

The Pricing of Structured Products – An Empirical Investigation of the German Market

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Abstract. This paper examines the issuer pricing of structured products during the exchange trade of November 2001. The daily closing quotes of roughly 170 reverse convertibles and 740 discount certificates are compared to values based on duplication strategies using call options traded on the Eurex (European Exchange). We investigate the average price differences dependent on product type, issuer, and underlying. A special focus lies on the possible influence of order flow, i. e. we analyze, using product life cycles and monyness as proxies, whether the price quotes depend on the expected volume of purchases and sales. The study reveals significant differences in the pricing of structured products, which can mostly be interpreted as being in favor of the issuing institution.

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1 Introduction

Structured financial products became popular in the U. S. in the 1980s and found their way to Europe in the mid-1990s during years of low interest rates. Meanwhile, the area of "financial engineering" has become an essential function in large investment firms and commercial banks.¹ In this article, we deal with two widespread forms of structured products, namely reverse convertibles and the very similar discount certificates. Reverse convertibles (or *equity-linked notes without principal protection*) were first introduced in the U. S. by Bankers Trust in 1993. Blue-chip companies like Coca-Cola, Pfizer or Johnson & Johnson served as underlyings. The market in the U. S. for these types of securities has since focussed on private wealth management for high net worth individuals.²

A reverse convertible has a fixed nominal value as well as an annual interest coupon, which generally extensively exceeds the market interest rate for corresponding standard bonds. While the interest coupons are normally due as regular payments, the special product feature in comparison to "normal" bonds is the issuer's right of redemption by either repayment of the bond's nominal value or delivery of a previously fixed number of specified shares at maturity. Discount certificates are a slightly modified version of reverse convertibles: a discount certificate typically offers one or a bundle of shares at a "discount" compared to the current market price. At maturity, these shares are physically delivered to the holder of such a certificate if their total value does not exceed a previously

¹ Structured products can generally be defined as combinations of elementary instruments from the spot and futures markets (e. g. stocks, interest rate products, derivatives). See e. g. *Das* (2000) for other classifications. In some definitions, even simple floaters are considered as structured products, since these can be formulated through several elements (forwards). Furthermore, in a different classification, asset backed securities are treated as structured products; see e. g. *Fabozzi* (1998), p. 3.

² See *Das* (2000), pp. 532-533 and pp. 555-560. In contrast, the market focus for principal-protected equity-linked notes is the retail market. For a brief history of the market development of structured products in the U. S., see *Toy/Ryan* (2000), pp. 335-337.

fixed maximum repayment amount.³ Otherwise, the certificate pays this amount in cash, i. e. in exchange for the discount, the owner of the certificate has a limited upside potential, compared to the direct investment in stocks. A discount certificate bears the risk of a total loss of capital, while a reverse convertible pays at least the interest coupon(s).

Reverse convertibles and discount certificates offer the attractive feature of facilitating short positions in options without the need for access to options exchanges. There are no explicit margin requirements, since the products' nominal values serve as collateral for the issuer. Thus, these securities are an easy means of implementing investment strategies based on neutral or slightly pessimistic expectations of future price scenarios. When trading structured products, transactions costs (e. g. bid-ask spreads) and commissions for the private investor are usually lower, compared to the corresponding single trades (buying bonds, selling options). This product category, therefore, generally offers a useful extension to the capital markets.

However, all structured products face the risk of trades at prices that differ substantially from the products' fair values. Given that there would otherwise be no liquid trade in the secondary market, issuers in general act as market makers for their own products during the exchange trade. Alternatively, structured products can be bought/sold over-the-counter from/to the issuing firm. As a consequence, almost any transaction involves the product's issuer as one partner of the trade. There is danger that, due to the rather complex valuation method, unfavorable prices will be quoted. As a rule of thumb, the higher the complexity of the products, the higher the margins incorporated in the quotes.

In the following we investigate the exchange trade of a broad range of reverse convertibles and discount certificates in Germany during November 2001 – a randomly chosen time period. Thereby, the main technique consists of comparing quoted product prices to costs

³ Instead of physical delivery of the underlying, contract conditions of both reverse convertibles and discount certificates occasionally provide cash settlements. For structured products on non-traded assets, e. g. indices, this is the only alternative.

of duplication strategies using options from the Eurex, the German/Swiss futures and options exchange. Since future volatilities are unobservable, implied volatilities serve as the most important indicators for the issuers' pricing. We expose differences and similarities among issuers, in order to provide insight into their pricing mechanisms. Additionally, we identify relevant factors behind the issuers' pricing policies. In particular, we propose an "order flow hypothesis" which states that the issuers orientate their pricing towards the expected volume of purchases and sales. Due to the lack of data on traded volumes, we rely on available variables that we believe to be most closely related to the trading patterns. To the best of our knowledge, no comparable investigation has so far been conducted in the German market.

Compared to appropriate duplication strategies, our study reveals an "overpricing" of both reverse convertibles and discount certificates. This result holds for almost all issuing institutions. We identify the products' relative life times and the moneyness of the implicit options positions as two important parameters of the pricing policy and thus provide evidence of the "order flow hypothesis". We conclude that potential buyers of reverse convertibles and discount certificates are charged high premia for the issuers' intermediation. These implicit commissions, as expected highest at issuance, have to be compared carefully with the buyers' alternative costs of duplication.

The paper is structured as follows: **Section 2** describes the approach of valuation by duplication. **Section 3** provides a literature survey of recent studies on the market for structured products. Our empirical analysis is presented in **Section 4**: after a description of the data base, we give an overview of the methodology, e.g. the setup of duplication strategies using options from the Eurex. The subsequent illustration of the results is complemented by an analysis of the order flow hypothesis. Finally, **Section 5** summarizes the main results and considers future developments in the market for structured products, as well as further research opportunities.

2 Valuation by Duplication

The valuation of reverse convertibles and discount certificates can be performed by the principle of duplication, i. e. the reconstruction of the product payment profiles by means of several single components. Leaving aside market frictions, e. g. transactions costs and tax influences, we use the following notation:

F	face value of a structured product;
T	product maturity;
t	current time;
τ	time-to-maturity ($\tau = T - t$);
r_f	riskless interest rate (continuously compounded);
r_d	interest rate adjusted for the default risk of bonds (continuously compounded);
S_t	market price of the underlying share at time t ;
D_i	i th dividend payment on the underlying asset, $i = 1, 2, \dots, n$;
t_i^D	date of the i th dividend payment, $i = 1, 2, \dots, n$ with $t \leq t_i^D \leq T$;
K	strike price of an option;
σ	volatility of the underlying asset (i. e. standard deviation of the asset's returns);
c_t	value of a European call option at time t ;
p_t	value of a European put option at time t ;
I_j	j th interest coupon, $j = 1, 2, \dots, m$;
t_j^I	date of the j th interest coupon payment, $j = 1, 2, \dots, m$ with $t \leq t_j^I \leq T$;
s	number of deliverable shares;
V_t	value of a structured product at time t .

