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How Dynamic Hedging Affects Stock Price Movements: Evidence from German Option and Certificate Markets*

Georg Fischer[1]

Abstract

We examine the impact of dynamic hedging demand of German option and discount certificate markets on the autocorrelation of German stock price changes. We theoretically model the demand of liquidity providers in the discount certificate market, a structured financial product with a concave payoff profile, asking whether dynamic hedging by certificate issuers induces negative return autocorrelation in stock markets. We find empirical evidence that the hedging demand of option issuers has a positive impact on return autocorrelation, while the opposite holds for certificate issuers, whose hedging demand enhances the negative return autocorrelation in the stock market. We thus theoretically and empirically provide evidence that there are persistent spillover effects from option and certificate markets to stock markets due to dynamic hedging activities.

Keywords: Structured products; Derivatives; Dynamic hedging; Stock return autocorrelation; Market microstructure

JEL Classification: D40, G12, G21

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1. Introduction

This study examines the impact of dynamic hedging demand of the German option and discount certificate markets on the autocorrelation of German stock price changes. We attribute a negative return autocorrelation in stock markets due to the dynamic hedging demand of the discount certificate market, a structured financial product with a concave payoff profile. In contrast, dynamic hedging demand of option markets, i.e. products with a convex payoff profile, imposes a positive return autocorrelation in the stock market. Thus, issuers' dynamic hedging demand due to individual stock options and certificates influences price movements of the underlying assets.

While previous studies examine the effect of dynamic hedging demand of option markets on the underlying asset outside Germany, this paper empirically examines the impact of dynamic hedging of options and structured financial products on the underlying in Germany. Furthermore, we model the effect of dynamic hedging of structured financial products, i.e. discount certificates, on the price movement in the underlying. There are three main reasons why extending the focus on discount certificates adds new insights to the existing option market literature. First, a unique feature of structured products is the absence of short selling by retail investors. Thus, discount certificate issuers face a less uncertain order flow behavior than option issuers. Secondly, in contrast to options, discount certificates possess a concave payoff profile, which to our knowledge has not been examined so far. Our theoretical model is applicable to all financial products with a concave payoff. Moreover, combining option and certificate markets into one theoretical model and an empirical analysis, allows us to examine the joint effect of both markets on the stock market. Thirdly, discount certificates are the most popular type of investment certificates in Germany, with a total trading volume in 2017 of almost EUR 8.0bn on the Euwax and Boerse Frankfurt Zertifikate AG[1] exchanges, which accounts for 39% of all investment certificates, and a volume of outstanding certificates of EUR 4.4bn as at December 2017.[2] This should ensure a sufficient volume to measure the impact on the stock market.

The payoff of discount certificates is equal to the cap if the underlying share price is above the cap at maturity, or is equal to the share price if the underlying price is below the cap level at maturity. However, the investor's upside benefits are limited with an increasing underlying price, and thus discount certificates will trade at a discount compared to the underlying. The product is attractive for investors expecting sideways or slightly downward price movements. The theoretical fair value of discount certificates can be calculated by applying the Black-Scholes option pricing model (Black and Scholes, 1973).

Our theoretical model is based on the assumption that option and certificate writers hedge dynamically at discrete time intervals. Option and certificate writers face a trade-off between hedging at a narrow (increasing transaction costs) and wide time interval (increasing hedging error) (e.g. Boyle and Vorst, 1992; Çetin et al., 2006; Leland, 1985; Whalley and Wilmott, 1997, 1999). The certificate and option writers hedge their exposure dynamically due to changes in the price of the underlying asset, for example in the case of a fundamental news shock. We extend the model of Yang and Zhang (2017) by discount certificates, and show that certificate (option) issuers possess a downward (upward) sloping demand curve for the underlying asset if the underlying asset value rises. The different demand curves derive from the payoff profile, i.e. the sign of the Greek gamma (the second derivative of the value function with respect to the underlying). This demand pressure, from certificate and option markets on

[1] The Euwax (European Warrant Exchange) is the trading segment of the Boerse Stuttgart, which offers a variety of leverage and investment products from issuers (see https://www.boerse-stuttgart.de/). Boerse Frankfurt Zertifikate AG is an exchange for structured financial products and a subsidiary of Deustche Boerse AG (see http://www.boerse-frankfurt.de/zertifikate/).
[2] See the website of the German Derivatives Association, available at www.deutscher-derivate-verband.de/.

the stock market, and hedging the exposure at fixed time intervals, affects the autocorrelation of stock returns.[3]

The effect of demand pressure within its own market has been documented for the stock market (Greenwood, 2005; Shleifer, 1986; Wurgler and Zhuravskaya, 2002) and option market (Bollen and Whaley, 2004; Gârleanu et al., 2009; Green and Figlewski, 1999). Entrop and Fischer (2018) show that transaction costs in the stock market influence the certificate market. However, this study focuses on the link between certificates and options to stock prices. This paper ties in with the studies by Yang and Zhang (2017) and Ni et al. (2017) who examine market makers' hedging mechanisms. We contribute to the existing literature in three ways: it is the first study to introduce a theoretical and empirical effect from the certificate markets to the stock market due to dynamic hedging. Secondly, we analyze the joint effect of hedging demand of certificate and option markets on the return autocorrelation in the stock market. Thirdly, in contrast to the previous two studies, we examine the hedging behavior of German option market.

The theoretical framework is empirically tested with data for options and certificates on single stocks, which were included in the DAX from 2006 until 2013. By using individual stocks, we are able to study the impact of hedging demand on the return autocorrelation in the cross section. The empirical hedging demand of certificate (option) issuers for stocks depends on (i) the sign and magnitude of the certificate's (option's) gamma and (ii) the net order flow of certificates (options), i.e. the number of contracts that must be hedged. We apply a Fama-MacBeth as well as fixed effect regression methodology. Then, we estimate a VAR system to model the causality relationships between the markets and the persistence of a hedging demand shock to the stock market.

[3] If the dynamic hedge is not delayed from the news shock, but instead occurs instantaneously, the effect of hedging is an increase in the stock price volatility (Ni et al., 2017).

We find empirical evidence that those stocks with higher hedging demand, either in the option or in the certificate market, induce higher autocorrelation in stock returns. The German stock market has an overall negative first-order autocorrelation.[4] The marginal impact of option issuers' hedging demand on return autocorrelation is positive. These findings are in line with results from Yang and Zhang (2017) for the U.S. market. In contrast to options, the marginal impact of certificate issuers' hedging demand enhances the negative return autocorrelation in the stock market. The effect of a marginal change in hedging demand of option and certificate issuers on return autocorrelation is robust for different models and estimation techniques. However, the statistical significance for certificates is weak in comparison to options. We attribute this empirical finding to the difference in size between both markets. The equity option market (Eurex) is by far larger than the discount certificate market (Euwax and Boerse Frankfurt Zertifikate AG). For example, in 2017, the total trading volume for equity options at Eurex was EUR 699.9bn, making it 87 times larger than the discount certificate market. In December 2017, the volume of outstanding equity options was 35 times larger than for discount certificates with EUR 155.7bn.[5] Additionally, we find a persistent spillover effect from the option and certificate market to the stock market, while controlling for all other variables defined in the VAR system. First, the marginal hedging demand of option and certificate issuers lead stock returns, when testing for Granger causalities, and not the other way around. Secondly, one shock in the option market leads to a positive cumulative return autocorrelation, whereas the shock in the certificate market leads to a negative cumulative return

[4] Many studies find a negative first-order autocorrelation of stock price changes, i.e. the following price move is more likely to be of the opposite sign than the previous one. Studies attribute this price behavior to bid/ask bounces and compensation for liquidity provision (Avramov et al., 2006; Campbell et al., 1993; Lehmann, 1990; Nagel, 2012). The observation of short-term memory (only up to a few minutes) in liquid markets is explained by market makers' knowledge edge (Guillaume et al., 1997; Roll, 1984). The occurrence of negative first-order autocorrelation of prices is in line with the notation of a martingale, as long as the difference is explained by transaction costs, i.e. a compensation for providing liquidity (Taleb, 1997). However, we are not per se interested in the total effect of the return autocorrelation in stock returns, but on the impact of hedging demand in option and certificate markets.

