interaction between initial hedging costs and the order flow (see Equation (5)), and secondly, the interaction between rebalancing costs and the order flow (see Equation (8)). Table IV reports the results providing unstandardized coefficients due to the interaction terms.

IHC and RC still have a positive effect on total premiums (columns (1) to (3)). If there are high initial hedging costs and asymmetric order flows, the positive coefficient of $IHCxOF$ reveals that issuers adjust the premium according to the order flow, i.e. investor's buying pressure leads to increases and selling pressure to decreases in premiums. For example, in column (3), the coefficient for IHC is 0.1180 and for $IHCxOF$ is 0.1436. As the average order flow is 0.0133 with a high variation, the effect of the interaction term is economically meaningful. The interaction term for rebalancing costs $RCxOF$ shows a negative relationship with total premiums. However, the effect is very small. Thus, the interaction effect is less pronounced for rebalancing costs than initial hedging costs.

[Insert Table IV about here.]

The effect of the interaction terms on the spread are shown in columns (4) to (6). IHC and RC still have a statistically significant positive effect. However, $IHCxOF$ shows a significant positive relationship with the spread at a one percent level only in column (6), and none of the interaction terms for rebalancing costs are statistically significant at a one percent level. The remaining variables are fully in line with the results from Section 6.2.

All in all, our results imply that issuers price initial hedging costs not only into the spread but also into the premium in the case of large changes in the inventory.

6.4. Simultaneous Equations Model

The standardized coefficients of the simultaneous equations model are reported in Table V. Column (1) presents the GMM-3SLS estimates without fixed effects, whereas column (2) includes issuer dummies. Most findings are in line with the empirical results from the previous analyses, for example, premiums and spreads are significantly negatively related. Hence, we discuss only deviations from previous results and stress some distinctive features.

[Insert Table V about here.]

The effect of IHC and RC remain the same when either explaining premiums or spreads. However, the economic significance of rebalancing costs on spreads is more distinctive than the results from Section 6.2; RC is now the fourth most influential determinant.

The influence of $GapRisk$ on spreads is still positive but loses significance. $JumpRisk$ is now negative throughout all coefficients, and thus issuers do not perceive downside jump risk as an additional cost factor. In Section 6.2, it had a significant positive relationship with spreads. The perfect hedge variables now show mixed results. In Section 6.2, the proxy for perfect hedge opportunities had a significant negative effect on premiums and spreads. The relationship was only significantly positive for American type options on spreads. Now, the variables are predominantly positive; this can hardly be interpreted but all effects are still economically insignificant.

The competition variable $Comp$ is still significant and negative thorough all coefficients; however, the economic significance on spreads increased. The same holds for the dividend DIV as already mentioned in Section 6.2.

7. Conclusion

This paper examines the joint determinants of premiums and spreads, focusing on various new pricing components of structured financial products. The focus of this paper is on issuer's price-setting behavior and how it is affected by hedging costs. We examine a large discount certificate dataset on DAX stocks that were tradable on the Euwax between January 2006 and

December 2013. The fair theoretical value is calculated using a structural model, which relaxes the assumption of market risk (underlying price) and issuer's credit (default) risk being independent.

We find strong evidence for a negative relation between premium and spread and vice versa (substitution effect). However, the respective key determinants still differ. The main economic factors significantly explaining the premium of discount certificates are profit-related, like dividends, credit risk, lifecycle effect and competition. While hedging costs and risks play a subordinate role in explaining the premium, there is clear evidence that initial hedging costs are also priced into the premium if there are inventory changes. The economically significant determinants for the spread are mainly hedging costs and non-hedgeable risks. We find that hedging costs are positively related to the spread, with initial hedging costs being economically the most significant determinant. Scalping risk leads to a higher minimum reservation spread − thus, issuers protect themselves from scalpers. Furthermore, competition plays an important role in reducing the spread for certificates. In contrast to the premium, we find a negative influence of the underlying's dividends on the spread.

We conclude that issuers predominantly use certificate's premiums to manually adjust to changes in the market, which are profit and inventory cost related, whereas the spread is mainly used for issuer's cost side management.