We assume continuous compounding in all calculations and quote time periods as fractions of a year. The most intuitive way of duplicating the profile of the reverse convertible is the combination of a coupon-bearing bond and a short position in European put options.⁴ On valuation day t , assuming a flat term structure of interest rates, the coupon-bearing bond has a value of $F e^{-r_d \tau} + \sum_{j=1}^m I_j e^{-r_d (t_j^I - t)}$. The interest advantage of the reverse convertible over a normal bond has to be offset with a short position in s put options on the underlying shares with strike price $K = \frac{F}{s}$. If the terminal share price S_T drops below K , equivalent to a total value of underlying shares ($s \cdot S_T$) of less than the principle value F , the issuer will choose repayment by s shares. In this case, the s put options will be exercised against the product's owner. Consequently, the theoretical product value V_t at time $t \leq T$ is given by:

$$V_t = F e^{-r_d \tau} + \sum_{j=1}^m I_j e^{-r_d (t_j^I - t)} - s \cdot p_t. \quad (1)$$

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 occurring until the option's maturity, i. e. $\sum_{i=1}^n D_i e^{-r_f (t_i^D - t)}$.⁵ Until the maturity of a European option, dividends will be paid and therefore only S^* is considered as the actual reference price of the underlying.⁶

In order to deal with the usage of call options, an alternative duplication strategy can be derived. Replacing S_t by $S_t^* = S_t - \sum_{i=1}^n D_i e^{-r_f (t_i^D - t)}$ and applying put-call parity for

⁴ The options bear no risk of default, since the structured products include short option positions and the paid nominal value serves as collateral.

⁵ For simplification, we assume that there is no risk attached to dividends. Therefore, we use r_f as the appropriate discount rate.

⁶ Thereby, it is generally assumed that the volatility of S_t^* equals the one for S_t . See e. g. *Hull (2003)*, p. 253.

European options,⁷ $c_t + Ke^{-r_f\tau} = p_t + S_t^*$, reveals:⁸

$$\begin{aligned} V_t &= Fe^{-ra\tau} + \sum_{j=1}^m I_j e^{-ra(t_j^I - t)} - s(c_t + Ke^{-r_f\tau} - S_t^*) \\ &= F(e^{-ra\tau} - e^{-r_f\tau}) + s(S_t^* - c_t) + \sum_{j=1}^m I_j e^{-ra(t_j^I - t)}. \end{aligned} \quad (2)$$

The European options can easily be valued by the well-known *Black/Scholes* option pricing model with $c_t = c_t(S_t^*, K, \sigma, r_f, \tau)$.⁹ For discount certificates, $I_j = 0$. Note that V_t gives the dirty price of the structured product in monetary units (i. e. including accrued interest), while during the exchange trade, at least in general, clean prices are quoted in percent.¹⁰

In order to judge quoted product prices, implied option positions are compared to options traded at the Eurex. However, stock options at the Eurex are American-style, i. e. they offer exercise prior to maturity. The *Black/Scholes* model can only be applied to these options, if it can be assured that early exercise is never optimal.¹¹ In order to deal with this aspect, we focus on American call options using the following relation: early exercise can only be rational immediately prior to a dividend date t_i^D . If $D_i \leq K(1 - e^{-r_f(t_{i+1}^D - t_i^D)})$ holds for all $i < n$ and if $D_n \leq K(1 - e^{-r_f(T - t_n^D)})$, it is never optimal to exercise American call options before maturity.¹² Only those Eurex options which satisfy these conditions can be treated as pure European-style. Therefore, implied volatilities can be extracted – with the current stock price S_t being replaced by S_t^* .

⁷ See e. g. *Hull* (2003), pp. 174-175.

⁸ Note that for some products in the German market, the issuer must choose the type of redemption (repayment of the face value or delivery of stocks) one week before the product's maturity. In this case, the remaining life time of the implicit options does not coincide with that of the product. Due to its neglectable influence, however, we will abstract from this effect.

⁹ See *Black/Scholes* (1973). p_t follows immediately from put-call-parity.

¹⁰ We apply the commonly accepted rule no. 251 of the ISMA (International Securities Markets Association) for calculating accrued interest.

¹¹ Otherwise, one would have to use numerical techniques, e. g. binomial trees.

¹² See e. g. *Hull* (2003), pp. 254-255.

3 Literature Review

The market for structured products which is analyzed in this paper, has rarely been the object of empirical study. *Chen/Kensinger* (1990) analyze "Market-Index-Certificates of Deposit" (MICD) in the U.S. market, which pay a guaranteed minimum interest rate and a variable interest rate pegged to the performance of the S&P 500.¹³ Their sample includes 18 of these products in January 1988 and 25 in January 1989 issued by Chase Manhattan and Murray Savings. A comparison of the implied volatility of the S&P 500 option with the implied volatility concerning the option component of the MICDs, reveals significant positive and negative differences between theoretical and market values. *Chen/Kensinger* find inconsistencies in the pricing among issuers, as well as among MICDs of different maturities and different types offered by the same issuer.

Chen/Sears (1990) investigate the "S&P 500 Index Note" (SPIN) issued by Salomon Brothers, which is very similar to the MICDs, but exchange-traded. They focus on development over time in the pricing of this product between its issuance in September 1986 and December 1987. After computing the differences between market and model prices (using ex-post, average implied and long-term implied volatilities), they diagnose overpricing in the first sub period of about 5 %. In the second and third sub period, the product was underpriced. Following *Chen/Sears*, the first sub period could represent a "seasoning" period for this new type of security.

Baubonis/Gastineau/Purcell (1993) analyze equity-linked certificates of deposit, similar to the MICDs examined by *Chen/Kensinger* (1990). However, the focus of *Baubonis/Gastineau/Purcell* is to provide a guide for banks. They discuss the functionality of such products and consider hedging and tax implications. In addition, they take a

¹³ It should be noted that these products have convex payment profiles (fixed minimum returns – principal-protected equity-linked notes), in contrast to the concave ones of reverse convertibles and discount certificates (fixed maximum returns – equity-linked notes without principal protection).

closer look at the products' cost structure. Using a Citicorp product as an example, they demonstrate that the bank can earn a gross fee of 2.5 % to 4 % of the selling price in the primary market. The authors argue that this might lead to criticism, since the fees are not disclosed in the same way as for mutual funds. However, compared to other equity-linked products, this fee seems appropriate.

With regard to overpricing at issuance and underpricing in the secondary market the results of *Wasserfallen/Schenk* (1996) are similar to those of *Chen/Sears* (1990). *Wasserfallen/Schenk* examine the pricing of 13 capital-protected products in the Swiss market, issued between January 1991 and April 1992. The comparison of the products' option components with the historical and the implied volatility of the Swiss Market Index, shows that the securities are sold slightly above their theoretical values. In the secondary market, the model overpredicts observed prices. With relative errors generally below 10 %, *Wasserfallen/Schenk* conclude that these products are generally fairly priced.

Another study for the Swiss market is conducted by *Burth/Kraus/Wohlwend* (2001), who test the initial pricing of 199 reverse convertibles and 76 discount certificates that were outstanding at August 1, 1999. Exchange-traded options are employed to assess the product pricing. The mispricing, mostly in favor of the issuing institution, differs among the 15 issuers. On average, the price differences between theoretical and market values are 1.91 % with a standard deviation of 2.39 %. They also observe differences in the pricing of fixed-coupon paying reverse convertibles (mean deviation: 3.22 %) and discount certificates (mean deviation: 1.40 %). In addition, the existence of a co-lead manager is identified as a significant factor influencing product prices at issuance.