[5] The Eurex is the largest European exchange for options and futures (see http://www.eurexchange.com/).

autocorrelation. However, the response to the option market is statistically more significant. Both findings are consistent with the theoretical model. Hence, we theoretically and empirically provide evidence that there are spillover effects from option and certificate markets to stock markets due to dynamic hedging activities.

Because the empirical hedging demand variable is partly influenced by the net order flow of options (or certificates), we must verify that hedging demand does not measure the effect of news entering the option market before the stock market (see Easley et al., 1998; Hong and Stein, 1999; Hu, 2014; Johnson and So, 2012; Pan and Poteshman, 2006). First, we follow Yang and Zhang (2017) and apply an instrumental variable. The instrumental variable does not depend on any news related measures like option volume. The results remain robust when applying the instrumental variable regression. Secondly, the discount certificate market is probably not the first choice for investors with an informational advantage. We find evidence that the empirical hedging demand of the certificate market has an impact on return autocorrelation. If we unintentionally measure the sensitivity of markets to news (and not the demand for hedging) with our variable, we should not observe a causality between certificate markets and stock markets, i.e. news should not enter the certificate market before the stock market.

The remainder of this paper is structured as follows: Section 2 provides a theoretical framework of dynamic hedging demand of option and certificate markets and models its impact on the return autocorrelation of stock markets. Section 3 describes the dataset and provides summary statistics. Section 4 explains the applied methodology and presents the empirical results as well as robustness tests. Section 5 provides a summary of the results and concludes the paper.

2. Model

In this section we describe the theoretical assumptions of how option and discount certificate issuers hedge their position, how the position is affected by changes in the underlying market and how issuers' re-hedging behavior influences the underlying stock price.

2.1. Hedging Demand of the Option Market

In line with the theoretical model from Yang and Zhang (2017), we argue that issuers of options dynamically hedge their exposure due to changes in the underlying market by actively trading the underlying, which in turn affects the stock price. The exposure for an issuer's portfolio of open positions is the scalar product of each option's value and the number of outstanding options. As the issuer gains the premium for writing options and does not speculate on movements in the underlying, each issuer's aim is to minimize his exposure to the underlying stock by dynamically hedging his position. Dynamic hedging implies rebalancing at discrete time intervals to maintain a minimum Greek exposure. The sensitivity of the issuer's option portfolio to changes in the underlying can be expressed by the Greeks delta (Δ) and gamma (Γ).

The issuer can only hedge his exposure by choosing the amount of held underlying stocks at time t and cannot influence the number or characteristic of sold options. The delta-neutral position protects the issuer against small price movements in the underlying because gains (losses) from the hedge offset losses (gains) from the option's position. However, larger price jumps change the delta of the option's position and the amount of additional stocks which need to be traded to remain delta-neutral, i.e. the number of required stocks depend on the change in delta for a change in the stock price. If the underlying price changes by one percent, the issuer must trade additional $\frac{\partial \Delta}{\partial S}\frac{S}{100} = \Gamma \frac{S}{100}$ shares of the underlying to remain delta-neutral. This implies an upward sloping demand curve for the issuer, i.e. an increase in the underlying price requires the issuer to purchase more shares. The demand is identical for put and call options. From the option issuer's point of view, call options have a negative delta and negative gamma, whereas put options have positive delta and a negative gamma. Consequently, a call option issuer has an initial long position in the underlying to neutralize the negative delta of the short call position ($\Delta_{call}^{short} < 0$) and must add positive delta (buying shares) to remain delta-neutral if the share price rises. The put option issuer has an initial short position in the underlying to neutralize the positive delta of the short put position ($\Delta_{put}^{short} > 0$) and must add positive delta (buying shares), i.e. reducing the short position in the underlying, to remain delta-neutral if the share price rises. In general, if the payoff of the option's short position is concave for the issuer (convex for the option buyer) or equivalently $\Gamma < 0$, there will be a positive relationship between an increase in the underlying price and demand for the underlying to maintain a delta-neutral position.

2.2. Hedging Demand of the Certificate Market

The promised payoff of a discount certificate by an issuer at maturity date T is given by:

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

where α is the cover ratio, i.e. the certificate refers to a fraction or a multiple of the underlying, 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 and X is the discount certificate's cap. The fair value of a default-free discount certificate equals the sum of a long default-free zero bond, with a face value X and maturity T, and a short European put option, with a strike price X and maturity T.[6] The Black and Scholes (1973) formula can be used to estimate the default-free

[6] Alternatively, the combination of a long position in the underlying, S_t, adjusted for intertemporal dividend payments, and a short European call option, with a strike price X and maturity T, can be used to calculate the fair value.

value of a the put option component. Thus, the theoretical fair value of the discount certificate is given by (see e.g. Baule et al., 2008):

$$DC_t = \alpha e^{-r(T-\tau)}\left(e^{-r(\tau-t)}X - p_t\right)$$

$$= \alpha e^{-r(T-\tau)}\left(e^{-r(\tau-t)}X + (S_t - Div_t)N(-a_1) - e^{-r(\tau-t)}XN(-b_1)\right) \quad (2)$$

with

$$a_1 = \frac{ln\left((S_t - Div_t)/X\right) + (r + \sigma^2/2)(\tau - t)}{\sigma\sqrt{\tau - t}}, \quad (3)$$

$$b_1 = a_1 - \sigma\sqrt{\tau - t}, \quad (4)$$

$$Div_{t,t<\tau_1<\tau_2<\tau} = e^{-r(\tau_1-t)}Div_1 + e^{-r(\tau_2-t)}Div_2, \quad (5)$$

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. 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. The payoff profile for the discount certificate buyer is concave due to the short put option component in Equation (2), whereas it is convex for the discount certificate issuer ($\Gamma > 0$).[7] 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 ($\Delta_{put}^{long} < 0$) and must reduce positive delta (selling shares), i.e. reducing the long position in the underlying, if the share price rises. In contrast to the option market, the issuer's demand for buying the underlying is anti-cyclical to the share price movement. While option issuers follow the trading strategy

[7] For our measure of hedging demand, we calculate the gamma from the put option component in Equation (2). However, one could also use the gamma calculated from call options as the gamma is identical for put and call options, given the same strike (Haug, 2007, p. 45).

of buy-high/sell-low, discount certificate issuers are exposed to the trading strategy of buy-low/sell-high.

2.3. Price Impact on the Underlying Market

In this section, we describe the impact of dynamic hedging demand of the option and certificate market on the stock market. First, we briefly review the model of Yang and Zhang (2017) who propose a theoretical framework which consists of two key agents: option issuer (OI) and fundamental investor (FI). Then, we extend the model by introducing a certificate issuer (CI) into the model.