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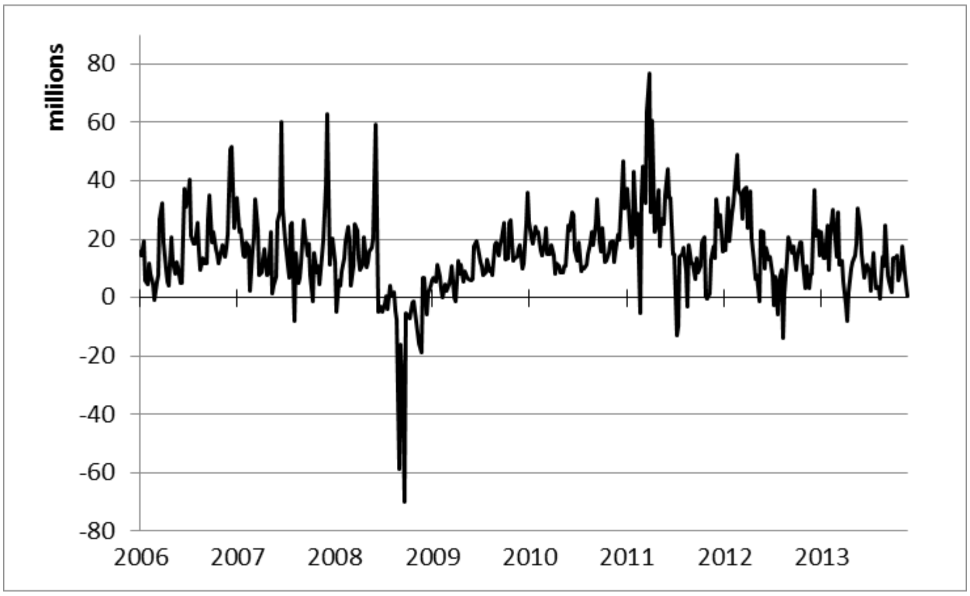

Figure 1. Weekly Average OrderFlow. This figure shows the difference between the weekly average buy and sell trading EUR volume in millions on the Euwax over the sample period.

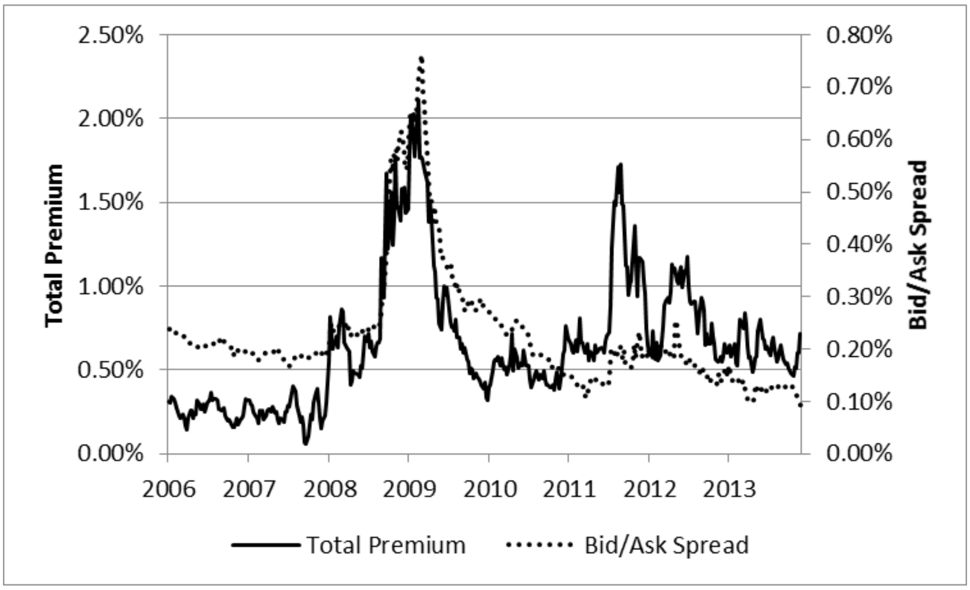

Figure 2. Weekly Average Total Premiums and Spreads. This figure shows the weekly average total premiums (*TP*, see Equation (26)) and spreads over the sample period. The spread is the difference between the ask and bid quote divided by the mid quote.

Table I. Quote Dataset: Moneyness, Time to Maturity and Spread at Issuance

This table presents means, medians and quartiles of the moneyness, time to maturity in years and spread of discount certificates at the issue date. Moneyness is defined as the underlying's stock price minus the certificate's cap level, divided by the cap. The spread is the difference between the ask and bid quote divided by the mid quote.

