Are structured products ‘fairly’ priced? 
An analysis of the German market for equity-linked instruments

Pavel A. Stoimenov, Sascha Wilkens *

Department of Finance, University of Muenster, Universitaetsstrasse 14-16, 48143 Muenster, Germany

Received 28 January 2004; accepted 2 November 2004
Available online 18 January 2005

Abstract

Based on a unique data set, this paper examines the pricing of equity-linked structured products in the German market. The daily closing prices of a large variety of structured products are compared to theoretical values derived from the prices of options traded on the Eurex (European Exchange). For the majority of products, the study reveals large implicit premiums charged by the issuing banks in the primary market. A set of driving factors behind the issuers’ pricing policies is identified, for example, underlying and type of implicit derivative(s). For the secondary market, the product life cycle is found to be an important pricing parameter.

© 2004 Elsevier B.V. All rights reserved.

JEL classification: G13; G24
Keywords: Structured products; Pricing; German market; Options; Implied volatility

1. Introduction

Structured financial products combine elementary instruments from the spot and futures markets (e.g., stocks, interest rate products, derivatives) and promise

* Corresponding author.
E-mail addresses: stoimenov@rwi-essen.de (P.A. Stoimenov), wilkens@gmx.de (S. Wilkens).
tailor-made risk/return profiles for investors. These securities, issued and sold by banks, became popular in the US in the 1980s and found their way to Europe in the mid-1990s during a period of low interest rates. In recent years, ‘financial engineering’ has become indispensable in most financial institutions. Structured products offer the feature of facilitating complex positions in options without the need for access to options exchanges. In the case of net short positions, there are no explicit margin requirements, since the products’ nominal values serve as collateral for the issuer. Thus, these securities, designed for retail investors, are an easy means of implementing complex investment strategies. When trading structured products, transactions costs (e.g., bid–ask spreads) and commissions for the private investor are usually lower than those for the corresponding single trades. In addition, structured products offer lifetimes ranging from a few months to several years, which thus often exceed those of exchange-traded options. Therefore, this product category generally constitutes a useful extension to the capital markets. Due to the large number of products and very heterogeneous nomenclature, however, the German market for structured products can hardly be described as transparent. A particularly important issue is the valuation of these instruments.

Despite the large size and rapid growth of the market for structured products, very little empirical research on the pricing has been undertaken. For a period of two months in 1988 and 1989, Chen and Kensinger (1990) analyze ‘Market-Index-Certificates of Deposit’ (MICD) in the US market, which pay a guaranteed minimum interest rate and a variable interest rate pegged to the performance of the S&P 500. A comparison of the implied volatility of the S&P 500 option with the implied volatility of the MICDs’ option components reveals significant positive and negative differences between theoretical and market values, as well as inconsistencies in the pricing among issuers and products with different maturities and types offered by the same institution. Chen and Sears (1990) investigate the ‘S&P 500 Index Note’ (SPIN) issued by Salomon Brothers, which is very similar to the MICDs, but exchange-traded. Computing the differences between market and model prices for the period from 1986 to 1987 (using ex post, average implied and long-term implied volatilities), they diagnose overpricing in the first sub-period and underpricing in the second and third sub-periods. Baubonis et al. (1993) analyze the cost structure of equity-linked certificates of deposit and demonstrate, using a Citicorp product as an example, that the bank can earn a gross fee of 2.5–4% of the selling price in the primary market. Wasserfallen and Schenk (1996) examine the pricing of capital-protected products issued in 1991/1992 in the Swiss market. The comparison of the products’ option components with those derived from historical and implied volatility of the Swiss Market Index shows that the securities are sold slightly above their theoretical values. In the secondary market, model values exceed observed prices. Another study of the Swiss market was conducted by Burth et al. (2001), who, employing exchange-traded options, assess the initial pricing of reverse convertibles and discount certificates outstanding in August 1999. The ‘mispricing’, generally in favor of the issuing institution, differs among the issuers as well as between fixed-coupon reverse convertibles and discount certificates. In addition, the existence of a co-lead manager is identified as a significant factor influencing product prices at issuance.
To the best of our knowledge, there is only one empirical study for the German market. Wilkens et al. (2003) analyze a large data set of ‘classic’ structured products, with and without coupon payments, on a variety of German stocks traded in November 2001. Extracting implied volatilities from comparable call options traded on the Eurex (European Exchange), fictitious product values are calculated and compared to prices quoted in the secondary market. The authors find evidence of an overpricing of structured products, which can mostly be interpreted as in favor of the issuing institution. In assessing the driving factors of pricing policies, Wilkens et al. (2003) conclude that issuers orient their pricing towards the product lifetime and the incorporated risk of a redemption by shares (given by the moneyness of the implicit options), bearing in mind the volumes of sales and repurchases to be expected from issuance until maturity.

The purpose of this study is to undertake the first investigation of the full range of equity-linked structured products in the German private retail banking sector. Based on a large and unique data set, we provide an innovative in-depth pricing analysis in both primary and secondary markets. Our study is also the first to incorporate structured products with implicit exotic option components, namely barrier and rainbow options. From a methodological point of view, the main technique consists in comparing product prices with theoretical (‘fair’) values using prices of exchange-traded options.

Our results suggest that, in the primary market, all types of equity-linked structured products are, on average, priced above their theoretical values and thus favor the issuing institution. However, the overpricing varies with underlying and product type. In general, more complex products incorporate higher implicit premiums. In the secondary market, the diagnosed overpricing decreases as the products approach maturity. This supports our ‘life cycle hypothesis’ according to which issuers orient their pricing to the remaining product lifetime in order to earn additional profit.

The paper is organized as follows: In Section 2, we develop a classification of equity-linked structured products in the German market and discuss the products’ main characteristics, payout profiles, and valuation approaches by duplication. Section 3 describes the objectives and hypotheses of the empirical analysis, while our methodology and data are given in Section 4. Section 5 presents the empirical results. The final Section 6 summarizes and provides an outlook for further research.

2. Equity-linked structured products in the German market

2.1. Classification

In both theory and practice, there is no general definition of the term ‘structured product’. In the following analysis, we will refer to those products that: (i) are issued by a bank and (ii) combine at least two single instruments of which (iii) at least one is a derivative.1 We focus on the market for equity-linked products, i.e., instruments

---

1 Cf., for example, Das (2000) for other classifications of ‘structured products’.
with stocks or stock indices as underlyings.\(^2\) To classify the products in the German market, we propose the typology given in Fig. 1. This allows an easy identification of product types, in spite of the large variety of product characteristics and heterogeneous nomenclature in this market.