The stock pays a final dividend at T of $F_0 + \sum_{j=0}^{T} \varepsilon_j$ with the fundamental value F_0 at $j = 0$ and $\varepsilon_j \sim N(0, 1)$ i.i.d., which represents fundamental factors such as a positive or negative news shock. The risk-free rate is assumed to be 0 and the quantity Q of supplied stocks is normalized with $Q = 1$. The option issuer and the fundamental investor trade in the underlying stock market. In contrast, the fundamental investor possesses a downward sloping demand curve, i.e. higher stock prices reduce the number of shares demanded by the investor. Yang and Zhang (2017) show that the negative relationship holds if (i) the investor's demand in the underlying stock depends on the expectations in $E[F_{t+1}]$ and (ii) has a constant absolute risk aversion $1/\gamma$, with γ measuring the risk tolerance:

$$\xi_t^{FI} = \gamma \cdot (E[F_{t+1}] - P_t), \tag{6}$$

where ξ_t^{FI} is the fundamental investor's demand for the underlying stock with price P_t. In the scenario with only the fundamental investor in the market where $\xi_t^{FI} = Q$, the equilibrium stock price P_t^{FI} is:

$$P_t^{FI} = E[F_{t+1}] - \frac{1}{\gamma} = F_0 + \sum_{j=1}^{t} \varepsilon_j - \frac{1}{\gamma}. \tag{7}$$

In the absence of derivative issuers, the equilibrium stock prices follow a random walk process because the stock price is only determined by the fundamental value ($F_0 + \sum_{j=1}^{t} \varepsilon_j$) less a risk premium ($1/\gamma$) which gives $Cov(P_{t+1}^{FI} - P_t^{FI}, P_t^{FI} - P_{t-1}^{FI}) = Cov(\varepsilon_{t+1}, \varepsilon_t) = 0$.

In this study, we apply a novel approach by adding both option and certificate issuers to the model, where the fundamental investor, option issuer and certificate issuer trade against each other on the demand side. Section 2.1 induces an upward sloping demand curve for the option issuer and Section 2.2 a downward sloping demand curve for the certificate issuer. The option and certificate issuer do not hedge every period but in $t \in \{0, 2, 4, \dots\}$. This reflects the fact that dynamic hedging imposes a tradeoff between hedging too frequently and leaving a hedging error due to discrete timing (see e.g. Leland, 1985; Whalley and Wilmott, 1997, 1999). This delayed hedging activity induces return autocorrelation in the stock market. The stock price P_t^* in the equilibrium $\xi_t^{FI} + \xi_t^{OI} + \xi_t^{CI} = Q$ for $t \in \{1, 3, 5, \dots\}$ and normalized quantity Q is:

$$P_t^* = E[F_{t+1}] - \frac{1}{\gamma} + \frac{\Delta_{t-1}^{OI} - \Delta_{t-1}^{CI}}{\gamma} = P_t^{FI} + \frac{\Delta_{t-1}^{OI} - \Delta_{t-1}^{CI}}{\gamma} \tag{8}$$

with the option issuer's demand for the underlying stock

$$\xi_t^{OI} = \Delta_{t-1}^{OI} \tag{9}$$

and the certificate issuer's demand for the underlying stock

$$\xi_t^{CI} = -\Delta_{t-1}^{CI}. \tag{10}$$

Likewise, the equilibrium for $t \in \{0, 2, 4, \dots\}$ is identical to Equation (8) to (10), except that Δ_{t-1} is replaced with Δ_t. Δ^{OI} is either the delta calculated from a long call ($\Delta_{call}^{long} > 0$) or long put option ($\Delta_{put}^{long} < 0$) and Δ^{CI} is the delta calculated from a long put position ($\Delta_{put}^{long} < 0$). Alternatively, we could have expressed the certificate issuer's demand as $\xi_t^{CI} = \Delta_{t-1}^{CI}$ and use the delta from a short put position ($\Delta_{put}^{short} > 0$). However, we decided to use the former to indicate the negative relationship between stock prices and the demand for stocks in Equation (10). Using Equation (8), the impact of a positive news shock ε_t (i.e. $\varepsilon_j = 0$ for $j \neq 1$) on the absolute equilibrium price change $P_{t+1} - P_t$ can be expressed with the gamma relationship $\Gamma_t^{OI} \approx \frac{\Delta_{t+1}^{OI} - \Delta_{t-1}^{OI}}{P_{t+1} - P_{t-1}}$ and $\Gamma_t^{CI} \approx \frac{\Delta_{t+1}^{CI} - \Delta_{t-1}^{CI}}{P_{t+1} - P_{t-1}}$ as:

$$P_{t+1} - P_t = \varepsilon_t \cdot \left(\frac{\Gamma_t^{OI} - \Gamma_t^{CI}}{\gamma} \right). \tag{11}$$

Thus, the combined effect of options and discount certificates depends on the sign of $\left(\frac{\Gamma_t^{OI} - \Gamma_t^{CI}}{\gamma} \right)$. If the combined effect is positive (negative), a positive (negative) autocorrelation occurs. The effect of the risk tolerance parameter is identical for hedging options and certificates. If the fundamental investor is highly risk tolerant, the impact of option and certificate hedging is reduced. The impact of hedging is reinforced if the risk tolerance falls, i.e. the investor reacts more sensitively towards hedging activities in the underlying market.

[Insert Figure 1 about here.]

Figure 1 shows the autocorrelation induced by a positive news shock ε_1 in period 1 if either the option or certificate issuer hedges with a delay in period 2. Without any hedging activities − that is, if only the fundamental investor participates in the underlying market − the returns after period 1 are zero and there is no autocorrelation. If both option and certificate issuers participate in the underlying market, the effect of autocorrelation is diminished or even eliminated because antithetic hedging behaviors offset each other.

We follow Yang and Zhang (2017) and measure the empirical hedging demand of the issuer by adjusting Γ, which is the key component of the model. As we are interested in its impact on return autocorrelation in the underlying market, Γ is normalized by shares outstanding $SharesOut_{it}$ for the underlying i at day t. Moreover, we adjust Γ with the stock price S_{it} because the theoretical framework assumes absolute returns, whereas empirical studies commonly use relative returns. The hedging demand of option issuers is:

$$HD_{it}^{OI} = \frac{1\% S_{it}}{SharesOut_{it}} \cdot \Gamma_{it,agg}^{OI} = \frac{1\% S_{it}}{SharesOut_{it}} \cdot \sum_{k} (written_{itk} \cdot \Gamma_{itk}^{OI}) \tag{12}$$

$$\approx \frac{1\% S_{it}}{SharesOut_{it}} \cdot \sum_{k} (100 \cdot \Delta OI_{itk} \cdot \Gamma_{itk}^{OI}). \tag{13}$$

with the aggregated gamma $\Gamma_{it,agg}^{OI}$ for the underlying i at day t, the number of written options $written_{itk}$ and the change in open interest ΔOI_{itk} of option k. Likewise, the hedging demand of a discount certificate issuer is:

$$HD_{it}^{CI} = \frac{1\% S_{it}}{SharesOut_{it}} \cdot \sum_{k} (\alpha_{ik} \cdot OrderFlow_{itk} \cdot \Gamma_{itk}^{CI}) \tag{14}$$

with

$$OrderFlow_{itk} = Volume_{itk}^{InvBuy} - Volume_{itk}^{InvSell}. \tag{15}$$

α_{ik} denotes the cover ratio of certificate k, $Volume_{itk}^{InvBuy}$ is the accumulated trading volume of investors buying certificate k and $Volume_{itk}^{InvSell}$ is the equivalent accumulated trading volume for investors selling the certificate back to the issuer.[8] Both hedging demands HD_{it}^{OI} and HD_{it}^{CI} measure the issuer's need to participate in the underlying market.

3. Data

Our dataset consists of three different markets: the European Exchange for options (Eurex), the European Warrant Exchange (Euwax) for certificates and equity level data. The dataset

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

contains all Eurex options and Euwax discount certificates written against stocks that were included in the German DAX30 index between January 2006 and December 2013.