Year	# of Issuances	Moneyness at Issuance				Time to Maturity at Issuance				Spread at Issuance			
		25%	Mean	Median	75%	25%	Mean	Median	75%	25%	Mean	Median	75%
2006	10,446	-9.38%	6.90%	1.23%	15.66%	1.30	1.89	1.65	2.19	0.09%	0.20%	0.15%	0.26%
2007	15,496	-9.30%	9.87%	4.99%	23.85%	1.22	1.62	1.47	1.88	0.08%	0.20%	0.14%	0.23%
2008	36,752	-9.15%	15.70%	10.73%	35.45%	0.96	1.33	1.24	1.61	0.10%	0.37%	0.19%	0.38%
2009	34,718	-6.82%	15.64%	9.12%	33.18%	0.65	1.18	1.06	1.57	0.10%	0.30%	0.18%	0.32%
2010	48,519	-6.78%	11.83%	5.88%	25.35%	0.58	1.11	1.01	1.48	0.05%	0.17%	0.11%	0.19%
2011	93,781	-6.18%	13.83%	8.51%	28.26%	0.59	1.12	1.04	1.57	0.05%	0.17%	0.09%	0.17%
2012	75,799	-8.29%	12.30%	5.79%	27.44%	0.55	1.08	1.00	1.45	0.04%	0.18%	0.09%	0.17%
2013	72,784	-7.47%	6.92%	2.97%	16.56%	0.59	1.07	1.03	1.45	0.03%	0.12%	0.06%	0.13%
2006-2013	388,295	-7.49%	11.96%	6.05%	25.75%	0.64	1.17	1.07	1.57	0.05%	0.19%	0.10%	0.20%

Table II. Average Spreads and Total Premiums per Year

The table reports average spreads and premiums of discount certificates from listed issuers at 9:30 a.m., 12:30 p.m., 3:30 p.m. and 5:35 p.m. written on DAX stocks in the secondary market from 01/2006 to 12/2013. N is the sample size per year. The spread is defined in Equation (14). Premium definitions for default-free (DFP), credit risk (CRP), and total premium (TP) are given in Equations (24), (25) and (26), respectively. CRP / TP is the fraction of the average credit risk premium on the average total premium. To correct for data and valuation errors, we truncated the lowest and highest 1% of the DFP distribution.

Year	N	Spread	Default-free Premium (DFP)	Credit Risk Premium (CRP)	Total Premium (TP)	CRP / TP
2006	6,894,692	0.21%	0.23%	0.02%	0.25%	7%
2007	10,606,424	0.19%	0.15%	0.09%	0.24%	37%
2008	25,107,751	0.33%	0.45%	0.43%	0.89%	49%
2009	30,708,473	0.44%	0.51%	0.55%	1.07%	51%
2010	30,448,320	0.22%	0.14%	0.34%	0.49%	70%
2011	52,376,131	0.16%	0.30%	0.63%	0.94%	67%
2012	67,399,864	0.17%	0.21%	0.60%	0.82%	73%
2013	55,646,023	0.13%	0.38%	0.23%	0.60%	38%
2006-2013	279,187,678	0.16%	0.30%	0.37%	0.66%	56%

Table III. Determinants of Total Premium and Spreads

This table reports estimated standardized coefficients of regressions described in Section 6.1 with either TP or $Spread$ as the dependent variable. Total Premium is defined as TP (see Equation (26)); the variable is instrumented in columns (5) and (6). Spread is the certificate's relative spread, based on the close bid and the close ask price (see Equation (14)); the variable is instrumented in in columns (2) and (3). IHC is the certificate's initial hedging costs at time t. RC is the certificate's rebalancing costs at time t. GapRisk is the overnight gap risk measured through a GARCH(1,1)-forecast of the overnight volatility, JumpRisk measures the downside jump risk via the implicit volatility skew slope, ScalperRisk is the risk of informed traders entering the market and is measured by the reservation spread. Vola stands for the implied volatility level of the underlying asset. CreditRiskPremium is the credit risk premium (Equation (25)). $OrderFlow$ is the net accumulated trading volume measured in euros within the time interval. PerfectHedge A and PerfectHedge E are dummy variables which are 1 if an American and European option, respectively, exists for the same date, underlying, strike and maturity date, and 0 otherwise. $Comp$ is a measure of competition, proxied by the number of similar certificates. TtM stands for time to maturity in years. DIV is the relative size of the expected dividend payments. Explanatory variables are described in more detail in Section 3. The controls used are: moneyness at quotes, the moneyness's square root, and the intraday return from the time of the quote until the underlying's market closure. All regressions are estimated with issuer-, underlying- and monthly time-fixed effects. Validity of the instrumental variables (IV) regressions is tested via the robust Kleibergen-Paap rk LM statistic of underidentification, Kleibergen-Paap rk Wald F statistic of weak identification (Kleibergen and Paap, 2006) and Hansen J statistic of overidentification (Hansen, 1982). Obs. denotes the number of observations. Standardized beta coefficients for all models; HAC t statistics in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