The classification refers to the products’ implicit option components. In a first step, we distinguish between products with *plain-vanilla* and those with *exotic option components*.\(^3\) While in a second step, ‘exotic’ products can be uniquely identified and named, a similar differentiation within the group of plain-vanilla products is not possible. Their payment profiles can be replicated by one or more plain-vanilla options, whereby the option type (call or put) and position (long or short) is product-specific. Therefore, we assign terms to these products that best characterize their payment profiles.

2.2. Products with plain-vanilla option components

2.2.1. ‘Classic’ products

A ‘classic’ structured product has the basic characteristics of a bond. As a special feature, the issuer has the right to redeem it at maturity either by repayment of its

---

\(^2\) Other underlyings, such as currencies or commodities, are of minor importance to the German market and are therefore excluded from our analysis.

\(^3\) Note that products combining plain-vanilla and exotic options in a single product and other recent innovations (e.g., ‘rolling certificates’) were not available at the time of our empirical study, cf. Sections 4 and 5, and are therefore excluded from our typology. We also point out that the large group of leverage products (e.g., ‘long certificates’ and ‘short certificates’), frequently advertised as ‘exchange-traded futures’, does not match our definition of structured products, because, from a theoretical perspective, these instruments are simple barrier options.
nominal value or delivery of a previously fixed number of specified shares.\(^4\) Most structured products can be divided into two basic types: with and without coupon payments, generally referred to as reverse convertibles and discount certificates.

In order to value structured products, we decompose them by means of duplication, i.e., the reconstruction of product payment profiles through several single components. Thereby, we ignore transactions costs and market frictions, e.g., tax influences. Additionally, we assume continuous compounding in all calculations and quote time periods (measured in calendar days) as fractions of a year. \(T\) denotes the product maturity and \(t\) the valuation day. The issuer’s decision on the form of redemption is generally due some days prior to maturity, on a reference day \(t_{\text{fixing}}\). The repayment/nominal value is referred to as \(N\), \(s\) gives the number of deliverable shares, \(r\) the risk-free interest rate (continuously compounded), \(Z_i\) the amount and \(t_{Z_i}\) the date of the \(i\)th coupon payment \((i = 1, 2, \ldots, n)\). Furthermore, the amount of the \(j\)th dividend payment on the underlying on a date \(t_{D_j}\) is denoted by \(D_j\) \((j = 1, 2, \ldots, m)\).

From an investor perspective, the purchase of a ‘classic’ product at time \(t\) is equivalent to entering two single positions. On the one hand, the investor buys one or more zero bonds.\(^5\) On the other hand, the investor enters a short position in \(s\) European put options with strike price \(K = N/s\). If, on the reference day, the stock price \(S_{t_{\text{fixing}}}\) drops below \(K\), i.e., \(sS_{t_{\text{fixing}}} < N\), redeeming in shares is advantageous for the issuer, who will exercise his option rights and deliver \(s\) units of the underlying at price \(K\). Since the issuer must already decide on the means of redemption in \(t_{\text{fixing}}\), whereas the exercise can only take place in \(T\), the value of the option position must be discounted for the time interval \([t_{\text{fixing}}, T]\). Let \(P^K_t\) denote the current value of a European put option with strike \(K\) and maturity at time \(t_{\text{fixing}}\); then the value of a ‘classic’ product, \(\text{SP}^{\text{Classic}}_t\), at \(t \leq t_{\text{fixing}}\) equals the difference between the zero bonds’ present values and the total value of the put options: \(^6\)

\[
\text{SP}^{\text{Classic}}_t = Ne^{-r(T-t)} + \sum_{i=1}^{n} Z_i e^{-r(t_{Z_i}-t)} - e^{-r(T-t_{\text{fixing}})}sP^K_t.
\]

Note that \(\text{SP}^{\text{Classic}}_t\) gives the dirty price of the structured product in monetary units (i.e., including accrued interest), whereas, during the exchange trade in reverse convertibles, at least in general, clean prices are quoted in percent.\(^7\)

For purposes of option valuation, it is necessary to take dividend payments into account. A common approach is the decomposition of the current stock price \(S_t\) into a risky component \(S'_t\) and the present value of future dividend payments until the

\(^4\) For purposes of product description, we assume that the underlying is a share. In contrast, for structured products on non-traded assets (e.g., stock indices), contract conditions provide cash settlement.

\(^5\) In the case of products with coupon payments, the duplication requires a coupon-bearing bond that can be stripped into zero bonds for the nominal value and for each of the coupons.

\(^6\) We assume a flat term structure of interest rates. The additional aspect of a possible default of the issuer is discussed in our empirical study, cf. Section 4.

\(^7\) We apply the commonly accepted rule no. 251 of the ISMA (International Securities Market Association) to calculate accrued interest.
option’s maturity, i.e., $\sum_{j=1}^{m} D_j e^{-r(T_j - t)}$. Therefore, only $S_t$ is considered as the reference price of the underlying.

An alternative way of duplicating the payment profile of a ‘classic’ product consists in employing put–call parity, which leads to the following valuation formula:

$$\begin{align*}
SP_{Classic}^t &= \sum_{i=1}^{n} Z_i e^{-r(T_i - t)} + e^{-r(T^* - t)} s \left( S_t^* - C^K_t \right). 
\end{align*}$$

The profit profile of a ‘classic’ product, duplicated as in Eq. (2), is displayed in Fig. 2(a).

**2.2.2. Corridor products**

For a corridor product, the payout depends on whether the stock price at maturity is quoted within a certain range. While, in a similar manner to a ‘classic’ product, the maximum repayment is given by $N$ (the upper reference price), a total loss occurs if the stock price is quoted below a fixed lower reference price at maturity. The easiest

---

---
way to duplicate a corridor product is to purchase \( s \) European call options with strike \( L \) = Lower reference price/s and value \( C^L_t \) and simultaneously to sell \( s \) European call options with strike \( K = N/s \) and value \( C^K_t \). Then the value \( \text{SP}^{\text{Corridor}}_t \) of a corridor product equals\(^{10} \)

\[
\text{SP}^{\text{Corridor}}_t = e^{-r(T - t)} s(C^L_t - C^K_t).
\]  

(3)

Fig. 2(b) shows the profit profile.