3.1. Datasets

The Eurex option dataset provides strike prices, maturity dates, daily settlement prices and daily open interest, i.e. the total number of unsettled contracts, of stock options traded at Eurex.[9] Because stock options with a time to maturity of more than 2.5 years are scarce and dividend forecasts are only available for two subsequent payments, we exclude the valuation days of options and certificates with a remaining time to maturity of > 2.5 years. The option dataset contains a total of 24.6 million daily observations from American (21.6 million) and European (3 million) type. The Euwax data consists of tick quotes and trades for 92,398 traded discount certificates, which were sourced from SIRCA Thomson Reuters Tick History (TRTH) database.[10] The trade data contains the exact timestamp of executed trades as well as the volume and trade price at which the trade was executed (see Appendix A). We apply the quote rule to classify each single trade as either 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.[11] We aggregate all trades on a given day to obtain the daily order flow for each traded certificate (Equation (15)). The daily equity level

[9] The data was provided by Karlsruher Kapitalmarktdatenbank of the Karlsruhe Institute of Technology.
[10] For more information, see www.sirca.org.au/products/. The base data on issued discount certificates were provided by the financial data provider Deriva GmbH. See Entrop and Fischer (2018) for a more detailed discussion on the characteristics and intraday quotes of discount certificates.
[11] We refrain from classifying 9.75% of the trades to minimize the error due to classifying trades inside the quotes (Ellis et al., 2000).

data includes individual stock characteristics like stock prices, volume, market capitalization or shares outstanding. The data was retrieved from Thomson Reuters Eikon. We then match all three markets into a panel data by aggregating the option and certificate data by the daily frequency of the equity level data.

Equations (13) and (14) require sensitivities gamma Γ for each option and certificate on a given day, respectively. As most Eurex stock options are of American type, we estimate gamma by using the Leisen-Reimer binomial tree model with daily discretization and two discrete dividend payments (Leisen and Reimer, 1996). The model improves the convergence compared to the Cox, Ross and Rubinstein model (1979). We derive gamma Γ from the Black-Scholes formula for European type options and discount certificates (Black and Scholes, 1973). Expected dividend payments are considered by using the escrowed dividend approach (Merton, 1973). When calculating the options' and certificates' Greeks, we use the closing price of their underlying stock. The volatility for the fair value of the discount certificate is the implied volatility from out-of-the-money American stock options, which is interpolated regarding cap and time to maturity. The default-free spot rate (r) is the government spot rate curve, estimated by 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. The expected dividend payment dates are the days after the expected dates of the shareholders meetings.

3.2. Variables and Summary Statistics

Table I shows the daily summary statistics for all variables in the dataset. The daily stock return r is adjusted for dividend and capital adjustments and the daily risk-free rate r_f is the one-month money market rate. The excess stock return r^e is the difference between log return and log risk-free rate, i.e. excess log returns. The option issuers' hedging demand HD^{OI} is defined in Equation (13) and is also separately calculated for options of American type. Certificate issuers' hedging demand HD^{CI} is defined in Equation (14). We truncate the lowest and highest one percent of the HD^{OI} and HD^{CI} distribution to correct for data and estimation errors. The market capitalization for each equity is MC, the euro volume (in thousands) is Vol and the unadjusted stock price is P.

[Insert Table I about here.]

The yearly average hedging demand of option and certificate issuers for DAX stocks from 01/2006 to 12/2013 is shown in Table II. During the financial crisis in 2008-2009 and 2011-2012, options' hedging demand for stocks decreased, due to a large decline in stock prices and a decline in open interest of options. Options and certificates are generally issued with strike prices near the underlying price, which leads to large gamma values, i.e. higher hedge sensitivities due to changes in the stock price. Conversely, large price changes in the underlying move the option far in-the-money or out-of-the-money, and thus previously issued options/certificates are less sensitive to stock price changes due to a lower gamma. However, the certificates' hedging demand for stocks decreased only in 2008 and sustained a high demand during 2011-2012. The underlying reason for this was the trading behavior of certificate investors. Net euro buy volume strongly decreased in 2008 but remained at a high level, aside from decline in stock prices, in the successive years (see Appendix A). Hence, a decrease in net buy volume reduces the demand for hedging because fewer contracts must be hedged.

[Insert Table II about here.]

4. Empirical Results

This section examines the impact of dynamic hedging on stock price dynamics. Equation (11) predicts that dynamic hedging activities of option writers induces positive return autocorrelation in the stock price movements, whereas dynamic hedging of discount certificate writers leads to negative return autocorrelation in the stock market. First, we use the Fama-MacBeth methodology and fixed effect regressions to test our prediction from Section 2. Both methods control for time effects by allowing for time varying intercepts or fixed effects. Secondly, we establish a VAR model and apply Granger causality tests and impulse response functions to further assess the relationship between dynamic hedging and return autocorrelation.

4.1. Fama-MacBeth and Fixed Effect Models

The empirical proxies for hedging demand of the Eurex option market (Equation (13)) or Euwax certificate market (Equation (14)) measure the issuers' demand for becoming active in the underlying stock market by either buying or selling the underlying stock. We are interested in the effect of a simultaneous positive change in the stock price and hedging demand on future stock price movements in the cross-section. In line with Yang and Zhang (2017), we set up a regression with lagged independent variables. We use a lag of one trading day and log transform all independent variables in the regression:

$$
\begin{aligned}
r^e_{i,t+1} = {} & \alpha_t + \beta_1 \cdot {r^e}_{i,t} \\
& + \beta_2 \cdot {LogHD^{OI}}_{i,t} \times {r^e}_{i,t} + \beta_3 \cdot {LogHD^{OI}}_{i,t} \\
& + \beta_4 \cdot {LogHD^{CI}}_{i,t} \times {r^e}_{i,t} + \beta_5 \cdot {LogHD^{CI}}_{i,t} \\
& + \sum_j \theta_j Controls_{i,t} \times {r^e}_{i,t} + \sum_k \phi_k Controls_{i,t} + \epsilon_{i,t+1}
\end{aligned} \tag{16}
$$

with i denoting the equity at time t, option issuer OI and certificate issuer CI. The Fama-MacBeth methodology estimates a regression for each day, with an individual intercept α_t in the cross-section, and takes the average of the estimated coefficients across time. Thus, the model tests for the cross-section if the variation in past returns forecasts the variation in future returns. Additionally, we perform a panel analysis by applying a time fixed effect model. Controls are the log market capitalization, log euro volume and log stock price. The coefficients of interest are β_2 and β_4, which measure the interaction term between the stock price and hedging demand for option issuers and certificate issuers, respectively. Equation (11) predicts $\beta_2 > 0$ for option markets and $\beta_4 < 0$ for certificate markets, i.e. a positive and negative marginal impact of hedging demand on return autocorrelation. The results for the Fama-MacBeth methodology (columns (1) to (3)) and the fixed effect models (columns (4) and (5)) are shown in Table III. The table indicates if the linear model is estimated by using Newey-West heteroskedasticity- and autocorrelation-consistent (HAC) standard errors (Newey and West, 1987).[12]

[Insert Table III about here.]

The lagged stock returns show a significant negative cross-sectional relationship for columns (1) to (4). This finding is often described as bid/ask bounce, i.e. stock prices bouncing between bid and ask prices (Roll, 1984). More recent research links this short-term reversal to liquidity provision for market-makers, who take the opposite position of public traders (Nagel, 2012). The estimated coefficient β_2, i.e. the marginal impact of log hedging demand of the option market on return autocorrelation, is significant and positive throughout all models. However, the positive return autocorrelation from the option market is on average not large

[12] The optimal lag length is specified as $H = int\left(4\left(\frac{N}{100}\right)^{\frac{2}{9}}\right)$, see Newey and West (1994), where N is the average time series length of all stocks.

enough to offset the negative relationship β_1 from lagged stock returns as $\beta_1 + \beta_2 \cdot mean(LogHD^{OI}{}_{i,t}) < 0$. In contrast, the estimate for β_4, i.e. the marginal impact of log hedging demand of the certificate market on return autocorrelation, is negative throughout and significant for the fixed effect model in column (4). The weaker significance of the certificate market compared to the option market can be linked to the fact that the trading volume is much higher for options than for discount certificates. Additionally, the economic magnitude of β_2 is slightly reduced when including the certificate market with the option market (column (3)). In our dataset, almost 11% of the Eurex options are European type options. The results are also robust if the hedging demand of option issuers is only calculated by using American type options. Table IV reports the same analysis as before, but now replacing $\mathrm{LogHD}^{\mathrm{OI}}$ with $\mathrm{LogHD}^{\mathrm{OI}}{}_{(\mathrm{american})}$. While there is clear evidence that hedging demand of the option market causes positive autocorrelation in the cross-section (see e.g. Yang and Zhang, 2017), this study also implies that hedging demand of discount certificate markets is associated with negative return autocorrelation. Despite the weak statistical significance of the certificate market, all findings are consistent with the theory in Section 2.