	Total Premium			Spread		
	No IV	IV		No IV	IV	
	(1)	(2)	(3)	(4)	(5)	(6)
Total Premium				+0.020*** (26.18)	-0.099*** (-37.80)	-0.114*** (-40.79)
Spread	+0.014*** (26.10)	-0.055*** (-44.98)	-0.061*** (-49.21)			
IHC	+0.001* (1.90)	+0.015*** (25.25)	+0.006*** (10.10)	+0.205*** (96.72)	+0.205*** (97.21)	+0.184*** (92.34)
RC	+0.008*** (24.31)	+0.010*** (28.47)	+0.009*** (25.14)	+0.023*** (41.19)	+0.024*** (42.59)	+0.030*** (53.54)
GapRisk	+0.044*** (59.06)	+0.053*** (71.29)	+0.043*** (58.17)	+0.137*** (68.70)	+0.142*** (69.47)	+0.116*** (57.51)
JumpRisk	-0.018*** (-55.94)	-0.017*** (-54.02)	-0.011*** (-34.83)	+0.007*** (8.87)	+0.005*** (6.05)	+0.003*** (4.56)
ScalperRisk	+0.027*** (26.92)	+0.039*** (37.30)	+0.025*** (24.03)	+0.167*** (105.87)	+0.170*** (107.71)	+0.153*** (101.91)
Vola			+0.076*** (176.21)			+0.166*** (83.79)
CreditRiskPremium	+0.473*** (936.74)	+0.472*** (929.66)	+0.449*** (853.64)	-0.022*** (-40.31)	+0.034*** (25.47)	+0.038*** (27.70)
OrderFlow	-0.004*** (-32.34)	-0.004*** (-32.30)	-0.004*** (-31.67)	+0.000 (1.44)	-0.000*** (-2.98)	-0.000 (-1.59)
PerfectHedge A	-0.007*** (-32.99)	-0.006*** (-27.08)	-0.010*** (-44.42)	+0.019*** (52.54)	+0.018*** (49.99)	+0.014*** (38.56)
PerfectHedge E	-0.005*** (-28.45)	-0.005*** (-30.18)	-0.004*** (-24.36)	-0.005*** (-23.63)	-0.006*** (-25.98)	-0.004*** (-19.37)
Comp	-0.020*** (-85.46)	-0.021*** (-90.92)	-0.022*** (-95.87)	-0.020*** (-81.16)	-0.023*** (-90.70)	-0.016*** (-63.80)
TtM	+0.132*** (362.98)	+0.133*** (363.42)	+0.045*** (108.28)	+0.005*** (13.30)	+0.021*** (45.95)	+0.071*** (120.23)
DIV			+0.199*** (470.50)			-0.013*** (-22.03)
Moneyness	Yes	Yes	Yes	Yes	Yes	Yes
Intraday Return	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Underyling FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
p-value of KP rk LM statistic		0.000	0.000		0.000	0.000
KP rk Wald *F* statistic		9,471	9,246		257,335	234,369
p-value of Hansen *J* statistic		0.219	0.223		0.872	0.764
Adj. R2	0.468	0.465	0.482	0.263	0.256	0.270
Obs.	83,152,248	83,152,248	83,152,248	83,152,248	83,152,248	83,152,248