4 Empirical Analysis of the German Market

4.1 Data Set

The timeframe of our analysis extends from November 1, 2001 through November 30, 2001, thus covering twenty-two trading days.¹⁴ From a market point of view, this period is characterized by a fairly steady market rebound. The German stock index DAX (Deutscher Aktienindex), representing thirty of the largest corporations with respect to trading volume and market capitalization, rose 7.6 %, while the NEMAX All-Share Index as the market indicator for the German high-tech market segment (Neuer Markt)¹⁵ climbed 12.6 %, both as part of the recovery from the September 11 losses.

General Data. For the risk-free interest rate, we assigned the one- to twelve-months Euribor (Euro Interbank Offered Rate) to the respective time-to-maturity. For $\tau > 11.5$ months, we applied the twelve-months rate. With respect to the appropriate default-adjusted interest rates of corporate bonds, we refer to the bond indices of Lehman Brothers¹⁶, which indicate average discrete credit spreads of approximately 100 basis points over Euribor. For the underlying stocks, we used the daily closing prices from the XETRA (Exchange Electronic Trading) system of the Frankfurt Stock Exchange. Since we had to take dividends into account, we used estimations of expected dividends and of expected payment dates until the business year 2003. Due to very unstable predictions of dividends for the NEMAX stocks, we considered only dividends for DAX stocks. This is, however,

¹⁴ Euribor data and stock prices were taken from Datastream. Information on expected dividends were obtained from the financial data provider OnVista (<http://www.onvista.de>), which also delivered the quote records for the structured products. We would like to thank *Dr. Carsten Friedrichs* for his assistance in obtaining this part of the data. The quote records were originally gathered from different data vendors, e. g. Reuters. The Eurex options data was provided by Deutsche Börse.

¹⁵ DAX and NEMAX are comparable to the Dow Jones Industrial and the NASDAQ Composite in the U. S.

¹⁶ "Pan-European Aggregate" – Corporate Bonds (one through three years to maturity) and Corporate Bonds (AAA rating). Source: Datastream.

not critical since only a few NEMAX companies pay – very low – dividends. Pursuing our duplication approach, we can examine only those underlyings for which options are traded on the Eurex. Hence, the data sets for both the structured products and the Eurex options refer to the thirty DAX companies and to eight NEMAX companies.¹⁷

Structured Products. Where obtainable, the data set includes the daily closing quotes of the products (i. e. bid/ask prices). For our analysis, we use the mid-quotes calculated as the arithmetic averages of the bid and ask quotes.¹⁸ We manually excluded quotes which were obviously mistyped or otherwise inconsistent.¹⁹ The remaining data set covers only those records for which a Eurex option could be assigned as a matching partner. We examine quote records of 169 different reverse convertibles and quote records of 737 different discount certificates. The composite of this data set, with respect to issuers and stock affiliation, can be obtained from **Table 1**.

[Insert Table 1 here ...]

Eurex Options. Following the duplication scheme from Section 2, we choose call options for rebuilding the product profiles. Transactions data were preferred to settlement prices, since the latter do not always reflect real trading opportunities. We applied the

¹⁷ NEMAX companies: Aixtron, Broadvision, Consors, EM.TV, Intershop, Mobilcom, Qiagen and T-Online.

¹⁸ The average percentual spread is 0.27 % for the reverse convertibles and 0.58 % for the discount certificates.

¹⁹ We eliminated those records where the implied options had either a time-to-maturity of less than or equal to seven calendar days or a price of less than 10 Euro Cent. Records with implicit options violating the upper ($c_t \leq S_t^*$) or lower ($c_t \geq S_t^* - Ke^{-r\tau}$) arbitrage boundaries, see *Hull* (2003), pp. 171-174, were excluded. Additional records for which the implied volatility could not be specified, were deleted as well. In order to allow for a well-founded diagnosis, products with less than three price observations in November 2001 were removed from the data base. Since Goldman-Sachs as well as J. P. Morgan offered only one structured product each, these two issuers were excluded from our analysis. Occasionally, for the period of 22 trading days, there were less than 22 quote records available. This led to an average of 18.2 (19.4) records per product for the reverse convertibles (discount certificates) in the data set resulting in a total number of 3,075 (14,308) records for the reverse convertibles (discount certificates).

same exclusion criteria as for the structured products.²⁰ Since the options are American-style and thus offer early exercise, we eliminated those options which did not fulfill the dividend criterion discussed in Section 2. The remaining set contains 42,052 trade records of which 41,141 belong to options with an underlying from the DAX and 911 with an underlying from the NEMAX. The data set shows that in some underlyings, due to little trading activity, there are only a few trade records available. That is especially true for the NEMAX stocks: while there are on average 62.3 records per underlying and trading day for the DAX options, we only have 5.2 records for the NEMAX options.

4.2 Methodology

4.2.1 Product Matching

First of all, a "matching" procedure for structured products and exchange-traded options has to be established. Bearing in mind the well-documented empirical phenomena concerning the implied volatilities of options – smile/smirk/sneer effect and term structure characteristic – the assignment should, in particular, minimize differences in both strike price and time-to-maturity. The matching mechanism, however, is not straightforward, since in a one-dimensional grouping approach, priority must be given to either the differences in strikes or in times-to-maturity. We employed a simple but, in our view, reasonable assignment mechanism: since it is commonly known from empirical research that the smile effect of implied volatility is much more evident than the term structure,²¹ we gave priority to the differences in strike prices. Hence, for any combination of product and possible Eurex options as matching partners, we applied the following rules: in the first step, those options are chosen that provide the lowest deviation in strike price.

²⁰ In addition, we excluded violations of the law-of-one-price (i. e. identical options traded at the same time at different prices).

²¹ See e. g. *Hull* (2003), pp. 334-337.

If there is more than one matching partner left, in the second step, the ones with the slightest deviation in time-to-maturity are chosen from the remaining set. Thirdly, the slightest deviation in trading time determined the choice between the matching partners from the remaining set. Finally, in the rare case of still more than one potential matching partner, one option was randomly selected.

The assignment procedure was conducted identically for both reverse convertibles and discount certificates. The results of the assignment of the Eurex options to the structured products is documented in **Table 2**. On average, we had approximately 100 Eurex options as potential matching partners per record. It can be deduced that the mean unsigned differences in strike prices (times-to-maturity) amount to 3.75 % (59.74 %) for the reverse convertibles and to 5.73 % (68.02 %) for the discount certificates. From the signed differences, one can obtain the fact that times-to-maturity of the assigned Eurex options are lower than for the products. This is due to the fact that the Eurex options have much shorter times-to-maturity than the structured products. With respect to the signed differences in strike prices, one cannot derive any biases. This is not surprising, since, in contrast to the times-to-maturity, the choice neither of the strikes of the Eurex options nor of the products is restricted. It is interesting to note that although there is little trading activity of the NEMAX options and we thus have fewer possible matching partners, the deviations of the NEMAX underlyings do not differ substantially from those of the DAX products. The average deviation in trading time amounted to approximately five hours for both reverse convertibles and discount certificates.