[Insert Table IV about here.]

4.2. Granger Causality

Next, we examine the lead-lag relationship between stock returns and hedging demand of option and certificate markets for the overall market. We estimate a vector autoregression (VAR) model with the daily average of the variables r^e, $LogHD^{OI}$, $LogHD^{CI}$, $LogMC$, $LogVol$ and $LogP$, as well as all interaction terms, e.g. $LogHD^{OI} \times r^e$. However, as we estimate a VAR, which includes lags by definition, we do not additionally lag the independent variables as in Section 4.1. The VAR uses 1,901 observations and is estimated with a constant. Based on the Akaike's information criterion, the optimal lag length is four trading days.

After estimating the VAR, we apply Granger causality test statistics. The Granger causality can be used to see if changes in hedging demand cause changes in stock price returns (hedging demand Granger-cause stock price returns). The bivariate form of the Granger Causality can be written as:

$$Y_t = \alpha + \sum_{i=1}^{k} \phi_{1i} X_{t-i} + \sum_{i=1}^{k} \gamma_{1i} Y_{t-i} + u_t \tag{17}$$

with H_0: $\phi_1 = \phi_2 = \cdots = \phi_p = 0$, and

$$X_t = \alpha + \sum_{i=1}^{k} \phi_{2i} X_{t-i} + \sum_{i=1}^{k} \gamma_{2i} Y_{t-i} + v_t \tag{18}$$

with H_0: $\gamma_1 = \gamma_2 = \cdots = \gamma_p = 0$,

where k is the optimal lag length. The Granger causality is often estimated in first-differenced logs, where non-stationary levels become stationary time-series, i.e. I(1), to avoid improper test statistics associated with non-stationary data. In particular, the Toda and Yamamoto (1995) procedure will be used to test the causality between hedging demand and stock prices. As a matter of fact, the standard Wald test cannot be used with non-stationary data as it does not follow the asymptotical Chi-square distribution. However, under the Toda and Yamamoto procedure, the Wald test follows a normal asymptotic distribution. Hence, the Granger causality, based on level VAR, can be tested without omitting important level information from the time series. Moreover, the methodology avoids biases from the unit root test which is carried on to the Granger causality, when transforming non-stationary levels, and testing for cointegration relationships.

[Insert Table V about here.]

Table V reports the Chi-square statistics and significance levels for selected variables. The variables of interest are the stock returns, hedging demand of option and certificate markets as well as the interaction effect between stock returns and hedging demand. The results support our previous findings that both $LogHD^{OI} \times r^e$ and $LogHD^{CI} \times r^e$ significantly Granger-cause r^e. The significance is statistically stronger for the option market, where the null hypothesis can be rejected at a one percent significance level, as compared to the certificate market with a significance level of five percent. All other lead-lag relationships are not significant at a 10% level. Thus, both interaction terms strongly lead stock returns, and not the other way around, even after controlling for volume, market capitalization and stock price.

4.3. Impulse Response Function

Next, we use the VAR and examine the impact of a one standard deviation innovation on another endogenous variable's current and future values by applying an orthogonalized impulse response function.[13] There are two reasons for orthogonalizing the impulses. First, the error terms and consequently the shocks are correlated across equations in the VAR system. Secondly, the model in Section 2 describes the effect of lagged hedging demands and lagged stock returns on future stock returns. We can impose a restriction on the contemporaneous impulse-response relationship by ordering the endogenous variables by degree of contemporaneous exogeneity. The causal ordering of the variables is as follows: stock returns, hedging demand of the option market, hedging demand of the certificate market and controls. Thus, the shock in stock returns affects all successive variables contemporaneously. However, the shock in option market's hedging demand is allowed to affect all remaining variables contemporaneously, but not stock returns. This ordering resembles the model assumptions that

[13] The results remain the same if we apply non-orthogonalized impulse response functions.

an increase in stock price has an immediate effect on hedging demand, while hedging demand stimulates the stock price with some time lag.

Figure 2 shows the effect of a one standard deviation (orthogonalized) impulse in hedging demand $LogHD \times r^e$ − for either the option (Panel A) or certificate market (Panel B) − to the stock returns equation over a period of 15 trading days. The response of r^e is shown in its units, i.e. excess log returns, on the vertical axis. The lower figures depict the cumulative orthogonalized impulse response functions for each panel. The 95% confidence intervals indicate the statistical significance of the response.

[Insert Figure 2 about here.]

We examine the response of future stock returns r^e to a current positive shock in option or certificate market's hedging demand due to an increase in stock returns, which is measured by $LogHD \times r^e$. Shocks to hedging demand of the option and certificate market can be useful to forecast stock returns up to six trading days. The response of the stock market to a shock in the option market is delayed compared to the shock in the certificate market. While the response to the option market is predominantly positive, the response to the certificate market is mainly negative. Examining the cumulative impulse response function gives a clearer picture. Recall that the model in Section 2 predicts a positive (negative) return autocorrelation for the option market (certificate market). Both cumulative impulse response functions indicate that there is a persistent spillover effect from the option and certificate market to the stock market, while controlling for all other variables defined in the VAR system. The shock in the option market leads to a positive cumulative return autocorrelation, whereas the shock in the certificate market leads to a negative cumulative return autocorrelation. Looking at the confidence band, the response to the option market is statistically more significant. Both findings are consistent with the model.

4.4. *Instrumental Variable Method*

The previous results show that there is a causality from option and certificate markets to stock markets, i.e. higher return autocorrelation, due to the dynamic hedging activities of issuers. As robustness tests, we check that our empirical hedging demand variable does not measure the effect of news entering the option market before the stock market (see e.g. Easley et al., 1998; Hong and Stein, 1999; Hu, 2014; Johnson and So, 2012; Pan and Poteshman, 2006), because our measure of hedging demand is partly influenced by the net order flow of options or certificates. The net order flow might alternatively measure the reaction of speculative traders to news events, and not solely the requirement of issuers hedging more financial products. We provide two robustness tests to support the findings from the previous sections:

First, we follow Yang and Zhang (2017) and apply an instrumental variable (IV) to hedging demand, i.e. the absolute difference between the (normalized) underlying stock price and the nearest round number. The instrument is not related to the option volume but proxies the hedging demand of option writers. Besides the net order flow, the second main driver of hedging demand is the option's gamma. The chosen instrument resembles the characteristics of gamma. The gamma is highest for options at-the-money, which in turn depends on the distance from the underlying stock price to the option's strike. Moreover, exchanges prefer to issue options with round strike prices, which relates to more hedging activities on the issuer's side. In contrast, the roundness of the stock price is not related to the fundamental value of a firm. Thus, the instrumental variable does not depend on any news-related measures like option volume, and we remove the potential endogeneity between changes in the firm's fundamental value and speculative trading in option markets. The instrument is generated by taking the absolute value of the difference between each underlying's stock price (normalized to two digits before the decimal point, e.g. 123 becomes 12.3) and its nearest multiple of five (in the case of 12.3: 10). Then we calculate the mean of the logged values over the last five trading days. We re-estimate the time fixed effect regression from Section 4.1 with (i) the hedging demand and (ii) its interaction with the excess stock return being instrumented. Table VI shows the estimated coefficients of the IV regressions for the hedging demand of the option and certificate market. The validity of the IV regressions is tested via the robust Kleibergen-Paap rk LM statistic of underidentification (Kleibergen and Paap, 2006) and Cragg-Donald Wald F statistic of weak identification (Cragg and Donald, 1993). The variable of interest, $LogHD \times r^e$, is significant and positive for the option market, whereas the estimated coefficient is significant and negative for the certificate market. Hence, the results remain the same when applying the IV regression.