2.2.3. Guarantee products

A guarantee product is a simple modification of a corridor product, because the potential loss is restricted by a fixed minimum repayment (guarantee). If the stock price at maturity falls below the reference value \( G = \text{Guarantee}/s \), the guaranteed amount will always be paid to the investor.\(^{11} \) Duplicating this additional feature requires the purchase of a risk-free bond with a face value equal to the total guaranteed amount. Hence, the value \( \text{SP}^{\text{Guarantee}}_t \) of a guarantee product can be obtained as follows:

\[
\text{SP}^{\text{Guarantee}}_t = \sum_{i=1}^{n} Z_i e^{-r(T - t)} s(C^G_t - C^K_t) + se^{-r(T - t)}.
\]  

(4)

The reconstruction of a guarantee product profit profile is illustrated in Fig. 2(c).

2.2.4. Turbo products

Turbo products have the following characteristics: If the underlying is quoted within a certain price range at maturity, the product owner participates twice in the development of the underlying (turbo effect). If \( L \) and \( K \) denote the lower and upper reference prices, there are three possible scenarios at maturity:

1. For \( S_f < L \), the product is redeemed in shares;
2. For \( L < S_f < K \), a cash settlement with \( s(2S_f - L) \) occurs;
3. For \( K < S_f \), the maximum amount, \( s(2K - L) \), is paid.

The profit profile for scenarios 1 and 2 can be rebuilt by entering \( s \) long positions in the underlying and \( s \) long positions in call options with strike \( L \) and value \( C^L_t \). In order to ensure that the upside potential in scenario 3 is limited, the profiles from the two long positions must be offset by selling \( 2s \) call options with strike \( K \) and value \( C^K_t \). Employing the dividend-adjusted stock price \( S^d_t \), leads to the value \( \text{SP}^{\text{Turbo}}_t \) for a turbo product:\(^{12} \)

\[10\] Coupon payments are not considered, since corridor products traded in the German market do not comprise interim payments.

\[11\] Another difference between corridor and guarantee products is the selection of the lower strike price: While for \( L \), any values in \( (0, K) \) are valid, the parameter \( G \) is linked to the guarantee amount via \( G = \text{Guarantee}/s \).

\[12\] Since turbo products traded in the German market do not offer coupon payments, once again, these are not considered.
The profit profile of a turbo product is given in Fig. 2(d).

2.3. Products with exotic option components

2.3.1. Barrier products

The most common form of structured products with implicit exotic option components are barrier products. For these securities, the choice of redemption depends on whether the underlying reaches a certain fixed price barrier during the product lifetime. The issuer of a knock-in product is allowed to deliver stocks at maturity only if the underlying reaches or crosses a previously fixed lower price barrier. In such a case, the knock-in product becomes a ‘classic’ one. If the underlying is always quoted above this barrier, the knock-in product pays the maximum amount, regardless of \( S_{fixing} \). For a knock-out product, the issuer loses his choice of redemption if the underlying reaches or crosses a previously fixed upper price barrier. In this event, the knock-out product turns into a regular bond.

To allow for the path-dependent issuer right, there must be a duplication using one-sided barrier instead of plain-vanilla put options. The duplication of a knock-in product requires the use of down-and-in puts (with value \( P_{DL,i}^K \)) that become worthless if the underlying does not reach the lower price barrier \( B < S_t \) until maturity and are otherwise equivalent to plain-vanilla options. The holder of a knock-out product implicitly sells up-and-out put options (with value \( P_{UO,i}^K \)) to the issuer. These options are knocked-out once the underlying reaches the upper barrier \( B > S_t \). In all other respects, they are equivalent to plain-vanilla options. Formally, the values \( SP_{KI}^t \) and \( SP_{KO}^t \) of a knock-in and knock-out product are given by: \(^{13}\)

\[
SP_{KI}^t = e^{-r(T-t_{fixing})} \left[ N \left( e^{r(T-t)} \right) + \sum_{i=1}^{n} Z_i e^{-r(T-t_i)} - e^{-r(T-t_{fixing})} S_{DL,i}^K \right],
\]

\[
SP_{KO}^t = e^{-r(T-t)} \left[ N \left( e^{r(T-t)} \right) + \sum_{i=1}^{n} Z_i e^{-r(T-t_i)} - e^{-r(T-t_{fixing})} S_{UO,i}^K \right].
\]

A special form of barrier instruments in the German market are partial-time knock-in products. For this class of securities, the barrier criterion is tested only within a certain time interval, generally a few months immediately prior to maturity. Therefore, duplication requires the use of partial-time knock-in options in Eq. (6).

2.3.2. Rainbow products

In contrast to ‘classic’ products, rainbow products comprise two underlyings. Apart from the possibility of redeeming the product by paying the nominal value,

\(^{13}\) While Eq. (1) in conjunction with put–call parity offers an alternative duplication scheme for ‘classic’ products via call options, Eqs. (6) and (7) cannot be simplified further.
where there is a share delivery, the issuer has the right to choose between two underlyings. With \( s^{(1)} \) and \( s^{(2)} \) denoting the number of deliverable shares with current prices \( S_t^{(1)} \) and \( S_t^{(2)} \) and \( N \) as the maximum repayment amount, the payout profile of a rainbow product is as follows:

- For \( s^{(1)} S_t^{(1)} > N \land s^{(2)} S_t^{(2)} > N \), the maximum amount will be paid;
- For \( s^{(1)} S_t^{(1)} < N \lor s^{(2)} S_t^{(2)} < N \), the underlying shares with the lowest total price will be delivered.

The value \( SP_t^{\text{Rainbow}} \) of a rainbow product can therefore be calculated as follows:

\[
SP_t^{\text{Rainbow}} = Ne^{-r(T-t)} + \sum_{i=1}^{n} Z_i e^{-r(T-Z_i)} = e^{-r(T-t)} P_{\text{min}}^N
\]

with \( P_{\text{min}}^N = P_{\text{min},t}(s^{(1)} S_t^{(1)}, s^{(2)} S_t^{(2)}) \) as a put option on the minimum of the two underlyings, belonging to the family of rainbow options.

3. Research objectives and hypotheses

The following empirical investigation aims at assessing the ‘fairness’ of the pricing of equity-linked structured products in the German market. The study thus searches to reveal implicit premiums or discounts incorporated in product prices quoted by the issuers, relative to theoretical ‘fair’ values. Furthermore, the purpose is to identify driving factors behind the issuers’ pricing policies. Therefore, we focus separately on primary and secondary markets.