In combination of the two dimensions strike and time-to-maturity, the matching results reflect the chosen matching approach. As we gave the strike the higher priority, it is stringent that they show smaller deviations. The ratio of strike and time-to-maturity deviations did not call into question the validity of our decision, since large deviations in the times-to-maturity do not affect option prices as much as deviations in the strikes.

[Insert Table 2 here ...]

4.2.2 Objects of Analysis

For each of the $M = 906$ structured products, our data base provides daily price quotes V_{ij}^{SP} , $i = 1, 2, \dots, M$, $j = 1, 2, \dots, N_i$ with $N_i \leq 22$ denoting the number of records for the i th product. One possible approach to compare product implied options with those traded at the Eurex, consists of investigating the differences in implied volatility, i. e. $\Delta\sigma_{ij} = \sigma_{ij}^{\text{SP}} - \sigma_{ij}^{\text{Eurex}}$. A positive value of $\Delta\sigma_{ij}$ is equivalent to a higher volatility, implicitly quoted by the issuer compared to similar options from the Eurex. Since structured products comprise a short position in options, $\Delta\sigma_{ij} > 0$ favors the buyer of the product, who receives an extra premium for his options sold. The contrary is true for $\Delta\sigma_{ij} < 0$. For practical purposes, however, a volatility-based measure is of limited use, since the influence of volatility differences on the pricing error depends on the concrete options position implied in the structured product. Firstly, the larger the total value of the options component, the more important the assumed volatility. Secondly, the sensitivity of an option's value to volatility misspecification depends on several parameters, e. g. the option's moneyness and time-to-maturity. An option with only a few days to maturity and quoted deep in-the-money is more or less immune even against large movements in volatility – its "vega" is approximately zero. Considering these characteristics, it seems more suitable to refer to the relative differences between theoretical values and real prices of the structured products:

$$\Delta V_{ij} = \frac{V_{ij}^{\text{SP}} - V_{ij}^{\text{Eurex}}}{V_{ij}^{\text{Eurex}}}. \quad (3)$$

V_{ij}^{Eurex} is obtained as the theoretical product price via (2), assuming volatility to be equal to $\sigma_{ij}^{\text{Eurex}}$. In order to reduce possible autocorrelation arising from the use of panel data and to cope with the problem of possible "outliers" among the pricing quotes, an average measure of the relative differences is employed. For each of the products, the time series

of ΔV_{ij} , $j = 1, 2, \dots, N_i$ is consolidated by calculating the arithmetic mean:

$$\Delta V_i = \frac{1}{N_i} \sum_{j=1}^{N_i} \Delta V_{ij}. \quad (4)$$

Thus, a maximum of 22 observations per product are condensed to one value ΔV_i per product. This value serves as the indicator of the issuer's pricing policy for the i th product.

4.3 Results

4.3.1 Average Price Deviations

Due to the different characteristics of the product types and underlyings, we find it useful to analyze reverse convertibles and discount certificates separately. The distributions of the average price deviations ΔV_i among both product groups are illustrated in **Figure 1**. The vast majority of values for ΔV_i is concentrated to the right of zero, representing demanded structuring premia from potential product buyers. This phenomenon holds for both reverse convertibles and discount certificates.

[Insert Figure 1 here ...]

Further divided into issuers, DAX and NEMAX underlyings, **Table 3** provides the detailed descriptive statistics for ΔV_i . On average, reverse convertibles on DAX stocks are priced at 3.04 % above duplication strategies based on Eurex options. Reverse convertibles by Westdeutsche Landesbank (WLB) are mid-quoted approximately 3.9 % above Eurex, making product purchases, on average, the most disadvantageous. Banque Nationale de Paris (BNP) and Sal. Oppenheim (OPP), the German market leader in this product class, follow with approximate premia charged to buyers of more than 3.0 %

on average. Positive average price deviations can also be observed among all issuers of reverse convertibles. Thereby, the range of values for ΔV_i varies substantially between -4.21 % and 8.34 %. The results for the NEMAX products are displayed separately: note that mean price deviations (3.89 %) are higher compared to the DAX underlyings. Bear in mind, however, that there are only two issuers and very few products in the NEMAX subsample.

For the set of DAX discount certificates, Table 3 reveals mean average price deviations of 4.20 %. The "ranking" of issuers states that the DAX products of BHF-Bank (BHF), HSBC Trinkaus & Burkhardt (HSB) and Société Générale (SOG) are among the most unfavorable for potential buyers. For example, judging from mid-quotes, buying the products of BHF-Bank is 8.48 % more expensive than establishing a replication strategy via Eurex options. The mean price deviations among all issuers provide a similar picture. Interestingly, we find a single issuer whose mid-quotes represent a higher volatility compared to the Eurex: discount certificates of WGZ-Bank are quoted at a price "discount" of 0.10 % on average. Selling options by buying discount certificates from WGZ-Bank is advantageous in comparison to a duplication strategy. Mean average price deviations in the NEMAX group are much higher than in the DAX group (4.20 % vs. 10.04 %). We conclude that product purchases with underlyings from the NEMAX high-tech sector are, on average, even more disadvantageous than for DAX stocks as base instruments. Remarkably, our data base of discount certificates contains several products whose average buying premium amounts to as much as 20 % for DAX underlyings and 29 % for NEMAX underlyings.

Further differentiations between the underlyings (not displayed here in detail) show very heterogeneous distributions. For the subgroup of reverse convertibles on DAX stocks, mean average price deviations range from 5.70 % for products on HypoVereinsbank AG to only 1.80 % for those on Siemens AG. Mean values for discount certificates on DAX

stocks vary between 9.46 % for HypoVereinsbank AG and 1.93 % for Schering AG as underlyings. Among the small group of reverse convertibles and discount certificates with NEMAX underlyings, the highest mean value of $\Delta V_i = 17.51$ % is observed for products on Consors AG. Finally, we take a brief look at differences between reverse convertibles and discount certificates on the same underlyings: for eight stocks, we do not have products in both classes. The remaining stocks do not permit a general statement. The largest differences in means are diagnosed for T-Online AG (5.70 % for the reverse convertibles vs. 12.83 % for the discount certificates) while products from both classes on E.ON AG are almost identically "mispriced" (3.51 % vs. 3.53 %).

[Insert Table 3 here ...]

In general, the analysis of quoted product prices shows, at least on average, that it would be less costly to rebuild nearly any of the product profiles as illustrated in Section 2 than to buy reverse convertibles and/or discount certificates at quoted (mid-)prices.

4.3.2 Influence of the Order Flow

As we have seen in the previous section, the pricing behavior among the issuers is, on average, clearly in favor of the product sellers. On the one hand, buying reverse convertibles or discount certificates is disadvantageous compared to a duplication strategy via Eurex options. On the other hand, issuers offer the possibility of buying back their products before maturity.²² With the bid-ask prices being substantially different quoted from the products' fair values, issuers have to bear the risk of investors selling back their positions at excessively high prices. Since the issuers do not know which kind of trade they are

²² According to the regulations of the market model of the European Warrant Exchange (EUWAX) in Stuttgart, the issuers have agreed to act as market makers. Hence, they always become the counterpart of a trade whenever there is no direct partner for the transaction.

facing when quoting bid and ask prices, the diagnosed mispricing makes sense only if there are on average, far more product sales than repurchases. Unfortunately, specific information on both exchange and off-exchange trading volumes is usually not publicly available.