Table IV. Hedging Costs and Changes in Inventory

This table reports estimated coefficients of regressions described in Section 6.1 with either TP or $Spread$ as the dependent variable. Total Premium is defined as TP (see Equation (26)); the variable is instrumented in columns (5) and (6). Spread is the certificate's relative spread, based on the close bid and the close ask price (see Equation (14)); the variable is instrumented in in columns (2) and (3). IHC is the certificate's initial hedging costs at time t, $IHCxOF$ is an interaction variable between the initial hedging costs and the order flow (Equation (6)). RC is the certificate's rebalancing costs at time t, $RCxOF$ is an interaction variable between the rebalancing costs and the order flow. GapRisk is the overnight gap risk measured through a GARCH(1,1)-forecast of the overnight volatility, JumpRisk measures the downside jump risk via the implicit volatility skew slope, ScalperRisk is the risk of informed traders entering the market and is measured by the reservation spread. Vola stands for the implied volatility level of the underlying asset. CreditRiskPremium is the credit risk premium (Equation (25)). $OrderFlow$ is the net accumulated trading volume measured in euros within the time interval. PerfectHedge A and PerfectHedge E are dummy variables which are 1 if an American and European option, respectively, exists for the same date, underlying, strike and maturity date, and 0 otherwise. $Comp$ is a measure of competition, proxied by the number of similar certificates. TtM stands for time to maturity in years. DIV is the relative size of the expected dividend payments. Explanatory variables are described in more detail in Section 3. The controls used are: moneyness at quotes, the moneyness's square root, and the intraday return from the time of the quote until the underlying's market closure. All regressions are estimated with issuer-, underlying- and monthly time-fixed effects. Validity of the instrumental variables (IV) regressions is tested via the robust Kleibergen-Paap rk LM statistic of underidentification, Kleibergen-Paap rk Wald F statistic of weak identification (Kleibergen and Paap, 2006) and Hansen J statistic of overidentification (Hansen, 1982). Obs. denotes the number of observations. HAC t statistics in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

	Total Premium			Spread		
	No IV	IV		No IV	IV	
	(1)	(2)	(3)	(4)	(5)	(6)
Total Premium				+0.0093***	-0.0457***	-0.0525***
				(26.18)	(-37.81)	(-40.79)
Spread	+0.0315***	-0.1184***	-0.1322***			
	(26.09)	(-44.98)	(-49.22)			
IHC	+0.0226**	+0.2936***	+0.1180***	+1.8074***	+1.8118***	+1.6257***
	(2.04)	(25.38)	(10.23)	(96.69)	(97.19)	(92.33)
IHCxOF	+0.1417***	+0.1435***	+0.1436***	+0.0106	+0.0184**	+0.0260***
	(13.91)	(14.45)	(14.34)	(1.17)	(2.06)	(3.02)
RC	+0.0013***	+0.0016***	+0.0015***	+0.0017***	+0.0018***	+0.0022***
	(24.31)	(28.46)	(25.19)	(41.13)	(42.53)	(53.49)
RCxOF	-0.0002***	-0.0002***	-0.0003***	+0.0001**	+0.0001*	+0.0000
	(-3.43)	(-3.21)	(-5.39)	(2.10)	(1.79)	(1.28)
GapRisk	+0.0532***	+0.0648***	+0.0522***	+0.0769***	+0.0800***	+0.0651***
	(59.06)	(71.29)	(58.17)	(68.70)	(69.47)	(57.51)
JumpRisk	-0.0045***	-0.0044***	-0.0028***	+0.0008***	+0.0005***	+0.0004***
	(-55.95)	(-54.02)	(-34.83)	(8.87)	(6.05)	(4.56)
ScalperRisk	+3.2069***	+4.5663***	+2.9680***	+9.0497***	+9.2418***	+8.2807***
	(26.91)	(37.29)	(24.02)	(105.88)	(107.72)	(101.91)
Vola			+0.0037***			+0.0038***
			(176.26)			(83.79)
CreditRiskPremium	+0.9080***	+0.9064***	+0.8608***	-0.0195***	+0.0304***	+0.0333***
	(936.70)	(929.61)	(853.59)	(-40.32)	(25.47)	(27.70)
OrderFlow	-0.0001***	-0.0001***	-0.0001***	-0.0000*	-0.0000***	-0.0000***
	(-33.24)	(-33.88)	(-31.50)	(-1.71)	(-4.28)	(-4.55)
PerfectHedge A	-0.0002***	-0.0002***	-0.0003***	+0.0003***	+0.0003***	+0.0002***
	(-33.01)	(-27.09)	(-44.43)	(52.54)	(49.98)	(38.56)
PerfectHedge E	-0.0003***	-0.0004***	-0.0003***	-0.0002***	-0.0002***	-0.0001***
	(-28.46)	(-30.19)	(-24.37)	(-23.63)	(-25.98)	(-19.37)
Comp	-0.0006***	-0.0006***	-0.0007***	-0.0003***	-0.0003***	-0.0002***
	(-85.40)	(-90.86)	(-95.80)	(-81.16)	(-90.69)	(-63.78)
TtM	+0.0029***	+0.0029***	+0.0010***	+0.0000***	+0.0002***	+0.0007***
	(363.02)	(363.46)	(108.32)	(13.33)	(45.96)	(120.22)
DIV			+0.0729***			-0.0022***
			(470.49)			(-22.03)
Moneyness	Yes	Yes	Yes	Yes	Yes	Yes
Intraday Return	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Underyling FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
p-value of KP rk LM statistic		0.000	0.000		0.000	0.000
KP rk Wald *F* statistic		9,471	9,246		257,342	234,378
p-value of Hansen *J* statistic		0.217	0.221		0.872	0.764
Adj. R2	0.468	0.465	0.482	0.263	0.256	0.270
Obs.	83,152,248	83,152,248	83,152,248	83,152,248	83,152,248	83,152,248