Since structured products cannot be sold short by investors, all trades in the primary market represent only issuer sales. Thus, if products are quoted above their theoretical values and held until maturity by investors, these are always disfavored, since, at the expiration date, the price reflects the actual product payoff. Where investors pursue buy-and-hold strategies and issuers are perfectly hedged, implicit premiums at issuance provide a source of income for the bank, which nets the surcharge as profit at maturity. Therefore, we hypothesize:

(H1) In the primary market, equity-linked structured products are priced, on average, above their theoretical values.

Although information on the issuers’ hedging costs is not publicly accessible, we must bear in mind that the variety in strikes and times-to-maturity as well as the liquidity of market-traded options depends on the underlying type, thus affecting hedging alternatives. Furthermore, some structured products incorporate options with extraordinary long times-to-maturity or even exotic options, which are not

\[\text{Bid–ask spreads that serve as a second source of income for the issuers, regardless of potential premiums or discounts, are not object of our analysis.}\]
available on derivatives exchanges. Therefore, with increasing divergence between option characteristics, the costs of replicating the products are likely to grow and, consequently, demands for higher premiums can be expected. Thus, our second hypothesis reads:

\[(H2)\] The overpricing at issuance is higher

(a) for products with stock underlyings than for those with index underlyings and

(b) for more complex products, compared to ‘classic’ instruments.

In the secondary market, investors are offered the alternative of selling the previously purchased products back to the bank. Since the issuers do not know in advance what volume of issued products will expire without previously being sold back, in the case of short-term or speculative investors, the profitability of incorporated premiums depends additionally on the issuers’ pricing policies over the product lifetime. If overpricing increases as maturity approaches, issuers bear the risk of loss when buying back their positions at excessively high prices. Therefore, temporal stability or even a decrease in required premiums can be expected. Bearing in mind that a repurchase requires a former sale, decreasing implicit premiums would favor the issuer, who gains the difference in premiums (‘life cycle hypothesis’).

Another reason for degradation in overpricing is the resolution of uncertainty over time. The time value of the product-embedded options, at least in general, declines systematically as maturity approaches and, ultimately, the price necessarily reflects the actual product payoff. Thus, because the intrinsic value is evident, the potential for the issuer to incorporate implicit premiums diminishes over the product lifetime. Furthermore, surcharges are likely to decrease steadily, since sudden sharp drops in overpricing cannot be justified to investors, especially against the background of strong competition among issuers.

Wilkens et al. (2003) present an additional argument supporting our life cycle hypothesis. With maturity approaching, sales decrease, since, on the one hand, the issuance volume is limited and, on the other hand, products with only a short time-to-maturity are demanded less often than those that were issued recently. As a result, the ratio between repurchases and sales increases over time and shortly before expiration, primarily repurchases, if any, occur. Based on this expected trading pattern, issuers would ideally orient their pricing towards the order flow during the product lifetime and systematically reduce demanded premiums. Hence, towards the end of the product lifetime, there may even be underpricing.

Based on the preceding discussion on the issuers’ pricing strategy after issuance of the products, we examine the following hypothesis:

\[(H3)\] In the secondary market, implicit premiums systematically decrease as maturity approaches.

The procedure for calculating theoretical ‘fair’ product values and the data we use to test our three hypotheses are described in the next section.
4. Methodology and data

Our empirical investigation is based on equity-linked structured products on the German stock index DAX (Deutscher Aktienindex), and on the 30 individual stocks from this index. The data set includes all products available in the German market on October 10, 2002, a randomly selected date. The mean time-to-maturity at issuance of the entire sample amounts to 1.47 years, with the majority of products (86%) having lifetimes ranging from 1 to 2 years. We analyze daily closing prices in direct off-market trades with the issuers.15

The first data block comprises daily closing prices at which products were first traded after issuance. This primary data relates to the period from August 31, 2001 through October 10, 2002. The second data block consists of daily closing prices in the secondary market on October 10, 2002. After eliminating obviously incorrect or incomplete records, our data base covers a total number of 2566 products. The composition is given in detail in Table 1.

In order to assess the pricing of structured products, we compute theoretical product values using the duplication formulas given in Section 2. Accordingly, ‘fair’ values of product-embedded stock or bond positions are easy to determine. The prices of the underlying stocks are daily closing quotes from the electronic XETRA trading system at the Frankfurt Stock Exchange. On the reference day of our study, the amounts and dates of dividend payments until 2002 are known. For the years 2003 and 2004, estimates are used.16 Risk-free interest rates for different time intervals are extracted from German (AAA) government bonds.

The key issue in our approach is the valuation of the product-embedded options. European plain-vanilla options are valued with the well-known Black and Scholes (1973) option pricing model with \[ C_t^S = C_t^K(S_t^r, K, \sigma, r, t_{\text{fixing}} - t) \]. In the case of dividends, the current stock price is reduced by the present value of future payments occurring until the product’s maturity. \[ S_t^r = S_t - \sum_{j=1}^{m} D_j e^{-r(t\Delta t_j)} \] is used as the input parameter.17 For products with European barrier options, we refer to the closed-form formulas of Rubinstein and Reiner (1991). With respect to dividend payments, we apply the same technique as for the plain-vanilla options. However, since discrete dividend payments can be of major importance for barrier options as they may cause an ‘activation’ or ‘deactivation’ when certain price barriers are crossed, the formula provides only reasonably good approximations. Partial-time barrier options are valued by the formulas provided by Heynen and Kat (1994). In the case of implied European rainbow options on the minimum of two assets, we employ the valuation model of Stulz (1982). The decomposition of the stock price in the case of dividend payments is not of major concern in this case. However, the valuation requires the

---

15 Data on the structured products was provided by OnVista.
16 Data on DAX and DAX stocks as well as dividend data was provided by Datastream and OnVista. Estimates for dividends were obtained from the financial press.
17 Cf. Section 2. It is generally assumed that the volatility of \( S_t^r \) equals the one of \( S_t \). Cf., for example, Hull (2003, p. 253).
return correlation between both underlyings as an input parameter. For reasons of practicality, we use historical (six-month) estimates.

In order to ensure that the calculated model values are ‘consistent’ with the prices of actively market-traded options, we use implied volatilities of Eurex options. These options are plain-vanilla and standardized in strike and time-to-maturity.