[Insert Figure 2 here ...]

In order to derive a relationship between the issuers' pricing policies and the order flow, we have to rely on adequate "proxies". Firstly, the life cycle of the products is a variable for which a close relation with the order flow can be fairly assumed. At issuance T_{Iss} , only sales can occur from the issuers' point of view. With maturity approaching, sales decrease since (i) the issuance volume is limited and (ii) products with only a short time-to-maturity are demanded less often than those that were issued recently. Moreover, as time progresses, product repurchases tend to increase, since investors, probably due to changed expectations concerning the future development of the underlying, prefer to offset their positions. Based on this expected trading pattern and recent trading experience, issuers would ideally orientate their pricing on the product life cycles. In order to assess this hypothesis, average price deviations, ΔV_i , are compared to the products' relative ages, $L_i = (t - T_{\text{Iss}}) / (T - T_{\text{Iss}}) \in [0; 1]$.²³ The scatter plots in **Figure 2, Panel (A)** illustrate the relation between mispricing and relative life times of the products – from issuance (0.0) to maturity (1.0). The dotted lines represent linear trends: in both subsamples, there is an overall decline in ΔV_i during the product life cycles. For the reverse convertibles, the value of $\Delta V_i = 0$ is reached just prior to product maturity. For the discount certificates under consideration, the premium for buyers ($\Delta V_i > 0$) turns statistically into a discount ($\Delta V_i < 0$) after approximately two thirds of the products' relative life times.

²³ As we employ aggregated time series of ΔV_{ij} November 15, 2001 is chosen as the fictious valuation day t .

Secondly, we assume that the moneyness of the implicit positions in put options might be driving the observed pricing pattern, because it determines the product's current risk to be redeemed by shares. We define the options' moneyness for product i on day $j = 1, 2, \dots, N_i$ by $M_{ij} = S_t/K_{ij}$ and condense the values to averages M_i , $i = 1, 2, \dots, N_i$ analog to (4). The relationship between M_i and ΔV_i is described in **Figure 2, Panel (B)**. Assuming a linear dependence, the average mispricing increases with the moneyness, i. e. the reduction of the put options' intrinsic values in both subsamples. Although the appropriateness, especially of a linear relationship, can be called into question, the results are plausible: as the implicit put options turn out-of-the-money, the probability of a product redemption by shares decreases. Therefore, the issuers demand an extra-premium when selling such products – a surcharge that cannot be justified however, if a hedging via Eurex options is possible. On the contrary, products with in-the-money options and an increased risk of a repayment by shares can be sold more easily when the structurers' premia are reduced.

Thirdly, besides the absolute level of mid-quotes, bid/ask spreads serve as a second pricing parameter for the issuers. The spreads can intensify or decrease the effect of intended price deviations and they are the only variable that can be observed directly. The product spreads, given by $\Psi_{ij} = (\text{Ask quote}_{ij} - \text{Bid quote}_{ij})/\text{Mid quote}_{ij}$, are consolidated to values Ψ_i , $i = 1, 2, \dots, N_i$ similar to (4). **Figure 2, Panel (C)** illustrates the relation between ΔV_i and Ψ_i : Contrary to L_i and M_i , the influence of the spread on pricing differences is less evident. Among the reverse convertibles, we observe declining price deviations for large spreads. This phenomenon could be explained as follows: if large price surcharges, given by $\Delta V_i > 0$, are not appropriate for the issuers (e. g. in the case of numerous expected repurchases), they could use widened spreads as alternative sources of earnings.²⁴ For the group of discount certificates, the results are more difficult to

²⁴ It should be noted that according to the market model, spreads at the EUWAX are limited.

interpret, since premia charged to potential buyers coincide with large spreads.

[Insert Table 4 here ...]

Combining our single graphical analyses from Figure 2 and assessing the order flow hypothesis from a formal econometric point of view, average price deviations (ΔV_i) are jointly regressed against the products' relative life times (L_i), the moneyness of the implicit put options (M_i), and the quote spreads (Ψ_i). In particular, we run the following regression:

$$\Delta V_i = a + b L_i + c M_i + d \Psi_i + \varepsilon_i \quad (5)$$

with $a, b, c, d \in \mathbb{R}$.²⁵ As we employ cross-sectional data, it should be considered whether this approach affects confidence levels in regression (5). In particular, heteroscedasticity causes usual confidence levels to be biased. In order to cope with this problem, standard errors are adjusted for heteroscedasticity of unknown form according to *White* (1980).²⁶

The results are given in **Table 4**. Due to the very small samples and the question of statistical validity, we refrain from discussing results for NEMAX products. Strikingly, the regression for DAX products leads to an adjusted coefficient of determination of $R_{\text{adj}}^2 \approx 0.53$ (0.48) for the DAX reverse convertibles (discount certificates), indicating the high explanatory power of our regression (5). Regression (5) reveals that for both reverse convertibles and discount certificates on DAX underlyings, the life cycle and the

²⁵ We verified in advance that the (up to three) explaining variables are linearly independent. For example, we could not detect any systematic adjustments of the spreads depending on the remaining life time of the products. Spreads are neither systematically narrowed nor widened as maturity approaches. With these preliminary analyses, we prevent large confidence intervals arising due to multicollinearity among the regressors.

²⁶ In general, a correction of standard errors according to *White* (1980) requires "large" samples. Note that even in case of heteroscedasticity and/or correlation of error terms, the OLS estimators of the regression coefficients are unbiased though not efficient. For further details see *Pindyck/Rubinfeld* (2001), pp. 57-84, pp. 146-152 and pp. 250-260. The alternative use of cumbersome techniques for calculating standard errors, e.g. bootstrapping (see *Davidson/MacKinnon* (1993), pp. 763-769), does not seem justified in the context of our investigation.

moneyness of the implicit put options are relevant factors for product pricing. Among the reverse convertibles, an influence of the spread cannot be proved at the 10 % level. Bearing in mind the questionable results for the influence of the spreads as discussed earlier in this section, we are concerned about the economic relevance of the spread for ΔV_i . Therefore, we additionally run regression (6), excluding the regressor Ψ_i :

$$\Delta V_i = a + b L_i + c M_i + \varepsilon_i \quad (6)$$

For both subsamples, reverse convertibles and discount certificates on DAX stocks, R_{adj}^2 is effected only slightly, compared to regression (5). Though not documented here in detail, the results from regressions (5) and (6) are very similar for the single issuers. For example, with only two exceptions, BHF-Bank (BHF) and Lehman Brothers (LEB), and for sufficiently high numbers of products, we diagnose negative slope coefficients for the life cycle ($b < 0$) among all issuers of reverse convertibles and discount certificates.²⁷ We thus find strong support for our order flow hypothesis.

As an important result, the rankings in Table 3 must be judged in the light of the composition of issuers' product portfolios. Since Table 4 has delivered striking evidence of systematic pricing policies according to the products' remaining life times and moneyness, direct comparisons of pricing biases among issuers should only be conducted for similar portfolio structures.