Table V. Simultaneous Equations Model

This table reports the simultaneous estimated standardized coefficients of regressions described in Section 6.4 with TP (see Equation (26)) and $Spread$ (see Equation (14)) as dependent and independent variables. IHC is the certificate's initial hedging costs at time t. RC is the certificate's rebalancing costs at time t. GapRisk is the overnight gap risk measured through a GARCH(1,1)-forecast of the overnight volatility, JumpRisk measures the downside jump risk via the implicit volatility skew slope, ScalperRisk is the risk of informed traders entering the market and is measured by the reservation spread. Vola stands for the implied volatility level of the underlying asset. CreditRiskPremium is the credit risk premium (Equation (25)). $OrderFlow$ is the net accumulated trading volume measured in euros within the time interval. PerfectHedge A and PerfectHedge E are dummy variables which are 1 if an American and European option, respectively, exists for the same date, underlying, strike and maturity date, and 0 otherwise. $Comp$ is a measure of competition, proxied by the number of similar certificates. TtM stands for time to maturity in years. DIV is the relative size of the expected dividend payments. Explanatory variables are described in more detail in Section 3. The controls used are: moneyness at quotes, the moneyness's square root, and the intraday return from the time of the quote until the underlying's market closure. Column (1) presents the GMM-3SLS estimates without fixed effects, whereas column (2) includes issuer dummies. Obs. denotes the number of observations. Standardized beta coefficients are reported; HAC t statistics in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

	(1)		(2)	
	Total Premium	Spread	Total Premium	Spread
Total Premium		-0.0304*** (-5.53)		-0.0554*** (-8.92)
Spread	-0.0466*** (-3.95)		-0.0538*** (-4.54)	
IHC	+0.0088 (1.51)	+0.3207*** (17.96)	+0.0117** (2.02)	+0.3187*** (17.94)
RC	+0.0281*** (8.21)	+0.0753*** (20.31)	+0.0227*** (6.62)	+0.0690*** (18.64)
GapRisk	+0.0362*** (9.43)	+0.0155 (1.36)	+0.0373*** (9.83)	+0.0183 (1.62)
JumpRisk	-0.0261*** (-8.32)	-0.0234*** (-6.41)	-0.0248*** (-8.04)	-0.0236*** (-6.58)
ScalperRisk		+0.1442*** (17.14)		+0.1476*** (17.76)
Vola	+0.1339*** (25.98)	+0.2927*** (21.48)	+0.1359*** (25.68)	+0.2996*** (21.75)
CreditRiskPremium	+0.6116*** (190.74)		+0.5968*** (163.69)	
OrderFlow	-0.0107*** (-12.11)	-0.0000 (-0.02)	-0.0095*** (-11.09)	+0.0009 (0.93)
PerfectHedge A	+0.0458*** (22.55)	+0.0158*** (6.05)	+0.0272*** (11.28)	-0.0012 (-0.34)
PerfectHedge E	-0.0120*** (-8.41)	+0.0026* (1.70)	-0.0051*** (-3.57)	+0.0077*** (4.81)
Comp	-0.0381*** (-17.32)	-0.0276*** (-8.90)	-0.0653*** (-25.61)	-0.0614*** (-19.58)
TtM	+0.0501*** (22.31)	+0.0253*** (6.49)	+0.0541*** (21.72)	+0.0422*** (9.96)
DIV	+0.0678*** (30.19)	-0.0407*** (-15.99)	+0.0766*** (34.39)	-0.0337*** (-13.09)
Moneyness	Yes		Yes	
Intraday Return	Yes		Yes	
Issuer FE	No		Yes	
Underyling FE	No		No	
Adj. R2	0.513	0.359	0.531	0.367
Obs.	596,681		596,681	

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