As we use the daily closing prices of structured products, we employ the daily settlement prices of Eurex options. Option data was provided by Deutsche Börse. Wilkens et al. (2003) prefer transactions data to settlement prices, since the latter do not always reflect real trading opportunities. However, transaction prices are recorded either on bid or ask side and are therefore subject to the bid–ask spread.
The underlyings are, among others, the DAX and DAX stocks.\textsuperscript{19} Since structured products are European-style, we consider it consistent to employ only European Eurex options to evaluate product prices. While DAX options are European, Eurex stock options can be exercised at any time prior to maturity. Thus, our approach requires the exclusion of all American stock put options as well as those American call options which may be exercised prematurely.\textsuperscript{20} The prices and thus the implied Black/Scholes volatilities of this selection of Eurex call stock options, together with Eurex call DAX options, provide our basis for valuing the product-embedded options.

The described ‘transfer’ of pricing information faces the problem of model-dependency. The extraction of implied volatilities from market-traded options depends on the particular model selected. Using the Black/Scholes approach, some well-documented empirical phenomena are likely to occur (cf. Hull, 2003, p. 336): Implied volatilities frequently depend on option moneyness (smile/smirk/sneer effect) and time-to-maturity (term structure of volatility). Therefore, when assigning these implied volatilities to structured products with plain-vanilla options, differences in both strike and time-to-maturity should be minimized. The matching mechanism, however, is not straightforward, since, in a one-dimensional grouping approach, priority must be given to differences in either strike or time-to-maturity. Because it is commonly known from empirical research that the smile effect of implied volatility is more pronounced than the term structure (cf. Hull, 2003, pp. 334–337, for Eurex DAX options Hafner and Wallmeier, 2001), we assign priority to differences in strike prices.\textsuperscript{21}

In the case of structured products with implicit exotic options, an additional assumption is necessary when using market-extracted implied volatilities from plain-vanilla options for valuation purposes. The implied Black/Scholes volatility must be a ‘suitable’ input parameter for the valuation model of the exotic options.\textsuperscript{22} Therefore, although we allow for volatility phenomena based on the Black/Scholes model by an appropriate ‘matching’ of option characteristics (strike and time-to-maturity), our results for ‘exotic’ structured products additionally rely on identical volatility structures in the markets for both plain-vanilla and exotic options.

Finally, we have to allow for the risk of issuer default as there is no institutional clearing for structured products. Therefore, on valuation day, we calculate average

\textsuperscript{19} For details on Eurex products and contract conditions cf. Eurex (2003).
\textsuperscript{20} The early exercise feature does not apply to American call options on non-dividend paying assets (cf. Hull, 2003, pp. 175–177). In the case of dividends, there will be no rational premature exercise if the condition \( D_i \leq K (1 - e^{-\left(\frac{r}{(1-D_i)}\right)} ) \forall i < m \land D_m \leq K (1 - e^{-\left(\frac{r}{(1-D_i)}\right)} ) \) holds (cf. Hull, 2003, p. 254).
\textsuperscript{21} This assignment procedure leads, on average, to unsigned differences in strike prices of 0.93% for the primary and 7.13% for the secondary data, while times-to-maturity between implied and market-traded options deviate, on average, by 225 days and 154 days respectively. As an alternative, one might rely on a two-dimensional interpolation/extrapolation of implied volatilities – a technique that, in our context, however, lacks appropriate Eurex options. Cf. the discussion in Wilkens et al. (2003, p. 66) and footnote 19.
\textsuperscript{22} For rainbow options that require two volatility inputs, market volatilities are extracted separately from two plain-vanilla options.
effective zero-coupon interest rates from bank bonds and compare them to the corresponding rates of government bonds. From this data, we deduct risk-adjusted repayment quotas for standardized time intervals of one year. For the entire period of our analysis, the standardized repayment quota amounts to 99.84% on average. Since interest rate spreads for investment-grade bonds increase only slightly with time-to-maturity, we assume spreads to be term-independent so that we can derive repayment quotas for any time-to-maturity. Allowing for the default risk, the theoretical ‘fair’ product values are derived by multiplying this quota with the product values according to Section 2. For purposes of quantifying an over- or underpricing of structured products, the calculated model values \( S_{Eurex} \) are compared to the issuers’ prices \( S_{Market} \). Relative price deviations,

\[
\Delta V_t = \frac{S_{Market} - S_{Eurex}^{\text{Eurex}}}{S_{Eurex}^{\text{Eurex}}},
\]

serve as measures for assessing the issuers’ pricing policies.

5. Results

5.1. Primary market

In order to analyze the pricing of structured products in the primary market, we refer to the first available closing price of each product. The empirical distributions of the relative price deviations \( \Delta V \) for stock and DAX underlyings are illustrated in Fig. 3. The vast majority of values for \( \Delta V \), 92% for the stock and 94% for the DAX products, is positive. As shown in the two histograms, the right tails of the empirical distributions obviously outweigh the left tails in both magnitude and frequency. Several product prices incorporate buying premiums of more than 30% in the stock group and more than 10% for the DAX.

Dividing the sample further by product type, Table 2 provides the detailed descriptive statistics for \( \Delta V \). At issuance, structured products on DAX stocks sell at an average of 3.89% above their theoretical values based on Eurex options. The average overpricing amounts to 3.67% for products with embedded plain-vanilla options, to 4.77% for barrier, and to 5.17% for rainbow products. All product types exhibit a positive mean price deviation, ranging from 1.45% for guarantee to 5.65% for corridor products. Relative implicit premiums for DAX products are, on average, lower

---

23 Since not all issuers offer appropriate market-traded bonds, we use daily average spreads for all issuers.

24 We would like to thank Frank Wellens for his assistance in collecting this part of the data.

25 For valuing vulnerable options cf., for example, the seminal paper by Hull and White (1995). Note that the implicit put options have shorter times-to-maturity compared to the bond component, but face the default risk until product maturity. Therefore, the default adjustment must refer to the remaining lifetime of the structured product, i.e., the whole interval \([t, T]\).

26 As pointed out in footnote14, potential earnings from bid–ask spreads are not considered in this paper.
and less variable than those for products with stock underlyings. However, the subsample is much smaller and contains only a few different product types.\(^{27}\)

These findings strongly support Hypothesis H1 that all types of equity-linked structured products are priced, on average, above their theoretical values. To assess the statistical significance of the observed mean overpricing, we employ one-sided \(t\)-tests. In all subsamples analyzed in Table 2, the null hypothesis \(E(DV) = 0\) can be rejected at the 1% level. However, due to several small subsamples and likely non-normally distributed relative price deviations \(DV\), we additionally employ non-parametric tests with 10,000 bootstrap samples.\(^{28}\) As a result, the hypothesis that structured products are ‘fairly’ priced at issuance can again be rejected for all subsamples \((p < 10^{-4})\).