²⁷ From the perspective of the single issuers the coefficients for the moneyness and the spread are not always statistically different from zero.

4.4 Critical Review

One might argue that our results cannot be generalized since they reflect only the market conditions during November 2001.²⁸ As support for our analysis, however, we cite a very recent study by *Stoimenov* (2003), who conducted a similar investigation in the German market. Although his primary goal is an analysis of "exotic structured products" (i. e. products with implicit positions in exotic options), the author also provides evidence relating to the pricing of regular reverse convertibles and discount certificates in the secondary market. As *Stoimenov* employs very similar methods and measures to our own, his analysis of the average product pricing in October 2002 serves as a benchmark for our results. *Stoimenov* reports mean average price deviations of 0.77 % across eight issuers of DAX reverse convertibles (287 products in total) and 1.50 % for DAX discount certificates issued by 19 firms (1,848 products in total). The work by *Stoimenov* provides very similar results to our proposed "order flow hypothesis". He employs a regression of the form $\Delta V_i = a + b L_i + \varepsilon_i$ and finds significantly negative slope coefficients b .²⁹ Summing up, the results presented by *Stoimenov* support both our observed "mispricing" pattern as well as our life cycle hypothesis. This indicates that our results are obviously not due only to unusual market conditions. Furthermore, for the most part, our results are consistent with the findings of *Burth/Kraus/Wohlwend* (2001). They report a significant pricing bias at issuance of both reverse convertibles and discount certificates in the Swiss market. Their analysis, however, is more straightforward since they only consider the primary market where there is no purchasing activity by issuers.

Another important point is the chosen matching procedure described in Section 4.2.1. As the critical basis for our study, we carefully re-examined the linking mechanism between the Eurex options and the structured products along two lines.

²⁸ Please note that, due to the restricted availability of pricing data, the analysis cannot easily be extended to longer time periods.

²⁹ Contrary to our analysis, *Stoimenov* does not correct standard errors for possible heteroscedasticity.

Firstly, we re-calculated pricing differences, giving the first priority to times-to-maturity instead of strikes. The results proved stable and very similar to those presented in the previous sections. Even with the possible presence of unusual patterns in the smile and term structure of implied volatilities after September 11, 2001 the main conclusions from our study remain valid. The findings are plausible, because, even in the case of a modified priority, large differences in times-to-maturity (cf. Table 2) cannot be avoided. Additionally, we approached the problem of "mismatches" from an econometric perspective: we added the consolidated relative differences in strike prices and times-to-maturity, $\Delta K_i = \frac{1}{N_i} \sum_{j=1}^{N_i} (K_{ij}^{\text{Eurex}} - K_{ij}^{\text{SP}}) / K_{ij}^{\text{Eurex}}$ and $\Delta \tau_i = \frac{1}{N_i} \sum_{j=1}^{N_i} (\tau_{ij}^{\text{Eurex}} - \tau_{ij}^{\text{SP}}) / \tau_{ij}^{\text{Eurex}}$, as explaining variables to regressions (5) and (6). For both reverse convertibles and discount certificates on DAX underlyings³⁰, $\Delta \tau_i$ emerged as a weakly significant factor with negative regression coefficients. This demonstrates that for structured products with longer times-to-maturity compared to available Eurex options ($(\tau_{ij}^{\text{Eurex}} - \tau_{ij}^{\text{SP}}) / \tau_{ij}^{\text{Eurex}} < 0$, on average), the value of ΔV_i tends to increase. The effect can be interpreted as a premium demanded by the issuers for providing long-term products with implicit options for which no analog products are available at the options exchange. For average relative differences in strikes, expressed by ΔK_i , no similar impact on ΔV_i can be detected.

Secondly, we considered the use of weighted averages of implied volatilities, following e.g. the calculation of the volatility index VIX at the Chicago Board Options Exchange (CBOE) or the VDAX for Eurex options. Unfortunately, we are confronted with the lack of appropriate data. Since we employ transactions data, we do not have many options traded at the same time.³¹ Even if the differences in trading time are ignored, an interpolation of options' implied volatilities faces the problem that there are many structured products which comprise option positions (i) that are far out-of-the-money or far in-the-

³⁰ In the NEMAX subgroups, there are too few observations to allow for profound statistical analysis.

³¹ Recall that we are concerned about using settlement prices instead, as these do not represent actual trading opportunities – especially in less liquid single-equity options markets (cf. Section 4.1).

money and/or (ii) that have a much longer time-to-maturity than Eurex options. This constellation would render the results from interpolations and extrapolations extremely unreliable.³²

³² For example, in case (i) two or more volatilities from Eurex options must be used for a one-dimensional linear or non-linear extrapolation. This requires assumptions about the smile pattern beyond observable strikes. For "intermediate" strike levels, interpolation of Eurex implied volatilities is feasible though of limited use: distances between Eurex strikes are rather small, so that interpolated values do not promise much better estimates than those at observable strikes. For case (ii) especially, extrapolation is even more critical, since we require volatility estimates for long times-to-maturity from short-term Eurex options. Consequently, crucial assumptions on the volatility term structure are necessary. Following the VIX example, the joint two-dimensional interpolation/extrapolation along both dimensions moneyness and time-to-maturity would probably be the best choice. However, linearity assumptions and large differences in both parameters due to Eurex options with strikes near-the-money and rather short times-to-maturity call this technique into question.

5 Summary and Outlook

We briefly reviewed the principle valuation approach for a special class of structured products, namely reverse convertibles and discount certificates. Comparing quoted prices with the costs of duplication strategies using exchange-traded options, we find a strong pricing bias favoring the product sellers. Both results hold for reverse convertibles and discount certificates. Distinguishing between market segments, DAX and NEMAX, and single underlyings, our analysis shows a generally heterogeneous picture. For the most part, the high-tech segment is subject to higher price deviations. In assessing the driving factors of the issuers' pricing policies, we find strong evidence of our order flow hypothesis. Clearly, issuers orientate their pricing towards the product life time 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.

With respect to our valuation approach, the known deficiencies and simplifications of the *Black/Scholes* option pricing model can be seen as critical. Fortunately, the used valuation schemes are extendible so as to incorporate even more parameters (e.g. a non-trivial structure of interest rates, stochastic volatility). However, the original *Black/Scholes* model is by far the most popular pricing approach. Its use (with slight modifications) among the issuers can, therefore, be reasonably assumed.

Bearing in mind the results presented in this paper, great care should be taken when judging quoted prices. In spite of the very easy access to structured products, experienced investors should still consider buying or selling options at derivatives exchanges with liquid trade. Nevertheless, it has to be acknowledged that a useful "packaging" of single components could justify the implicitly demanded margins as compensation for the issuers' structuring service for offering these products, including the commitment to provide liquid trading of the products. Furthermore, an "exact" replication of the payment profile via

options exchanges is not possible, e. g. in the case of long times-to-maturity. With the help of structured products, however, the issuers provide access to non-standard options positions, so that the observed premia can also be interpreted as commissions for this market extension.