[Insert Table VI about here.]

Secondly, we show that the empirical hedging demand of the certificate market has had an impact on return autocorrelation. If we unintentionally measure the sensitivity of markets to news (and not the demand for hedging) with our variable, we should not observe a causality between certificate markets and stock markets, i.e. news should not enter the certificate market before the stock market. Discount certificates are unlikely to be the first choice to exploit informational advantages about changes in the firm's fundamentals.

5. Conclusion

This paper examines the role of liquidity providers, i.e. option and certificate issuers, and how their dynamic hedging can affect the underlying asset. We compare the effect of dynamic hedging for two different financial products: options with a convex payoff and discount certificates with a concave payoff. This study contributes to the literature in three ways: it is the first study to introduce a theoretical and empirical effect from the certificate markets to the stock market due to dynamic hedging. Secondly, we analyze the joint effect of hedging demand of certificate and option markets on the return autocorrelation in the stock market. Thirdly, in contrast to previous studies, we examine the hedging behavior of the German option market.

The theoretical framework shows that the hedging demand of option issuers introduces positive return autocorrelation, while the opposite holds for certificate issuers, whose hedging demand induces negative return autocorrelation in the stock market. An increase in the fundamental value of an underlying asset (stocks) requires the liquidity provider of the derivative to become active in the underlying market to reduce the exposure by using dynamic hedging. If there is a positive news event, the demand of the option issuer for buying more stocks is positive, whereas the discount certificate issuer has a negative demand for stocks. The empirical demand for hedging is measured by utilizing the characteristics of options and discount certificates (gamma) as well as the characteristics of each market (net order flow).

We find evidence that dynamic hedging demand of the German option market induces positive autocorrelation of stock returns. In contrast, the return autocorrelation in stock prices is negative for the German discount certificate market. Moreover, the effect of dynamic hedging demand of the option market is statistically more pronounced and dominates the influence of the certificate market due to its distinct market size. Nonetheless, when applying a VAR model, both markets show a persistent price impact on the return autocorrelation. Hence, we theoretically and empirically provide evidence that there are spillover effects from certificate to stock markets due to dynamic hedging activities. The results remain the same when we measure hedging demand isolated from the traded volume of options or certificates and apply an instrumental variable regression.

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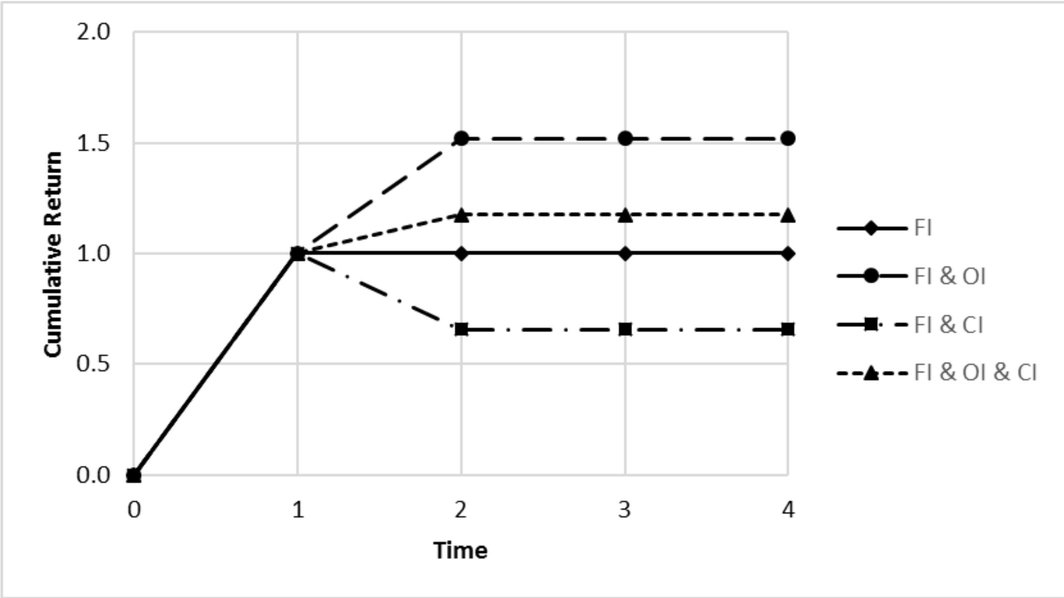

Figure 1. Impulse Response. This figure shows the impact on return autocorrelation for the model described in Section 2.3 with following input parameters: $\boldsymbol{F_0 = 50}$, $\boldsymbol{\varepsilon_1 = 1}$, $\boldsymbol{X^{OI} = 50}$, $\boldsymbol{T^{OI} = 1}$, $\boldsymbol{X^{CI} = 40}$, $\boldsymbol{T^{CI} = 1}$, $\boldsymbol{r_f = 0}$, $\boldsymbol{\sigma = 0.3}$ and $\boldsymbol{\gamma = 0.05}$. Each line represents a combination of agents participating in the underlying market: fundamental investor (FI), option issuer (OI) and certificate issuer (CI).