The results presented in Table 2 are also consistent with H2. To test the statistical significance, we conduct a linear regression with the dependent variable \(DV\). The explanatory variables are dummies, accounting for the fact that a product belongs to a certain type. This is done separately for stock and DAX underlyings, as shown in Table 2. Since all independent variables are qualitative, the regression represents a model for comparing means of different groups and is thus analogous to ANOVA (analysis of variance). DAX_TURBO, DAX_KNOCK_IN, and DAX_PT_KNOCK_IN stay for turbo, knock-in, and partial-time knock-in products on the DAX while STOCK_CORRIDOR, STOCK_GUARANTEE, STOCK_TURBO, STOCK_KNOCK_IN, STOCK_PT_KNOCK_IN, STOCK_KNOCK_OUT, and STOCK_RAINBOW denote the corresponding product types with stock underlyings. All variables are assigned the value 1 if the product belongs to the respective

---

\(^{27}\) Concentrating on ‘classic’ products, further differentiation among underlyings shows that the average overpricing ranges from 2.04\% to 8.15\%. With regard to the issuing institution, average price deviations vary considerably between 0.17\% (standard deviation: 0.98\%) and 6.40\% (standard deviation: 5.57\%) above Eurex.

type and 0 otherwise. STOCK takes on the value 1 if a product has a stock underlying and 0 for the DAX.

With this coding of the variables, the effects have the following interpretation: Since no dummy variables are defined explicitly for ‘classic’ products, the constant term (CONSTANT) measures the mean relative price deviation for ‘classic’ DAX products. The effect of STOCK gives the difference in means between ‘classic’ stock products and ‘classic’ DAX products and enables a test of the null hypothesis that the average price deviations for stock and DAX underlyings within this product type coincide (H2a). The effects of the other dummy variables measure the difference in means of $D_V$ between respective product type and ‘classic’ products within the same underlying group, accounting for the fact that the pricing for DAX and stock underlyings may not be identical. Since ‘classic’ products are the simplest and most widespread type of structured products, analyzing these effects provides a direct test of our complexity hypothesis, H2b.

We estimate the effects using the ordinary least-squares (OLS) approach. The descriptive statistics in Table 2 indicate heterogeneous distributions of $D_V$ between product types. Therefore, the assumption of homoscedastic, normally distributed error disturbances is questionable. Heteroscedasticity does not affect the unbiasedness and consistency of OLS regression estimators, but it does affect their efficiency. In addition, the estimated variances of the estimated effects are biased and inconsis-
tent, causing faulty inferences when testing statistical hypotheses.\textsuperscript{29} To correct for heteroscedasticity, we bootstrap the regression model in order to estimate the sampling distribution of the estimated effects. Bootstrap samples are obtained by randomly resampling cases from the data, since this method does not require the assumption of variance homogeneity and thus has the advantage of potential robustness to heteroscedasticity, especially for large data sets.\textsuperscript{30}

Table 3 summarizes the regression results for the comparison of means between the different product types and also reports one-sided $p$-values obtained from standard $t$-tests and from a set of 10000 bootstrap samples.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Effect (%)</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$t$-test</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>2.06</td>
<td>0.000</td>
</tr>
<tr>
<td>DAX_TURBO</td>
<td>0.44</td>
<td>0.421</td>
</tr>
<tr>
<td>DAX_KNOCK_IN</td>
<td>0.83</td>
<td>0.220</td>
</tr>
<tr>
<td>DAX_PT_KNOCK_IN\textsuperscript{a}</td>
<td>0.43</td>
<td>0.347</td>
</tr>
<tr>
<td>STOCK</td>
<td>1.57</td>
<td>0.000</td>
</tr>
<tr>
<td>STOCK_CORRIDOR</td>
<td>2.02</td>
<td>0.000</td>
</tr>
<tr>
<td>STOCK_GUARANTEE</td>
<td>$-2.19$</td>
<td>0.099</td>
</tr>
<tr>
<td>STOCK_TURBO</td>
<td>$-0.25$</td>
<td>0.281</td>
</tr>
<tr>
<td>STOCK_KNOCK_IN</td>
<td>1.43</td>
<td>0.000</td>
</tr>
<tr>
<td>STOCK_PT_KNOCK_IN\textsuperscript{a}</td>
<td>0.80</td>
<td>0.007</td>
</tr>
<tr>
<td>STOCK_KNOCK_OUT</td>
<td>$-0.74$</td>
<td>0.259</td>
</tr>
<tr>
<td>STOCK_RAINBOW</td>
<td>1.54</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Sample size: 2566

The table provides OLS effect estimates and one-sided $p$-values, calculated from standard $t$-tests and bootstrapping with 10000 samples and resampling of cases.

\textsuperscript{a} PT: partial-time.

Table 3 summarizes the regression results for the comparison of means between the different product types and also reports one-sided $p$-values obtained from standard $t$-tests and from a set of 10000 bootstrap samples. ‘Classic’ products on stock underlyings are found to incorporate a significantly higher average structuring premium of 1.57\% compared to their DAX counterparts. Bearing in mind that ‘classic’ products constitute about 75\% of the database, these results provide statistical support for H2a.\textsuperscript{31}

For statistical inference with respect to H2b, we focus on the remaining effects, measuring the differences in means compared to the two control groups of ‘classic’ DAX and ‘classic’ stock products. All variables referring to DAX products exhibit slightly positive effects, though none is significant according to standard $t$-tests and the subsamples are rather small. On the contrary, bootstrap $p$-values for knock-in and partial-time knock-in products indicate a significant difference in means.

\textsuperscript{29} Cf., for example, Pindyck and Rubinfeld (1998, pp. 146–148) and Greene (2003, pp. 217–219).

\textsuperscript{30} For further details cf. Davison and Hinkley (1997, pp. 264–266), and Efron and Tibshirani (1993, pp. 113–115).

\textsuperscript{31} We refrain from comparing means between DAX stocks and DAX products within the other product types since there are either no DAX subsamples at all or they are too small.
compared to 'classic' products. Within the stock group, guarantee, turbo, and knock-out types show a lower average overpricing than 'classic' products, although the null hypothesis of equal means cannot be rejected on a t-test basis. Conversely, the bootstrap suggests a significantly negative effect (−2.19%) for guarantee products, while the statistical inference for turbo and knock-out products remains the same. Corridor, knock-in, partial-time knock-in, and rainbow products embody buying premiums at issuance that, on average, significantly exceed those demanded for the 'classic' product type. The magnitude of this extra charge ranges from 0.80% for partial-time knock-in to 2.02% for corridor products. Although somewhat ambiguous, these results are consistent with our hypothesis H2b. The fact that more complex products, especially those with embedded exotic options, incorporate, at least on average, higher relative price deviations from their theoretical values than common 'classic' products, supports our assumption on the role of issuer hedging costs.