The market for structured products is still very attractive for issuers, due to the almost total absence of restrictions with regard to underlyings and contract conditions. Examples of recent developments in the German market for structured products are callable step-up bonds, bull, bear and condor bonds, kick start certificates, barrier and two-asset products. Further research could concentrate on product classes apart from the ones considered in this paper, probably providing an even greater insight into the issuers' pricing policies. Wider investigations could consider the pricing stability over time. In addition, taking transactions costs into account, an investigation of concrete arbitrage strategies between the market for structured products and derivatives exchanges seems promising.

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	Reverse convertibles		Discount certificates		Total no. of prod.	
	169		737		906	
	DAX	NEMAX	DAX	NEMAX	DAX	NEMAX
Whole sample	164	5	704	33	868	38
Bankges. Berlin (BGB)	7	1	–	–	7	1
BHF-Bank (BHF)	26	–	78	2	104	2
BNP Paribas (BNP)	3	–	39	–	42	–
Citibank (CIT)	–	–	29	10	29	10
Commerzbank (CBK)	7	–	57	–	64	–
Crédit Lyonnais (CLY)	–	–	13	–	13	–
Deutsche Bank (DBK)	–	–	18	–	18	–
Dresdner Bank (DRB)	–	–	29	–	29	–
DZ Bank (DZB)	–	–	120	15	120	15
HSBC Tr. & B. (HSB)	–	–	30	3	30	3
HypoVereinsbank (HVB)	22	–	38	–	60	–
Lang & Schwarz (LAS)	–	–	64	–	64	–
Lehman Brothers (LEB)	–	–	10	–	10	–
Sal. Oppenheim (OPP)	87	4	66	–	153	4
Société Générale (SOG)	–	–	23	3	23	3
UBS Warburg (UBS)	–	–	76	–	76	–
WestLB (WLB)	12	–	11	–	23	–
WGZ-Bank (WGZ)	–	–	3	–	3	–

Table 1: Analyzed products.

	Strike prices			
	Average(ΔK)		Average($ \Delta K $)	
Reverse convertibles	0.562	0.68%	2.656	3.75%
– DAX	0.590	0.73%	2.698	3.70%
– NEMAX	-0.446	-1.30%	1.091	5.48%
Discount certificates	-1.211	-0.87%	3.674	5.73%
– DAX	-1.234	-0.91%	3.724	5.50%
– NEMAX	-0.622	0.14%	2.419	11.65%

	Times-to-maturity				
	Average(τ)	Average($\Delta\tau$)		Average($ \Delta\tau $)	
Reverse convertibles	0.740	-0.429	-51.87%	0.468	59.74%
– DAX	0.745	-0.432	-51.93%	0.472	59.78%
– NEMAX	0.570	-0.292	-49.93%	0.337	58.31%
Discount certificates	1.201	-0.844	-64.92%	0.863	68.02%
– DAX	1.200	-0.841	-64.70%	0.861	67.84%
– NEMAX	1.237	-0.921	-70.67%	0.932	72.39%

A negative sign represents a lower strike/time-to-maturity of the assigned Eurex option in comparison to the respective product.

Table 2: Matching of processed records with Eurex options.

	Average price deviation (ΔV_i)							
	DAX				NEMAX			
	Mean	Std.	Min.	Max.	Mean	Std.	Min.	Max.
I. Reverse convertibles								
WLB	3.89%	1.56%	1.50%	7.17%	–	–	–	–
BNP	3.73%	0.40%	3.28%	4.06%	–	–	–	–
OPP	3.37%	2.04%	-3.32%	8.34%	4.58%	1.81%	1.99%	6.16%
HVB	2.88%	1.51%	0.94%	7.28%	–	–	–	–
CBK	2.80%	1.58%	0.35%	5.01%	–	–	–	–
BGB	2.38%	1.75%	0.13%	5.81%	1.14%	–	1.14%	1.14%
BHF	1.87%	1.66%	-4.21%	5.44%	–	–	–	–
All	3.04%	1.91%	-4.21%	8.34%	3.89%	2.20%	1.14%	6.16%
II. Discount certificates								
BHF	8.48%	3.73%	1.73%	20.03%	14.90%	4.65%	11.61%	18.19%
HSB	6.21%	3.98%	-0.56%	13.50%	14.32%	4.26%	9.48%	17.52%
SOG	6.08%	2.89%	0.02%	11.40%	7.08%	6.71%	-0.44%	12.48%
OPP	4.67%	2.86%	-0.58%	12.96%	–	–	–	–
DZB	4.54%	3.29%	-0.82%	16.81%	12.54%	8.21%	0.18%	29.19%
BNP	4.21%	1.76%	1.30%	8.62%	–	–	–	–
LAS	3.75%	2.63%	-0.94%	9.87%	–	–	–	–
CBK	3.20%	2.00%	-0.48%	7.66%	–	–	–	–
WLB	3.14%	2.49%	-0.92%	8.03%	–	–	–	–
DBK	3.00%	1.77%	-0.45%	6.86%	–	–	–	–
UBS	2.83%	2.24%	-0.40%	10.75%	–	–	–	–
CIT	2.35%	1.60%	0.22%	5.83%	4.92%	4.79%	-1.94%	13.04%
CLY	2.32%	1.19%	0.40%	4.20%	–	–	–	–
HVB	1.93%	1.17%	-0.77%	4.08%	–	–	–	–
DRS	1.61%	0.97%	0.01%	4.12%	–	–	–	–
LEB	0.78%	0.83%	-0.68%	1.99%	–	–	–	–
WGZ	-0.10%	2.36%	-2.28%	2.41%	–	–	–	–
All	4.20%	3.29%	-2.28%	20.03%	10.04%	7.46%	-1.94%	29.19%

Issuers are "ranked" by their mean average price deviations for DAX products.

Table 3: Statistics for average price deviations.

N	a	t -value	b	t -value	c	t -value	d	t -value	F -value	R^2_{adj}	
I. Reverse convertibles											
(a) DAX products											
R1	164	0.0180	2.17**	-0.0491	-10.70***	0.0333	4.48***	0.6136	0.58	62.38***	0.5305
R2	164	0.0202	2.73***	-0.0483	-10.53***	0.0325	4.49***	–	–	93.71***	0.5322
(b) NEMAX products											
R1	5	0.0601	0.13	0.1440	1.48	0.1132	0.62	-87.3924	-0.70	1.21	0.1365
R2	5	-0.1994	-1.35	0.1021	0.82	0.2062	2.28*	–	–	2.88	0.4842
II. Discount certificates											
(a) DAX products											
R1	704	0.0158	2.89***	-0.0877	-18.58***	0.0473	8.63***	1.1669	4.71***	218.43***	0.4813
R2	704	0.0204	3.62***	-0.0883	-18.45***	0.0495	8.50***	–	–	281.55***	0.4439
(b) NEMAX products											
R1	33	0.0596	0.99	-0.2214	-2.67***	0.0058	0.11	4.2652	1.87*	5.64***	0.3033
R2	33	0.1193	2.06**	-0.2530	-2.90***	0.0348	0.63	–	–	5.58***	0.2224

Table 4: Analysis of factors influencing average price deviations.