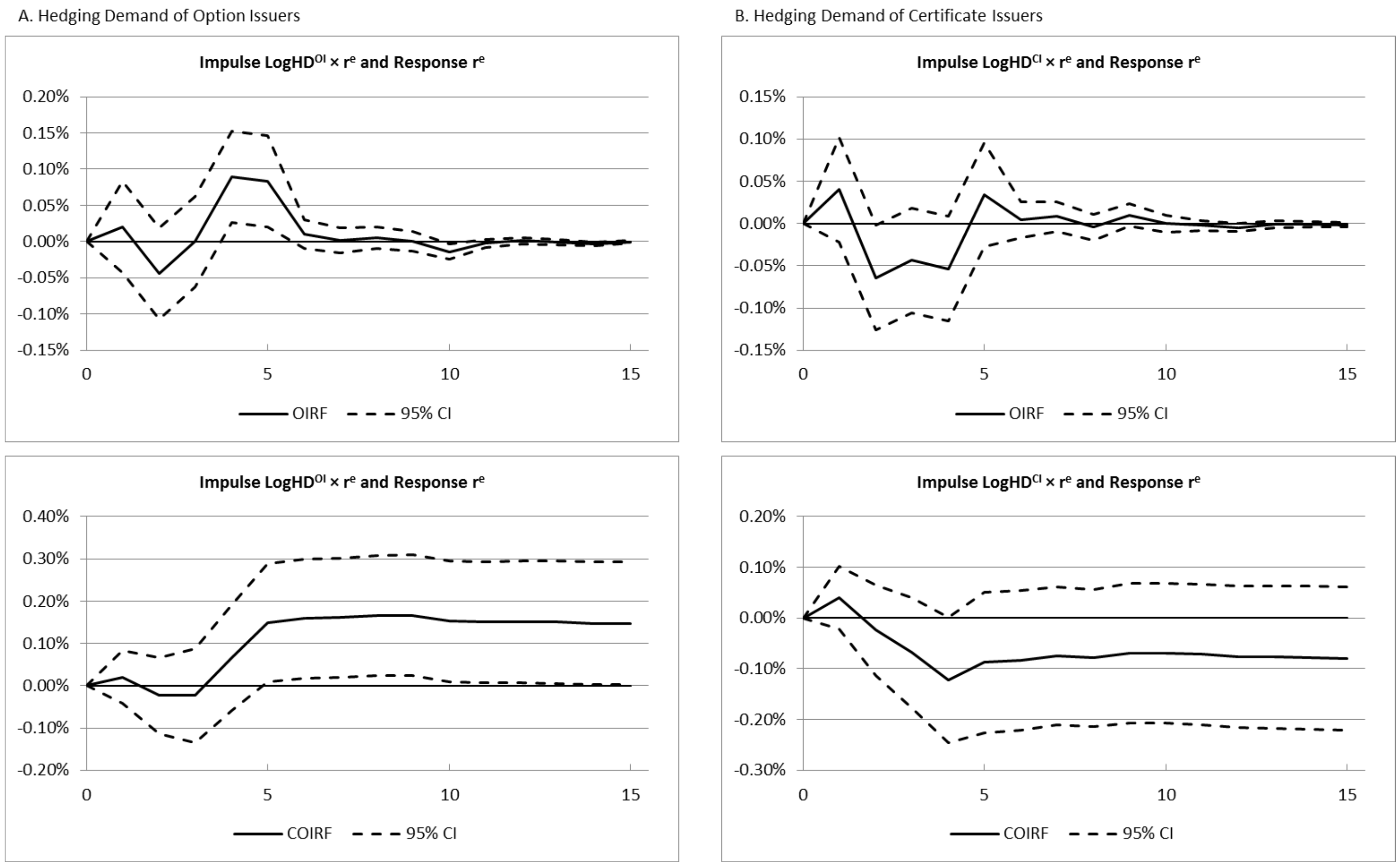

Figure 2. VAR: Impulse Response Function. The solid line displays the orthogonalized impulse response function (OIRF) and cumulative orthogonalized impulse response function (COIRF). The 95% confidence intervals indicate the statistical significance of the response (dashed line). The graphs show the effect of a one standard deviation impulse in hedging demand, for either the option (Panel A) or certificate market (Panel B), to the stock returns equation over a period of 15 trading days (horizontal axis). The response of $\boldsymbol{r^e}$ is shown in its units, i.e. excess log returns, on the vertical axis.

Table I. Summary Statistics

This table presents daily summary statistics for the main variables. The daily stock return r is adjusted for dividend and capital adjustments and the daily risk-free rate r_f is the one-month money market rate. The excess stock return r^e is the difference between log return and log risk-free rate. The option issuers' hedging demand HD^{OI} is defined in Equation (13) and is also separately calculated for options of American type. Certificate issuers' hedging demand HD^{CI} is defined in Equation (14). The market capitalization for each equity is MC, the euro volume (in thousands) is Vol and the unadjusted stock price is P. N = 70,576.

Variable	*in*	Mean	Std. Dev.	Min	Max
r	%	0.037	2.434	-72.78	123.73
r_f	%	0.007	0.008	0.00	0.04
r^e	%	0.001	2.427	-130.16	80.49
HD^{OI}	*BPS*	0.202	0.463	-1.79	4.08
$HD^{OI\ (american)}$	*BPS*	0.202	0.463	-1.79	4.08
HD^{CI}	*BPS*	0.001	0.002	-0.01	0.02
MC	*/1,000*	21.240	19.477	0.13	267.88
Vol	*/1,000*	1.757	6.135	0.00	625.11
P		55.163	39.676	0.39	893.14

Table II. Summary Statistics: Hedging Demand per Year

This table reports the yearly average hedging demand of option and certificate issuers for DAX stocks from 01/2006 to 12/2013. The option issuers' hedging demand HD^{OI} is defined in Equation (13) and certificate issuers' hedging demand HD^{CI} is defined in Equation (14).

Variable	Year	*in*	Mean	Std. Dev.	N
HD^{OI}	2006		0.2690	0.5430	8,608
	2007		0.2890	0.5860	8,831
	2008		0.2370	0.5270	8,958
	2009	BPS	0.1840	0.4640	9,104
	2010		0.2240	0.5220	8,977
	2011		0.1620	0.3590	8,746
	2012		0.1240	0.2690	8,706
	2013		0.1260	0.2750	8,646
	Total		0.2020	0.4630	70,576
HD^{CI}	2006		0.0006	0.0020	8,608
	2007		0.0005	0.0019	8,831
	2008		0.0001	0.0019	8,958
	2009	BPS	0.0005	0.0019	9,104
	2010		0.0009	0.0024	8,977
	2011		0.0010	0.0027	8,746
	2012		0.0010	0.0028	8,706
	2013		0.0009	0.0027	8,646
	Total		0.0007	0.0023	70,576

Table III. Fama-MacBeth and Fixed Effect Models

This table reports estimated coefficients of the regressions described in Section 4.1. The excess stock return r^e is the difference between log return and log risk-free rate. The option issuers' hedging demand HD^{OI} is defined in Equation (13) and certificate issuers' hedging demand HD^{CI} is defined in Equation (14). The market capitalization for each equity is MC, the euro volume (in thousands) is Vol and the unadjusted stock price is P. All independent variables are log transformed. Columns (1) to (3) apply the Fama-MacBeth methodology and columns (4) and (5) are fixed effect models. NW SE indicates if the linear model is estimated by using Newey-West heteroskedasticity- and autocorrelation-consistent (HAC) standard errors. Obs. denotes the number of observations. t statistics are shown in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Variable	Coef. (Hyp.)	Fama-MacBeth			Fixed Effect Model	
		(1)	(2)	(3)	(4)	(5)
r^e	β_1	-0.352***	-0.164*	-0.305***	-0.074***	-0.074
		(-3.50)	(-1.76)	(-2.63)	(-2.82)	(-0.83)
$LogHD^{OI} \times r^e$	β_2 (+)	722.937*		718.071*	347.523***	347.523**
		(1.87)		(1.93)	(5.09)	(2.04)
$LogHD^{OI}$	β_3	8.876		12.750**	-1.316	-1.316
		(1.49)		(1.98)	(-0.79)	(-0.79)
$LogHD^{CI} \times r^e$	β_4 (−)		-7.338E+04	-5.171E+04	-3.076E+04**	-3.076E+04
			(-0.90)	(-0.61)	(-2.45)	(-1.43)
$LogHD^{CI}$	β_5		-69.867	-57.560	-516.188	-516.188
			(-0.05)	(-0.04)	(-1.57)	(-1.60)
$LogMC \times r^e$		0.010	0.013	0.011	0.017***	0.017**
		(1.03)	(1.44)	(1.10)	(4.70)	(2.23)
LogMC		0.000	0.000	0.000	-0.009***	-0.009
		(0.60)	(0.49)	(0.59)	(-4.49)	(-0.86)
$LogVol \times r^e$		0.027***	0.026***	0.027***	-0.014***	-0.014
		(3.88)	(3.86)	(3.59)	(-4.03)	(-1.33)
LogVol		-0.000*	-0.000	-0.000	0.000	0.000
		(-1.78)	(-1.04)	(-1.50)	(-0.18)	(-0.14)
$LogP \times r^e$		-0.013	-0.018**	-0.017*	0.000	0.000
		(-1.41)	(-1.96)	(-1.69)	(-0.68)	(-0.54)
LogP		-0.000	-0.000	-0.000	0.000*	0.000
		(-1.07)	(-1.57)	(-1.50)	(1.75)	(1.37)
Constant		-0.001	0.001	-0.001		
		(-0.32)	(0.83)	(-0.47)		
NW SE		Yes	Yes	Yes	No	Yes
(Avg.) R2		0.361	0.363	0.420	0.370	0.370
Obs.		70,512	70,512	70,512	70,512	70,512