5.2. Secondary market

In order to assess the life cycle hypothesis H3, we refer to the price data from the secondary market on October 10, 2002. Table 4 contains the detailed descriptive statistics for $\Delta V$ and the mean relative life stages, $L = (t - T_{\text{issue}})/(t_{\text{fixing}} - T_{\text{issue}}) \in [0, 1]$, for the different product types. In the secondary market, structured products on DAX stocks sell for an average of 2.32% above Eurex. Products with embedded plain-vanilla (barrier, rainbow) options yield a mean overpricing of 2.07% (4.56%, 3.72%), which corresponds to a reduction of 1.60% (0.21%, 1.45%) compared to the extra charges at issuance. Excluding knock-in and knock-out products, all product types in the secondary market are less overpriced than at issuance. Bearing in mind the late average life stage of the subsample ($L = 82\%$), the observed market prices for guarantee products even lie below their model values. The same phenomenon applies to structured products on the DAX, which are quoted with an average discount of 0.11% though at an early relative stage in the life span ($L = 27\%$).

Fig. 4 illustrates the relationship between $\Delta V$ and $L$ separately for stock and DAX underlyings. The two scatter plots visualize two major effects of the life cycle on relative mispricing. First, in both subsamples, there is an overall decline in $\Delta V$ as maturity approaches. Assuming linear trends, implicit premiums ($\Delta V > 0$) for products with stock underlyings statistically turn into a discount ($\Delta V < 0$) after approximately 70% of the products' relative lifetimes. For DAX products, the value of $\Delta V = 0$ is reached shortly after issuance ($L = 0.2$). Second, the variability of $\Delta V$ decreases noticeably for products approaching expiration.

In order to test the statistical significance of H3, we assume a linear relationship between implicit premiums and life cycle and regress relative price deviations ($\Delta V_i$) on the products' relative lifetimes ($L_i$).\(^\text{32}\)

\(^{32}\)Assessing their order flow hypothesis, Wilkens et al. (2003) identify the moneyness of the implicit options as a significant explanatory variable. The use of moneyness is not justified in the context of our investigation, since our data set includes products with more than one option component, as well as those with exotic options.
Table 4
Statistics for relative price deviations in the secondary market

|                      | Relative price deviations ($\Delta V$) |                      |                      |                      |                      |                      |                      |
|----------------------|----------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                      | DAX stocks                              | DAX                  |                      |                      |                      |                      |
|                      | $N$ | Mean (%) | Std. (%) | Min. (%) | Max. (%) | Skew. | $L$ (%) | $N$ | Mean (%) | Std. (%) | Min. (%) | Max. (%) | Skew. | $L$ (%) |
| All                  | 2286 | 2.32     | 4.27     | -21.98   | 27.61    | 1.01  | 37      | 258  | -0.11    | 1.84     | -4.67    | 12.87   | 1.60  | 27      |
|                      |     |          |          |          |          |       |         |      |          |          |          |        |        |
| **Plain-vanilla products** |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
| ’Classic’            | 1921 | 2.11     | 3.85     | -18.38   | 24.18    | 1.12  | 38      | 242  | -0.14    | 1.79     | -4.67    | 12.87   | 1.59  | 28      |
| Corridor             | 36   | 2.68     | 11.49    | -14.91   | 27.61    | 0.53  | 28      |      |          |          |          |        |        |
| Guarantee            | 5    | -0.66    | 0.80     | -2.09    | -0.26    | -2.21 | 82      |      |          |          |          |        |        |
| Turbo                | 79   | 1.10     | 4.09     | -5.68    | 18.98    | 1.73  | 47      | 3    | 0.60     | 5.76     | -2.76    | 7.25    | 1.73  | 35      |
| All                  | 2041 | 2.07     | 4.12     | -18.38   | 27.61    | 1.17  | 38      | 245  | -0.13    | 1.85     | -4.67    | 12.87   | 1.64  | 28      |
|                      |     |          |          |          |          |       |         |      |          |          |          |        |        |
| **Barrier products**  |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
| Knock-in             | 47   | 8.34     | 5.40     | -3.41    | 19.64    | -0.44 | 32      |      |          |          |          |        |        |
| PT-knock-in$^a$      | 137  | 3.35     | 4.52     | -21.98   | 18.38    | -0.40 | 31      | 13   | 0.41     | 1.65     | -1.28    | 4.59    | 1.32  | 23      |
| Knock-out            | 8    | 3.06     | 3.30     | -1.18    | 7.41     | 0.08  | 46      |      |          |          |          |        |        |
| All                  | 192  | 4.56     | 5.16     | -21.98   | 19.64    | -0.03 | 32      | 13   | 0.41     | 1.65     | -1.28    | 4.59    | 1.32  | 23      |
|                      |     |          |          |          |          |       |         |      |          |          |          |        |        |
| **Rainbow products** |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
| All                  | 53   | 3.72     | 3.80     | -5.14    | 11.63    | 0.05  | 41      |      |          |          |          |        |        |

Slight deviations in the number of products compared to the primary market occur partly due to the additional elimination of few inconsistent records, but mainly because of barrier products that were ‘knocked in’ or ‘knocked out’ and thereby transformed into ‘classic’ products or regular bonds (these barrier products are not considered here).

$^a$ PT: partial-time.
\[ \Delta V_i = a + b L_i + \epsilon_i, \quad a, b \in \mathbb{R}. \]  
\[ (10) \]

As revealed by the scatter plots in Fig. 4, we strongly suspect the presence of heteroscedasticity in the error terms ($\epsilon_i$) and therefore again apply the bootstrap algorithm. Here, the method of resampling cases has the additional advantage of robustness not only in inconstant-variance but also in non-linear models.\(^{33}\) The regression results for each product type appear in Table 5. All intercepts are positive and, except for corridor ($p = 0.05$) and ‘classic’ DAX products ($p = 0.09$), significant at the 1% level for both the one-sided $t$-test and bootstrap.\(^{34}\) These findings are consistent with the evidence from the primary market. The slope coefficients for all product types are negative and also, except for corridor products ($p = 0.16$), highly significant according to both tests. The magnitude ranges from $-1.55\%$ for ‘classic’ DAX to $-12.91\%$ for rainbow products. We note, however, that while the explanatory power of the model, measured by $R^2$, reaches values of up to 0.67 for individual product types in the stock group, the overall goodness of fit for the DAX products is very poor ($R^2 = 0.06$).\(^{35}\)

Overall, our results for the secondary market accord fully with H3. As discussed in Section 3, the decline of implicit premiums with time approaching maturity can be caused by several factors. For example, the fact that premiums are replaced by discounts over the product lifetime supports the order flow effect discussed in Wilkens et al. (2003), according to which issuers orient their pricing towards the expected volume of purchases and sales. In conclusion, we emphasize that, due to the time

\(^{33}\) For further details cf. Davison and Hinkley (1997, pp. 264–266) and Efron and Tibshirani (1993, pp. 113–115).