Average price deviations (ΔV_i) are regressed against the products' relative life times (L_i), the moneyness of the implicit put options (M_i), and the quote spreads (Ψ_i): (R1) $\Delta V_i = a + bL_i + cM_i + d\Psi_i + \varepsilon_i$; (R2) $\Delta V_i = a + bL_i + cM_i + \varepsilon_i$. Standard errors are adjusted for heteroscedasticity of unknown form according to *White* (1980). *** significant on 1 % level; ** significant on 5 % level; * significant on 10 % level (two-sided tests for regression coefficients). R^2_{adj} denotes the value of the adjusted R^2 (coefficient of determination).

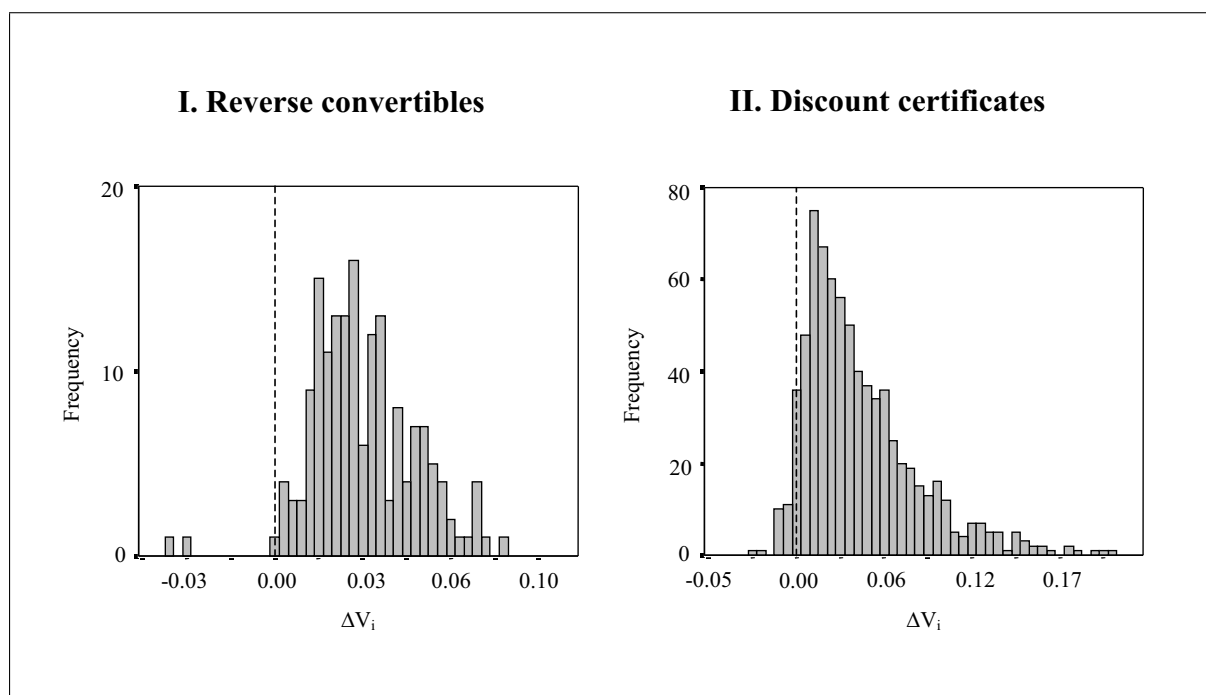


Figure 1: Distributions of average price deviations among reverse convertibles and discount certificates.

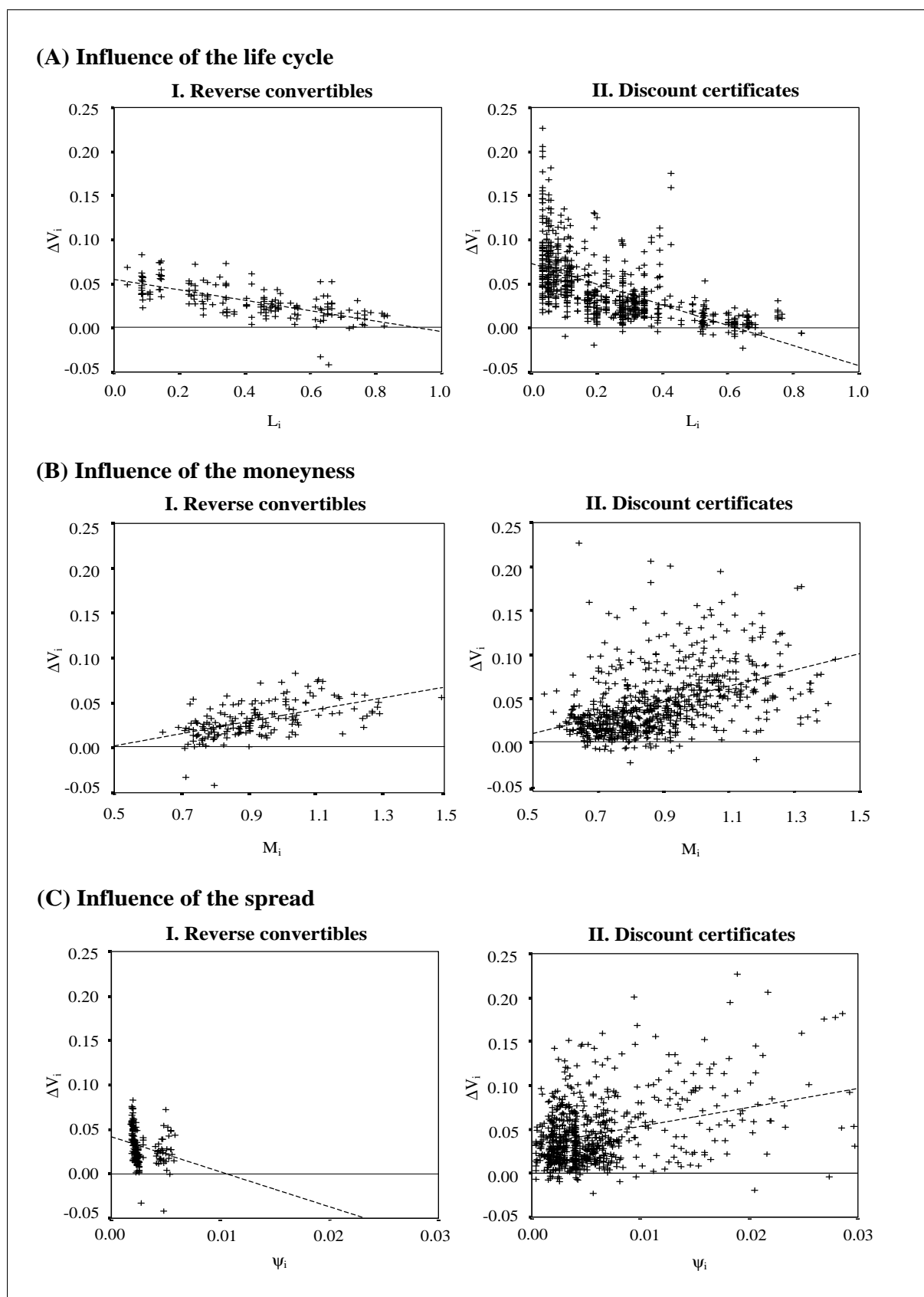


Figure 2: Average price deviations depending on (A) the products' life cycles, (B) the moneyness of the implicit options, and (C) the spreads.