Table IV. Fama-MacBeth and Fixed Effect Models: American Options

This table reports estimated coefficients of regressions described in Section 4.1. The excess stock return r^e is the difference between log return and log risk-free rate. The option issuers' hedging demand HD^{OI} is defined in Equation (13) and is calculated for options of American type. Certificate issuers' hedging demand HD^{CI} is defined in Equation (14). The market capitalization for each equity is MC, the euro volume (in thousands) is Vol and the unadjusted stock price is P. All independent variables are log transformed. Columns (1) and (2) apply the Fama-MacBeth methodology and columns (3) and (4) are fixed effect models. NW SE indicates if the linear model is estimated by using Newey-West heteroskedasticity- and autocorrelation-consistent (HAC) standard errors. Obs. denotes the number of observations. *t* statistics are shown in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Variable	Coef. (Hyp.)	Fama-MacBeth		Fixed Effect Model	
		(1)	(2)	(3)	(4)
r^e	β_1	-0.355***	-0.307***	-0.074***	-0.074
		(-3.53)	(-2.65)	(-2.82)	(-0.83)
$LogHD^{OI\ (american)} \times r^e$	β_2	734.983*	722.996*	347.541***	347.541**
	(+)	(1.90)	(1.94)	(5.09)	(2.04)
$LogHD^{OI\ (american)}$	β_3	8.507	12.495*	-1.338	-1.338
		(1.42)	(1.93)	(-0.80)	(-0.80)
$LogHD^{CI} \times r^e$	β_4		-5.167E+04	-3.076E+04**	-3.076E+04
	(−)		(-0.61)	(-2.45)	(-1.43)
$LogHD^{CI}$	β_5		-53.657	-515.932	-515.932
			(-0.04)	(-1.57)	(-1.60)
$LogMC \times r^e$		0.010	0.011	0.017***	0.017**
		(1.05)	(1.13)	(4.70)	(2.23)
LogMC		0.000	0.000	-0.009***	-0.009
		(0.60)	(0.57)	(-4.49)	(-0.86)
$LogVol \times r^e$		0.027***	0.027***	-0.014***	-0.014
		(3.88)	(3.60)	(-4.03)	(-1.33)
LogVol		-0.000*	-0.000	0.000	0.000
		(-1.77)	(-1.48)	(-0.18)	(-0.14)
$LogP \times r^e$		-0.014	-0.017*	0.000	0.000
		(-1.44)	(-1.71)	(-0.68)	(-0.54)
LogP		-0.000	-0.000	0.000*	0.000
		(-1.07)	(-1.49)	(1.75)	(1.37)
Constant		-0.000	-0.001		
		(-0.28)	(-0.44)		
NW SE		Yes	Yes	No	Yes
(Avg.) R2		0.361	0.420	0.370	0.370
Obs.		70,512	70,512	70,512	70,512

Table V. VAR: Granger Causality

This table reports Granger causality test statistics from a VAR with the daily average of the variables r^e, $LogHD^{OI}$, $LogHD^{CI}$, $LogMC$, $LogVol$ and $LogP$, as well as all interaction terms with r^e. The VAR is estimated with a constant, a lag length of 4 trading days, and uses 1,901 observations. The column "Equation" indicates the dependent variable in the VAR. The column "Excluded Variable" reports the variable which is used for the null hypothesis that all coefficients on lags are equal to zero, i.e. does not Granger-cause the dependent variable. For the sake of clarity, the table reports only Chi-square statistics and significance levels for selected variables. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Equation	Excluded Variable	Chi-Square
r^e	$LogHD^{OI}$	2.18
r^e	$LogHD^{OI} \times r^e$	14.68***
r^e	$LogHD^{CI}$	5.56
r^e	$LogHD^{CI} \times r^e$	13.01**
$LogHD^{OI}$	r^e	3.91
$LogHD^{OI} \times r^e$	r^e	0.72
$LogHD^{CI}$	r^e	3.13
$LogHD^{CI} \times r^e$	r^e	0.48

Table VI. Fixed Effect Models with Instrumental Variable Methods

This table reports estimated coefficients of the instrumental variables (IV) regressions described in Section 4.4. The excess stock return r^e is the difference between log return and log risk-free rate. The option issuers' hedging demand HD^{OI} is defined in Equation (13) and certificate issuers' hedging demand HD^{CI} is defined in Equation (14). The hedging demand variable and its interaction with the excess stock return are instrumented. The market capitalization for each equity is MC, the euro volume (in thousands) is Vol and the unadjusted stock price is P. All independent variables are log transformed. All IV regressions are estimated with time fixed effects. Validity of the IV regressions is tested via the robust Kleibergen-Paap rk LM statistic of underidentification (Kleibergen and Paap, 2006) and Cragg-Donald Wald F statistic of weak identification (Cragg and Donald, 1993). Obs. denotes the number of observations. t statistics are shown in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Variable	Coef. (Hyp.)	Fixed Effect Model (IV) (1)	(2)
r^e	β_1	-2.394* (-1.77)	0.234** (2.04)
$LogHD^{OI} \times r^e$	β_2 (+)	1.810E+04* (1.73)	
$LogHD^{OI}$	β_3	-170.816 (-0.52)	
$LogHD^{CI} \times r^e$	β_4 (−)		-3.893E+05** (-2.55)
$LogHD^{CI}$	β_5		1.029E+04 (0.41)
$LogMC \times r^e$		-0.155 (-1.51)	0.036*** (4.74)
LogMC		0.001 (0.45)	0.000 (0.43)
$LogVol \times r^e$		-0.023*** (-2.62)	-0.015*** (-4.27)
LogVol		0.001 (0.53)	-0.000 (-0.69)
$LogP \times r^e$		0.093 (1.46)	-0.025*** (-4.96)
LogP		0.000 (1.28)	0.000 (0.75)
p-value of KP rk LM statistic		0.051	0.000
Cragg-Donald Wald F statistic		1.85	6.00
Adj. R2		-0.345	0.351
Obs.		70,512	70,512

Appendix A. Discount Certificate: Trade Classification

Appendix A.1 summarizes the trade dataset with a total of 910,406 trades at Euwax. While the number of investor buys diminished after the crisis in 2008, discount certificates gained further attractiveness from 2010 on. The number of sell trades peaked in 2008 and slightly increased again in 2011. Buy trades exceeded the investor sell trades by a factor of almost three before 2008, but thereafter the factor decreased to below two. This might suggest that fewer investors held certificates until maturity. In our dataset from 2006 to 2013, the total buy and sale trading volume was EUR 13.7bn and EUR 7.5bn, respectively. In line with the number of trades, the difference between buy and sell trading volume was the lowest in 2008. The average trading volume for buys and sales in our dataset is EUR 25,390 and EUR 26,681, respectively.

[Insert Appendix A.1 about here.]

Appendix A.1. Trade Dataset: Classification

This table presents the number of trades, number of non-classified trades, number of initiated investor buys and investor sells, the total trade volume in million EUR, the difference between total trade volume in million EUR and the average trade volume in EUR per trade classification.

					Total			Mean	
					Million Euro Volume			Euro Volume	
Year	Obs	No Class.	#InvBuy	#InvSell	InvBuy	InvSell	Buy-Sell	InvBuy	InvSell
2006	102,804	8.5%	70,225	23,814	1,535	619	917	21,865	25,977
2007	118,412	12.5%	75,867	27,701	1,892	979	913	24,933	35,335
2008	118,368	15.8%	53,186	46,494	1,265	1,112	153	23,782	23,918
2009	98,660	17.1%	52,462	29,369	1,226	657	569	23,365	22,361
2010	119,015	12.0%	69,709	34,966	1,820	886	935	26,115	25,328
2011	126,081	3.6%	77,738	43,861	2,399	1,226	1,173	30,864	27,949
2012	127,314	4.9%	78,955	42,061	2,037	1,132	905	25,798	26,906
2013	99,752	4.6%	62,594	32,614	1,555	885	670	24,841	27,129
2006-2013	910,406	9.8%	540,736	280,880	13,729	7,494	6,235	25,390	26,681

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