\(^{34}\) Note that the sample of turbo DAX products contains only three observations. Therefore, we do not discuss the results from this subgroup.

\(^{35}\) The results from regression (10) are also very similar for individual issuers (not shown here in detail). To exclude possible inconsistencies due to different product types, we focus only on ‘classic’ products. With only two exceptions, we observe a negative and, in most cases, highly significant influence of the life cycle ($b < 0$) on the mispricing for all issuers.
Table 5
Analysis of the ‘life cycle hypothesis’ in the secondary market

<table>
<thead>
<tr>
<th>DAX stocks</th>
<th>DAX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a (%)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>4.99</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Plain-vanilla products

| ‘Classic’        | 4.57        | 0.000 0.000   | -6.55       | 0.000 0.000   | 0.2075 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | 0.28        | 0.057 0.085   | -1.55       | 0.001 0.001   | 0.0376 |
|                  |             | Bootstrap     |             | Bootstrap     |
| Corridor         | 6.55        | 0.000 0.000   | 0.2075      | 0.001 0.001   | 0.0376 |
|                  |             | Bootstrap     |             | Bootstrap     |
| Guaranteea       | -           | -             | -           | -             |
|                  | -           | -             | -           | -             |
| Turbo⁵          | 6.43        | 0.000 0.000   | -11.36      | 0.000 0.000   | 0.4903 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | 7.39        | 0.089 -       | -19.31      | 0.081 -       | 0.9372 |
| All              | 4.64        | 0.000 0.000   | -6.76       | 0.000 0.000   | 0.1938 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | 0.36        | 0.027 0.051   | -1.78       | 0.000 0.001   | 0.0461 |

Barrier products

| Knock-in         | 9.96        | 0.000 0.000   | -5.06       | 0.006 0.003   | 0.1322 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | -           | -             | -           | -             |
| PT-knock-in⁶     | 6.68        | 0.000 0.000   | -10.83      | 0.000 0.000   | 0.3414 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | 1.96        | 0.002 0.007   | -6.89       | 0.002 0.001   | 0.5548 |
| Knock-out⁷       | 8.05        | 0.003 -       | -10.95      | 0.016 -       | 0.5659 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | -           | -             | -           | -             |
| All              | 7.13        | 0.000 0.000   | -8.11       | 0.000 0.000   | 0.2010 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | 1.96        | 0.002 0.007   | -6.89       | 0.002 0.001   | 0.5548 |

Rainbow products

| All              | 8.95        | 0.000 0.000   | -12.91      | 0.000 0.000   | 0.6663 |
|                  |             | Bootstrap     |             | Bootstrap     |
|                  | -           | -             | -           | -             |
|                  | -           | -             | -           | -             |
|                  | -           | -             | -           | -             |

Average price deviations ($\Delta V_i$) are linearly regressed against the products’ relative lifetimes ($L_i$): $\Delta V_i = a + bL_i + \epsilon_i$, $a, b \in \mathbb{R}$; one-sided p-values are obtained from standard $t$-tests and bootstrapping with 10000 samples and resampling of cases.

- a: OLS regression not applicable.
- b: Some samples too small for bootstrap analysis.
dependence of the diagnosed mispricing, the ‘fairness’ of issuer pricing in the secondary market should always be evaluated under consideration of the relative product lifetime and specific investment strategy.

6. Summary and outlook

This paper analyzes the German market for equity-linked structured products from both theoretical and empirical perspectives. Based on the classification and description of the product characteristics, duplication and valuation schemes for these instruments are described. An extensive and unique empirical study investigates the pricing of structured products on DAX stocks and the DAX by comparing issuer prices from the primary and secondary markets to model values derived from Eurex options. The main results can be summarized as follows. In the primary market, all types of equity-linked structured products are priced, on average, above their theoretical values, disfavoring buyers who hold their positions until maturity. The underlying type, stock vs. index, is found to be one of the pricing factors. We also provide evidence that, for example, products with embedded exotic options are subject to even higher premiums, compared to common ‘classic’ products. This supports our hypothesis that the degree of overpricing is related to the issuer hedging costs. In the secondary market, surcharges systematically decrease as products approach maturity. This phenomenon holds for almost all subgroups of products and indicates that, in the case of repurchases, the issuing bank nets the premium difference as profit.

These results suggest that a careful analysis is necessary when trading equity-linked structured products. In spite of the very easy access to these instruments, experienced investors should still consider replicating the products’ payoffs on options exchanges. However, it should be acknowledged that a useful ‘packaging’ of single components could justify the implicitly demanded premiums as compensation for the issuers’ structuring service. For example, structured products offer investors to enter into short positions in options with extraordinary long times-to-maturity or exotic options, which are not available on derivatives exchanges. Thus, the costs of replicating these products are likely to be higher than the applied models suggest. In addition, issuers commit themselves to providing liquid exchange and off-market trading. Therefore, without further information on hedging, capital, and other bank-specific costs, no evaluation of the profitability of structured products for the issuing institution can be made.

The German market for structured products is still growing, with a range of new products emerging regularly, especially due to the almost total absence of restrictions regarding underlyings and contract conditions. Further research might analyze recent product innovations not considered in this paper or focus on pricing patterns over time, probably revealing an even deeper insight into the issuers’ pricing policies. More complex valuation approaches, such as those with a stochastic volatility, could be employed in order to better reflect the real costs of duplication.
Acknowledgments

We are particularly grateful to the editor and two anonymous referees for providing insightful comments and suggestions. We also appreciate helpful discussions with Carsten Erner, Ulrich Mueller-Funk, Ulrich Sonnemann, Ingolf Terveer, and Mark Trede. Feedback from participants at the 2003 German Finance Association meeting and especially Christian Schlag on a former related study is gratefully acknowledged.

References